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CoVis 3

Visual Representaion of three-dimensional Data and Functions of two Variables

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Abstract

The visualisation of information is a broad area of study not uniquely associated with computing. Its origins can be traced back to the earliest attempts at cartography. It is, however, with the development of computing technology that the discipline has flourished. It is not simply that the technology has allowed for more detailed visual representations to be produced, it is equally the case that the wealth of data available and the understanding of its importance have accelerated the demand for its analysis. The range of modern visualisation is huge, including medical imaging, engineering simulations and geographical and meteorological analysis.

Information can come in many forms – the two most common to visualisation are numerical data and functional representation. This thesis investigates visualisation methods for both mathematical functions of two variables and three-dimensional data. In particular I examined techniques as contour plots and surface plots.

Within the bounds of this project *OpenGL* turned out to be the most powerful tool regarding visualisation of information. Due to the procedural architecture of *OpenGL* and an ambition to learn the core architecture of *Microsoft Windows®*, I decided to exclusively implement this project in *Win32®*, for which I pay particular attention in this dissertation.

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1 Introduction

Numerical data, in its raw form, is extremely difficult to assimilate. The larger and more complicated the datasets, the more unlikely it is that a reader will be able to ascertain the most implicit characteristics of the information from the basic data. An effective graphical representation should clearly display the critical features of the data.

1.1 Visualisation

Visualisation of data starts with a facility to visualise mathematical functions. Mathematical functions of two variables $f(x,y)$ can describe three dimensional surfaces, where each value of x and y defines a certain function value. These values can then be transferred to the z-axis $z=f(x,y)$. Figure 1.1 shows a surface generated by the mathematical function $f(x,y)=0$. As this formula describes that every point on the XY-plane equals 0, the resulting surface has no elevations.

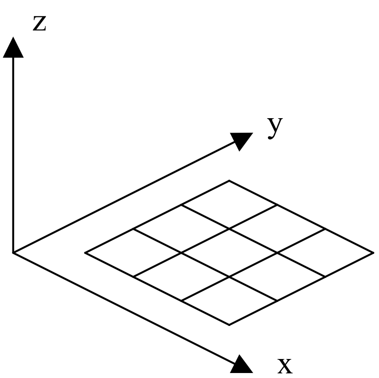

Figure 1.1 Representation of mathematical functions on XY-plane

In order to understand mathematical formulas with two variables, we have to consider these formulas from a very basic point of view. Mathematical functions with one variable $f(x)$ describe curves. This occurs because each value of x defines a certain value in y direction $y = f(x)$. Figure 1.2 shows the curve of the formula for $f(x)=x^2$.

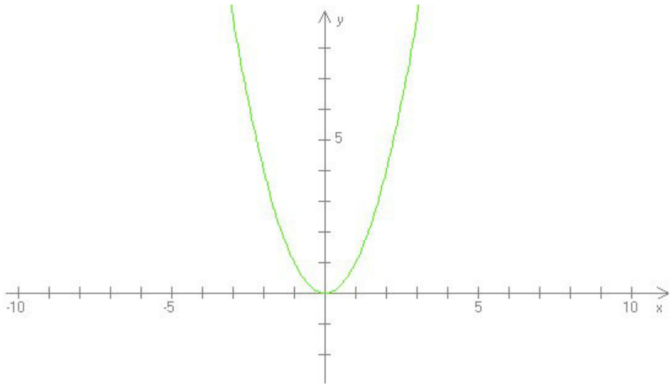

Figure 1.2: Curve of mathematical function $f(x)=x^2$

As already discussed, the definition of surfaces needs formulas of two variables. In three dimensions, it is possible to define a formula depending on x (which is meant by *f(x)*) to either the y axis or the z axis of the coordinate system. If we apply the formula $f(x)=x^2$ to the z axis, and also the formula $f(y)=y^2$ to the z axis, these two formulas describe an outline for a surface.

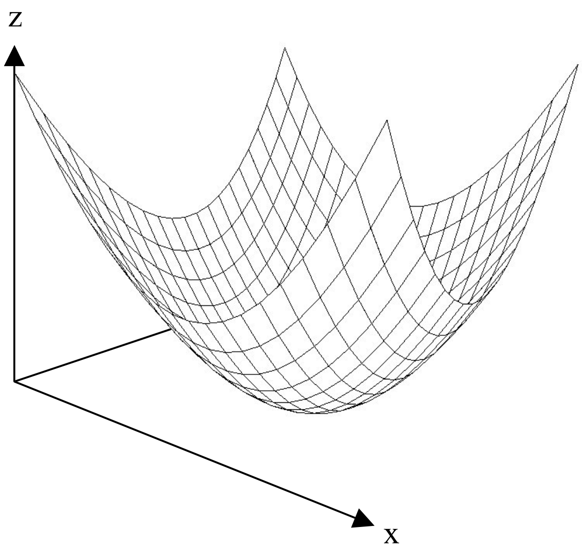

Figure 1.3: Visualisation of a mathematical function of two variables $f(x,y)=x^2+y^2$

However, the difficult part is to find how to combine these formulas. A simple way of achieving this is to add both values for x and y. This results in the formula $f(x,y)=x^2+y^2$. Figure 1.3 illustrates this mathematical function of two variables.

In engineering it is a broadly common to describe surfaces with mathematical functions. For example car manufacturing needs methods to describe aerodynamic surfaces for bonnets or wings. In these situations mathematical functions are better suited than data points connected by lines because surfaces described by mathematical functions provide an infinite accuracy. One problem with functions however is that they can only be represented by a series of data points calculated from the function. A mathematical function can only be approximated by a dataset, containing a finite number of sample points.

Nevertheless, data can also be obtained by direct measuring of physical objects. Nowadays there are many areas where huge quantities of measured data have to be visualised (e.g. in scientific and medical areas). In medical areas it is vital to facilitate the view of parts of the human body or even the entire human body. There are also methods to obtain data from the surface of an object. One such technique is laser scanning. This technique simply measures the distance from the object's surface to the laser. The laser then continues scanning and recording data from every spot of the object. This method is not only applicable in medical areas; it can be used for almost every object. Often there is a need for displaying objects that are obscured from direct view. One example for this is the visualisation of objects hidden by the human body like the heart or the lever. This is already possible through the discovery of X-Rays. Another methods involve the collection of data by ultrasonic.

However, there are also very powerful techniques for visualising three-dimensional data as two-dimensional representations. For maps it is necessary to have a technique to visualise data of the third dimension – the height. Therefore contour lines provide a very good representation of heights. A contour line joins points of equal elevation so that everything within the boundaries of one contour line is at approximately the same elevation.

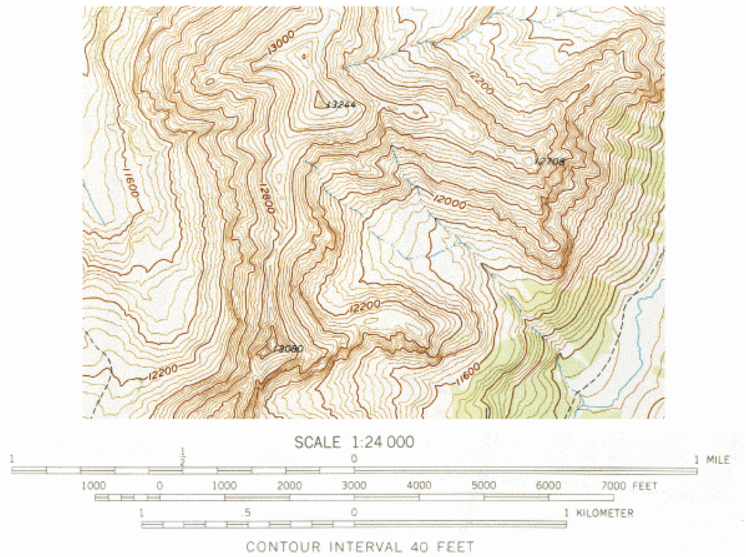

Figure 1.4: Typical contour plot