

# Fast semi-automated point cloud cleaning

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## 1 Introduction

The Zamani Project is an initiative aimed towards digitally preserving cultural heritage sites in Africa. This goal is achieved by visiting culturally significant sites and documenting their spatial domain. The end result are highly accurate 3D models of documented sites.

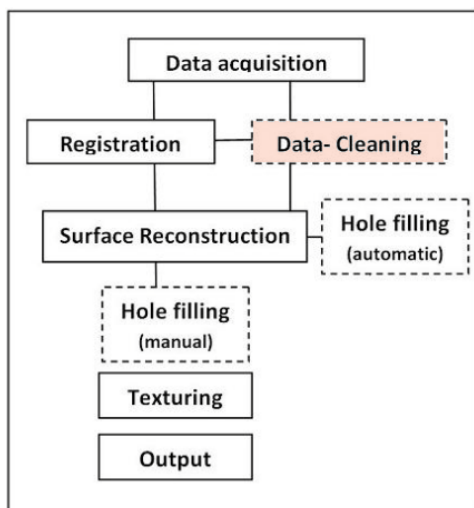


Figure 1: Processing pipeline [6]

The 3D models that are produced is the product of a processing pipeline that starts with data acquisition (see Figure 1) [6]. Laser range scanners and optical cameras are used to capture the spatial domain. Following this, the point clouds acquired need to be cleaned and registered onto one coordinate space. Cleaning can be performed before or after registra-

tion. The surface reconstruction step triangulates the point cloud and produces a geometric model. Missing data or holes can be automatically filled during this step or manually afterwards. Finally, site photography is used to texture the model.

The focus of this project is on the cleaning step of this pipeline. Cleaning involves the removal of unwanted noise from point clouds. Noise can be classified into three categories. Static noise, dynamic noise and instrument noise. Static noise are unwanted objects that do not move. Examples can include vegetation, cars and equipment. Dynamic noise are unwanted objects, such as birds or people, that move through the scan. Instrument noise occurs when part of laser beam hits a near objects and part of it hits a far object. The result is that the average distance of the two objects is recorded.

A typical scan may take an experienced person anywhere between 30 minutes to 2 hours to clean. Given that one requires 500 - 1000 scans to cover a typical heritage site, this stage of the processing pipeline takes a considerable amount of time [6].

In the Zamani project, vegetation is considered to be the most problematic type of noise. The objective of this project is to develop a system to accelerate the removal of vegetation from point clouds.

In the next section shortcomings in existing systems and a overview of related work. The subsequent section will outline the project aims after which research questions will be formulated. Research methods will then be discussed. Finally the project timeline will be presented.

## 2 Background

Point cloud cleaning implies the classification and grouping of point corresponding to noise. This classification can be performed manually by the user or it can be fully automated. In between these two extremes there are semi automated methods that let the user automatically segment local features. Automated approaches can save time but can compromise accuracy.

In the cultural heritage domain there is a strong emphasis on preserving detail. Every point is considered valuable information. It is thus very important that noise is accurately classified.

### 2.1 Existing systems

Manual segmentation tools allow users to to achieve the highest degree of accuracy. Lasso selection is one such tool that is available in a number of commercial packages. [3, 2, 9]. It allows the user to draw a two dimensional polygon around points displayed on screen. Unfortunately, hidden points behind the intended selection may be removed accidentally. Therefore, it may be tedious to use when noise is not easily isolated. Despite this issue, it is currently the primary point cloud cleaning method used by members of the Zamani project. Three dimensional selection brushes can give a user more control over which points are removed [3]. They are however still highly manual and time consuming.

Somewhat more intelligent cleaning can be achieved with different families of fill tools. Fill tools recursively add neighbouring points to a selection based on various metrics such as distance or intensity [3]. Automatically achieving the correct selection is unlikely, therefore systems may allow one to edit a selection before removing points [3].

For most industrial applications, once the necessary features in a point cloud have been identified, the level of detail is reduced by creating CAD models. The majority of point cloud editing packages cater for such applications. Segmentation tools from such packages may thus exhibit some inaccuracies that may lead to valid points being discarded which is unacceptable when working with heritage data.

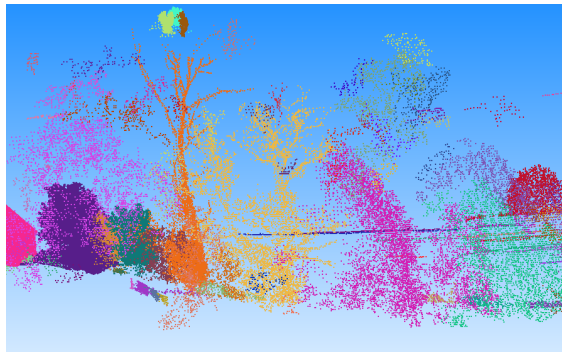


Figure 2: Distance clustering [9]

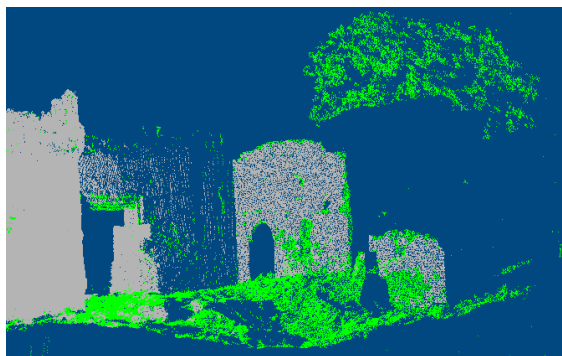


Figure 3: Automated segmentation of vegetation [11]

Global segmentation or classification schemes can remove a lot of the effort associated with point cloud cleaning. In 3DReshaper [9], a point clustering approach is used to isolate distinct objects based on the distance between neighbouring points. However, because the point density of a laser scan usually decreases as points fall away from the scanner, this approach tends to produce large clusters close to the origin, and many small groups of clusters further away. Automated classification schemes take higher dimensional features into account in order to identify clusters corresponding to ground points, vegetation and buildings [10, 11, 1]. While this may be of great for land surveyors or architects, such fully automated methods tend to lack the precision required for cultural heritage purposes.

There is certainly room to reduce the amount of

Package name	Segmentation feature			Open source
	Simple	Intelligent	Auto	
Terrascan [10]			ground points, vegetation, buildings	✗
Pointools Edit [3]	lasso select rectangle select, ball/cube brush select	fill select with distance threshold, fill with colour or intensity similarity, plane select		✗
VR Mesh Studio [11]		power lines	ground, vegetation, roofs, planes	✗
Carlson PointCloud [1]			clear isolated and duplicate points, extract bare earth	✗
3D Reshaper [9]	lasso select		clustering with distance metric, clustering colours, remove isolated points	✗
Cyclone [2]	lasso select	fill with smoothness similarity		✗
Meshlab [12]	plane select, single point select		isolated point removal	✓

Table 1: Existing systems

productivity one has to sacrifice for precision, especially in open source tools. Meshlab [12], is currently the only known open source system that provides point cloud cleaning features. It is primarily aimed at processing triangulated meshes and therefore lacks some raw point cloud cleaning features. The recently introduced point editing features, such as point picking and plane selection, performs somewhat sluggish on larger point clouds, and are not very efficient.

## 2.2 Related work

Automated point cloud segmentation is not a new problem. There is however, very little available research related to the segmentation of cultural heritage data. Some success has been achieved in automatically segmenting sites into surfaces and edges through the use of Principle Component Analysis [8]. What makes the segmentation of heritage data hard, is that scanned structures can exhibit very complex geometries that is hard to classify [8].

A variety of point feature schemes that are used extensively in robotics, could potentially be exploited in the cultural heritage domain. A number of popular point feature algorithms have been implemented and is freely available in the Point Cloud Library [4]. These include Fast Point Feature Histograms, Spin images, Global Fast Point Feature Histogram [4].

Classification can be achieved by though either heuristic schemes [8] or probabilistic models [7, 5]. Approaches based on machine learning have been shown to be effective.

## 3 Research question

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## 4 Aims (expand)

Why am I doing it?

Inputs, outputs How many points How large do point set become we only deal with small point sets

In collaboration with geomatics

The aim of this research is to produce a system that will allow users to clean cultural heritage data in a

fast and effective manner. The focus will be on finding ways to remove the most problematic artefacts as identified by the Zamani project. In descending order of importance, the focus will thus be on removing vegetation, people, and equipment.

Existing point feature schemes will be investigated, as well as heuristic and machine learning approaches to segmentation. In order to ensure fast response times, cleaning methods will be accelerated with OpenCL.

## 5 Evaluation

Overall:

Performance metrics Total time taken to clean Given cleaning objectives Measure accuracy Perform diff against benchmark scan Compare old vs new Prior training to account for practice effects of leica point cloud Time performance

Each tool Interview : Expert user opinion Sufficient accuracy Confidence information

Remember to try clean out points in scan 1 that was already clean in scan 2.

What about pairwise registration and scanning framework?

Quantitative study (Expert users) Geomatics students Should be experienced

The system will be evaluated in a user study. The speed and accuracy of the existing system will be compared to Zamani's current system [2]. Interviews will also be conducted to assess the usability of the system.

### 5.1 Milestones

Task	Due date
Research Proposal	May 2012
Background Chapter	October 2012
Technical Report	November 2012
System Design Chapter	December 2012
Implementation Chapter	March 2013
Conference Paper	June 2013
First Thesis Draft	July 2013
Final Draft	August 2013

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