Morphological Techniques in the Iterative Closest Point Algorithm

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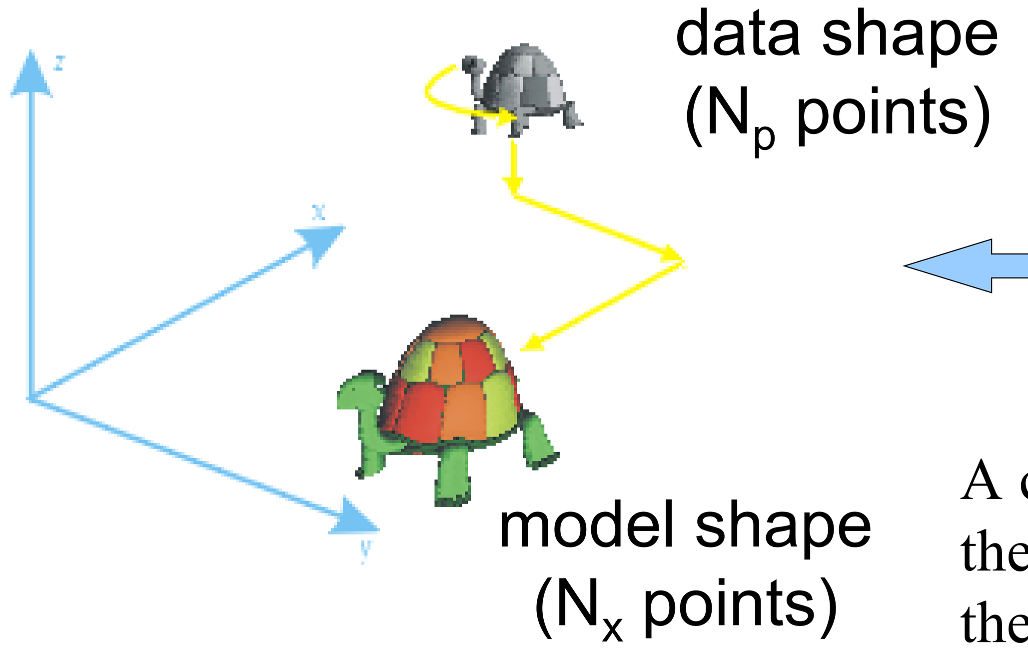


Abstract

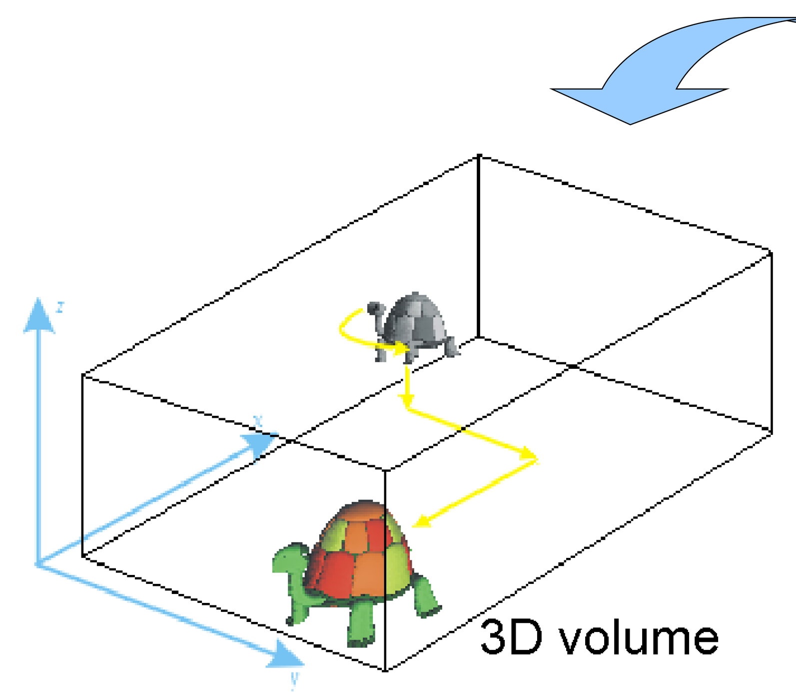
The Iterative Closest Point (ICP) algorithm faces a key registration problem: given a “model” 3-D shape and a “data” 3-D shape, estimate the optimal translation and rotation that register the two shapes by minimizing the mean square Euclidean distance between them.

A crucial drawback of the algorithm is the high computational complexity of the **closest point operator**. This is clearly an $O(N_x N_p)$ operation.

```
ICP Algorithm("data" point set P, "model" point set X)
. . .
main loop
{    . . .
     for each data point p in P associate p with
     the model point in X which is closest to p.
     . . .
}
```

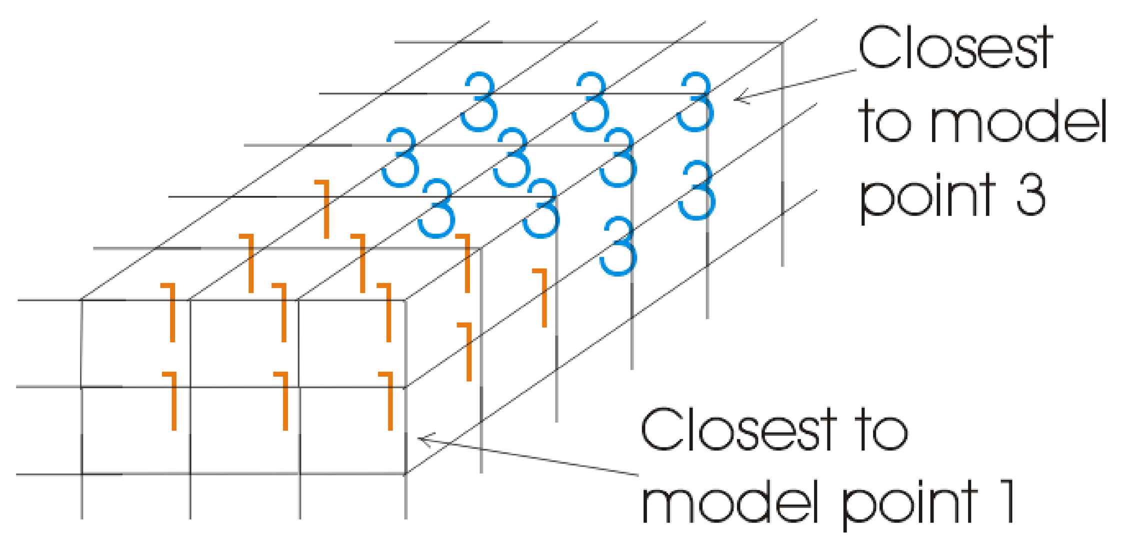
We remove this inefficiency with the use of appropriate morphological techniques. The operator’s complexity declines to $O(N_p)$.

The Method



First, a 3-D volume that contains both shapes is found. The volume is implemented as an integer 3-D array.

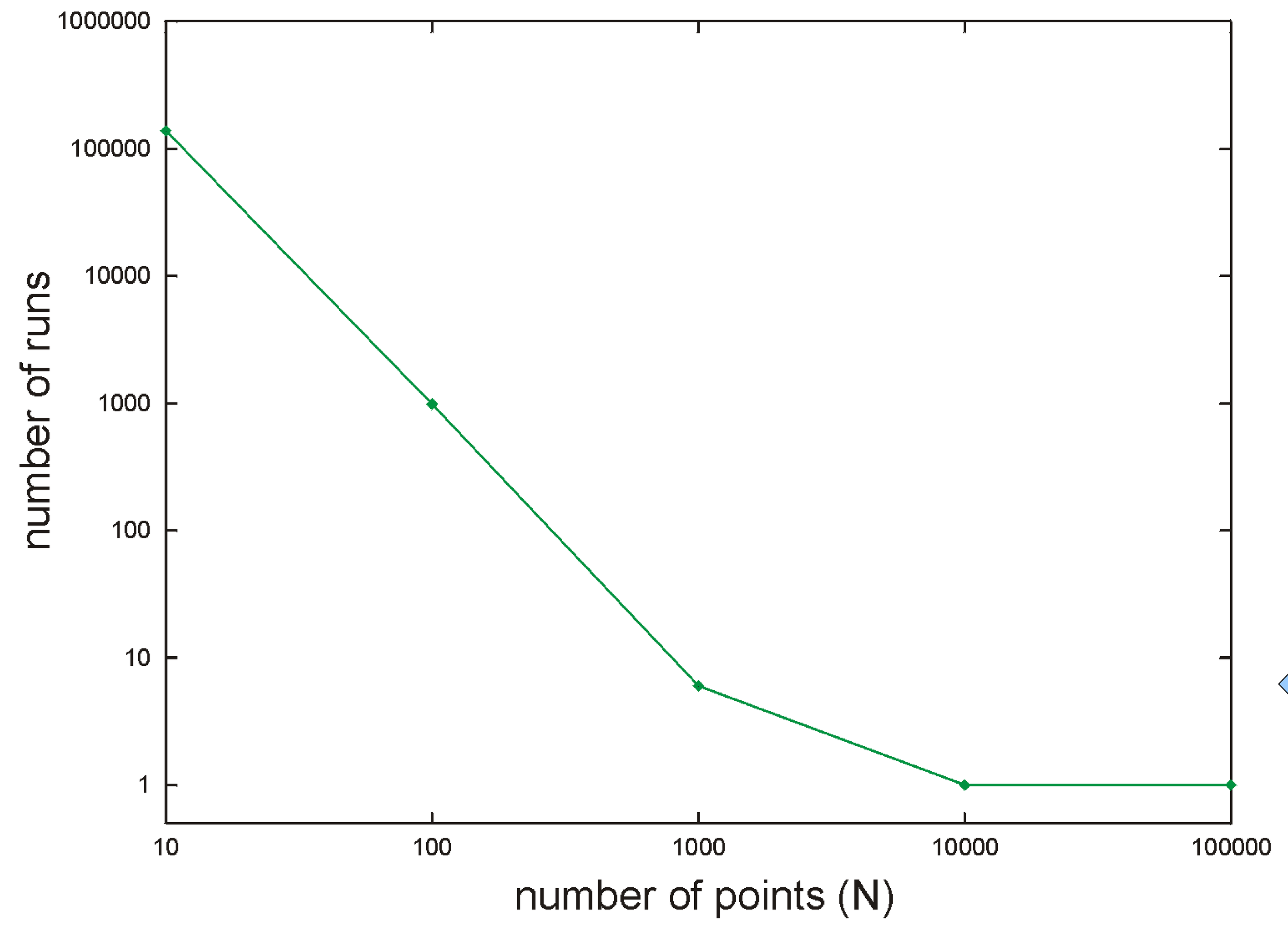
Then, the discrete Voronoi diagram of the points of the model shape is constructed within the volume. That is, each voxel in the volume is set to the index (1,2,…,N_x) of the closest model point.



Finally, the ICP algorithm is run, with a **faster implementation of the closest point operator**. Minimum distance calculation is replaced by a simple reference to the proper voxel of the volume.

```
ICP Algorithm("data" point set P, "model" point set X, volume V)
. . .
main loop
{    . . .
     for each data point p in P associate p with the model point V[p].
     . . .
}
```

We name the method *Morphological ICP Algorithm*, as opposed to the *classical ICP algorithm*.

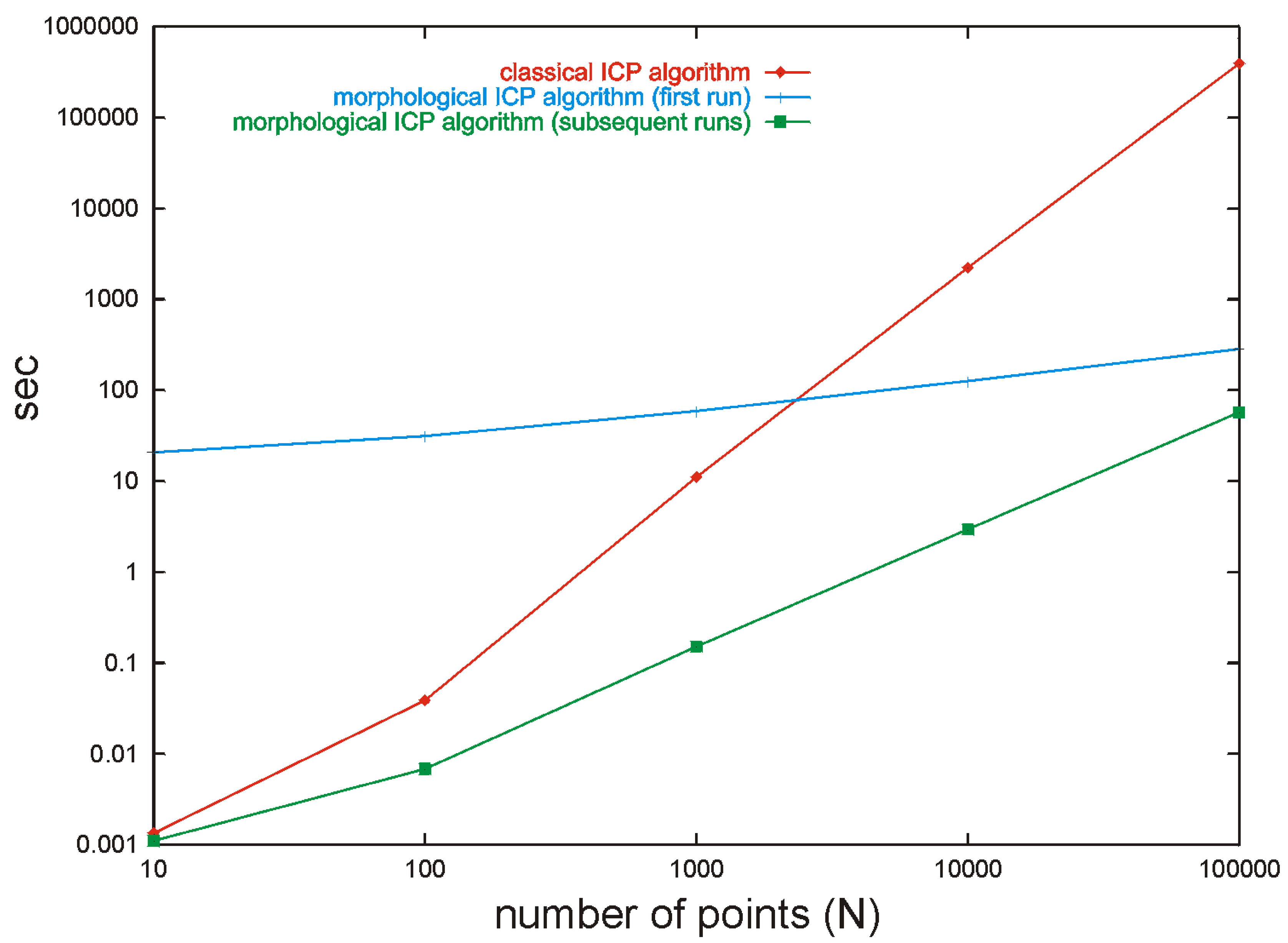


Results

Comparative experiments have been performed on model and data shapes that reside within a **100×100×100 volume** and **consist of N points each**, for several values of N. Measurements of the time performance of the classical and the morphological ICP algorithm justify the choice of the latter in cases where at least one of the following is true:

1. *the number of model/data points is large (N > 1000)* (See blue line versus red line).
2. *for the same model and data shapes, the algorithm has to run a lot of times, till the best matching is found.*
3. *many data shapes are to be matched with the same model shape.*

In cases 2 and 3, the Voronoi diagram can be constructed **only once**, during the first run of the algorithm (blue line), and be used by all subsequent runs (green line).



For each value of N, there is a minimum number of runs over which the morphological ICP algorithm becomes the best choice. The variation of this number proves the usefulness of the morphological ICP algorithm.