Content analysis in information visualisation research: implications for engineering education

Pao-Nan Chou

National University of Tainan
Tainan, Taiwan

ABSTRACT: The present study attempted to identify current trends in information visualisation research by conducting a content analysis of a refereed journal. Based on the results of the content analysis, potential research topics were proposed that related to information visualisation and engineering education. The 115 articles published in the journal, *Information Visualization,* between 2002 and 2007 were categorised. Three exploration directions are: a) research area; b) keywords used; and c) research methods used. It is hoped the proposed research framework may facilitate the discussion of information visualisation between engineering educators.

INTRODUCTION

Human beings are visual creatures [1]. People tend to employ visual representations, such as figures and tables to comprehend large amounts of information [2]. The aim of visualisation is to allow users to view the information contents with a qualitative understanding [3].

Information visualisation is defined as *…a computer-aided process that aims to reveal insights into an abstract phenomenon by transforming abstract data into visual-spatial forms* [4]. The purpose of information visualisation is to *…optimize the use of our perceptual and visual-thinking ability in dealing with phenomena that might not readily lend themselves to visual-spatial representations* [4].

Information visualisation is a relatively young research topic that relates to a number of research fields: scientific visualisation, information retrieval and geographic information systems [4]. Since 1990, the number of journal articles discussing information visualisation has grown exponentially [4][5]. This increasing trend has also led to the emergence of a peer-reviewed international journal called *Information Visualization*, which is often regarded as one of the sub-categories in the field of human-computer interaction [4][5]. To date, information visualisation has been applied to digital libraries, data mining, financial data analysis, market studies, manufacturing production control and drug discovery [6].

Currently, information visualisation is still a new concept in the field of engineering education. The purpose of this study was to propose potential research topics related to information visualisation and engineering education through the results of content analysis of a refereed journal. It is hoped that the proposed research framework may facilitate the discussion of information visualisation between engineering educators.

RESEARCH METHOD

According to Schwandt, content analysis is *a generic name for a variety of means of textual analysis that involve comparing, contrasting, and categorizing a corpus of data to test hypotheses* [7]. Gall et al's content analysis approach to analysing data was used in this study [8]. Three major steps are listed as follows:

Specifying Research Questions

The main inquiry is to identify current trends in information visualisation research. Three exploration directions are: a) research area; b) keywords used; and (c) research methods used.

Selection of Journal Articles for Analysis

Information Visualisation was chosen as a targeted journal because it is not only an international refereed journal, but also the only journal focusing on information visualisation topics.

Selection of Topics for Analysis

The journal articles selected for this study were published from 2002 spring to 2007 summer. The reason for choosing this timeframe was that the targeted journal was founded in 2002 and downloadable full-text files were limited in 2007. The number of journal articles analysed in this study was 115, and excluded editor, book review and workshop summary articles. The distribution profile of journal articles by publication year is listed in Table 1.

Table 1: Profile of journal articles by publication year.

Publication Year	Number of Journal Articles
2002	17
2003	21
2004	18
2005	18
2006	24
2007	17
Total	115

RESULTS

Research Area

The research area was divided into the following categories:

a) Biology: displaying and analysing large-scale experiment data, such as gene expression data.
b) Business and Finance: designing e-commercial application, displaying and analysing stock performance.
c) Communication: applied in media design and media studies, and analysing network data.
d) Computer Science, HCI (human-computer interface) and Internet Technology: including security protection, computational linguistics algorithms.
e) Education: designing concept maps, providing productive reading techniques and collaboration.
f) Engineering: enhancing engineering design.
g) Geography: designing GeoVisual applications and text label displays on maps.
h) Knowledge Management: developing digital libraries; designing systems that help knowledge discovery and knowledge management.
i) Linguistics: Analysing linguistic data.
j) Medical Data: simulating and analysing medical data, including cancer detection, anatomical geometry and human body scanning.
k) Meteorology: climate modelling and visualisation data of temperature, humidity, wind and atmospheric pressure.
l) Statistics: statistical data analysis and visualisation.
m) Social Science: assisting organisational studies, analysing social infusion patterns and social behaviours.
n) Others: not covered in the categories above.

Table 2 summaries the number of articles appearing in the above categories.

Table 2: Research area by six-year publication.

Research Area	Number of Articles
1. Biology	16
2. Geography	13
3. Education	12
4. Computer Science	8
5. Business	8
6. Knowledge Management	7
7. Social Science	6
8. Medical	6
9. Communication	6
10. Engineering	4
11. Linguistics	2
12. Statistic	2

Table 2 shows that information visualisation is an interdisciplinary research field, integrating understanding and applications from different academic disciplines.

Based on the researcher's educational background, education-related topics were specifically examined. Among 12 education-related articles, three sub-categories were discovered, and they are: computer-aided learning (*The design of a mathematical mindtool* in 2003); digital concept maps (a whole issue in 2006); and visual-aided on-line collaborations (*A visual environment for collaborative sense-making* in 2007).

Keywords Used

A visualisation tool called TagCrowd (see Figure 1) was used to analyse keywords appearing in the journal articles. The purpose of keyword analysis was to identify any frequent scholarly terminologies that may emerge in an annual publication. The results of analysis are in Table 3.

Figure 1: Tool for analysing keywords (TagCrowd).

Table 3: Frequent scholarly terminologies.

Publication Year	Frequent Scholarly Terminologies*
2002	data and information visualisation, user design, interface design, interaction design, media design and data mining
2003	data and information visualisation, network analysis, network visualisation and data mining
2004	data visualisation, graph layout and drawing, multidimensional scaling, data analysis, cluster analysis and software visualisation
2005	data and information visualisation, data analysis, scientific discovery, pattern discovery and link analysis
2006	data and information visualisation, data mining, visual analytic, concept map and knowledge visualisation
2007	data and information visualisation, data mining and visual analytic

* Closely similar terminologies are replaced by the above representative terminologies

Obviously, since the targeted journal focuses on information visualisation, data and information visualisation are the most used keywords during the six years of publication. It was also found that most of the journal articles had broad terms that could not describe the main ideas or key variables of the papers.

Research Methods

Research methods were divided into three categories:

a) Theoretical inquiry: a study that aimed to discuss past literature and propose new viewpoints.
b) Evaluation research: a study that aimed to investigate the impact of a model or programme by using specific evaluation methods.
c) Developmental research: a study aimed to designing and developing a product without evaluation results.

Table 4 shows the three categories by publication year.

Table 4: Research methods by publication year.

Research Method	2002	2003	2004	2005	2006	2007
1. Theoretical inquiry	7	0	0	0	0	5
2. Evaluation research	5	9	11	12	12	10
3. Developmental research	5	11	7	6	5	9
Total	17	21	18	18	24	17

Table 5 displays the above three categories over the six years of publication.

Table 5: Research Methods over six years of Publication

Research Method	Six years of publication	Per cent
1. Theoretical inquiry	12	11%
2. Evaluation research	59	52%
3. Developmental research	43	37%
Total	115	100%

It was found that evaluation research dominated half of the six years of publication. In contrast, few studies focus on theoretical inquiry. A feasible reason is that the targeted journal is science-based and discourages theoretical-based studies. In other words, a scientific inquiry needs experiments and evaluation methods to verify the theoretical hypotheses.

DISCUSSION

In Chou and Chang's study, five popular research themes in engineering education are:

- engineering epistemologies;
- engineering learning mechanisms;
- engineering learning systems;
- engineering diversity and inclusiveness;
- engineering assessment [9].

According to these five themes, potential research topics related to information visualisation were proposed in Table 6.

Table 6: Research topics related to information visualisation.

Research Theme	Potential Research Topics
Engineering Epistemologies	1. Visual information in engineering students' competence gaps between industries and schools (e.g. Gap map showing competence gaps) 2. Visual analysis in engineering students' attitudes toward engineering learning (e.g. Pattern discovery about students' attitudes) 3. Visual analysis in engineering students' retention and dropout (Structural equation models on the related factors about retention and dropout)
Engineering Learning Mechanisms	1. Visual design in instructional media for engineering learning (e.g. simulation visualisation) 2. Visual comparison of engineering learning aids (e.g. concept maps VS static images) 3. Visual representations of instructional techniques for engineering learning (e.g. Visual structure analysis of instructional techniques)
Engineering Learning Systems	1. Visual analysis in engineering curriculum development (e.g. Curriculum map design and development) 2. Visual analysis in academic programme

	development (e.g. Knowledge visualisation regarding programme design) 3. Data mining in international networks of engineering education (e.g. Visual representations in network analysis)
Engineering Diversity and Inclusiveness	1. Visual information in minority groups (e.g. Data about learning profiles and preferences) 2. Visual analysis in gender issues (e.g. Structural equation models on the related factors) 3. Visual analysis in K-12 engineering education (e.g. Construction of pipeline map)
Engineering Assessment	1. Visual representation of faculty teaching and institution assessment (e.g. Scaling visualisation) 2. Visual analysis in assessment methods (e.g. Measurement visualisation)

The potential research topics appearing in Table 6 are based on the results of the content analysis. Since past information visualisation studies tended to use the evaluation method to design research questions, more emphasis on theoretical and developmental methods is needed for the combination of information visualisation and engineering education research.

CONCLUSION

The research trend of information visualisation and its application into the field of engineering education was explored in this study. Through content analysis, several patterns were identified in information visualisation. Based on these patterns, 15 potential research topics related to five research themes were proposed. Future research may adopt different research designs to explore these topics.

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