IDENTIFICATION OF DEVELOPABLE LAND USING TIN-BASED DIGITAL TERRAIN MODELLING

Alias Abdul-Rahman and **Ghazali Desa**
Department of Geoinformatics
Faculty of Surveying and Real Estate
Skudai, Johor Bahru, Johor,
MALAYSIA.
E-mail: alias@fu.utm.my

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ABSTRACT

Rapid physical development in most developing countries have created a number of problems to various related agencies. One of the problems is to identify the most suitable land for the development. This paper reports some preliminary results of research work using DTM for the identification. TIN data structure was selected to generate a DTM of a study area in Langkawi Island, Malaysia. The study shows that the identification of developable land can be achieved quite straight forward using TIN-based DTM and some overlay operation available in most GIS software.

KEY WORDS: DTM, TIN, Digitization, Land_Use.

INTRODUCTION

Rapid physical development in most developing countries have created a number of problems to various related agencies especially to the local authorities. Malaysia, still categorized as a developing nation, faces many problems in her effort to implement the developmental projects. One of the problems is to identify the most suitable land for physical development. This paper reports some preliminary results of a research works conducted for a local authority. Most local authority in Malaysia are still unaware of the potential of Digital Terrain Modelling (DTM) especially for the identification of developable land. In the project, Triangular Irregular Network (TIN)-based DTM was utilized. Map of land suitability are produced through the overlay function of GIS. This paper provides discussion on some of the prominent DTM data structures with a particular emphasis on TIN structure. Why TIN and not the other structure e.g. grid or random points DTM? One of the reasons is that the TIN structure offers more interesting features than the grid. For example, breaklines and important points can be easily accommodated. A combination of these points and breaklines with the original DTM data eventually produces more accurate and high fidelity earth surface representation. This paper also describes on the process of a generating the DTM and the land suitability identification. Finally, some results and discussion are provided.

DTM DATA STRUCTURES

DTM may be generated from various forms of data structure, among the prominent structures are: grid, contour, random, and triangular irregular network (TIN). A brief description of each data structure is provided for in this section.

Grid

It is the most simplest structure. The points were arranged in a uniform (regular) or irregular pattern. The square grid is the most common structure. The separation in x (i.e. easting) and y (i.e. northing) are usually at equal distance. Intersection points or grid points indicated with x, y, and z (height) coordinates. The z (height) coordinate could be a measured or an interpolated point. This structure has several advantages, for instance the neighboring point is implicitly defined, meaning, the location of a particular height is simply defined by its x and y position, i.e. the topology of the point is implicitly defined. The disadvantage of this structure is that it is not tailored to the terrain roughness. Traditionally, most of the DTM data were stored in this form, this is mainly due to the way they were originally captured.

Random

The points were distributed randomly. Data acquisition technique such as field surveying (total station), photogrammetry (random sampling) produces this kind of pattern. The problem with this pattern is that the topology of the points is not easy to defined.

Contour

This is another common way of storing DTM data. Points with equal height were depicted in one same line, i.e. known as a contour line. Contours are usually depicted on topographic maps. The contours normally converted to digital form by manual or automatic digitizing for further processings. Digital contours data is easy to handle and manipulate, for instance in DTM. Its easiness and simplicity to handle, made the data popular for DTM generation.

Triangular Irregular Network (TIN)

By definition a TIN is formed by a series of irregular triangles. Each triangle consists of three nodes, and each node has x, y, z coordinates. These nodes represent data points, and they are not interpolated (i.e. every point is utilized). For example, the nodes may come from measured random spot heights of field surveying, or they may come from selective photogrammetric sampling, or they may be the result of digitizing of contours, etc. A connection of any three 'proper' nodes forms a triangle, and if further connections are made to these data points, then a network called TIN is established. The word 'proper' in the preceding line, means a process of connecting the three nodes by a systematic triangulation algorithm, e.g. using Delaunay triangulation (Huber, 1995). The TIN data structure actually has been used for terrain representation for quite sometime, back to 1970's (Peucker et al, 1978). Now the structure is being utilized in quite a number of GIS and mapping software (Kumler, 1994). The structure has the following advantages:

- the size and shapes of the triangles varies according to terrain roughness (i.e. in flat surface, the size tend to be larger than in rougher terrain).
- ability to handle breaklines and specific points into the triangle network.
- 'saddle point problem' as in grid structure can be avoided.
- some of the computation tasks are easy to perform, e.g. slope and aspect calculation.

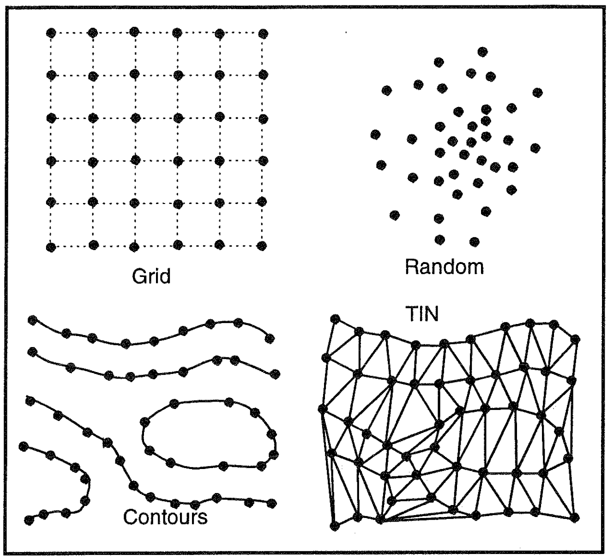

Figure 1 Some of the most prominent DTM data structures.

Besides the advantages offered by the TIN, it has some limitations, e.g. need more computer storage space to store the triangle nodes, triangle sides, and the topology information. In this aspect, the grid is much simpler and takes less space.

Since the structure (i.e. TIN) offers several advantages, thus we adopted it in an attempt to identify the most developable land.

TIN-based Applications

This section reviews some of the typical DTM applications, namely, contouring, and slope-aspect mapping.

Contouring. One of the common output of DTM is contour map. The contours may be generated in different ways, but in TIN it is appropriate to interpolate the contours using simple method (e.g. linear interpolation) then followed by line smoothing (Alias, 1992). The contour interval also play a role. Larger interval may represent course terrain, on the other hand, the smaller interval may effect the storage, interpolation speed, and producing touching contour lines in steep slopes. So the chosen interval should reflect what we are going to do with the contours. Generally, application which needs detailed information should go for smaller interval, whereas larger interval for the less detail.

Slope-Aspect Mapping. This is one of the basic elements for analyzing and visualizing terrain characteristics. This function is often included in a standard GIS software, e.g. ESRI's Arc/Info. The slope and aspect can be computed quite straight forward from TIN data. Each triangle has three nodes, normal vector of triangle can be calculated. Then the slope and aspect can be generated from directional angles of the normal vector (Alias, 1992).

STUDY AREA

The study area is Langkawi Island, situated in the north west of peninsular Malaysia. It is an island of undulated terrain. The study area cover an area of approximately 32,200 hectares. Two sheets of topographic map at scale of 1:25000 were used. Contour lines from this maps were captured by manual digitizing to form a digital contours. This is the main DTM data in the project. Other information such as road network, rivers, landuses, shorelines, reserved forest, tourist and residential areas were also extracted from the topographic maps and other available maps.

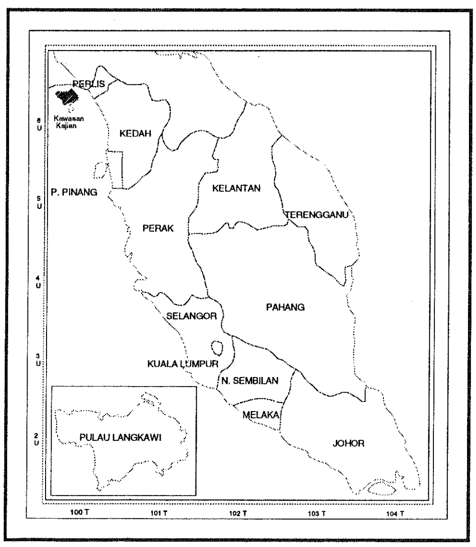

Figure 2 Location map of the study area.

METHOD

The goal of this project is to identify the most developable land for the selected area (see the study area). To achieve this goal, two main processes were carried out, namely, DTM generation, and the overlay operation. The overlay and buffering operation is done by using a standard GIS functions. The following development criteria were used for land identification.

- Built-up areas.
  Only the outside of this area is considered as developable land.

- Reserved forest areas.
  This is one of the protected area. Physical development is not allowed in this government reserved area.

- Existing historical, recreational (e.g. golf fields) and tourist areas.
  Only the outside of this area is considered developable.

- Any areas with surface slope < 20 degrees.
  Slope of the earth surface has been considered as one of the important restrictions in physical land development. This measure has been imposed by the housing authority. Building constructions on the slope surface is only allowed within this slope category.

This list of criteria is not comprehensive, but it's enough and meet our project's goal. The next section describes the two main processes in detail.

DTM Generation

Digital terrain models were generated from contours. The contours of 20 meter-interval were digitized from the existing topographic maps. A commercial DTM program, i.e. TIN Surface Modelling of Arc/Info software was used to generate the TIN-based DTM.

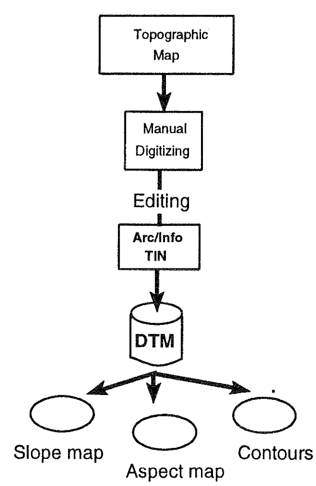

Figure 3 DTM generation flow

The entire study area has created 150,000 triangles and consumed about 50 MB storage space. The following figure shows the DTM generation process.

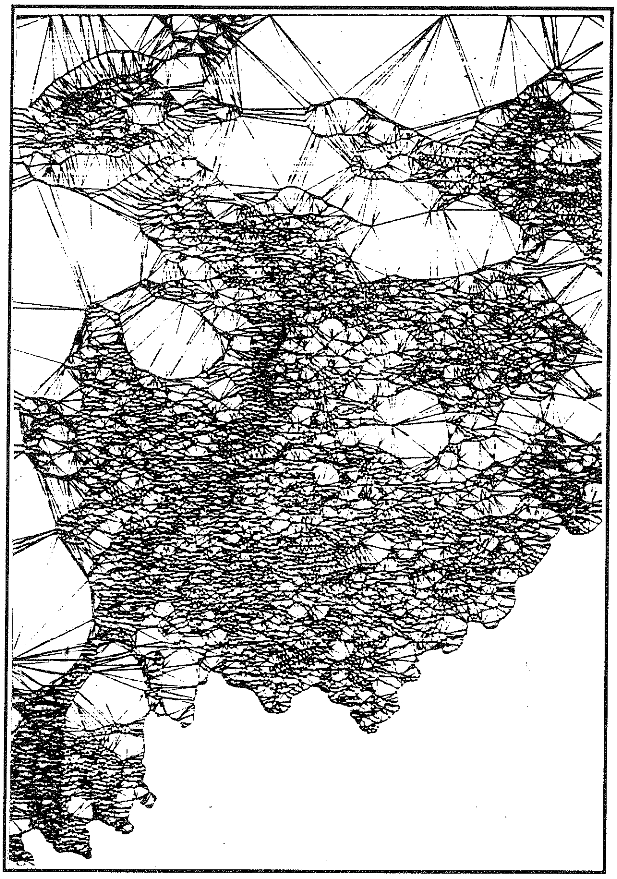

Figure 4 Part of the generated TINs for the study area.

Identification Process

The overlay and buffering functions were used to identify and map the developable land. The steps may be summarized as follows:

- Generate TIN-DTM for the entire area.
- Create slope map of < 20 degrees.
- Create coverage polygon of the selected slope area.
- Create coverage polygon of the selected criteria i.e. polygon of built-up area, polygon of reserved forest, and polygon of existing recreational and tourist areas.
- Perform the buffering for the areas based on selected criteria. Table below shows the buffering parameters.

Criteria layer	Buffer distance (m)
Built-up area	2000
Leisure area (e.g. golf field)	3000
Historical and tourist site	1000

- Perform the overlay operations using the generated polygons of the selected criteria to identify the land, see Figure 5.

RESULTS AND DISCUSSION

Figure 6 shows the map of a suitable land for development in the study area. The study shows that the identification of developable land can be achieved quite straight forward using TIN-based DTMs and some overlay operations. The criteria selected influenced the mapping of the developable land. In this project, based on the selected criteria, local authority can visualized the potential land for development.

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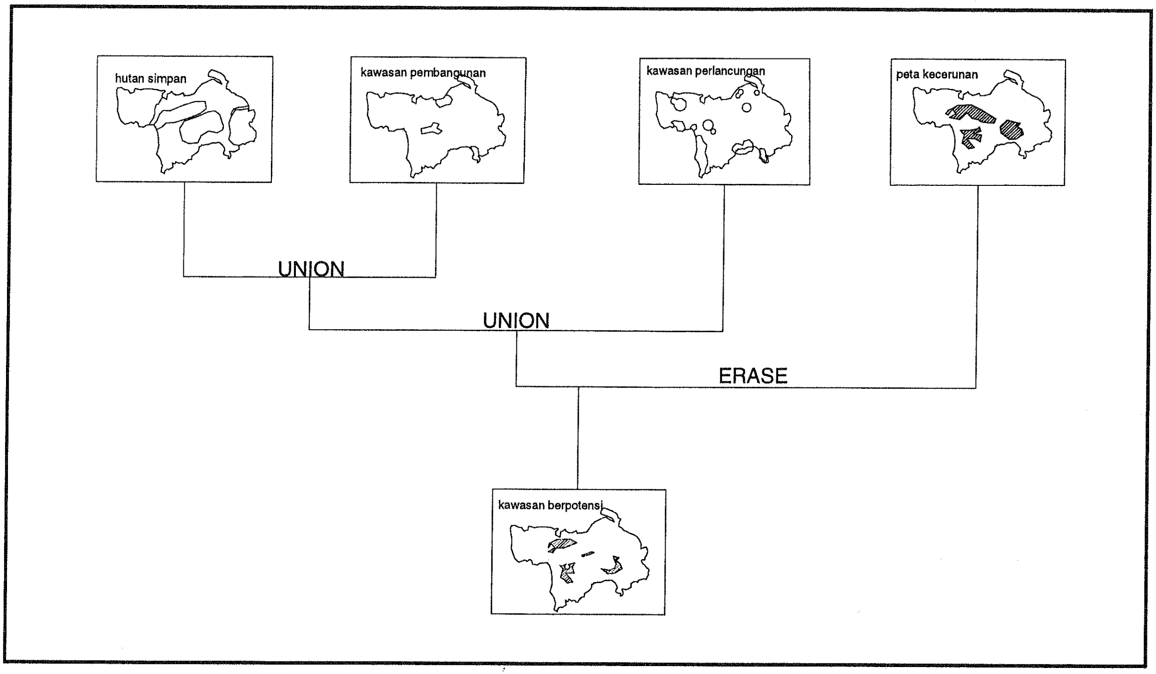

Figure 5 The mapping procedure of the developable land; top-row maps: "reserved forest area"; "built-up area", "existing recreational area", and "slope map" of < 20 degrees; bottom map: the map of developable land.

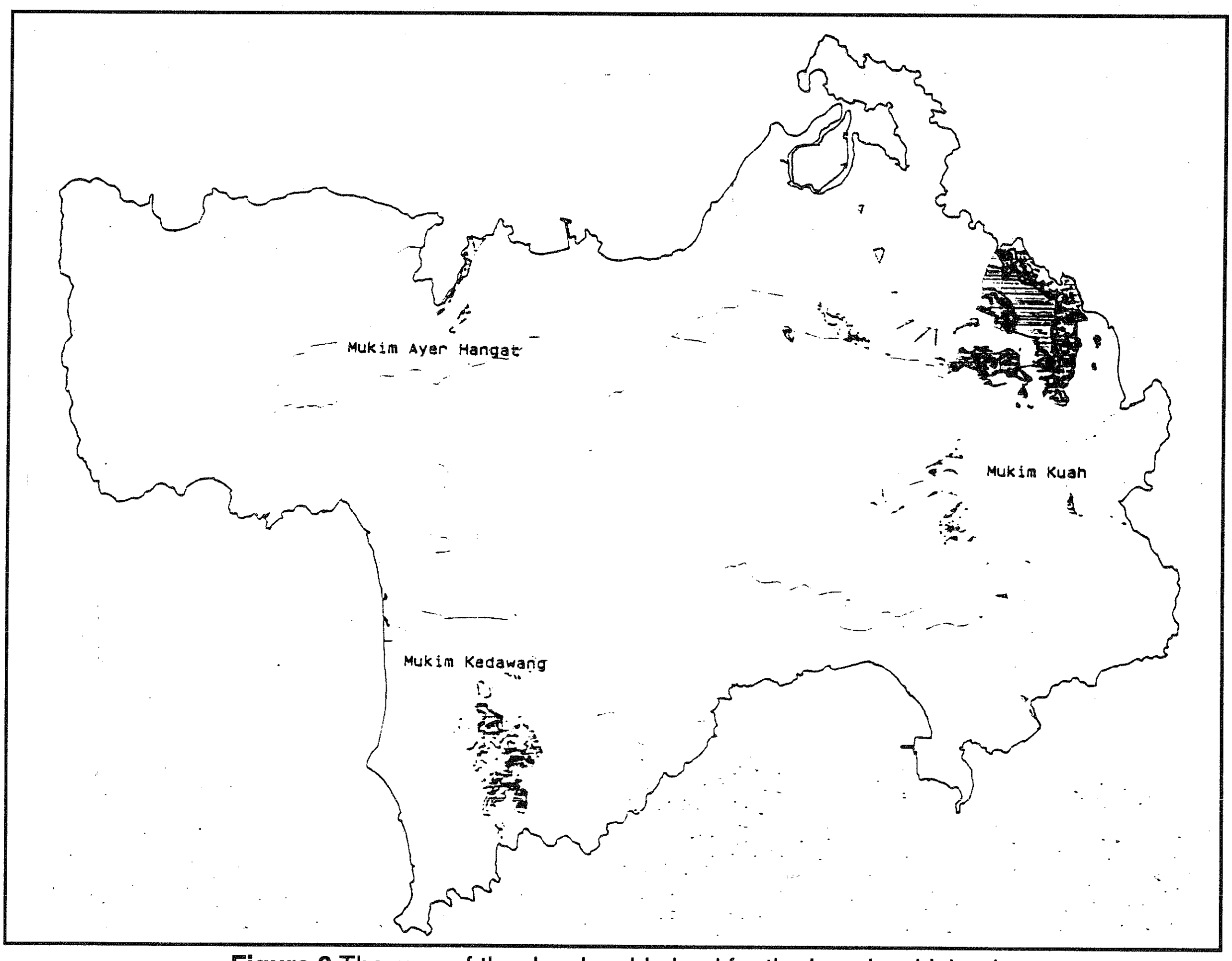

Figure 6 The map of the developable land for the Langkawi Island