CLOUD COMPARE PLUGINS FOR THE SEGMENTATION OF MASONRY WALLS: A GUIDE FOR USERS

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1 Introduction

The Cyberbuild Lab at the University of Edinburgh, in collaboration with Historic Environment Scotland, have developed a tool for the semi-automatic segmentation of stone walls into individual masonry units. This tool has been coded in C++ language and implemented as two plugins for CloudCompare, a powerful free open source software for point cloud data processing, which is widely used by experts in this field.

The first plugin is devoted to the automatic segmentation of masonry walls into individual stones and mortar regions. The second plugin supports the manual segmentation of stones and mortar regions. That second plugin can be used for two alternative objectives: correcting the output of the automatic segmentation or creating a new segmentation from scratch.

This manual only covers the functionalities of the developed plugins. For further information on the use of CloudCompare, an extensive user guide can be found in the official website[1].

In the following sections, both automatic and manual segmentation processes are detailed, step by step, providing the user with the information needed to produce an effective segmentation of a digitalised masonry wall.

[1] http://www.cloudcompare.org/doc/qCC/CloudCompare%20v2.6.1%20-%20User%20manual.pdf

2 Automatic Segmentation Plugin

The objective of this plugin is to automatically detect stones and mortar joints within a masonry wall, segmenting and saving the outcomes as distinct entities that can be later exploited independently. More information on the segmentation algorithm can be found in Valero et al. (2018)[2]

2.1 Input Requirements

A point cloud containing an individual masonry wall. To obtain good results, it is highly recommended to clean the data before running the segmentation; this means that data not belonging to the wall should be removed. Additionally, and depending on the specifications of the machine running the process, we recommend loading and processing only one point cloud at a time.

2.2 Process Steps

1. Load the point cloud containing the wall through the menu *File>Open*. Note that most point cloud formats are supported by CloudCompare.
2. Then, select the point cloud. This can be done as illustrated in Figure 1, by clicking on the cloud's name in the *DB tree* window (labelled 1 in Figure 1). If done correctly, a yellow bounding box should appear in the 3D viewer around the selected point cloud, meaning that the specific cloud is selected.
3. Click on the automatic segmentation plugin icon (labelled 2 in Figure 1) to run the segmentation process.

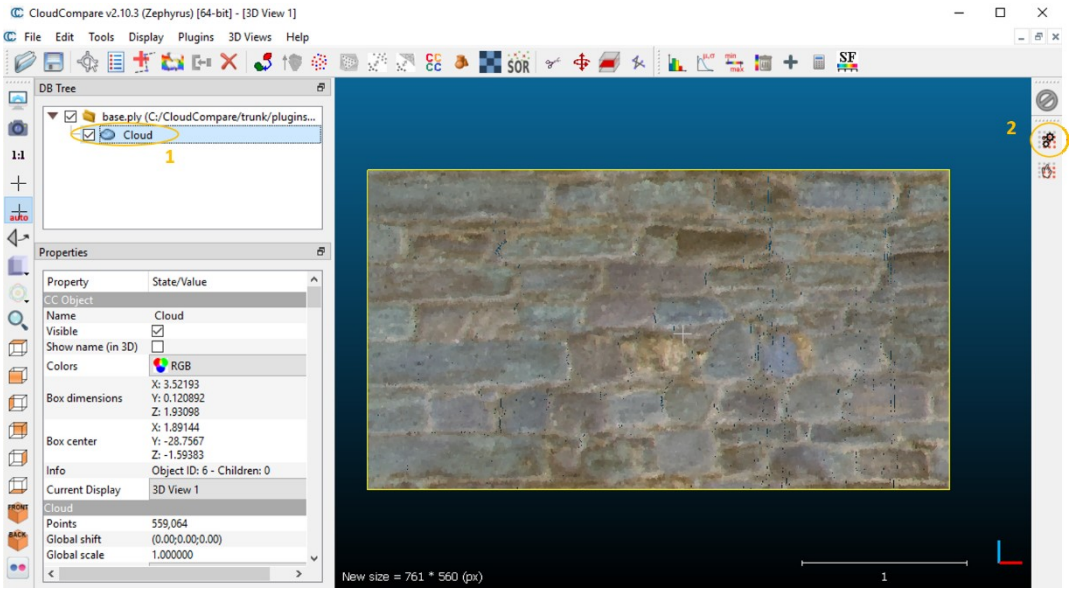

Figure 1: Point cloud of a masonry wall loaded in CloudCompare

[2] Automatic segmentation of 3D point clouds of rubble masonry walls, and its application to building surveying, repair and maintenance. Automation in Construction 96, 2018. https://doi.org/10.1016/j.autcon.2018.08.018

4. After clicking the icon, a dialogue window (see Figure 2) will appear that exposes some operations performed and parameters used by the algorithm. These are:
   - Automatic segmentation. This should be checked to run the automatic segmentation process.
   - Mortar maps. If checked, mortar maps, containing both width and depth information, are calculated.
   - Approximated width of mortar joints (in centimetres). Note that selecting a value too small may lead to over-segmentation; selecting a value too large may lead to under-segmentation. Finding the optimal value may require testing two or three different values, as well as using the measurement tool of CloudCompare to get a reliable initial estimate.
   - Size of the "segmentation window" (in meters), which is used to divide the wall in rectangular patches to facilitate the segmentation process. This may not need to be changed. Advanced users may only consider changing this if processing time is slow or results are very poor for particular areas of the wall.

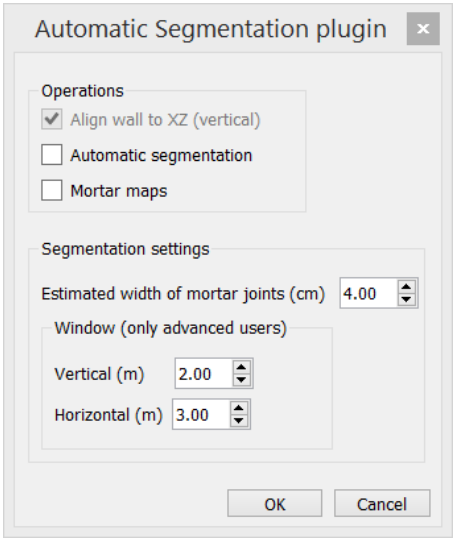

Figure 2 Dialogue window showing the exposed parameters

5. Once the segmentation is performed, the outcome of the process is shown in the DB tree window. As can be seen in Figure 3 (a), the following objects are generated:
   - One stone cloud (called *f_cloudStones*), which contains points classified (i.e. labelled per stone) according to the automatically-detected stone structure of the wall. These are better shown in Figure 3 (b). Note that this cloud can be coloured differently, for example by assigning a different colour to each stone, which may help identify individual masonry units in the cloud. This can be done in *Properties* window under *Color>Scalar Field*.
   - One mortar cloud (*f_cloudMortar*). When identified (as in Figure 3 (c)), this contains points belonging to the mortar joints.
   - A folder named *Stone contours* that contains the stones' boundaries which serve as a visual aid to easily identify the stones identified during the segmentation stage.
   - A cloud containing the centre line of the mortar joints (Figure 3 (d)), which can be coloured according to the depth or width of mortar joints. To show these colourings, select the Mortar Maps point cloud in the *DB tree* and then, go to *Properties* window and select Scalar field under *CCObject>Colors*. Depth or width maps can be chosen in *Properties* window*>Scalar Field>Active*. The colourbar showing information about the

measured distances can be activated by checking the box *Visible* under *Properties* window*>Color Scale*.

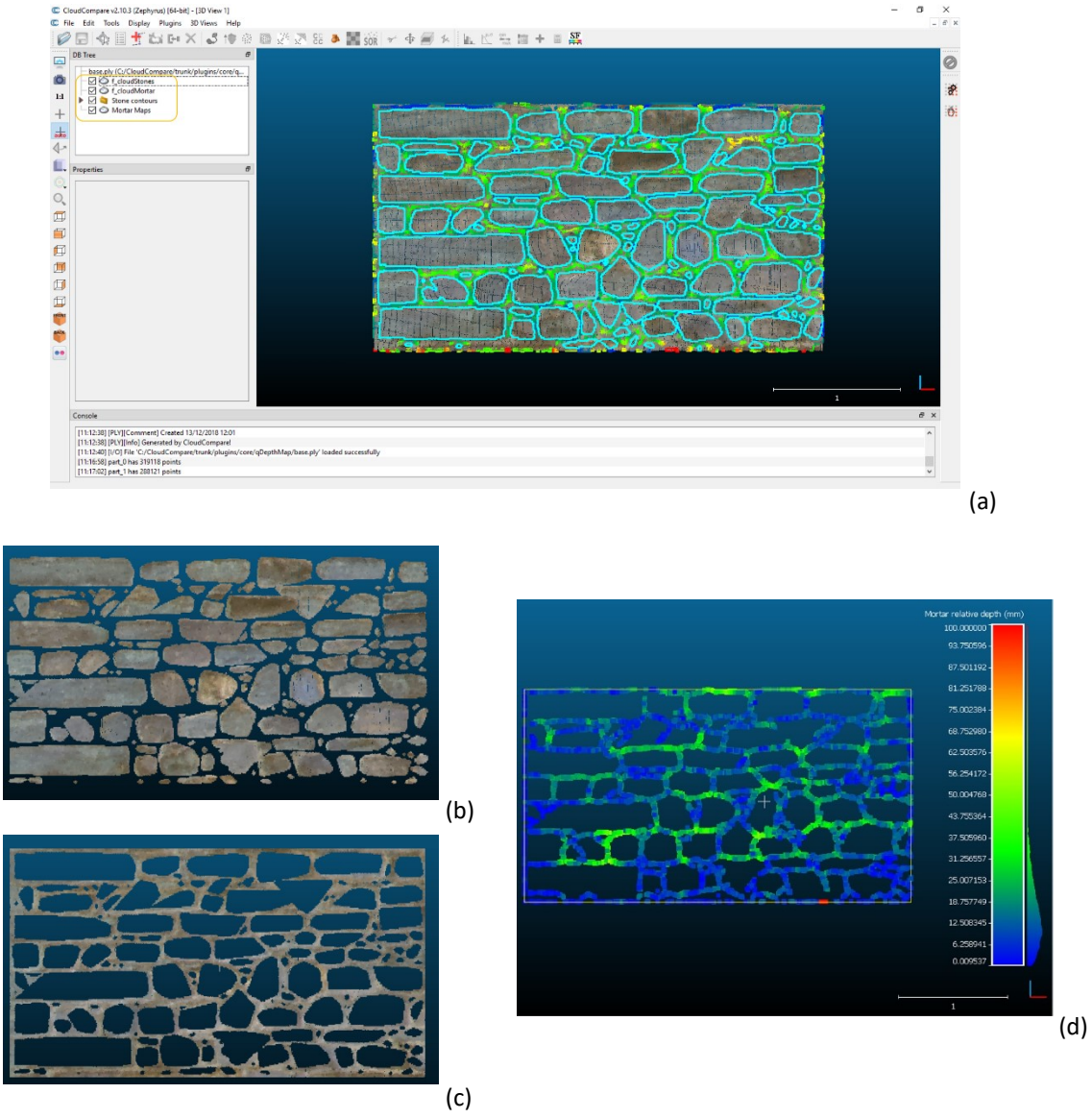

Figure 3 Outcome of the segmentation process

Following the previous recommendation of keeping the database clear, and to avoid potential performance issues, the original point cloud can be removed from the *DB tree* at the end of the process. This can be done by right-clicking on it and selecting *Delete*.

Once the segmentation process is completed, each entity within the DB tree can be saved individually or combined with other entities in one of the multiple formats supported by CloudCompare, according to the user's needs. For example, if the user wants to save the stone cloud from Figure 3(b), left click on *f_cloudStones*, then click on *Save* button.

3 Manual segmentation plugin

This plugin can be used to manually segment a point cloud of a masonry wall, or to correct and edit the segmentation of one that has been already subject to a previous segmentation process, either automatic (Section 2) or manual.

3.1 Manually segment the point cloud of a masonry wall

In this case, the point cloud containing the wall has not been processed (i.e. segmented), so the full segmentation process will be performed manually.

3.1.1 Input Requirements

- First, verify that the name of the loaded point cloud does not include the sequences "mortar" and/or "stone", as these are reserved words for the plugin's outputs.
- The point cloud containing the wall is expected to fit a XZ plane (i.e. to be vertical).

N.B.: The alignment of a point cloud to a XZ plane can be done through the dialog window of the automatic segmentation plugin .

3.1.2 Process Steps

1. Load the point cloud containing the wall through the menu *File>Open*. Note that most point cloud formats are supported by CloudCompare.
2. Then, select the point cloud. This can be done as illustrated in Figure 1, by clicking on the cloud's name in the *DB tree* window. If done correctly, a yellow bounding box should appear in the 3D viewer around the selected point cloud, meaning that the specific cloud is selected.
3. Delimitate the boundaries of the stones, which can be done following these two options:

    - **Option a**: for each stone, create a polyline delimiting it using the *Segment*[3] tool
        - The viewer should be set to the front view. This can be done by clicking on the *Set front view* icon . Note that once you start the Segment tool, the view is locked and cannot be changed anymore. The usage of the Segment tool requires conducting the segmentation in a top-down view of the wall.
        - Select the *polygonal selection* tool → ; NOT the *rectangular* one.

[3] More information on the Segment tool can be found at http://bit.ly/segmentCC

- Start drawing the 2D polyline (left click for each vertex), and right click at the end of each stone to release the polyline drawing functionality. Then, click the *Save* button on the segmentation panel  to export the segmentation polyline. Polylines should be saved to the *DB Tree*.

- **Option b**: draw polylines using the *Trace*[4] tool 

  For this option, the viewer change the 3D viewpoint while drawing the polyline. This option is particularly useful when stone edges are hard to detect from a 2D view.

  - Start drawing the 2D polyline (left click for each vertex), and right click at the end of each stone drawing to stop the tracing functionality. Then click on the "confirm polyline creation and exit" button on the tracing panel 

.
  - If asked, after running the plugin, whether to close the polyline, select *Yes.*

4. After the desired stones´ contours have been delimited, click on the manual segmentation plugin icon  . This will complete the segmentation of the point cloud. The produced entities after the segmentation are similar to the ones obtained in the automatic process (see previous section for additional information).

3.2 Correcting the segmentation results after an automatic process

After running an automatic segmentation process, results may not be as accurate as expected, in which case users may want to correct and/or complete them. These post-processing operations can be divided in two groups: (re)definition of stone boundaries (for new or already existing stones) or deletion of stone segments. Note that mortar regions are all parts of the wall that are not stone segments. Figure 4 illustrates these operations. Blue lines represent stones boundaries, and, on the left-hand image, yellow polylines represent manually added and removed polylines. While free-form segmentation polylines are to create/modify boundaries, rectangular polylines are used to delete incorrect stone segments.

NB: If variables are renamed after the process, they should keep their "type" in their new name. For example, objects of type contour, should keep the sequence *contour* in it. However, renaming variables is not advisable.

[4] More information on the Trace Polyline tool can be found at http://bit.ly/tracePolyline

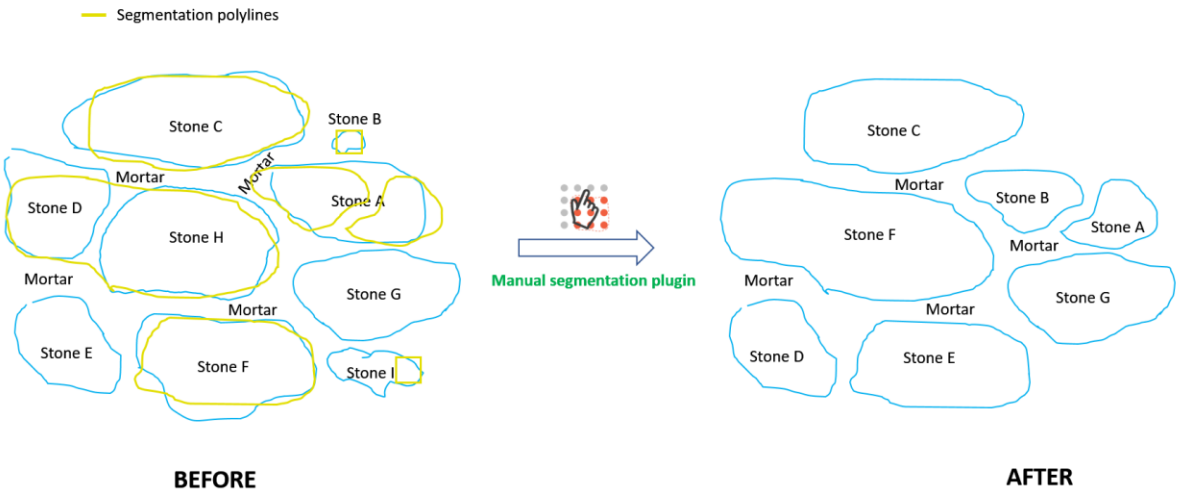

Figure 4 Manual correction of automatic segmentation

3.2.1 Process Steps

1. Select any point cloud.
2. Use the *Segmentation* tool → (after selecting 2D front view) or the *Tracing* tool to **redefine** the boundaries of existing stones or to **define** new ones, following the process detailed in Section 3.1.2. Remember the *right click* and *Save* operations after drawing each polyline.
3. Use the *Segmentation* tool's *rectangular selection* → to **delete** stones (e.g. misidentified mortar). Remember the *right click* and *Save* operations after drawing each polyline.

The produced entities after the segmentation are similar to the ones obtained in the automatic process (see previous section for additional information).

4 Rendering point clouds

Segmentation results, as well as other point clouds or models loaded into CloudCompare, may be subsequently rendered to a file containing a high resolution image. This operation can be performed by means of a CloudCompare internal tool called *Render to file* (see Figure 5).

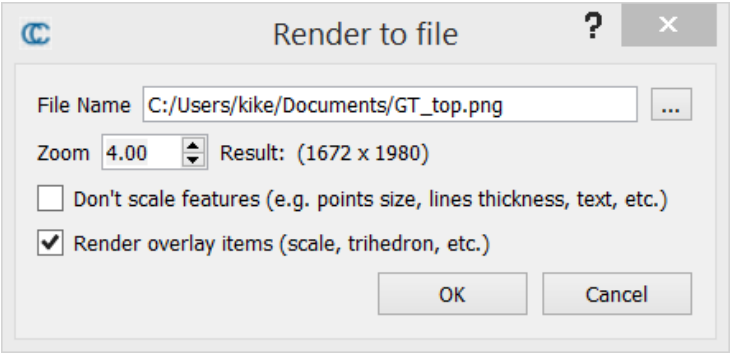

Figure 5 Render to file dialogue

4.1 Input requirements

- At least one object (e.g. point cloud) must be present in the *DB tree.*

4.2 Process steps

1. Check (i.e. make visible) in the DB tree the objects to be rendered onto the image.
2. Modify the point/line size according to the requirements and add potential features such as colorbars (see Point 5 in Section 2.2 for more information on this).
3. If required, adjust background and text colour, through menu *Display>Display settings>Colors and Materials*. Other display options, like lights, materials, etc. can be additionally modified in that dialogue.
4. Render the content of your working space to a file by means of *Display>Render to File.*
    a. Enter the name of the file (including the path to the containing folder) and the extension of the desired format.
    b. Adjust the "Zoom" variable according to the user's requirements. Note that the size, in pixels, of the rendered imaged is shown on the right-hand side.
    c. Check the "Render overlay items" option and click *OK*.