Chapter 1:

Introduction

1. Introduction

1.1 Project background

Tremendous advances in networking and data storage technology have increased their capacity to transmit and store data respectively. High-speed networking technologies such as Fast Ethernet, Gigabit Ethernet, ATM and Fiber Channel offer data transmission rates in the range of hundreds of megabits per second and above. Improvements in storage technology also mean that the cost of storing data per megabyte is becoming cheaper.

However, regardless of the supply of network bandwidth and storage capacity, the supply never seems to be enough to cater for the demand. Congestion and quality of service are important issues in managing a network. Steps taken to improve the quality of service in a network include congestion control and traffic management.

Compression can be used to reduce the size of data, thus minimizing the bandwidth consumed in transmitting the data over a network, for example in an IP-based network such as the Internet, where the bandwidth is shared among many users. A smaller size enables more efficient transmission of data over the network, thereby reducing the amount of time required to transfer the data. The amount of storage capacity required is also reduced.

Data compression can thus be viewed as a complementary measure to reduce the burden on the network and storage infrastructure. Any reduction in the size of the data achieved by applying compression will always be welcomed, provided that the trade-offs (such as the processing overhead required to compress and decompress the data) are acceptable.

Many data compression algorithms have been developed to deal with all types of data, for example audio, still image, video, text and binary files. In this dissertation, the compression of road map images was investigated. Road maps are an example of spatial data, which is an important component of *Geographical Information Systems* (GIS).

A *Geographical Information System* (GIS) is a computer system used to perform various operations on geographical data. It is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information (*The GIS Glossary- E-H*, 2002). A GIS may be used by various levels of users, from the general public to scientists, researchers and cartographers; from decision makers and planners to utility managers, transportation officials and resource managers. Its function may be as simple as serving maps in digital form for visualization, or as a more complex analysis tool in a spatial decision support system.

At the heart of a GIS are spatial data. Spatial data refers to data with a specified geographic location. It contains information about the location of a geographic feature, and additionally its shape and the relationships among the features (*The GIS Glossary- Q-S*, 2002). Spatial data are collected from diverse sources. Figure 1.1 shows examples of spatial data sources. Figure 1.2 depicts some of these examples. The data sources for a comprehensive GIS are probably more numerous and of greater variety than in most other information systems. Indeed, as Bernhardsen (1999) remarks, a GIS is a true mixed-data system.

GIS

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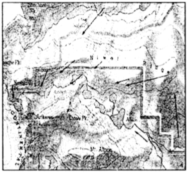
Spatial data

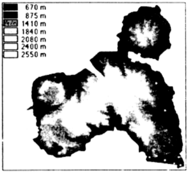
- basemaps
  - topographic map
  - elevation model
  - transportation
  - hydrology
  - toponymy
  - satellite images
  - aerial photographs
- environmental data
  - wetlands
  - flood zones
- socio-economic data
  - population census
  - land ownership

Figure 1.1: Example of sources for spatial data (adapted from Longley *et al.*, 2001)

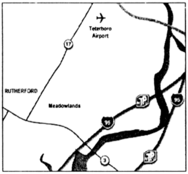
To aid users in visualizing the data, *maps* are often used to display spatial data graphically. A map represents, in abstract form, the physical features of a portion of the Earth's surface. Symbols, signs and text are used to represent the features. For example, rivers may be represented by curved lines, location of towns by a dotted symbol along with its name, and different elevation by contour lines. Certain features may be emphasized, generalized or altogether omitted, depending what is to be shown and what the user is interested in. For example, road maps may only need to show roads and the location of buildings, but not the height above sea level. There are many types of maps, depending on the application, what the user wants to see and how he wants to see it.



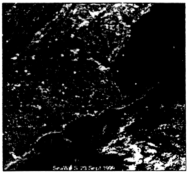
(A) Topographic map



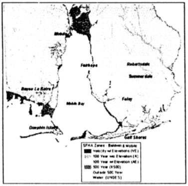
(B) Elevation model



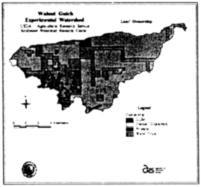
(C) Transportation map



(D) Satellite image



(E) Flood zones map



(F) Land ownership map

Figure 1.2: Examples of spatial data

The widespread use of the Internet, in particular the World Wide Web, has opened up a whole new range of opportunities for geographical data search and distribution. The potential of applying GIS over the Internet is something of interest to many researchers, as evidenced by the amount of research on web-based GIS and mapping applications in recent years (Baumann, 2001; Li *et al.*, 2001; Ye *et al.*, 2001; Barclay *et al.* 2000; Stojanovic *et al.*, 2000; Soomro *et al.*, 1999; Wei *et al.*, 1999; Meng *et al.*, 1997). The Internet provides easy access of data to the user from any location in the world, as long as he is 'online'. Mobile and wireless systems are increasingly used to connect to the Internet. It is now conceivable for a user with a notebook computer, connected wirelessly to the Internet, using a GIS application while out on the field, to access data from remote GIS server.

It is also advantageous to use the Internet to distribute spatial data, compared to more traditional mediums such as CD-ROMs. The data sets can be stored, maintained and updated at the data publisher's server. When a user requests for the data, the most current data is available. Therefore, the user does not need to store or maintain any of the data. Even if he chooses not to discard the data, all that he needs to do is to check for the latest update, or perhaps subscribe to a mailing list to be informed of the latest updates to the data. A user may also not need the whole data set, but only a small portion of it. The data publisher saves cost by offering the data through a server rather than producing CD-ROMS, letting the user download data as he wishes. The Internet may well "become a GIS trading exchange" (Bernhardsen, 1999).

Having said all that, the focus of this dissertation will be in the context of a relatively simple application, Internet mapping. Because there are a wide variety of maps, the focus will be on road maps. For example, a web site that serves road maps to users should be of considerable interest to the general public, especially drivers, travelers, expatriates and tourists. Several websites already offer such a service, for example the Virtual Malaysia Tourism Portal (http://www.virtualmalaysia.com) and Mapquest (http://www.mapquest.com).

In such an application, the map is usually served in the form of an image. Without compression, the size of an image will be prohibitively large for transferring over the Internet. For example, consider an image where each pixel is represented by a 24-bit value, as is the case when using the RGB colour model. If its width is 600 pixels and height is 400 pixels, the size of the image is 720,000 bytes. The transmission time for an image of this size will take at least more than 103 seconds over a 56 kbps line (as in the case of a dial-up connection).

Viewing a web page which takes that much time to load is undoubtedly annoying to most users. Therefore, applying compression will be useful to reduce the transmission time by reducing the size of the image. Of course, the user may have access through a high-speed broadband connection. However, as mentioned earlier, compression will still be useful in order to reduce the load on the network infrastructure as a whole.

1.2 Objective

The major objective of this dissertation is to study, implement, analyze and evaluate effective lossless compression methods for road map images. In detail, the objectives are as follows:

1. To provide an overview of data compression and the various methods available for compressing still images.
2. To study effective lossless methods for compressing road map images, taking into consideration the characteristics of road map images.

3. To implement the enhanced lossless compression methods. A lossless method based on arithmetic coding with adaptive context-based statistics modeling[1] is chosen. Two approaches, bitplane coding and Prediction by Partial Matching (PPM), will be considered for comparison.
4. To run a series of test on the implemented enhanced compression methods using a set of randomly selected road map images.
5. To analyze the results obtained and evaluate the performance of the compression method.

1.3 Scope

The objective of the dissertation is the lossless compression of selected road map images. The following assumptions are made to define the scope:

1. The main focus is on the compression effectiveness of the methods, that is, how much compression can be achieved. As such, during implementation of the methods, issues such as memory and execution time are relegated to secondary concerns.
2. Analysis and evaluation of the results are based on the experimental results obtained.

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[1] The statistics model contains the symbol probability information required by the arithmetic coder. In an adaptive model, the model is built and updated as the compression process goes along. In context-based statistics modeling, the symbol probability information is obtained based on the context in which the symbol appears.

1.4 Motivation

While popular file formats such as the *Graphics Interchange Format* (GIF) can be used to represent road map images, and GIF itself applies compression on the data, the compression is not optimal, as far as size is concerned. This dissertation is aimed at studying more effective compression methods for road map images. By effectively compressing the images, the size of the data is reduced. This enables more efficient transmission of data over a network and contributes to lessening the burden on the network infrastructure.

1.5 Organization of chapters

This dissertation report is organized into six chapters. The rest of the report is organized as follows. Chapter 2 contains a literature review on the subject of data compression, in particular, image compression. The principle of data compression is outlined and various compression methods available are surveyed. Chapter 3 contains the methodology. The concept of arithmetic coding is described, followed by details of the implementation used. Context modeling using bitplane coding and PPM are also outlined. The chapter also explains how the road map images to be used for testing were obtained. Chapter 4 presents in detail the implementation of bitplane coding and PPM. An additional implementation which combines both methods is also presented. The results from testing the implementations are presented, analyzed and discussed in Chapter 5. Finally, Chapter 6 concludes with a summary of the work done and results.