Fast Simultaneous Gravitational Alignment of Multiple Point Sets

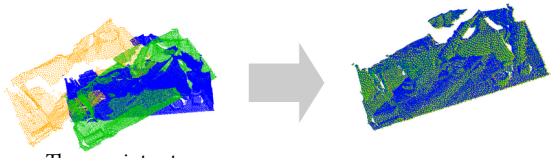
Vladislav Golyanik Soshi Shimada Christian Theobalt

Max Planck Institute for Informatics Saarland Informatics Campus

3DV 2020

Rigid Point Set Alignment

Recovery of a displacements and correspondences between point sets



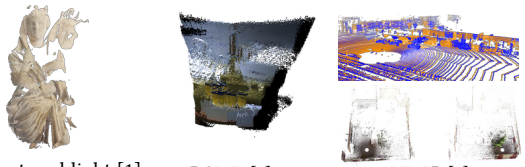
Three point sets Registration result

Contributions

i) The first gravitational method for multi-body point set alignment
ii) Acceleration of globally multiply-linked point interactions with a 2^D-tree; this data structure enables a new fast shape signature based on polynomial fitting
iii) Experimental evaluation with SotA results

Related Works

Different Data Modality



Structured light [1] RGB-D [2] LIDAR [3]

Joint Alignment

Ten point sets Registration result [2] Gravitational approach [1]

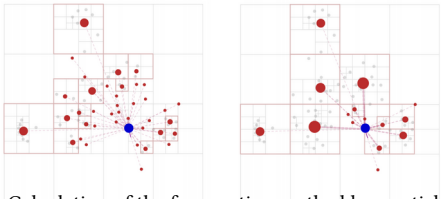
Multi-Body Gravitational Approach

Gravitational potential energy with Barnes-Hut acceleration:

$$\mathbf{E_C(T)} = \sum_{l=1}^{L} \sum_{i=1}^{|\boldsymbol{Y}_l|} \sum_{\mathbf{c}_j \in \mathbf{C}_{l,i}} \left(m^l_{\mathbf{p}_i} \, m_{\mathbf{c}_j} \left\| g(\mathbf{T}_l, \mathbf{p}^l_i) - \mathbf{c}_j \right\|_2 \right)$$

$g(\cdot)$: rigid translation operator $\mathbf{T}$: set of transformations to be recovered

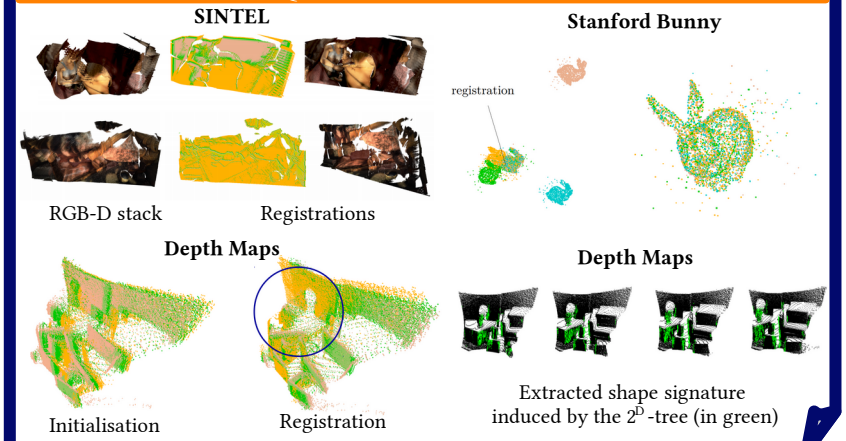
For each point set $\boldsymbol{Y}_l$, evaluate the gravitational potential at point $\mathbf{p}^l_i \in \boldsymbol{Y}_l$ induced by the fetched clusters $\mathbf{c}_j \in \mathbf{C}_{l,i}$ from the 2^D-tree.



Calculation of the force acting on the blue particle

Results

Qualitative Results



RGB-D stack Registrations

Initialisation Registration Extracted shape signature induced by the 2^D-tree (in green)

Results

Metrics

growing reference (GRef) *one-to-many* (1-M)

The average 3D RMSE error:

$$e_{3D} = \binom{L}{2}^{-1} \sum_{\{i,j\} \in \Phi} \frac{\|g(\mathbf{T}_i, \boldsymbol{Y}_i) - g(\mathbf{T}_j, \boldsymbol{Y}_j)\|_{\mathcal{F}}}{\|g(\mathbf{T}_i, \boldsymbol{Y}_i)\|_{\mathcal{F}}}$$

Φ denotes all combinations of two point sets out of L

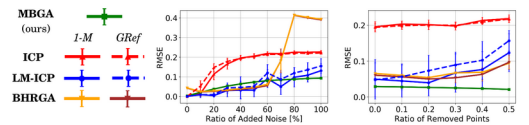
$\binom{L}{2} = |\Phi|$ is the total number of combinations

+ std. dev. of RMSE denoted by σ

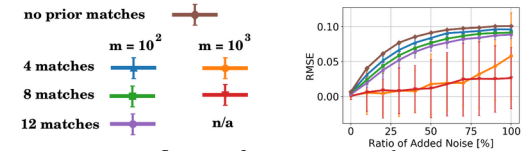
Quantitative Results

		ICP[4]	LM-ICP[5]	BHRGA[1]	JRMPC [2]	MBGA
N	e_{3D}	0.2244	0.1435	0.392	**1.5E-4**	**9.4E-2**
	σ	6.4E-3	3.7E-2	1.4E-3	**5.6E-5**	**1.1E-3**
R	e_{3D}	0.2181	0.1403	**9.6E-2**	**1.3E-3**	**2.1E-2**
	σ	8E-3	4.1E-2	**1.7E-2**	**3.6E-4**	**4.8E-4**

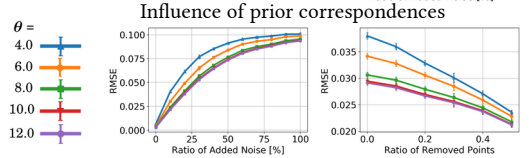
N: 100% of added uniform noise R: 100% of randomly removed points



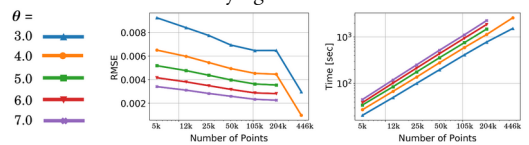
Comparison against pairwise algorithms



Influence of prior correspondences



Varying 2^D-tree threshold



Runtime vs Accuracy

References

[1] V. Golyanik et al. Accelerated Gravitational Point Set Alignment with Altered Physical Laws. In ICCV, 2019
[2] G. D. Evangelidis and R. Horaud. Joint alignment of point sets with batch and incremental expectation maximization. TPAMI, 2018.
[3] F. Järemo Lawin et al. Density adaptive point set registration. In CVPR, 2018.
[4] P. J. Besl and N. D. McKay. A method for registration of 3-d shapes. TPAMI, 1992.
[5] A. Fitzgibbon. Robust registration of 2d and 3d point sets. In BMVC, 2003.