Space-Efficient Visualisation of Large Hierarchies

Quang Vinh Nguyen

A thesis submitted for the degree of
Doctor of Philosophy in Computing Sciences
at the
University of Technology, Sydney

Faculty of Information Technology
University of Technology, Sydney
Sydney, Australia

2005

CERTIFICATE OF AUTHORSHIP/ORIGINALITY

Date	**August 05**
Author	**Quang Vinh Nguyen**
Title	**Space-Efficient Visualisation of Large Hierarchies**
Degree	**Doctor of Philosophy in Computing Sciences**

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidate

Acknowledgements

I would like to take this opportunity to express my sincere gratitude to my supervisor, Dr. Mao Lin Huang, for his enormous academic guidance and financial support, encouragement, advice, and for giving me the opportunity to do a Ph.D at the Faculty of Information Technology at the University of Technology, Sydney. Mao Lin provides me not only a great academic guidance, but also a large degree of freedom in my research, for both of which I am very grateful.

I also would like to express my sincere thank to my co-supervisor, Prof. Chengqi Zhang, for his great help and useful advice.

I would like to thank Prof. Igor Hawryszkiewycz for giving me the opportunity to carry out one of my case study using the *LiveNet* system, which makes it much more valuable to my thesis. I have leant a lot from the experiment, as well as from the discussions with Igor. I also wish to acknowledge the great support of Dongbai Xue for his eager help when I worked with the *LiveNet* system.

Great thanks are due to A/Prof. Tom Hintz and all members of Computer Vision Research Group for their generous helps, supports, and the exchange of knowledge toward the completion of my Ph.D. I would acknowledge the effort of A/Prof. Tom Hintz for the English correction.

I would like to thank Prof. Peter Eades and his Information Visualisation group members, who have given me opportunities to share and exchange the knowledge during the group meetings at the University of Sydney, Australia.

I would also thank all of my colleagues, academics and technical staffs of Faculty of Information Technology, the Graduate School and the Vice-Chancellor's Conference Fund at the University of Technology, Sydney who directly or indirectly help me on the road toward the completion of my Ph.D, especially to Ryan Heise, Robert P. Biuk-Aghai, and Ai Zhong Lin.

The author would acknowledge the appreciation to the markers of Tree-Maps and Space-Tree software (University of Maryland's Human-Computer Interaction Lab). These two softwares are very useful for my research and experiment.

Last but not least, I would like to thank my parents, my grandma, and my sisters for their continuous encouragement and support. I would also thank my girlfriend, Kim Chi Nguyen, who has always stayed side by side to make this Ph.D possible.

To my beloved parents & my loved girlfriend

Table of Contents

List of Figures

List of Tables

List of Equations

Abstract

Relational information visualisation concerns viewing relational data, where the underlying data model is a graph. Hierarchical visualisation is one of hot topics in graph visualisation in which the data is organised in a hierarchical structure. As the amount of information, that we want to visualise, becomes larger and the relations become more complex, classical visualisation techniques and hierarchical drawing methods tend to be inadequate.

Traditional hierarchical visualisation algorithms are more concerned with the readability of the layouts. They usually do not consider the efficient utilisation of the geometrical plane for the drawings. Therefore, for most hierarchical layouts, a large portion of display space is wasted as background. The aim of this research is to investigate a space-efficient approach to handle the visualisation of large hierarchies in two-dimensional spaces.

This thesis introduces a new graph visualisation approach called *enclosure+ connection* for visualizing large hierarchies. This approach maximises the space utilisation by taking advantages of the traditional enclosure partitioning approach, while it retains the display of a traditional node-link diagram to hopefully provide users a direct perception of relational structures.

The main contribution of this thesis is layout and navigation algorithms for visualising large hierarchies. Two layout algorithms, the *space-optimised tree* and the *EncCon tree*, have been developed to achieve the space-efficient visualisation. Both algorithms use the enclosure concept to define layout of hierarchies, which ensure the efficient utilisation of display space. Two *focus+context* navigation and interaction methods have been proposed to cooperate with the visualization of large hierarchies. Several advanced computer graphics approaches, such as *graphic distortion* and *transparency*, are used for the development of these navigation methods.

Two case studies have been implemented to evaluate the layout algorithms and the associated navigation methods. The first case study is an application of a shared collaborative workspace which aims to provide users with a better assistance for visual manipulation and navigation of knowledge-based information. The second case study is a visual browser for navigating large-scale online product catalogues.

Although the case studies have provided some useful evaluation, formal usability studies would be required to justify fully the effectiveness of these layout and navigation methods. Although this task has not carried out in this research, the author has presented his usability study's plan as a future work.

Terminology

- **A graph $G = \{V, E\}$:** is defined as a pair (V, E), where V is a set of vertices, and E is a set of edges between the vertices $E = \{(u,v) \mid u, v \in V\}$.
- **A tree**: is a connected graph without a cycle.
- **A rooted tree:** consists of a tree $T(r)$ and a distinguished vertex r. The vertex r is called the root of T. In other words, T can be viewed as a directed acyclic graph with all edges oriented away from the root. If (μ, ν) is a directed edge in T, we then say μ is the father of ν, or ν is a child of μ. If T contains vertex ν, then the sub-tree $T(\nu)$ rooted at ν is the sub-graph induced by all vertices on paths originating from ν.
- **A leaf vertex:** is a vertex with no children.
- **A node:** represents a vertex with its displaying properties.
- **Weight $w(\nu)$:** represents the weight of vertex ν.
- **Wedge $wg(\nu)$:** is defined by a vertex μ, line l goes through μ, and a clockwise angle $\alpha(\nu)$; where μ is the father of ν. Thus, we have $wg(\nu) = \{\mu, l, \alpha(\nu)\}$ (see Figure 2.3).
- **Local region $R(\nu)$:** is an area which contains the drawing of a sub-tree $T(\nu)$.
  - At the Space-Optimised Tree model: $R(\nu)$ is a polygon that is defined by the wedge $wg(\nu)$ and one (or more) cutting edges (boundaries of other local regions) that cross the line l in $wg(\nu)$ (see Figure 2.4).
  - At the EncCon model: $R(\nu)$ *is* a rectangle.
- **Layered visualisation LV:** consists of two graphical layers L_1 and L_2 of the information that are appeared in an overlapped manner in the visualisation, $LV = L_1 + L_2$ (see Figure 3.8). Each layer is the medium for the drawing of graph G or a sub-graph $G_l \in G$. At any time, a graph G_i drawn in L_1 is always a sub-graph of G_j drawn in L_2. Thus, we constantly have $G_i \in G_j \in G$.