Medical Image Processing for Diagnostic Applications

Iterative Closest Point Algorithm – Variants

Online Course – Unit 71

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Topics

Efficient Variants of the ICP Algorithm

Summary

Take Home Messages

Further Readings

Efficient Variants of the ICP Algorithm [1]

Variants grouped by affecting one of the following six stages of the algorithm:

1. Selection of some points in one or both meshes
2. **Matching** these points to samples in the other mesh
3. Weighting the corresponding pairs appropriately
4. Rejecting certain pairs based on looking at each pair individually or considering the entire set of pairs
5. Assigning an **error metric** based on the point pairs
6. **Minimizing** the error metric

(1) Selection of Points

- Always using all available points
- Uniform subsampling of the available points
- Random sampling (with a different sample of points at each iteration)
- Selection of points with high intensity gradient, in variants that use per-sample color or intensity to aid in alignment
- Each of the preceding schemes may select points on only one mesh, or select source points from both meshes
- Using distribution of normals among the selected points

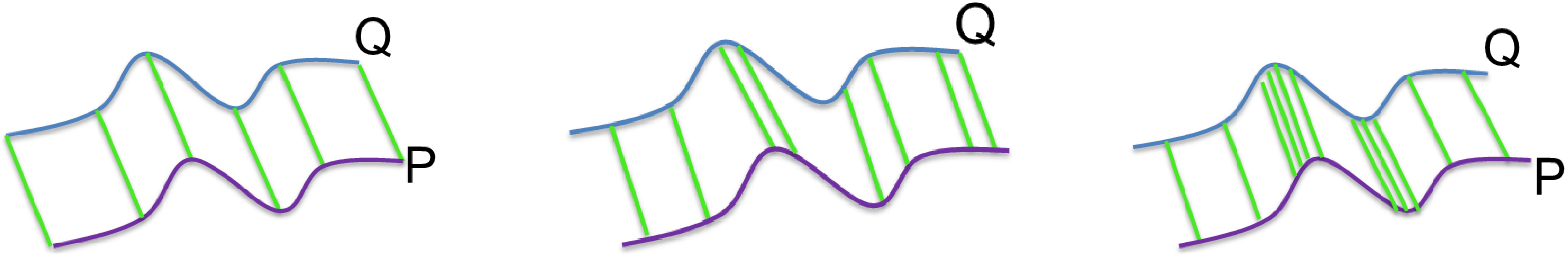

Figure 1: Possible selection strategies

(3) Weighting of Pairs

- Constant weight
- Assigning lower weights to pairs with greater point-to-point distances
- Weighting based on compatibility of normals
- Weighting based on the expected effect of scanner noise on the uncertainty in the error metric

Algorithm 1: Iterative closest point

Input : Two point clouds: P, Q
Output: Transformation $\boldsymbol{T}$, which aligns P and Q

$\boldsymbol{T} \leftarrow \boldsymbol{T}_0$;
while *not converged* **do**
  for $i \leftarrow 1$ **to** N **do**
    $\boldsymbol{c}_i \leftarrow$ `GetClosestPointInQ(`$\boldsymbol{T} \cdot \boldsymbol{p}_i$`)`;
    if $\|\boldsymbol{T} \cdot \boldsymbol{p}_i - \boldsymbol{c}_i\| \leq \theta_{max}$ **then**
      $\omega_i \leftarrow 1$;
    else
      $\omega_i \leftarrow 0$;
    end
  end
  $\boldsymbol{T} \leftarrow \arg\min_{\boldsymbol{T}} \sum_i^N \omega_i \|\boldsymbol{T} \cdot \boldsymbol{p}_i - \boldsymbol{c}_i\|^2$;
end

(4) Rejecting Pairs

- Rejection of corresponding points more than a given distance apart
- Rejection of the worst n% of pairs based on some metric
- Rejection of pairs whose point-to-point distance is larger than some multiple of the standard deviation of distances
- Rejection of pairs that are not consistent with neighboring pairs
- Rejection of pairs containing points on mesh boundaries

Figure 2: Possible rejection strategies

Pros and Cons

+ Simplicity
+ Relatively quick performance (implemented with kd-trees for closest-point look up)

- Implicit assumption of full overlap of the shapes (maximum distance threshold)
- Theoretical requirement: points are taken from a known surface (different discretizations)

Topics

Efficient Variants of the ICP Algorithm

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- Take Home Messages
- Further Readings

Take Home Messages

Summary of the last three units:

- ICP = Iterative Closest Point
- Introduced early 1990s
- Goal: Find transformation between two point clouds via minimization of the difference
- Different data types
- Point-to-Point Metric
  - SVD
  - Quaternions
- Point-to-Plane Metric
- Variants of the ICP

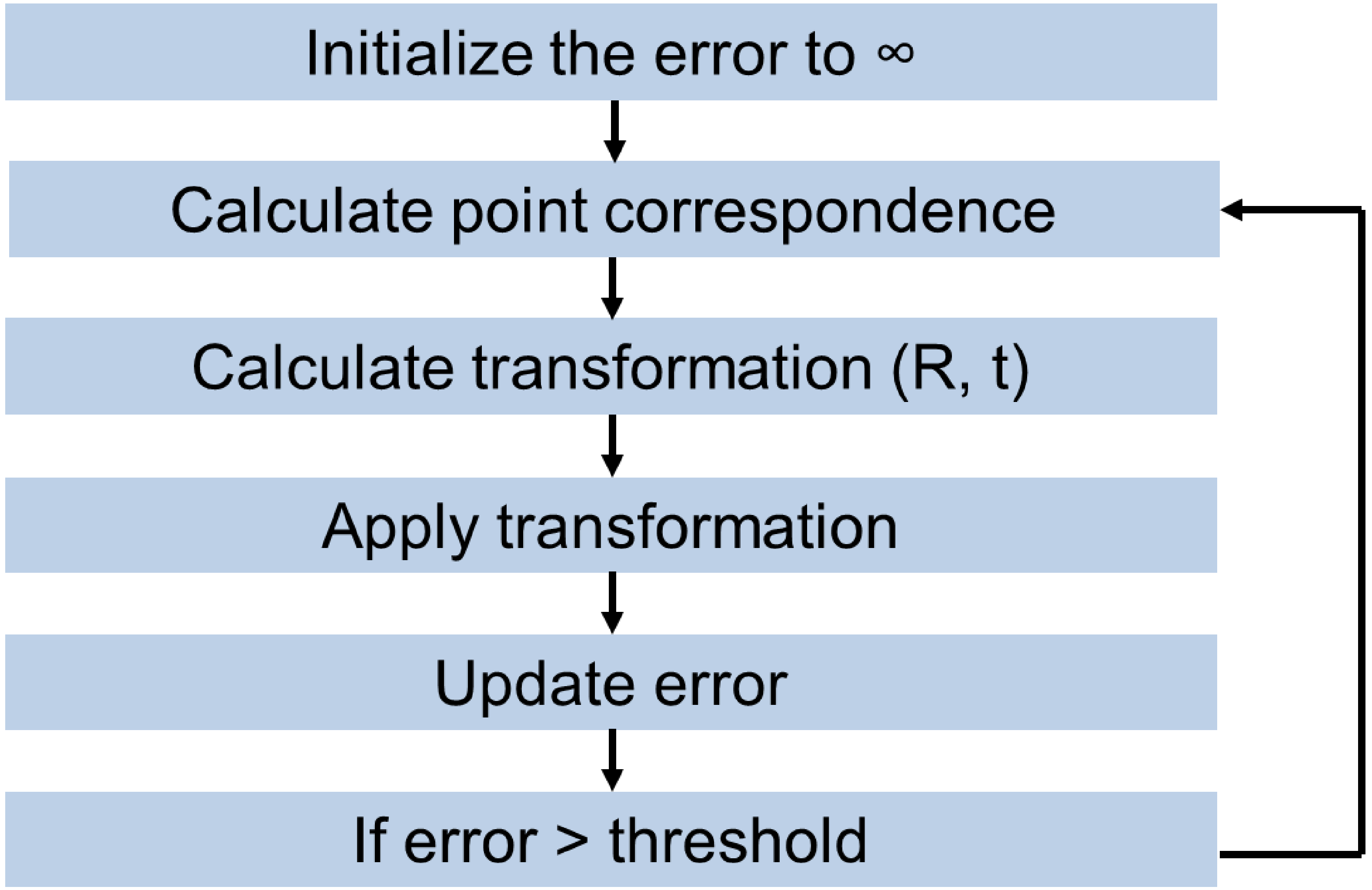

Figure 3: Scheme of the ICP algorithm

Further Readings

[1] Szymon Rusinkiewicz and Marc Levoy. "Efficient Variants of the ICP Algorithm". In: *Third International Conference on 3-D Digital Imaging and Modeling, 28 May – 1 June, Quebec City, Canada. Proceedings*. IEEE, 2001, pp. 145–152. DOI: 10.1109/IM.2001.924423.

[2] Aleksandr V. Segal, Dirk Haehnel, and Sebastian Thrun. "Generalized-ICP". In: *Robotics: Science and Systems V, Seattle, USA, June 28 – July 1, 2009*. MIT Press, 2009. DOI: 10.15607/RSS.2009.V.021.