# CREATING AND USING MASK IMAGES FOR SEGMENTATION IN POINT CLOUD DATA

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**ABSTRACT:**

The task of preparing the training data for machine learning is tedious but crucial for accurate results. Aiming at labelling meaningful features semi-automatically rather than manually in order to reduce time, we hereby present initial results for two cases of 13th century Seljuk brick-ornamentation. As our broader research involves machine learning methods for the segmentation of digital survey data for creating meaningful three-dimensional models, the primary goal here is to determine the parts of the patterns from the whole composition and to use this data for different buildings of the genre. Prior to any machine learning, labelling the data of either a whole pattern or pieces of a pattern is a time-consuming task prone to errors. We propose a semi-automated mask generating model for labelling. In order to create the black and white mask images of the original photographs, we utilise the colour difference between the pattern parts. Examined samples have at least three visually distinguishable colours that are turquoise, black and natural. We use photogrammetry-based survey data and image processing to create attributed point clouds and eventually 3D digital models. Using the ready batch processing of a commercial software, we create a distinct mask and apply it to all images of the photogrammetry process. Point cloud data is then created with RAW images, and the generated masks are used to filter desired patterns. As such, we are able to easily label the bricks in the point cloud towards a machine learning training set.

## 1. INTRODUCTION

Seeking efficient ways to segment architectural heritage survey data for meaningful digital models, we focus on filtering certain features of the real-world data acquired by photogrammetry and detecting patterns on historic brick walls.

Brick has been one of the leading construction and ornamental elements in architecture, and one historical example is Seljuk monumental architecture with unique glazed-ceramic and brick ornamental patterns on both interior and exterior surfaces (Hill and Grabar, 1967, Bakırer, 1980). Our sample set includes two interior cases from Sırçalı and İnce Minareli Madrasas in Konya, Turkey. In order to better understand the design and construction of these, and to build reliable digital models for reconstruction and conservation purposes, documenting and creating an inventory of this heritage in all states of ageing and possible variations is essential.

Photogrammetry and laser scanning are the most common modern tools used for documenting architectural elements rapidly, cost-efficiently, and with a reasonable accuracy level (Huang, You, 2016). Detecting brick shapes from the point cloud data of masonry walls have precedence in literature (Shen, et al., 2019, Sithole, 2008). In our study, we focus on the earlier step of preparing for shape detection by pre-processing the photogrammetric point cloud data. We generate mask images using original photographs to filter the brick units that make up the patterns. In subsequent research that is beyond the scope of this paper, we use the filtered point cloud data in a deep neural network training set known as Dynamic Graph Convolution Neural Network (DGCNN) (Wang et al., 2019) which is based on the Dynamic Graph CNN, a general neural network architecture designed to treat directed graphs with vertex labels containing complex information (Phan et al., 2018). Machine learning helps with the fast and accurate processing of survey data as required in heritage documentation (Nguyen, Le, 2013). For analysis and segmentation, it is necessary to first create a suitable point cloud from the images obtained on-site, and our work realises this by conceiving mask images from the photographs and forming the point cloud with these filtered images.

Some effective masks in image processing consist of the shades of black, white and grey to represent the visibility of the pixels (Heilmann, 2021). We employ a similar principle. Black represents the non-visible pixels, and white represents the visible pixels. To match with these corresponding shades, there are a few variables in the bricklaying process: brick units, mortar, and the colour of the brick units. In most cases, the mortar colour is visually distinguishable from that of the brick units in Seljuk ornaments (Figure 3). We select the same colour bricks and shade them as white while shading the other areas black. Grey is unnecessary in this process because photogrammetry software does not recognize any value between black and white while selecting. We use the colour differences to generate the black and white masks to prepare the training data.

With the proposed workflow, the process of filtering the patterns is easier and reduces the efforts for further data gathering. Filtered patterns are intended for use in machine learning to identify the shapes that make up the patterns and, in turn, their relations and generative rules in our broader research.

## 2. METHODOLOGY

Our method consists of three technical stages, namely the creation of the point cloud data, mask generation, and segmentation of data. We rely on commercial software in our workflow: Adobe Photoshop to generate masks, Agisoft Metashape to create point cloud data and filtering, and Cloud Compare for segmentation. We use original uncompressed and minimally processed raw images (in a raw file format) to create an ideal point cloud data. We generate masks afterwards.

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The approach to masking is based on colour differences between the bricks in the selected sample. Nevertheless, the data includes not only the sharp colour changes between the bricks but also the colour variations on each brick surface due to wear, damage, or simply, the material properties. More than one colour sampling is essential. For each selected area of the dome surface, we obtain at least ten different colour samples from a selection of the bricks that form it and export them with RGB values to represent the colour range of the pattern to be used to create the mask images. Consequently, we generate nine different masks corresponding to each repeating part of the pattern on the dome surface as can be seen in the top image in Figure 3.
Automatically generated masks are not suitable for use in their raw forms because of the deformations in the images like reflection, blur, and noise. At this point, it is possible to manually correct any errors. The generated masks are then imported into the Agisoft Metashape and they are used one by one to select and delete areas other than patterns from the original point cloud data. Finally, separately obtained point cloud data are imported into Cloud Compare and segmented in desired labels.

## 3. POINT CLOUD DATA PROCESSING

**Figure 1.** The ideal point cloud of İnce Minareli Madrasa's dome created by raw images.

Point cloud data creation is a basic process with unique variables such as point intensity, image formats, depth map precision. Raw images give the best result for creating ideal data with minimal disruption. We used a DSLR camera with a stock lens and a tripod for low light conditions. Also, different manual settings were adjusted according to the buildings' environmental conditions (Table 1). However, in order to make the selection better in the final process, there is a need for detailed point cloud data so that all the settings are selected in the target. There are two steps to reach the dense point cloud which we need for the final product. The first step is to align photographs where the only critical setting is high accuracy. This is essential for the next step which is to build a dense cloud as it requires a high resolution for a proper selection to occur. The second step may deliver millions of points but this number could be reduced in later stages.

| | İnce Minareli Madrasa | Sırçalı Madrasa |
|---|---|---|
| Camera | Sony α6000 | Sony α6000 |
| Lens | 16-50mm F3.5-5.6 | 16-50mm F3.5-5.6 |
| Auto focus | Yes | Yes |
| ISO | 600 | 100 |
| F-stop | F/3.5 | F/8 |
| Shutter speed | 1/15 sec | 1/45 sec |
| Number of images | 65 | 90 |
| Image format | .arw | .arw |

**Table 1.** Photogrammetry data gathering information.

## 4. GENERATING MASKS BY COLOUR RANGE

The interior surface of the dome of İnce Minaret Madrasa has four different colours of bricks, namely turquoise, purple, brown, and naked, while the wall panel in Sırçalı Madrasa has three, turquoise, black, and naked. The aim is to filter all these colours step by step.

### 4.1 Colour Range Selection

For a practical selection of the colour range in an image, we use minimal settings such as fuzziness and eyedropper provided as tools in the commercial software Adobe Photoshop. Best results are acquired when the fuzziness value is low, as an increased value may yield unwanted pixels in the selection (Figure 2).
The fuzziness value is kept at 30 as we take as many samples as needed from different parts of the image using the eyedropper tool. This way, we have defined a range for one particular type of brick colour to serve the purpose of capturing only those particular brick units. Once this is complete for all four of the brick colours, the areas of particular brick units are defined and the corresponding RGB data are delivered in separate ".axt" files.

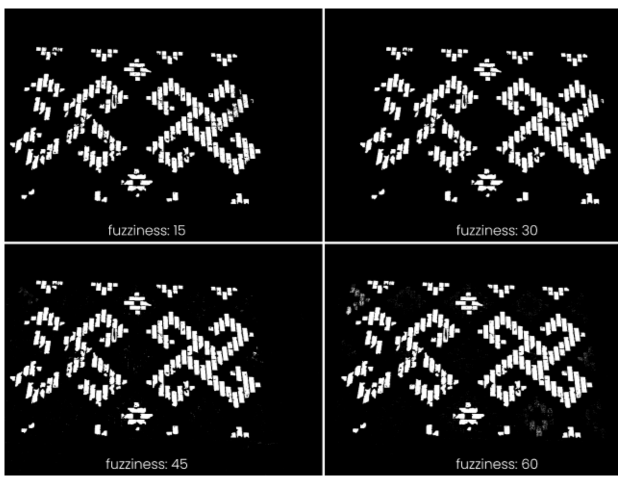


**Figure 2.** Colour range selection with different values of fuzziness for turquoise-coloured bricks in Sırçalı Madrasa.


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### 4.2 Selection Correction

Establishing the correct colour range is the first step of the proper selection process. There could be jagged edges or small pieces and areas separate from the brick unit. In order to fix these kinds of noise problems, we use the select and mask options of Adobe Photoshop (Table 2). There are a few essential settings in this menu to get the best results in selection. The first one is contrast. The default option for this applies a gradient colour fill through the edges of the selection. Differently, we had aimed to have wholly black and white pixels for the mask images. Smooth edges were unnecessary for this study, so the contrast setting was applied as 100%.

The other essential setting in this menu is the radius value for the area of refinement utilised in edge detection. Increasing this value helps to overcome the gaps caused by separated pieces. For smaller values, some cracks on the brick surface have caused errors and inaccurate selections in the first selection step. Increasing the radius value results in the inclusion of some pixels that serve as connectors between the separate pieces of the brick data. In our example, the value of 20 pixels gives accurate results. Surely, the ideal value for this radius is dependent on the image resolution.

| | |
|---|---|
| Edge Detection Radius | 20 px |
| Smooth | 0 |
| Feather | 0 px |
| Contrast | 100% |
| Shift Edge | 0% |

**Table 2.** Select and Mask Settings

These adjustments help us eliminate minor errors in the selection of the colour range. The two sample sets display variance in this process based on the different characteristics of surface shapes, the visual design, and the conditions of their setting in the buildings they take part in.

The dome of İnce Minareli Madrasa is an interior surface that is punctured with a skylight opening. The lighting conditions, the far distance to the photographic lens, and its curved shape are the most challenging parts for generating point cloud data and consequently creating masks based on colour information.

The ornamental wall in Sırçalı Madrasa is an outdoor surface situated in the courtyard of the building. Almost homogenous lighting and a setting with a height suitable for taking close-range photographs and its flat surface make it relatively ideal for our purposes.

After calibrating the selection in the image, the first selected pieces are filled with the colour white, and every other pixel is filled with the colour black. Suggested labelling methods are used in both cases. Each case has its unique problems in the process, and how we handled them is explained below.

### 4.3 Batch Process and Manuel Intervention for Fixing Errors

The lighting conditions for the dome of the İnce Minareli Madrasa are not ideal for photography. There are inconsistent reflections on the brick surfaces because of direct sunlight coming in from above and centre. In order to handle these distinctive colour properties in images, the overall shape was divided into parts according to the desired pattern masking process. The dome surface is visually composed of nine slices. Eight of these are mirrored pairs whereas one is unique. We treat these slices from the data as nine images, and in the process of generating the masks for the turquoise-coloured bricks, we use these nine images to focus on. We select each pattern before the batch process. Because all of the photographs corresponding to the slices are taken from the same spot central to the dome, the colour values of the surfaces are similar to each other. The selection of the essential photographs was followed by colour sampling and saving the data in a ".axt" file format. While all the steps up to this point are done, it needs to be recorded for later batch operations, and the action recording feature in Photoshop is suitable for this step. After importing the image into Photoshop, we start the action recording and do all the steps we have explained so far. Finally, the only thing that needs to be done is to run the batch process. All the nine mask images from the original İnce Minareli Madrasa images gave results with a high rate of success. The exception was the group of small turquoise pieces at the topmost circle of the dome that are not part of the surface pattern and therefore unwanted in the selection (Figure 4). After the batch process, these kinds of errors can easily be and are fixed manually by painting the unwanted white pixels black with the brush tool.

**Figure 3.** The nine equal parts of the dome (top), a general view of the dome in relation to the space below (bottom).

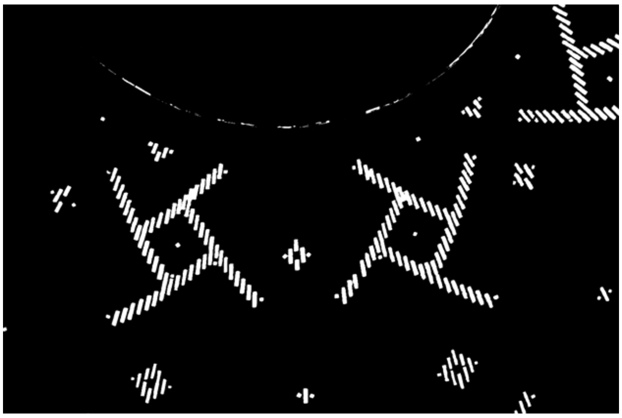

**Figure 4.** An example of a generated mask for the İnce Minareli Madrasa dome with the erroneous topmost circle.

After getting the successful masks, the same method is used for the wall in Sırçalı Madrasa. Unlike the multiple photos of İnce Minareli Madrasa, the entire wall fits in a single image which we can rely on to generate the masks. We use the same technique except for the batch process. After removing the unwanted parts manually, we simultaneously acquire the mask images for the black and turquoise bricks (Figure 5).

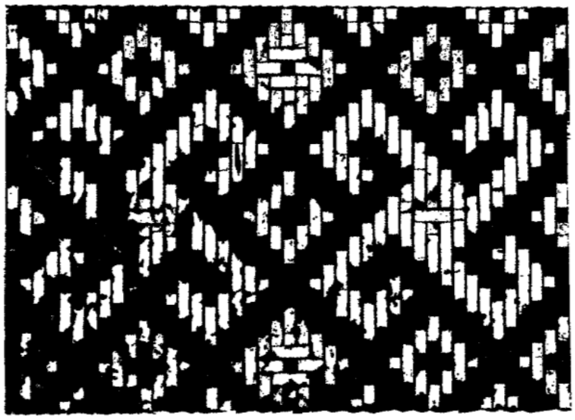

**Figure 5.** The mask generated from Sırçalı Madrasa's black and turquoise bricks combined.

## 5. IMPORTING MASKS AND FILTERING PATTERNS

As mentioned before, the ideal point cloud data of both the dome of İnce Minareli Madrasa and the wall in Sırçalı Madrasa are created using Agisoft Metashape where the selection of points in the cloud via masks has been a critical feature.

Raw images are imported, and once cameras are aligned, we have generated the dense point cloud with colour data in medium quality and mild depth map. About five million points were generated in both cases without filtering. The first step in the filtering process was also importing and matching the generated masks with aligned cameras. We add a "*_mask*" suffix to the generated masks' names to detect them correctly. After importing the masks, we apply the "select points by masks" tool in the upper tab and choose the imported masks. The tool successfully selected the points except for the white areas in the images. We deleted selected points by the tool and finally exported the point cloud data as ".ply" file format to use in Cloud Compare for future segmentation and training sets.

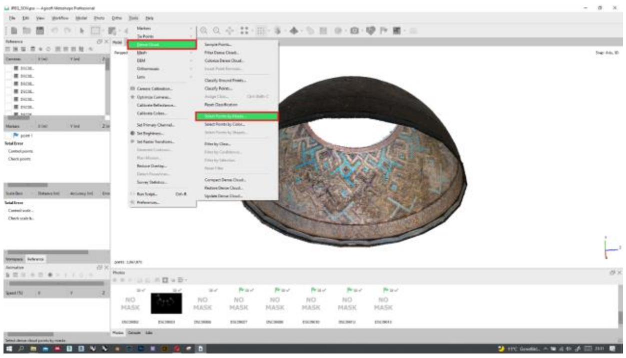

**Figure 6.** A screen shot of the point selection using masks in Agisoft Metashape.

**Figure 7.** Filtered turquoise bricks in the dome of İnce Minareli Madrasa.

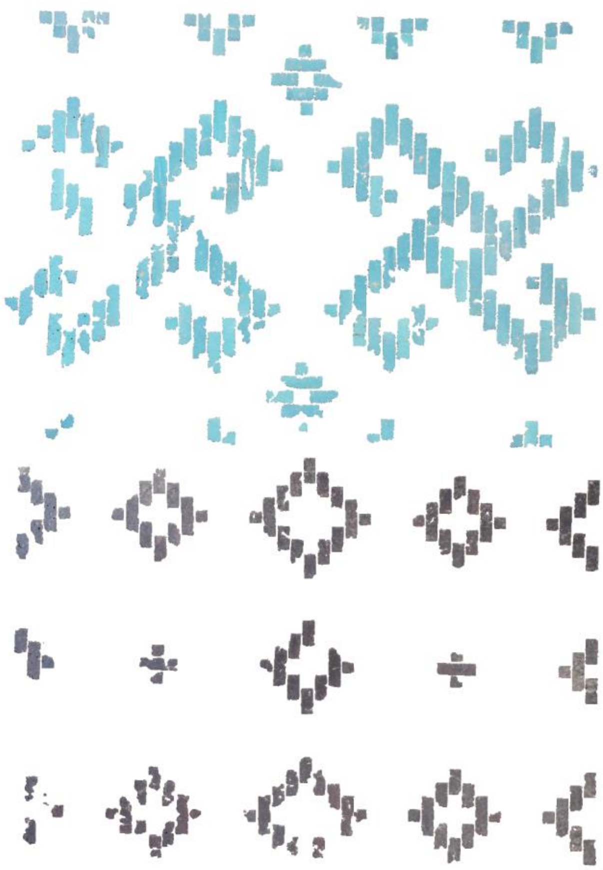

**Figure 8.** Filtered turquoise bricks (top) and black bricks (bottom) of the wall in Sırçalı Madrasa.


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## 6. SEGMENTATION

After exporting the all-dense point clouds separately as a PLY file format, we imported them into Cloud Compare for labelling the points and preparing the training set data. Labelled points will be the training data for further recognition of the patterns. The selection of segmented point clouds obtained in the previous steps is shown in Figure 9.

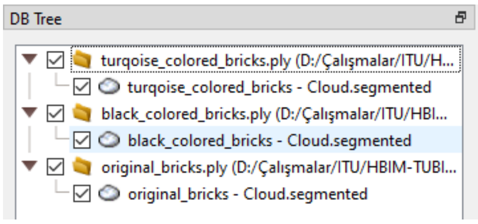


**Figure 9.** Segmented points in Cloud Compare DB Tree.

Three unique points cloud data of different coloured bricks are named separately according to their specifications. Naming was also an essential step for training inputs and outputs because we aimed for differentiated brick units at the end of the research.

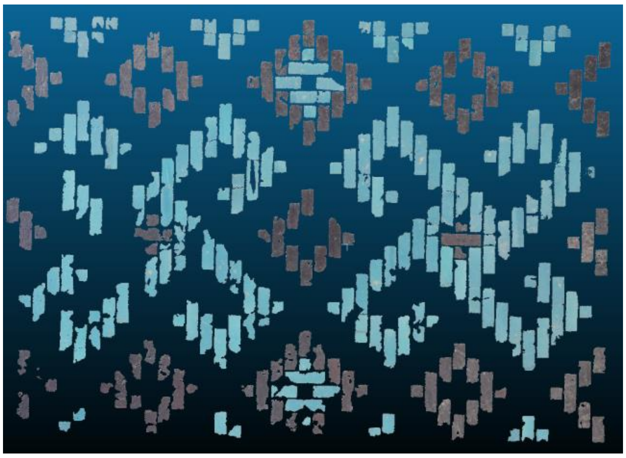

**Figure 10.** A screen shot of Cloud Compare 3D view panel.

## 7. DISCUSSION

Point cloud segmentation is a time-consuming process in real-world data analysis. In this study of preparing data for analysing the ornamental patterns in Seljuk architecture, it has been critical to reduce the time and effort in processes that are prone to manual errors and to improve the results in DGCNN with adequate data (Wang et al., 2019). In a future paper, we will be able to corroborate the success of the training data our method has so far delivered with the DGCNN algorithm. The preliminary results show the precision of the filtered point cloud data.
The unique examples of decorative brick laying patterns in Seljuk architecture are a rich corpus that is inventoried only visually. By developing methods to identify individual bricks and the different patterns they make, we aim to expand the inventory with extra layers of knowledge of bricklaying and the relations between bricks. The colour features of bricks offer an advantage for differentiating the patterns initially and semi-automatically.
There are comprehensive studies on detecting structural elements of historical buildings with RANSAC-based plane fitting segmentation, and sufficient accessible datasets for the training process (Murtiyoso, Grussenmeyer, 2019). Available data about ornamental details in these kinds of buildings are insufficient for machine learning, so this causes the main problem of the study.
One of the problems in identifying brick units in the İnce Minareli Madrasa has been the noisy and unclear point cloud data. Even the rough segmentation of the larger motifs by tracing their outer edges manually takes a long time due to the curved surface and the noise in the data. Our approach to segmenting with image masks has delivered successful results. The results in the more straightforward case of the Sırçalı Madrasa have been better. As a case, it is suitable for manual selection and segmentation, which we were able to compare with our approach. Comparing the segmentation time to numerical data is not meaningful as the amount of manual work time is usually just too much. This semi-automated method is more valuable than the typical approach for more complex shapes and cases with noisy data. The labelling of the point cloud data of the dome offered such a case where the approach delivered successful results.
As we mentioned before, the other important goal was obtaining an accurate training data set. Whole point cloud data could be noisy and unhealthy, but a few quality images might be enough to get good results. This idea led us to a successful result in the case of İnce Minareli Madrasa's dome in terms of data accuracy.

## 8. CONCLUSION AND OUTLOOK

Ornamental patterns in Seljuk Architecture have unique sets of shape rules and making rules. These rules are expressed with the help of different brick or stone layouts, such as the examples in our research. In order to recognise the rules behind these instances of cultural heritage, patterns should be first extracted and then analysed correctly. The primary purpose of our research is to make an algorithm with the help of deep neural network training. In this process, providing the data to the training set is a time-consuming and lengthy process. The training set needs a proper dataset to use for future cases.
This research aims to shorten the dataset preparation process by suggesting an image processing technique. A limited number of mask images are generated and used to filter and segment the desired points, which create patterns in the structures.
A semi-automated approach was proposed and tested in two different cases with different features. In the dome case, because there were too noisy and unhealthy images, manual work was a little more, but it was still more straightforward than a completely manual process in Cloud Compare.
The research aimed to speed up the segmentation process for preparing training data sets using present image editing programs such as Adobe Photoshop. This method only uses the images' colour information and does the filtering with this information. In future studies, we will be working on an image processing algorithm that helps us detect the brick units by using their colour values and normal vector information. We aim to handle the errors in generating the masks step and reduce the manual work by doing this.

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