

ICP module

The Iterative Closest Point Algorithm module is the file `icpa.dll`. If this DLL exists in the directory of EIKONA3D when the program starts, a sub-menu called *ICP Algorithm* is added under the *Modules* menu. The menu options of this sub-menu provide two methods (*Classical* and *Morphological*) of Iterative Closest Point Algorithm (ICPA).

The Classical method accomplishes the original ICPA which proposes a solution to a key registration problem in computer vision: given a cloud of 3D model points and a cloud of 3D data points, estimate the optimal translation and rotation that register the two point clouds by minimizing the mean square Euclidean distance between them. This method is described in [1]. A crucial drawback of this method is the high computational complexity of the closest point operator. The Morphological method solves this problem by using a 3D array representing a volume and by constructing the Voronoi diagram of the model points within this volume, by using the morphological Voronoi tessellation method. Then, the ICP algorithm is employed, with distance calculations substituted by simple array references.

An important application of the Iterative Closest Point Algorithm is to register actual data sensed from a 3D object with an ideal 3D model. It is also useful in multimodal 3D image registration in medical imaging (e.g. between NMR and CT volumes), in the shape equivalence problem, as well as in estimating the motion between point sets when the point correspondences are not known. The procedure followed for each method in our module is described below:

1. Classical ICP Algorithms

This menu option performs the Classical ICP algorithm. In this method the user has first to select the model and data volumes (Figure 1-2) which can be only grayscale. Normal projection of the object seen in Figures 1-2 can be seen in Figure 3. It is strongly recommended that the model and data volumes should have the same size. Then he has to define the appropriate parameters for the *Initial Rotation Vector* and the *Threshold* through the *Classical ICP Algorithm* dialog box (Figure 3). These two parameters are described in detail below.

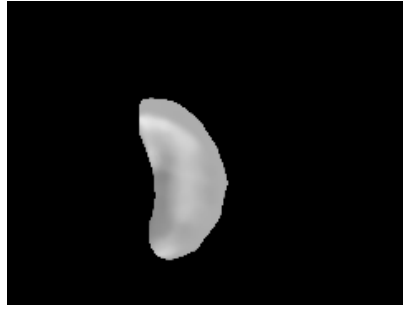


Figure 1: A frame of the model volume.



Figure 2: A frame of the data volume (the model volume rotated and translated along x-axes and translated along y-axes).

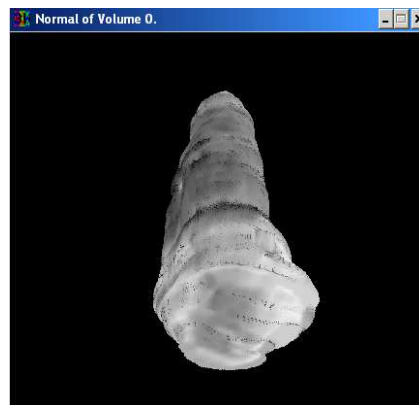


Figure 3: Normal projection of the object seen in Figures 1-2.

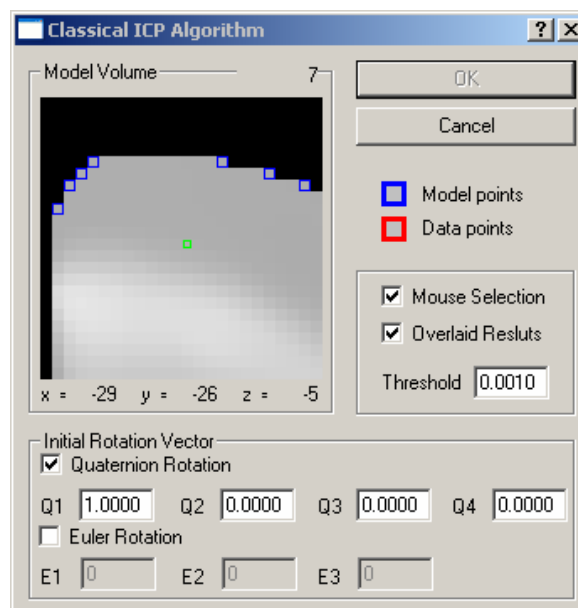


Figure 4: The Classical ICP Algorithm dialog box.

Initial Rotation Vector: There are two options. User can select one initial vector each time. The Quaternion Rotation is a four dimensional vector which is applied to the data points set before the ICP Algorithm starts. A possible convergence of the algorithm in a local minimum depends on this vector. The only way to make sure that we reach the global minimum is to start the algorithm from different initial rotation vector. So if you are not satisfied with the result or if the final mean square error is not small enough, try another initial rotation vector. The rotation vector (1,0,0,0) corresponds to no rotation. The Euler Rotation is a three dimensional vector and works in a similar manner with the previous rotation vector. (The rotation vector (0, 0, 0) corresponds to no rotation).

Threshold: This is used to terminate the algorithm when the change in mean square error, between two iterations of the closest point operator, falls below threshold. You can reduce this threshold if you are not satisfied with the result. Also in this dialog box there is the option *Mouse Select*. If this option is checked, the user is able to select with his mouse the model and data points by clicking on the corresponding volumes. Alternatively, he can define automatically these two points sets by selecting two volumes, after he has pressed the *OK* button and if the option *Mouse Select* is not checked. In such a case, the points of each set are defined by the non-zero voxel values of the selected volumes, which must be grayscale. A simple method to take these two volumes from the model and data volumes is by applying a threshold to them. In the dialog box, there is also the option *Overlaid results*. If this option is checked, when the process terminates, the user will be prompted to select an output volume where the model and the registered volumes are shown overlaid to the same buffer. Furthermore, there is a view area, where the user can see an enlarged small part of the model or data volume. He can also see the current position of the mouse in the volume and the number of points of the corresponding point set. In this area a model point is displayed with a blue rectangle around it, while a data point is displayed with a red rectangle around it. This allows him to select and view the model and data points.

On the next step, if the user has decided to select the model and data points sets automatically, he will be prompted to select the corresponding volumes. After this the Classical ICP Algorithm starts execution. A progress dialog box shows the number of

model and data points and the mean square error of the current iteration. At this point the user is able to interrupt the whole process by pressing the *Cancel* button.

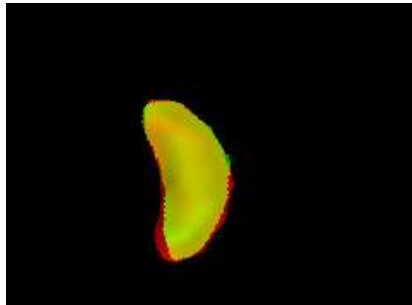


Figure 5: A frame of the overlaid model (red channel) and registered (green channel) volumes of Figures 1-2.

When the algorithm terminates the user is prompted to select the output volumes where the data volume will be registered and where the overlaid model and registered volumes will be shown (Figure 5) and then the *Results* dialog box (Figure 6) will appear. This dialog box shows the results of the algorithm such as the rotation (both in quaternion and Euler space) and translation vectors. Furthermore, it displays the duration of each step of the algorithm:

CPO: This refers to the calculation of the closest point correspondence only.

CPO mean: This is the mean duration of the CPO for one iteration of the algorithm.

ICP pure: This refers to the time needed for ICP algorithm, excluding CPO.

ICP: This is the total duration of the ICP algorithm.

Finally, there is the same view area with the *Classical ICP Algorithm* dialog box, which helps the user to check, if the result of the algorithm is acceptable, since he can see together the model and the registered data points and the correspondence between them.

2. Morphological ICP

This menu option performs the Morphological ICP method. In this method, the user has first to select the model and data volumes and then the model and data points volumes. Attention should be paid to the model and data points sets in order to avoid unexpected results. For example, the model points volume must be large enough to include the data points set and its probable rotation during the ICPA. Otherwise it is possible that some of the data points fall out of the Voronoi tessellation volume and

the result may not be reliable enough. At this point we have to mention that the center of the axes is the middle of the volume. Thus, it is preferable to have the same dimensions for all used volumes.

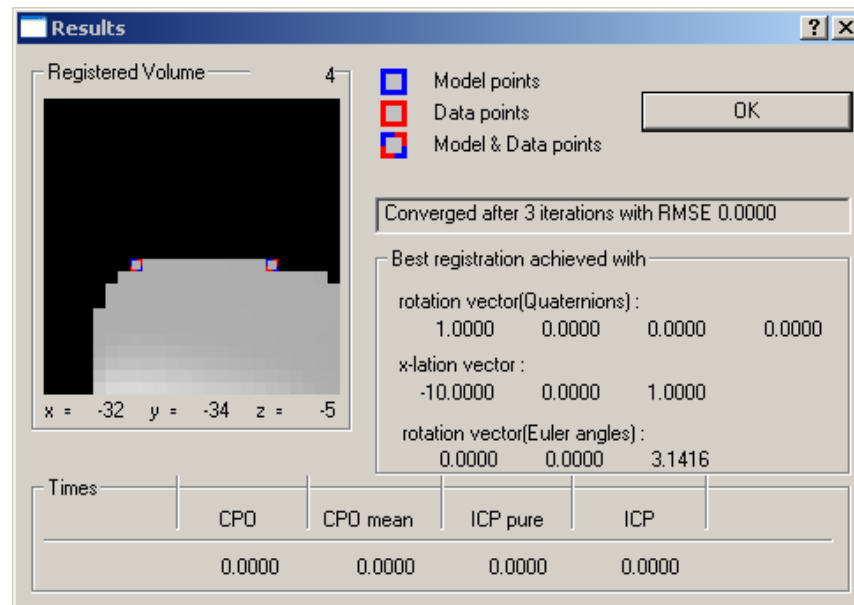


Figure 6: The *Results* dialog box for the Classical ICP Algorithm.

Through the *Morphological ICP Algorithm* dialog box the user can define the *Initial Rotation Vector* and the *Threshold* parameters which are the same to the ones of the *Classical ICP Algorithm* dialog box. In the dialog box, there is also the option *Overlaid results*. If this option is checked, when the process terminates, the user will be prompted to select an output volume where the model and the registered volumes are shown overlaid to the same buffer.

Also in this dialog box he can decide whether he will save or load the result volume of the Voronoi tessellation process by checking the corresponding options (Figure 7) which are described below:

Load Tessellation: If this option is checked, the user will be prompted to select the tessellation file from the disk before the ICP Algorithm starts. This tessellation file must correspond to the currently selected model points volume, otherwise the result will not be correct.

Save Tessellation: If this option is checked, the user will be prompted to enter a name for the tessellation file after the Voronoi tessellation process. This tessellation file can

be used in the future when we want to register another data volume with the same model volume.

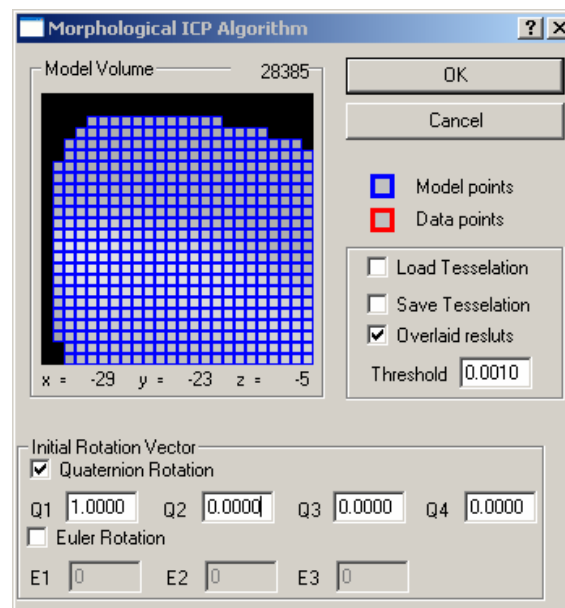


Figure 7: The Morphological ICP Algorithm dialog box.

With these two options we can avoid the time consuming tessellation process, if we want to run the Morphological ICP Algorithm several times for the same model and model points volume.

After this, the Voronoi tessellation starts the execution if the user has not loaded a tessellation file, while a progress dialog box shows the current elapsed time and the estimated time for this process. Then, the Morphological ICP Algorithm starts and the progress dialog box shows the number of model and data points and the mean square error of the current iteration. At this dialog box the user is able to interrupt the whole process by pressing the *Cancel* button.

When the algorithm terminates the user is prompted to select the output volume where the data volume will be registered and where the overlaid model and registered volumes will be shown (Figure 5) and then the *Result* dialog box (Figure 8) will appear.

This dialog box is the same with the Classical ICP method except for two elements:

VT: This refers to the duration of the Voronoi tessellation process.

ICP full: This is the entire duration of the Morphological ICP algorithm.

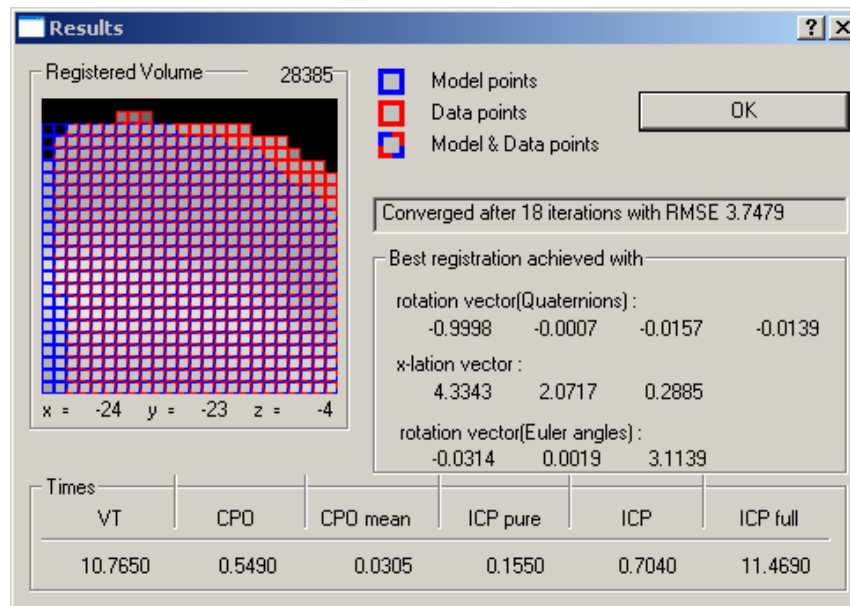


Figure 8: The *Results* dialog box for the Morphological ICP Algorithm. The only difference with the corresponding dialog box of the Classical ICP Algorithm is the times VT and ICP full.

Finally we have to mention that a help context has been implemented so the user can have a small description of each element at any dialog box.

References

- [1] N.Nikolaidis, I.Pitas '3D image processing algorithms', Wiley 2000.