Ph.D. Dissertation in Digital Contents and Information Studies

Temporal Based Thematic Discovery and Characterization in the Domain of Human Computer Interaction and Information Behavior

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Graduate School of School of Convergence Science and Technology

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Digital Contents and Information Studies Major

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Abstract

In this dissertation we proposed a combination bibliometric, graph theory and card sorting methods to discover and characterize the research themes in the domains of Human Computer Interaction/User Experience (HCI/UX) and Information Behavior (IB). For the first case, 519 papers, during the period of 1990-2016 were retrieved from Web of Science, published in the area HCI/UX using the search strategy (Human Computer Interaction and User Experience). The time-frame of the first research was petitioned into three time intervals (1990-1999, 2000-2009, and 2010-2016) to show Temporal based pattern discovery. The behavior related papers were found dominant in the case of HCI/UX analysis. Therefore, we focused on Information Behavior related aspects in our second research in this dissertation by selecting the representative journal of the clusters of citation network of journals related HCI/UX i.e. Computers in Human Behavior for Analysis.

The aim is to make the in-depth exploration of the research themes Information Behavior within the general context of HCI/UX. 4771 papers published in journal of computers in human behavior starting 1990-2017 were included. The time span for the second research was partitioned into three, namely; 1990-2003, 2004-2010 and 2011-2017.

In both cases ADKs network was constructed and clustered for the three time periods using simple center algorithm. Clusters were considered as themes of research. Cluster networks were used to highly associated ADKs through their co-occurrence that formed a theme to help extract different research themes. The central

ADK in a cluster network is used as a name of a theme name based on simple clustering algorithm, which gives more weight to the ADK with higher degree centrality in the cluster as representative of a cluster. The themes discovered through these process were grouped into different high level concepts perhaps subject matters addressed using card sorting methods by experts and color coded. Those color codes were used across the rest of the analysis i.e. evolution pattern discovery and strategic diagram based classification based on centrality and density into different roles and level internal maturity of themes.

Evolution pattern discovery was used to show the evolution linkages of themes in different periods. This in turn gives insights to the level of paradigm shift (thematic dynamism) in the field. To show the conceptual periodic overlap, we used the overlapping map (stability diagram). It showed the level of newly emerged, obsolete, and overlapped ADKs in different periods. In both cases the number of thematic areas and conceptual (ADKs) stability increased while thematic dynamism increased over the time intervals. For example, in the case of HCI/UX domain, the stability of ADKs increased from 15% between in 2000-2009 to 52 % in during 2010-2016 while thematic dynamisms were 100% and 83% for similar periods respectively. The conceptual stability in Information Behavior has increased from 39% for the period 2004-2010 to 74% for the period 2011-2017 while thematic dynamism is 100% and 88% for those periods respectively. One, eight and twelve themes were discovered for the time intervals 1990-1999, 2000-20009, 2010-2016 respectively in case of HCI/UX. Three, eleven and thirty-four themes were discovered for the periods 1990-2003, 2004-2010, and 2011-2017 respectively in

the case of Information Behavior. The variety and dynamics is huge for in the thematic areas of Information Behavior. In the case of high level concepts, in concepts six themes were related to measurements of HCI/UX, six themes were related to technology/systems, five themes were related to methods/approaches in the case of HCI/UX over the entire time span covered in the research. A total of 17 unique thematic areas were discovered over the entire time span. In the case of IB, seventeen themes belong to human factor/behavioral issues, eleven themes related to theories/concepts, ten themes belong to technology/systems, and seven themes are related learning environments. A total of 45 unique themes were detected in the IB domain for the entire time period.

Overall, the proposed methods are effective to discover and characterize the thematic areas of research in both cases as we answered our research questions successfully. Therefore, these methods are promising in discovering and characterizing research themes in similar interdisciplinary fields of studies as are test successful on HCI/UX and IB domain, which are highly interdisciplinary domains.

Keyword:

Human Computer Interaction/User Experience, Information Behavior, Bibliometric, Graph theory, Thematic Discovery, Thematic Characterization, Author Defined Keywords, Network Analysis

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Chapter One

Introduction

1.1 Background

1.1.1 Definition of Thematic Structure

A formal definition of scientific knowledge is "a fact acquired through scientific methods" (Hess and Ostrom, 2007). By the scientific methods it means, it must be tested by the established scientific principles, peer reviewed, accepted for publication and consequently published (Rosenthal and Rsosnow, 1991). Scientific literatures are the medium through which the scientific knowledge is communicated to the scientific community (Fanelli, 2011; Rosenthal and Rsosnow, 1991). Scientific literatures take different forms (Fanelli, 2011). Among them, patents and technical reports, thesis or dissertations, conference proceedings and journals are the primary ones in the publication pyramid from low to high maturity respectively (Öchsner, 2013). 1.5 million Journal articles are published annually in more than 25,000 journals (Öchsner, 2013). As time goes, the volume of the publications grow, diversify in its research thematic areas and converge with other disciplines to the level that it poses challenges to scientific community to get important insights about the Thematic structure and characterization (Fanelli, 2011, Öchsner, 2013). Therefore, thematic discovery and characterization is a

process through which the thematic structure of a certain field would be discovered for the understanding the thematic dynamism of over periods.

The thematic discovery and characterization includes trends in scholarly exchange and dynamics in thematic areas of research (Callon et al., 1983, Small, 1998, Callon et al., 1991; liu et al., 2014, Cobo et al, 2015). Discovering and characterizing the thematic areas, identification of in certain field of study are key issues to understand the knowledge structure and intellectual progresses in one field of study (Callon et al, 1991; Small, 1998; Cobo et al, 2015). The dynamics within the thematic area of any field of study include emergence, growth, divergence (specialization), and convergence, obsolescence and re-emergence (Cobo et al. 2015; Hess and Ostrom, 2007). Therefore, driving the hidden knowledge regarding these facts in the thematic structure from large size of scientific publication has been hot research topic (Small 1998, Noyons, 1999; Cobo et al., 2011). Thus we proposed the discovery and characterization of thematic areas of thematic structure in Human Computer Interaction and Information behavior for the last 28 years using a combination of graph theory, bibliometric quantive and qualitative analysis methods. The field of study is highly interdisciplinary in its nature, ever emerging in thematic structure and deals with innovative interactive systems. Therefore, its thematic structure is complex and hard to grasp. As a result, discovery and characterization of its thematic dynamism is key for

community of scholars and practice. The approach follow empirical study for understanding its knowledge structure (Hassenzahl et al., 2006; Forlizzi and Battarbee, 2004). In this dissertation, we focused on the thematic discovery and characterization of HCI and Information Behavior. For thematic discovery, we used concepts of graph theory called clusters. For characterization of the discovered thematic areas, we used graph properties called centrality, which measures the inter-thematic interaction or connection and density, which measures the intra-thematic cohesion (internal maturity) of thematic areas. From bibliometric, we used the concepts of evolution pattern discovery strategy, strategy of discovering conceptual periodic conceptual overlap, where concept of analysis is being Author Defined Keywords (ADKs). Classification of themes based role and level of maturity using centrality and density respectively was perf strategic diagram. Categorization into high level concepts, perhaps subject matter addressed by a group of themes using card sorting method was also performed. The unit of analysis is Author Defined Keywords (ADKs). The co-occurrence of ADKs in different papers forms a network metrics. Network is normalized using association strength. Simple center algorithm was used for clustering the network. Clusters are taken as thematic areas. Two cases are covered in these dissertation using similar methods. Case one dealt with the thematic discovery and characterization of research thematic areas in HCI/UX. The second case

covered thematic discovery and characterization in the domain of Information Behavior (IB).

1.1.2 Background: HCI/UX

Human Computer Interaction (HCI) is one of the interdisciplinary field of study focusing on the emerging innovative interactive systems (Dix, 2009), as such, it involves design, evaluation and implementation of interactive computing systems (Peerce et al., 2004). In short, it deals with the interaction between humans and machines (devices). User Experience (UX), the totality of human feelings, perceptions and expectation regarding accepting, adopting and using a product or a service is becoming part and parcel of HCI in this digital society (Hassenzahl and Tractinsky, 2006; Dix et al., 2009). It is becoming important part of HCI over time as HCI tends to be more human oriented (Myers, 1998; Hassenzahl and Tractinsky, 2006). As an areas of research and practice, 1980s is a time mark for HCI foundations as a scientific field of study (Myers, 1998). Primarily the origin of HCI was in computer science and information systems and focused on graphical based user interface design and basic programming (Myers, 1998). Later on, the research foci in HCI is shifted to include usability evaluations, interaction design and user experiences, which are more human oriented to meet users' perceptions, needs and requirements (Myers, 1998; Hassenzahl et al., 2006). User experience is

focusing on systems' human oriented core values, which include desirability (emotionally appealing), usefulness (relevance to problems of users), accessibility (accessible to all end users regardless physical conditions), reliability (trusted and dependable), usability (easily learned and used for intended goal), and findability (easily navigable)[1] . Thus, User Experiences has become important aspects of human computer interaction to enhance the acceptance or adoption and usage of computing systems in a more pleasurable way. As such, it deals with not only effectiveness and efficiency of using computing devices/ systems to attain the intended user goal (s) as in the traditional usability but also about beauty and hedonic features of systems to make the artifact a more appealing one and pleasurable one (Hassenazahl et al., 2006). Human oriented HCI is rooted in many fields like ergonomics, psychology, philosophy, anthropology and design (Myers, 1998). Cognitive experiments, participatory techniques, theoretical frameworks like activity theory, situated actions and distributed cognition were developed to make HCI/UX a full-fledged field of research over time that takes social and contextual situation into considerations (Dix et al., 2009; Hassenazahl et al., 2006; Myers, 1998).

[1] User Experience Basics. https://www.usability.gov/what-and-why/user-experience.html

As a result of these developments, various venues of intellectual and industrial discourse platforms were flourished to serve as forum of exchanging views, which strengthened the thematic structure overtime (Myers, 1998). The research outcomes and practice based innovative technical reports of a field of study started to boom over time (Clemmensen, and Roese, 2010). In 1982, ACM Interest Group on Computer Human Interaction (SIGCHI) was founded to serve as a scholarly discourse of both academia and industry emphasizing humans (Myers, 1998; liu et al., 2014).

Many researchers presented their seminal publications in the early 1980s attributed HCI as a field browning its foundational concepts from computer science, human factors and ergonomics and cognitive psychology while having its own theories, models, and frameworks (Card et al., 1983; Norman and Draper, 1986; Winograd and Flores, 1986). Many journals appeared as a venue of scientific papers related to HCI/UX. To mention few, journal of interacting with computers, computers in human behavior and International journal of human-computer studies, journal of behavior & information technology are among the top venues publishing papers containing the two concepts together (Urgessa, et al., 2017). According the survey we have made, currently we have more than 250 journals which publishes at least one paper at the intersection User experience and Human Computer Interaction and indexed in WoS though the major ones are few in number (Urgessa, et al.,

2017). Moreover, User Experience as aspect of human computer interaction in particular and computing systems in general is becoming very important and being taken as a success factors for companies in the digital industry and consequently becoming a research area and a career line for many overtime (Wilson, 1981).

Hence studying the thematic structure of that connects the two important phenomena based on empirical data is important to shape its future research directions (Hassenzahl and Tractinsky, 2006).

Therefore, this dissertation is motivated to use available publication data and emerging state-of –the art analysis methods ascan opportunities to drive new insights in the thematic structure Human Computer Interaction/ User Experience.

Discovering and characterizing thematic structure would guide policy makers, academia, researchers and industry for well-informed research thematic area identification and hence increase efficiency and avoids duplication of efforts and resources in HCI/UX community of scholars.

1.1.3 Role of Information Behavior in the Context of HCI/UX and the Need to Analysis it publications

Human behavior is an important issue to accept, adopt, interact and use technology or/and services (Hudlicka, 2003). The feelings, emotions and

personality trait before or/and after using the products and services are more psychological in general and human behavioral issues in particular. Making computing devices and systems context aware is also another important issue (Abowd et al., 1999; Schmidt, 2005; Pantic, 2007). Change in human behavior as a result of use of computing devices and services is also another important issue (Davis, 2001). The behavioral change due to use technology can be good or bad, it lays within the way human being uses it but not intrinsic in itself (Godzinski, 2005). It would be important to study the role of human behavior with regard to information sources, channels, processing and sharing (IB) in the context of HCI/UX to reduce its negative effect on human behavior and wellbeing, and maximize is positive outcomes in human life (Ghani, 1994). As a result of these facts, many research outcomes connecting computing devices/systems and human behavior have been published and available in the scientific publication databases of WoS.

The citation network analysis of journals which published papers related to HCI/UX is made as a preliminary high level research interests of the scholars in the area in the third chapter-case one of this dissertation. Information Behavior (IB) related journal publications clusters are by far higher by number of publications than other high level research categories identified (Urgessa et al. 2017).

If these publications are analyzed systematically, they would reveal insights regarding trends and thematic dynamics in the past and present and imply the future prospects of the relationship between computing devices/systems, information use and human behavior which we call it Information Behavior (IB) in this dissertation.

Therefore, the thematic structure and dynamism in Information behavior in particular and in-depth in the context of HCI/UX is explored with similar methods in the first case (HCI/UX) from large publication base over time in this dissertation.

1.2 Rationale

This area of research is not yet empirically explored while it very important to clearly map research thematic structure for making informed decision for future research directions to HCI/UX and IB communities (Hassensahl et al., 2004, Boyack, 2005). The intersection of these domains taken as cases can be good example of how different field of can be converged and form a dynamic scientific knowledge base over time (Myers, 1998).

On top this, we have big data (meta-data of publications) but little insight out of it (Graham, 2006; Cobo et al., 2015, Urgessa et al. 2017). It is challenging to deal with large volume publication data to extract important insights for

policy makers, researchers and practice community to make a wise decision for research directions.

Moreover; there is an opportunity that there are state of the art analysis techniques combining bibliometric and graph theory and related qualitative analysis like card sorting method to discover and characterize thematic areas in the thematic structure of any domain of interest. When we come to HCI/UX and IB, it is a typical interdisciplinary and complex field of study. There are new methods, strategies and techniques to deal with such research problems.

Therefore, in this research, we proposed a combination bibliometric, graph theory and qualitative methods for thematic discovery and characterization in the domains of HCI/UX and IB focusing on Author Defined Keywords (ADKs) as a unit of analysis over the course of 28 years.

1.2 Research Objectives

1.3.1 Main Objective

The general objective this study is temporal based thematic discovery and characterization in the domain of HCI/UX and IB using a combination concepts bibliometric and graph theory.

1.3.2 Specific Objectives

The specific objectives of the research that guides us for the attainment of the general research objective are to:

- Show the general trends in HCI/UX and Information Behavior over periods of time
- Discover thematic areas HCI/UX and Information Behavior (IB) based on ADKs network clustering methods
- Group the discovered themes into high level concepts using card sorting methods.
- Color code themes based on the grouping in each domain
- Discover the thematic evolution patterns and level of conceptual periodic overlapping in areas of research over periods
- Classify the detected themes into different categories to show their level of development and their role to shape the entire thematic structure
- Present the quantitative graph properties and bibliometric measures to characterize individual themes discovered with combination of group color codes in both researches for the periods analysis
- Interpret the results the results from each methods and/or combination of methods

- Discuss key findings and their implications for both domains

1.5. Research Questions

This research is intended to answer the following research questions. The research questions are aligned with the specific objectives of the research.

RQ1. What are the thematic research areas and their evolution patterns over periods in both domains?

RQ2. How the themes are classified and evaluated by their level of development, the role they play to shape the knowledge Structure over periods?

RQ3. How is the level of overlap of ADKs evaluated over periods in both domains?

RQ4: How the discovered themes are grouped into high level concepts of the subject matter addressed?

1.6 Significance and Contribution

This research adds new understanding of the general patterns, trends and thematic structures in the area of HCI/UX and IB. It also shades light on evolution patterns, level of ADKs (conceptual) periodic overlap, obsolescence's, and level of development and role of thematic areas in shaping the entire thematic structure of the domains of selected as cases of studies. It also identifies thematic characteristics in terms of subject matters addressed. It drives knowledge from the actual contents as represented by the authors of

the papers without subjective manipulation of the researchers alike that of traditional literature survey. It covers large size of publications over longer time interval (28 years). The time dimension, graph properties and bibliometric analysis and card sorting method to group the discovered themes into high level concepts by experts extends the reliability of the research. It would show the research directions of over 28 years related to the converged research field HCI/UX and IB as two cases and imply important research issues of the future based on the past and the current trends. It would be a cornerstone for future researches in the area.

The result would help guide the academia, scientific researchers and community of practice, sponsors and editors of the scientific journals to make the right decision making regarding research thematic area selections. It also enables researchers to target right journal venue for publications as well as help them to combine different fields relevant to the study area to drive their new research topics from the thematic network of themes as a result of this research in both domains.

1.6 Structure of the Dissertation

This dissertation is organized into five chapters. The first chapter deals with introductory remarks. The second chapter discusses methods, techniques, strategies and tools used in the research in the thematic structure of HCI/UX

and IB for driving research ideas for in-depth exploratory research in the area. Chapter three covers the first case study entitled “Author Defined Keyword Network Analysis for Temporal Based Thematic Discovery and Characterization in Human computer Interaction/User Experience”. Chapter four presents the second case study, which explored temporal based thematic discovery and characterization in Information Behavior in the context of HCI/UX, whose idea originated from the data of the case. Chapter five discusses the general take away and conclusion of the research processes, findings and future implications.

Chapter Two
Methodology and Operational Definitions

2.1 General Framework of the Research

The general framework of the procedures followed in this dissertation is as presented in Figure 1.1. The first step is dealing with setting research goal and deciding on different tools, techniques and methods to achieve the intended research goals. The second step is identification of the right data source to address the stated research goal and acquiring the data. The third step is data preprocessing as the original data obtained is fragmented, messy huge and inconvenient for insight discovery (more time and energy was allocated here). It needs different preprocessing activities for data integration as the source allows downloading only 500 records at a time, dimensionality reduction and avoiding duplications, selection of the right segment of dataset and making preliminary insight for further exploration through statistical summary measures. The fourth one is visualization, analysis and interpretation of the result. The final one is writing up using the following discovered insights in the whole processes focusing on easy presentations for the readers' understanding.

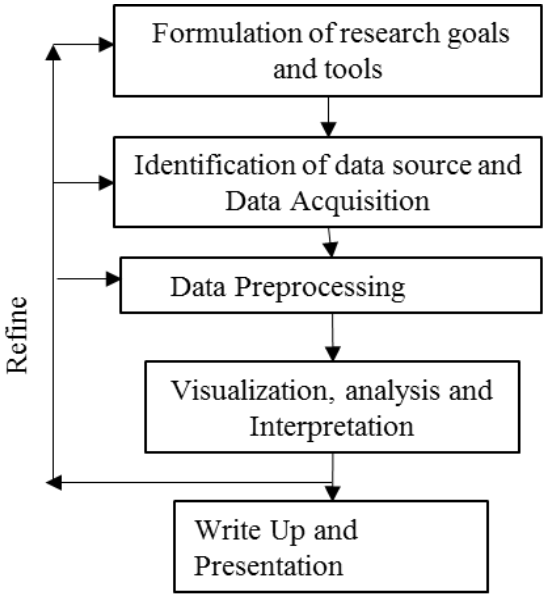


Figure 1.1 General Framework of the Dissertation

2.2 Data and Decision Procedure

2.2.1 Data for Case One

All journal articles dealt with HCI and UX together were searched in Web of Science starting from 1990-2016. Web of Science is owned by Thomson Reuters, started in 1960s, most comprehensive and hosts esteemed multidisciplinary journal articles across all fields of studies having above 10,000 journals[2]. We made a topic search where the two phrases are searched

[2] UCL. Research Library (2016) Measuring the reach of your publications using Web of Science accessed http://libguides.ioe.ac.uk

either in Title, Author Defined Keywords, ISWoS Word plus or in abstract of the journal articles in the Web of science database. 519 papers were retrieved. The search statement is:

TOPIC: (User Experience and Human Computer Interaction)

Timespan: 1990-2016

2.2.2 Data for Case Two

We retrieved all 4771 papers published in this journal of computers in human behavior starting from 1990 up to 2017-July_31 and included all in the analysis of chapter four. The selection of the journal was based on the finding in the research one, chapter three of this dissertation that big high level research category discovered is computing, human and behavior related, which we call it Information Behavior. Journal of computers in human behavior happened to be a representative of this research category with its high impact as well as its number of papers.

Therefore, we used the search strategy:

PUBLICATION NAME: (Computers in Human Behavior)

Timespan: 1990-2017.

2.3 Operational Definition of Bibliometric and Graph Theory

One of the systematic ways to explore the trends and dynamics in the thematic strucure of certain field of study is mining meta-data of the scientific literatures published in the area over long period time (Callon et al 1986; Courtel et al, 1998, Van Eck et al. 2007). State-of-the-art analysis methods for this purpose are the concept of bibliometric and graph theory (Otte and Rousseau, 2002; Chen, 2006; Leidesdorff, 2004; Bettencourt, et al., 2009; Cobo, 20011). There are different methods in bibliometric analysis to explore the thematic structure in any domain. Thematic discovery and characterization in terms level of development, impotence in the entire thematic structure, evolution patterns, periodic conceptual overlapping are among the most important ways to deal with thematic understanding (Schneider, 2004). The analysis can be made at the level of words, journal articles or other descriptors like author, institutions, citations and bibliography of the scientific articles (Ding, 2001; Callon, et al., 1991; Altman et al, 2011). The bibliometric analysis methods include co-word analysis, co-authorship analysis, co-citation analysis and bibliographic coupling analysis (Cobo et al. 2015). Different analysis method reveals different dimensions of the thematic structure. For example co-word analysis enables concept based thematic discovery and characterization (Callon et al. 1986; He, 19999; Callon et al. 1991, Callon et al, 1983, Cobo et al. 2015). Co-authorship analysis enables to discover the social structure or collaboration

among authors of the thematic structure (Acedo et al., 2006; Liu et al., 2005; Huang et al., 2011, Altman et al. 2011). Co-citation or/and bibliographic coupling analysis enables to discover the intellectual thematic structure (Small, 1999, Huang et al.2011).

Graph theory contributed a lot to the social network analysis in characterizing the network by nodes, which can be any item or object of interest and the link between the nodes called edges (Callon et al., 1986; He, 1999; Altmann, 2011,). The network of nodes can be clustered based on their similarity or association or affinity or proximity (Courtel et al 1998; Liu, 2014; Callon, 1991; Small, 1998, 2011; Otte, 2002). The clusters properties like centrality and density can provide important information about the status of the clusters both internally within the clusters as well as the clusters' interaction in the entire network the thematic structure (Liu, 2014).

Centrality and density of the clusters provide important information regarding the inter-cluster cohesion and intra-cluster interactions or connections respectively (liu, 2014, Cobo et 2015). So, strategic diagram is based on these three important graph theory properties (clusters, centrality and density) to classify themes to different roles and levels of internal maturity. Centrality and density in our research is based on Callon's centrality and density formula in this dissertation (Callon et al., 1991).

Centrality of a certain cluster or theme is calculated by the formula:

$$\text{Centrality} = 10 \sum \text{AS (ADKiADKj)} \qquad (2.1)$$

Where AS is edge (link) strength or Association Strength), ADK i is ADK in one cluster and ADK j is an ADK in another cluster or theme.

Density measures the intra-cluster or thematic cohesion. It is calculated by the formula:

$$\text{Density} = 100 \frac{\sum \text{AS(ADKiADKj)}}{n} \qquad (2.2)$$

Where AS is association strength, ADKi and ADKj are two ADKs connected to each other in the same theme or a cluster and *n* is the number of ADKs in the theme.

Therefore, the centrality and density of clusters are presented for each time intervals of analysis in both cases and used to map the discovered themes of each time interval to the strategic diagram to classify based on the role they play in thematic structure as core, basic, emerging and peripheral.

The framework for thematic mapping in this research is presented in Figure 2.1.

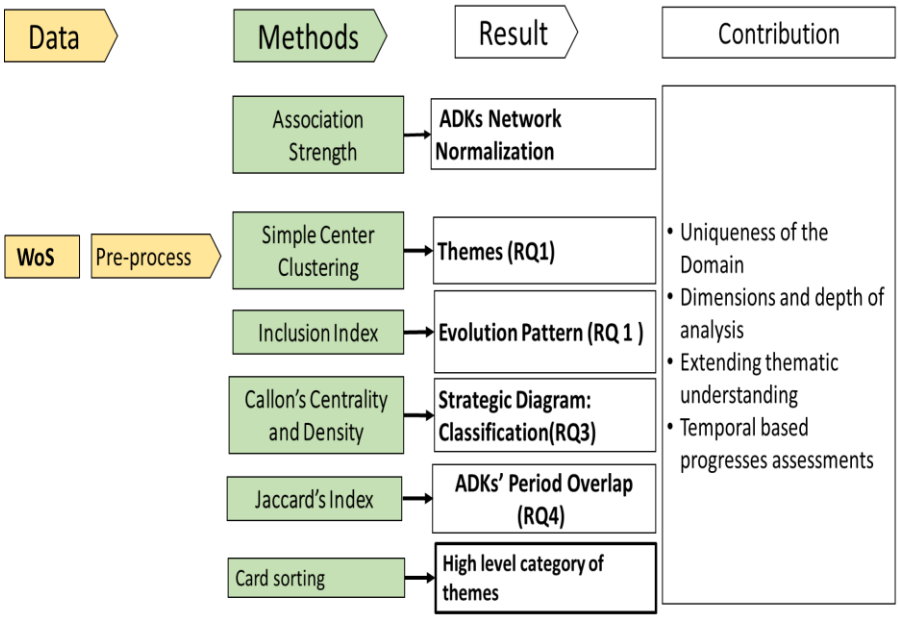


Figure 2.1. General Method of Thematic Discovery and Characterization

2.3.1 Techniques, Strategies and Algorithms

2.3.1.1 Definition of Network Matrix, Normalization, Evolution and Overlapping Measures

In our research, the co-occurrence of ADK i and j is $ADK_{ij.}$ ADKi is the frequency of occurrences of ADK i alone in the paper and ADKj is the frequency of occurrences of ADK j alone in the paper. There are different similarity, evolution and overlapping measures used at different times by different researchers. These include association strength (Couter et al., 1998; Van Eck and Waltman, 2010), Inclusion Index (Cobo et al., 2011), Jacard' Index (Peters and Van Raan, 1993). Salton's cosine (Salton's and Mc Gill, 1983, Cobo, et al., 2011). In our research, we implemented association

strength for network normalization, Inclusion Index for evolution pattern discovery and Jacard's index for discovering the conceptual (ADKs) period overlap for their varying advantages for each case.

The following formula used to measure association strength between two ADKs' co-occurrence is:

$$AS = \frac{(ADKij)^2}{ADKi.ADKj} \qquad \text{Where } 0<=AS<=1 \qquad (2.1)$$

Association Strength can also be called Affinity Index (Peters and Van, 1993) or Probabilistic Affinity index (Zitt et al., 2000). Association strength can also be called Equivalence Index (Callon et al., 1991, Cobo et al., 2011).

Inclusion index is calculated by the formula

$$\text{Inclusion Index} = \frac{ADKij}{\min\,[ADKi,\ ADKj]} \qquad (2.3)$$

Where min [ADK_i, ADK_j] is the minimum of frequency of occurrences of ADKi and ADKj.

The Jaccard's index is simply intersection divided by union of ADK i and ADK j and calculated by the formula:

$$\text{Jaccard's Index} = \frac{ADKij}{(ADKi+ADKj)-ADKij} \qquad (2.4)$$

Soltan's cosine, the co-occurrence divided by the square of their product. It is calculated by the formula:

$$\text{Salton's cosine} = \frac{\text{ADKij}}{\sqrt{\text{ADKi}.\text{ADKj}}} \qquad (2.5)$$

These measures can be used in best combination, in which they provide good results for a particular research question for network normalization, evolution pattern discovery, and overlapping map among thematic research areas in the thematic structure. For example association strength is good at showing evolutional hierarchy based on semantics (Courter et al, 1998). Inclusion Index is good for including similar concepts together at the expense of sematic hierarchy (Courtel et al., 1998, Cobo et al., 2015). Jacard Index is good for measuring the level of the semantic overlap among words in a database (He, 1999)

Therefore, in this dissertation, in the first paper (chapter three), association strength is used for similarity measure (network normalization), Inclusion Index is used for evolution pattern discovery of research themes over periods of analysis. Jaccard's Index is used for indicating the overlapping between themes of different time intervals.

2.3.1.2 Operational Definition of Evolution Pattern Discovery Strategy

Evolution map is used to detect the longitudinal evolution of thematic areas. It can be calculated using association strength, Equivalence Index, inclusion index or Salton's cosine using the formula given under 2.3.1.1. The structure of the evolution map is presented in Figure 2.2.

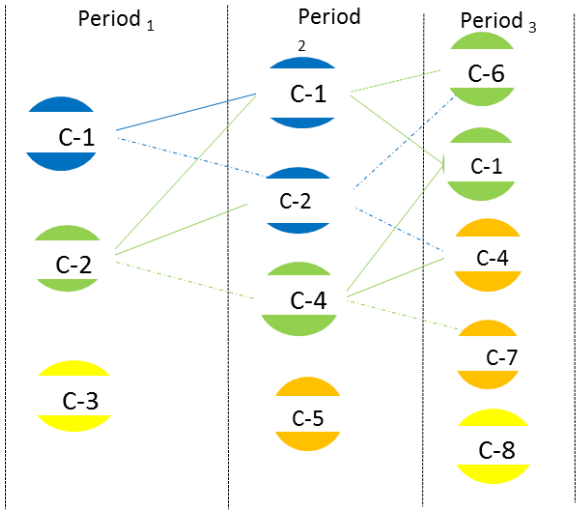


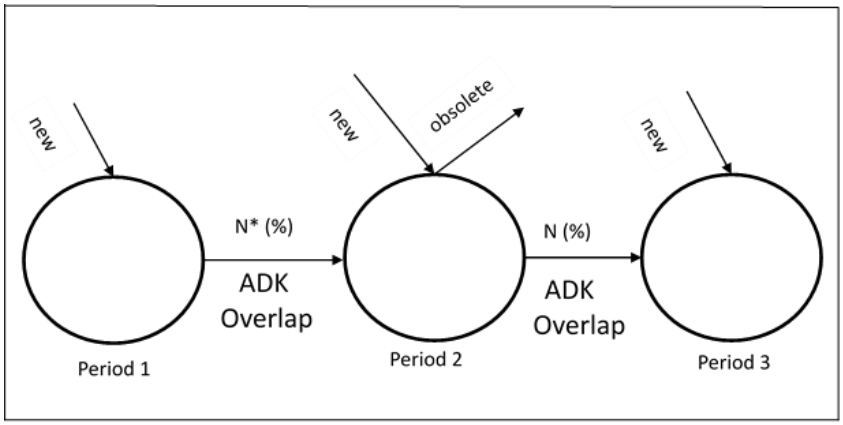
Figure 2.2. Strategy to Measure Evolution Pattern Discovery

Suppose that C-1 to C-8 in Figure 2.3 are the union of a set of all clusters or themes of the three time intervals. The color of themes are examples of the themes group based on subject matter. The three time intervals are Time interval 1, Time interval 2, and Time interval 3. Time Interval 1 has clusters or themes: C-1, C-2, and C-3. Time interval 2 has clusters: C-1 and C-2 (continued from time interval 1), C-4 and C-5 (new to time interval 2). Time interval 3 has clusters: C-6, C-7 and C-8 (new themes to the time interval), C-

1 and C-4 (continued from time interval 2). The relationship links between themes used in this example is association strength or inclusion index in our case. The relationship links between themes (clusters) of different time intervals, in Figure 2.2 are of two type. The solid line shows the continuance of the themes or sharing the main ADKs. For example C-1 in time 1 is linked to C-1 in time interval 2 by solid line to indicate cluster that C-1 has continued as a theme over the two time intervals; time interval 1 and time interval 2 by the same name. Broken line shows origination of new theme from the previous one but by sharing non central ADK(s) or weak tie between two themes different time intervals. For example, look at the relationship links between clusters C-2 in time interval 1 and cluster C-4 in time 2 in Figure 2.2 is a week tie. C-3 in time interval 1, C-5 in time interval 2 and C-8 in time interval 3 are isolate themes and their status and relative position can be determined using strategic diagram based on the Centrality and density measures of the themes in different time periods.

2.3.1.3 Operational Definition of Overlapping Pattern Discovery Strategy

The overlap map indicates the thematic stability in terms of number of ADKS, which are obsolete and newly emerged between time intervals. The operational definition given to the overlapping map used in this dissertation is presented in Figure 2.3



N*: Number of ADKs passed to the next period.

Figure 2.3 Strategy to measure the level ADKs time Overlap or Stability over Time

2.3.1.4 Operational Definition of Strategic Diagram

Strategic diagram is a two-dimensional space by the level of centrality (X-axis) and density (Y-axis). It has four quadrants used to classify the detected or discovered over the time intervals into different status/positions (Courter, 1998; Callon et al., 1991; Small, 1998; Liu et al., 204; Cobo et al., 2015). The structure of strategic diagram is presented in Figure 2.4.

Quadrant 1 is the quadrant with high level of centrality and density. The themes classified into this quadrant are those, which have high level of inter-cluster interaction and strong intra-cluster cohesion. This themes are assumed to be both core to the shaping of entire knowledge structure of research field as well self-sustaining within themselves to stand as autonomous theme of research in a particular time interval. It shows high level of importance or

influence of themes in field of study's knowledge structure serving as a central role. They also internally well developed.

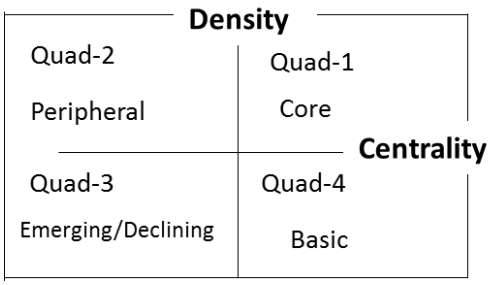


Figure 2.4. Structure of Strategic Diagram to Classify the Thematic Areas by Centrality and Density

Quadrant-2 of the strategic is a quadrant with low level of centrality and high level of density. This means this quadrant displays those themes, which are internally well grown (with high intra-cluster cohesion) but weak in playing central role in shaping the whole structure of field of study. In short, themes classified in this quadrant are said to be highly developed and isolates or peripheral themes.

Quadrant-3 is a quadrant with both low centrality and density. Themes classified in this quadrant are those which both are internally less developed or weak intra-cluster cohesion as well as weak inter-cluster interaction (peripheral). These themes are said to emerging or declining.

Quadrant-4 displays themes of strong centrality and low density. Themes appearing in this quadrant are those with strong inter-cluster interaction and

weak intra-cluster interaction. They are weak in sustaining themselves as strong theme or less developed but their role to shape entire knowledge structure is high due to their higher centrality values. Therefore, these themes are said to be basic and transversal theme. They can also be said central and undeveloped.

2. 3.1.5. Cluster/Thematic Network

It is a sub-graph of the entire network containing strongly association or similar ADKs based on their co-occurrence metrics. Simple center clustering algorithms is used for clustering purpose to give less weight to meaningless co-occurrence of all the times and pick the central ADKs based on degree centrality. The example of cluster network can be understood from Figure 2.5. The name of the cluster is the central ADK, in this example ADK_1. The central ADK is not necessarily popular according to the simple center clustering algorithms. It looks for the ADK, which has a connection to all of the rest of the member ADKs in the same clusters. There is also connection between the member ADKs. The thickness of the edge between ADKs in the cluster is proportional to the association strength. The size of the node ADKs in the cluster network is proportional to their individual popularity. Individual ADK's popularity is the frequency among the journal articles. There are different clustering algorithms for clustering the network ADKs into themes

such as simple centers algorithm is used to cluster the ADKs network into themes.

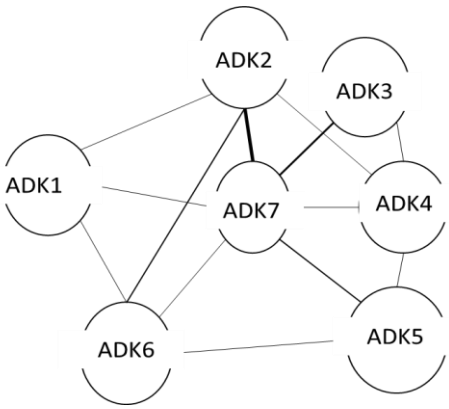


Figure 2.5. The Structure of Cluster or Thematic sub-graph, in this example, there are seven ADKs in the cluster or thematic sub-graph, the theme name would be ADK_7

Suppose, the cluster network in figure 2.5 has 7 ADKs. Having different node degrees and association strengths among themselves and frequencies or popularity. ADK1 has degree centrality of 3. ADK2 has degree centrality of 4. ADK3 has degree centrality of 3. ADK4 has degree centrality of 4. ADK5 has degree centrality of 2. ADK6 has degree centrality of 3. ADK7 has degree centrality of 6. In this example, the simple center clustering algorithm picks ADK7 as the cluster or theme name because of its highest degree centrality. ADK7 might not be popular but just central all the member nodes or ADKs though.

2.4 Summary of Methods

In this dissertation, we focused on discovering and characterization of thematic areas in thematic structure of the domain of Human Computer Interaction (HCI)/User Experience using Author Defined Keyword (ADKs) Network Analysis, which is the type of co-word analysis. The performance/quality analysis of the discovered thematic research areas are performed. The performance analysis is made using number of journal articles, citations received and h-index related the detected thematic areas. We used cluster network, evolution maps, overlapping map to study the theme structure, evolution lines and conceptual stability respectively. We also evaluated discovered themes in terms of the bibliometric performance indicator linking the themes to articles. Number of articles, citation and H-index of articles related themes were used as performance measures.

Nodes are ADKs and edges are their co-occurrence in different journal papers together. A group of ADKs having strong association strength through their co-occurrences are grouped together into a cluster. Clusters of ADKs network are considered themes of research areas of the field of study under investigation i.e. HCI/UX. The theme is represented (named) by the most central ADK in the cluster network using the simple center algorithm (Cobo et al, 2011). Centrality and Density of themes used to measure the intra-cluster

cohesion and inter-cluster coupling of the discovered thematic areas respectively. Therefore, we combined a flavor of graph theory and bibliometric to discover thematic areas and character them in many dimensions for the deep understanding of the thematic areas of HCI/UX in chapter three and four.

Chapter Three

Author Defined Keywords Network Analysis for Temporal Thematic Discovery and Characterization in Human Computer Interaction/User Experience

Abstract

This paper explores thematic structure at the intersection of user experience and human computer interaction areas of research using Author Defined Keywords co-occurrence network analysis. 519 journal articles were retrieved from the Web of Science published within the time frame of 1990 to 2016 containing both concepts. The time-frame was petitioned into three periods (1990-1999, 2000-2009, and 2010-2016) Temporal based analysis. The Temporal trends were visualized and analyzed and it is increasing in every aspect. The network was created based on the co-occurrences of ADKs. Evolution map, stability diagram and strategic diagrams were used to see the dynamics of thematic areas in the field of study over periods. The discovered thematic areas were explained in terms of centrality and density of thematic networks. The number of thematic areas and their stability increased over period but still nearly 52% between 2000-2009 and 2010-2016. Evolution relationships of thematic areas of different periods were also observed and it gets complex over time. Themes are increasing and changing in naming in shaping the field of study over time in every quadrant of the strategic diagram.

It is interesting to see how the field gets more motor themes and develop new themes over time.

Keywords

User Experience, Human Computer Interaction, Author Defined Keyword Network, Scientific knowledge, Graph theory, Bibliometric

3.1 Introduction

3.1.1 Overview

User experience is people's overall feeling of perceiving or using a certain product, system or service[3] .The experience can be from perceived use or response after usage. Its goal is making sure that technology is for improving human's lives, not to complicate it.[4] The historical timeline of the domain can be traced back to Leonardo Da Vinci's "Kitchen Nightmares"[5] to the Disney's world who was thought to be the first UX designer.[6] Another important timeline is the recognition of user experience as a job position in Apple in 1995[7]. The evolution of personal computers in 1970s opened new opportunity for User Experience/Human Computer Interaction (HCI) field of study in its increasing role in digital world (Marcus et al., 2013). Moreover, the emergence of many digital interactive systems like smartphone and related operating systems service platforms such as iOS, Android, web 2.0 services, cloud computing, virtual and augmented reality, Internet of Things (IoT) have opened a new horizon for the role of the User Experience (UX) aspect of human computer interaction as a profession and research area (Marcus et al., 2013). Companies made it a critical success factor over time in the effort to

[3] Ergonomics of human-system interaction. User experience accessed https://www.iso.org
[4] Technology to Improve Our Lives accessed from http://www.huffingtonpost.com
[5] Sullivan, Brian. Leonardo's Kitchen Nightmare available at http://boxesandarrows.com
[6] Walt Disney: The World's First UX Designer accessed from http://uxmag.com
[7]The brief history of user experience accessed from http://blog.invisionapp.com

make their digital products more appealing, user friendly, simple and ensure their efficient usage by the end users. As an interdisciplinary and a multidisciplinary field of study, roots of HCI/UX are many. Among them, the main contributors to the emergence UX/ HCI include affective computing, information architecture, human factors and ergonomics, psychology, anthropology etc. (Kujala et al., 2014, Hassenzahl et al., 2006). New field of studies contributed as a theoretical, methodological and/or areas of applications as time goes on. Roots of ergonomics and human factors in turn include philosophy, cognitive science, psychology, anthropology and sociology, industrial design and computer science (Bardzell et al., 2015). Therefore, it is important and necessary to study the development trends, new evolutions, continuance, obsolescence and overlapping concepts in thematic research areas of the thematic structure over periods in the field of study. The insight obtained from finding would aid the researchers, planners, policy makers and sponsors of academic research platforms. The rationale behind this research is knowing the past and current trends, structure and evolution in this field of study helps to figure out its future perspectives. It is important to see the research trends over time from the scientific publication point of view in proper domains to discover the current trends to imagine the future prospects of the field. The scope of research is limited to the journal articles to which

aspects of HCI/UX are covered, and to answer the question what is knowledge structure in the field within the defined scope.

To do this, it is important to identify the most comprehensive data source for the journal articles. Web of Science (WoS) is a more comprehensive database for these kinds of journal articles. For conducting the research, we proposed Author Defined Keywords (ADKs) co-occurrence network analysis method based on graph theory and bibliometric (Leibowitz, 2005; liu et al., 2014; Noack, 2009). This approach is considered a systematic way of gaining high level yet useful insights from large publication bases, which otherwise wouldn't have been possible (Cobo et al., 2015).

The social network properties to find out high level insight from the network graph are centrality and density of clusters (Callon et al., 1991). The centrality of the clusters was shown by the link strength and number co-occurrences of individual ADKs, which we consider in this research as nodes. We used also centrality and density of the themes to see dynamics of thematic areas using strategic diagram. Thematic evolution map and stability diagram were used for indicating thematic evolutions and overlap in different time intervals. The group of ADKs with strong association strength forms clusters. Those discovered clusters represent research thematic areas. The association strength between keywords (nodes) is measured by the number of co-occurrences

ADKs in different papers. The network is visualized based on co-occurrence of ADKs.

The finding would reveal high level yet important insights with regard to HCI/UX thematic structure form large publication data. Discovery of such a knowledge/insight would be important information as an easy reference for researchers, academicians, practitioners and sponsors of the research platforms to make informed thematic area selection for research venues. The assumptions for selecting ADKs analysis of content of the journal articles and structure of the thematic structure is described in following subsection 1.2.

3.1.2 Assumptions to Use Author Keyword Analysis

Assumptions to use ADK as unit of analysis include (Callon et al., 1991; Callon et al. 1983; liu et al., 2014) first, Authors of scientific articles choose their technical terms (keywords) carefully so that it represents the contents. The second assumption is that when different terms (keywords) are used together in the same article, it is because the author is either recognizing or postulating some non-trivial relationship between/among them. Another important assumption that makes ADK important content indicators is, if enough different authors appear to recognize the same relationship, then that relationship may be assumed to have some significance within that particular area of study. Lastly ADK are assumed to be descriptors of the contents

therein. The assumptions assert that, it is possible to systematically represent the content of the journal articles by ADK even though representativeness of the ADK may vary by the level of experience and expertise of the authors. Therefore based on this assumptions, ADKs network visualization and analysis over a certain time frame of 1990-2016 is proposed to systematically explore the impact and knowledge structure of HCI/UX.

3.1.3 Significance and Justification

The research is aimed at contributing new insight to understanding of the thematic structure in User Experience/Human Computer Interaction. It discovers research thematic and characterizing them over periods, which has not been explored (Hassenzahl et al. 2006). It would address questions like what is the relationship between HCI research and User Experience practices, question has been research inspirations for the user experience community but not empirically addressed from publication data of large size. Therefore, our research is focused on assessing both quantitatively and qualitatively, research thematic areas that combines HCI and UX.

The insights discovered would be important to show research directions to research and development policy makers, researchers and the industries. Past and current patterns are current status are discussed and future implications were made since the dynamism of thematic areas and the conceptual stability

observed in in past would imply the future research areas. It would be of more significance as a corner step for future research in this area.

3.1.4. Organization of the Paper sections of Chapter Three

The paper is structured into five sections having their own subsections. Section one covers introduction, section two discusses related works. Section three describes the specific methodology used to conduct research particular to this part. Section four covers visualization and analysis of ADKs network and section five briefly summarizes the key findings and conclusive remarks.

3.2 Related Works

3.2.1 Keyword Co-occurrence Network and its Foundation

The base for ADKs network analysis and visualization techniques is graph theory (Altmann et al., 2011; liu et al., 2014). Graph theory gives a base for objects (items) to be treated as nodes (vertices). Nodes can be people, themes, institutions, or web pages, etc. in general sense. In this research ADKs are considered nodes in our research. The co-occurrence of the ADKs in the same paper is considered as a link/connection/edge, afterwards used as an edge in this research. The connected node can be clustered based on keywords similarity measure or association strength. Visualization in the form of a

network graph gives easy and comprehensive insight. The method has been used in other domains to discover important research thematic areas in other fields of study. In biology, the method was used to discover the global stem cell research direction over 16 years (Zyoud et al., 2016). In chemistry, the method was used to identify to quantitatively assess the research trends in volatile organic compounds (Zhang et al., 2010). In the case of healthcare, a co-word network was used in disease pattern identification particularly to quantitatively and qualitatively assess the research trends of Parkinson's disease (li et al., 2008) and to discover the knowledge structure of general practitioners research in the healthcare profession (Hong et al., 2016). Co-word network analysis was used to indicate topics in data mining researches in tourism (Law et al., 2007).There are different approaches for clustering and mapping knowledge structures (Boyack and Noyons, 2014). The approach of clustering the knowledge structure can be made by marking the nodes in similar clusters or by using a unified approach, in which clusters are identified by colors and nodes take the color of the cluster. In our case, network normalized by the association strength is cluster using simple center clustering algorithm and individual separate cluster network is visualized. A single cluster network is treated as a theme and the name of a theme is the central ADK of the cluster network. This work is a comprehensive analysis in HCI/UX and Information Behavior knowledge structure, not yet explored in

the depth and dimension we proposed. The originality is ensured in terms of the approach used and the point of view.

3.2.2 The Need and Importance to Understand the Thematic Structure of HCI/UX

The field of Human computer interaction is a complex research area due to its multidisciplinary and interdisciplinary nature (Allam et al., 2010). As an interdisciplinary and a multidisciplinary field of study, it evolved from many field of studies. The dynamics is very within shorter times compared to other field of studies. It is complex since it deals with technological advancement and the creation of innovative interactive systems aligned with human behavioral and cognitive models. Understanding the dynamics of the thematic structure of such a complex field of study needs a systematic, less costly and comprehensive method (Bartneck and Hu, 2009). The user experience aspect of HCI is very important part, which has becoming a career line for many as well as a critical research field in the area of HCI (Hassenzahl et al., 2006).

Many researchers had made efforts to undertake research to understand the knowledge structure of related fields in computing in general and of HCI in particular using many techniques from CHI conferences papers as well as other sources. To mention a few, which were conducted in computing fields research area, two decades of HCI papers keywords were analyzed, to

characterize the intellectual structure of CHI conference using hierarchical clustering method and strategic diagram from ACM digital library conference papers(liu et al., 2014). Author keyword co-occurrence network was used to map online health information seeking behavior focusing on parallelship network with countries as a network actors (li et al., 2015). The quantitative analysis of contributions of countries and organizations to CHI conferences were analyzed using bibliometric analysis method and it was found that only 7.8 of the countries contribute to the 80% of the conference papers with USA ranked first from ACM digital library (Bartneck and Hu, 2009). The preliminary work of exploring HCI/UX journal articles' keywords network analysis has been made conference from Web of Science and this research is an enhancement of it by adding more journal articles for time interval of 2016 (Urgesaa et al. 2017).

Our approach varies either by data source, method of analysis and scope or clustering method used or visualization technique or detail and dimension of analysis from other related works. However, we acknowledge that our research idea is developed stepping on the shoulder of others who have made a tremendous contribution in science mapping and analysis in the other areas of studies and similar areas.

3.3 Methodology

3.3.1 Data

For an overview of historical timelines of HCI/UX, historical literatures were summarized as a background of the study domain. For the Author Defined Keyword co-occurrence network, publication data was obtained from the web of science within the timeframe of 1990 to 2016 to explore the emergence of new research thematic areas in the past two decades and the first half of the current decade. 519 articles were retrieved and included in the analysis. Articles considered were, those which dealt with both user experience and human computer interaction together to keep the scope of the research to aspect of UX related to HCI. For the part of ADKS network creation and analysis, ADKs were extracted and preprocessing was made to avoid duplications and the eventual misinterpretations and interfaces.

3.3.2 Data Preprocessing

Data reduction techniques used were limiting the ADKs' of occurrence to minimum of two. We also used the feature of searched similar words by

plurals, find similar ADKs and ADK groups by distance (by levenshtein distance) to avoid duplications and merged or removed based on the meaningfulness of the ADKs. Duplicates such as synonyms, identified and were also handled manually. The search terms Human Computer Interaction and User experience were also removed because obviously, they dominate other ADKs.

3.3.3 Visualization and Analysis Tools and Methods

The network metrics is co-occurrence analysis. The unit (concept) of analysis is Author Defined Keyword (ADKs). Time intervals of analysis are 1990-1999, 2000-2009 and 2010-2016 for temporal analysis. Normalization of network measure used was association strength. Clustering algorithm used was simple centers clustering algorithm. Simple centers clustering algorithm is very important to avoid the dominance of less meaningful co-occurrence of most of the time and detect simple centers based on maximum node degrees within the cluster. The minimum cluster size was limited to 1 and maximum to 15 (to avoid unnecessary cluster network complexity).

Inclusion index and Jaccard's index were used for evolution mapping and overlap mapping respectively. Strategic diagram was used to classify themes into four quadrats, which indicate internal strengths of themes and role the paly in entire thematic structure. Strategic diagram is a two dimensional space

having for quadrants. Quadrant I represents motor themes. Quadrant II represents well developed and isolated themes. Quadrant III represents emerging or declining theme and quadrant IV represents basic and transversal themes. The network or sub-graph of each thematic area identified in each time interval are illustrated (see Figures 3.3 to 3.5). The graph properties of the thematic areas in each time intervals in HCI/UX were presented in Table 3.5 and 3.6. For the evolution and conceptual overlapping patterns of this research area, see Figures 3.7 and 3.8.

3.4 Analysis

3.4.1 Basic Statistics

3.4.1.1 Statistics on Journals and Related Disciplines

To general understand further scholarly exchange platforms and convergence of different disciplines to shape this field of study, we observed top ten journal venues of the scientific articles. We also identified research disciplines contributed to the development of the thematic structure so far for this research area. The field of study is highly interdisciplinary and its top ten contributing fields and areas are identified systematically from journal sources and subject categories of the journals from the perspective of journal articles dealing with both Human Computer Interaction and User Experience and available in WoS. The cross disciplinary and interdisciplinary nature of HCI/UX can be inferred from the journal venues. This information is summarized in Table 3.1.

Table 3.1. Top Ten Journal Venues by Paper Contribution and Citation to HCI/UX

Top 10 Journal by contribution				Top 10 journals by citation		
Rank	Journals	Count	Percent	Rank	Journals	Citations
1	Interactions with Computers	32	6.17%	1	International Journal of Human Computer Studies	768
2	International Journal of Human Computer Studies	31	5.97%	2	Behavior and Information Technology	570
3	Computers in Human Behaviors	28	5.39%	3	Computers in Human Behavior	460
4	Behavior and Information Technology	20	3.85%	4	Interacting with Computers	447
5	International Journal of Human Computer Interaction	17	3.28%	5	Personal and Ubiquitous Computing	380
6	Multimedia Tools and Applications	15	2.89%	6	User modeling and User Adaptive Interaction	335
7	Lecture Notes in Computer Science	12	2.31%	7	Computers	291
8	Human Factors	9	1.73%	8	ACM Transactions on Information Systems	250
9	Ergonomics	7	1.35%	9	International Journal of Human-Computer Interaction	230
10	Universal Access in the Information Society	6	1.16%	10	Journal of Advertising	200

The source journals of papers from which the keywords were extracted and related disciplines in the subject category shows that this field of study is

highly interdisciplinary and cross-disciplinary in nature. The disciplines related to or contributed to the thematic structure of HCI/UX are mainly from computer science, behavioral sciences, psychology, information science, ergonomics, engineering, human factors, communication, healthcare systems, business and economics, and telecommunication.

We specifically observed which specialization of the first three in a row contributed more to the development of the field. Accordingly, we found out that from computer science, cybernetics, computer science-ergonomics, artificial intelligence, information systems, software engineering, interdisciplinary applications, and computer science theories and methods are at the top. From engineering, industrial design is dominant. From psychology, psychology multidisciplinary, experimental psychology and applied psychology are the dominant contributors.

3. 4.1.2 Journal Articles and Author Defined Keywords

In this section, we briefly explain the basic statistics regarding the journal articles, ADKs, authors, references used by researchers, sources of references by time intervals. The time interval of analysis was from 1990 to 2016. It has a total of 519 journal articles. The 519 articles were partitioned into three sub-time intervals to see growth over the decades, namely 1990-1999 containing only 44 papers (8%), 2000-2009 containing 165(32%), 2010-2016 contains

310 journal articles (60%) as shown in Figure 3.1. The number of journal articles has increased considerably over the three time intervals. Even the first half of the current decade has nearly double that of 2000s. The growth of the number articles during 2000-2009 is nearly 4 times that of 1990-1999. The growth in the number of articles during the first half of the current decade is seven times that 1990-1999. There are on average three keywords per article. The number of ADKs usage per article also increased over years but generally in articles, less than or equal to three ADKs were used frequently.

There is a total of 1765 Author Defined Keywords. 96(5%) ADKs belongs to the 1990-1999, 516 (29%) ADKs belong to the time interval 2000-2009, and 1153 (65%) ADKs belong to the time interval 2010-2016. There is a significant increase in the number ADK in across the time intervals. The growth in the number of ADK from 1990-1999 to 2000-2009 is 5.4 times. The growth for that of 2000-2009 and 2010-2016 is 2.2 times. The growth in ADK 1990-1999 and 2010-2016 is 12 times. The growth in ADK usage follows the same pattern with the journal articles (see Figure 3.1).

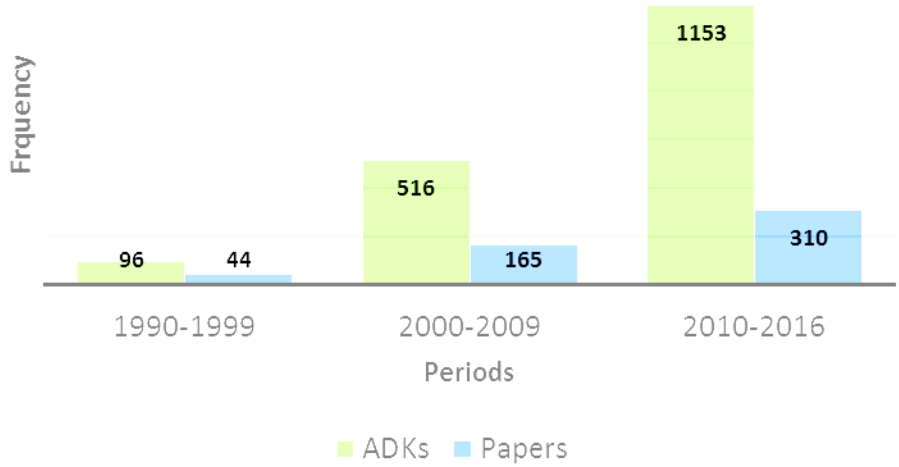


Figure 3. 1. Distribution of Number of papers and ADKs by Time Intervals having dealt with in HCI/UX

When we specifically observe individual years, the growth from 1990 to 2011 is slow and with little ups and downs. However, the growth of the journal articles published in the area of HCI/UX starting from 2011 has shown a continuous dramatic increase. The average number of papers per year for the whole years is 19. After 2011, the average paper per year is 49, nearly tripled the average per year number for the entire time interval. With regard to the ADKs vs their occurrences, 86% of the ADKs appeared only once in an article. Only 247 (14%) of the ADKs occurred twice and more in the articles. Those 14% of the ADKs would be important to show the thematic structure with their co-occurrence relationship (liu et al., 2014, Callon et al., 1991). Therefore, they are considered to be included in the final construction of the network

visualization and analysis. Popularity and Centrality (Coreness values) of individual ADKs is presented in Table 3.2. This information is important to indicate the popularity (research interests) and centrality (influence) of individual ADKs in the entire knowledge structure over the whole time span for analysis.

Table 3.2. Centrality and Popularity of Individual ADKs in the Entire Time Span (top ten levels) in HCI/UX

Level	ADKs	Centrality	level	ADKs	Popularity
1	Usability	59	1	Usability	24
2	Human Factors	51	2	User interface	21
3	Design	41	3	Design, Human Factors	12
4	User Interface	38	4	Affective computing, interface design	11
5	Experimentations	36	5	Ubiquitous computing	10
6	Interface Design	28	6	Virtual Reality, user studies	9
7	Performance	23	7	Experimentation, emotion, software engineering, multimodal interaction	8
8	Virtual Reality	20	8	Performance, evaluation, human computer interface, e-learning, aesthetics	7
9	Ubiquitous Computing	19	9	User centered design, internet, Interaction design, eye tracking, mobile devices,	6
10	Affective Computing	17	10	user modeling, user centered design, social interaction, presence, motivation, gesture recognition, cognition	5

Since, the thematic network is based on simple centers principle within the cluster in period, it does not tell the centrality and popularity of individual concept (ADK), it is important to show the research interest (popularity) and influence of individual ADKs for the entire time of analysis and thematic structure of HCI/UX, which may not be obtained from the themes analysis.

3. 4.1.3. Discovery of High Level Research Categories at the Intersection of HCI and UX

To discover the high level research categories, citation network of the 254 journals, which published at least one paper related HCI/UX is visualized and clustered (Garfeild, 1972; Otte and Ronald, 2002; Carelo-Nadina, 2008). For each of the 254 journal articles published at least one paper related to HCI and UX together, within the time frame of 1990 to 2016, the total link strength of journals citation network was calculated and the journals with the strongest total links were selected and visualized. Consequently, only 49 journals had strong citation link to each other. The network normalized by the association strength (Courtel et al., 1998, Van-Eck et al. 2007) between journals and laid out by linlog modular class (Jackomy et al. 2014) applied to get optimal cluster of research interests of focus in the context of HCI/UX. We discovered six clusters of journals citation network as presented in six different colors as shown in Figure 3.2. The detected six clusters are summarized in Table 3.3. In the citation network, the color intensity from blue to red of the clusters shows

the level of cluster density or internal development of the category of the research.

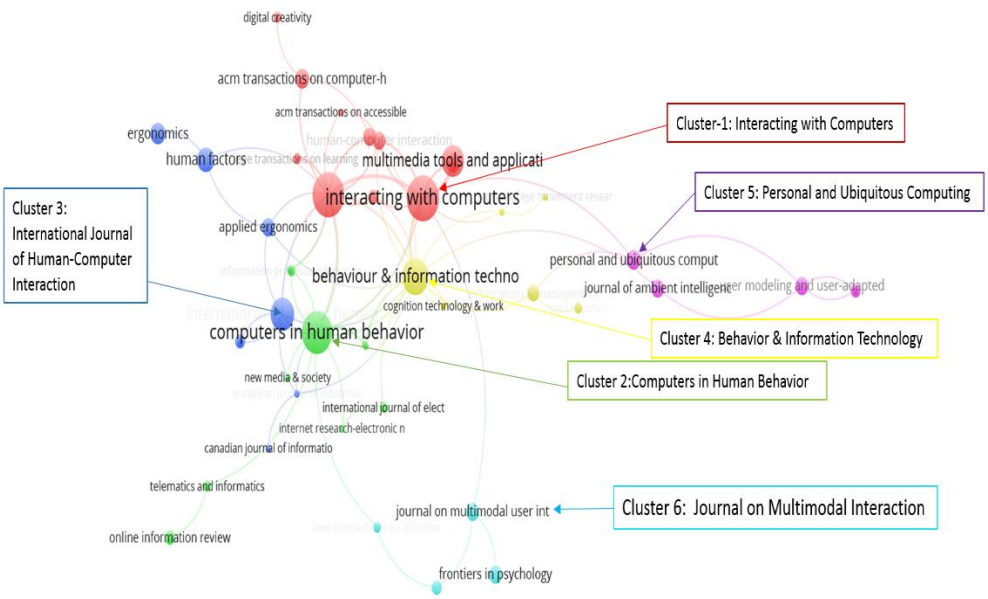


Figure 3.2 Citation Network of Journals Published Papers in HCI/UX domain, 6 clusters with different colors red, green, and blue to show level of maturity or density high. Moderate and low respectively

The cluster name is the journal name with bigger fonts in each cluster based on the degree centrality (citation link). For readability, clusters with their member citing journals are summarized Table 3.3. Accordingly, cluster 1 (Interacting with Computers) has a cluster size of 15. The second cluster (Computers in human behavior) has a cluster size of 10. But when we search the publications size of the journals, journal of computers in human behavior is 4771. The number of publication for journal of interacting with computer is 933.

Table 3.3. Clusters of citation Network of Journals Contributed to the development of HCI/UX Thematic structure and Member Journals

Number	Cluster Name	Cluster size	Member Journals in the Cluster
1	Interacting with computers	15	International Journal of Human Computer Studies ACM Transaction of Accessible Computing ACM Transaction on Human Computer Interaction Advances in Human Computer Interaction Computers and Industrial Engineering Digital Creativity, Human- Computer Interaction IEEE transaction on Learning Technologies Internet Research Journal of Intelligent Manufacturing Journal of Medical Systems, Journal of the association of Information Science and Technology Multimedia tools and applications Universal access in information society
2	Computers in Human Behavior	10	Information Processing and Management International Journal of Electronic Commerce Displays, Eurasia Journal of Mathematics Science and Technology education European Review of Applied Psychology Internet Research-electronic networking applications and policy New media and society Online Information Review, Telematics and Informatics
3	International Journal of Human-Computer Interaction	8	Applied Ergonomics Canadian journal of Journal of library and Information Science Codesign-International journal of cocreation in design and the Arts Ergonomics European Journal of Industrial Engineering Human Factors International Journals of Medical Informatics
4	Behavior and Information Technology	7	ACM transaction on Information Systems Cognition Technology and Work Information and Management International Journal of Industrial Ergonomics Journal of eye movement Research Travail Humain
5	Personal and Ubiquitous Computing	5	International Journal of Engineering Education, Journal of Ambient Intelligence and Smart Environment Requirements Engineering User Modeling and User Adapted Interaction
6	Journal of Multimodal User Interfaces	4	Frontier in Psychology, IEEE transactions on cybernetics, IEEE on Affective computing

Using conceptual hierarchy, the six clusters are categorized into three broad categories of research interests in the context of HCI/UX. These three categories are:

Category 1: Clusters 1 and 3 were combined: Computing, Humans and Interactions (well matured category)

Category 2: Clusters 2 and 4 were combined: Computing, Humans and Behavior or Information Behavior (selected as the topic of the second case in this dissertation) (matured category)

Category 3: Cluster 5 and 6: Ubiquitous Computing and Multimodal User Interface (emerging one)

Therefore, the whole 519 articles published in the 254 journal are considered and covered in chapter three, in this chapter (chapter three) of the dissertation.

Chapter four of this dissertation deals with one of three high level research categories systematically detected by the above procedure i.e. Information Behavior.

3.4.2 Visualization of ADKs' Cluster Network and Analysis

As discussed in the methodology section, in chapter 2 in general methodology and section 3 particular to this chapter, the purpose of this subsection is to map thematic areas, thematic areas' evolution, and conceptual overlaps in the thematic formation of different periods. The classification of the thematic

areas into different status and roles is also performed based on centrality and density of the cluster or thematic networks.

For this purpose constructing and clustering the ADKs network into thematic areas is important. We constructed the ADKs network, mapped thematic area evolutions using evolution map, classified the detected thematic areas using strategic diagram for their relative position and observed their overlapping using stability map. We also characterized the discovered thematic areas using number of articles, citations, h-index.

The network of each thematic areas were presented for each sub-time interval. The properties of the detected thematic areas (clusters) is presented in Tables 3.4 and 3.5.

In all cases, the occurrence of the keyword included in the construction of the network was limited to at least two. A minimum of 1 and maximum of 15 ADKs are included in a thematic network.

3.4.2.1 Thematic Networks of Time Interval 1990-1999

The time interval of 1990-1999 accounted only for 44 papers, ADKs having at least one occurrence. The simple network of this time interval is as presented in Figure 3.3, case A and case B. Case A treats this time interval's construction of network with same parameters as other time intervals. However only one

theme (user interface) showed up in this time interval when minimum occurrence is fixed to two.

The first time interval was investigated by giving special parameters in terms number of occurrence of ADKs in case B for the interest of observing low level themes emerged during this early time interval. In Figure 3.3, case of A, User Interface is at the center and the network is named by it. In the case Figure 3.3, case B, the Training became a central concept and user interface became a member concept of Training thematic area. Related to Training, concepts: software engineering, human factors, end users, user interface, mental models and motivation were very important. In terms of the strength of link, Human Factors and User Interface are highly linked to training. The link between human factors and software engineering is too strong during this early time. The concept (ADK) motivation is strongly linked to end user. Over all, it is possible to say that the early time is devoted to user interface engineering and focus on training for better usability.

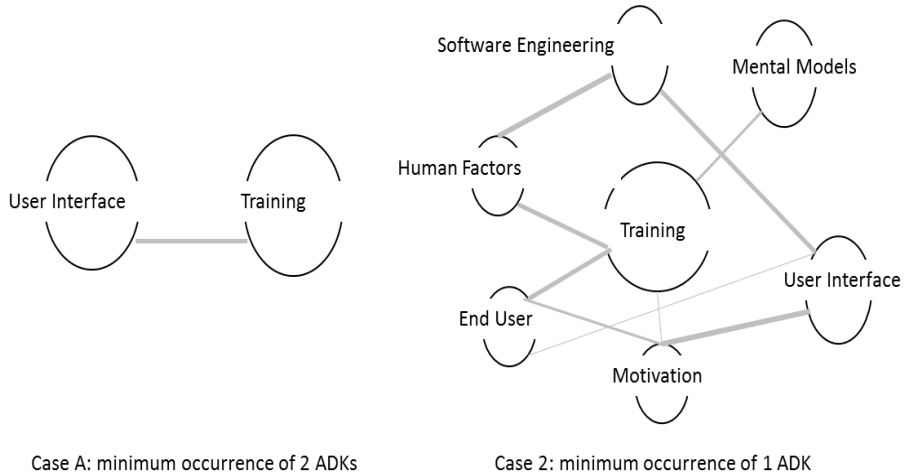


Figure 3. 3: Thematic Network of the time interval 1990-1999 in HCI/UX

3.4.2.2 Thematic Networks of the Time Interval 2000-2009

During this time interval, a total of 516 keywords were used in 165 journal articles. Out of tis 108 ADKs were included in the thematic network formation after preprocessing. Figure 3.4 shows the networks of thematic areas generated during this time interval. The number of clusters or thematic areas have grown from one in the time interval 1990-1999 to eight in this time interval with the same parameters. The eight thematic areas are *Usability, User Research, Design, Presence, and Psychometrics, Decision Support Systems, Software Design and Adaptive Systems*. Software design and adaptive systems thematic areas are very simple clusters having on two member nodes (themes). Software Design is linked only to concept self-service. Adaptive System is

linked to learning. Decision Support System thematic area has related concepts Anthropomorphism and Interaction. In the subgraphs or thematic network for this time interval, ***Usability and User Research*** thematic areas are with a complex and large cluster size (maximum cluster size set as a parameter i.e. 15 for cluster formation). It is also proved from the strategic diagram Figure 3.4 that both happen to be in quadrant of core (mainstream) thematic areas during this time interval. This means they are both strongly central and highly dense thematic areas in shaping the thematic structure of HCI/UX during this time interval. Usability strongly linked with member concepts- experience design and technology acceptance. The big concepts in the cluster network of Usability include: hypermedia, interface design, Artificial Intelligence, cognitive models, user centered design and human factors. A strong link between members concepts (ADKs) observed in this thematic area network is information visualization and ontologies, between navigation and Artificial intelligence. The big concepts (ADKs) in the thematic network of User Research include ubiquitous computing, user interface, augmented reality, task performance and context awareness, speech recognition, participatory design in this time interval. Design thematic network took a star network shape. It is at center of multimedia, electronic commerce, instruction, experimentation and education. We presented a separate clusters network of this period in Figure 3.3.

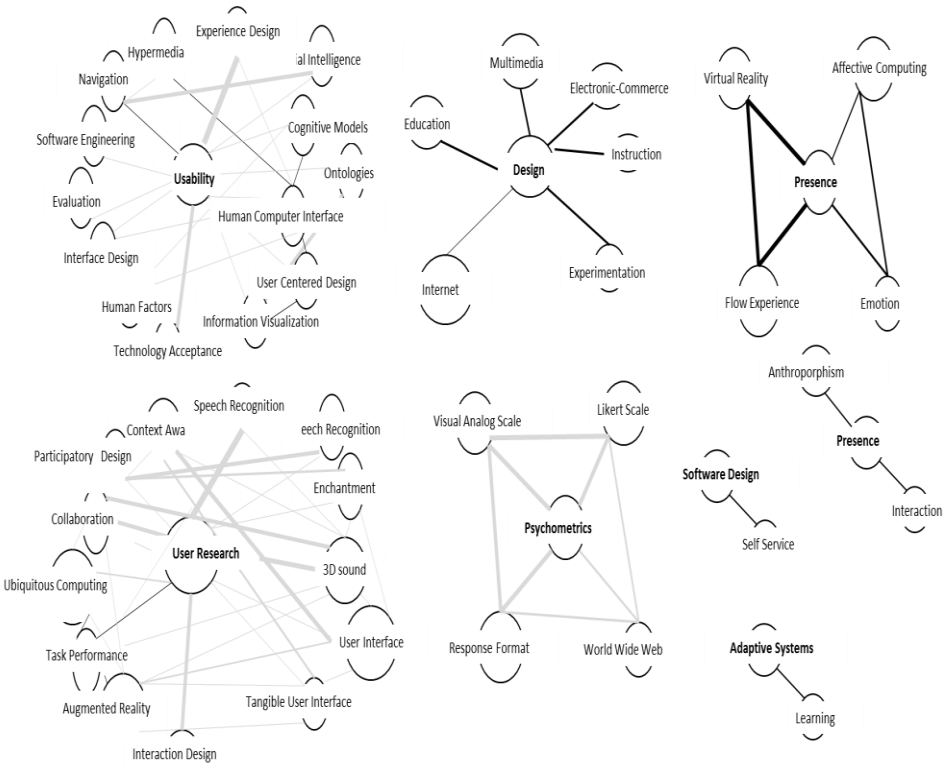


Figure 3.4. Thematic Areas Subgraphs of the Time Interval 2000-2009 in HCI/UX, bold ADKs at the center are theme names

3.4.2.3 Thematic Networks of Time Interval 2010-2016

The thematic areas discovered were during this period are *Usability, Aesthetics, Design, Emotion, User Interface, Ubiquitous Computing, Emotion, Virtual Reality, Recommender Systems, and Empirical Studies in HCI, Human Centered Design, Computer Vision and Haptics. Design* thematic area has continued from the period 2004-2010 but got complex in this time interval. *Usability* continued from 2000-2009 but got less sparse.

Aesthetics evolved as a big new thematic area network here with the cluster size of 15 in this time interval. User Interface thematic area has re-evolved in this time interval as thematic area with the maximum cluster sized used to cluster network i.e. fifteen ADKs belong to this thematic area. Ubiquitous Computing is newly evolved as a thematic area with cluster size of eleven.

Thematic areas Emotion and Virtual Reality seven and three member concepts (ADKs) respectively. The rest of thematic areas *Recommender Systems, and Empirical Studies in HCI, Human Centered Design, Computer Vision and Haptics* have member concepts of two.

With regard to the inter-time interval linkage, we need to see level of thematic evolutions, overlaps and relative strengths as a motor (mainstream), basic, emerging or declining and developed and isolated themes. The two subsections 4.3 and 4.5 will deal with exploring these issues.

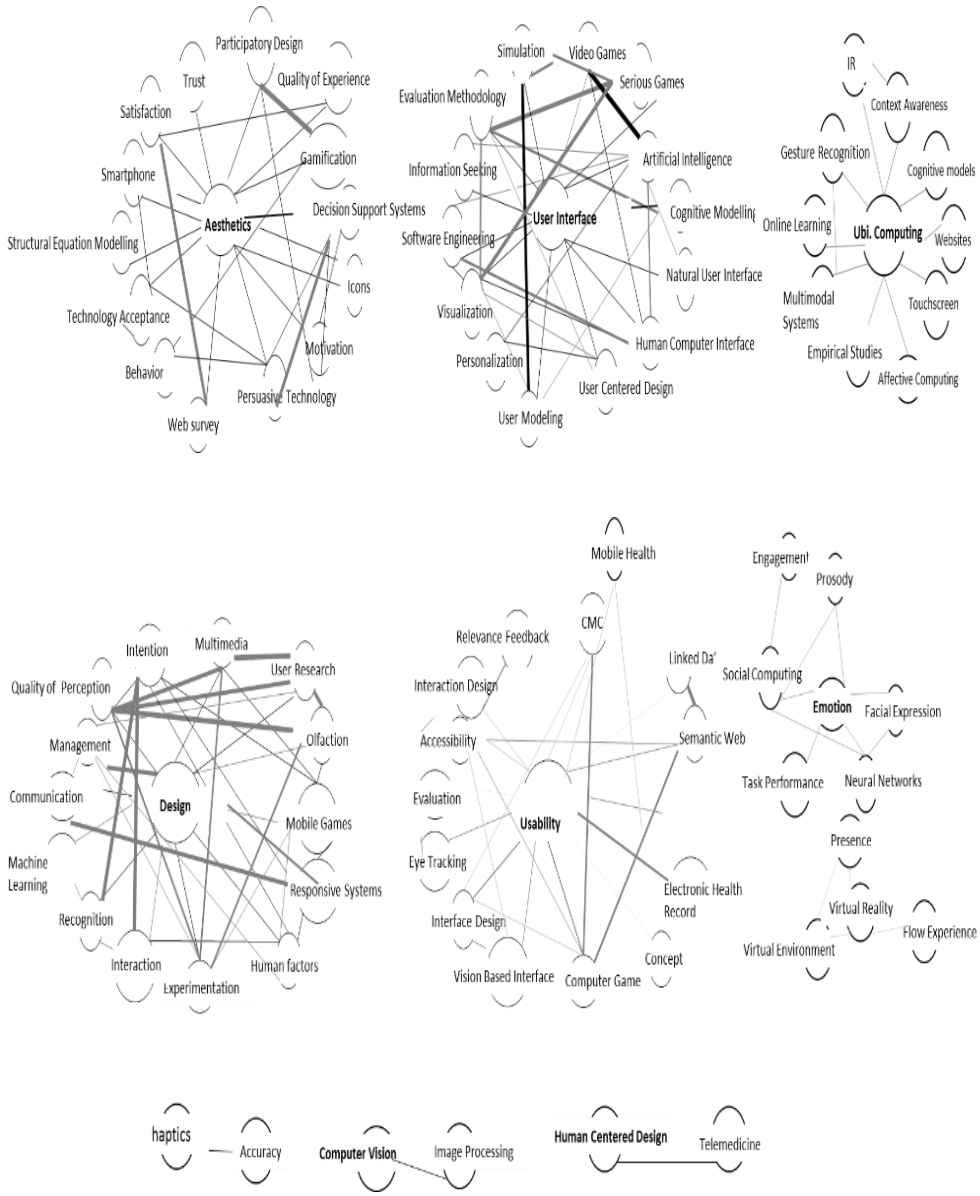


Figure 3.5. Thematic Areas subgraphs of the of Time Interval 2010-2016

3.4.3 Card Sorting of the Thematic Areas Discovered in the Domain of HCI/UX

To add another analysis dimension, the themes discovered in all time intervals are mixed and manually categorized into different high level concepts using card sorting methods by experts. Example of the result of the card sorting is as presented in Figure 3.6. The final grouping of the themes after discussion with the experts, are labeled with high level concept, which represent the group as a subject matter they addressed. The groups were color coded. The groups' details are summarized in Table 3.4.

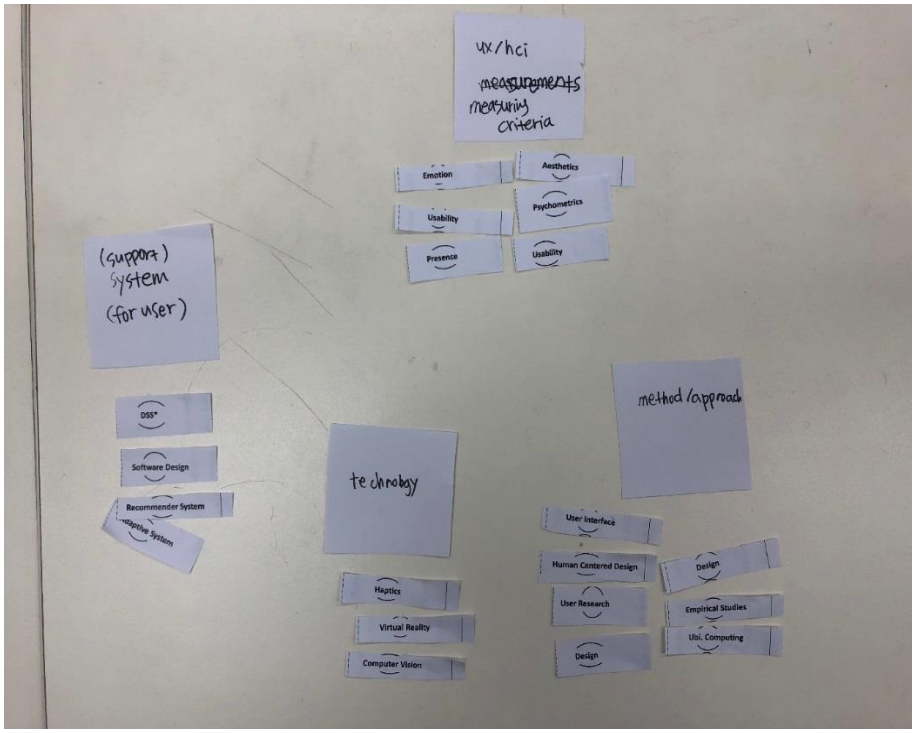


Figure 3.6. Sample Card sorting to group the Discovered Themes in HCI/UX Domain.

Table 3.4: Group of Discovered Themes in HCI/UX Domain by High Level Concepts and Color Code

Group Number	Group Name	Member Themes	Color Code
1	**Measurement**	1. Usability 2. Psychometrics 3. Presence 4. Aesthetics 5. Emotion	
2	**Technology**	1. Virtual Reality 2. Computer Vision 3. Haptics	
3	**Systems**	1. Decision Support Systems 2. Adaptive Systems 3. Recommender Systems	
4	**Methods/Approach**	1. User Interface 2. Human Centered Design 3. User Research 4. Design 5. Empirical Studies 6. Ubiquitous Computing	

When we see Table 3.4, the domain dealt more on methodology/approach and measurement criteria to study interaction with, users' behavior and usages of technology and/or systems. These groups' color codes are used as color of themes in evolution pattern discovery and themes classifications. The high level concepts Technology and Systems are not mutually exclusive groups but it's for septicity of discussion in this context. It can be grouped as Technology/System together.

The thematic area User Interface can also be appearing anywhere in technical or approach/method, however we considered it as an approach in the paradigm shifts of HCI/UX as the early time of HCI dealt with ensuring designing, implantation and

effectiveness and efficient user interface for interacting with technology/systems. Over period, the paradigm shifted to User Research in 2000-2009 (see Figure 3.8, evolution pattern). In 2010-2016, the paradigm shifted to Usability, User Interface Aesthetics as core areas. Usability is considered as a measurement criterion for the effective and efficient interaction with technology/systems to achieve users intended goal in this research.

3.4.4 Themes Overlapping and Evolution Pattern Discovery in HCI/UX over Time Intervals

In this subsection, we map the dynamics of thematic areas in terms of conceptual (ADKs) overlap and thematic evolution patterns.

3.4.4.1 Conceptual Period Overlap

The thematic overlapping is mapped using Jaccard's Index. Thematic evolutions were mapped using Inclusion Index, since it has more advantage to group similar ADKs together compared to Jaccard's Index as defined in chapter three. The stability diagram, which shows the conceptual overlapping trend of the field of study over time intervals for final dataset used for thematic network analysis is illustrated in Figure 3.5.

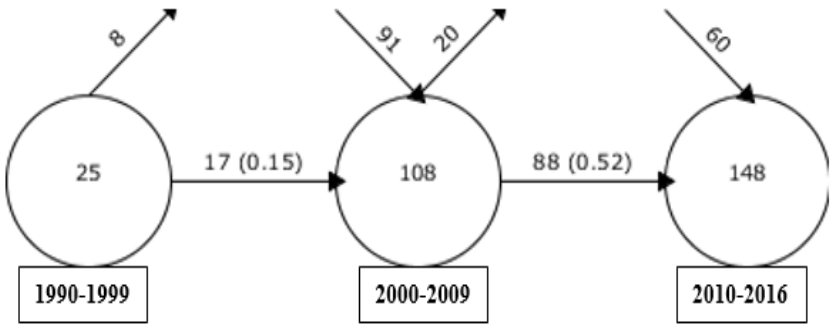


Figure 3.7. ADKs Stability Diagram in Thematic Areas Formation over the Three Time intervals in HCI/UX

As you can see, only 15% of the ADKs was contributed from the time interval of 1990-1999 to form the thematic research areas of the 2000-2009. 85% of concepts (ADKs) that formed the themes during 2000-2009 were newly emerged. The time interval 2000-2009 contributed 52% to the formation of thematic areas of 2010-2016. Only 48% of the ADKs formed the thematic areas of 2010-2016 were newly emerged. This shows that, there an increasing conceptual stability over period due to the increase ADKs overlap. Though there is a higher dynamism of thematic areas, conceptual stability increased between 2000-2009 and 2010-2016 than between 1990-1999. 32% of the themes in 1990-1999 were obsolete to pass to the thematic areas formation in the time interval of 2000-2009. 18% of the themes in the time interval of 2000-2009 were obsolete to pass to the thematic formation of time interval of 2010-2016. In Figure 3.8, we can see the evolution and interlinkages in the manner that it shows the origins of thematic areas as well as their relative development.

3.4.4.2 Evolution Pattern Discovery in the Domain of HCI/UX

In the evolution pattern discovery map, only one strong thematic area was evolved during 1990-1999 i.e. User Interface is at the root of the thematic areas evolved in later periods.

User Interface from 1990-1999, has a thematic overlap with User Research in the time interval 2000-2009. They are linked with solid lines because User Interface became a member concept of the theme User Research in 2000-2009. This shows that the focus from User Interface based approach to HCI/UX study to the broader human oriented approach i.e User Research. Usability and Design continued from 2000-2009 to 2010-2016. This indicates that these two thematic areas are sustaining their autonomy as a focus area of research over last decade and the current decade in the domain of HCI/UX.

Usability, User research and Presence thematic areas in 2000-2009 served as origins for the emergence of big thematic areas in 2010-2016. Usability thematic area in 2000-2009 served as the origin of Aesthetics, Design, and User Interface and Ubiquitous Computing research thematic areas. User Research thematic area from 2000-20009 has a contribution for the evolution of Aesthetics, Design, User Interface, Usability, Ubiquitous Computing and Emotion thematic areas in 2010-2016.

Presence in 2000-2009 has strong conceptual link with Virtual Reality in 2010-2016. Presence in virtual space was an issue during 2000-2009. It became a concept studied in context virtual reality in 2010-2016 or a measurement criterion on how people feel presence in the virtual space.

Decision Support System has strong conceptual link to Aesthetics through sharing main concept i.e. decision support systems became a member concept of Aesthetics and shared none main none main ADK with Design thematic area. Adaptive Systems and Software Design thematic areas are isolate thematic areas in 2000-2009 in terms of evolution line the thematic structure of HCI/UX.

More isolate thematic areas without evolution links evolved in 2010-2016 because in their thematic formation, they didn’t share any concept from the preceding period. These are Haptics, Computer Vision, Empirical Study, and Human Centered Design and Recommender Systems. When we investigate their relative position in a strategic diagram, they happened to be in the well-developed and peripheral quadrant. See Figure 3.9.

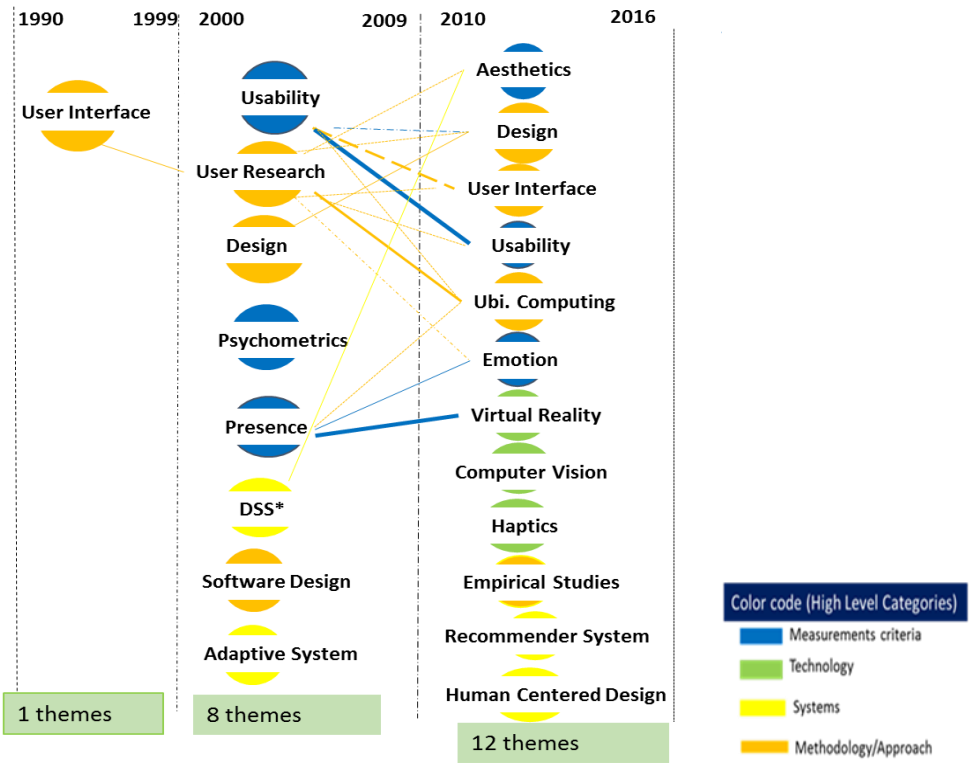


Figure 3.8. Evolution Patterns and Subject Matter Groups by colors of Thematic Areas over the Three Time intervals

3. 4.5 Strategic Diagram of the Three Time intervals of HCI/UX

In Strategic Diagram, the X axis show the centrality and Y axis shows density of the themes. It is helpful to show the motor, basic (transversal), declining or emerging and developed and isolated thematic areas in certain field in four quadrants. It is used in many similar works as effective strategy to classify thematic areas using centrality and density ranges (minimum 0 to maximum

1). The structure and detailed description of strategic diagram is presented in presented in in chapter two (methodology)

Table 3.5. Clusters and Their Graph Properties of the Time intervals 1990-1999 and 2000-2009 in HCI/UX

Time Interval	Cluster No	Theme Name	Centrality Range	Density Range
1990-1999	1	User Interface	1	1
2000-2009	1	Usability	1	0.62
	2	Use Research	0.75	0.75
	3	Design	0.62	0.5
	4	Adaptive System	0.62	0.12
	5	Psychometrics	0.5	1
	6	Decision Support System	0.38	0.25
	7	Presence	0.25	0.88
	8	Software Design	0.12	0.38

Table 3.6. Clusters and Their Graph Properties of the Time intervals 2010-2016 for HCI/UX

Time Interval	1	Cluster Name	Centrality Range	Density Range
2010-2016	1	Usability	1	0.33
	2	Aesthetics	0.92	0.92
	3	Design	0.83	1
	4	Emotion	0.67	0.42
	5	User Interface	0.67	0.83
	6	Ubiquitous Computing	0.58	0.08
	7	Virtual Reality	0.5	0.17
	8	Human Centered Design	0.42	0.25
	9	Recommender Systems	0.33	0.25
	10	Empirical Study	0.25	0.58
	11	Computer Vision	0.17	0.25
	12	Haptics	0.08	0.5

Values centrality range and density range are used to classify the themes in the four quadrants of strategic diagram in Figure 3.9. As mention in the operational definition, centrality measures the strength inter thematic

connections and density measures the intra-thematic total link strength (cohesion). High centrality means the theme has high level of influence as a center of the thematic structure. Themes with higher centrality would have two roles in the entire knowledge structure i.e. either core/mainstream or basic role.

Less centrality means theme has less influence in being central to the entire thematic structure. Themes with weak centrality plays either emerging/declining role or developed and peripheral role.

High density means the discovered theme has strong internal cohesion to stand as autonomous thematic area to be studied in certain particular time. Themes with high density would have two possible roles i.e. either core/mainstream or developed and peripheral role.

Low density means the theme has less likely stand by itself as autonomously to be studied. Themes with low density would have two possible roles i.e. play an emerging role or basic role in the entire thematic structure. To know the roles themes in the entire thematic landscape based on the combination of these possibilities, we need to map into the strategic diagram. The classification themes role for HCI/UX is presented in Figure 3.9. Based on these definitions the themes in Figure 3.9 can be interpreted as follows.

The theme one User Interface in HCI/UX domain during 1990-1999 has happened to be core/main theme. There was no basic theme, emerging

/declining theme or developed and peripheral theme during this period. It was so early during this time interval in the scientific base of this domain connecting HCI and UX.

During 2000-2009, two core/mainstream themes i.e. User Research and Usability and Design appeared as core/mainstream themes. Psychometrics was highly dense and moderately central and between developed and peripheral. The highly developed and isolated theme during 2000-2009 is Presence, which is highly linked to virtual reality in thematic evolution pattern map during 2010-2016.

The two emerging or declining themes are decision support systems and software design during 2000-2009. Design is on the border to consider a motor theme during this time interval. The one basic and transversal theme in scientific discourse of this field was adaptive systems.

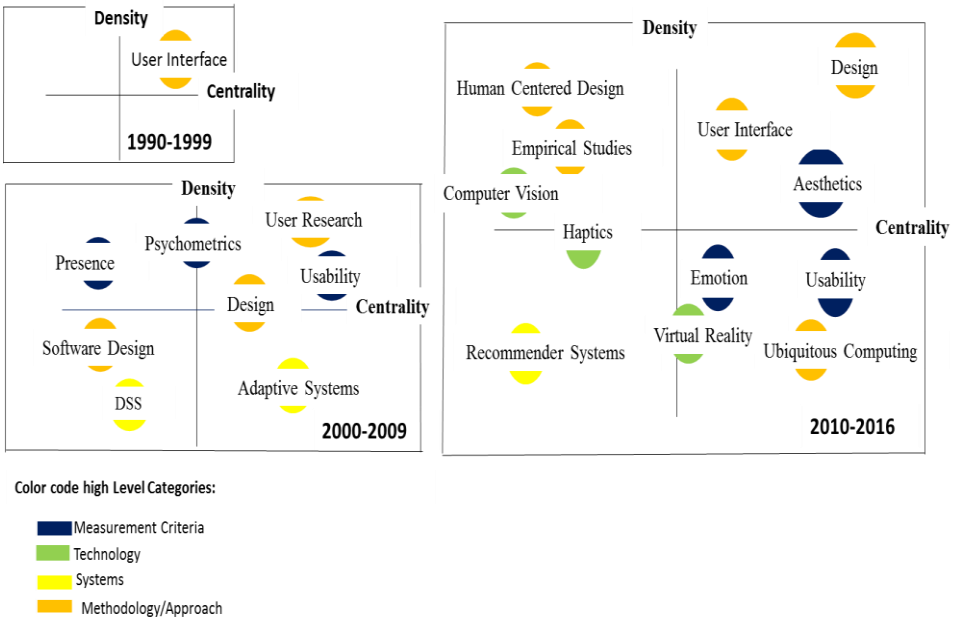


Figure 3.9. Classification of using by Centrality and Density (positions) and high level concepts (colors) for the three Time Intervals

During the 2010-2016, User Interface (re-emerged) and Aesthetics became two new important core themes and Design continues as a core from previous period. This shows that core changes over/main stream changes over period.

Usability, Ubiquitous Computing and Emotion, become basic and transversal themes in this time interval. Virtual reality became on the emerging or declining. Recommender systems is in the emerging/declining area during this time interval.

Highly developed and isolated themes during this time interval were Human Centered Design, Empirical Studies, Computer Vision and Haptics.

This shows that the field's thematic landscape is dynamic. Other researcher's findings (Liu et al., 2014) showed that HCI field has no motor themes from CHI conference papers. However, our finding shows that the situation in WoS is different and this area of study is getting more core/mainstream themes over time in its thematic structure. This shows that the journal captures more stable perspectives of the thematic than conference, which deals with more emerging issues and hence more unstable thematic structure or lack of core/mainstream areas.

3.5 Chapter Summary and Conclusion

Overall, the themes are growing and dynamically changing in quadrants of the strategic diagram. To summarize the dynamism in themes role, maturity and high level concepts and evolution patterns and conceptual overlap together over the three periods in HCI/UX is as presented Figure 3.10.

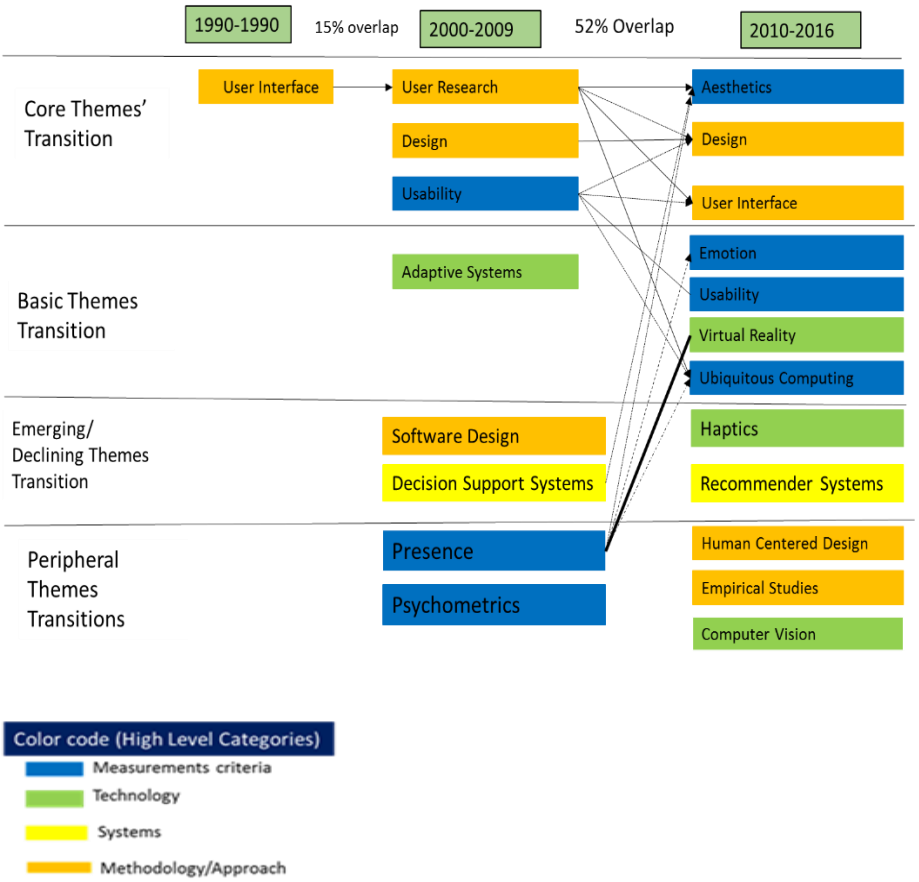


Figure 3.10 Summary of findings, paradigm shifts, evolution patterns, high level Concepts and conceptual over Periods

We combined a variety of approaches, discovered and characterized thematic areas of HCI/UX. We used the concept of graph theory and bibliometrics to visualize and analyze the ADKs cluster network. We have used concept of co-occurrence of ADKs as network metrics. Clusters of the ADKs network enabled us to detect themes containing group of highly associated ADKs. The discovered themes are grouped together into high level concept that showed subject matter addressed by the group of themes. high level concepts and their themes are; methodology/approach (User Interface, Human Centered Design, User Research, Design, Empirical Studies and Ubiquity) and measurement related themes (Usability, Psychometrics, Presence, Aesthetics and Emotions) to study interaction, users and/or usage of various technologies/systems (Virtual Reality, Computer Vision, Haptics, Decision Support Systems, Adaptive Systems and Recommender System) . To see how these themes were evolved over periods, evolution pattern discovery of themes with their group color was visualized from ADKs time overlap. Over 3 decades, themes profligate. Themes merge (converge) and split (specialize) over period, get more diversified and interconnected. All these tells us that focus of research shifted from one theme to another them over periods. High level of thematic dynamism e.g. Themes dynamism: 100% from period 1 to period 2, 83% from period 2 to period.

Early approach to HCI/UX is User Interface (approach). Got diversified subject matter (approaches and technology) dominates over period.

Centrality of the clusters showed how the themes interact with each other to shape the entire thematic structure in HCI/UX. Density of the clusters provided important information regarding which thematic areas are internally cohesive and well developed to stand by themselves as thematic areas over the three periods of analysis.

Strategic diagram helped us to classify the thematic areas discovered based on the graph properties centrality, density and the subject matter (by color of the group).

The concept of time (temporal analysis) by partitioning publications into time intervals enabled as to see the Temporal based evolution patterns of thematic areas in the field of HCI/UX. User Interface engineering and training were two big issues during 1990. Usability, User research, design and Presence were big thematic areas during 2000-2009. These got more specialized in the time interval 2010-2016 since their member ADKs in the thematic network during 2000-2009 were grown themes in 2010-2016. Usability and Design also sustained their thematic status over the last two time intervals. The themes detected in the year 2010-2016 and their member ADKs would be important research themes in the years to come based on the pattern observed between the periods 2000-20009 and 2010-2016.The field of study is still dynamic and

in shaping as its stability conceptual stability between 2000-2009 and 2010-2016 is less than 52%. The thematic stability is 16% for the same period.

Regarding general trends, we showed the countries contributed most towards the development of the thematic structure of the field. The development in the journal articles and the peak time for development trend i.e. since 2011, increase dramatic. We identified the top journal venues for research outcomes in the area. The top disciplines contributed to the development of the thematic structure of HCI/UX are also identified.

By discovering important insights and dynamics of the thematic structure of the HCI/UX, from a large publication dataset, we have proved that the proposed methods is effective to address the stated research goals, as we could answer all our research questions in a satisfactory way with the stated limitations of using ADKs for content representation and coverage of data from only one source. This approach is promising in identifying complex knowledge in the body of knowledge that exists in converged field of studies in the future. This study can be extended to further bibliometric analysis like co-citation network analysis, co-authorship network analysis and bibliographic coupling network analysis to dig into specific social and intellectual thematic structure in the future. This paper mainly focused on the conceptual (thematic) thematic structure of the research area.

Chapter Four

Author Defined Keyword Network Analysis for Thematic Discovery and characterization in Information Behavior Domain

Abstract

This paper presents the thematic areas of the convergence between Information Behavior over time-frame of 28 years (1990-2017). It also presents general trends and patterns over time. 4771 journal articles published in the journal of computers in human behavior over the stated time-frame were retrieved from Web of Science. The timeframe was partitioned into three 1990-2003, 2004-2010, and 2011-2017 for longitudinal conceptual and thematic analysis. Author Defined Keywords' (ADKs) co-occurrence network analysis was used for discovering the thematic research areas. We combined different techniques of graph theory and bibliometric analysis methods for thematic extraction characterization in the research area. It was found that the themes of research grew from three in the time interval 1990-2003 to eleven in 2004-2010 and 34 in the time interval 2011-2017. The growth is dramatic and dynamics is huge for thematic areas connecting Information Behavior over the three periods. Research themes Computers, Human Computer Interaction and Gender Difference in the first time interval were at the root of multiple and specialized research thematic areas in the latter two time intervals. The

research effort in this convergence research area revolve around how elements of human behavior affect technology perception, acceptance and/or adoption, interaction and use computing devices and applications as well as role of technology in changing human behavior and consequential impacts on social and individual well-being. It also touches how to make technology more human behavior aware.

Keywords

Information Behavior, Computing, Thematic Structure, bibliometric, thematic discovery, Thematic Characterization

4.1. Introduction

4.1.1. Background

These days computing devices or digital technologies and applications are ubiquitous and pervasive in every walk of life of human being (Johanson et al., 2002; Attewel, 1992). The computing devices takes a form of personal computers, smartphones, the Internet, web applications, mobile applications, digital assistants, wearables, Internet of Things and cloud computing etc. (Jeon et al. 2007). There are a lot of applications and services available through these computing devices and applications platforms (Prieto and Revilla, 2005). The areas of applications include communication, education, business, healthcare, education, entertainment, military, manufacturing, transportation, engineering, energy saving, research etc… (Luck et al., 2993; Attewell, 1992; Kittur et al., 2008; Park et al., 2015). Human behavior is a very important aspect of human life relevant to computing field of study in this digital age (luck, 2003). Innovative interactive systems flourishing these days are to be used by humans. As such, the perception, adoption, acceptance, interaction and usage are affected by human behavior. Uses of those devices and applications also affects human behavior and wellbeing (Prieto and Revilla, 2005). There is also a notion that asserts benefits that computing or digital technologies and applications provide to human beings are not intrinsic within

themselves but lay within the way we use them in our everyday life (Godzinski, 2005).

This is to say that the effect of use of computing devices and applications would be good or bad based on the way people use them. From philosophical point of view, these issues extend to ethics of technology use (Boyle et al., 2011). There is also an effort to make digital interactive systems more human behavior (context)-aware to promote better user experiences, particularly in the growing interest in Artificial Intelligence (Boyel et al., 2011; Chen and Kotz, 2000).

Therefore, human behavior has been important subject of study related to computing systems (digital technologies) since people began using computing devices as a tool to solve human problems to successfully survive in its environment pertaining to information processing, sharing, storage, communication and collaboration (Boyle et al., 2011; Pantic, 2007).

As a result of this, many research works have been conducted at the intersection of computing and human behavior. Those works extend to explore impacts of use of computing devices and services on individual and social groups and the role of human behavior in in successfully interacting and utilizing those technologies and services in the digital ecosystem (Devis, 2001; Ross et al., 2009; Morahan-Martin and Schumacher, 2000; Kreijns et al., 2003; Zhao et al., 2008; Correa et al., 2010; Webster, 1993).

Careful revisiting of the research outcomes connecting Information Behavior has tremendous importance for the community of scholars and practice to show the past and current trends and to figure out its future perspectives. Exploring the past and present scientific publications of large size over long time intervals would show trends, patterns, evolutions, linkages, level of developments (impact and influences), diversification and obsolescence of thematic areas of research and their performances at the intersection of these two important aspects of human life in the digital age (Curtail, 1986; coulter et al., 1998; He, 1999; Cobo et al., 2011). This helps to make good research planning and use the effort, energy and money to the right direction. It also helps the increase the relevance to research outcomes to address the timely research problem and consequently contribute to the human wellbeing.

It also helps to understand the dynamism in the research themes, the social structure and the intellectual composition and collaborations (Courtail, 1986; Leydesdorff and Rafols, 2009; Porter, and Rafols, 2009).

One of the venues for communicating the intellectual outcomes of the scholars are journals (Popper, 2014). In the 1960s, it was assumed that the number of publications doubles every 20 years however in 1990s it happened to be doubling every 20 months (He, 1999, pp. 34). As the size of publications dramatically increases, however, it is not easy to extract important insights for the research community (He, 1999, Huang et al., 2017).

Researcher make discoveries and advance scientific progresses in laboratories or field observation to change the world, others follow their works and know the world and make further scientific discoveries to make a world a better place. The relationship among the discoveries or dynamics in scientific findings is not easy to understand. The power of the words researchers uses to represent their work is great since they embed their understanding in their field of study on paper to let others know (He, 1999). Following their text and finding the relationship among them helps to understand the scientific discoveries (Coulter, 1986; Callon et al. 1991; Courtail, 1998).

Therefore, our research is aimed at exploring the thematic areas of focus and their dynamics in the thematic structure at the crossroad of computing and human behavior. We discovered thematic areas and characterize them using Author Defined Keyword co-occurrence network analysis (Boyle et al., 2011; Leydesdorff and Rafols, 2009). There was no scientific work that explored the convergence between Information Behavioryet.

This approach is free of subjectivity or manipulation of the researchers unlike that of traditional literature survey of limited number of papers. This approach directly discovers patterns from the actual work of scientific publications of large size as authors represented the content in their work by ADKs (Coulter et al. 1998; Liu et al., 2014; Callon et al, 1991).

We characterized the discovered themes with more dimension of analysis as possible combining from graph theory and bibliometric like clusters and their graph properties (centrality and Density), evolutions linkages and conceptual overlap, classification of themes into different type of role and level of development based on centrality over periods (Porter and Rafols, 2009; liu et al., 2014; Cobo et al. 2015).

For this purpose, selecting the appropriate journal whose publication source can tell the story is mandatory [Neuhaus et al., 2008; Liu et al., 2014; Cobo et al. 2015]. In exploring the knowledge structure of User Experience/Human Computer Interaction in the first research of this dissertation, it was found that journal of computers in human behavior is one of the top contributing journals to the interdisciplinary domain Information Behavior within the context of HCI/UX.

Therefore, Journal of Computers in Human Behavior is selected to be analyzed in this research to answer our research questions. The next step was selecting the appropriate bibliographic database to acquire the full bibliographic records of the journal articles. We found that web of Science (WoS) is a comprehensive bibliographic database for peer reviewed journal articles (Ellegaard and Wallin, 2015). We retrieved 4771 journal articles published in the journal over the timeframe of 1990-2017-July-31st in plain text format with full bibliographic records. Since ISIWoS allows only 500

records to download at a time, we should have iterated for ten times to get the whole journal articles. The ten fragmented text files were integrated into a single text file for further preprocessing, visualization and analysis.

SciMAT science mapping software was used for preprocessing and analysis; since it has comprehensive functionalities for our research goal. Extensive preprocessing activities were carried out to avoid duplications due to word forms, synonyms, abbreviations, for time slicing, and partitioning the timeframe into time interval to make the data more meaningful and suitable for longitudinal analysis.

Descriptive statistical summary measures of papers, Author Defined Keywords (ADKs), authors, contributions and collaborations patterns were made. The unit of analysis is Author Defined Keywords (ADKs), which is a co-word analysis. The network metrics used was co-occurrence of ADKs and normalized by association strength. The 28 years' timeframe was partitioned into four time intervals having each seven years of intervals (1990-1996, 1997-203, 2004-2010 and 2011-2017) primarily. The experiment was carried for thematic area mapping for those time intervals. Since the first time interval 1990-1996 has not shown any theme for the minimum parameter used for thematic network mapping, we decided to merge the first two time intervals into one-time interval i.e. 1990-2003 to get a more meaningful pattern of thematic area linkages over time intervals. The final time intervals used were

1990-2003 (14 years), 2004-2010 (7years), and 2011-2017 (7 years). Then the final result of the three-time interval was visualized, interpreted and analyze.

4.1.2 Significance and Importance of the research

These days we are in a situation where there is much data and less knowledge as many researchers in the data mining and big data often describe (Han and Kamber , 2011). There is a strong need of discovering trends and patterns using state of the art analysis techniques in this ever increasing publication base to drive new insights (Bornmann and Leydesdorff, 2014). These days, data is ever growing in volume over time exponentially in every walk of human life (Larsen, Von, 2010). Publication meta-data is not exceptional, where we have over 25, 000 journals and over 50 million journal papers published in a refereed journal (Larsen, Von, 2010). In addition, we are observing a growing interest in convergence of different field of study, which promotes collaboration and innovation by answering research questions that cannot be answered by any single field of the converged ones (Wuchty et al., 2007). Studying a complex relationship of science in such converging field of study is not easy. Information Behavior (conformation information technology and behavioral science) would be good case in mention of the convergence phenomena. Given the growing number of publication basis, and convergence nature of the research area, discovering important dynamics in

the body of knowledge of the selected topic is very important (Kosinski et al., 2013).

Doing so, we can show the big picture of thematic areas in the behavioral dimension of computing within the context of HCI/UX. This in turn facilitates, informed decision making with regard to research planning in the domain. It also helps research thematic area selection and increases efficiency by avoiding duplication of research efforts and promote well targeted innovative and problem solving research in the area. It also enables to evaluate the status of the research themes the doamin over the last 28 years. It can also be a corner stone for further explorative research in this area using similar and additional methods.

4. **1.3 Structure of the Chapter**

The chapter is structured into five sections having their own subsections. Section one covers introduction, section two discusses related works. Section three covers visualization and analysis of ADKs network and section five briefly summarizes the key findings and conclusive remarks.

4. 2. Related Works

4. 2.1 Works of High Impact in the Information Behavior

The role of individual differences, experience, intention, perception and attitude of computer and Internet use and related anxiety, self-efficacy in computer use were addressed by many researchers (Schumacher and Morahan-Martin, 2001; Durndell and Haag, 2002; Wang and Emurian, 2005, Chua et al., 199; Ong and Lai, 2006) . The importance of human personality traits, motivations, identity construction and digital empowerment and support groups in social network sites, particularly Facebook were also addressed by many researchers (Ross et al., 2009; Zhao et al., 2008; Correa et al, 2010). The issues of flow, behavioral intentions, and network neutrality, and motivation theory related to mobile banking and social media use were also investigated (Webseter et al., 1993; Luarn and Lin, 2005; Lin and Lu, 2011, Kuo et al.,?) Issues like problematic internet uses, cyberbullying and their consequences were studied using cognitive behavioral models (Davis, 2001; Morahan-Martin and Schumacher, 2000; Caplan, 2002; Charlton, and Danforth, 2007). Pitfalls in social interactions in computer-supported collaborative learning, cognitive skills, group learning, efficacy of individual and group learning, gender differences, face to face vs online learning were also addressed (Kreijns et al., 2003; Kirschner et al., 2008; Janssen, et al., 2009). Issues related to

cognitive load, multitasking, social media use vs academic performance, media induced task switching while studying, too much social media vs attentive reading, use of social media and personality were also studied well (Corea et al., 2010; Ryan and Xenos, 2011; Kirschner and Karpinski, 2010). Topics such as virtual life, virtual gaming, finding virtual visual similarity, maternity in virtual world and romantic virtual life were also investigated (Pierce, 2009; Drouin and Landgraff, 2012). Topics like crowdsourcing of user studies, improving online community experiences, adoption of online services and purchasing behavior and the issue of trust in virtual life were among well studied topics (Kittur et al. 2008; Preece et al., 2004; Zhang et al., 2014; MäNtymäKi and Salo, 2011; Wang and Chen, 2012). The studies addressed both the enabling part of computing technologies and side effect of the way people use them as well as role of human behavior in technology acceptance, adoption and use. The studies also showed the role of computing devices in changing the way people behave. However, it doesn't implicate any intrinsic harm within the technology itself, rather the benefits or negative implications lies within the way people use them.

4.2.2. Bibliometric and Graph Theory as Methods for Thematic Discovery and Characterization

A map of science shows the spatial representation of how disciplines, field of study, specialties of research thematic area evolve and dynamically changing

over time (Cobo et al., 2015; Bornmann and Leydesdorff, 2014; Larsen and Von, 2010; Small, 1999). Its analogy is the way the geographic map shows the details of geo-political and physical relationship of the features of the earth through abstraction (Small, 1999). It is powerful for simplification and high level representation of the thematic structure for easy comprehension and understanding (Cobo et al., 2011; Small, 1999). There are different software tools, techniques and methods available to explore the thematic structure of particular field of study (Van Eck, and waltman, 2010; Cobo et al., 2011). The map of thematic structure based on the publications' big data is the structure that systematically imposed on a collection of intellectual outcomes and their relationship based on established scientific tools, method for systematic understanding (Callon et al., 1991, Small, 1999; Liu, 2014). As such, it can be called discovery of knowledge about knowledge, where getting insight from large knowledge base is difficult. The detailed description of each method, tools, techniques and strategies used in this research were thoroughly discussed in chapter two of this dissertation. In this research, we used Author Defined Keywords co-occurrence network, which is a type the co-word analysis in bibliometric.

The aim exploring the research thematic areas of the behavioral dimension of computing. The journal selection based on the finding in chapter three of this dissertation. When we see the application of bibliometric and graph theory for

exploring the research themes in the thematic structure by other researchers in the related areas so far include, the knowledge structure of 25 years of journal knowledge based systems was explored using bibliometric analysis (Cobo et al., 2015). The chi conference intellectual progress from 2004-2013 was mapped in (liu et al., 2014) using co-word network analysis using graph theory and concluded that CHI has no main stream thematic areas. Software engineering area was also studied (McKain et al., 2005). Information Science field of study was also investigated (Jeong and Kim, 2005).

The thematic structure of user experience was explored using author Keywords network analysis in (Urgessa et al., 2017) and areas of focus over time intervals were identified. When we come to computing and human behavior, there is no research work related to exploring the convergence phenomena between these two fields of studies using rigorous analysis methods so far. In addition, this area of research is found to be large portion of research interests in the context of HCI/UX. Thus why we aimed to apply these techniques, methods and tools to explore and assess the thematic research areas connecting computing and behavioral science.

4.3 Visualization and Analysis

4. 3.1 Descriptive Statistical Distributions

We retrieved 4771 papers with full publication records were included in the analysis. 227 (5%) of the total belongs to the 1990-1996. 280 (6%) of the total were published within the second time interval 1997-2003. The number of papers published in the third time interval 2004-2010 is 864 (18%). In the fourth time interval (2010-2017, Jul, 31st), the number of paper was 3400 (71%). The growth in the interest of converging points of Information Behavior is dramatically increasing particularly in the last 7 years. With respect of participation of the authors, 10, 412 authors, including the co-authors participated in the last 28 years to publish their scientific papers in the journal. The authors used 142,327 references. The reference to paper ratio is 29:1 on average. The total number of Author Defined Keywords (ADKs) is 17029. Both the number of authors and papers increased dramatically over the three-time interval of analysis. The time intervals 1990-1996 and 1997-2003 were merged into one period 1990-2003 and the latter two were left as they are for longitudinal thematic analysis. See the summary in Table 4.1.

Table 4.1. Number of Authors, papers and ADKs for the three time intervals used for analysis in the IB domain over the three Period

Time intervals	Number of papers	Number of ADKs
1990-2003	507	1308
2004-2010	864	3741
2011-2017	3400	11980
Total	**4771**	**17029**

4.3.2 Popularity and Centrality of Individual ADKs

Before longitudinal analysis, the popularity and centrality of the individual Author Defined Keywords of the whole paper published in the research area in Information Behavior were calculated and the top twenty were presented in Table 4.2. The popularity of individual ADKs would not be seen in the cluster in the temporal analysis since it is named by the most central ADK using the simple centers algorithms for each period. The popularity of the ADK is its frequency among the papers as used by authors. It shows the importance or interest of the researchers in the particular ADK. The centrality of the ADK is the total link strength that an individual ADK has in the entire thematic structure and it shows the degree at which it would serve as the center of the entire knowledge structure the area of research. Centrality shows the influence of the keyword in the research area. Table 4.2 is summarizing these two important issues

Table 4.2. Top Twenty Popular and Central ADKs in Information Behavior Domain over the last 28 years.

Top 20 Popular ADKs			Top 20 Central ADKs		
Rank	ADKs	Popularity	Rank	ADKs	Centrality
1	Social Media	265	1	Facebook	549
2	Facebook	240	2	Social Media	501
3	Internet	209	3	Internet	395
4	Computer Mediated communication	114	4	Personality	238
5	Personality	106	5	Gender	225
6	Gender	102	6	Computer Mediated Communication	195
7	Internet Addiction	92	7	Motivation	182
8	Adolescents	82	8	Internet Addiction	167
9	Motivation	81	9	Adolescents	162
10	E-learning	69	10	Technology	137
11	Collaborative Learning	67	11	Video Games	131
12	Self-Efficacy	64	12	Self-Efficacy	128
13	Twitter	64	13	Twitter	127
14	***Trust****	63	14	Self-disclosure	125
15	Cyberbullying	62	15	Anxiety	119
16	Video Games	61	16	***Loneliness***	113
17	Technology	58	17	Cyberbullying	107
18	***Cognitive Load***	53	18	*Depression*	104
19	Self-disclosure, ***Human Computer Interaction***, Computer Anxiety, Uses and Gratification	52	19	E-learning	101
20	Theory	49	20	***Self-esteem***, uses and gratification	100

**** Bold and Italic are ADKs which belong to only one of the attribute i.e. either central or popular but not both***

4.3.3 Theme Networks of the three Time Intervals

Theme network shows the inter-connection between or among the ADKs falling in the same cluster and considered as theme. They are sorted by the centrality of the cluster for each time interval. Theme name is the central ADKs for each cluster. For example, in Figure 4.2, Cluster one's name is Computers and so on. The following parameters were used for analysis. Unit of analysis is ADKs. Data reduction technique used by was limiting the minimum occurrence of ADKs threshold to five. The network metrics used was co-occurrence of ADKs. Similar clustering algorithm is used with that of the first research (simple center algorithm). Minimum and maximum number of ADK in cluster is set to 1 and 15. The whole networks of the first period is presented the top cluster/thematic network of the two latter periods are illustrated. C-1 to C-n labeled for more identification of each cluster.

4.3.3.1 Thematic Network of the Time interval 1990-2003

This time interval has got three themes and their cluster or thematic network is as presented in Figure 4.1. The clusters or themes are represented by Computers, Human Computer Interaction and Gender Differences, which are the central ADKs for the cluster networks as shown Figure 4.1.

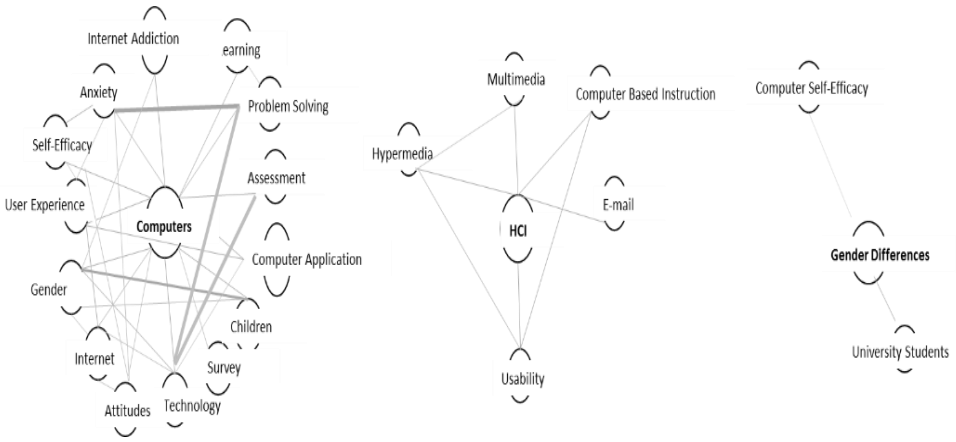


Figure 4.1 Cluster or Thematic Networks of the three themes during Time interval 1990-2003 in IB Domain

4.3.3.2. Thematic Network of the Time interval 2004-2010

This time interval has got eleven clusters or themes of research at the intersection of computing and human behavior. The top nine significant network clusters or themes are Figure 4.2.

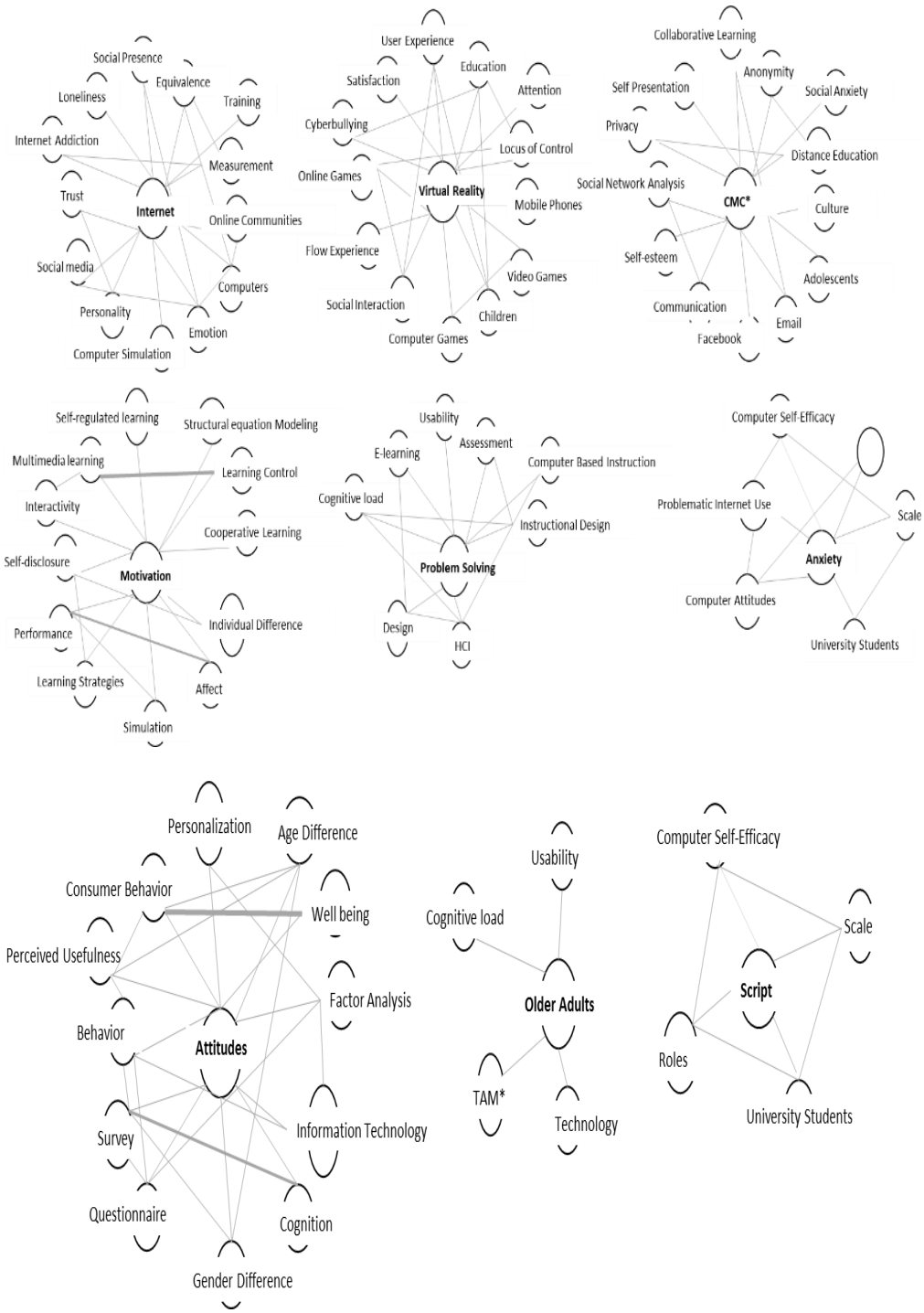


Figure 4.2. Cluster or Thematic Networks of major Themes in IB for the Time Interval 2004-2010

4.3.3.3 Thematic Network of the Time interval 2011-2017

Figures 4.3 (a to c) shows thirty-four themes were detected in this time interval.

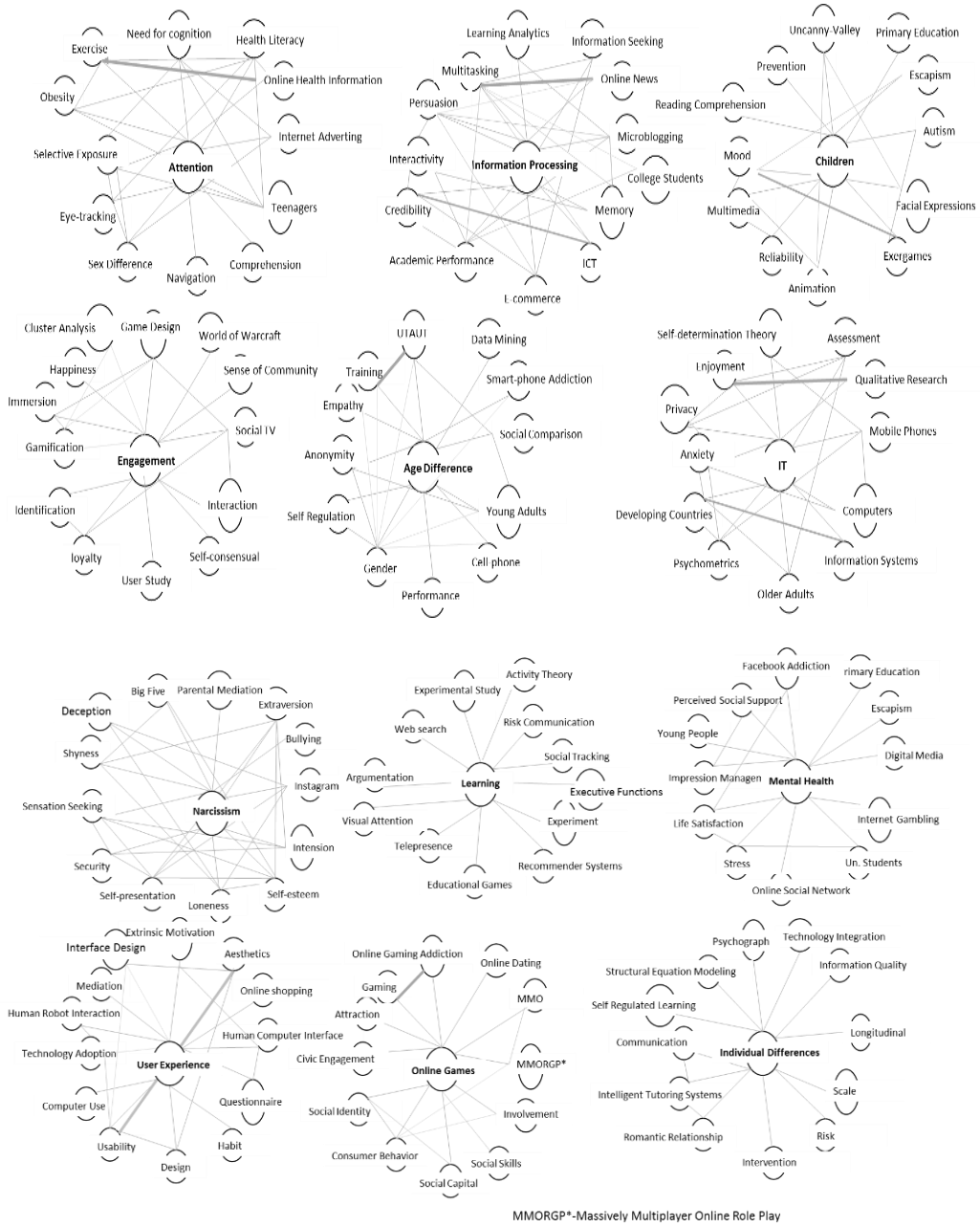


Figure 4.4 (a). Cluster or Thematic Networks of Top Twelve clusters of the Time interval 2011-2017

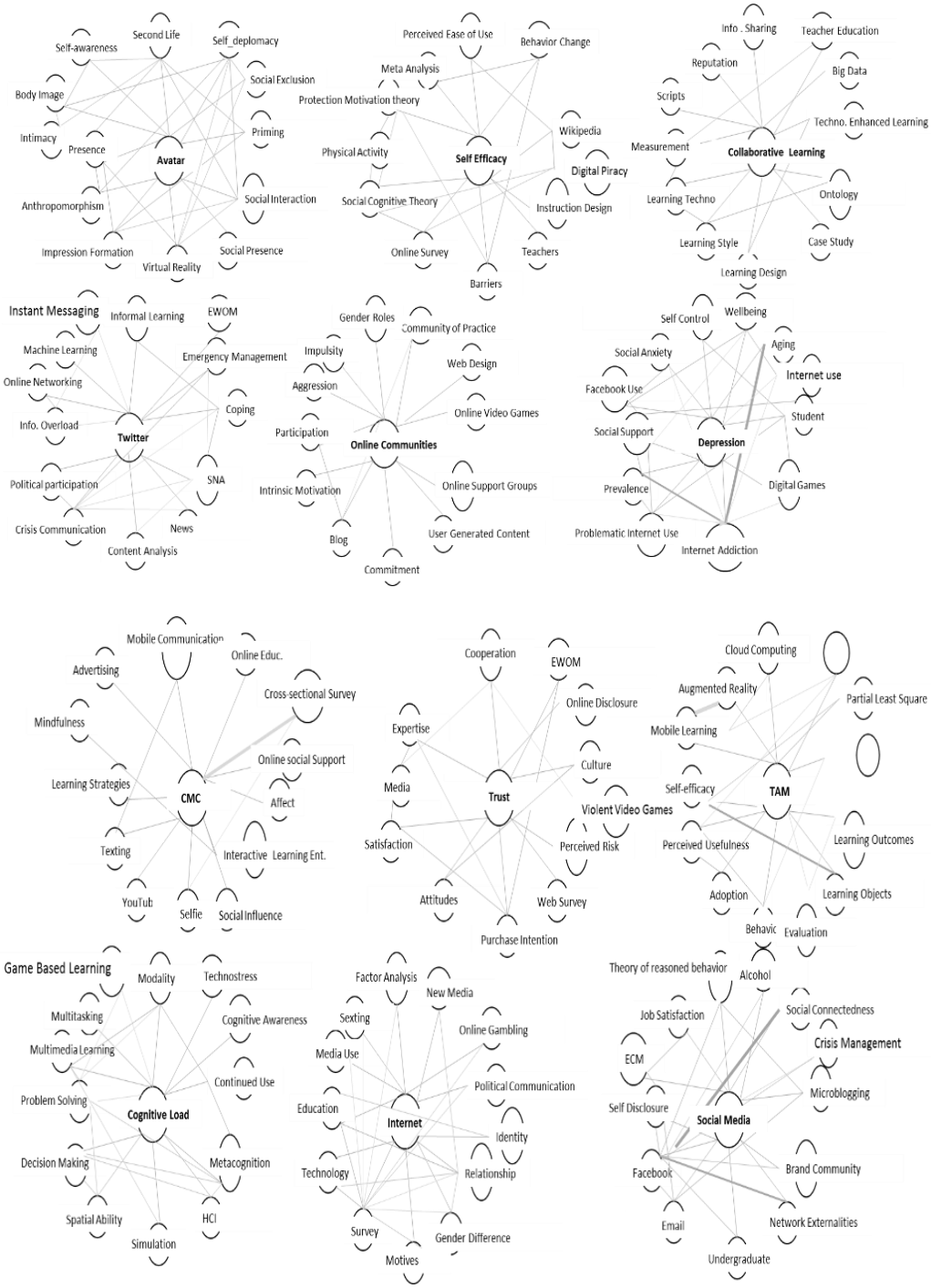


Figure 4.4 (b). Cluster or Thematic Networks (13 to 24 Themes of the Time Interval 2011-2017), the bold ADKs at the center are theme names based on simple center algorithm

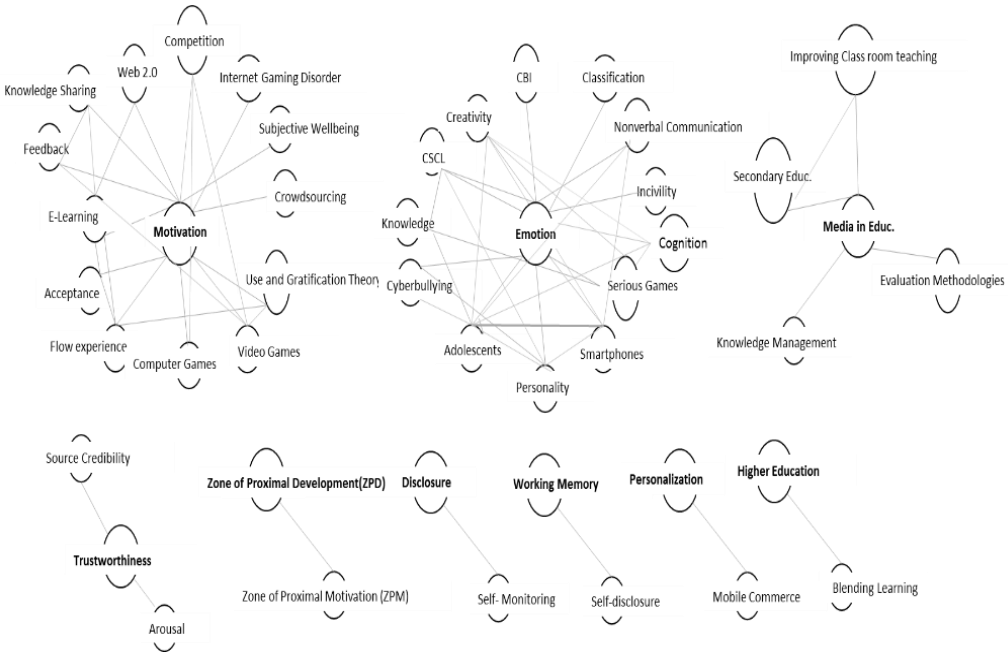


Figure 4.4 (c). Cluster or Thematic Networks (25 to 34 Themes) of the Time interval 2011-2017, the bold ADKs at the center are theme names based on simple center **algorithm**

3.3.4 Card Sorting for Grouping the Discovered Themes in the Domain of Information Behavior

The discovered themes through clustering over the three periods of analysis were grouped into high level concepts using card sorting method based on subject matter. Three experts were involved in card sorting and the agreed up on groups of themes were labeled with high level concept, which is believed would represent them subject matter wise and color coded. The sample card sorting based grouping is presented in Figure 4.4.

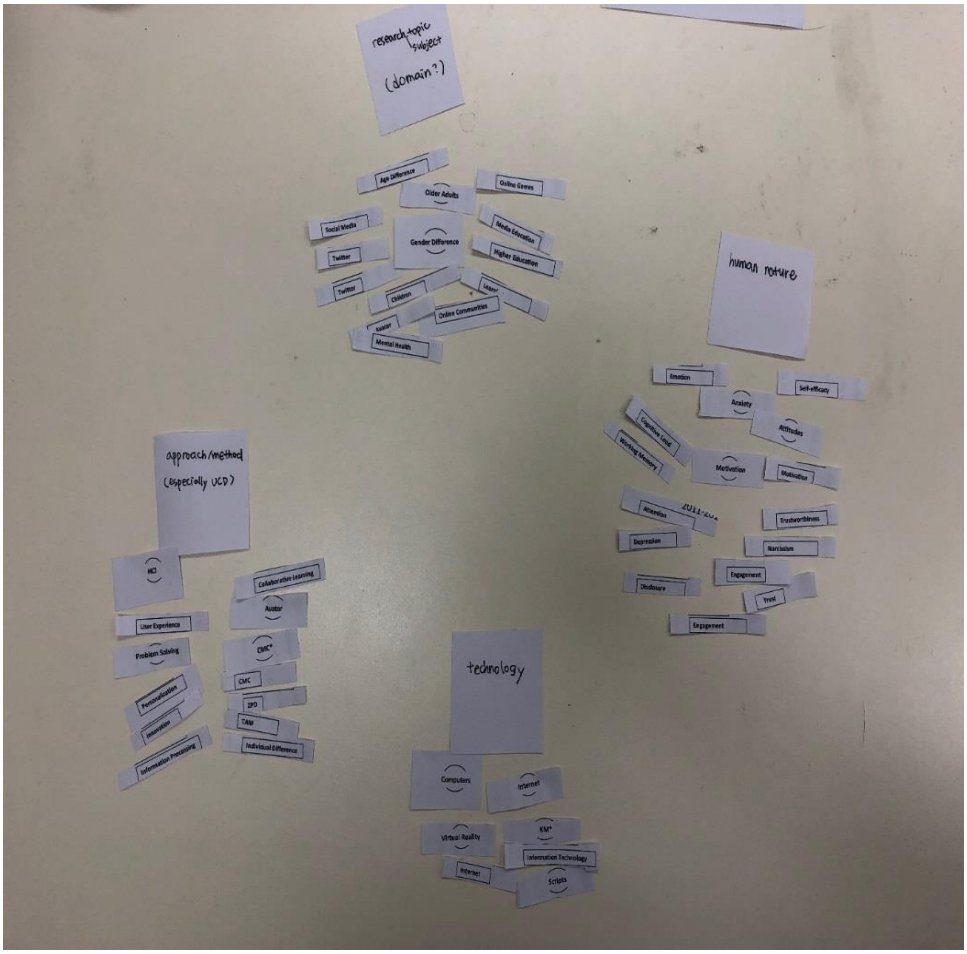


Figure 4.4. Sample Card sorting discovered Themes in the Domain of Information Behavior

According to the final grouping, the discovered themes in these domain belongs to four category of high level of concepts as presented in Table 4.3.

Table 4.3. Groups of Discovered Themes and Color Codes in Information Behavior based on high level concepts

#Group	Group Name	Member Themes	Color Code
1	**Theories/ Approaches**	Human Computer Interaction, Problem Solving, Scripts, Information Processing, Engagement, User Experience, Self-Efficacy, Cognitive Load, Working Memory, TAM, ZPD (11 themes)	
2	**Technology/ Systems**	Computers, Information Technology, Virtual Reality, CMC, Internet, Avatar, Online Games, Online Communities, Twitter, Social Media (10 themes)	
3	**Human Factors/Behavior**	Gender Difference, Motivation, Attitudes, Anxiety, Older Adults, Attention, Children, Individual Difference, Age Difference, Trust, Trustworthiness, Motivation, Emotion, Disclosure, Mental Health, Depression, Narcissism (17 themes)	
4	**Learning**	Knowledge Management(KM), Collaborative Learning, Learning, Media in Education, Higher Education, Innovation, Personalization (7 themes)	

The final grouping and the color codes are used in the evolution patterns discovery in Figure 4.5 and themes classification based level centrality and density in the strategic diagram in Figures 4.6 to 4.8.

4.3.5 Evolution Pattern Discovery of Themes of Research in Information Behavior

Figure 4.5 indicates the evolution patterns and subject matter composition of themes over three time intervals. The years at the top indicates the intervals of the three time intervals. Time interval 1 is from 1990 to 2003, time interval 2 is from 2004 to 2010. Time interval 3 is from 2011 to 2017. The spheres in different colors indicate nodes or themes represented by the most central theme in cluster network during the particular time interval. The evolution is mapped using inclusion index. Three themes for the time interval 1990-2003 had less complex evolution relationship with the 11 themes discovered during the 2004-2010. However, the evolution relationship of the themes in the time interval 2004-2010 to the 34 thematic areas (clusters) in the time interval 2011-2017 were too complex. This shows how the research interest this domain of study is growing over time with a complex conceptual (ADKs) links.

Accordingly, Computers (technology), Human Computer Interaction (approach) and Individual Difference (human factor) thematic areas in the time interval 1990-2003 are at the root of specialization of themes in latter periods. So it tells us that the time interval 1990-2003 of this domain mainly focused on computers, how to best interact with computers and the role of gender differences as a factor related interacting with computers.

Computer from thematic area the technology category in 1990-2003, has a strong link with Internet (technology), Problem Solving (theory/approach), and Anxiety (human factor) themes and shared ADKs with human factors/ behavioral categories like Motivation, Attitudes, Virtual Reality, and Older Adults themes in the time interval 2004-2010. The eleven themes of research identified during the time interval of 2004-2010 are all new by name (100%). No one theme appeared by the same name from 1990-2003 in this time interval. This shows that there extremely high level of thematic dynamism during the two early time intervals. This shows dynamism in naming of the research thematic area due to more specialization in evolution processes. In other words, it is to say the newly emerged ADKs or ADKs, which were not central focus of research in preceding period is promoted to central positions in the clusters in themes' formation in the evolution process.

Internet, Avatar, and Motivation continued as thematic area with their name from 2004-2010 to the time interval 2011-2017 (continuance increases over period by 12%). Thirty-one themes (88%) of the themes evolved during the time interval 2011-2017 were with new names. As times goes the name of thematic areas change but sharing keywords. Therefore, we can say there is high level of dynamism as only few of themes crossed time intervals with similar name still. There is growth in terms of the number of thematic areas as well. The growth in the number of research themes in the second time interval

is nearly 4 times of the first time interval. The growth in the number of themes in the third time interval is 3 times that the second time interval. For the complete list and their graph properties in the three time intervals, see Table 4.4 to 4.6. A lot of evolutional hierarchy can be extracted from this evolution map to easily see the changing emphasis of research thematic areas over period, which can also show paradigm shift in the research interest. The next is to show the role in the entire knowledge structure and level internal of development of each theme in each time interval. Discovering to what level the concepts (ADKs) are overlapping from period to period is very important and his issue are identified in subsection 4.3.5 and 4.3.6.

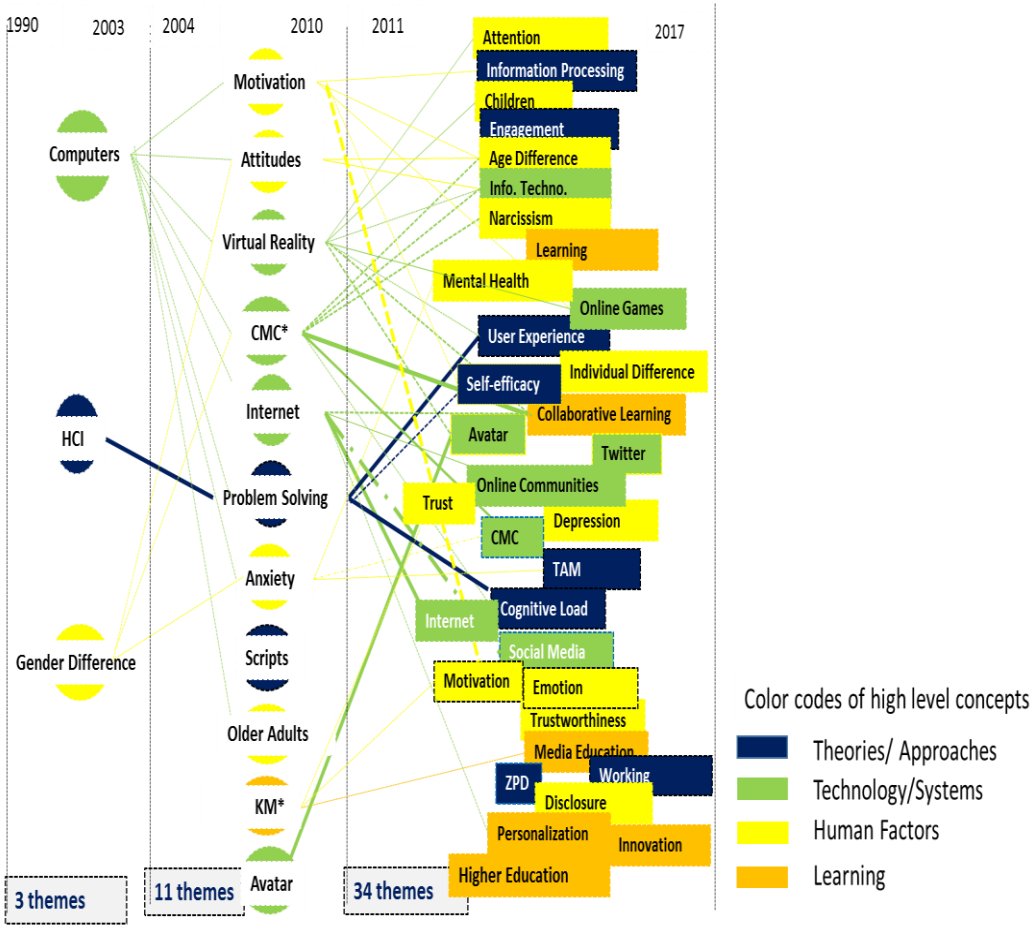


Figure 4.5. Themes' Evolution Patterns of the Three Time Intervals in the Domain of Information Behavior for three Time Interval

As the evolution pattern in Figure 4.5 shows human factors/behavior related themes have been growing dramatically followed by theories/approaches over periods. In general, all areas have been growing dramatically.

4.3.6 Classification of the Detected Themes of Research Using Centrality and Density in Strategic Diagram

The classification of the detected themes of research at the crossroad of Information Behavior is presented for each time interval in this subsections 4.3.4.1 to 4.3.4.3. In the diagram the nodes (ovals) are themes, which belong to a particular time interval, the labels are name of themes or clusters of ADKs and H-index of articles associated to a particular theme. X-axis is centrality, Y-axis is density of the particular theme. The structure of strategic diagram and detailed description is given in methodology chapter two Figure 2.6.

We classified the detected thematic areas of each time interval to the strategic diagram for categorization of the status of the thematic areas in shaping the convergence of the two research themes over time intervals.

4.3.6.1 Thematic Classification of the Time interval 1990-2003

The strategic diagram of this time interval is presented in the Figure 4.6. Only one strongly central (core) and moderately dense (developed) thematic area i.e. Computers was detected. There was also one strongly dense (internally cohesive) or well developed but less central thematic area i.e. Human Computer Interaction.

The basic or transversal theme is Gender Difference in this time interval. Gender Difference theme, though it is less internally cohesive or less

developed, its contribution as a central theme is high. See Figure 4.6. The emerging or declining quadrant is vacant during the time interval 1990-2003.

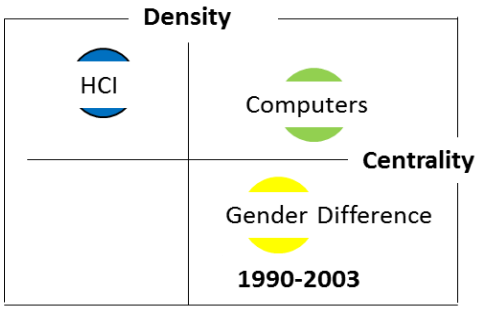


Figure 4.6. Strategic Diagram of the time interval 1990-2003 in the IB Domain, Computers (technology) is core, HCI (theory /approach) is peripheral, Gender Difference (human factor)

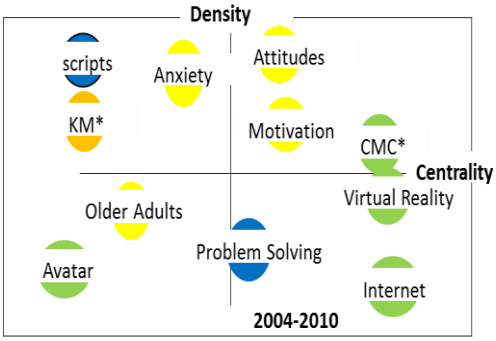
Table 4.4. Summary of clusters' properties of the themes detected during (1990-2003)

Rank	Theme Name	Centrality	Centrality range	Density	Density range
1	Computers	3.93	1	3.99	0.67
2	Gender Difference	1.96	0.67	1.05	1
3	Human computer Interaction	1.81	0.33	4.33	0.33

3.3.6. 2 Thematic Classification for the Time interval 2004-2010

The time Interval 204-2010 had got themes in all quadrants. See Figure 4.7. Three themes appeared in the motor or mainstream thematic area in the strategic diagram. These are Attitudes, Motivation and Computer-Mediated Communication. These themes were having both high intra-cluster cohesion and inter-cluster coupling or links. The highly developed and isolated themes during this time interval are Scripts,

Knowledge Management and Anxiety thematic areas. They had high intra-thematic cohesion and low inter-cluster coupling i.e. they are strong to stand as autonomous theme to study but their role in the entire knowledge is low. Anxiety was highly performing (h-index of 23) during this period.



KM*: Knowledge Management,

CMC*: is Computer Mediated Communication

Figure 4.7. Strategic diagram of the time interval 2004-2010 in IB Domain, more human factor related core (Attitude and Motivation), More technical basic (Virtual Reality and Internet)

Older Adults and Avatar themes appeared as emerging or declining themes. Both have higher importance to play central role in the whole thematic structure but internally weak to stand an autonomous thematic area to be studied or they are aligned to the mainstream thematic areas. One insight, which worth mentioning is that the mainstream had shifted from technical aspects to more human aspects in this time interval (motivation and attitude are behavioral and Computer mediated communication is technical). See Table 4.5 for the complete reference of clusters' properties of the themes discovered during this time interval.

Table 4.5. Summary of clusters' properties of the themes detected during 2004-2010

Rank	Theme Name	Centrality	Centrality Range	Density	Density Range
1	Knowledge Management	14.16	1	0.82	0.73
2	Older-Adults	13.22	0.91	2.12	0.36
3	Scripts	12.93	0.82	2.61	1
4	Anxiety	12.31	0.73	3.94	0.82
5	Problem Solving	10.96	0.64	2.73	0.18
6	Internet	6.14	0.55	1.22	0.09
7	Computer Mediated Communication	5.4	0.45	3.35	0.55
8	Virtual Reality	3.69	0.36	1.65	0.45
9	Attitudes	2.52	0.27	7.57	0.91
10	Motivation	2.35	0.18	2.96	0.64
11	Avatar	1	0.09	1.39	0.27

4.3.6.3 Thematic Classification of the Time Interval 2011-2017

During 2011-2017, the number of themes evolved in each quadrant of the strategic diagram increased and almost evenly distributed. See Figure 4.8. In the motor or mainstream or core thematic areas, number of themes are nearly three times that of the 2004-2010 in this time Interval. The themes that appeared as the mainstream are Attention, Children, Information Technology, Information Processing, Online Games, and Twitter, Avatar and Individual Differences and User Experience. Avatar is developed to motor theme in this time interval from emerging theme in 2004-2010. The highly performing mainstream or core theme is Information technology (h-index of 24) followed by Individual Difference, Twitter and Information Processing (all with h-index

of 21). These themes are well developed and strongly central themes of the thematic structure connecting computing and human behavior.

The themes, which appeared in the highly developed and isolated quadrant of the strategic diagram are also 8 in number during this time interval. These are Depression, Narcissism, Collaborative learning, Media in Education, Trustworthiness, Working Memory, Disclosure and Zone of Proximal Development and mental health. The highly performing ones are Depression and Narcissism themes each having h-index of 22 followed by collaborative learning (h-index of 15) and Media in Education (h-index of 10).

All of the themes this quadrant are new by themes' name. Mental health theme came between quadrant II and III, between declining and emerging, and highly developed and isolated themes. It seems that all the psychological health related thematic areas are internally well developed but peripheral to the whole thematic structure connecting Information Behavior during this period. Eight themes appeared in the emerging or declining thematic area during this time interval. These are Social Media, Technology Acceptance Model, Trust, Age Difference, Higher Education, Personalization, and Innovation.

In this time interval the majority of the themes belongs to quadrant IV (the basic themes) there are 9 themes in this quadrant, namely; Emotion, Motivation, Internet, Computer Mediated Communication, Online

Communities, Cognitive load, Engagement, Self-efficacy and learning. Internet thematic areas existed in the same quadrant in the time interval 2004-2010. For the detail of clusters' or theme's status in terms of graph properties i.e. centrality and density and bibliometric of themes identified during the time interval 2011-2017, refer to Table 4.6. Therefore, we can say the themes are growing more in the motor or mainstream areas than in the other areas in research area. There is a paradigm shifts among thematic areas as themes, which were once motor themes becomes basic or transversal, in the other time interval and so on. There were also disappearing themes by their previous names in the next time interval for example the eleven themes emerged during 2004-2010 were all with 100 % new names and in 2011-2017, 88% of the themes were with new names. ADKs, which were member of a clusters in previous time interval grew to themes in next time intervals for example anxiety, problem solving and Internet, which were member themes in the cluster or computers theme during the first time interval, became themes in the second time intervals. Similarly, user experience, self-efficacy and collaborative learning, social media which were concept members of clusters during 1990-2003 and 2004-2010 grew to a thematic research area in the time interval 2011-2017. Virtual reality and knowledge management which were a theme in 2004-2010 became ADK of a theme Avatar in the time interval 2011-2017. In so doing we can tell the complex dynamism in the thematic structure

of Information Behavior using different tools, techniques, methods and strategies from graph theory and bibliometric.

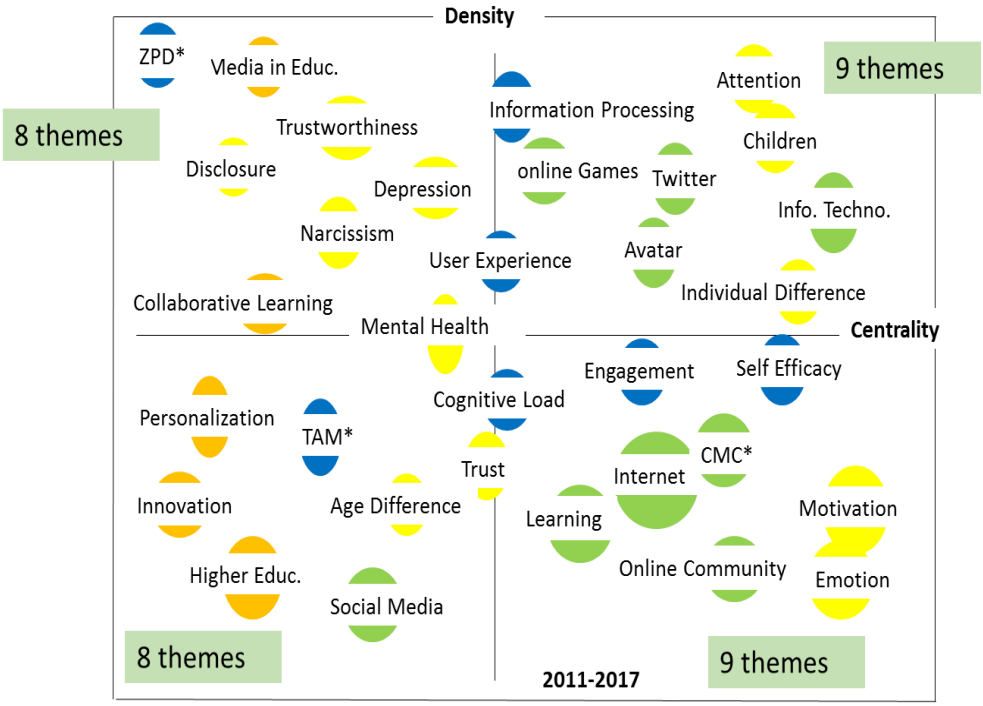


Figure 4.8. Strategic diagram of the time interval 2011-2017 in IB Domain, this period balanced thematic areas in emerging, basic and core themes, strong scientific base.

In terms of the subject matter, following the color, see Table 4.3 for color code, we observe almost similar distribution of technology/system in the core area, basic area is observed. Almost similar distribution of technical and human factor in the core area is seen from the Figure 4.8. Theories/approaches and technical themes have almost similar distribution in the basic thematic area. Learning related themes dominates the emerging area. Human factor is dominant in the peripheral area, highly developed but less interacting with other themes in the entire knowledge structure.

The characteristic feature, of the discovered themes, which include centrality and density ranges, which are used to map the themes to strategic diagram in this time interval are presented in Table 4.6

Table 4.6. Summary of Clusters' Properties detected research themes during 2011-2017 in IB domain

Rank	Theme Name	Centrality	Range	Density	Range
1	Emotion	15	1	0.26	0.06
2	Information Technology	14.58	0.97	1.42	0.79
3	Motivation	14.49	0.94	0.33	0.12
4	Individual Difference	14.24	0.91	1.19	0.56
5	Children	14.12	0.88	2.62	0.91
6	Attention	13.99	0.85	2.81	0.97
7	Self-Efficacy	13.57	0.82	0.97	0.44
8	Computer Mediated Communication	13.16	0.79	0.72	0.29
9	Online communities	13.08	0.76	0.36	0.15
10	Twitter	12.96	0.74	1.3	0.71
11	Avatar	12.92	0.71	1.28	0.68
12	Internet	12.8	0.68	0.68	0.26
13	Online Games	12.75	0.65	1.45	0.82
14	Engagement	12.08	0.62	1	0.47
15	Learning	12.02	0.59	0.64	0.24
16	Information Processing	11.74	0.56	2.02	0.88
17	Cognitive Load	11.67	0.53	0.82	0.41
18	User Experience	11.65	0.5	1.27	0.65
19	Trust	11.64	0.47	0.72	0.32
20	Mental Health	11.39	0.44	1.16	0.5
21	Age difference	11.1	0.41	0.73	0.35
22	Depression	11.08	0.38	1.35	0.76
23	Social media	11.08	0.35	0.22	0.03
24	Technology Acceptance Model	10.9	0.32	0.54	0.21
25	Narcissism	10.27	0.29	1.32	0.74
26	Collaborative Learning	9.29	0.26	1.19	0.53
27	Media in Education	4.45	0.24	2.78	0.94
28	Trustworthiness	2.81	0.21	1.85	0.85
29	Working Memory	2.04	0.18	1.25	0.62
30	Personalization	1.37	0.15	0.76	0.38
31	Innovation	1.15	0.12	0.5	0.18
32	Higher Education	0.96	0.09	0.27	0.09
33	Disclosure	0.94	0.06	1.19	0.59
34	Zone of Proximal development	0	0.03	10	1

4.3.7 Level of Time Overlapping of ADKs in the three Periods

As it was mentioned in the introductory section of this dissertation, an overlapping map shows the relative stability of research concepts, in this case ADKs emergence, obsolescence, continuity and overlapping in longitudinal or temporal patterns. The conceptual (ADKs) overlapping map at the intersection of Information Behavior is presented in Figure 4.9. For mapping the overlapping of the thematic areas over time intervals, we used Jaccard's index as in the first research

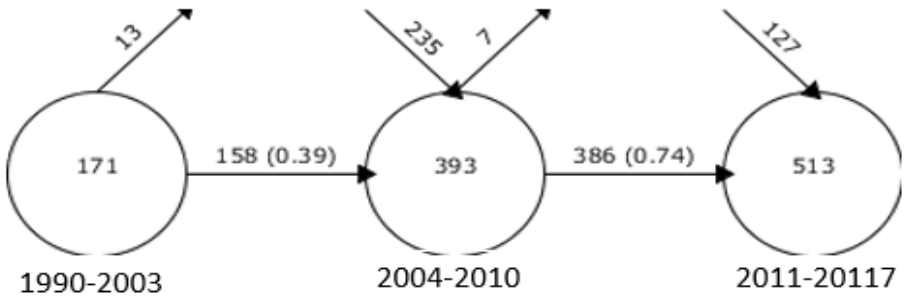


Figure 4.9. Conceptual (ADKs) Time Overlap diagram in Information Behavior Domain using Jaccard's Index

Surprisingly there is a 74% ADKs overlap that formed thematic areas of the time intervals 2004-2010 and 2011-2017, this shows that how authors are repeating the keywords of previous works instead of creating new concepts or knowledge representation. Only 26% of ADKs formed the thematic areas of

the last period are newel emerged. The overlap of concepts (ADKs) between the two periods 1990-2003 and 2004 and 2004-2010 is 39%. Out of the 171 ADKs which satisfies the minimum frequency of occurrence to construct the ADKs network during 1990-2003, 158 (92%) continued to the next period i.e. 2004-2010. The new concepts emerged during 2004-2010 is 61%. The obsolescence of ADKs between 1990-2003 and 2004-2010 is 8%. Continuity of the ADKs between the periods 2004-2010 and 2011-2017 is 98%. This shows that only 2% was obsolete to continue to the next period. Over all, conceptual overlapping considerably increased over periods.

However; from the evolution pattern discovery, we obtained that 100%, 88% of the themes are new by name though they shared ADKs from the previous years during 2004-2010 and 2011-2017 respectively. This means that there is higher possibility for the newly emerged concepts or ADKs to take the central place in the cluster network during the 2004-2010 and 2011-2017 to form new research theme. This is the advantage of using simple center algorithm for clustering purpose since it gives weight to the simple centers. Therefore, we can conclude that there is an increasing conceptual stability while there is huge dynamism in the thematic areas over periods.

4.8 Chapter Summary and Conclusion

We have proposed a combination of graph theory and bibliometric analysis techniques, methods and tools to explore the convergence between Information Behavior from articles published in journal of computers in human behaviors from 1990-2017 (28 years). We have made descriptive statistical summaries key bibliographic indicators to see trends and patterns of over time. It showed tremendous increase of research interest connecting both fields of study the development in the early days was slow until 2007. Number of publications, number of authors, number of Author Defined Keywords and collaborations particularly after 2007, which seems coincided with emergence of the online social media platforms, smartphones, cloud computing platforms and other ubiquitous devices.

For thematic area mapping, we used themes of clusters to detect themes of research from 4771 journal articles using Author Defined Keywords (ADKs). Clusters centrality and density to measure internal cohesion and inter-cluster coupling of the clusters (themes) detected to shape knowledge structure of converted fields of study respectively. Strategic diagram was used to classify the detected themes into more meaningful high level thematic areas. With combination of techniques, we have shown the trends, structure and dynamism of thematic areas that exist at the crossroad of Information Behavior as far as the journal of computers in human behavior is concerned. The main issues

revolve around role of individual differences, trust, memory, emotion, motivation, personality, attitudes, perceptions, attentions etc. for adopting, accepting, interacting and using computers and related technologies, and services such as computer mediated collaborative learning, computer mediated communication, virtual reality, social network sites, mobile banking etc. for personalized and interaction and good user experience, and problem solving. The main issues observed in the research themes were also about changes in human behavior and psychological health as a result of impact of use of computing devices and services or phobia related to it such as anxiety, depression, mental health, addiction to online services, narcissism and related big five personality issues. The other issues reflected in the thematic areas are concepts or theories related HCI, Problem Solving, Self-Efficacy, User Experience, Cognitive Load, Information Processing, Working Memory, Disclosure, TAM, ZPD and related themes.

Chapter Five

5.1 General Summary and Conclusion

The dissertation contains two paper. We started in identifying area of research interests at intersection of user experience and human computer interaction. Web of science indexed journal articles related to the research topic were retrieved. For intersection of user experience and human computer interaction, we retrieved 519 journal articles for the first paper. 4771 journal articles were identified and retrieved to make in-depth analysis of behavioral dimension of HCI/UX for the second paper. This would help researchers to focus on relevant domains to generate research topics and target relevant journal venues for them researches in the HCI/UX field of study. The idea of second paper is obtained from the finding of the first paper by making citation network cluster analysis and detecting three major categories of research interest by researchers contributed their work to the area namely: 1) Human, computers and interaction. 2) Human, computing and behavior (information behavior) and 3. personal and ubiquitous computing. So for the purpose of scoping and its major contributions, we selected the human, computing and behavior (Information Behavior) of HCI/UX in the second paper. We selected journal of computers in human behavior for analysis as it represented the clusters belonging to Information behavior. The number paper published in this journal within the timeframe set for analysis i.e. 1990-2017-July is 4771. We proposed

a combination of graph theory and bibliometric to explore the thematic structure of HCI/UX for both papers. Preprocessing of the retrieved data and temporal analysis of trends were made and indicated increasing trends in terms of number of papers, number of Author Defined Keywords, number of authors and countries' collaboration in interdisciplinary research area.

The thematic areas of three different time intervals were detected using various techniques as elaborated in methodology in chapter two and indicated that number of themes generally grew over time intervals in both cases. The detected themes were categorized into different groups showing different subject matters such as technology/systems, Theories/approaches, Measurement criteria, learning and human factors by experts in the area. The groups were labeled and color coded. Those colors were used as colors of themes in the evolution pattern discovery map and strategic diagram.

The evolution patterns of thematic identified three important things. 1) The themes which belongs to each period. 2) The evolution links between themes of two different consecutive periods. 3) The subject matter to which the themes in each period belongs using the color code the concepts. The ADKs time overlap map showed three important things: 1 number of ADKs used in analysis after preprocessing, which has passed from one-time interval to another time interval. 2) It identified as newly emerged ADKs in every time

interval. 3) It indicated the number of ADKs, which were obsolete in certain time interval to pass to the next period. These three indicators enabled us to evaluate the low level conceptual (ADKs) stability in the thematic formation of different time interval of analysis of the thematic structure of both cases covered in this dissertation of (Case 1: HCI/UX and Case 2 : IB) . The thematic structure in HCI/UX is still in shaping as its conceptual stability 52% in the period 2010-2016. Its thematic dynamism is 83% during same period.

It is indicated that thematic research areas, which are internally strong as well as having great role in shaping the entire thematic structure are increasing over time. This indicates that the scientific knowledge of HCI/UX is gaining strong base for the future, which also shows increased specializations as well as diversification by subject matter of the research thematic areas. From measurement criteria category (Usability, Emotion and Aesthetics), From approach (User Interface, Ubiquitous Computing and Design) and from Technology (Virtual Reality) are among core and basic themes during 2010-2016 that continues to shape the thematic structure of HCI/UX in the years to come from the previous patterns.

The Information Behavior domain is fertile area of research in terms of number of thematic areas as well as having balanced thematic structure. The core and basic themes and their member ADKs during 2011-2017 in this research

would highly play important role in shaping the thematic structure in the years to come as the pattern between 1990-2003 and 2004-2010 shows this trend. Core themes in Information behavior during this time interval include User Experience, Attention, Children, Information Technology, Online Games, Individual Differences and Information Processing. The basic and transversal themes are Emotion, Motivation, Online Communities, Internet, Computer Mediated Communication, Learning, Cognitive Load and Engagement.

Over all, Gender Difference (from human side/factor), Computers (from technical group), User Interface and Human Computer Interaction (in the group of methods/approach) thematic areas during the early time intervals were at the root of all the diversification and specialization of the rest of the thematic areas over the recent years. Themes highly proliferate over the three periods (3, 11 and 34 for three periods respectively).

High level of thematic dynamism (100% and 88% for two later periods respectively by theme' name). Complex evolution links over periods, shows high level of specialization and merging of themes. Clear paradigm shifts are observed in terms of themes and their high level concepts. We expect increase in thematic overlap in the years to come as it increased from 0 between the two early periods to 12% between period 2 to period 3 i.e. 4 themes (12%)

continued as themes namely; Motivation, Internet, Avatar and CMC themes over the two later periods.

As successfully discovered and characterized the thematic areas in both cases, the proposed method achieved the intended research goals of focusing on ADKs network analysis using graph theory and bibliometric. This work can be extended into further understanding of the social, intellectual landscape using other bibliometric analysis methods like co-authorship network, co-citation network and bibliographic coupling for exploring the convergence trends in the research domains. This dissertation focused mainly on the conceptual or thematic mapping using ADKs as a concept of analysis.

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Abstract

In this dissertation we proposed a combination bibliometric, graph theory and card sorting methods to discover and characterize the research themes in the domains of Human Computer Interaction/User Experience (HCI/UX) and Information Behavior (IB). For the first case, 519 papers, during the period of 1990-2016 were retrieved from Web of Science, published in the area HCI/UX using the search strategy (Human Computer Interaction and User Experience). The time-frame of the first research was petitioned into three time intervals (1990-1999, 2000-2009, and 2010-2016) to show Temporal based pattern discovery. The behavior related papers were found dominant in the case of HCI/UX analysis. Therefore, we focused on Information Behavior related aspects in our second research in this dissertation by selecting the representative journal of the clusters of citation network of journals related HCI/UX i.e. Computers in Human Behavior for Analysis.

The aim is to make the in-depth exploration of the research themes Information Behavior within the general context of HCI/UX. 4771 papers published in journal of computers in human behavior starting 1990-2017 were included. The time span for the second research was partitioned into three, namely; 1990-2003, 2004-2010 and 2011-2017.

In both cases ADKs network was constructed and clustered for the three time periods using simple center algorithm. Clusters were considered as themes of research. Cluster networks were used to highly associated ADKs through their co-occurrence that formed a theme to help extract different research themes. The central

ADK in a cluster network is used as a name of a theme name based on simple clustering algorithm, which gives more weight to the ADK with higher degree centrality in the cluster as representative of a cluster. The themes discovered through these process were grouped into different high level concepts perhaps subject matters addressed using card sorting methods by experts and color coded. Those color codes were used across the rest of the analysis i.e. evolution pattern discovery and strategic diagram based classification based on centrality and density into different roles and level internal maturity of themes.

Evolution pattern discovery was used to show the evolution linkages of themes in different periods. This in turn gives insights to the level of paradigm shift (thematic dynamism) in the field. To show the conceptual periodic overlap, we used the overlapping map (stability diagram). It showed the level of newly emerged, obsolete, and overlapped ADKs in different periods. In both cases the number of thematic areas and conceptual (ADKs) stability increased while thematic dynamism increased over the time intervals. For example, in the case of HCI/UX domain, the stability of ADKs increased from 15% between in 2000-2009 to 52 % in during 2010-2016 while thematic dynamisms were 100% and 83% for similar periods respectively. The conceptual stability in Information Behavior has increased from 39% for the period 2004-2010 to 74% for the period 2011-2017 while thematic dynamism is 100% and 88% for those periods respectively. One, eight and twelve themes were discovered for the time intervals 1990-1999, 2000-20009, 2010-2016 respectively in case of HCI/UX. Three, eleven and thirty-four themes were discovered for the periods 1990-2003, 2004-2010, and 2011-2017 respectively in

the case of Information Behavior. The variety and dynamics is huge for in the thematic areas of Information Behavior. In the case of high level concepts, in concepts six themes were related to measurements of HCI/UX, six themes were related to technology/systems, five themes were related to methods/approaches in the case of HCI/UX over the entire time span covered in the research. A total of 17 unique thematic areas were discovered over the entire time span. In the case of IB, seventeen themes belong to human factor/behavioral issues, eleven themes related to theories/concepts, ten themes belong to technology/systems, and seven themes are related learning environments. A total of 45 unique themes were detected in the IB domain for the entire time period.

Overall, the proposed methods are effective to discover and characterize the thematic areas of research in both cases as we answered our research questions successfully. Therefore, these methods are promising in discovering and characterizing research themes in similar interdisciplinary fields of studies as are test successful on HCI/UX and IB domain, which are highly interdisciplinary domains.

Keyword:

Human Computer Interaction/User Experience, Information Behavior, Bibliometric, Graph theory, Thematic Discovery, Thematic Characterization, Author Defined Keywords, Network Analysis

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Chapter One

Introduction

1.1 Background

1.1.1 Definition of Thematic Structure

A formal definition of scientific knowledge is "a fact acquired through scientific methods" (Hess and Ostrom, 2007). By the scientific methods it means, it must be tested by the established scientific principles, peer reviewed, accepted for publication and consequently published (Rosenthal and Rsosnow, 1991). Scientific literatures are the medium through which the scientific knowledge is communicated to the scientific community (Fanelli, 2011; Rosenthal and Rsosnow, 1991). Scientific literatures take different forms (Fanelli, 2011). Among them, patents and technical reports, thesis or dissertations, conference proceedings and journals are the primary ones in the publication pyramid from low to high maturity respectively (Öchsner, 2013). 1.5 million Journal articles are published annually in more than 25,000 journals (Öchsner, 2013). As time goes, the volume of the publications grow, diversify in its research thematic areas and converge with other disciplines to the level that it poses challenges to scientific community to get important insights about the Thematic structure and characterization (Fanelli, 2011, Öchsner, 2013). Therefore, thematic discovery and characterization is a

process through which the thematic structure of a certain field would be discovered for the understanding the thematic dynamism of over periods.

The thematic discovery and characterization includes trends in scholarly exchange and dynamics in thematic areas of research (Callon et al., 1983, Small, 1998, Callon et al., 1991; liu et al., 2014, Cobo et al, 2015). Discovering and characterizing the thematic areas, identification of in certain field of study are key issues to understand the knowledge structure and intellectual progresses in one field of study (Callon et al, 1991; Small, 1998; Cobo et al, 2015). The dynamics within the thematic area of any field of study include emergence, growth, divergence (specialization), and convergence, obsolescence and re-emergence (Cobo et al. 2015; Hess and Ostrom, 2007). Therefore, driving the hidden knowledge regarding these facts in the thematic structure from large size of scientific publication has been hot research topic (Small 1998, Noyons, 1999; Cobo et al., 2011). Thus we proposed the discovery and characterization of thematic areas of thematic structure in Human Computer Interaction and Information behavior for the last 28 years using a combination of graph theory, bibliometric quantive and qualitative analysis methods. The field of study is highly interdisciplinary in its nature, ever emerging in thematic structure and deals with innovative interactive systems. Therefore, its thematic structure is complex and hard to grasp. As a result, discovery and characterization of its thematic dynamism is key for

community of scholars and practice. The approach follow empirical study for understanding its knowledge structure (Hassenzahl et al., 2006; Forlizzi and Battarbee, 2004). In this dissertation, we focused on the thematic discovery and characterization of HCI and Information Behavior. For thematic discovery, we used concepts of graph theory called clusters. For characterization of the discovered thematic areas, we used graph properties called centrality, which measures the inter-thematic interaction or connection and density, which measures the intra-thematic cohesion (internal maturity) of thematic areas. From bibliometric, we used the concepts of evolution pattern discovery strategy, strategy of discovering conceptual periodic conceptual overlap, where concept of analysis is being Author Defined Keywords (ADKs). Classification of themes based role and level of maturity using centrality and density respectively was perf strategic diagram. Categorization into high level concepts, perhaps subject matter addressed by a group of themes using card sorting method was also performed. The unit of analysis is Author Defined Keywords (ADKs). The co-occurrence of ADKs in different papers forms a network metrics. Network is normalized using association strength. Simple center algorithm was used for clustering the network. Clusters are taken as thematic areas. Two cases are covered in these dissertation using similar methods. Case one dealt with the thematic discovery and characterization of research thematic areas in HCI/UX. The second case

covered thematic discovery and characterization in the domain of Information Behavior (IB).

1.1.2 Background: HCI/UX

Human Computer Interaction (HCI) is one of the interdisciplinary field of study focusing on the emerging innovative interactive systems (Dix, 2009), as such, it involves design, evaluation and implementation of interactive computing systems (Peerce et al., 2004). In short, it deals with the interaction between humans and machines (devices). User Experience (UX), the totality of human feelings, perceptions and expectation regarding accepting, adopting and using a product or a service is becoming part and parcel of HCI in this digital society (Hassenzahl and Tractinsky, 2006; Dix et al., 2009). It is becoming important part of HCI over time as HCI tends to be more human oriented (Myers, 1998; Hassenzahl and Tractinsky, 2006). As an areas of research and practice, 1980s is a time mark for HCI foundations as a scientific field of study (Myers, 1998). Primarily the origin of HCI was in computer science and information systems and focused on graphical based user interface design and basic programming (Myers, 1998). Later on, the research foci in HCI is shifted to include usability evaluations, interaction design and user experiences, which are more human oriented to meet users' perceptions, needs and requirements (Myers, 1998; Hassenzahl et al., 2006). User experience is

focusing on systems' human oriented core values, which include desirability (emotionally appealing), usefulness (relevance to problems of users), accessibility (accessible to all end users regardless physical conditions), reliability (trusted and dependable), usability (easily learned and used for intended goal), and findability (easily navigable)[1] . Thus, User Experiences has become important aspects of human computer interaction to enhance the acceptance or adoption and usage of computing systems in a more pleasurable way. As such, it deals with not only effectiveness and efficiency of using computing devices/ systems to attain the intended user goal (s) as in the traditional usability but also about beauty and hedonic features of systems to make the artifact a more appealing one and pleasurable one (Hassenazahl et al., 2006). Human oriented HCI is rooted in many fields like ergonomics, psychology, philosophy, anthropology and design (Myers, 1998). Cognitive experiments, participatory techniques, theoretical frameworks like activity theory, situated actions and distributed cognition were developed to make HCI/UX a full-fledged field of research over time that takes social and contextual situation into considerations (Dix et al., 2009; Hassenazahl et al., 2006; Myers, 1998).

[1] User Experience Basics. https://www.usability.gov/what-and-why/user-experience.html

As a result of these developments, various venues of intellectual and industrial discourse platforms were flourished to serve as forum of exchanging views, which strengthened the thematic structure overtime (Myers, 1998). The research outcomes and practice based innovative technical reports of a field of study started to boom over time (Clemmensen, and Roese, 2010). In 1982, ACM Interest Group on Computer Human Interaction (SIGCHI) was founded to serve as a scholarly discourse of both academia and industry emphasizing humans (Myers, 1998; liu et al., 2014).

Many researchers presented their seminal publications in the early 1980s attributed HCI as a field browning its foundational concepts from computer science, human factors and ergonomics and cognitive psychology while having its own theories, models, and frameworks (Card et al., 1983; Norman and Draper, 1986; Winograd and Flores, 1986). Many journals appeared as a venue of scientific papers related to HCI/UX. To mention few, journal of interacting with computers, computers in human behavior and International journal of human-computer studies, journal of behavior & information technology are among the top venues publishing papers containing the two concepts together (Urgessa, et al., 2017). According the survey we have made, currently we have more than 250 journals which publishes at least one paper at the intersection User experience and Human Computer Interaction and indexed in WoS though the major ones are few in number (Urgessa, et al.,

2017). Moreover, User Experience as aspect of human computer interaction in particular and computing systems in general is becoming very important and being taken as a success factors for companies in the digital industry and consequently becoming a research area and a career line for many overtime (Wilson, 1981).

Hence studying the thematic structure of that connects the two important phenomena based on empirical data is important to shape its future research directions (Hassenzahl and Tractinsky, 2006).

Therefore, this dissertation is motivated to use available publication data and emerging state-of –the art analysis methods ascan opportunities to drive new insights in the thematic structure Human Computer Interaction/ User Experience.

Discovering and characterizing thematic structure would guide policy makers, academia, researchers and industry for well-informed research thematic area identification and hence increase efficiency and avoids duplication of efforts and resources in HCI/UX community of scholars.

1.1.3 Role of Information Behavior in the Context of HCI/UX and the Need to Analysis it publications

Human behavior is an important issue to accept, adopt, interact and use technology or/and services (Hudlicka, 2003). The feelings, emotions and

personality trait before or/and after using the products and services are more psychological in general and human behavioral issues in particular. Making computing devices and systems context aware is also another important issue (Abowd et al., 1999; Schmidt, 2005; Pantic, 2007). Change in human behavior as a result of use of computing devices and services is also another important issue (Davis, 2001). The behavioral change due to use technology can be good or bad, it lays within the way human being uses it but not intrinsic in itself (Godzinski, 2005). It would be important to study the role of human behavior with regard to information sources, channels, processing and sharing (IB) in the context of HCI/UX to reduce its negative effect on human behavior and wellbeing, and maximize is positive outcomes in human life (Ghani, 1994). As a result of these facts, many research outcomes connecting computing devices/systems and human behavior have been published and available in the scientific publication databases of WoS.

The citation network analysis of journals which published papers related to HCI/UX is made as a preliminary high level research interests of the scholars in the area in the third chapter-case one of this dissertation. Information Behavior (IB) related journal publications clusters are by far higher by number of publications than other high level research categories identified (Urgessa et al. 2017).

If these publications are analyzed systematically, they would reveal insights regarding trends and thematic dynamics in the past and present and imply the future prospects of the relationship between computing devices/systems, information use and human behavior which we call it Information Behavior (IB) in this dissertation.

Therefore, the thematic structure and dynamism in Information behavior in particular and in-depth in the context of HCI/UX is explored with similar methods in the first case (HCI/UX) from large publication base over time in this dissertation.

1.2 Rationale

This area of research is not yet empirically explored while it very important to clearly map research thematic structure for making informed decision for future research directions to HCI/UX and IB communities (Hassensahl et al., 2004, Boyack, 2005). The intersection of these domains taken as cases can be good example of how different field of can be converged and form a dynamic scientific knowledge base over time (Myers, 1998).

On top this, we have big data (meta-data of publications) but little insight out of it (Graham, 2006; Cobo et al., 2015, Urgessa et al. 2017). It is challenging to deal with large volume publication data to extract important insights for

policy makers, researchers and practice community to make a wise decision for research directions.

Moreover; there is an opportunity that there are state of the art analysis techniques combining bibliometric and graph theory and related qualitative analysis like card sorting method to discover and characterize thematic areas in the thematic structure of any domain of interest. When we come to HCI/UX and IB, it is a typical interdisciplinary and complex field of study. There are new methods, strategies and techniques to deal with such research problems.

Therefore, in this research, we proposed a combination bibliometric, graph theory and qualitative methods for thematic discovery and characterization in the domains of HCI/UX and IB focusing on Author Defined Keywords (ADKs) as a unit of analysis over the course of 28 years.

1.2 Research Objectives

1.3.1 Main Objective

The general objective this study is temporal based thematic discovery and characterization in the domain of HCI/UX and IB using a combination concepts bibliometric and graph theory.

1.3.2 Specific Objectives

The specific objectives of the research that guides us for the attainment of the general research objective are to:

- Show the general trends in HCI/UX and Information Behavior over periods of time
- Discover thematic areas HCI/UX and Information Behavior (IB) based on ADKs network clustering methods
- Group the discovered themes into high level concepts using card sorting methods.
- Color code themes based on the grouping in each domain
- Discover the thematic evolution patterns and level of conceptual periodic overlapping in areas of research over periods
- Classify the detected themes into different categories to show their level of development and their role to shape the entire thematic structure
- Present the quantitative graph properties and bibliometric measures to characterize individual themes discovered with combination of group color codes in both researches for the periods analysis
- Interpret the results the results from each methods and/or combination of methods

- Discuss key findings and their implications for both domains

1.5. Research Questions

This research is intended to answer the following research questions. The research questions are aligned with the specific objectives of the research.

RQ1. What are the thematic research areas and their evolution patterns over periods in both domains?

RQ2. How the themes are classified and evaluated by their level of development, the role they play to shape the knowledge Structure over periods?

RQ3. How is the level of overlap of ADKs evaluated over periods in both domains?

RQ4: How the discovered themes are grouped into high level concepts of the subject matter addressed?

1.6 Significance and Contribution

This research adds new understanding of the general patterns, trends and thematic structures in the area of HCI/UX and IB. It also shades light on evolution patterns, level of ADKs (conceptual) periodic overlap, obsolescence's, and level of development and role of thematic areas in shaping the entire thematic structure of the domains of selected as cases of studies. It also identifies thematic characteristics in terms of subject matters addressed. It drives knowledge from the actual contents as represented by the authors of

the papers without subjective manipulation of the researchers alike that of traditional literature survey. It covers large size of publications over longer time interval (28 years). The time dimension, graph properties and bibliometric analysis and card sorting method to group the discovered themes into high level concepts by experts extends the reliability of the research. It would show the research directions of over 28 years related to the converged research field HCI/UX and IB as two cases and imply important research issues of the future based on the past and the current trends. It would be a cornerstone for future researches in the area.

The result would help guide the academia, scientific researchers and community of practice, sponsors and editors of the scientific journals to make the right decision making regarding research thematic area selections. It also enables researchers to target right journal venue for publications as well as help them to combine different fields relevant to the study area to drive their new research topics from the thematic network of themes as a result of this research in both domains.

1.6 Structure of the Dissertation

This dissertation is organized into five chapters. The first chapter deals with introductory remarks. The second chapter discusses methods, techniques, strategies and tools used in the research in the thematic structure of HCI/UX

and IB for driving research ideas for in-depth exploratory research in the area. Chapter three covers the first case study entitled “Author Defined Keyword Network Analysis for Temporal Based Thematic Discovery and Characterization in Human computer Interaction/User Experience”. Chapter four presents the second case study, which explored temporal based thematic discovery and characterization in Information Behavior in the context of HCI/UX, whose idea originated from the data of the case. Chapter five discusses the general take away and conclusion of the research processes, findings and future implications.

Chapter Two
Methodology and Operational Definitions

2.1 General Framework of the Research

The general framework of the procedures followed in this dissertation is as presented in Figure 1.1. The first step is dealing with setting research goal and deciding on different tools, techniques and methods to achieve the intended research goals. The second step is identification of the right data source to address the stated research goal and acquiring the data. The third step is data preprocessing as the original data obtained is fragmented, messy huge and inconvenient for insight discovery (more time and energy was allocated here). It needs different preprocessing activities for data integration as the source allows downloading only 500 records at a time, dimensionality reduction and avoiding duplications, selection of the right segment of dataset and making preliminary insight for further exploration through statistical summary measures. The fourth one is visualization, analysis and interpretation of the result. The final one is writing up using the following discovered insights in the whole processes focusing on easy presentations for the readers' understanding.

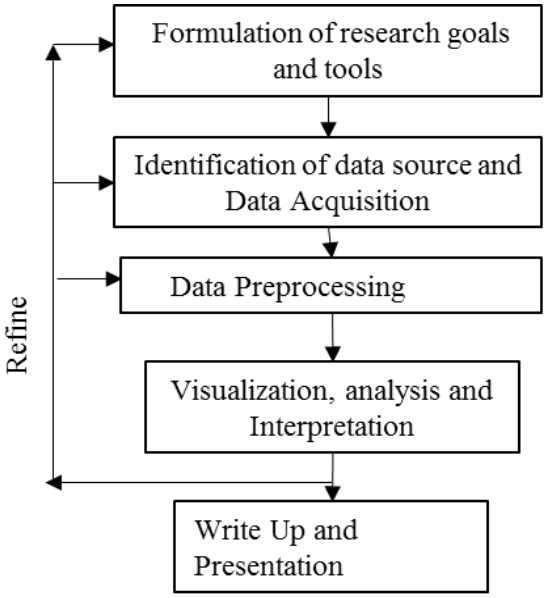


Figure 1.1 General Framework of the Dissertation

2.2 Data and Decision Procedure

2.2.1 Data for Case One

All journal articles dealt with HCI and UX together were searched in Web of Science starting from 1990-2016. Web of Science is owned by Thomson Reuters, started in 1960s, most comprehensive and hosts esteemed multidisciplinary journal articles across all fields of studies having above 10,000 journals[2]. We made a topic search where the two phrases are searched

[2] UCL. Research Library (2016) Measuring the reach of your publications using Web of Science accessed http://libguides.ioe.ac.uk

either in Title, Author Defined Keywords, ISWoS Word plus or in abstract of the journal articles in the Web of science database. 519 papers were retrieved. The search statement is:

TOPIC: (User Experience and Human Computer Interaction)

Timespan: 1990-2016

2.2.2 Data for Case Two

We retrieved all 4771 papers published in this journal of computers in human behavior starting from 1990 up to 2017-July_31 and included all in the analysis of chapter four. The selection of the journal was based on the finding in the research one, chapter three of this dissertation that big high level research category discovered is computing, human and behavior related, which we call it Information Behavior. Journal of computers in human behavior happened to be a representative of this research category with its high impact as well as its number of papers.

Therefore, we used the search strategy:

PUBLICATION NAME: (Computers in Human Behavior)

Timespan: 1990-2017.

2.3 Operational Definition of Bibliometric and Graph Theory

One of the systematic ways to explore the trends and dynamics in the thematic strucure of certain field of study is mining meta-data of the scientific literatures published in the area over long period time (Callon et al 1986; Courtel et al, 1998, Van Eck et al. 2007). State-of-the-art analysis methods for this purpose are the concept of bibliometric and graph theory (Otte and Rousseau, 2002; Chen, 2006; Leidesdorff, 2004; Bettencourt, et al., 2009; Cobo, 20011). There are different methods in bibliometric analysis to explore the thematic structure in any domain. Thematic discovery and characterization in terms level of development, impotence in the entire thematic structure, evolution patterns, periodic conceptual overlapping are among the most important ways to deal with thematic understanding (Schneider, 2004). The analysis can be made at the level of words, journal articles or other descriptors like author, institutions, citations and bibliography of the scientific articles (Ding, 2001; Callon, et al., 1991; Altman et al, 2011). The bibliometric analysis methods include co-word analysis, co-authorship analysis, co-citation analysis and bibliographic coupling analysis (Cobo et al. 2015). Different analysis method reveals different dimensions of the thematic structure. For example co-word analysis enables concept based thematic discovery and characterization (Callon et al. 1986; He, 19999; Callon et al. 1991, Callon et al, 1983, Cobo et al. 2015). Co-authorship analysis enables to discover the social structure or collaboration

among authors of the thematic structure (Acedo et al., 2006; Liu et al., 2005; Huang et al., 2011, Altman et al. 2011). Co-citation or/and bibliographic coupling analysis enables to discover the intellectual thematic structure (Small, 1999, Huang et al.2011).

Graph theory contributed a lot to the social network analysis in characterizing the network by nodes, which can be any item or object of interest and the link between the nodes called edges (Callon et al., 1986; He, 1999; Altmann, 2011,). The network of nodes can be clustered based on their similarity or association or affinity or proximity (Courtel et al 1998; Liu, 2014; Callon, 1991; Small, 1998, 2011; Otte, 2002). The clusters properties like centrality and density can provide important information about the status of the clusters both internally within the clusters as well as the clusters' interaction in the entire network the thematic structure (Liu, 2014).

Centrality and density of the clusters provide important information regarding the inter-cluster cohesion and intra-cluster interactions or connections respectively (liu, 2014, Cobo et 2015). So, strategic diagram is based on these three important graph theory properties (clusters, centrality and density) to classify themes to different roles and levels of internal maturity. Centrality and density in our research is based on Callon's centrality and density formula in this dissertation (Callon et al., 1991).

Centrality of a certain cluster or theme is calculated by the formula:

$$\text{Centrality} = 10 \sum \text{AS (ADKiADKj)} \qquad (2.1)$$

Where AS is edge (link) strength or Association Strength), ADK i is ADK in one cluster and ADK j is an ADK in another cluster or theme.

Density measures the intra-cluster or thematic cohesion. It is calculated by the formula:

$$\text{Density} = 100 \frac{\sum \text{AS(ADKiADKj)}}{n} \qquad (2.2)$$

Where AS is association strength, ADKi and ADKj are two ADKs connected to each other in the same theme or a cluster and *n* is the number of ADKs in the theme.

Therefore, the centrality and density of clusters are presented for each time intervals of analysis in both cases and used to map the discovered themes of each time interval to the strategic diagram to classify based on the role they play in thematic structure as core, basic, emerging and peripheral.

The framework for thematic mapping in this research is presented in Figure 2.1.

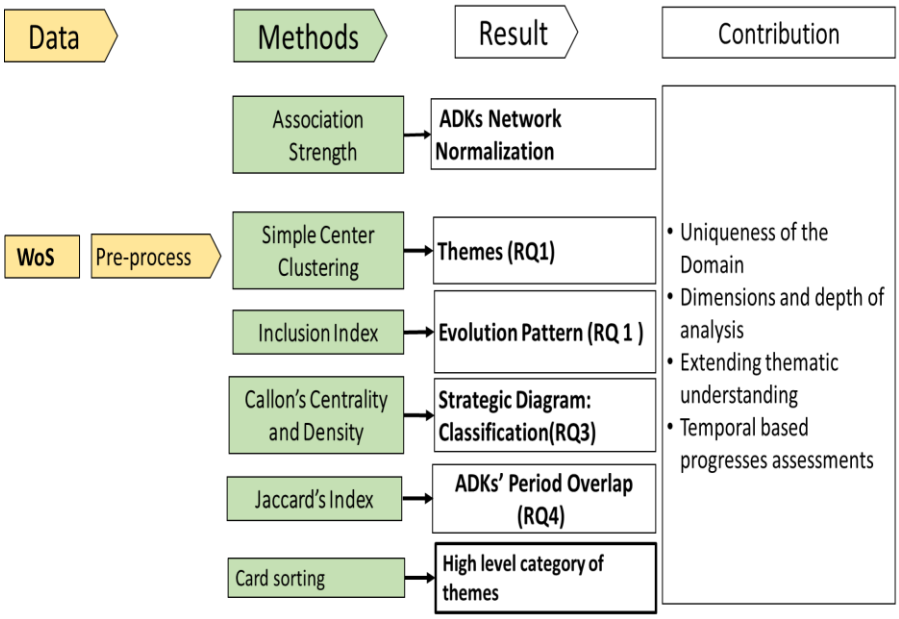


Figure 2.1. General Method of Thematic Discovery and Characterization

2.3.1 Techniques, Strategies and Algorithms

2.3.1.1 Definition of Network Matrix, Normalization, Evolution and Overlapping Measures

In our research, the co-occurrence of ADK i and j is $ADK_{ij.}$ ADKi is the frequency of occurrences of ADK i alone in the paper and ADKj is the frequency of occurrences of ADK j alone in the paper. There are different similarity, evolution and overlapping measures used at different times by different researchers. These include association strength (Couter et al., 1998; Van Eck and Waltman, 2010), Inclusion Index (Cobo et al., 2011), Jacard' Index (Peters and Van Raan, 1993). Salton's cosine (Salton's and Mc Gill, 1983, Cobo, et al., 2011). In our research, we implemented association

strength for network normalization, Inclusion Index for evolution pattern discovery and Jacard's index for discovering the conceptual (ADKs) period overlap for their varying advantages for each case.

The following formula used to measure association strength between two ADKs' co-occurrence is:

$$AS = \frac{(ADKij)^2}{ADKi.ADKj} \qquad \text{Where } 0<=AS<=1 \qquad (2.1)$$

Association Strength can also be called Affinity Index (Peters and Van, 1993) or Probabilistic Affinity index (Zitt et al., 2000). Association strength can also be called Equivalence Index (Callon et al., 1991, Cobo et al., 2011).

Inclusion index is calculated by the formula

$$\text{Inclusion Index} = \frac{ADKij}{\min\,[ADKi,\ ADKj]} \qquad (2.3)$$

Where min [ADK_i, ADK_j] is the minimum of frequency of occurrences of ADKi and ADKj.

The Jaccard's index is simply intersection divided by union of ADK i and ADK j and calculated by the formula:

$$\text{Jaccard's Index} = \frac{ADKij}{(ADKi+ADKj)-ADKij} \qquad (2.4)$$

Soltan's cosine, the co-occurrence divided by the square of their product. It is calculated by the formula:

$$\text{Salton's cosine} = \frac{\text{ADKij}}{\sqrt{\text{ADKi}.\text{ADKj}}} \qquad (2.5)$$

These measures can be used in best combination, in which they provide good results for a particular research question for network normalization, evolution pattern discovery, and overlapping map among thematic research areas in the thematic structure. For example association strength is good at showing evolutional hierarchy based on semantics (Courter et al, 1998). Inclusion Index is good for including similar concepts together at the expense of sematic hierarchy (Courtel et al., 1998, Cobo et al., 2015). Jacard Index is good for measuring the level of the semantic overlap among words in a database (He, 1999)

Therefore, in this dissertation, in the first paper (chapter three), association strength is used for similarity measure (network normalization), Inclusion Index is used for evolution pattern discovery of research themes over periods of analysis. Jaccard's Index is used for indicating the overlapping between themes of different time intervals.

2.3.1.2 Operational Definition of Evolution Pattern Discovery Strategy

Evolution map is used to detect the longitudinal evolution of thematic areas. It can be calculated using association strength, Equivalence Index, inclusion index or Salton's cosine using the formula given under 2.3.1.1. The structure of the evolution map is presented in Figure 2.2.

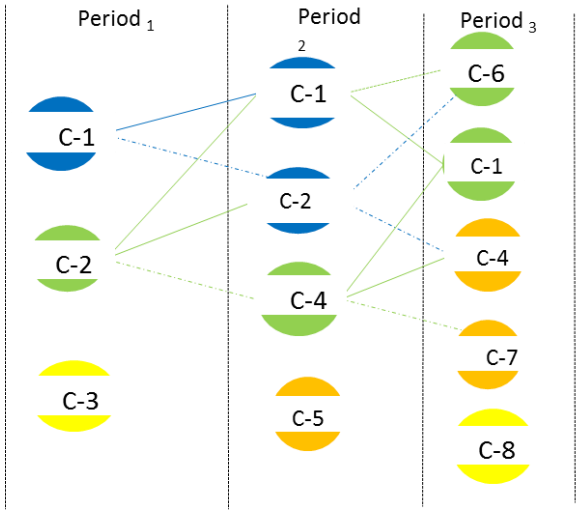


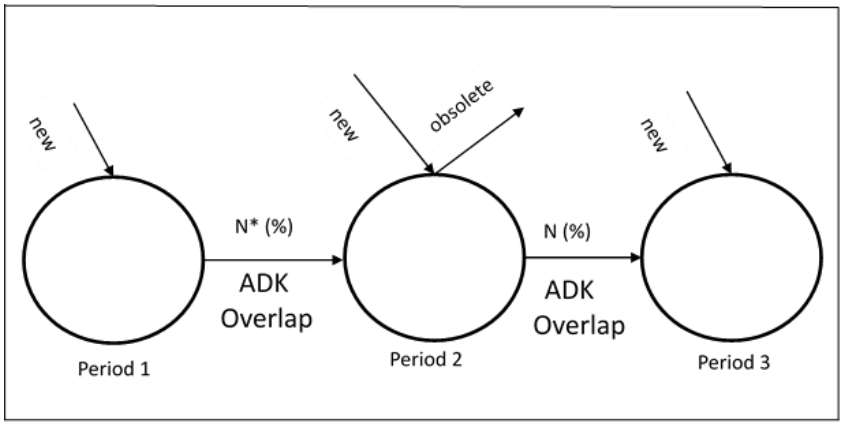
Figure 2.2. Strategy to Measure Evolution Pattern Discovery

Suppose that C-1 to C-8 in Figure 2.3 are the union of a set of all clusters or themes of the three time intervals. The color of themes are examples of the themes group based on subject matter. The three time intervals are Time interval 1, Time interval 2, and Time interval 3. Time Interval 1 has clusters or themes: C-1, C-2, and C-3. Time interval 2 has clusters: C-1 and C-2 (continued from time interval 1), C-4 and C-5 (new to time interval 2). Time interval 3 has clusters: C-6, C-7 and C-8 (new themes to the time interval), C-

1 and C-4 (continued from time interval 2). The relationship links between themes used in this example is association strength or inclusion index in our case. The relationship links between themes (clusters) of different time intervals, in Figure 2.2 are of two type. The solid line shows the continuance of the themes or sharing the main ADKs. For example C-1 in time 1 is linked to C-1 in time interval 2 by solid line to indicate cluster that C-1 has continued as a theme over the two time intervals; time interval 1 and time interval 2 by the same name. Broken line shows origination of new theme from the previous one but by sharing non central ADK(s) or weak tie between two themes different time intervals. For example, look at the relationship links between clusters C-2 in time interval 1 and cluster C-4 in time 2 in Figure 2.2 is a week tie. C-3 in time interval 1, C-5 in time interval 2 and C-8 in time interval 3 are isolate themes and their status and relative position can be determined using strategic diagram based on the Centrality and density measures of the themes in different time periods.

2.3.1.3 Operational Definition of Overlapping Pattern Discovery Strategy

The overlap map indicates the thematic stability in terms of number of ADKS, which are obsolete and newly emerged between time intervals. The operational definition given to the overlapping map used in this dissertation is presented in Figure 2.3



N*: Number of ADKs passed to the next period.

Figure 2.3 Strategy to measure the level ADKs time Overlap or Stability over Time

2.3.1.4 Operational Definition of Strategic Diagram

Strategic diagram is a two-dimensional space by the level of centrality (X-axis) and density (Y-axis). It has four quadrants used to classify the detected or discovered over the time intervals into different status/positions (Courter, 1998; Callon et al., 1991; Small, 1998; Liu et al., 204; Cobo et al., 2015). The structure of strategic diagram is presented in Figure 2.4.

Quadrant 1 is the quadrant with high level of centrality and density. The themes classified into this quadrant are those, which have high level of inter-cluster interaction and strong intra-cluster cohesion. This themes are assumed to be both core to the shaping of entire knowledge structure of research field as well self-sustaining within themselves to stand as autonomous theme of research in a particular time interval. It shows high level of importance or

influence of themes in field of study's knowledge structure serving as a central role. They also internally well developed.

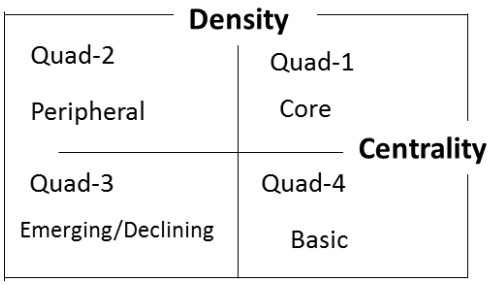


Figure 2.4. Structure of Strategic Diagram to Classify the Thematic Areas by Centrality and Density

Quadrant-2 of the strategic is a quadrant with low level of centrality and high level of density. This means this quadrant displays those themes, which are internally well grown (with high intra-cluster cohesion) but weak in playing central role in shaping the whole structure of field of study. In short, themes classified in this quadrant are said to be highly developed and isolates or peripheral themes.

Quadrant-3 is a quadrant with both low centrality and density. Themes classified in this quadrant are those which both are internally less developed or weak intra-cluster cohesion as well as weak inter-cluster interaction (peripheral). These themes are said to emerging or declining.

Quadrant-4 displays themes of strong centrality and low density. Themes appearing in this quadrant are those with strong inter-cluster interaction and

weak intra-cluster interaction. They are weak in sustaining themselves as strong theme or less developed but their role to shape entire knowledge structure is high due to their higher centrality values. Therefore, these themes are said to be basic and transversal theme. They can also be said central and undeveloped.

2. 3.1.5. Cluster/Thematic Network

It is a sub-graph of the entire network containing strongly association or similar ADKs based on their co-occurrence metrics. Simple center clustering algorithms is used for clustering purpose to give less weight to meaningless co-occurrence of all the times and pick the central ADKs based on degree centrality. The example of cluster network can be understood from Figure 2.5. The name of the cluster is the central ADK, in this example ADK_1. The central ADK is not necessarily popular according to the simple center clustering algorithms. It looks for the ADK, which has a connection to all of the rest of the member ADKs in the same clusters. There is also connection between the member ADKs. The thickness of the edge between ADKs in the cluster is proportional to the association strength. The size of the node ADKs in the cluster network is proportional to their individual popularity. Individual ADK's popularity is the frequency among the journal articles. There are different clustering algorithms for clustering the network ADKs into themes

such as simple centers algorithm is used to cluster the ADKs network into themes.

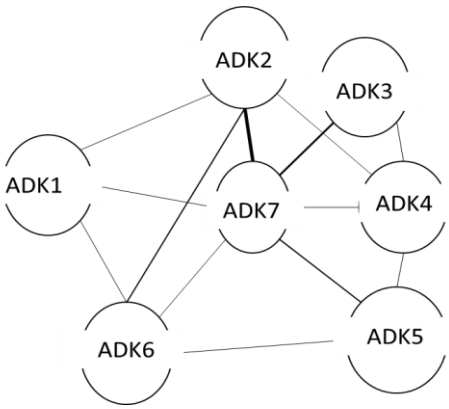


Figure 2.5. The Structure of Cluster or Thematic sub-graph, in this example, there are seven ADKs in the cluster or thematic sub-graph, the theme name would be ADK_7

Suppose, the cluster network in figure 2.5 has 7 ADKs. Having different node degrees and association strengths among themselves and frequencies or popularity. ADK1 has degree centrality of 3. ADK2 has degree centrality of 4. ADK3 has degree centrality of 3. ADK4 has degree centrality of 4. ADK5 has degree centrality of 2. ADK6 has degree centrality of 3. ADK7 has degree centrality of 6. In this example, the simple center clustering algorithm picks ADK7 as the cluster or theme name because of its highest degree centrality. ADK7 might not be popular but just central all the member nodes or ADKs though.

2.4 Summary of Methods

In this dissertation, we focused on discovering and characterization of thematic areas in thematic structure of the domain of Human Computer Interaction (HCI)/User Experience using Author Defined Keyword (ADKs) Network Analysis, which is the type of co-word analysis. The performance/quality analysis of the discovered thematic research areas are performed. The performance analysis is made using number of journal articles, citations received and h-index related the detected thematic areas. We used cluster network, evolution maps, overlapping map to study the theme structure, evolution lines and conceptual stability respectively. We also evaluated discovered themes in terms of the bibliometric performance indicator linking the themes to articles. Number of articles, citation and H-index of articles related themes were used as performance measures.

Nodes are ADKs and edges are their co-occurrence in different journal papers together. A group of ADKs having strong association strength through their co-occurrences are grouped together into a cluster. Clusters of ADKs network are considered themes of research areas of the field of study under investigation i.e. HCI/UX. The theme is represented (named) by the most central ADK in the cluster network using the simple center algorithm (Cobo et al, 2011). Centrality and Density of themes used to measure the intra-cluster

cohesion and inter-cluster coupling of the discovered thematic areas respectively. Therefore, we combined a flavor of graph theory and bibliometric to discover thematic areas and character them in many dimensions for the deep understanding of the thematic areas of HCI/UX in chapter three and four.

Chapter Three

Author Defined Keywords Network Analysis for Temporal Thematic Discovery and Characterization in Human Computer Interaction/User Experience

Abstract

This paper explores thematic structure at the intersection of user experience and human computer interaction areas of research using Author Defined Keywords co-occurrence network analysis. 519 journal articles were retrieved from the Web of Science published within the time frame of 1990 to 2016 containing both concepts. The time-frame was petitioned into three periods (1990-1999, 2000-2009, and 2010-2016) Temporal based analysis. The Temporal trends were visualized and analyzed and it is increasing in every aspect. The network was created based on the co-occurrences of ADKs. Evolution map, stability diagram and strategic diagrams were used to see the dynamics of thematic areas in the field of study over periods. The discovered thematic areas were explained in terms of centrality and density of thematic networks. The number of thematic areas and their stability increased over period but still nearly 52% between 2000-2009 and 2010-2016. Evolution relationships of thematic areas of different periods were also observed and it gets complex over time. Themes are increasing and changing in naming in shaping the field of study over time in every quadrant of the strategic diagram.

It is interesting to see how the field gets more motor themes and develop new themes over time.

Keywords

User Experience, Human Computer Interaction, Author Defined Keyword Network, Scientific knowledge, Graph theory, Bibliometric

3.1 Introduction

3.1.1 Overview

User experience is people's overall feeling of perceiving or using a certain product, system or service[3] .The experience can be from perceived use or response after usage. Its goal is making sure that technology is for improving human's lives, not to complicate it.[4] The historical timeline of the domain can be traced back to Leonardo Da Vinci's "Kitchen Nightmares"[5] to the Disney's world who was thought to be the first UX designer.[6] Another important timeline is the recognition of user experience as a job position in Apple in 1995[7]. The evolution of personal computers in 1970s opened new opportunity for User Experience/Human Computer Interaction (HCI) field of study in its increasing role in digital world (Marcus et al., 2013). Moreover, the emergence of many digital interactive systems like smartphone and related operating systems service platforms such as iOS, Android, web 2.0 services, cloud computing, virtual and augmented reality, Internet of Things (IoT) have opened a new horizon for the role of the User Experience (UX) aspect of human computer interaction as a profession and research area (Marcus et al., 2013). Companies made it a critical success factor over time in the effort to

[3] Ergonomics of human-system interaction. User experience accessed https://www.iso.org
[4] Technology to Improve Our Lives accessed from http://www.huffingtonpost.com
[5] Sullivan, Brian. Leonardo's Kitchen Nightmare available at http://boxesandarrows.com
[6] Walt Disney: The World's First UX Designer accessed from http://uxmag.com
[7]The brief history of user experience accessed from http://blog.invisionapp.com

make their digital products more appealing, user friendly, simple and ensure their efficient usage by the end users. As an interdisciplinary and a multidisciplinary field of study, roots of HCI/UX are many. Among them, the main contributors to the emergence UX/ HCI include affective computing, information architecture, human factors and ergonomics, psychology, anthropology etc. (Kujala et al., 2014, Hassenzahl et al., 2006). New field of studies contributed as a theoretical, methodological and/or areas of applications as time goes on. Roots of ergonomics and human factors in turn include philosophy, cognitive science, psychology, anthropology and sociology, industrial design and computer science (Bardzell et al., 2015). Therefore, it is important and necessary to study the development trends, new evolutions, continuance, obsolescence and overlapping concepts in thematic research areas of the thematic structure over periods in the field of study. The insight obtained from finding would aid the researchers, planners, policy makers and sponsors of academic research platforms. The rationale behind this research is knowing the past and current trends, structure and evolution in this field of study helps to figure out its future perspectives. It is important to see the research trends over time from the scientific publication point of view in proper domains to discover the current trends to imagine the future prospects of the field. The scope of research is limited to the journal articles to which

aspects of HCI/UX are covered, and to answer the question what is knowledge structure in the field within the defined scope.

To do this, it is important to identify the most comprehensive data source for the journal articles. Web of Science (WoS) is a more comprehensive database for these kinds of journal articles. For conducting the research, we proposed Author Defined Keywords (ADKs) co-occurrence network analysis method based on graph theory and bibliometric (Leibowitz, 2005; liu et al., 2014; Noack, 2009). This approach is considered a systematic way of gaining high level yet useful insights from large publication bases, which otherwise wouldn't have been possible (Cobo et al., 2015).

The social network properties to find out high level insight from the network graph are centrality and density of clusters (Callon et al., 1991). The centrality of the clusters was shown by the link strength and number co-occurrences of individual ADKs, which we consider in this research as nodes. We used also centrality and density of the themes to see dynamics of thematic areas using strategic diagram. Thematic evolution map and stability diagram were used for indicating thematic evolutions and overlap in different time intervals. The group of ADKs with strong association strength forms clusters. Those discovered clusters represent research thematic areas. The association strength between keywords (nodes) is measured by the number of co-occurrences

ADKs in different papers. The network is visualized based on co-occurrence of ADKs.

The finding would reveal high level yet important insights with regard to HCI/UX thematic structure form large publication data. Discovery of such a knowledge/insight would be important information as an easy reference for researchers, academicians, practitioners and sponsors of the research platforms to make informed thematic area selection for research venues. The assumptions for selecting ADKs analysis of content of the journal articles and structure of the thematic structure is described in following subsection 1.2.

3.1.2 Assumptions to Use Author Keyword Analysis

Assumptions to use ADK as unit of analysis include (Callon et al., 1991; Callon et al. 1983; liu et al., 2014) first, Authors of scientific articles choose their technical terms (keywords) carefully so that it represents the contents. The second assumption is that when different terms (keywords) are used together in the same article, it is because the author is either recognizing or postulating some non-trivial relationship between/among them. Another important assumption that makes ADK important content indicators is, if enough different authors appear to recognize the same relationship, then that relationship may be assumed to have some significance within that particular area of study. Lastly ADK are assumed to be descriptors of the contents

therein. The assumptions assert that, it is possible to systematically represent the content of the journal articles by ADK even though representativeness of the ADK may vary by the level of experience and expertise of the authors. Therefore based on this assumptions, ADKs network visualization and analysis over a certain time frame of 1990-2016 is proposed to systematically explore the impact and knowledge structure of HCI/UX.

3.1.3 Significance and Justification

The research is aimed at contributing new insight to understanding of the thematic structure in User Experience/Human Computer Interaction. It discovers research thematic and characterizing them over periods, which has not been explored (Hassenzahl et al. 2006). It would address questions like what is the relationship between HCI research and User Experience practices, question has been research inspirations for the user experience community but not empirically addressed from publication data of large size. Therefore, our research is focused on assessing both quantitatively and qualitatively, research thematic areas that combines HCI and UX.

The insights discovered would be important to show research directions to research and development policy makers, researchers and the industries. Past and current patterns are current status are discussed and future implications were made since the dynamism of thematic areas and the conceptual stability

observed in in past would imply the future research areas. It would be of more significance as a corner step for future research in this area.

3.1.4. Organization of the Paper sections of Chapter Three

The paper is structured into five sections having their own subsections. Section one covers introduction, section two discusses related works. Section three describes the specific methodology used to conduct research particular to this part. Section four covers visualization and analysis of ADKs network and section five briefly summarizes the key findings and conclusive remarks.

3.2 Related Works

3.2.1 Keyword Co-occurrence Network and its Foundation

The base for ADKs network analysis and visualization techniques is graph theory (Altmann et al., 2011; liu et al., 2014). Graph theory gives a base for objects (items) to be treated as nodes (vertices). Nodes can be people, themes, institutions, or web pages, etc. in general sense. In this research ADKs are considered nodes in our research. The co-occurrence of the ADKs in the same paper is considered as a link/connection/edge, afterwards used as an edge in this research. The connected node can be clustered based on keywords similarity measure or association strength. Visualization in the form of a

network graph gives easy and comprehensive insight. The method has been used in other domains to discover important research thematic areas in other fields of study. In biology, the method was used to discover the global stem cell research direction over 16 years (Zyoud et al., 2016). In chemistry, the method was used to identify to quantitatively assess the research trends in volatile organic compounds (Zhang et al., 2010). In the case of healthcare, a co-word network was used in disease pattern identification particularly to quantitatively and qualitatively assess the research trends of Parkinson's disease (li et al., 2008) and to discover the knowledge structure of general practitioners research in the healthcare profession (Hong et al., 2016). Co-word network analysis was used to indicate topics in data mining researches in tourism (Law et al., 2007).There are different approaches for clustering and mapping knowledge structures (Boyack and Noyons, 2014). The approach of clustering the knowledge structure can be made by marking the nodes in similar clusters or by using a unified approach, in which clusters are identified by colors and nodes take the color of the cluster. In our case, network normalized by the association strength is cluster using simple center clustering algorithm and individual separate cluster network is visualized. A single cluster network is treated as a theme and the name of a theme is the central ADK of the cluster network. This work is a comprehensive analysis in HCI/UX and Information Behavior knowledge structure, not yet explored in

the depth and dimension we proposed. The originality is ensured in terms of the approach used and the point of view.

3.2.2 The Need and Importance to Understand the Thematic Structure of HCI/UX

The field of Human computer interaction is a complex research area due to its multidisciplinary and interdisciplinary nature (Allam et al., 2010). As an interdisciplinary and a multidisciplinary field of study, it evolved from many field of studies. The dynamics is very within shorter times compared to other field of studies. It is complex since it deals with technological advancement and the creation of innovative interactive systems aligned with human behavioral and cognitive models. Understanding the dynamics of the thematic structure of such a complex field of study needs a systematic, less costly and comprehensive method (Bartneck and Hu, 2009). The user experience aspect of HCI is very important part, which has becoming a career line for many as well as a critical research field in the area of HCI (Hassenzahl et al., 2006).

Many researchers had made efforts to undertake research to understand the knowledge structure of related fields in computing in general and of HCI in particular using many techniques from CHI conferences papers as well as other sources. To mention a few, which were conducted in computing fields research area, two decades of HCI papers keywords were analyzed, to

characterize the intellectual structure of CHI conference using hierarchical clustering method and strategic diagram from ACM digital library conference papers(liu et al., 2014). Author keyword co-occurrence network was used to map online health information seeking behavior focusing on parallelship network with countries as a network actors (li et al., 2015). The quantitative analysis of contributions of countries and organizations to CHI conferences were analyzed using bibliometric analysis method and it was found that only 7.8 of the countries contribute to the 80% of the conference papers with USA ranked first from ACM digital library (Bartneck and Hu, 2009). The preliminary work of exploring HCI/UX journal articles' keywords network analysis has been made conference from Web of Science and this research is an enhancement of it by adding more journal articles for time interval of 2016 (Urgesaa et al. 2017).

Our approach varies either by data source, method of analysis and scope or clustering method used or visualization technique or detail and dimension of analysis from other related works. However, we acknowledge that our research idea is developed stepping on the shoulder of others who have made a tremendous contribution in science mapping and analysis in the other areas of studies and similar areas.

3.3 Methodology

3.3.1 Data

For an overview of historical timelines of HCI/UX, historical literatures were summarized as a background of the study domain. For the Author Defined Keyword co-occurrence network, publication data was obtained from the web of science within the timeframe of 1990 to 2016 to explore the emergence of new research thematic areas in the past two decades and the first half of the current decade. 519 articles were retrieved and included in the analysis. Articles considered were, those which dealt with both user experience and human computer interaction together to keep the scope of the research to aspect of UX related to HCI. For the part of ADKS network creation and analysis, ADKs were extracted and preprocessing was made to avoid duplications and the eventual misinterpretations and interfaces.

3.3.2 Data Preprocessing

Data reduction techniques used were limiting the ADKs' of occurrence to minimum of two. We also used the feature of searched similar words by

plurals, find similar ADKs and ADK groups by distance (by levenshtein distance) to avoid duplications and merged or removed based on the meaningfulness of the ADKs. Duplicates such as synonyms, identified and were also handled manually. The search terms Human Computer Interaction and User experience were also removed because obviously, they dominate other ADKs.

3.3.3 Visualization and Analysis Tools and Methods

The network metrics is co-occurrence analysis. The unit (concept) of analysis is Author Defined Keyword (ADKs). Time intervals of analysis are 1990-1999, 2000-2009 and 2010-2016 for temporal analysis. Normalization of network measure used was association strength. Clustering algorithm used was simple centers clustering algorithm. Simple centers clustering algorithm is very important to avoid the dominance of less meaningful co-occurrence of most of the time and detect simple centers based on maximum node degrees within the cluster. The minimum cluster size was limited to 1 and maximum to 15 (to avoid unnecessary cluster network complexity).

Inclusion index and Jaccard's index were used for evolution mapping and overlap mapping respectively. Strategic diagram was used to classify themes into four quadrats, which indicate internal strengths of themes and role the paly in entire thematic structure. Strategic diagram is a two dimensional space

having for quadrants. Quadrant I represents motor themes. Quadrant II represents well developed and isolated themes. Quadrant III represents emerging or declining theme and quadrant IV represents basic and transversal themes. The network or sub-graph of each thematic area identified in each time interval are illustrated (see Figures 3.3 to 3.5). The graph properties of the thematic areas in each time intervals in HCI/UX were presented in Table 3.5 and 3.6. For the evolution and conceptual overlapping patterns of this research area, see Figures 3.7 and 3.8.

3.4 Analysis

3.4.1 Basic Statistics

3.4.1.1 Statistics on Journals and Related Disciplines

To general understand further scholarly exchange platforms and convergence of different disciplines to shape this field of study, we observed top ten journal venues of the scientific articles. We also identified research disciplines contributed to the development of the thematic structure so far for this research area. The field of study is highly interdisciplinary and its top ten contributing fields and areas are identified systematically from journal sources and subject categories of the journals from the perspective of journal articles dealing with both Human Computer Interaction and User Experience and available in WoS. The cross disciplinary and interdisciplinary nature of HCI/UX can be inferred from the journal venues. This information is summarized in Table 3.1.

Table 3.1. Top Ten Journal Venues by Paper Contribution and Citation to HCI/UX

Top 10 Journal by contribution				Top 10 journals by citation		
Rank	Journals	Count	Percent	Rank	Journals	Citations
1	Interactions with Computers	32	6.17%	1	International Journal of Human Computer Studies	768
2	International Journal of Human Computer Studies	31	5.97%	2	Behavior and Information Technology	570
3	Computers in Human Behaviors	28	5.39%	3	Computers in Human Behavior	460
4	Behavior and Information Technology	20	3.85%	4	Interacting with Computers	447
5	International Journal of Human Computer Interaction	17	3.28%	5	Personal and Ubiquitous Computing	380
6	Multimedia Tools and Applications	15	2.89%	6	User modeling and User Adaptive Interaction	335
7	Lecture Notes in Computer Science	12	2.31%	7	Computers	291
8	Human Factors	9	1.73%	8	ACM Transactions on Information Systems	250
9	Ergonomics	7	1.35%	9	International Journal of Human-Computer Interaction	230
10	Universal Access in the Information Society	6	1.16%	10	Journal of Advertising	200

The source journals of papers from which the keywords were extracted and related disciplines in the subject category shows that this field of study is

highly interdisciplinary and cross-disciplinary in nature. The disciplines related to or contributed to the thematic structure of HCI/UX are mainly from computer science, behavioral sciences, psychology, information science, ergonomics, engineering, human factors, communication, healthcare systems, business and economics, and telecommunication.

We specifically observed which specialization of the first three in a row contributed more to the development of the field. Accordingly, we found out that from computer science, cybernetics, computer science-ergonomics, artificial intelligence, information systems, software engineering, interdisciplinary applications, and computer science theories and methods are at the top. From engineering, industrial design is dominant. From psychology, psychology multidisciplinary, experimental psychology and applied psychology are the dominant contributors.

3. 4.1.2 Journal Articles and Author Defined Keywords

In this section, we briefly explain the basic statistics regarding the journal articles, ADKs, authors, references used by researchers, sources of references by time intervals. The time interval of analysis was from 1990 to 2016. It has a total of 519 journal articles. The 519 articles were partitioned into three sub-time intervals to see growth over the decades, namely 1990-1999 containing only 44 papers (8%), 2000-2009 containing 165(32%), 2010-2016 contains

310 journal articles (60%) as shown in Figure 3.1. The number of journal articles has increased considerably over the three time intervals. Even the first half of the current decade has nearly double that of 2000s. The growth of the number articles during 2000-2009 is nearly 4 times that of 1990-1999. The growth in the number of articles during the first half of the current decade is seven times that 1990-1999. There are on average three keywords per article. The number of ADKs usage per article also increased over years but generally in articles, less than or equal to three ADKs were used frequently.

There is a total of 1765 Author Defined Keywords. 96(5%) ADKs belongs to the 1990-1999, 516 (29%) ADKs belong to the time interval 2000-2009, and 1153 (65%) ADKs belong to the time interval 2010-2016. There is a significant increase in the number ADK in across the time intervals. The growth in the number of ADK from 1990-1999 to 2000-2009 is 5.4 times. The growth for that of 2000-2009 and 2010-2016 is 2.2 times. The growth in ADK 1990-1999 and 2010-2016 is 12 times. The growth in ADK usage follows the same pattern with the journal articles (see Figure 3.1).

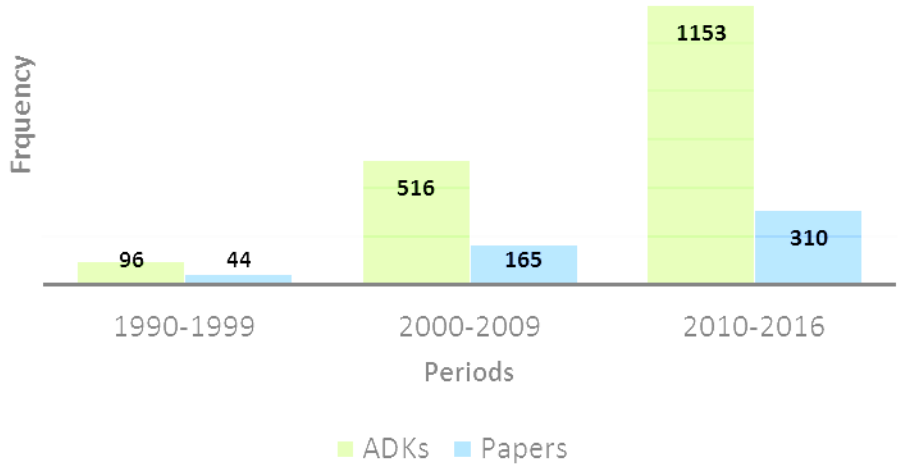


Figure 3. 1. Distribution of Number of papers and ADKs by Time Intervals having dealt with in HCI/UX

When we specifically observe individual years, the growth from 1990 to 2011 is slow and with little ups and downs. However, the growth of the journal articles published in the area of HCI/UX starting from 2011 has shown a continuous dramatic increase. The average number of papers per year for the whole years is 19. After 2011, the average paper per year is 49, nearly tripled the average per year number for the entire time interval. With regard to the ADKs vs their occurrences, 86% of the ADKs appeared only once in an article. Only 247 (14%) of the ADKs occurred twice and more in the articles. Those 14% of the ADKs would be important to show the thematic structure with their co-occurrence relationship (liu et al., 2014, Callon et al., 1991). Therefore, they are considered to be included in the final construction of the network

visualization and analysis. Popularity and Centrality (Coreness values) of individual ADKs is presented in Table 3.2. This information is important to indicate the popularity (research interests) and centrality (influence) of individual ADKs in the entire knowledge structure over the whole time span for analysis.

Table 3.2. Centrality and Popularity of Individual ADKs in the Entire Time Span (top ten levels) in HCI/UX

Level	ADKs	Centrality	level	ADKs	Popularity
1	Usability	59	1	Usability	24
2	Human Factors	51	2	User interface	21
3	Design	41	3	Design, Human Factors	12
4	User Interface	38	4	Affective computing, interface design	11
5	Experimentations	36	5	Ubiquitous computing	10
6	Interface Design	28	6	Virtual Reality, user studies	9
7	Performance	23	7	Experimentation, emotion, software engineering, multimodal interaction	8
8	Virtual Reality	20	8	Performance, evaluation, human computer interface, e-learning, aesthetics	7
9	Ubiquitous Computing	19	9	User centered design, internet, Interaction design, eye tracking, mobile devices,	6
10	Affective Computing	17	10	user modeling, user centered design, social interaction, presence, motivation, gesture recognition, cognition	5

Since, the thematic network is based on simple centers principle within the cluster in period, it does not tell the centrality and popularity of individual concept (ADK), it is important to show the research interest (popularity) and influence of individual ADKs for the entire time of analysis and thematic structure of HCI/UX, which may not be obtained from the themes analysis.

3. 4.1.3. Discovery of High Level Research Categories at the Intersection of HCI and UX

To discover the high level research categories, citation network of the 254 journals, which published at least one paper related HCI/UX is visualized and clustered (Garfeild, 1972; Otte and Ronald, 2002; Carelo-Nadina, 2008). For each of the 254 journal articles published at least one paper related to HCI and UX together, within the time frame of 1990 to 2016, the total link strength of journals citation network was calculated and the journals with the strongest total links were selected and visualized. Consequently, only 49 journals had strong citation link to each other. The network normalized by the association strength (Courtel et al., 1998, Van-Eck et al. 2007) between journals and laid out by linlog modular class (Jackomy et al. 2014) applied to get optimal cluster of research interests of focus in the context of HCI/UX. We discovered six clusters of journals citation network as presented in six different colors as shown in Figure 3.2. The detected six clusters are summarized in Table 3.3. In the citation network, the color intensity from blue to red of the clusters shows

the level of cluster density or internal development of the category of the research.

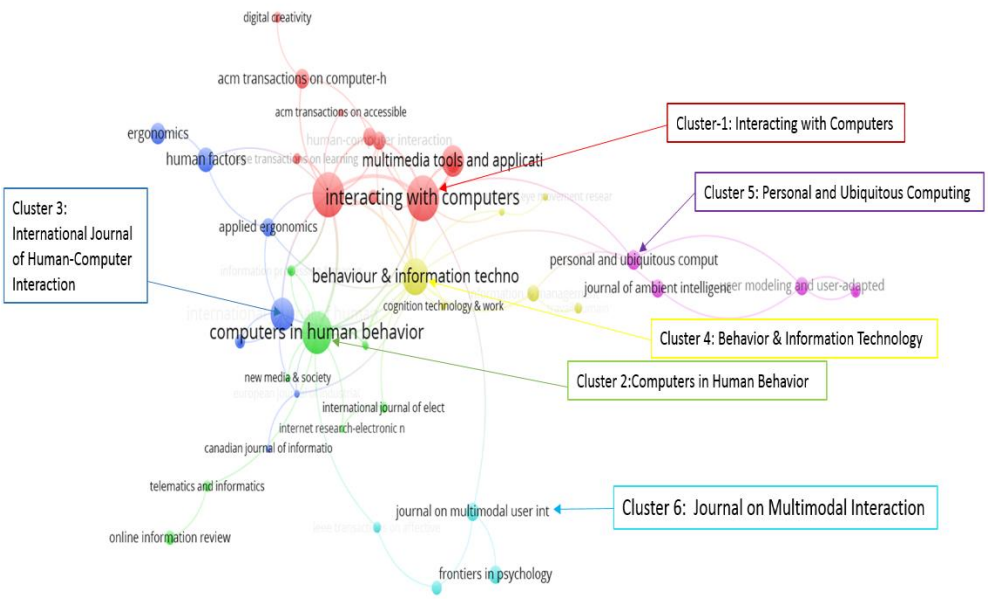


Figure 3.2 Citation Network of Journals Published Papers in HCI/UX domain, 6 clusters with different colors red, green, and blue to show level of maturity or density high. Moderate and low respectively

The cluster name is the journal name with bigger fonts in each cluster based on the degree centrality (citation link). For readability, clusters with their member citing journals are summarized Table 3.3. Accordingly, cluster 1 (Interacting with Computers) has a cluster size of 15. The second cluster (Computers in human behavior) has a cluster size of 10. But when we search the publications size of the journals, journal of computers in human behavior is 4771. The number of publication for journal of interacting with computer is 933.

Table 3.3. Clusters of citation Network of Journals Contributed to the development of HCI/UX Thematic structure and Member Journals

Number	Cluster Name	Cluster size	Member Journals in the Cluster
1	Interacting with computers	15	International Journal of Human Computer Studies ACM Transaction of Accessible Computing ACM Transaction on Human Computer Interaction Advances in Human Computer Interaction Computers and Industrial Engineering Digital Creativity, Human- Computer Interaction IEEE transaction on Learning Technologies Internet Research Journal of Intelligent Manufacturing Journal of Medical Systems, Journal of the association of Information Science and Technology Multimedia tools and applications Universal access in information society
2	Computers in Human Behavior	10	Information Processing and Management International Journal of Electronic Commerce Displays, Eurasia Journal of Mathematics Science and Technology education European Review of Applied Psychology Internet Research-electronic networking applications and policy New media and society Online Information Review, Telematics and Informatics
3	International Journal of Human-Computer Interaction	8	Applied Ergonomics Canadian journal of Journal of library and Information Science Codesign-International journal of cocreation in design and the Arts Ergonomics European Journal of Industrial Engineering Human Factors International Journals of Medical Informatics
4	Behavior and Information Technology	7	ACM transaction on Information Systems Cognition Technology and Work Information and Management International Journal of Industrial Ergonomics Journal of eye movement Research Travail Humain
5	Personal and Ubiquitous Computing	5	International Journal of Engineering Education, Journal of Ambient Intelligence and Smart Environment Requirements Engineering User Modeling and User Adapted Interaction
6	Journal of Multimodal User Interfaces	4	Frontier in Psychology, IEEE transactions on cybernetics, IEEE on Affective computing

Using conceptual hierarchy, the six clusters are categorized into three broad categories of research interests in the context of HCI/UX. These three categories are:

Category 1: Clusters 1 and 3 were combined: Computing, Humans and Interactions (well matured category)

Category 2: Clusters 2 and 4 were combined: Computing, Humans and Behavior or Information Behavior (selected as the topic of the second case in this dissertation) (matured category)

Category 3: Cluster 5 and 6: Ubiquitous Computing and Multimodal User Interface (emerging one)

Therefore, the whole 519 articles published in the 254 journal are considered and covered in chapter three, in this chapter (chapter three) of the dissertation.

Chapter four of this dissertation deals with one of three high level research categories systematically detected by the above procedure i.e. Information Behavior.

3.4.2 Visualization of ADKs' Cluster Network and Analysis

As discussed in the methodology section, in chapter 2 in general methodology and section 3 particular to this chapter, the purpose of this subsection is to map thematic areas, thematic areas' evolution, and conceptual overlaps in the thematic formation of different periods. The classification of the thematic

areas into different status and roles is also performed based on centrality and density of the cluster or thematic networks.

For this purpose constructing and clustering the ADKs network into thematic areas is important. We constructed the ADKs network, mapped thematic area evolutions using evolution map, classified the detected thematic areas using strategic diagram for their relative position and observed their overlapping using stability map. We also characterized the discovered thematic areas using number of articles, citations, h-index.

The network of each thematic areas were presented for each sub-time interval. The properties of the detected thematic areas (clusters) is presented in Tables 3.4 and 3.5.

In all cases, the occurrence of the keyword included in the construction of the network was limited to at least two. A minimum of 1 and maximum of 15 ADKs are included in a thematic network.

3.4.2.1 Thematic Networks of Time Interval 1990-1999

The time interval of 1990-1999 accounted only for 44 papers, ADKs having at least one occurrence. The simple network of this time interval is as presented in Figure 3.3, case A and case B. Case A treats this time interval's construction of network with same parameters as other time intervals. However only one

theme (user interface) showed up in this time interval when minimum occurrence is fixed to two.

The first time interval was investigated by giving special parameters in terms number of occurrence of ADKs in case B for the interest of observing low level themes emerged during this early time interval. In Figure 3.3, case of A, User Interface is at the center and the network is named by it. In the case Figure 3.3, case B, the Training became a central concept and user interface became a member concept of Training thematic area. Related to Training, concepts: software engineering, human factors, end users, user interface, mental models and motivation were very important. In terms of the strength of link, Human Factors and User Interface are highly linked to training. The link between human factors and software engineering is too strong during this early time. The concept (ADK) motivation is strongly linked to end user. Over all, it is possible to say that the early time is devoted to user interface engineering and focus on training for better usability.

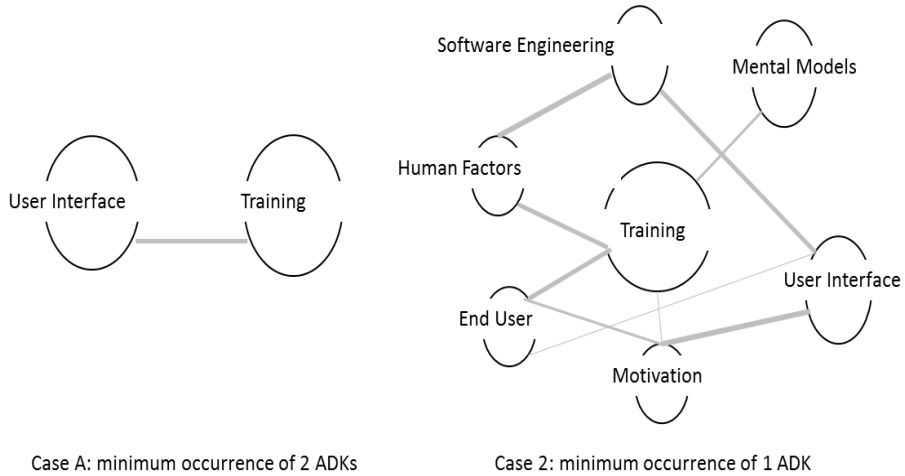


Figure 3. 3: Thematic Network of the time interval 1990-1999 in HCI/UX

3.4.2.2 Thematic Networks of the Time Interval 2000-2009

During this time interval, a total of 516 keywords were used in 165 journal articles. Out of tis 108 ADKs were included in the thematic network formation after preprocessing. Figure 3.4 shows the networks of thematic areas generated during this time interval. The number of clusters or thematic areas have grown from one in the time interval 1990-1999 to eight in this time interval with the same parameters. The eight thematic areas are *Usability, User Research, Design, Presence, and Psychometrics, Decision Support Systems, Software Design and Adaptive Systems*. Software design and adaptive systems thematic areas are very simple clusters having on two member nodes (themes). Software Design is linked only to concept self-service. Adaptive System is

linked to learning. Decision Support System thematic area has related concepts Anthropomorphism and Interaction. In the subgraphs or thematic network for this time interval, ***Usability and User Research*** thematic areas are with a complex and large cluster size (maximum cluster size set as a parameter i.e. 15 for cluster formation). It is also proved from the strategic diagram Figure 3.4 that both happen to be in quadrant of core (mainstream) thematic areas during this time interval. This means they are both strongly central and highly dense thematic areas in shaping the thematic structure of HCI/UX during this time interval. Usability strongly linked with member concepts- experience design and technology acceptance. The big concepts in the cluster network of Usability include: hypermedia, interface design, Artificial Intelligence, cognitive models, user centered design and human factors. A strong link between members concepts (ADKs) observed in this thematic area network is information visualization and ontologies, between navigation and Artificial intelligence. The big concepts (ADKs) in the thematic network of User Research include ubiquitous computing, user interface, augmented reality, task performance and context awareness, speech recognition, participatory design in this time interval. Design thematic network took a star network shape. It is at center of multimedia, electronic commerce, instruction, experimentation and education. We presented a separate clusters network of this period in Figure 3.3.

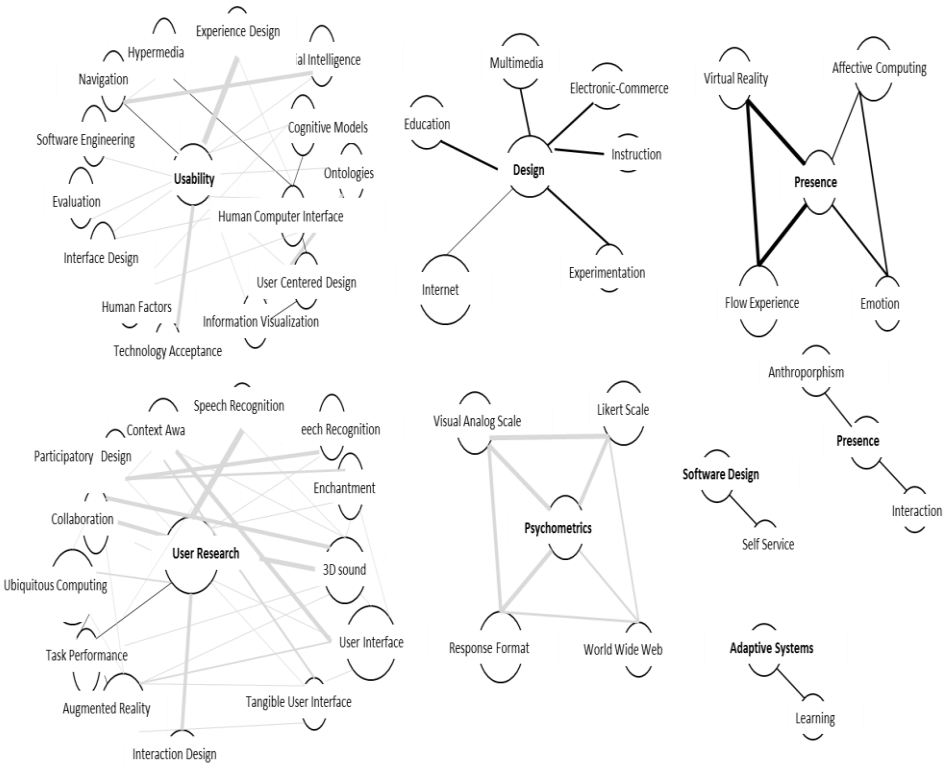


Figure 3.4. Thematic Areas Subgraphs of the Time Interval 2000-2009 in HCI/UX, bold ADKs at the center are theme names

3.4.2.3 Thematic Networks of Time Interval 2010-2016

The thematic areas discovered were during this period are *Usability, Aesthetics, Design, Emotion, User Interface, Ubiquitous Computing, Emotion, Virtual Reality, Recommender Systems, and Empirical Studies in HCI, Human Centered Design, Computer Vision and Haptics. Design* thematic area has continued from the period 2004-2010 but got complex in this time interval. *Usability* continued from 2000-2009 but got less sparse.

Aesthetics evolved as a big new thematic area network here with the cluster size of 15 in this time interval. User Interface thematic area has re-evolved in this time interval as thematic area with the maximum cluster sized used to cluster network i.e. fifteen ADKs belong to this thematic area. Ubiquitous Computing is newly evolved as a thematic area with cluster size of eleven.

Thematic areas Emotion and Virtual Reality seven and three member concepts (ADKs) respectively. The rest of thematic areas *Recommender Systems, and Empirical Studies in HCI, Human Centered Design, Computer Vision and Haptics* have member concepts of two.

With regard to the inter-time interval linkage, we need to see level of thematic evolutions, overlaps and relative strengths as a motor (mainstream), basic, emerging or declining and developed and isolated themes. The two subsections 4.3 and 4.5 will deal with exploring these issues.

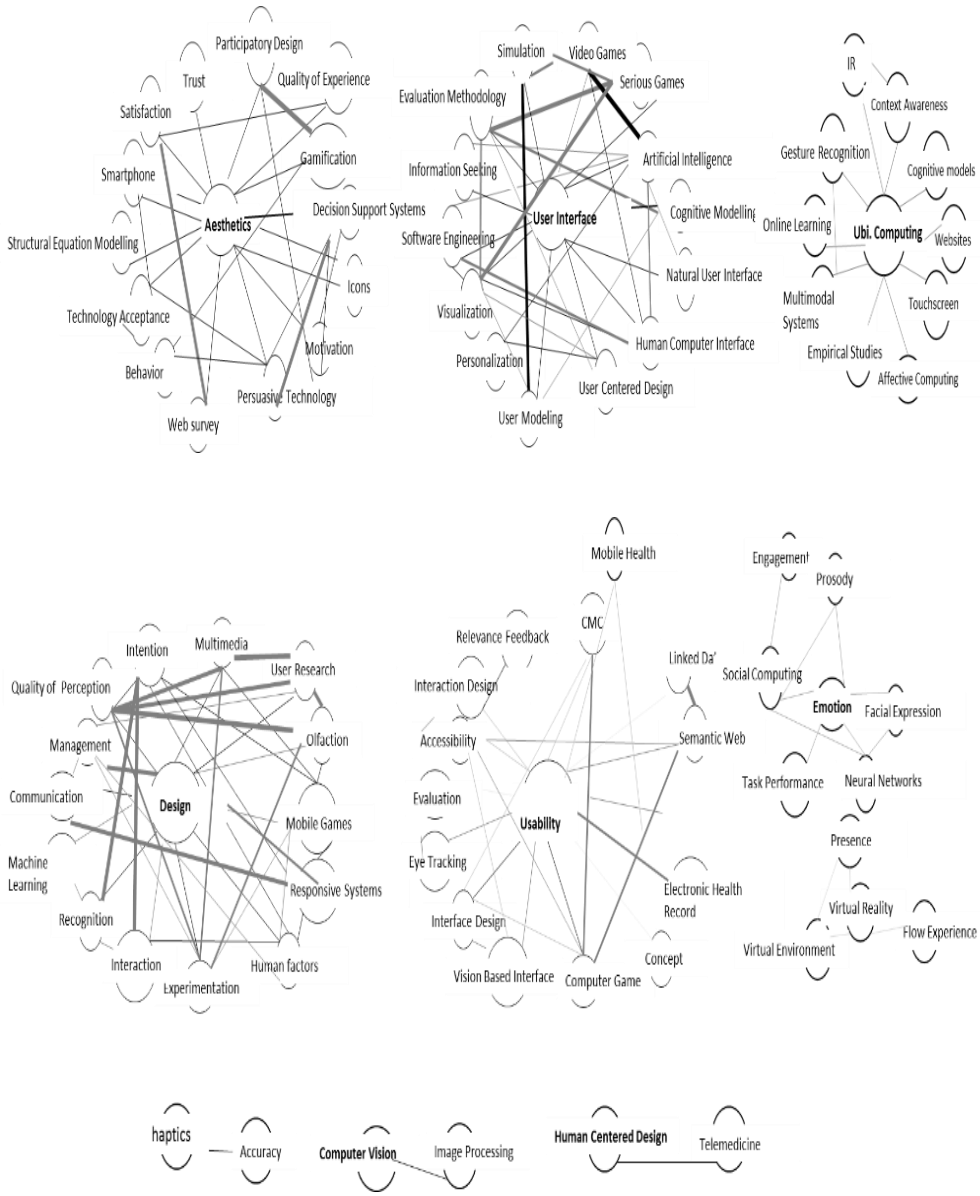


Figure 3.5. Thematic Areas subgraphs of the of Time Interval 2010-2016

3.4.3 Card Sorting of the Thematic Areas Discovered in the Domain of HCI/UX

To add another analysis dimension, the themes discovered in all time intervals are mixed and manually categorized into different high level concepts using card sorting methods by experts. Example of the result of the card sorting is as presented in Figure 3.6. The final grouping of the themes after discussion with the experts, are labeled with high level concept, which represent the group as a subject matter they addressed. The groups were color coded. The groups' details are summarized in Table 3.4.

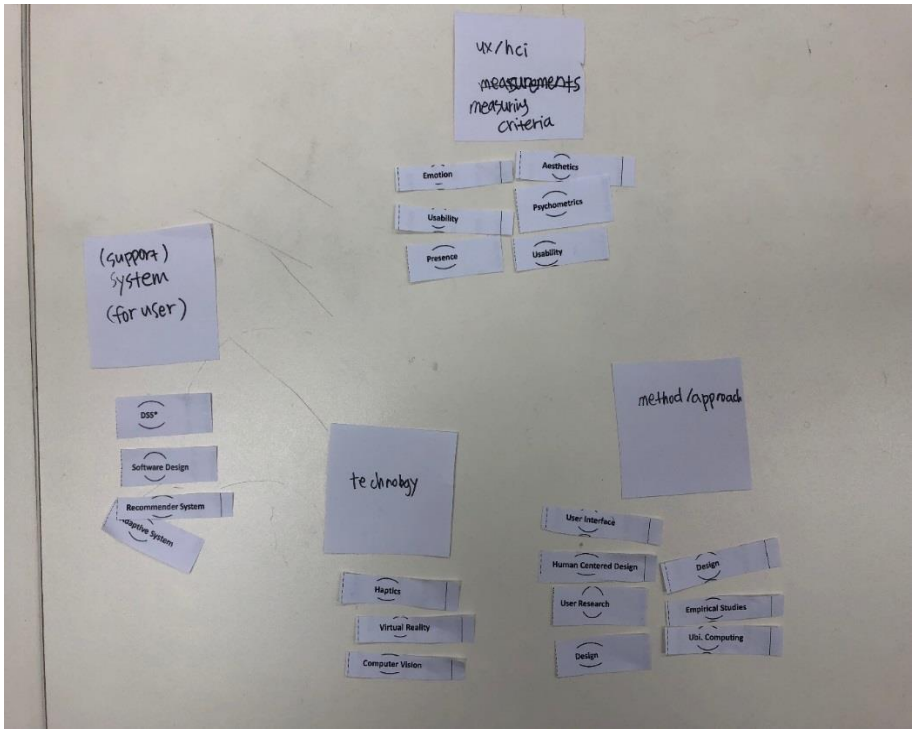


Figure 3.6. Sample Card sorting to group the Discovered Themes in HCI/UX Domain.

Table 3.4: Group of Discovered Themes in HCI/UX Domain by High Level Concepts and Color Code

Group Number	Group Name	Member Themes	Color Code
1	**Measurement**	1. Usability 2. Psychometrics 3. Presence 4. Aesthetics 5. Emotion	
2	**Technology**	1. Virtual Reality 2. Computer Vision 3. Haptics	
3	**Systems**	1. Decision Support Systems 2. Adaptive Systems 3. Recommender Systems	
4	**Methods/Approach**	1. User Interface 2. Human Centered Design 3. User Research 4. Design 5. Empirical Studies 6. Ubiquitous Computing	

When we see Table 3.4, the domain dealt more on methodology/approach and measurement criteria to study interaction with, users' behavior and usages of technology and/or systems. These groups' color codes are used as color of themes in evolution pattern discovery and themes classifications. The high level concepts Technology and Systems are not mutually exclusive groups but it's for septicity of discussion in this context. It can be grouped as Technology/System together.

The thematic area User Interface can also be appearing anywhere in technical or approach/method, however we considered it as an approach in the paradigm shifts of HCI/UX as the early time of HCI dealt with ensuring designing, implantation and

effectiveness and efficient user interface for interacting with technology/systems. Over period, the paradigm shifted to User Research in 2000-2009 (see Figure 3.8, evolution pattern). In 2010-2016, the paradigm shifted to Usability, User Interface Aesthetics as core areas. Usability is considered as a measurement criterion for the effective and efficient interaction with technology/systems to achieve users intended goal in this research.

3.4.4 Themes Overlapping and Evolution Pattern Discovery in HCI/UX over Time Intervals

In this subsection, we map the dynamics of thematic areas in terms of conceptual (ADKs) overlap and thematic evolution patterns.

3.4.4.1 Conceptual Period Overlap

The thematic overlapping is mapped using Jaccard's Index. Thematic evolutions were mapped using Inclusion Index, since it has more advantage to group similar ADKs together compared to Jaccard's Index as defined in chapter three. The stability diagram, which shows the conceptual overlapping trend of the field of study over time intervals for final dataset used for thematic network analysis is illustrated in Figure 3.5.

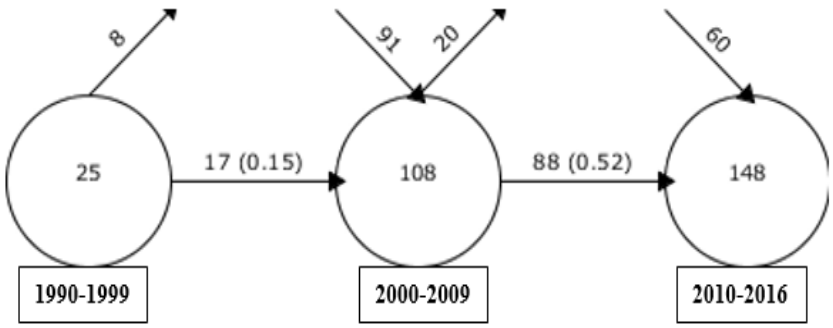


Figure 3.7. ADKs Stability Diagram in Thematic Areas Formation over the Three Time intervals in HCI/UX

As you can see, only 15% of the ADKs was contributed from the time interval of 1990-1999 to form the thematic research areas of the 2000-2009. 85% of concepts (ADKs) that formed the themes during 2000-2009 were newly emerged. The time interval 2000-2009 contributed 52% to the formation of thematic areas of 2010-2016. Only 48% of the ADKs formed the thematic areas of 2010-2016 were newly emerged. This shows that, there an increasing conceptual stability over period due to the increase ADKs overlap. Though there is a higher dynamism of thematic areas, conceptual stability increased between 2000-2009 and 2010-2016 than between 1990-1999. 32% of the themes in 1990-1999 were obsolete to pass to the thematic areas formation in the time interval of 2000-2009. 18% of the themes in the time interval of 2000-2009 were obsolete to pass to the thematic formation of time interval of 2010-2016. In Figure 3.8, we can see the evolution and interlinkages in the manner that it shows the origins of thematic areas as well as their relative development.

3.4.4.2 Evolution Pattern Discovery in the Domain of HCI/UX

In the evolution pattern discovery map, only one strong thematic area was evolved during 1990-1999 i.e. User Interface is at the root of the thematic areas evolved in later periods.

User Interface from 1990-1999, has a thematic overlap with User Research in the time interval 2000-2009. They are linked with solid lines because User Interface became a member concept of the theme User Research in 2000-2009. This shows that the focus from User Interface based approach to HCI/UX study to the broader human oriented approach i.e User Research. Usability and Design continued from 2000-2009 to 2010-2016. This indicates that these two thematic areas are sustaining their autonomy as a focus area of research over last decade and the current decade in the domain of HCI/UX.

Usability, User research and Presence thematic areas in 2000-2009 served as origins for the emergence of big thematic areas in 2010-2016. Usability thematic area in 2000-2009 served as the origin of Aesthetics, Design, and User Interface and Ubiquitous Computing research thematic areas. User Research thematic area from 2000-20009 has a contribution for the evolution of Aesthetics, Design, User Interface, Usability, Ubiquitous Computing and Emotion thematic areas in 2010-2016.

Presence in 2000-2009 has strong conceptual link with Virtual Reality in 2010-2016. Presence in virtual space was an issue during 2000-2009. It became a concept studied in context virtual reality in 2010-2016 or a measurement criterion on how people feel presence in the virtual space.

Decision Support System has strong conceptual link to Aesthetics through sharing main concept i.e. decision support systems became a member concept of Aesthetics and shared none main none main ADK with Design thematic area. Adaptive Systems and Software Design thematic areas are isolate thematic areas in 2000-2009 in terms of evolution line the thematic structure of HCI/UX.

More isolate thematic areas without evolution links evolved in 2010-2016 because in their thematic formation, they didn’t share any concept from the preceding period. These are Haptics, Computer Vision, Empirical Study, and Human Centered Design and Recommender Systems. When we investigate their relative position in a strategic diagram, they happened to be in the well-developed and peripheral quadrant. See Figure 3.9.

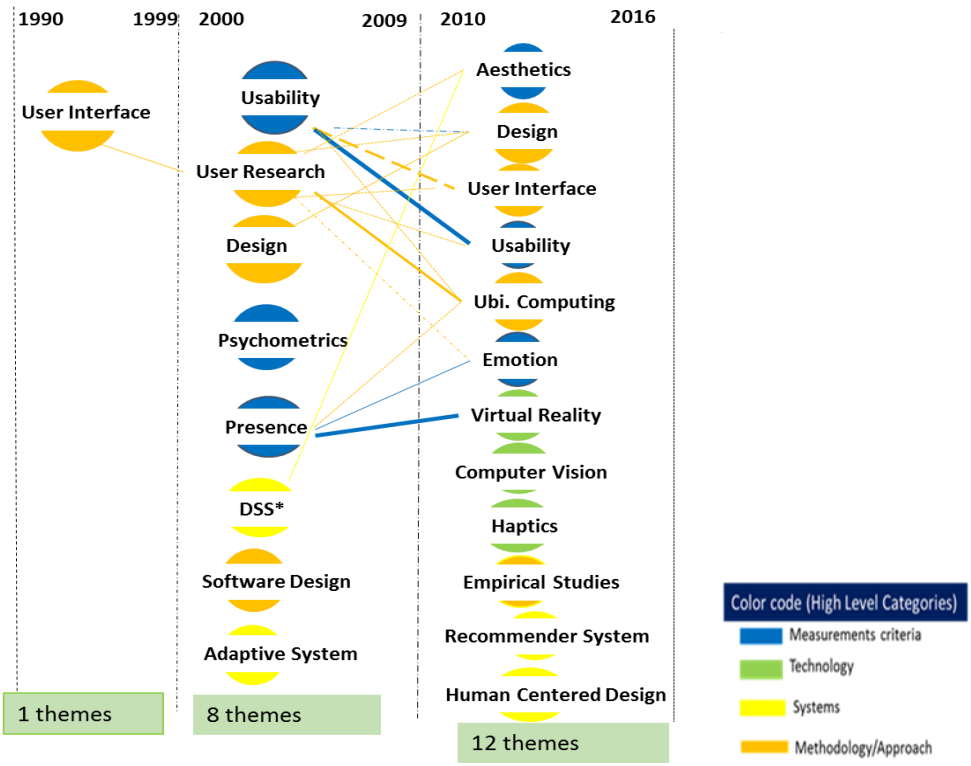


Figure 3.8. Evolution Patterns and Subject Matter Groups by colors of Thematic Areas over the Three Time intervals

3. 4.5 Strategic Diagram of the Three Time intervals of HCI/UX

In Strategic Diagram, the X axis show the centrality and Y axis shows density of the themes. It is helpful to show the motor, basic (transversal), declining or emerging and developed and isolated thematic areas in certain field in four quadrants. It is used in many similar works as effective strategy to classify thematic areas using centrality and density ranges (minimum 0 to maximum

1). The structure and detailed description of strategic diagram is presented in presented in in chapter two (methodology)

Table 3.5. Clusters and Their Graph Properties of the Time intervals 1990-1999 and 2000-2009 in HCI/UX

Time Interval	Cluster No	Theme Name	Centrality Range	Density Range
1990-1999	1	User Interface	1	1
2000-2009	1	Usability	1	0.62
	2	Use Research	0.75	0.75
	3	Design	0.62	0.5
	4	Adaptive System	0.62	0.12
	5	Psychometrics	0.5	1
	6	Decision Support System	0.38	0.25
	7	Presence	0.25	0.88
	8	Software Design	0.12	0.38

Table 3.6. Clusters and Their Graph Properties of the Time intervals 2010-2016 for HCI/UX

Time Interval	1	Cluster Name	Centrality Range	Density Range
2010-2016	1	Usability	1	0.33
	2	Aesthetics	0.92	0.92
	3	Design	0.83	1
	4	Emotion	0.67	0.42
	5	User Interface	0.67	0.83
	6	Ubiquitous Computing	0.58	0.08
	7	Virtual Reality	0.5	0.17
	8	Human Centered Design	0.42	0.25
	9	Recommender Systems	0.33	0.25
	10	Empirical Study	0.25	0.58
	11	Computer Vision	0.17	0.25
	12	Haptics	0.08	0.5

Values centrality range and density range are used to classify the themes in the four quadrants of strategic diagram in Figure 3.9. As mention in the operational definition, centrality measures the strength inter thematic

connections and density measures the intra-thematic total link strength (cohesion). High centrality means the theme has high level of influence as a center of the thematic structure. Themes with higher centrality would have two roles in the entire knowledge structure i.e. either core/mainstream or basic role.

Less centrality means theme has less influence in being central to the entire thematic structure. Themes with weak centrality plays either emerging/declining role or developed and peripheral role.

High density means the discovered theme has strong internal cohesion to stand as autonomous thematic area to be studied in certain particular time. Themes with high density would have two possible roles i.e. either core/mainstream or developed and peripheral role.

Low density means the theme has less likely stand by itself as autonomously to be studied. Themes with low density would have two possible roles i.e. play an emerging role or basic role in the entire thematic structure. To know the roles themes in the entire thematic landscape based on the combination of these possibilities, we need to map into the strategic diagram. The classification themes role for HCI/UX is presented in Figure 3.9. Based on these definitions the themes in Figure 3.9 can be interpreted as follows.

The theme one User Interface in HCI/UX domain during 1990-1999 has happened to be core/main theme. There was no basic theme, emerging

/declining theme or developed and peripheral theme during this period. It was so early during this time interval in the scientific base of this domain connecting HCI and UX.

During 2000-2009, two core/mainstream themes i.e. User Research and Usability and Design appeared as core/mainstream themes. Psychometrics was highly dense and moderately central and between developed and peripheral. The highly developed and isolated theme during 2000-2009 is Presence, which is highly linked to virtual reality in thematic evolution pattern map during 2010-2016.

The two emerging or declining themes are decision support systems and software design during 2000-2009. Design is on the border to consider a motor theme during this time interval. The one basic and transversal theme in scientific discourse of this field was adaptive systems.

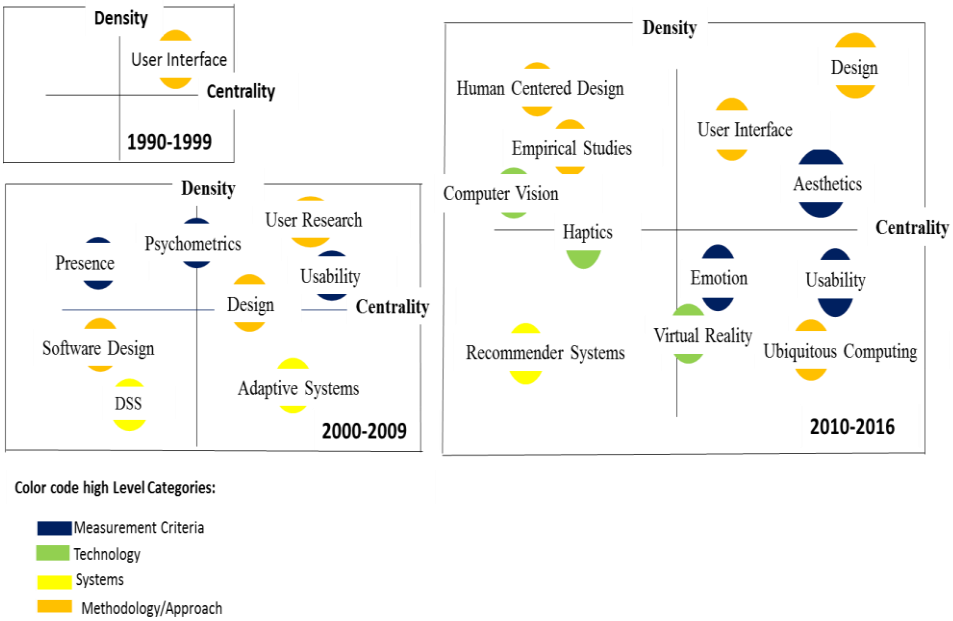


Figure 3.9. Classification of using by Centrality and Density (positions) and high level concepts (colors) for the three Time Intervals

During the 2010-2016, User Interface (re-emerged) and Aesthetics became two new important core themes and Design continues as a core from previous period. This shows that core changes over/main stream changes over period.

Usability, Ubiquitous Computing and Emotion, become basic and transversal themes in this time interval. Virtual reality became on the emerging or declining. Recommender systems is in the emerging/declining area during this time interval.

Highly developed and isolated themes during this time interval were Human Centered Design, Empirical Studies, Computer Vision and Haptics.

This shows that the field's thematic landscape is dynamic. Other researcher's findings (Liu et al., 2014) showed that HCI field has no motor themes from CHI conference papers. However, our finding shows that the situation in WoS is different and this area of study is getting more core/mainstream themes over time in its thematic structure. This shows that the journal captures more stable perspectives of the thematic than conference, which deals with more emerging issues and hence more unstable thematic structure or lack of core/mainstream areas.

3.5 Chapter Summary and Conclusion

Overall, the themes are growing and dynamically changing in quadrants of the strategic diagram. To summarize the dynamism in themes role, maturity and high level concepts and evolution patterns and conceptual overlap together over the three periods in HCI/UX is as presented Figure 3.10.

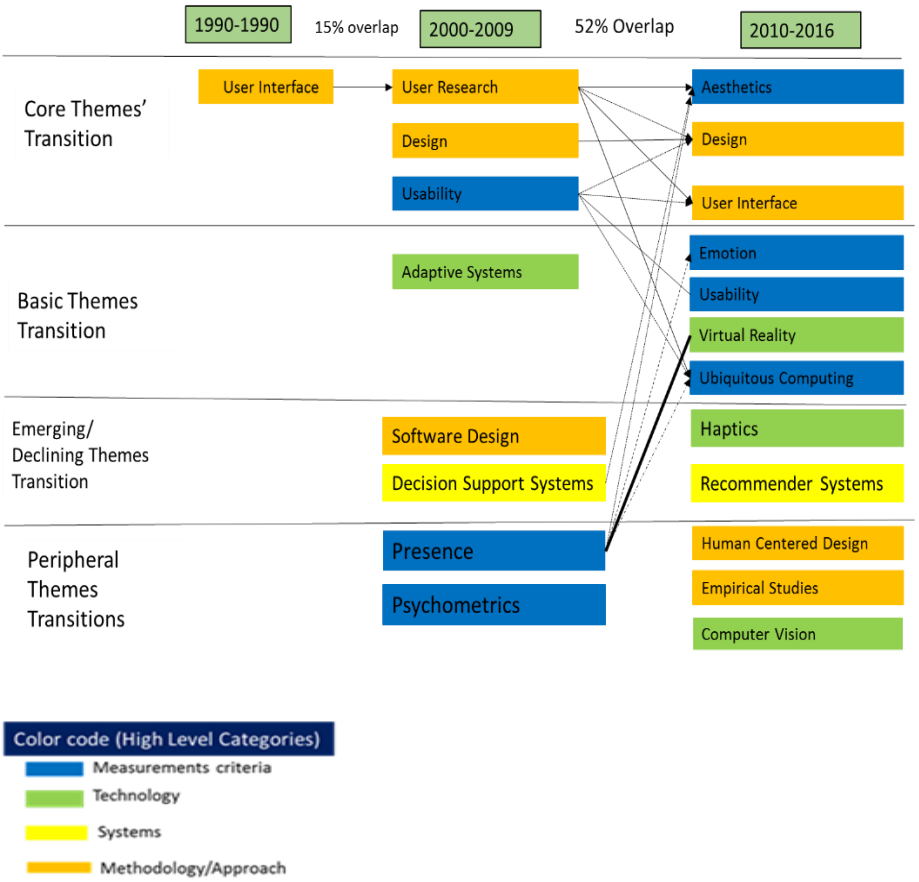


Figure 3.10 Summary of findings, paradigm shifts, evolution patterns, high level Concepts and conceptual over Periods

We combined a variety of approaches, discovered and characterized thematic areas of HCI/UX. We used the concept of graph theory and bibliometrics to visualize and analyze the ADKs cluster network. We have used concept of co-occurrence of ADKs as network metrics. Clusters of the ADKs network enabled us to detect themes containing group of highly associated ADKs. The discovered themes are grouped together into high level concept that showed subject matter addressed by the group of themes. high level concepts and their themes are; methodology/approach (User Interface, Human Centered Design, User Research, Design, Empirical Studies and Ubiquity) and measurement related themes (Usability, Psychometrics, Presence, Aesthetics and Emotions) to study interaction, users and/or usage of various technologies/systems (Virtual Reality, Computer Vision, Haptics, Decision Support Systems, Adaptive Systems and Recommender System) . To see how these themes were evolved over periods, evolution pattern discovery of themes with their group color was visualized from ADKs time overlap. Over 3 decades, themes profligate. Themes merge (converge) and split (specialize) over period, get more diversified and interconnected. All these tells us that focus of research shifted from one theme to another them over periods. High level of thematic dynamism e.g. Themes dynamism: 100% from period 1 to period 2, 83% from period 2 to period.

Early approach to HCI/UX is User Interface (approach). Got diversified subject matter (approaches and technology) dominates over period.

Centrality of the clusters showed how the themes interact with each other to shape the entire thematic structure in HCI/UX. Density of the clusters provided important information regarding which thematic areas are internally cohesive and well developed to stand by themselves as thematic areas over the three periods of analysis.

Strategic diagram helped us to classify the thematic areas discovered based on the graph properties centrality, density and the subject matter (by color of the group).

The concept of time (temporal analysis) by partitioning publications into time intervals enabled as to see the Temporal based evolution patterns of thematic areas in the field of HCI/UX. User Interface engineering and training were two big issues during 1990. Usability, User research, design and Presence were big thematic areas during 2000-2009. These got more specialized in the time interval 2010-2016 since their member ADKs in the thematic network during 2000-2009 were grown themes in 2010-2016. Usability and Design also sustained their thematic status over the last two time intervals. The themes detected in the year 2010-2016 and their member ADKs would be important research themes in the years to come based on the pattern observed between the periods 2000-20009 and 2010-2016.The field of study is still dynamic and

in shaping as its stability conceptual stability between 2000-2009 and 2010-2016 is less than 52%. The thematic stability is 16% for the same period.

Regarding general trends, we showed the countries contributed most towards the development of the thematic structure of the field. The development in the journal articles and the peak time for development trend i.e. since 2011, increase dramatic. We identified the top journal venues for research outcomes in the area. The top disciplines contributed to the development of the thematic structure of HCI/UX are also identified.

By discovering important insights and dynamics of the thematic structure of the HCI/UX, from a large publication dataset, we have proved that the proposed methods is effective to address the stated research goals, as we could answer all our research questions in a satisfactory way with the stated limitations of using ADKs for content representation and coverage of data from only one source. This approach is promising in identifying complex knowledge in the body of knowledge that exists in converged field of studies in the future. This study can be extended to further bibliometric analysis like co-citation network analysis, co-authorship network analysis and bibliographic coupling network analysis to dig into specific social and intellectual thematic structure in the future. This paper mainly focused on the conceptual (thematic) thematic structure of the research area.

Chapter Four

Author Defined Keyword Network Analysis for Thematic Discovery and characterization in Information Behavior Domain

Abstract

This paper presents the thematic areas of the convergence between Information Behavior over time-frame of 28 years (1990-2017). It also presents general trends and patterns over time. 4771 journal articles published in the journal of computers in human behavior over the stated time-frame were retrieved from Web of Science. The timeframe was partitioned into three 1990-2003, 2004-2010, and 2011-2017 for longitudinal conceptual and thematic analysis. Author Defined Keywords' (ADKs) co-occurrence network analysis was used for discovering the thematic research areas. We combined different techniques of graph theory and bibliometric analysis methods for thematic extraction characterization in the research area. It was found that the themes of research grew from three in the time interval 1990-2003 to eleven in 2004-2010 and 34 in the time interval 2011-2017. The growth is dramatic and dynamics is huge for thematic areas connecting Information Behavior over the three periods. Research themes Computers, Human Computer Interaction and Gender Difference in the first time interval were at the root of multiple and specialized research thematic areas in the latter two time intervals. The

research effort in this convergence research area revolve around how elements of human behavior affect technology perception, acceptance and/or adoption, interaction and use computing devices and applications as well as role of technology in changing human behavior and consequential impacts on social and individual well-being. It also touches how to make technology more human behavior aware.

Keywords

Information Behavior, Computing, Thematic Structure, bibliometric, thematic discovery, Thematic Characterization

4.1. Introduction

4.1.1. Background

These days computing devices or digital technologies and applications are ubiquitous and pervasive in every walk of life of human being (Johanson et al., 2002; Attewel, 1992). The computing devices takes a form of personal computers, smartphones, the Internet, web applications, mobile applications, digital assistants, wearables, Internet of Things and cloud computing etc. (Jeon et al. 2007). There are a lot of applications and services available through these computing devices and applications platforms (Prieto and Revilla, 2005). The areas of applications include communication, education, business, healthcare, education, entertainment, military, manufacturing, transportation, engineering, energy saving, research etc… (Luck et al., 2993; Attewell, 1992; Kittur et al., 2008; Park et al., 2015). Human behavior is a very important aspect of human life relevant to computing field of study in this digital age (luck, 2003). Innovative interactive systems flourishing these days are to be used by humans. As such, the perception, adoption, acceptance, interaction and usage are affected by human behavior. Uses of those devices and applications also affects human behavior and wellbeing (Prieto and Revilla, 2005). There is also a notion that asserts benefits that computing or digital technologies and applications provide to human beings are not intrinsic within

themselves but lay within the way we use them in our everyday life (Godzinski, 2005).

This is to say that the effect of use of computing devices and applications would be good or bad based on the way people use them. From philosophical point of view, these issues extend to ethics of technology use (Boyle et al., 2011). There is also an effort to make digital interactive systems more human behavior (context)-aware to promote better user experiences, particularly in the growing interest in Artificial Intelligence (Boyel et al., 2011; Chen and Kotz, 2000).

Therefore, human behavior has been important subject of study related to computing systems (digital technologies) since people began using computing devices as a tool to solve human problems to successfully survive in its environment pertaining to information processing, sharing, storage, communication and collaboration (Boyle et al., 2011; Pantic, 2007).

As a result of this, many research works have been conducted at the intersection of computing and human behavior. Those works extend to explore impacts of use of computing devices and services on individual and social groups and the role of human behavior in in successfully interacting and utilizing those technologies and services in the digital ecosystem (Devis, 2001; Ross et al., 2009; Morahan-Martin and Schumacher, 2000; Kreijns et al., 2003; Zhao et al., 2008; Correa et al., 2010; Webster, 1993).

Careful revisiting of the research outcomes connecting Information Behavior has tremendous importance for the community of scholars and practice to show the past and current trends and to figure out its future perspectives. Exploring the past and present scientific publications of large size over long time intervals would show trends, patterns, evolutions, linkages, level of developments (impact and influences), diversification and obsolescence of thematic areas of research and their performances at the intersection of these two important aspects of human life in the digital age (Curtail, 1986; coulter et al., 1998; He, 1999; Cobo et al., 2011). This helps to make good research planning and use the effort, energy and money to the right direction. It also helps the increase the relevance to research outcomes to address the timely research problem and consequently contribute to the human wellbeing.

It also helps to understand the dynamism in the research themes, the social structure and the intellectual composition and collaborations (Courtail, 1986; Leydesdorff and Rafols, 2009; Porter, and Rafols, 2009).

One of the venues for communicating the intellectual outcomes of the scholars are journals (Popper, 2014). In the 1960s, it was assumed that the number of publications doubles every 20 years however in 1990s it happened to be doubling every 20 months (He, 1999, pp. 34). As the size of publications dramatically increases, however, it is not easy to extract important insights for the research community (He, 1999, Huang et al., 2017).

Researcher make discoveries and advance scientific progresses in laboratories or field observation to change the world, others follow their works and know the world and make further scientific discoveries to make a world a better place. The relationship among the discoveries or dynamics in scientific findings is not easy to understand. The power of the words researchers uses to represent their work is great since they embed their understanding in their field of study on paper to let others know (He, 1999). Following their text and finding the relationship among them helps to understand the scientific discoveries (Coulter, 1986; Callon et al. 1991; Courtail, 1998).

Therefore, our research is aimed at exploring the thematic areas of focus and their dynamics in the thematic structure at the crossroad of computing and human behavior. We discovered thematic areas and characterize them using Author Defined Keyword co-occurrence network analysis (Boyle et al., 2011; Leydesdorff and Rafols, 2009). There was no scientific work that explored the convergence between Information Behavioryet.

This approach is free of subjectivity or manipulation of the researchers unlike that of traditional literature survey of limited number of papers. This approach directly discovers patterns from the actual work of scientific publications of large size as authors represented the content in their work by ADKs (Coulter et al. 1998; Liu et al., 2014; Callon et al, 1991).

We characterized the discovered themes with more dimension of analysis as possible combining from graph theory and bibliometric like clusters and their graph properties (centrality and Density), evolutions linkages and conceptual overlap, classification of themes into different type of role and level of development based on centrality over periods (Porter and Rafols, 2009; liu et al., 2014; Cobo et al. 2015).

For this purpose, selecting the appropriate journal whose publication source can tell the story is mandatory [Neuhaus et al., 2008; Liu et al., 2014; Cobo et al. 2015]. In exploring the knowledge structure of User Experience/Human Computer Interaction in the first research of this dissertation, it was found that journal of computers in human behavior is one of the top contributing journals to the interdisciplinary domain Information Behavior within the context of HCI/UX.

Therefore, Journal of Computers in Human Behavior is selected to be analyzed in this research to answer our research questions. The next step was selecting the appropriate bibliographic database to acquire the full bibliographic records of the journal articles. We found that web of Science (WoS) is a comprehensive bibliographic database for peer reviewed journal articles (Ellegaard and Wallin, 2015). We retrieved 4771 journal articles published in the journal over the timeframe of 1990-2017-July-31st in plain text format with full bibliographic records. Since ISIWoS allows only 500

records to download at a time, we should have iterated for ten times to get the whole journal articles. The ten fragmented text files were integrated into a single text file for further preprocessing, visualization and analysis.

SciMAT science mapping software was used for preprocessing and analysis; since it has comprehensive functionalities for our research goal. Extensive preprocessing activities were carried out to avoid duplications due to word forms, synonyms, abbreviations, for time slicing, and partitioning the timeframe into time interval to make the data more meaningful and suitable for longitudinal analysis.

Descriptive statistical summary measures of papers, Author Defined Keywords (ADKs), authors, contributions and collaborations patterns were made. The unit of analysis is Author Defined Keywords (ADKs), which is a co-word analysis. The network metrics used was co-occurrence of ADKs and normalized by association strength. The 28 years' timeframe was partitioned into four time intervals having each seven years of intervals (1990-1996, 1997-203, 2004-2010 and 2011-2017) primarily. The experiment was carried for thematic area mapping for those time intervals. Since the first time interval 1990-1996 has not shown any theme for the minimum parameter used for thematic network mapping, we decided to merge the first two time intervals into one-time interval i.e. 1990-2003 to get a more meaningful pattern of thematic area linkages over time intervals. The final time intervals used were

1990-2003 (14 years), 2004-2010 (7years), and 2011-2017 (7 years). Then the final result of the three-time interval was visualized, interpreted and analyze.

4.1.2 Significance and Importance of the research

These days we are in a situation where there is much data and less knowledge as many researchers in the data mining and big data often describe (Han and Kamber , 2011). There is a strong need of discovering trends and patterns using state of the art analysis techniques in this ever increasing publication base to drive new insights (Bornmann and Leydesdorff, 2014). These days, data is ever growing in volume over time exponentially in every walk of human life (Larsen, Von, 2010). Publication meta-data is not exceptional, where we have over 25, 000 journals and over 50 million journal papers published in a refereed journal (Larsen, Von, 2010). In addition, we are observing a growing interest in convergence of different field of study, which promotes collaboration and innovation by answering research questions that cannot be answered by any single field of the converged ones (Wuchty et al., 2007). Studying a complex relationship of science in such converging field of study is not easy. Information Behavior (conformation information technology and behavioral science) would be good case in mention of the convergence phenomena. Given the growing number of publication basis, and convergence nature of the research area, discovering important dynamics in

the body of knowledge of the selected topic is very important (Kosinski et al., 2013).

Doing so, we can show the big picture of thematic areas in the behavioral dimension of computing within the context of HCI/UX. This in turn facilitates, informed decision making with regard to research planning in the domain. It also helps research thematic area selection and increases efficiency by avoiding duplication of research efforts and promote well targeted innovative and problem solving research in the area. It also enables to evaluate the status of the research themes the doamin over the last 28 years. It can also be a corner stone for further explorative research in this area using similar and additional methods.

4. **1.3 Structure of the Chapter**

The chapter is structured into five sections having their own subsections. Section one covers introduction, section two discusses related works. Section three covers visualization and analysis of ADKs network and section five briefly summarizes the key findings and conclusive remarks.

4. 2. Related Works

4. 2.1 Works of High Impact in the Information Behavior

The role of individual differences, experience, intention, perception and attitude of computer and Internet use and related anxiety, self-efficacy in computer use were addressed by many researchers (Schumacher and Morahan-Martin, 2001; Durndell and Haag, 2002; Wang and Emurian, 2005, Chua et al., 199; Ong and Lai, 2006) . The importance of human personality traits, motivations, identity construction and digital empowerment and support groups in social network sites, particularly Facebook were also addressed by many researchers (Ross et al., 2009; Zhao et al., 2008; Correa et al, 2010). The issues of flow, behavioral intentions, and network neutrality, and motivation theory related to mobile banking and social media use were also investigated (Webseter et al., 1993; Luarn and Lin, 2005; Lin and Lu, 2011, Kuo et al.,?) Issues like problematic internet uses, cyberbullying and their consequences were studied using cognitive behavioral models (Davis, 2001; Morahan-Martin and Schumacher, 2000; Caplan, 2002; Charlton, and Danforth, 2007). Pitfalls in social interactions in computer-supported collaborative learning, cognitive skills, group learning, efficacy of individual and group learning, gender differences, face to face vs online learning were also addressed (Kreijns et al., 2003; Kirschner et al., 2008; Janssen, et al., 2009). Issues related to

cognitive load, multitasking, social media use vs academic performance, media induced task switching while studying, too much social media vs attentive reading, use of social media and personality were also studied well (Corea et al., 2010; Ryan and Xenos, 2011; Kirschner and Karpinski, 2010). Topics such as virtual life, virtual gaming, finding virtual visual similarity, maternity in virtual world and romantic virtual life were also investigated (Pierce, 2009; Drouin and Landgraff, 2012). Topics like crowdsourcing of user studies, improving online community experiences, adoption of online services and purchasing behavior and the issue of trust in virtual life were among well studied topics (Kittur et al. 2008; Preece et al., 2004; Zhang et al., 2014; MäNtymäKi and Salo, 2011; Wang and Chen, 2012). The studies addressed both the enabling part of computing technologies and side effect of the way people use them as well as role of human behavior in technology acceptance, adoption and use. The studies also showed the role of computing devices in changing the way people behave. However, it doesn't implicate any intrinsic harm within the technology itself, rather the benefits or negative implications lies within the way people use them.

4.2.2. Bibliometric and Graph Theory as Methods for Thematic Discovery and Characterization

A map of science shows the spatial representation of how disciplines, field of study, specialties of research thematic area evolve and dynamically changing

over time (Cobo et al., 2015; Bornmann and Leydesdorff, 2014; Larsen and Von, 2010; Small, 1999). Its analogy is the way the geographic map shows the details of geo-political and physical relationship of the features of the earth through abstraction (Small, 1999). It is powerful for simplification and high level representation of the thematic structure for easy comprehension and understanding (Cobo et al., 2011; Small, 1999). There are different software tools, techniques and methods available to explore the thematic structure of particular field of study (Van Eck, and waltman, 2010; Cobo et al., 2011). The map of thematic structure based on the publications' big data is the structure that systematically imposed on a collection of intellectual outcomes and their relationship based on established scientific tools, method for systematic understanding (Callon et al., 1991, Small, 1999; Liu, 2014). As such, it can be called discovery of knowledge about knowledge, where getting insight from large knowledge base is difficult. The detailed description of each method, tools, techniques and strategies used in this research were thoroughly discussed in chapter two of this dissertation. In this research, we used Author Defined Keywords co-occurrence network, which is a type the co-word analysis in bibliometric.

The aim exploring the research thematic areas of the behavioral dimension of computing. The journal selection based on the finding in chapter three of this dissertation. When we see the application of bibliometric and graph theory for

exploring the research themes in the thematic structure by other researchers in the related areas so far include, the knowledge structure of 25 years of journal knowledge based systems was explored using bibliometric analysis (Cobo et al., 2015). The chi conference intellectual progress from 2004-2013 was mapped in (liu et al., 2014) using co-word network analysis using graph theory and concluded that CHI has no main stream thematic areas. Software engineering area was also studied (McKain et al., 2005). Information Science field of study was also investigated (Jeong and Kim, 2005).

The thematic structure of user experience was explored using author Keywords network analysis in (Urgessa et al., 2017) and areas of focus over time intervals were identified. When we come to computing and human behavior, there is no research work related to exploring the convergence phenomena between these two fields of studies using rigorous analysis methods so far. In addition, this area of research is found to be large portion of research interests in the context of HCI/UX. Thus why we aimed to apply these techniques, methods and tools to explore and assess the thematic research areas connecting computing and behavioral science.

4.3 Visualization and Analysis

4. 3.1 Descriptive Statistical Distributions

We retrieved 4771 papers with full publication records were included in the analysis. 227 (5%) of the total belongs to the 1990-1996. 280 (6%) of the total were published within the second time interval 1997-2003. The number of papers published in the third time interval 2004-2010 is 864 (18%). In the fourth time interval (2010-2017, Jul, 31st), the number of paper was 3400 (71%). The growth in the interest of converging points of Information Behavior is dramatically increasing particularly in the last 7 years. With respect of participation of the authors, 10, 412 authors, including the co-authors participated in the last 28 years to publish their scientific papers in the journal. The authors used 142,327 references. The reference to paper ratio is 29:1 on average. The total number of Author Defined Keywords (ADKs) is 17029. Both the number of authors and papers increased dramatically over the three-time interval of analysis. The time intervals 1990-1996 and 1997-2003 were merged into one period 1990-2003 and the latter two were left as they are for longitudinal thematic analysis. See the summary in Table 4.1.

Table 4.1. Number of Authors, papers and ADKs for the three time intervals used for analysis in the IB domain over the three Period

Time intervals	Number of papers	Number of ADKs
1990-2003	507	1308
2004-2010	864	3741
2011-2017	3400	11980
Total	**4771**	**17029**

4.3.2 Popularity and Centrality of Individual ADKs

Before longitudinal analysis, the popularity and centrality of the individual Author Defined Keywords of the whole paper published in the research area in Information Behavior were calculated and the top twenty were presented in Table 4.2. The popularity of individual ADKs would not be seen in the cluster in the temporal analysis since it is named by the most central ADK using the simple centers algorithms for each period. The popularity of the ADK is its frequency among the papers as used by authors. It shows the importance or interest of the researchers in the particular ADK. The centrality of the ADK is the total link strength that an individual ADK has in the entire thematic structure and it shows the degree at which it would serve as the center of the entire knowledge structure the area of research. Centrality shows the influence of the keyword in the research area. Table 4.2 is summarizing these two important issues

Table 4.2. Top Twenty Popular and Central ADKs in Information Behavior Domain over the last 28 years.

Top 20 Popular ADKs			Top 20 Central ADKs		
Rank	ADKs	Popularity	Rank	ADKs	Centrality
1	Social Media	265	1	Facebook	549
2	Facebook	240	2	Social Media	501
3	Internet	209	3	Internet	395
4	Computer Mediated communication	114	4	Personality	238
5	Personality	106	5	Gender	225
6	Gender	102	6	Computer Mediated Communication	195
7	Internet Addiction	92	7	Motivation	182
8	Adolescents	82	8	Internet Addiction	167
9	Motivation	81	9	Adolescents	162
10	E-learning	69	10	Technology	137
11	Collaborative Learning	67	11	Video Games	131
12	Self-Efficacy	64	12	Self-Efficacy	128
13	Twitter	64	13	Twitter	127
14	***Trust****	63	14	Self-disclosure	125
15	Cyberbullying	62	15	Anxiety	119
16	Video Games	61	16	***Loneliness***	113
17	Technology	58	17	Cyberbullying	107
18	***Cognitive Load***	53	18	*Depression*	104
19	Self-disclosure, ***Human Computer Interaction***, Computer Anxiety, Uses and Gratification	52	19	E-learning	101
20	Theory	49	20	***Self-esteem***, uses and gratification	100

**** Bold and Italic are ADKs which belong to only one of the attribute i.e. either central or popular but not both***

4.3.3 Theme Networks of the three Time Intervals

Theme network shows the inter-connection between or among the ADKs falling in the same cluster and considered as theme. They are sorted by the centrality of the cluster for each time interval. Theme name is the central ADKs for each cluster. For example, in Figure 4.2, Cluster one's name is Computers and so on. The following parameters were used for analysis. Unit of analysis is ADKs. Data reduction technique used by was limiting the minimum occurrence of ADKs threshold to five. The network metrics used was co-occurrence of ADKs. Similar clustering algorithm is used with that of the first research (simple center algorithm). Minimum and maximum number of ADK in cluster is set to 1 and 15. The whole networks of the first period is presented the top cluster/thematic network of the two latter periods are illustrated. C-1 to C-n labeled for more identification of each cluster.

4.3.3.1 Thematic Network of the Time interval 1990-2003

This time interval has got three themes and their cluster or thematic network is as presented in Figure 4.1. The clusters or themes are represented by Computers, Human Computer Interaction and Gender Differences, which are the central ADKs for the cluster networks as shown Figure 4.1.

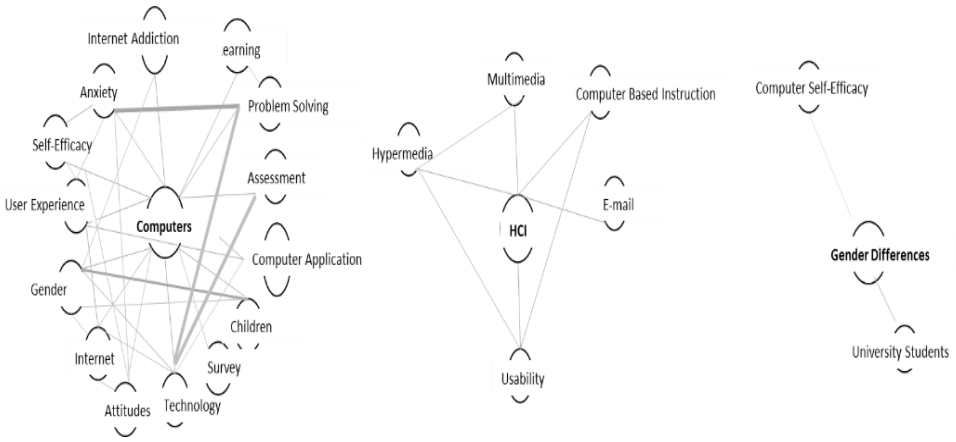


Figure 4.1 Cluster or Thematic Networks of the three themes during Time interval 1990-2003 in IB Domain

4.3.3.2. Thematic Network of the Time interval 2004-2010

This time interval has got eleven clusters or themes of research at the intersection of computing and human behavior. The top nine significant network clusters or themes are Figure 4.2.

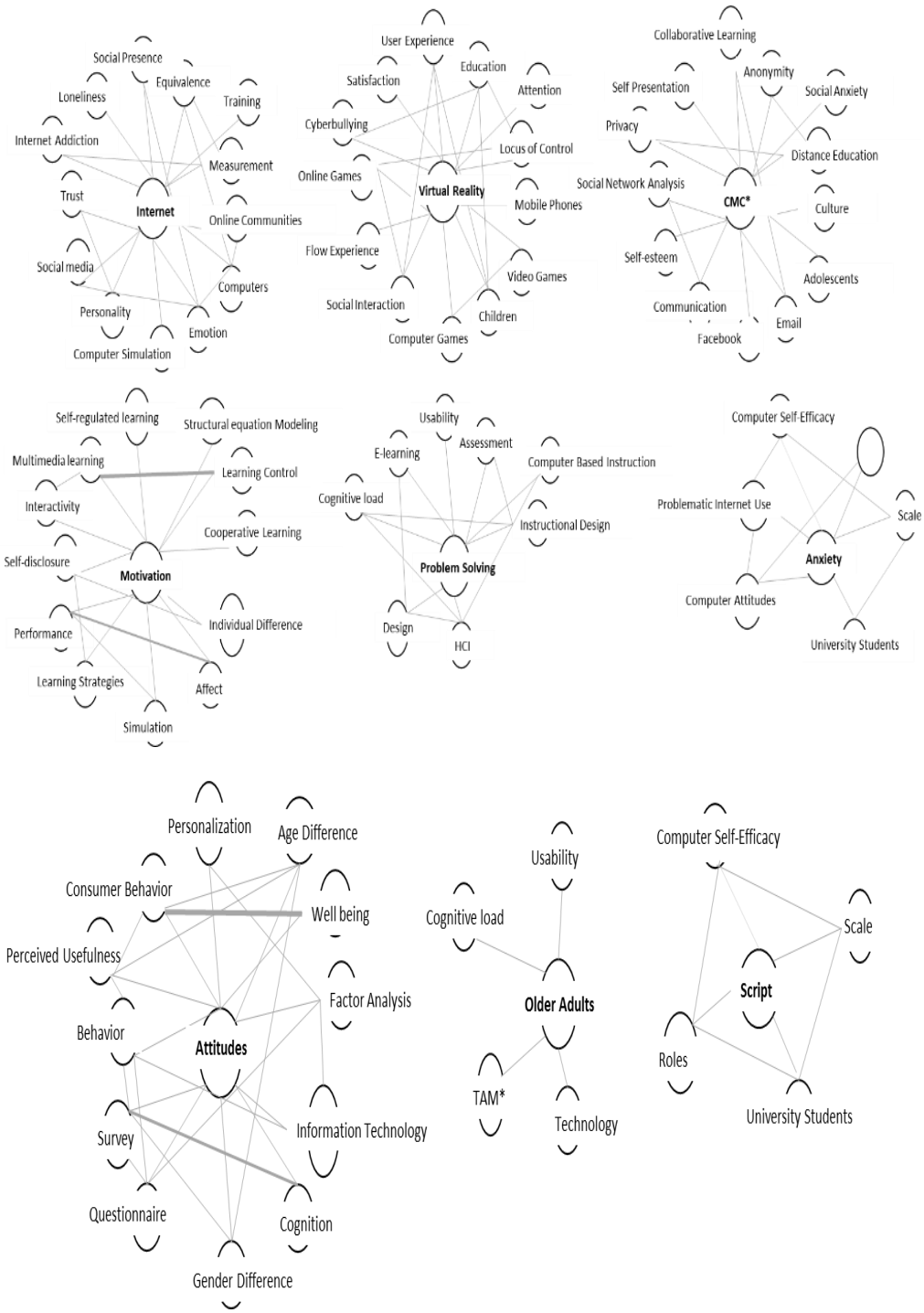


Figure 4.2. Cluster or Thematic Networks of major Themes in IB for the Time Interval 2004-2010

4.3.3.3 Thematic Network of the Time interval 2011-2017

Figures 4.3 (a to c) shows thirty-four themes were detected in this time interval.

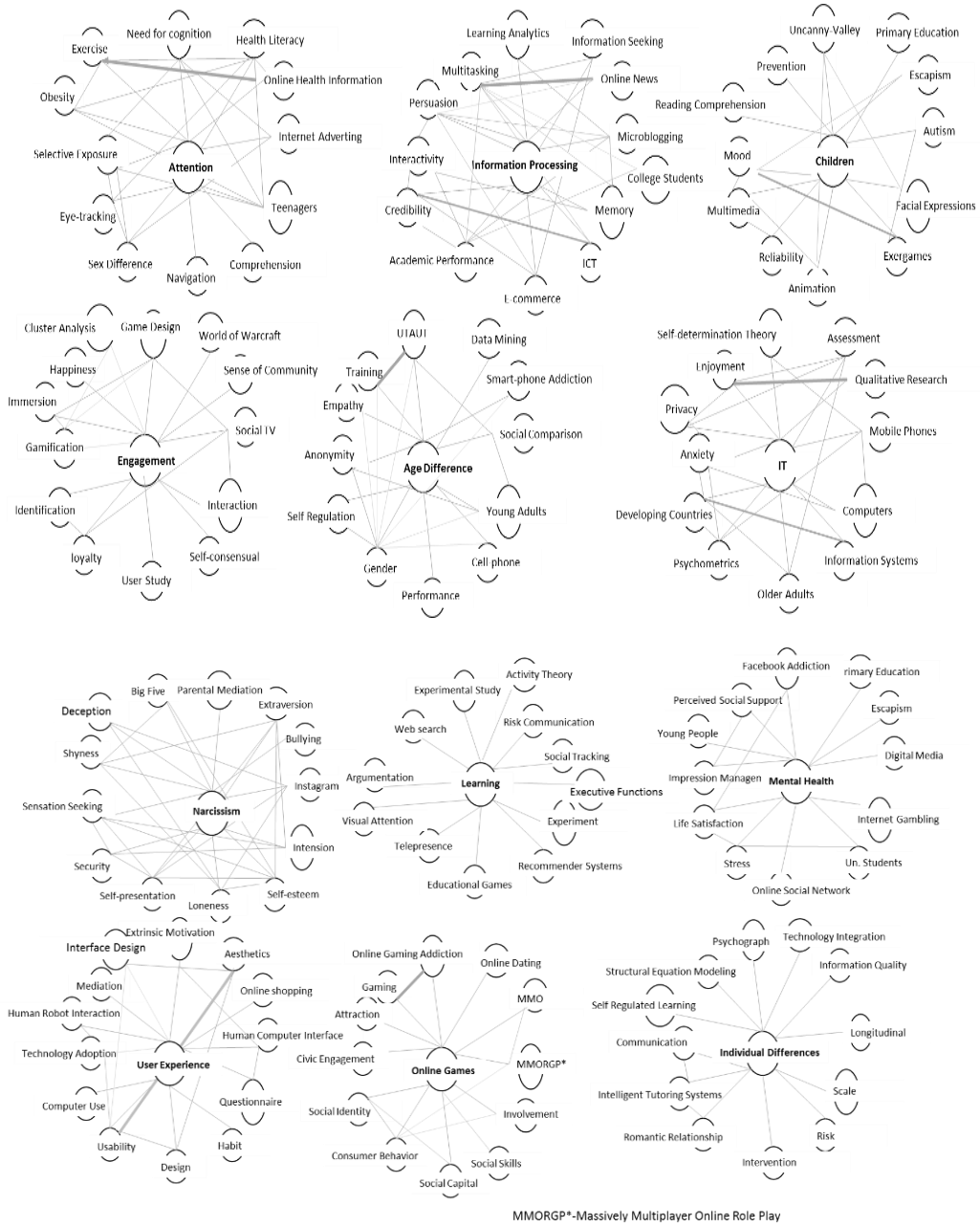


Figure 4.4 (a). Cluster or Thematic Networks of Top Twelve clusters of the Time interval 2011-2017

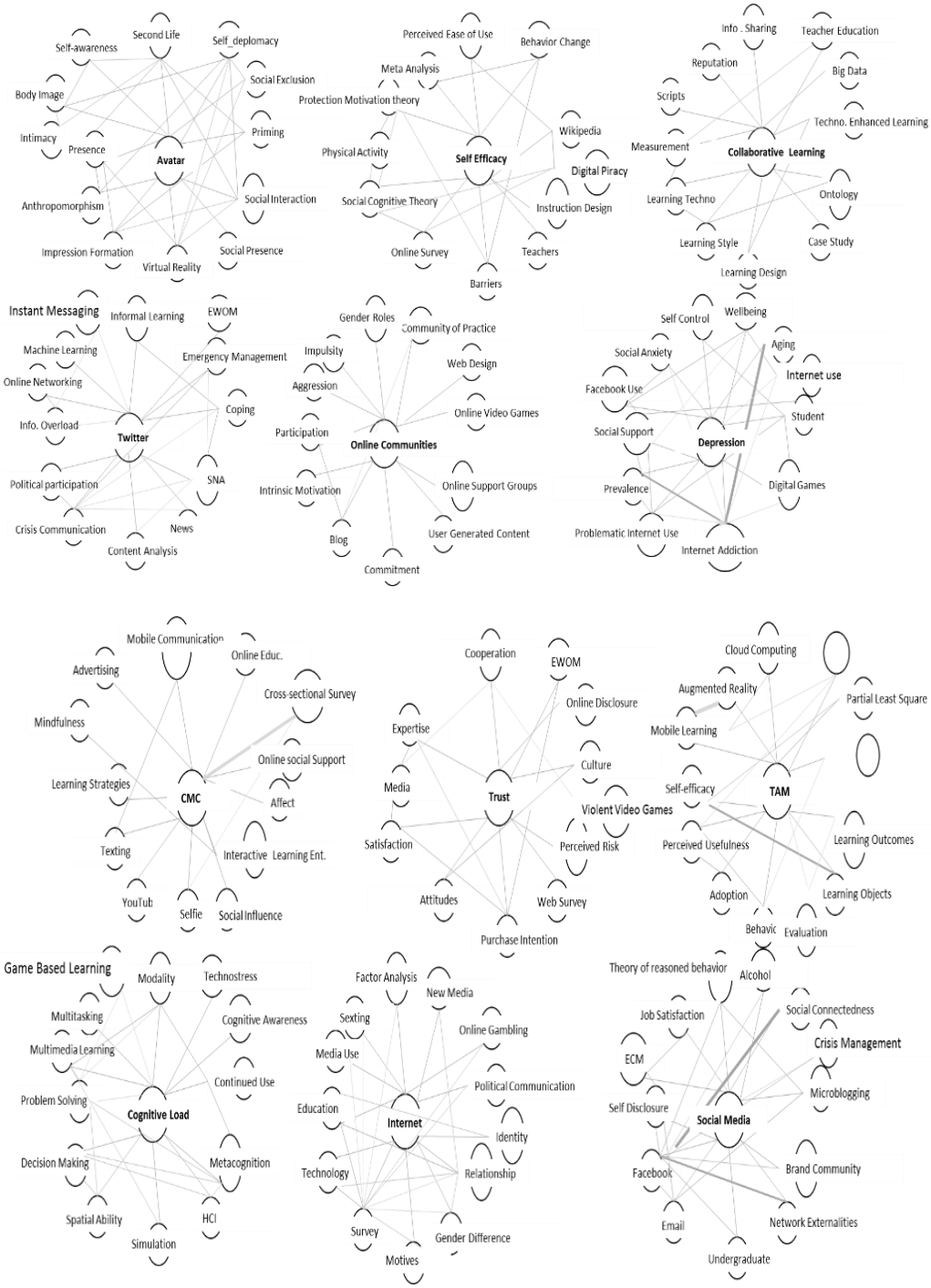


Figure 4.4 (b). Cluster or Thematic Networks (13 to 24 Themes of the Time Interval 2011-2017), the bold ADKs at the center are theme names based on simple center algorithm

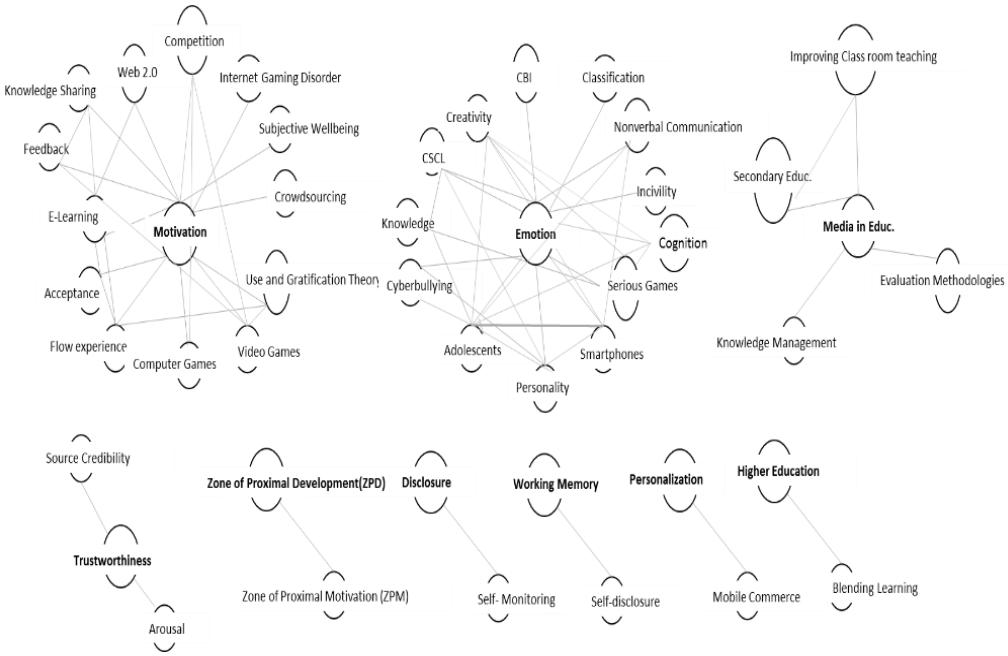


Figure 4.4 (c). Cluster or Thematic Networks (25 to 34 Themes) of the Time interval 2011-2017, the bold ADKs at the center are theme names based on simple center **algorithm**

3.3.4 Card Sorting for Grouping the Discovered Themes in the Domain of Information Behavior

The discovered themes through clustering over the three periods of analysis were grouped into high level concepts using card sorting method based on subject matter. Three experts were involved in card sorting and the agreed up on groups of themes were labeled with high level concept, which is believed would represent them subject matter wise and color coded. The sample card sorting based grouping is presented in Figure 4.4.

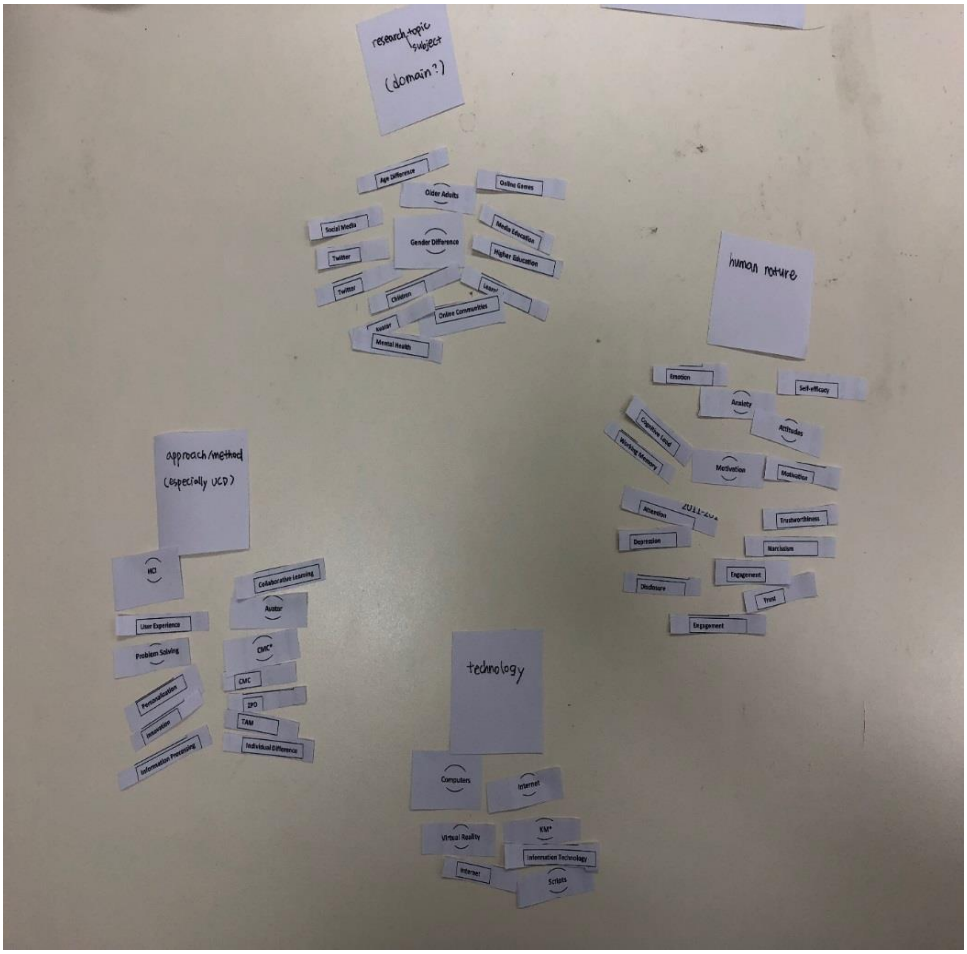


Figure 4.4. Sample Card sorting discovered Themes in the Domain of Information Behavior

According to the final grouping, the discovered themes in these domain belongs to four category of high level of concepts as presented in Table 4.3.

Table 4.3. Groups of Discovered Themes and Color Codes in Information Behavior based on high level concepts

#Group	Group Name	Member Themes	Color Code
1	**Theories/ Approaches**	Human Computer Interaction, Problem Solving, Scripts, Information Processing, Engagement, User Experience, Self-Efficacy, Cognitive Load, Working Memory, TAM, ZPD (11 themes)	
2	**Technology/ Systems**	Computers, Information Technology, Virtual Reality, CMC, Internet, Avatar, Online Games, Online Communities, Twitter, Social Media (10 themes)	
3	**Human Factors/Behavior**	Gender Difference, Motivation, Attitudes, Anxiety, Older Adults, Attention, Children, Individual Difference, Age Difference, Trust, Trustworthiness, Motivation, Emotion, Disclosure, Mental Health, Depression, Narcissism (17 themes)	
4	**Learning**	Knowledge Management(KM), Collaborative Learning, Learning, Media in Education, Higher Education, Innovation, Personalization (7 themes)	

The final grouping and the color codes are used in the evolution patterns discovery in Figure 4.5 and themes classification based level centrality and density in the strategic diagram in Figures 4.6 to 4.8.

4.3.5 Evolution Pattern Discovery of Themes of Research in Information Behavior

Figure 4.5 indicates the evolution patterns and subject matter composition of themes over three time intervals. The years at the top indicates the intervals of the three time intervals. Time interval 1 is from 1990 to 2003, time interval 2 is from 2004 to 2010. Time interval 3 is from 2011 to 2017. The spheres in different colors indicate nodes or themes represented by the most central theme in cluster network during the particular time interval. The evolution is mapped using inclusion index. Three themes for the time interval 1990-2003 had less complex evolution relationship with the 11 themes discovered during the 2004-2010. However, the evolution relationship of the themes in the time interval 2004-2010 to the 34 thematic areas (clusters) in the time interval 2011-2017 were too complex. This shows how the research interest this domain of study is growing over time with a complex conceptual (ADKs) links.

Accordingly, Computers (technology), Human Computer Interaction (approach) and Individual Difference (human factor) thematic areas in the time interval 1990-2003 are at the root of specialization of themes in latter periods. So it tells us that the time interval 1990-2003 of this domain mainly focused on computers, how to best interact with computers and the role of gender differences as a factor related interacting with computers.

Computer from thematic area the technology category in 1990-2003, has a strong link with Internet (technology), Problem Solving (theory/approach), and Anxiety (human factor) themes and shared ADKs with human factors/ behavioral categories like Motivation, Attitudes, Virtual Reality, and Older Adults themes in the time interval 2004-2010. The eleven themes of research identified during the time interval of 2004-2010 are all new by name (100%). No one theme appeared by the same name from 1990-2003 in this time interval. This shows that there extremely high level of thematic dynamism during the two early time intervals. This shows dynamism in naming of the research thematic area due to more specialization in evolution processes. In other words, it is to say the newly emerged ADKs or ADKs, which were not central focus of research in preceding period is promoted to central positions in the clusters in themes' formation in the evolution process.

Internet, Avatar, and Motivation continued as thematic area with their name from 2004-2010 to the time interval 2011-2017 (continuance increases over period by 12%). Thirty-one themes (88%) of the themes evolved during the time interval 2011-2017 were with new names. As times goes the name of thematic areas change but sharing keywords. Therefore, we can say there is high level of dynamism as only few of themes crossed time intervals with similar name still. There is growth in terms of the number of thematic areas as well. The growth in the number of research themes in the second time interval

is nearly 4 times of the first time interval. The growth in the number of themes in the third time interval is 3 times that the second time interval. For the complete list and their graph properties in the three time intervals, see Table 4.4 to 4.6. A lot of evolutional hierarchy can be extracted from this evolution map to easily see the changing emphasis of research thematic areas over period, which can also show paradigm shift in the research interest. The next is to show the role in the entire knowledge structure and level internal of development of each theme in each time interval. Discovering to what level the concepts (ADKs) are overlapping from period to period is very important and his issue are identified in subsection 4.3.5 and 4.3.6.

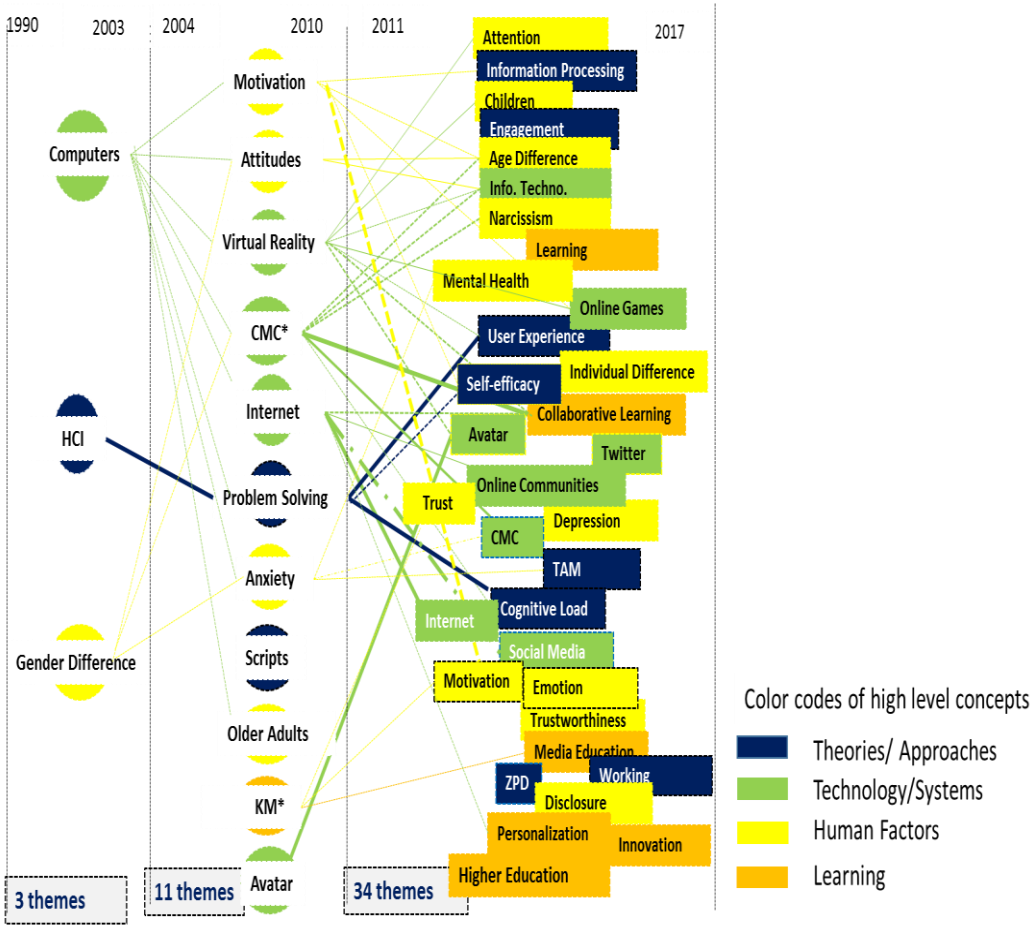


Figure 4.5. Themes' Evolution Patterns of the Three Time Intervals in the Domain of Information Behavior for three Time Interval

As the evolution pattern in Figure 4.5 shows human factors/behavior related themes have been growing dramatically followed by theories/approaches over periods. In general, all areas have been growing dramatically.

4.3.6 Classification of the Detected Themes of Research Using Centrality and Density in Strategic Diagram

The classification of the detected themes of research at the crossroad of Information Behavior is presented for each time interval in this subsections 4.3.4.1 to 4.3.4.3. In the diagram the nodes (ovals) are themes, which belong to a particular time interval, the labels are name of themes or clusters of ADKs and H-index of articles associated to a particular theme. X-axis is centrality, Y-axis is density of the particular theme. The structure of strategic diagram and detailed description is given in methodology chapter two Figure 2.6.

We classified the detected thematic areas of each time interval to the strategic diagram for categorization of the status of the thematic areas in shaping the convergence of the two research themes over time intervals.

4.3.6.1 Thematic Classification of the Time interval 1990-2003

The strategic diagram of this time interval is presented in the Figure 4.6. Only one strongly central (core) and moderately dense (developed) thematic area i.e. Computers was detected. There was also one strongly dense (internally cohesive) or well developed but less central thematic area i.e. Human Computer Interaction.

The basic or transversal theme is Gender Difference in this time interval. Gender Difference theme, though it is less internally cohesive or less

developed, its contribution as a central theme is high. See Figure 4.6. The emerging or declining quadrant is vacant during the time interval 1990-2003.

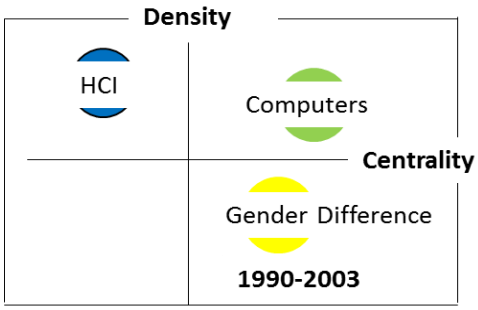


Figure 4.6. Strategic Diagram of the time interval 1990-2003 in the IB Domain, Computers (technology) is core, HCI (theory /approach) is peripheral, Gender Difference (human factor)

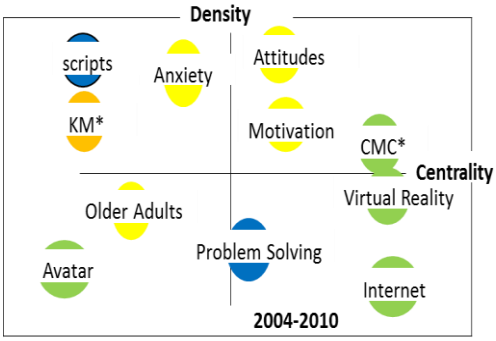
Table 4.4. Summary of clusters' properties of the themes detected during (1990-2003)

Rank	Theme Name	Centrality	Centrality range	Density	Density range
1	Computers	3.93	1	3.99	0.67
2	Gender Difference	1.96	0.67	1.05	1
3	Human computer Interaction	1.81	0.33	4.33	0.33

3.3.6. 2 Thematic Classification for the Time interval 2004-2010

The time Interval 204-2010 had got themes in all quadrants. See Figure 4.7. Three themes appeared in the motor or mainstream thematic area in the strategic diagram. These are Attitudes, Motivation and Computer-Mediated Communication. These themes were having both high intra-cluster cohesion and inter-cluster coupling or links. The highly developed and isolated themes during this time interval are Scripts,

Knowledge Management and Anxiety thematic areas. They had high intra-thematic cohesion and low inter-cluster coupling i.e. they are strong to stand as autonomous theme to study but their role in the entire knowledge is low. Anxiety was highly performing (h-index of 23) during this period.



KM*: Knowledge Management,

CMC*: is Computer Mediated Communication

Figure 4.7. Strategic diagram of the time interval 2004-2010 in IB Domain, more human factor related core (Attitude and Motivation), More technical basic (Virtual Reality and Internet)

Older Adults and Avatar themes appeared as emerging or declining themes. Both have higher importance to play central role in the whole thematic structure but internally weak to stand an autonomous thematic area to be studied or they are aligned to the mainstream thematic areas. One insight, which worth mentioning is that the mainstream had shifted from technical aspects to more human aspects in this time interval (motivation and attitude are behavioral and Computer mediated communication is technical). See Table 4.5 for the complete reference of clusters' properties of the themes discovered during this time interval.

Table 4.5. Summary of clusters' properties of the themes detected during 2004-2010

Rank	Theme Name	Centrality	Centrality Range	Density	Density Range
1	Knowledge Management	14.16	1	0.82	0.73
2	Older-Adults	13.22	0.91	2.12	0.36
3	Scripts	12.93	0.82	2.61	1
4	Anxiety	12.31	0.73	3.94	0.82
5	Problem Solving	10.96	0.64	2.73	0.18
6	Internet	6.14	0.55	1.22	0.09
7	Computer Mediated Communication	5.4	0.45	3.35	0.55
8	Virtual Reality	3.69	0.36	1.65	0.45
9	Attitudes	2.52	0.27	7.57	0.91
10	Motivation	2.35	0.18	2.96	0.64
11	Avatar	1	0.09	1.39	0.27

4.3.6.3 Thematic Classification of the Time Interval 2011-2017

During 2011-2017, the number of themes evolved in each quadrant of the strategic diagram increased and almost evenly distributed. See Figure 4.8. In the motor or mainstream or core thematic areas, number of themes are nearly three times that of the 2004-2010 in this time Interval. The themes that appeared as the mainstream are Attention, Children, Information Technology, Information Processing, Online Games, and Twitter, Avatar and Individual Differences and User Experience. Avatar is developed to motor theme in this time interval from emerging theme in 2004-2010. The highly performing mainstream or core theme is Information technology (h-index of 24) followed by Individual Difference, Twitter and Information Processing (all with h-index

of 21). These themes are well developed and strongly central themes of the thematic structure connecting computing and human behavior.

The themes, which appeared in the highly developed and isolated quadrant of the strategic diagram are also 8 in number during this time interval. These are Depression, Narcissism, Collaborative learning, Media in Education, Trustworthiness, Working Memory, Disclosure and Zone of Proximal Development and mental health. The highly performing ones are Depression and Narcissism themes each having h-index of 22 followed by collaborative learning (h-index of 15) and Media in Education (h-index of 10).

All of the themes this quadrant are new by themes' name. Mental health theme came between quadrant II and III, between declining and emerging, and highly developed and isolated themes. It seems that all the psychological health related thematic areas are internally well developed but peripheral to the whole thematic structure connecting Information Behavior during this period. Eight themes appeared in the emerging or declining thematic area during this time interval. These are Social Media, Technology Acceptance Model, Trust, Age Difference, Higher Education, Personalization, and Innovation.

In this time interval the majority of the themes belongs to quadrant IV (the basic themes) there are 9 themes in this quadrant, namely; Emotion, Motivation, Internet, Computer Mediated Communication, Online

Communities, Cognitive load, Engagement, Self-efficacy and learning. Internet thematic areas existed in the same quadrant in the time interval 2004-2010. For the detail of clusters' or theme's status in terms of graph properties i.e. centrality and density and bibliometric of themes identified during the time interval 2011-2017, refer to Table 4.6. Therefore, we can say the themes are growing more in the motor or mainstream areas than in the other areas in research area. There is a paradigm shifts among thematic areas as themes, which were once motor themes becomes basic or transversal, in the other time interval and so on. There were also disappearing themes by their previous names in the next time interval for example the eleven themes emerged during 2004-2010 were all with 100 % new names and in 2011-2017, 88% of the themes were with new names. ADKs, which were member of a clusters in previous time interval grew to themes in next time intervals for example anxiety, problem solving and Internet, which were member themes in the cluster or computers theme during the first time interval, became themes in the second time intervals. Similarly, user experience, self-efficacy and collaborative learning, social media which were concept members of clusters during 1990-2003 and 2004-2010 grew to a thematic research area in the time interval 2011-2017. Virtual reality and knowledge management which were a theme in 2004-2010 became ADK of a theme Avatar in the time interval 2011-2017. In so doing we can tell the complex dynamism in the thematic structure

of Information Behavior using different tools, techniques, methods and strategies from graph theory and bibliometric.

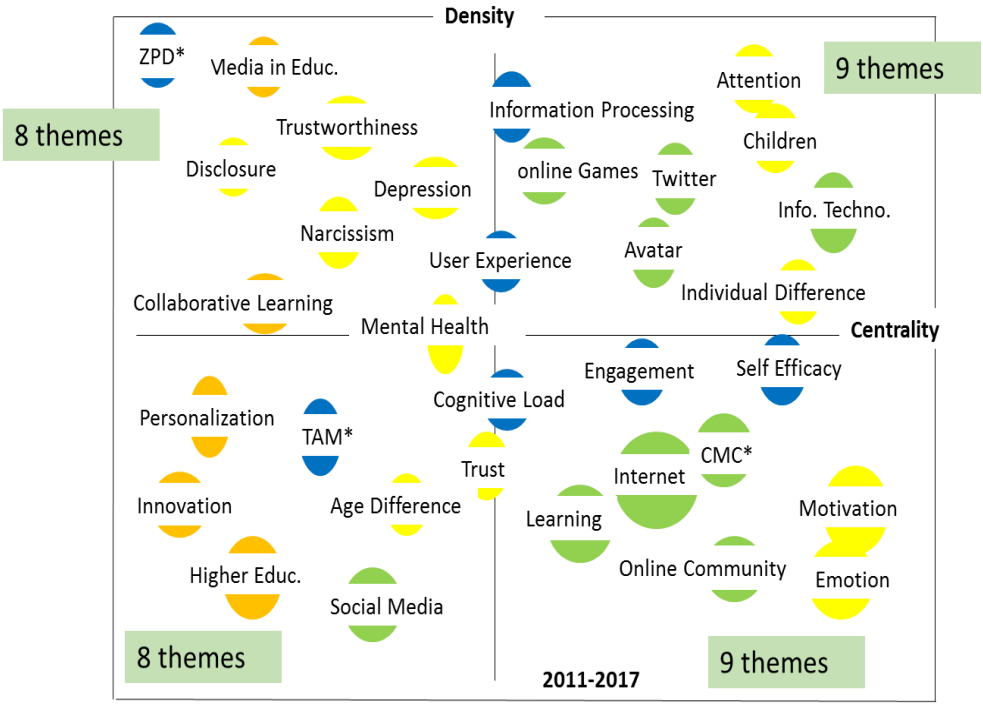


Figure 4.8. Strategic diagram of the time interval 2011-2017 in IB Domain, this period balanced thematic areas in emerging, basic and core themes, strong scientific base.

In terms of the subject matter, following the color, see Table 4.3 for color code, we observe almost similar distribution of technology/system in the core area, basic area is observed. Almost similar distribution of technical and human factor in the core area is seen from the Figure 4.8. Theories/approaches and technical themes have almost similar distribution in the basic thematic area. Learning related themes dominates the emerging area. Human factor is dominant in the peripheral area, highly developed but less interacting with other themes in the entire knowledge structure.

The characteristic feature, of the discovered themes, which include centrality and density ranges, which are used to map the themes to strategic diagram in this time interval are presented in Table 4.6

Table 4.6. Summary of Clusters' Properties detected research themes during 2011-2017 in IB domain

Rank	Theme Name	Centrality	Range	Density	Range
1	Emotion	15	1	0.26	0.06
2	Information Technology	14.58	0.97	1.42	0.79
3	Motivation	14.49	0.94	0.33	0.12
4	Individual Difference	14.24	0.91	1.19	0.56
5	Children	14.12	0.88	2.62	0.91
6	Attention	13.99	0.85	2.81	0.97
7	Self-Efficacy	13.57	0.82	0.97	0.44
8	Computer Mediated Communication	13.16	0.79	0.72	0.29
9	Online communities	13.08	0.76	0.36	0.15
10	Twitter	12.96	0.74	1.3	0.71
11	Avatar	12.92	0.71	1.28	0.68
12	Internet	12.8	0.68	0.68	0.26
13	Online Games	12.75	0.65	1.45	0.82
14	Engagement	12.08	0.62	1	0.47
15	Learning	12.02	0.59	0.64	0.24
16	Information Processing	11.74	0.56	2.02	0.88
17	Cognitive Load	11.67	0.53	0.82	0.41
18	User Experience	11.65	0.5	1.27	0.65
19	Trust	11.64	0.47	0.72	0.32
20	Mental Health	11.39	0.44	1.16	0.5
21	Age difference	11.1	0.41	0.73	0.35
22	Depression	11.08	0.38	1.35	0.76
23	Social media	11.08	0.35	0.22	0.03
24	Technology Acceptance Model	10.9	0.32	0.54	0.21
25	Narcissism	10.27	0.29	1.32	0.74
26	Collaborative Learning	9.29	0.26	1.19	0.53
27	Media in Education	4.45	0.24	2.78	0.94
28	Trustworthiness	2.81	0.21	1.85	0.85
29	Working Memory	2.04	0.18	1.25	0.62
30	Personalization	1.37	0.15	0.76	0.38
31	Innovation	1.15	0.12	0.5	0.18
32	Higher Education	0.96	0.09	0.27	0.09
33	Disclosure	0.94	0.06	1.19	0.59
34	Zone of Proximal development	0	0.03	10	1

4.3.7 Level of Time Overlapping of ADKs in the three Periods

As it was mentioned in the introductory section of this dissertation, an overlapping map shows the relative stability of research concepts, in this case ADKs emergence, obsolescence, continuity and overlapping in longitudinal or temporal patterns. The conceptual (ADKs) overlapping map at the intersection of Information Behavior is presented in Figure 4.9. For mapping the overlapping of the thematic areas over time intervals, we used Jaccard's index as in the first research

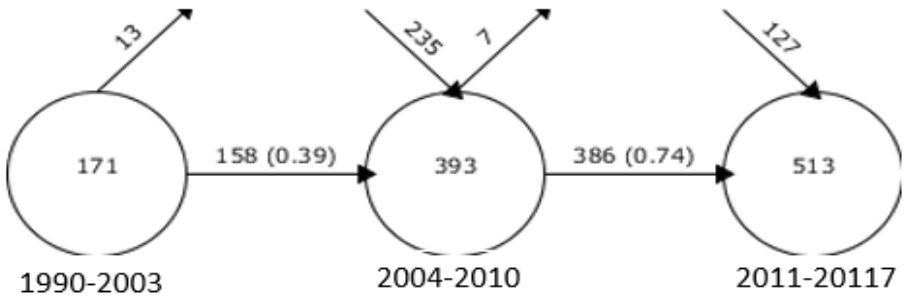


Figure 4.9. Conceptual (ADKs) Time Overlap diagram in Information Behavior Domain using Jaccard's Index

Surprisingly there is a 74% ADKs overlap that formed thematic areas of the time intervals 2004-2010 and 2011-2017, this shows that how authors are repeating the keywords of previous works instead of creating new concepts or knowledge representation. Only 26% of ADKs formed the thematic areas of

the last period are newel emerged. The overlap of concepts (ADKs) between the two periods 1990-2003 and 2004 and 2004-2010 is 39%. Out of the 171 ADKs which satisfies the minimum frequency of occurrence to construct the ADKs network during 1990-2003, 158 (92%) continued to the next period i.e. 2004-2010. The new concepts emerged during 2004-2010 is 61%. The obsolescence of ADKs between 1990-2003 and 2004-2010 is 8%. Continuity of the ADKs between the periods 2004-2010 and 2011-2017 is 98%. This shows that only 2% was obsolete to continue to the next period. Over all, conceptual overlapping considerably increased over periods.

However; from the evolution pattern discovery, we obtained that 100%, 88% of the themes are new by name though they shared ADKs from the previous years during 2004-2010 and 2011-2017 respectively. This means that there is higher possibility for the newly emerged concepts or ADKs to take the central place in the cluster network during the 2004-2010 and 2011-2017 to form new research theme. This is the advantage of using simple center algorithm for clustering purpose since it gives weight to the simple centers. Therefore, we can conclude that there is an increasing conceptual stability while there is huge dynamism in the thematic areas over periods.

4.8 Chapter Summary and Conclusion

We have proposed a combination of graph theory and bibliometric analysis techniques, methods and tools to explore the convergence between Information Behavior from articles published in journal of computers in human behaviors from 1990-2017 (28 years). We have made descriptive statistical summaries key bibliographic indicators to see trends and patterns of over time. It showed tremendous increase of research interest connecting both fields of study the development in the early days was slow until 2007. Number of publications, number of authors, number of Author Defined Keywords and collaborations particularly after 2007, which seems coincided with emergence of the online social media platforms, smartphones, cloud computing platforms and other ubiquitous devices.

For thematic area mapping, we used themes of clusters to detect themes of research from 4771 journal articles using Author Defined Keywords (ADKs). Clusters centrality and density to measure internal cohesion and inter-cluster coupling of the clusters (themes) detected to shape knowledge structure of converted fields of study respectively. Strategic diagram was used to classify the detected themes into more meaningful high level thematic areas. With combination of techniques, we have shown the trends, structure and dynamism of thematic areas that exist at the crossroad of Information Behavior as far as the journal of computers in human behavior is concerned. The main issues

revolve around role of individual differences, trust, memory, emotion, motivation, personality, attitudes, perceptions, attentions etc. for adopting, accepting, interacting and using computers and related technologies, and services such as computer mediated collaborative learning, computer mediated communication, virtual reality, social network sites, mobile banking etc. for personalized and interaction and good user experience, and problem solving. The main issues observed in the research themes were also about changes in human behavior and psychological health as a result of impact of use of computing devices and services or phobia related to it such as anxiety, depression, mental health, addiction to online services, narcissism and related big five personality issues. The other issues reflected in the thematic areas are concepts or theories related HCI, Problem Solving, Self-Efficacy, User Experience, Cognitive Load, Information Processing, Working Memory, Disclosure, TAM, ZPD and related themes.

Chapter Five

5.1 General Summary and Conclusion

The dissertation contains two paper. We started in identifying area of research interests at intersection of user experience and human computer interaction. Web of science indexed journal articles related to the research topic were retrieved. For intersection of user experience and human computer interaction, we retrieved 519 journal articles for the first paper. 4771 journal articles were identified and retrieved to make in-depth analysis of behavioral dimension of HCI/UX for the second paper. This would help researchers to focus on relevant domains to generate research topics and target relevant journal venues for them researches in the HCI/UX field of study. The idea of second paper is obtained from the finding of the first paper by making citation network cluster analysis and detecting three major categories of research interest by researchers contributed their work to the area namely: 1) Human, computers and interaction. 2) Human, computing and behavior (information behavior) and 3. personal and ubiquitous computing. So for the purpose of scoping and its major contributions, we selected the human, computing and behavior (Information Behavior) of HCI/UX in the second paper. We selected journal of computers in human behavior for analysis as it represented the clusters belonging to Information behavior. The number paper published in this journal within the timeframe set for analysis i.e. 1990-2017-July is 4771. We proposed

a combination of graph theory and bibliometric to explore the thematic structure of HCI/UX for both papers. Preprocessing of the retrieved data and temporal analysis of trends were made and indicated increasing trends in terms of number of papers, number of Author Defined Keywords, number of authors and countries' collaboration in interdisciplinary research area.

The thematic areas of three different time intervals were detected using various techniques as elaborated in methodology in chapter two and indicated that number of themes generally grew over time intervals in both cases. The detected themes were categorized into different groups showing different subject matters such as technology/systems, Theories/approaches, Measurement criteria, learning and human factors by experts in the area. The groups were labeled and color coded. Those colors were used as colors of themes in the evolution pattern discovery map and strategic diagram.

The evolution patterns of thematic identified three important things. 1) The themes which belongs to each period. 2) The evolution links between themes of two different consecutive periods. 3) The subject matter to which the themes in each period belongs using the color code the concepts. The ADKs time overlap map showed three important things: 1 number of ADKs used in analysis after preprocessing, which has passed from one-time interval to another time interval. 2) It identified as newly emerged ADKs in every time

interval. 3) It indicated the number of ADKs, which were obsolete in certain time interval to pass to the next period. These three indicators enabled us to evaluate the low level conceptual (ADKs) stability in the thematic formation of different time interval of analysis of the thematic structure of both cases covered in this dissertation of (Case 1: HCI/UX and Case 2 : IB) . The thematic structure in HCI/UX is still in shaping as its conceptual stability 52% in the period 2010-2016. Its thematic dynamism is 83% during same period.

It is indicated that thematic research areas, which are internally strong as well as having great role in shaping the entire thematic structure are increasing over time. This indicates that the scientific knowledge of HCI/UX is gaining strong base for the future, which also shows increased specializations as well as diversification by subject matter of the research thematic areas. From measurement criteria category (Usability, Emotion and Aesthetics), From approach (User Interface, Ubiquitous Computing and Design) and from Technology (Virtual Reality) are among core and basic themes during 2010-2016 that continues to shape the thematic structure of HCI/UX in the years to come from the previous patterns.

The Information Behavior domain is fertile area of research in terms of number of thematic areas as well as having balanced thematic structure. The core and basic themes and their member ADKs during 2011-2017 in this research

would highly play important role in shaping the thematic structure in the years to come as the pattern between 1990-2003 and 2004-2010 shows this trend. Core themes in Information behavior during this time interval include User Experience, Attention, Children, Information Technology, Online Games, Individual Differences and Information Processing. The basic and transversal themes are Emotion, Motivation, Online Communities, Internet, Computer Mediated Communication, Learning, Cognitive Load and Engagement.

Over all, Gender Difference (from human side/factor), Computers (from technical group), User Interface and Human Computer Interaction (in the group of methods/approach) thematic areas during the early time intervals were at the root of all the diversification and specialization of the rest of the thematic areas over the recent years. Themes highly proliferate over the three periods (3, 11 and 34 for three periods respectively).

High level of thematic dynamism (100% and 88% for two later periods respectively by theme' name). Complex evolution links over periods, shows high level of specialization and merging of themes. Clear paradigm shifts are observed in terms of themes and their high level concepts. We expect increase in thematic overlap in the years to come as it increased from 0 between the two early periods to 12% between period 2 to period 3 i.e. 4 themes (12%)

continued as themes namely; Motivation, Internet, Avatar and CMC themes over the two later periods.

As successfully discovered and characterized the thematic areas in both cases, the proposed method achieved the intended research goals of focusing on ADKs network analysis using graph theory and bibliometric. This work can be extended into further understanding of the social, intellectual landscape using other bibliometric analysis methods like co-authorship network, co-citation network and bibliographic coupling for exploring the convergence trends in the research domains. This dissertation focused mainly on the conceptual or thematic mapping using ADKs as a concept of analysis.

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