Generating and Visual Representation of Heightmaps

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Literature Review

ABSTRACT

Determining the heights of trees from a heightmap is a useful tool for agricultural farmers. Tree estimation or extraction from a heightmap involves the removal of the ground plane values from height data of farmland to leave you with a heightmap containing height information for just the trees. This Literature review focuses on exploring various ways to generate heightmaps of tree farmland and the creation of synthetic heightmaps that can be used to test such a tree height extraction algorithm and determine its accuracy. We explore methods to create synthetic digital maps which are comparable to tree groves in their geographical features and in the distribution of trees. We also explore the creation of heightmaps from real world data captured from drones and satellites.

CCS CONCEPTS

• Computing methodologies → Computer Graphics, Modeling and simulation

KEYWORDS

Digital Elevation Model, GIS, Heightmap

1. Introduction

Manual collection of tree height data is a slow tedious process. Many farmers instead monitor their farmland with drones commonly referred to as UAVs (Unmanned Aerial Vehicle). drones can quickly and efficiently gather large amounts of imagery and GIS (Geographic Information System) data that is useful to farmers in analysis of their crops, time saving and helping improve the yield of their farms [1]. Knowing the heights of trees is an important factor in managing tree farmland. Tree height information can be used to monitor growth metrics, areas in danger of soil erosion and keep farms within possible greening regulations [2].

One of the most common forms of representing height information over a landscape is that of a heightmap or DEM (Digital Elevation Model). A heightmap is a discrete 2-dimensional grid of elevation values that can be viewed as a raster image.

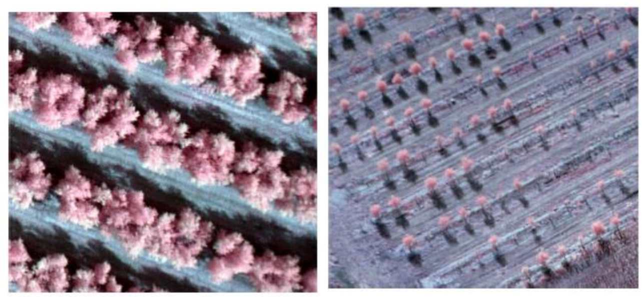

Fig. 1. UAV images of tree groves [2]

The goal of this research will be to develop image processing algorithms to accurately determine the heights of trees from such a heightmap without the ground plane interfering with tree height estimation, unfortunately the accuracy of these algorithms is difficult to determine without "ground truth" manual measurements of farmland trees and terrain imaged by the drone to generate the input heightmap.

This literature review explores methods for generating synthetic heightmaps for which the heights of trees are known, for testing purposes. These synthetic heightmaps can be processed by the extraction methods we develop to test the accuracy of our algorithms on well define ground truth data. We also review how heightmaps are generated from drone data and the impact on results of using heightmap data of different resolutions.

2. Background

Much of the research that has gone into height extraction algorithms from heightmaps has been focused on urban areas. Edge detection and ground plane removal can be used to find the heights of buildings where there is a significant difference between the ground and non-ground objects and you have clear visibility of the ground in the majority of the image [3].

Our topic differs in that we are trying to process an image of trees where it is difficult to tell whether height data represents a tree or ground and where large amounts of the ground are occluded by tree cover. Feature extraction of natural features such as this are difficult to do with image processing [4].

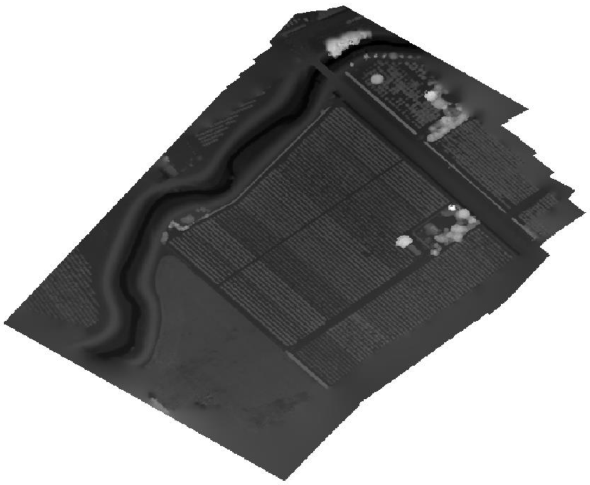

Fig. 2. Heightmap of tree farmland we will be using as our input data

Height maps contain information about the height data of a landscape. This means that you can use a heightmap to determine the heights of trees if you were able to subtract the height of the ground below them to leave you just the tree height. This brings up two important problems in the tree height extraction problem.

Firstly, determining whether a data point on the heightmap represents part of a tree or part of the ground plane. Edge detection has been explored on tree objects in images before [5], however seldom requiring as much accuracy as we require for a top down view.

Secondly the dilemma of interpolating the ground accurately for areas where the tree occludes the ground plane. For these reasons generated ground truth test heightmaps for the extraction algorithm would need to incorporate variations of realistic ground elevations for farmland as well as sufficient tree cover to simulate farmland groves.

3. Visual Representation of Heightmaps

To represent our test and input data visually is a vital component in determining whether our test data is appropriate to use with our algorithms. Visual representation can be used to compare the test data with realistic tree groves and show that the required dominant features are present.

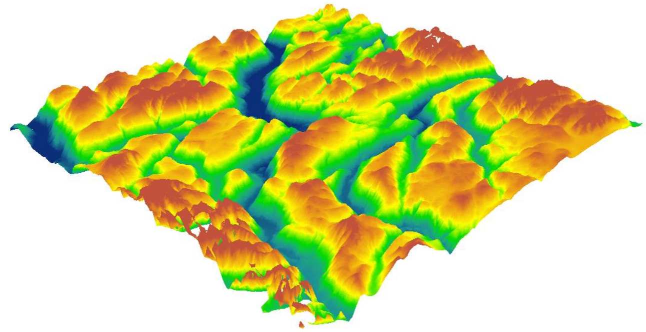

Fig. 3. Example of a DEM (Digital Elevation Model)

3.1 Digital Elevation Models

A digital elevation model or DEM is a 3D representation of a terrains surface which can be used to effectively visualize height data. Data can be recorded in different ways to produce a DEM. Comparisons have been done of three common methods for sourcing data to generate a DEM for the Narran Lakes Ecosystem in Australia [6]. The methods used were a nine-second DEM survey, a DGPS (Differential Global Positioning System) survey and a LiDAR (Light Detection and Ranging) survey.

The nine-second DEM survey was sourced from the GEODATA 9 Second Digital Elevation Model Version 3 which is a survey that is conducted over the whole of Australia to record landscape data. The data recorded in this survey makes up a model where each data point represents an approximate height elevation for a 9 second by 9 second area in longitude and latitude.

DGPS is the use of fixed, recorded positions to adjust GPS signals and make them more accurate.

LiDAR is a method for measuring distances and geographical data using a laser light being aimed at a point on the ground and the reflection of this light being measured by a sensor. LiDAR sensors use a wavelength in infrared making it difficult to measure landscape under water. For this reason, the LiDAR survey was supplemented with additional DGPS data for the parts of the landscape that were underwater.

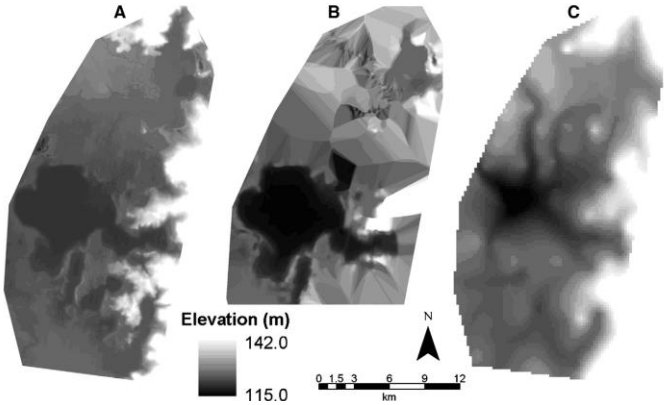

Fig. 4. Resultant DEMs (A) LiDAR, (B) DGPS, (C) 9 second-DEM[6]

The results from the study indicate LiDAR was much more accurate in generating high resolution DEMs with the DGPS and 9 second-DEM surveys resulting in a crude representation of the targeted Narran area. The LiDAR survey also was able to more accurately model the landscape's numerous large cracks in the soil. This means that slight changes in the landscape's ground plane were picked up by the LiDAR model and perhaps this would be a preferred method for sourcing our farmland input data.

InSAR (Interferometric Synthetic-Aperture Radar) can also be used to in record landscape data [7]. SAR is a technique where sophisticated processing of data recorded from radar is used to produce images of target areas. InSAR uses multiple of these SAR produced images in combination to produce DEMs that are highly accurate in resolution. Other advantages of InSAR include being able to record at night and through cloud cover. The results of this study indicated much higher resolution DEMs than LiDAR and DGPS at the expense of a larger amount of computer processing.

4.2 TIN surfaces

An alternative 3D representation of landscape data can be in the form of a Triangular Irregular Network (TIN). Used in GIS to represent the morphology of terrain surfaces. TIN models are less available than DEMS and more computationally expensive to build and process but can be used to model smaller areas with higher precision [8]. The model is made up of nodes for each point of input data recorded on a landscape. This way the model preserves the input data as the nodes are not interpolated. Edges connecting the nodes result in a surface of triangles.

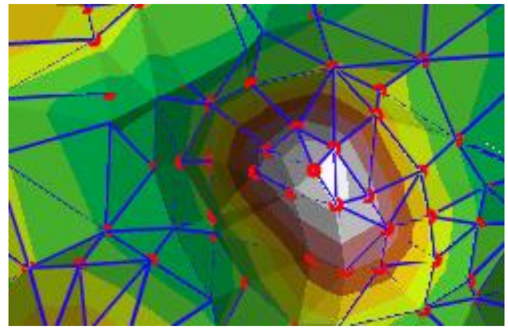

Fig. 5. Example of a TIN model

5 Generating Synthetic Maps

We explore different methods to create synthetic digital models representing our farmland. We research methods to create the ground terrain and then methods to create trees to add to the terrain.

5.1 Generating Landscapes

Creating realistic artificial landscapes can be done in various ways. Procedural methods such as fractal generation, physical simulation and example-based learning can be used to create realistic varying forms of landscape [9].

Fractal generation is the use of mathematical functions and recursion to generate shapes that are natural in appearance. Fractals offer complex patterns which can sometimes model realistically how vegetation grows and landscape is formed.

Physical simulation changes digital landscape data to be more realistic through graphics engines which model realistic physics concepts such as erosion. Such methods can be computationally expensive especially for large landscapes.

Example-based methods make use of existing terrain data to create new terrain data based upon certain requirements. An underlying structure may be specified such as a drawing of a landscape and using terrain example images the algorithms in example-based methods best match the dominant features such as hills and valleys with the drawing. For areas of the drawing with no dominant features the algorithms will generate insignificant data. DEMs can be used as example terrain data.

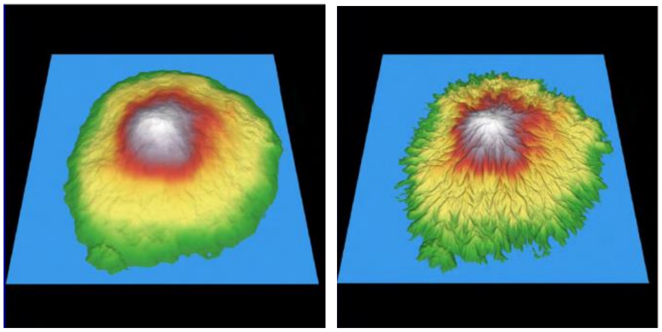

Fig. 6. Example effect of erosion simulation on a fractal-generated terrain [9]

Example-based synthesis methods are shown to be effective in creating mountainous landscapes [10]. a reference DEM is used as example terrain data and combined with an input drawing or 'sketch map' of the terrain as a specification. Example based methods can be adapted to handle small-scale synthesis by breaking up the sketch map into smaller sketches and looking for structural similarities in the example DEM.

Such methods are effective for large mountainous landscapes but can also simulate smaller and more detailed hills and valleys. This may prove an effective method for generating DEMs for our farmland terrain which is small scale and requires fewer extreme changes in height. DEMs captured from these methods need interpolation to fill in areas where no data was captured, the amount of which changes with the resolution of the images captured. Drastic changes in height of the landscape affect the resultant image negatively [11].

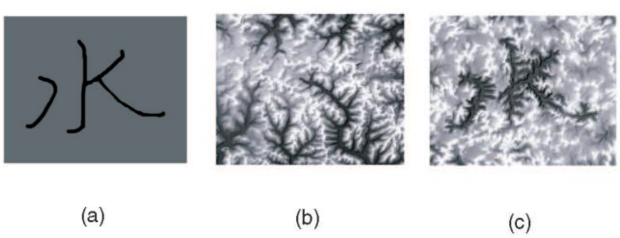

Fig. 7. (a) input sketch drawing (b) DEM example terrain (c) output DEM terrain [10]

5.2 Generating Trees in Heightmaps

Trees can be imposed upon our synthetic heightmaps, but the positioning, shape and size of the trees is important in order to mimic the groves in our farmland heightmaps. It is not necessary however to model a full realistic tree, but just the tree canopy as this is the view that our Drone Imagery gives us and is what is important to us in determing where the ground and trees are. Research has been done on the design of full digital trees and the modelling of vegetation onto landscape [12]. Topographical features such as elevation and slope of the land have been used as factors altering the distribution and density of trees drawn onto landscape. Generation of trees and bushes using fractals and mathematical functions can be done as well.

L-systems, another procedural based method, can be used in the modelling of forest or tree models. Lindenmayer systems or L-systems provide a modelling technique that can be used to create geometric shapes or strings using a collection of production rules and an alphabet of symbols or shapes. L-systems can efficiently be done in parallel [13] and were specifically designed by Aristid Lindenmayer to simulate natural growth, specifically the development of bacteria. There are methods to improve the efficiency of the L-system and reduce the memory overhead of the algorithms involved [14], however this method still proves too expensive and overly complex for what is required of our trees and will not be explored.

Our digital trees could also be made manually by simply choosing appropriate values as tree heights or drawing tree objects and adding these to the grid values of an existing heightmap.

5.3 Accessing Existing GIS data

Various websites provide a rich source of data for Height maps and GIS data that could be used. Such sources could provide data that we could use as a reference to make realistic height maps for our testing or to test our extraction algorithm directly. USGS (United States Geological Survey) [15] provides scientific data related to geological mapping and could be a source of DEMs. The ALOS Global Digital Surface Model [16] is a data set captured by the ALOS satellite using an optical sensor. The ALOS data set has been used for ecological surveys including estimating canopy heights and the decline of forests [17].

6. Discussion

It is evident that the topic of our research has not been so widely researched. Few researchers find reason to create synthetic heightmaps as there is much data readily available from online GIS sources. Many of the articles on height extraction from a heightmap or DEM are more focused on urban areas where the objects in the image have clear bounds and few objects occlude others, however the topics that surround our research have been widely researched in the field of GIS.

DEMs provide a common visual representation of digital terrains. On a smaller scale, objects such as trees can be viewed as part of the landscape and be incorporated into DEMs which suits our purposes. DEMs are typically created from techniques using real world measuring and imaging, but synthetic DEMs can be created which appropriately simulate a tree grove to test our tree height extraction algorithms.

There are methods that can be used to draw heightmaps such as procedural methods which can create random but realistic 3D maps. These are more complex but will be quicker to produce a large volume of test images. Research into the design of digital trees can give us ideas on how to design tree canopies using fractals and mathematical functions. We can also manually create data representing our trees and superimpose this on our heightmaps. Adding trees to our synthetic landscapes could be done by manually superimposing tree objects on an existing DEM or another synthetically created one. This manual method would be simpler but more time consuming to create large volumes of test images. This manual data representing a tree object can be made through simply drawing or writing appropriate values to the grid of elevation data in our heightmaps multiple times to create a tree canopy.

Table 1: Feature requirements for our test DEMs

Surface Texture	Smooth
Tree density	Ranging from thick to sparse
Slope angle	Gentle
Ground visibility	Ranging from low to High
Natural Realism	Ranging from simple geometric shapes to Realistic tree canopy shapes
Variability of objects imposed on ground plane	Only one type of tree per image

The requirements in the design of our synthetic test DEMs are dictated by the focus area of the study. Our focus is on tree farmland which results in neat and uniform groves of trees on hilly areas. Trees in our input data will have a range of density so ground will not always be visible. We will need test DEMs which incorporate simple geometric shapes to represent trees to test the ground interpolation as well as more natural realistic canopy shapes to test our ground detection algorithms. The required landscape will be relatively simple so this must be considered when generating the ground terrain.

7. Conclusions

In handling our creation of an ideal ground plane to test on we will be using a simple manual method for creating heightmaps as well as sourcing existing DEMs on hill landscapes and terrain. TIN surfaces will not be considered as they are typically used for complex variations in the landscape which is not required for our focus. For the purposes of this research it will not be necessary to use such complex methods such as procedural generation of terrain as our topic focuses on simple tree farmland landscapes which are relatively small sized areas with only sleight changes in ground height. To generate our trees, we require simple height changes to represent the trees and a sufficient canopy radius as the focus is on the ground plane below them. Therefore, we will not need complex tree modelling and trees can simply be manually designed for ground heightmaps and duplicated across them.

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