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MeshAlign v.2

User Manual

Abstract

Post-processing tools are the software instruments needed to transform the raw data produced by 3D scanners (basically, a set of range maps) into optimized and application-oriented representations, which should integrate geometry and appearance and run smoothly in distributed environments.

This document, Deliverable **4.2.1** describes the features and usage of the MeshAlign 2 tool.

Deliverable **4.2, First Release of Post-Processing Tools** is composed by

- **4.2.1** Alignment Tool: MeshAlign v.2 with User Manual
- **4.2.2** Merge Tool: MeshMerge v.1 with User Manual

MESHALIGN V.2 *User Manual*

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Introduction

To capture the entire geometry of an object in 3D scanning, it is often necessary to take multiple scans of the same object from different vantage points. Each scan covers different parts of an object and these scans, when converted to 3d meshes, must be aligned to each other in the same coordinate space.
MeshAlign2 is a program which can be used for aligning these meshes to construct a complete model of an object. In this program, mesh alignments are organized in a tree-structure, which allows meshes to be aligned in a hierarchy of relationships. Meshes are added to a group tree-node at different levels in the tree hierarchy, and alignments are propagated from parent tree-nodes to children tree-nodes. Groups of meshes can be aligned while maintaining the relationships between meshes in the group. As meshes, or groups of meshes, are added one by one to the tree-structure, alignment calculations are preformed in one global coordinate space. This allows alignment calculations between the different meshes/groups to be made continuously during the building process. When working with objects that are represented with a large number of meshes it is very important to have an intuitive and simple way to manipulate relationships between meshes and groups of meshes.

This short user manual is organized as follows. To give the user an idea about how the program interface is organized, section 2 describes the program layout, In section 3, there is a step by step alignment example. Then three basic MeshAlign2 elements and their respective properties are explained in sections 4, 5, and 6: the meshes, the groups, and the alignment arcs.

1. Program layout

In the leftmost section of the main MeshAlign2 window (see Figure1), there is a list representation of a tree-structure that displays the groups, meshes, and arcs for the current project.

Global is the name of the overall group and top tree node; subgroups can be created under it.

The groups are represented in the tree structure with a general group icon and a group name.

The meshes are represented with a general mesh icon, the original filename, an id-number, and a specific color. By clicking on the plus sign next to a mesh icon further information about the mesh is shown: the number of vertices (*vn*), the number of faces (*fn*), and the size of its bounding-box (*bb*, coordinates for the "right-upper-back" and "left-lower-front" corner).
Additional information about alignment relationships, known as alignment *arcs*, can be seen by clicking on the plus sign next to a arc icon.
The red-colored group icon in the tree-structure (*Global* in the example in Figure1) indicates the current *working group* (5.2.Select as working group).
The cyan-colored mesh or group icon (mesh 004 in the example in Figure1) in the tree-structure indicates which mesh or group is selected.

A gray check next to the mesh or group icon, shows if it has been fixed into alignment position. A mesh or group that displays a gray check and has been aligned and fixed in place is referred to as being ***glued***. (see subsection 4.4."Glueing the meshes" and 5.3. "Glueing the groups").

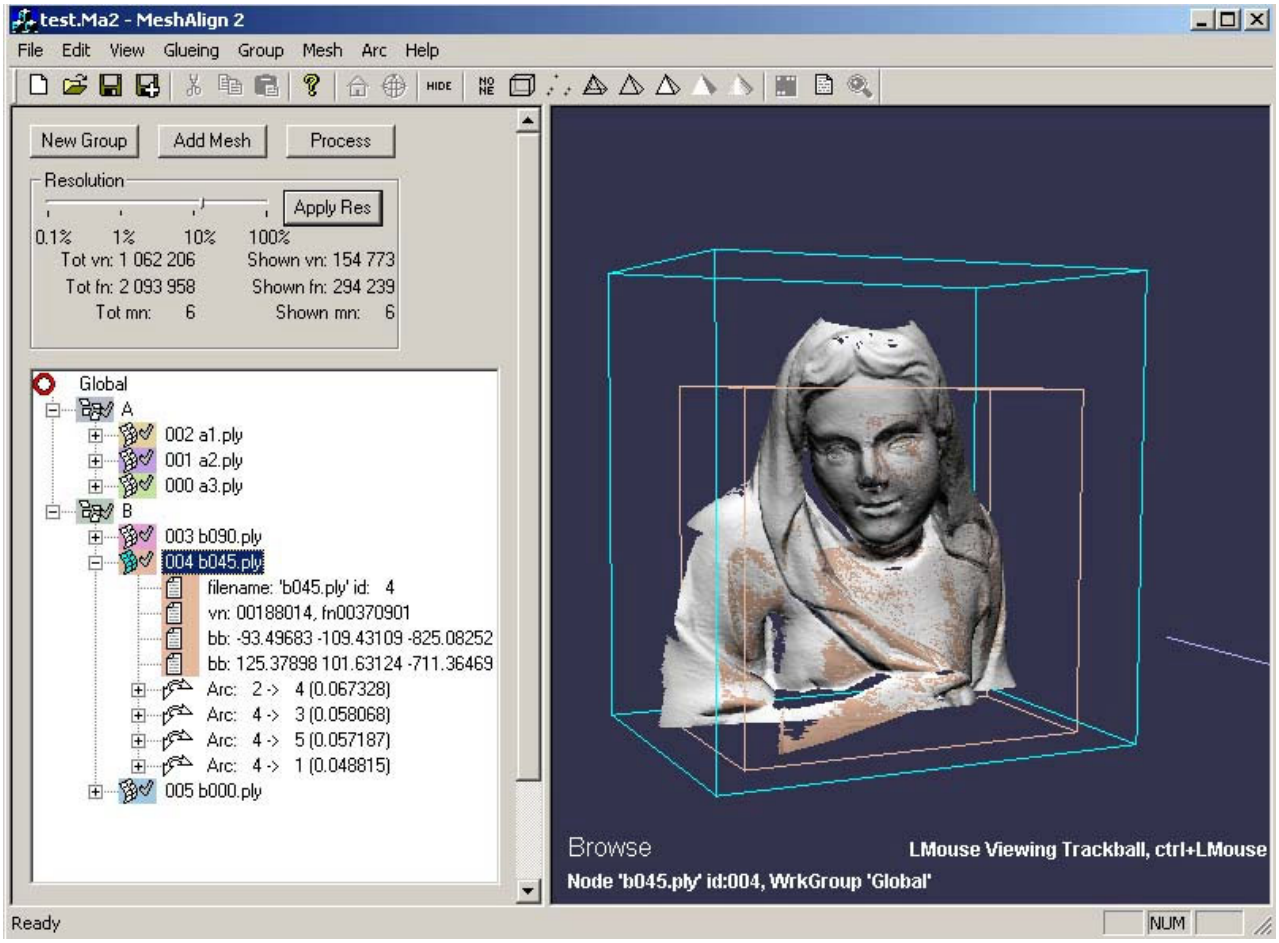


Figure1. *The MeshAlign v.2 layout.*

Above the tree-structure there is a set of buttons: one that adds a new group (***NewGroup***), one that adds a new mesh (***AddMesh***), and one that processes a new alignment (***Process***). There is also a sliding cursor that changes the visualization resolution of the meshes in the working group; a change in resolution affects just the visual presentation of the meshes and does not affect the alignment calculation accuracy. Below the resolution slider is a display of how many of the original vertices and faces (***Tot vn*** and ***Tot fn***) are shown at the current resolution level (***Shown vn*** and ***Shown fn***). Also shown is information about the total number of meshes in the project (***Tot mn***) and how many meshes are currently being considered in the alignment calculations (***Shown mn***).

The menus and toolbar across the top of the window includes tools for normal file options (open, save, etc) and rendering options.

The rightmost section of the main window is used for mesh visualization and reflects choices made in the tree-structure, the current alignment solution, and options that the user has selected.

Only the meshes selected in red as the *working group* in the tree-structure are visible in the main window. When new meshes are added into the project they are placed in the working group and the alignment process (if the button ***Process*** is pressed) is only performed on the meshes (and groups) within the present working group.

The cyan colored mesh/group in the tree-structure (selected by a left click) is also an important distinction. When the pyramid shaped visualization buttons in the top toolbar are pressed the visualization mode will be changed for the currently cyan selected mesh/group. When a mesh (or a group) within the working group is selected it is shown with its specific id-color and its bounding-box in the visualization window. If a mesh that does not belong to the current working group is selected it will just be visualized with its bounding-box in the visualization window.
In the lower part of the visualization window section, additional information is displayed, e.g.: which is the selected group or mesh, which is the current working group, how to control the trackball and how to perform the chosen operation.

2. Getting started, a short example

In this section a simple MeshAlign2 project will be presented step by step.

1. Start up the program MeshAlign2
2. Create a new sub-group (node) under Global (in the tree-structure, positioned to the left in the program window) by clicking on the name Global and then pressing the button *NewGroup*. The name of the new group, Group00, can be changed by double-clicking on the name, by clicking *RightMouse* > *Rename*, by pressing F2 or by choosing the menu option *Group* > *Rename*.
3. Select the new group as the current working group (so it is designated as the group being operated on) by *RightMouse* > *SelectasWorkingGroup* (or with the menu option *Group* > *SelectasWorkingGroup*).
4. Press the button *AddMesh* and open the meshes that you want to put in the new group (the meshes can also be loaded by the menu option *Group* > *AddMesh* or by selecting the group and clicking *RightMouse* > *AddMesh*).
5. To increase the resolution of the meshes, move the resolution handle (Figure2a), placed in the upper left corner of the program window, to a higher percentage level and press the button *ApplyRes*.
6. Mark one of the meshes and click *RightMouse* > *GlueHere* (or chose the menu option *Glueing* > *GlueHere*). This will lock the mesh in its present location and this position will be the reference point for the whole group.
7. Select the visible unglued mesh and click *RightMouse* > *ManualGlueing* (or chose the menu option *Glueing* > *ManualGlueing*). Place the mesh in the right position with respect to the mesh (can also be a whole group) it is going to be glued to. The mesh can be moved by rotation (*LeftMouse*), panning (*MidMouse* or *Ctrl+LeftMouse*). To change between the trackball for the single mesh and for the whole scene press *Esc*. When the positioning is completed, press the *Process* button in order to calculate the arc that aligns the mesh to the already glued one.
8. To inspect and improve the alignment arc, click on the plus next to one of the glued meshes in the tree structure and then select the arc. An alternative could be to choose the menu option *Group* > *SelectWorstArc*, which selects the worst arc in the group and in this example there is only one arc made. If there had been many glued meshes in the group, it could be useful to click *RightMouse* > *InspectCurrentArc* (or choose the menu alternative *Arc* > *InspectCurrentArc*). This in order to extract just the two meshes that belong to the specific arc and to see them better. When the arc is selected do *RightMouse* > *RecomputeArc*, which probably will improve the arc and decrease the error (the error is the number shown in the parentheses next to the arc in the tree). To try to reduce the error even more, the parameters for the computation can be changed by *RightMouse* > *AlignmentParamCurrentArc*. To deselect the arc (hide the error vectors in the right window) click *RightMouse* > *UnSelect*. If being in the inspection mode, first click *RightMouse* > *InspectCurrentArc* and then *RightMouse* > *UnSelect*.

9. Unhide one of the other unglued meshes by mark it and click *RightMouse > Un-ExcludeMesh.* Choose the point based glueing by *RightMouse > PointBasedGlueing* or through the menu option *Glueing > PointBasedGlueing.* This will show a split window to the right where the group is visible in the rightmost part and the mesh to be glued in the leftmost. Now, four pairs of connection points have to be set between the group and the mesh. *Ctrl+Shift+LeftMouse* are used to place a point. All four points for one of the sides can be positioned directly and then the corresponding four in the other window. Alternatively, the four pairs of points can be positioned alternately. Try to spread the points as much as possible over the surface. If some point is misplaced the process can be restarted by *RightMouse > PointBasedGlueing* (to interrupt the glueing process) and then again *RightMouse > PointBasedGlueing* (to restart the process). This restarting of the process can also be done through the menu choice *Glueing > PointBasedGlueing.* When the four pairs of points have been positioned in a satisfactory way the result can be inspected by clicking *RightMouse > PointBasedGlueing* in the tree-structure on the newly glued mesh. This shows just the translation and rotation done for the mesh and still no alignment has been calculated. If the placement seems all right, press the button *Process* and the mesh will be aligned to the rest of the meshes in the group. To improve the arcs in the group follow the instructions in step 9 above.

10. Repeat step 7-9 for all the loaded meshes in the group in order to have them all glued and aligned. Choose step 7 (ManulaGlueing) or 10 (PointBassedGlueing) depending on the preferable glueing method. Usually point-based glueing is faster than manual glueing but for meshes with few good reference points and low curvature it might be easier to get a good result with manual glueing.

11. Create a new group as described in step 2. Repeat step 3, 4 and 5 to load a set of meshes into this second group. Glue the meshes (step 6-10 above) with the preferable glueing method (step 8 or 10).

12. Now you have two separate groups in the global project and they need to be connected to each other. This is done in the same way as for the meshes; now the groups can be considered as single meshes. Select Global as the working group by marking it and clicking *RightMouse > SelectasWorkingGroup* (or choose the menu option *Group > SelectasWorkingGroup*). Next step is to lock one of the two groups in space (by *RightMouse > GlueHere* or the menu option *Glueing > GlueHere*). Then the second group is connected to the first one in one of the ways described in step 7 (manual glueing) and 9 (point based glueing).

The procedure described above can be used for all meshes that are needed to build up the reconstruction of the original object.

3. Meshes

The basic building element in MeshAlign2 is the mesh. The mesh is a surface piece that holds the geometrical description of a part of a real object. MeshAlign2 supports the format *.ply*.

3.1. Loading the meshes

The mesh is loaded to the project through the button *NewMesh*, the menu option *Mesh* > *NewMesh* or by clicking *RightMouse* > *AddMesh* on the selected group. The loaded mesh gets a particular id-number (click on plus next to the mesh to see this number) and a special color. When the mesh is selected in the tree-structure it gets a cyan-colored indication and in the visualization window a bounding-box (with the same color as the mesh) points out the special mesh. All the meshes that the user wants to add to the project have to be loaded from the same directory and it is not possible to add a mesh that has the same name as one already loaded. If a mesh is loaded by mistake it can be removed by choosing the menu alternative *Mesh* > *Dele*te*Mesh* or by clicking *RightMouse* > *DeleteMesh* (when the mesh is selected in the tree-structure).

3.2. Visualizing the meshes

The resolution of the meshes in the project can be changed by moving the resolution handle (see Figure 2.a) to a desired percentage level and then pressing the button *Apply*. Observe that this is just a change in the visualized resolution and does not affect the aligning process. By clicking on the different visualization buttons in the tool bar (see Figure 2.b), the visualization mode for the selected mesh can be modified.

a b

Figure2. (a) *The handle to change the (visualized) resolution of the meshes.*
(b) *The buttons (in the tool bar) to change the visualization mode of the selected mesh.*

To hide a mesh or group from the visualization window, the button *Hide* in the visualization bar can be pressed when the mesh is selected in the tree-structure. A hidden mesh is not visible in the main window but is still included in alignment processes. If it is desirable to hide as well as omit a mesh from alignment calculations, it can be excluded. To exclude a mesh or a group like this there are three possibilities (for all of them the mesh has to be selected in the tree-structure), either to press the button *Exclude (XCLD)* in the tool bar, or to choose the menu option *Mesh* > *ExcludeMesh* or to click *RightMouse* > *ExcludeMesh*. In very big projects there can be several meshes or groups that

do not give a significant contribution to the final model and by excluding them from the calculations the user can speed up the processing time.

If a mesh is selected in the tree-structure and the option *RightMouse > LookAtCurrentMesh* is chosen the view is centered in respect to the mesh selected.

3.3. Moving the meshes

A mesh can be moved between groups in the tree-structure by "drag-and-drop" and within a group by selecting it and clicking *RightMouse > MoveMeshUp/Down,* choosing menu option *Mesh > MoveMeshUp/Down* or by using the short commands *Ctrl+Up/Ctrl+Down*.

An unglued mesh can be moved in the scene by clicking *RightMouse > Transform* and choosing one of the three possibilities; *Reset, MoveToOrigin* or *MoveToCenter*. The option *Reset* will move the selected mesh to its original position (if it has been processed it will be moved to the position it had after the processing). The alternative *MoveToOrigin* moves the mesh to the scene origin (showed by colored axis) and the *MoveToCenter* places the mesh in the center of the bounding-box of the current working group. If an already glued mesh needs to be re-glued, the mesh should be unglued and a *Transform > Reset* preformed. This will move it back to its original position and reset the translation and rotation with respect to the global system.

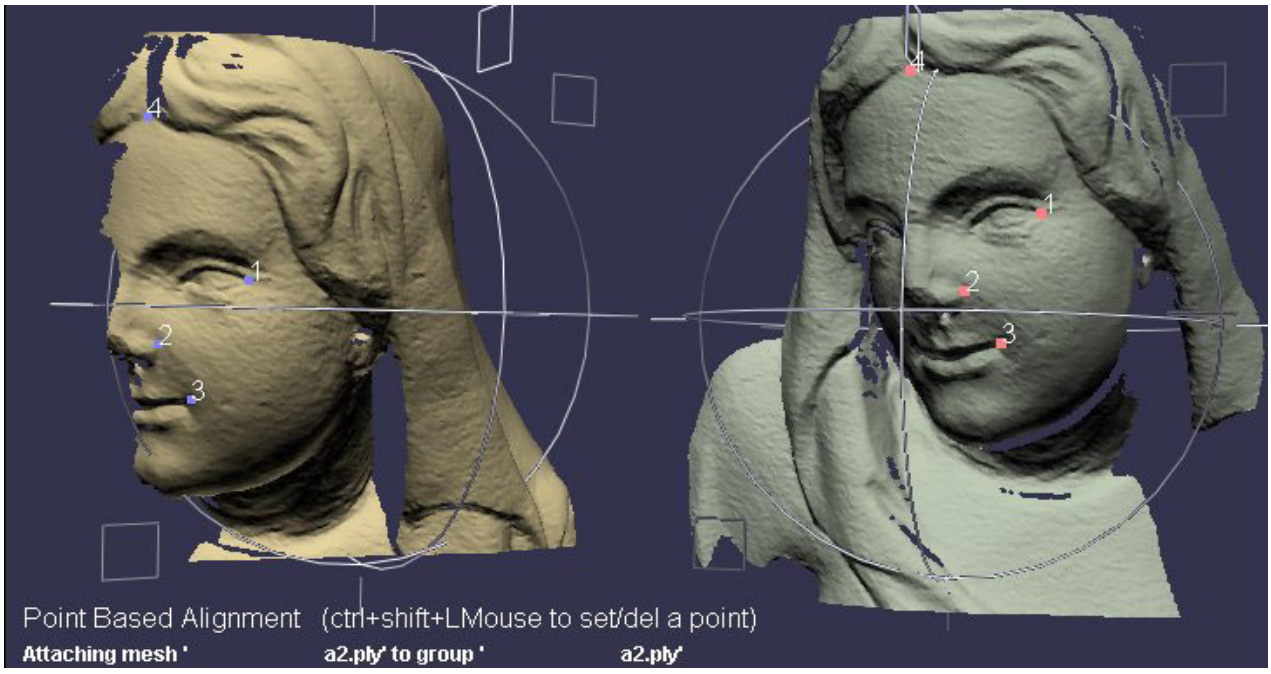


Figure3. *The point-based glueing. The mesh that is being glued to the left and the reference mesh (can also be a whole group) to the right.*

3.4. Glueing the meshes

When the meshes have been loaded into a group they have to be glued and processed to give them the correct placement in space (rotation and translation) and to calculate the alignment arcs. The first mesh in a group can be glued with menu option *Glueing* > *GlueHere* or by clicking *RightMouse* > *GlueHere* on the selected mesh. This mesh will be a reference point for the other meshes in the group. Each of them can be aligned to this initial mesh in two different ways.
The first possibility is to use manual glueing (*RightMouse* > *ManualGlueing* or menu *Glueing* > *ManualGlueing*), which gives the user the ability to move and rotate the mesh freely until it is placed in the correct position.
The other possibility is to use point-based glueing (*RightMouse* > *PointBasedGlueing* or menu *Glueing* > *PointBasedGlueing*), which allows the user to point out four pairs of points between the reference mesh (or group) and the mesh that is going to be glued (see Figure3).

After one of the glueing methods is used (either positioning the mesh in manual glueing or selected points in point-based glueing), the alignment can be calculated by pressing the button *Process*. When using point-based glueing, it is sometimes useful to have a preview of how the mesh will be located (based on the four point pairs), without performing the real alignment process. After the four point pairs have been placed, click once more *RightMouse* > *PointBasedGlueing* or choose menu option *Glueing* > *PointBasedGlueing*; the translation and rotation for the mesh is shown without calculating the alignment arcs. If the result is satisfactory, the button *Process* can be pressed (this will compute the alignment arcs) and if not, the mesh can be unglued (by *RightMouse* > *UnGlue* or choosing menu option *Glueing* > *UnGlue*) and then glued again in the same way as previously described. When the *Process* button has been pressed and the alignment process is finished, the program has created a set of arcs that connect the glued mesh with the rest of the already glued meshes in the group. These arcs can be seen by clicking on the plus next to the mesh in the tree-structure.

4. Groups

Organizing your meshes into groups can help keep your project organized and flexible; creating groups in the project reduces the number of project elements, which is necessary when dealing with very large projects. It is a good idea to create groups that contain meshes which represent similar geometry on the scanned object. Thus, after a group has been glued and processed it can be considered and treated as a single mesh.

4.1. Creating, visualizing & moving a group

A new group can be created by selecting the group under which the new group is going to be placed (usually Global) and then clicking *RightMouse* > *NewGroup*, choosing menu option *Group* > *NewGroup* or pressing the button *NewGroup*. The name of the group can be changed by clicking *RightMouse* > *Rename* on it, by selecting the menu choice *Group* > *Rename*, or by simply double click on the group name. Also the groups, just like the meshes, get specific colors and corresponding bounding-boxes and different visualization modes can be selected in the tool bar. A group can be moved in the tree-structure by "drag-and-drop" and it can be deleted by clicking *RightMouse* > *DeleteGroup* or by selecting the menu option *Group* > *DeleteGroup*.

Unglued groups can, just as the unglued single meshes, be moved to the origin of the scene. This is done by clicking *RightMouse* > *MoveToOrigin* on the selected group in the tree. This can be done even for the group *Global* (that also has to be *Unglued* first), which moves all meshes to the scene origin and makes the model easier to control.

4.2. Select as working group

A group can be selected as working group by marking it in the tree-structure and clicking *RightMosue* > *SelectasWorkingGroup* or by choosing the menu alternative *Group* > *SelectasWorkingGroup*. This means that the operations that are done (e.g. processing the glued meshes, adding new meshes, selecting worst arc) will only affect this particular group.

4.3. Glueing the groups

When all the meshes in the groups have been glued and processed (Section 4.4.) the same aligning procedure can be applied to the groups themselves. The groups can be considered as single meshes and they can be operated in the same way as the individual meshes. When the groups are going to be glued and processed, the group that holds them (usually Global) has to be selected as working group (Section 5.2.). One of the unglued groups is marked and glued with the menu option *Glueing* > *GlueHere* or by *RightMouse* > *GlueHere*. The other groups are then glued to this first one by either manual glueing or by point-based glueing (as described in Section 4.4.), depending

on which methods is best suited for the particular case. To calculate the alignment between the different groups the button *Process* is pressed, exactly as it was done for the separate meshes.

4.4. Select worst arc in a group

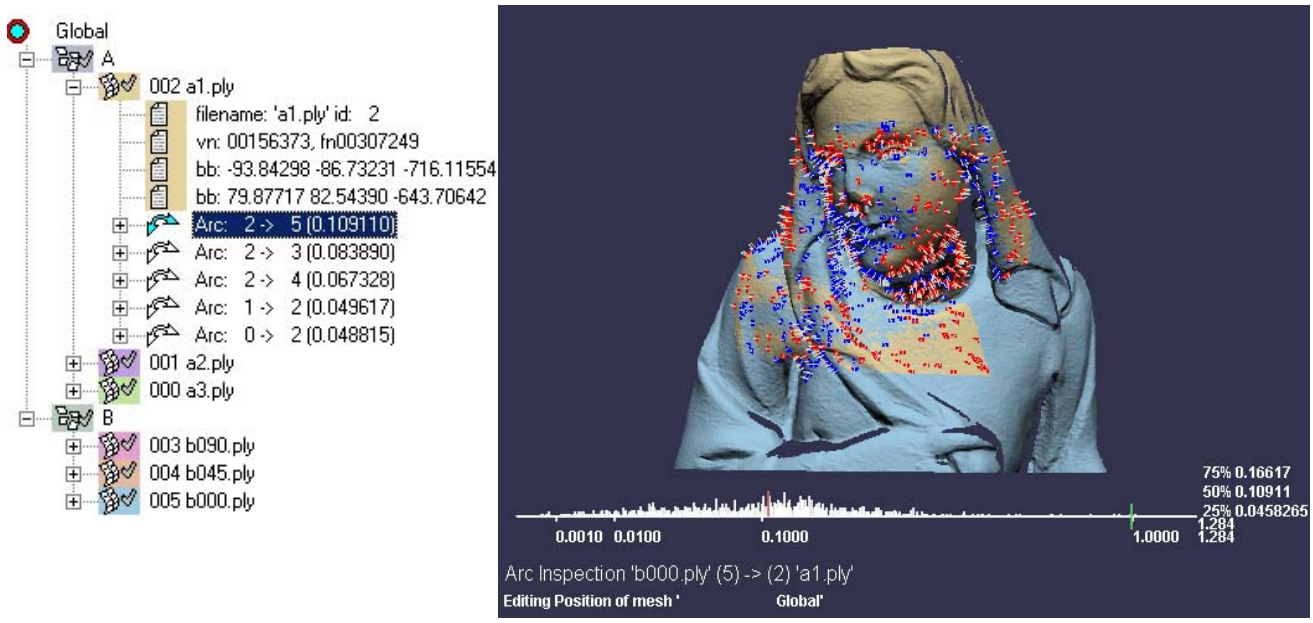
In order to improve the arc between two meshes (or groups) with highest error in a group, click on the group and *RightMouse > SelectWorstArc* or select one of the menu options *Group > SelectWorstArc* or *Arc > SelectWorstArc*. This will point out the worst arc, the arc with the biggest error, within the selected group.

5. Arcs

Arcs are created between different meshes (or groups) when they have been glued and the button *Process* is being pressed. An arc is the result of a mesh-to-mesh alignment and stores the rigid transformation that aligns a mesh to the other one. The error of an arc is a measure of how well the overlap between two meshes can be made coincident. All the arcs involving a given mesh can be seen in the tree-structure by clicking on the plus-sign next to the mesh. A mesh will have one arc for every connection it has with another mesh.

5.1. Id-numbers & errors of an arc

Next to the arc icon in the tree-structure (Figure4a), there are two id-numbers which indicate which two meshes the arc connects. Beside the id-numbers there is a number that shows the error of the arc and this demonstrates with what accuracy one mesh has been connected to another. If the error number is for example 0.1 it means that 50% of the connecting points (between the two meshes) have an error less than 0.1 in unit of the mesh (usually, range maps are given in millimeters). When an arc is selected in the tree-structure, this 50% limit can also be seen in the lower right part of the visualization window (see Figure 4b), together with the 25% and 75% limits. Furthermore, there is a distribution graph illustrating how the errors of the connection points are spread (red line showing the 50% limit).



a b

Figure4. a. *The arc in the tree-structure with the id-numbers of the connected meshes and the 50% error limit.*
b. *The visualization of the arc with the error vectors for each connection point, the error distribution graph and the different error limits (25%, 50% and 75 %.).*

5.2. Improving an arc

If clicking *RightMouse* > *InspectCurrentArc* or choosing menu option *Arc* > *InspectCurrentArc,* the two meshes that belong to the arc are shown (in the visualization window) together with error vectors for all the connection points. To improve the error for the arc the option *RightMouse* > *RecomputeArc* or the menu alternative *Arc* > *RecomputeArc* can be chosen. This operation will recalculate the arc and if the alignment parameters have been changed the arc will hopefully be improved. The alignment parameters for the marked arc can be changed by *RightMouse* > *AlignmentParamCurrentArc* or by the menu option *Arc* > *AlignmentParamCurrentArc*. Also the global alignment parameters (default for all arcs) can be changed through the menu alternative *Arc* > *AlignmentParamDefaults*. To get out of the inspection mode for an arc, click again *RightMouse* > *InspectCurrentArc* or choose *Arc* > *InspectCurrentArc* and to hide the error vectors click *RightMouse* > *UnSelect* or select in menu *Arc* > *UnSelect*.

If the user wants to take away an arc he/she can do *RightMouse* > *DeleteArc* or use the menu alternative *Arc* > *DeleteArc.* This command will delete the arc but if the group is processed again there will be a new arc calculated between these two meshes. If the user instead wants to make sure that the arc is not considered anymore in the project it can be indicated as invalid by *RightMouse* > *InvalidateArc* or through the menu alternative *Arc* > *InvalidateArc*. This will put a special invalidation symbol on this particular arc, which indicates that no arc exists between the two meshes with these id-numbers and will not be created in future calculations either.