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**CONCEPTUAL DESIGN FRAMEWORK FOR INFORMATION  
VISUALIZATION TO SUPPORT MULTIDIMENSIONAL DATASETS  
IN HIGHER EDUCATION INSTITUTIONS**



**DOCTOR OF PHILOSOPHY  
UNIVERSITI UTARA MALAYSIA  
2016**



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Universiti Utara Malaysia

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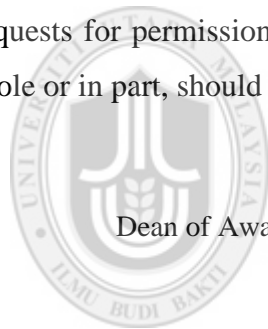
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## Ikhtisar

Visualisasi maklumat (InfoVis) digunakan dalam pelbagai aplikasi kerana keupayaannya menyelesaikan masalah lambakan maklumat dalam data institusi. Para pembuat polisi dan pembuat keputusan di institusi pengajian tinggi (IPT) juga tidak terlepas daripada masalah lambakan maklumat semasa berinteraksi dengan data pelajar disebabkan oleh kepelbagaian dimensinya. Hal ini mengekang proses pembuatan keputusan dan kerana itu satu kerangka kerja reka bentuk konsep InfoVis tersendiri diperlukan untuk menghasilkan alatan InfoVis khusus domain. Sehubungan itu, matlamat kajian ini adalah untuk mereka bentuk kerangka kerja InfoVis yang dilengkapi dengan teknik penyampaian kandungan dan proses sistematik dalam menzahirkan InfoVis khusus domain bagi menangani data pelajar IPT. Terdapat empat fasa yang terlibat dalam kajian ini: 1) kajian pengguna untuk mengkaji, mendapat dan memberi keutamaan pada data pelajar yang menjadi pilihan kepada polisi IPT. Dimensi data pelajar yang sepadan kemudiannya dikategorikan, 2) kajian tinjauan melalui analisis kandungan terhadap kepustakaan reka bentuk InfoVis, dan padanan terhadap dapatan daripada kajian pengguna untuk mencadangkan teknik visualisasi, interaksi dan herotan yang sesuai, 3) pembangunan reka bentuk kerangka kerja secara konsep yang menyepadukan model teknik tersebut dengan proses reka bentuk berpandukan penyesuaian kejuruteraan perisian dan model reka bentuk InfoVis, 4) penilaian terhadap kerangka kerja yang dicadangkan melalui tinjauan pakar, prototaip, penilaian heuristik, dan penilaian pengalaman pengguna. Bagi sebuah InfoVis yang mampu menyampaikan dan mewakili pilihan pengetahuan eksplisit, serta menyokong kepelbagaian dimensi data pelajar dan proses pembuatan keputusan, kajian mendapati bahawa 1) *mouse-on*, *mouse-on-click*, *mouse on-drag*, *drop down menu*, *push button*, kotak semak, dan *dynamics cursor hinting* adalah teknik yang sesuai untuk interaksi, 2) *zooming*, gambaran menyeluruh dengan perincian, penatalan, dan eksplorasi adalah teknik yang sesuai untuk herotan, dan 3) carta garis, *scatter plot*, *map view*, carta bar dan carta pai adalah teknik yang sesuai untuk visualisasi. Sokongan teori kepada kerangka kerja yang dicadangkan mengesyorkan bahawa ketetapan dalam *preattentive processing theory*, *cognitive-fit theory*, dan *normative and descriptive theories* mesti diikuti bagi membolehkan InfoVis membantu persepsi, kognisi dan pembuatan keputusan. Kajian ini menyumbang kepada bidang InfoVis, proses pembuatan keputusan berpandukan data, dan proses penggunaan data pelajar.

**Kata Kunci:** Visualisasi maklumat, Institusi pendidikan tinggi, Kerangka kerja reka bentuk konsep, teknik penyampaian kandungan, proses pembuatan keputusan berpandukan data.

## Abstract

Information Visualization (InfoVis) enjoys diverse adoption and applicability because of its strength in solving the problem of information overload inherent in institutional data. Policy and decision makers of higher education institutions (HEIs) are also experiencing information overload while interacting with students' data, because of its multidimensionality. This constraints decision making processes, and therefore requires a domain-specific InfoVis conceptual design framework which will birth the domain's InfoVis tool. This study therefore aims to design HEI Students' data-focused InfoVis (HSDI) conceptual design framework which addresses the content delivery techniques and the systematic processes in actualizing the domain specific InfoVis. The study involved four phases: 1) a users' study to investigate, elicit and prioritize the students' data-related explicit knowledge preferences of HEI domain policy. The corresponding students' data dimensions are then categorised, 2) exploratory study through content analysis of InfoVis design literatures, and subsequent mapping with findings from the users' study, to propose the appropriate visualization, interaction and distortion techniques for delivering the domain's explicit knowledge preferences, 3) conceptual development of the design framework which integrates the techniques' model with its design process –as identified from adaptation of software engineering and InfoVis design models, 4) evaluation of the proposed framework through expert review, prototyping, heuristics evaluation, and users' experience evaluation. For an InfoVis that will appropriately present and represent the domain explicit knowledge preferences, support the students' data multidimensionality and the decision making processes, the study found that: 1) mouse-on, mouse-on-click, mouse on-drag, drop down menu, push button, check boxes, and dynamic cursor hinting are the appropriate interaction techniques, 2) zooming, overview with details, scrolling, and exploration are the appropriate distortion techniques, and 3) line chart, scatter plot, map view, bar chart and pie chart are the appropriate visualization techniques. The theoretical support to the proposed framework suggests that dictates of preattentive processing theory, cognitive-fit theory, and normative and descriptive theories must be followed for InfoVis to aid perception, cognition and decision making respectively. This study contributes to the area of InfoVis, data-driven decision making process, and HEI students' data usage process.

**Keywords:** Information Visualization, Higher Education Institutions, Conceptual Design Framework, content delivery techniques, data-driven decision making process

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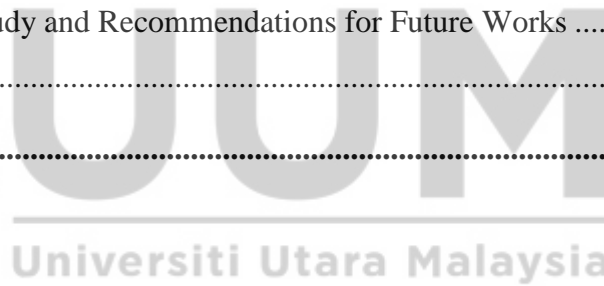
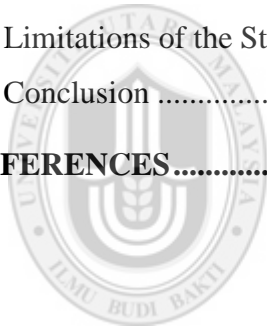
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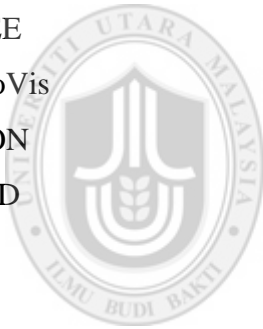
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## List of Abbreviations

2D	Two Dimensional
3D	Three Dimensional
ACM	Association of Computing Machineries
BI	Business Intelligence
DSS	Decision Support System
EDA	Exploratory Data Analytics
HCI	Human Computer Interaction
HEI	Higher Education Institution
HSDI	HEI Students' Data InfoVis
ICT	Information Communication Technology
IEEE	Institute of Electrical and Electronic Engineers
InfoVis	Information Visualization
JSON	JavaScript Object Notation
UCD	Users-centered Design



Universiti Utara Malaysia

# **CHAPTER ONE**

## **BACKGROUND OF THE STUDY**

### **1.1 Introduction**

This chapter espouses the need for Information Visualization framework to support students' data-related decision making process of higher education institutions. It provides the overview of the study, motivation, and the preliminary investigation. This chapter discusses the problem statement, enlists the research questions and the research objectives of this study. It highlights the scope which signifies the boundary of the research conducted. The research deliverables, the study's contributions, research design that explains the research framework and the thesis structure are also included. Lastly, a summary of the chapter is presented.

### **1.2 Overview of the Study**

Information Visualization (InfoVis) is a branch of Visualization if seen as a field of study (Spence, 2007; Shneiderman & Plaisant, 2010). In this respect, there is also scientific visualization which borders on representation of scientific data such as tensor data, unsteady flow, model and software using appropriate technique and tools (Wright, 2007).

Ware (2000), however, defines visualization as a graphical representation of concepts and data in a manner that supports decision making. Visualization, as human activity, had been in existence far before the computing era. It characterises the period of cave painting, imagery of human and all forms of ancient artistic

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