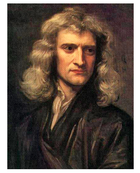
Gravitational Approach for Point Set Registration

Vladislav Golyanik[12], Sk Aziz Ali[1] and Didier Stricker[12]
[1]University of Kaiserslautern, Germany
[2]German Research Center for Artificial Intelligence, Kaiserslautern, Germany



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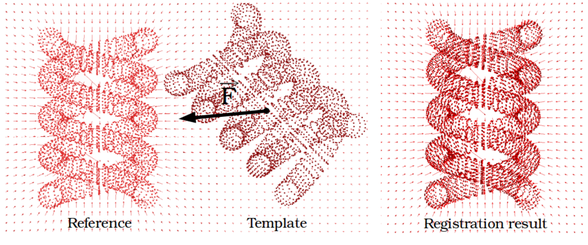
Problem/Motivation

- Given two point sets (a reference and a template), to recover is a **rigid** transformation as well as correspondences between the point sets
- Motivation: **well parallelizable** rigid point set registration methods are sensitive to noise, whereas robust methods are not fully scalable
- We propose to formulate rigid point set registration as a **collisionless N-body simulation** problem; using a new interpretation leads to a conceptually new algorithm with unique properties

Overview of the method

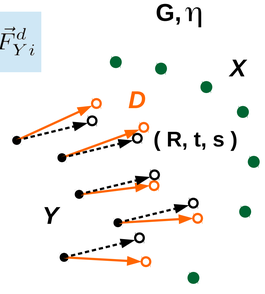


$$\vec{F}_{Yi} = -Gm^{Yi} \sum_{j=1}^{N} \frac{m^{Xj}}{(\|r^{Yi} - r^{Xj}\|^2 + \epsilon^2)^{3/2}} \hat{\mathbf{n}}_{ij}$$

$$\vec{F}^d_{Yi} = -\eta\, \vec{v}^{Yi} \qquad \boxed{\vec{\mathbf{f}}_{Yi} = \vec{F}_{Yi} + \vec{F}^d_{Yi}}$$

$$\vec{v}^{t+1}_{Yi} = \vec{v}^t_{Yi} + \Delta t\, \frac{\vec{\mathbf{f}}_{Yi}}{m^{Yi}} \quad \text{(velocity)}$$

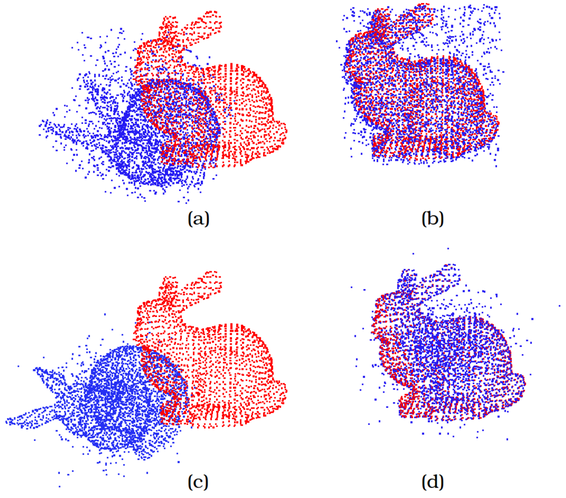
$$\vec{d}^{t+1}_{Yi} = \Delta t\, \vec{v}^t_{Yi} \quad \text{(displacement)}$$

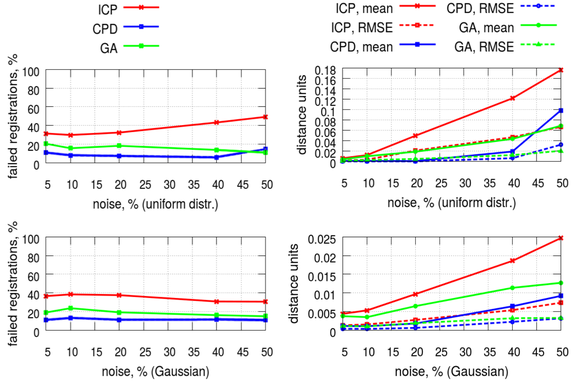


Gravitational potential energy:

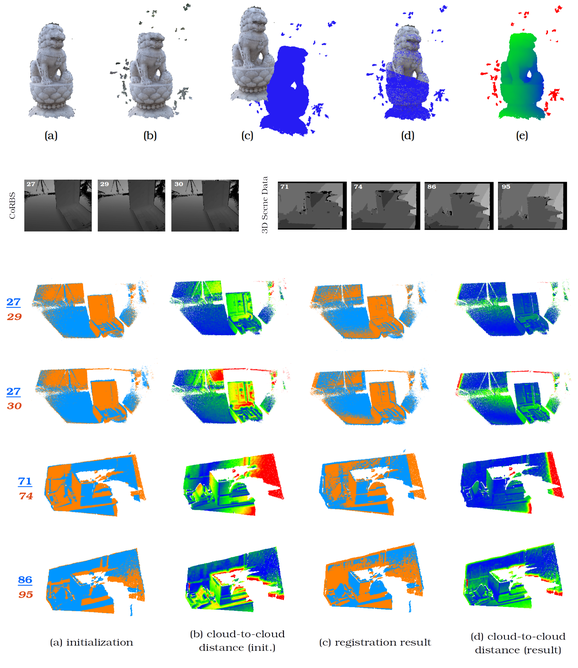
$$E(\mathbf{R},\mathbf{t},\mathbf{s}) = -G \sum_{i,j} \frac{m^{Yi}\, m^{Xj}}{\|\mathbf{R}\, r^{Yi}\, \mathbf{s} + \mathbf{t} - r^{Xj}\| + \epsilon}$$

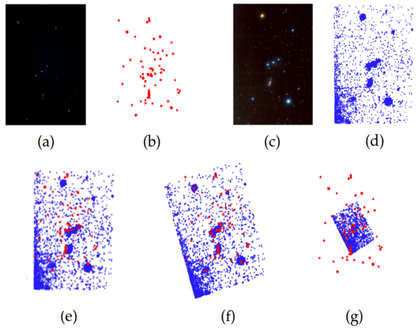
Experiments (Synthetic Data)





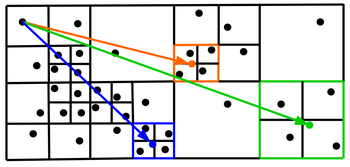
Experiments (Real Data)





Acceleration methods

- Ahman-Cohen (AC) neighbour scheme
- Barnes-Hut (BH-) octree (quadtree in 2D)
- Fast multipole methods (FFM)
- A precomputed mean force field ("particle-mesh")
- Subsampling, coarse-to-fine strategy
- kd-trees
- Parallel hardware



$$\mathcal{O}(MN)$$
$$\mathcal{O}(M \log N)$$
$$\mathcal{O}(M+N)$$

References

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