Section views from 3D laser-scanned buildings Project Proposal

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CCS CONCEPTS

• **Computing methodologies → Mesh models**.

KEYWORDS

mesh models, feature extraction, slicing, voxels

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1 PROJECT DESCRIPTION

Modelling structures is a very difficult task, and modelling them effectively is a lot more difficult. Before the emergence of computer CAD software, engineers and architects had been limited to drawing/communicating visually on 2D surfaces which required a great deal of time and effort. With the improvement of technology, they are now able to scan models in 3D using devices such as laser scanners. These devices are capable of collecting millions of data points in a matter of seconds, with considerable accuracy. These 3D models must still be interpreted, depending on the context. The Zamani project [15] is a group that collects 3D data of structures that are mostly historical landmarks across Afro-Eurasia using laser scanners. The scanned structures can be thousands of years old and they have deteriorated from their original form, leading to very rough surfaces which may be difficult to analyse. These 3D models can be represented in several ways, but most commonly are either 3D meshes or 3D point clouds. 3D meshes are usually in the form of interconnected triangles — as a primitive polygon — through vertices, where as 3D point clouds are sets of points in Cartesian space . Both of these data representation methods are from 3D scanners. 3D point clouds [6] are very fast to create using scanners with great accuracy ,but surface information is lost for rendering processes and 3D point clouds are very difficult to convert into 3D meshes. The focus in this project will be on 3D meshes.

The objective in this project is to model section views, elevations and ground plans [7] from the 3D meshes provided by The Zamani group. Section views, elevations and ground plans are images drawn by architects to represent dwellings, buildings and other structures in CAD systems in the form of blueprints. Section views depict what one is supposed to see when cutting away (vertically in this case) a 3D object to show what's inside, such as representing a basin when cutting into a bathroom. Elevation depicts what we see from outside of a 3D structure like the front view of a house. And ground plans depict when we cut away horizontally and throw away the top section, such as showing the structure of the walls in a house.

The methods of which this is done is by slicing 3D mesh models [11] and feature extraction [20]. The types of images we are attempting to extract from the 3D mesh look like figure 1. The Colosseum [3] is multiple storeys so the image represents four different storey in the ground plan where assumed symmetry is applied. This image only shows an ideal version but what is expected is very rough and noisy images to be produced i.e. the Colosseum has deteriorated a lot over the year so it would not look like this image currently . Using such images, we will be able to present these structures to a greater audience in an easier format to comprehend than 3D meshes. In the case of The Zamani Project, they will be able to preserve the necessary heritage sites and document them for future usage as some structures tend to deteriorate into almost nothing over time.

2 PROBLEM STATEMENT

Extensive amounts of research have been done on 2D model from 3D mesh sequences, but most of it is based on mathematically ideal 3D model with close to no noise. In this project, we were asked by The Zamani Project to find a way of producing robust and accurate feature extraction and 3D sliding methods for the data they collect from the heritage site. The majority of the literature does not deal with feature extraction and 3D slicing together, and does not deal with models that are as complex as these structures. The literature separates it into feature extraction and 3D slicing. We are required to create a tool that will take in ply formats as input and produce an output in TIFF format of elevations, sections and other views of the heritage sites.

Just to clarify, the aims of the project are:

(1) Implement a method feature extraction from 3D mesh models.
(2) Implement a method of slicing 3D mesh model into various views.

The aims of the project revolve around being able to accurately produce 2D models and the following research questions formed:

- Will the literature be not too abstract that we'll get a fair amount of knowledge to be able complete the project?

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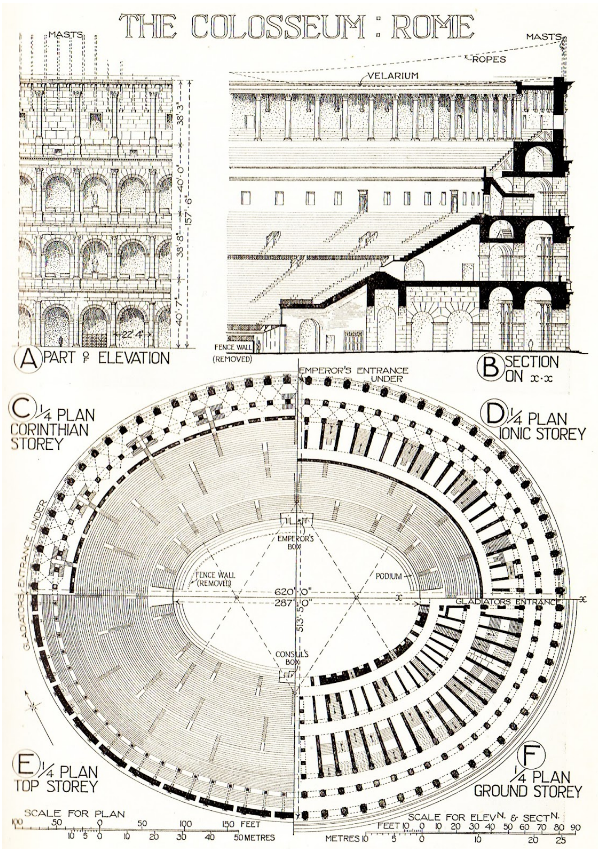

Figure 1: Condensed Architectural drawings of The Colosseum

- Are there 3D mesh processing library that will be able handle the expected noise?
- Since we are working with large data sizes, will processing them be fast enough for The Zamani Project?

3 RELATED WORK

In this section we looks at various methods proposed by researchers for feature extraction and 3D slicing.

3.1 Feature Extraction Methods

The rapid growth of the 3D model industry has led to a demand for various techniques to analyse models. One method developed is feature extraction which has played an important role in the development of other methods such as non photo-realistic rendering [2], mesh re-meshing[1] and surface segmentation[16]. Algorithm which use first and second derivatives have been developed expanding from their 2D counter parts.These methods using first and second derivatives[4, 12] are affected by noise in models hence produce substandard results on noisy inputs. Higher order derivatives are calculated using either surface fitting methods[12] or local estimation methods [4, 17].

Meidoniet al [18]proposed the tensor voting algorithms to tackle the problem of poor extraction on noisy models. The method executes in two passes with one pass to infer normal and the second to extract surfaces and curves. Kim et al [9] and Page et al [14] go further to improve the method and show that the method is robust to noisy models and that they can handle sharp edges. Further research has been done with Wang et al [23] proposing a hybrid approach which uses normal tensor voting in the first pass to detect edges and refinement of the edges to extract real features by using a salient measure algorithm. The image shown in 4 showing the results from the algorithm proposed by Wang et al.

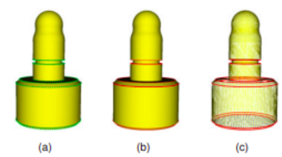

Figure 2: Detected feature lines [23]

3.2 3D slicing Methods

The methods that have attempted have been strongly centred around the use of rapid slicing [8] and additive manufacturing [19]. These are under the umbrella of multiple slicing planes. They are very effective when dealing with creating moulds for products like car parts. A lot of the literature has to be look at a theoretical approach since the consider very abstract cases. These methods are widely used for 3D printing as the printer can only work layer by layer to produce.

The usage of voxel is also very applicable, make it very easy when slice as they would appear similar to how picture look when they are made of pixels. They carry a lot of their strain from storing them with their assigned attributes. A lot of voxels would be needed to accurately represents a structure like the Mesoamerican pyramids [13] due to their sheer size.

They have not been applied to the scale of structures such as the Sistine Chapel or the Kaaba in Mecca. This is the attempt of this project, applying these methods in a great scale.

4 METHODOLOGY AND PROCEDURES

In this section we are going to analyse the proposed methodology to be used in tackling the various aspects of the project. The figure 3 shows the structure of the system. A Bottom-up approach is illustrated with the first stage being reading the input and preprocessing the output such as cleaning or reducing noise. Then the project is separated into two aspects feature extraction and 3D slicing .

4.1 Data Acquisition

The 3D models required for the project will be provided through the Zamani database[15] of heritage sites. These are used as input for the final system and can be edited to increase various aspects or decrease various aspects of the model. A contingency plan was made to use models from the internet in the case that the team is not

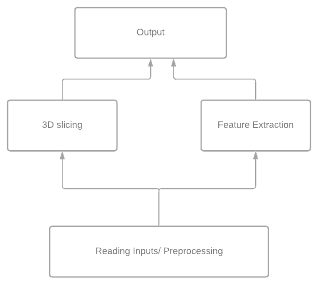

Figure 3: The structure of the proposed system.

able to access the Zamani project database. This data acquisition process applies to both feature extraction and 3D slicing.

4.2 Reading 3D Models

Before applying feature extraction or 3D slicing the 3D models need to be read into memory for further processing. Many methods to read in 3D meshes have been proposed however in this research we are going to use existing libraries. The proposed library is mesh lab [5] which has feature to clean the read data and can be used for pre - processing of the model.

4.3 Feature Extraction

As shown in section 3.1 various methods have been explored by researchers which perform well with different inputs depending on the noise. 3D models from scanned models generally have noise hence the need for a method that is robust. This project will implement a tensor voting system proposed by Wang et al[22]. The method avoids pre-processing of the 3D models which changes the surfaces. This method proved to be best for the project considering the input and compared to other methods explored it was best suited . In the first phase the lines are detected using the tensor voting algorithm[23]. If required results are produced ,the second phase will enhance the quality of the results by using the neighbor supporting algorithm proposed by Wang et al[23]. To accelerate the execution of the project built libraries such as Mesh lab [5] will be used in building the solution.

4.4 3D slicing

The methods that are used for 3D slicing vary from the literature. The most applicable one is the multiple slicing planes technique. This method is the most used for slicing 3D. The main reason for choosing this method is it has multiple algorithms that it has been implementing throughout time. It has been optimised to a great degree for efficiency and accuracy. This method is a lot less computationally expensive compared to voxelization [21] and the data storage is a lot less complicated. With voxel storage amount is highly dependent of the size of the voxels. Now, the algorithms vary from the Sweep Plane[10], Triangle Grouping [19] and others for multiple slicing planes. Another problems this partially solved by this method is being able to retrieve data past the slicing plane. Some form of superposition between the slicing planes is required where planes further than the original slice plane are carefully layered on the original plane to provide more detail.

An expected challenge in implementing this method is finding data processing libraries that will be simple enough to be able to manipulate the data. Some form of interface will be required for the Zamani Project to use this tool.

The testing priority for this method is to use black box testing so the Zamani Project can easily test can also validate with past data that has achieved the desired result.

5 ETHICAL, PROFESSIONAL AND LEGAL ISSUES

The ethical issues that come with the project is that the candidates of the project will need external support from the supervisors, the Zamani project and Patrick Marais. The candidates of this project have limited experience in working with these kinds of drawings. There is need for external users to test the system results. Users have different perceptions on the relevance of the elevations and features hence there is need for experts in the field such as Architects or Civil engineers however if available members from the Zamani project may fulfil that role. The system to be developed will not have imparts on its users as it only provides insights.

The application for ethical clearance in this project must be submitted by the due date in the deliverables (section 7.4). This application is done through the faculty department. It must clearly outline what aspects of the project require the clearance such as external contributors for what elements of the project.

The legal aspect of the project is were going to be using resources that are publicly available. The libraries utilised will be open source. And when the project is completed, is anyone has an interest in the results of the project will make the source code open source unless the university has a valid reason to contest this. Any

6 EXPECTED OUTCOMES

This section outlines what results are anticipated from the project.

6.1 System

The software would be able to take in data in ply format, process and manipulate it for the required feature lines and views, and then output a TIFF format as results. This system would be encapsulates in an interface for easy usability for the users.

6.2 Key success indicators

The main indicator of success is the production of feature lines and, desired section views, elevations and ground plans from 3D Meshes. In addition to the aforementioned the system should produce results that are meaningful that the intended users which is the Zamani project can infer insights from. Another success indicator is the project is carried out in the required time without any major delays in submitting the deliverables.

6.3 Impact

The project would allow for a very easy conversion from 3D mesh model to the desired images in a very quicker manner than traditionally having and engineer or architect drawing the required images. It somewhat automates this process of conversion. The methods explored by this project have not been thoroughly tested in sites such as degraded heritage sites hence the paper will explore and test the robustness of the tensor voting Algorithms [23] and the multiple slicing planes technique.

7 PROJECT PLAN

7.1 Timeline

' The project will run over a space of 3 months with all the milestones and goals illustrated in the gantt chart in the appendix.

7.2 Risk and Strategies

The Risk matrix is at the end of the document in the Appendix

7.3 Resources required

In order to tackle the research there is need for Python libraries developed by expects that executes aspects of the project such as reading in meshes and processing them. After developing the code data from the Zamani Project is required in order to test if the output is expected.

7.4 Milestones

The major milestones of the project are illustrated in the table below.

ID	Milestones	Due Date
1	Handing in Literature review	04 Jun 2021
2	Handing in Project Proposal	24 Jun 2021
3	Final code submission	08 October 2021
4	Design Web Page/Poster	18 October 2021

7.5 Deliverables

The deliverables for the research and their due dates are listed in the table below.

ID	Deliverable	Due Date
1	Literature review	04 Jun 2021
2	Project Proposal	24 Jun 2021
3	Ethics application	12 July 2021
4	Presentation	9 July 2021
5	Initial Software feasibility demonstration	13 August 2021
6	Complete draft of paper	6 September 2021
7	Final project paper submission	17 September 2021
8	Final code submission	08 October 2021
9	Poster due	11 October 2021
10	Web Page	18 October 2021

8 WORK ALLOCATION

The deliverables such as the final paper and web-page will be handles but both team members. This include the pre-processing and reading of input of the code. After pre-processing the project separates in to two sub-projects with the 3D slicing part of the project being tackled by Sizwe and the feature extraction by Claudious.

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Appendix

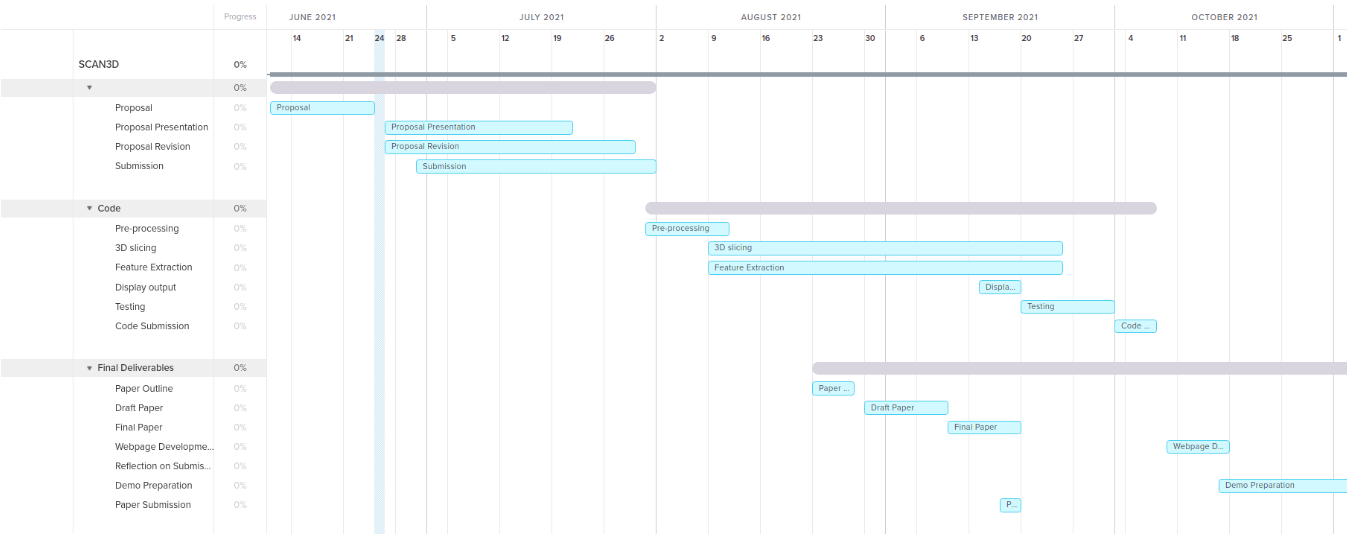

Figure 4: Gantt Chart

Risk	Probability	Impact	Mitigation
Delay or not ability to retrieve data from the Zamani Project	Medium	High	Find alternative sources of data to test the project while still trying to contact Zamani for input.
Memory issues because we are working with large data sets	Medium	High	try solving smaller segment of the project then join them at the end.
Scope creep by trying to optimise the algorithms or even implement one from scratch	Low	Medium	Do not deviate too much from what's required. Regular progress check ins with the supervisor.
The loss of source code from disasters such a computer crashes	Low	High	Keep backing up the source code in various forms such as Github.

Table 1: Risk Matrix