PARTIAL 3D OBJECT RETRIEVAL

Guide: Dr. Shankar G.

Presented by:
1. Apoorva Malemath
2. (USN-01FE16BCS041)

Outline

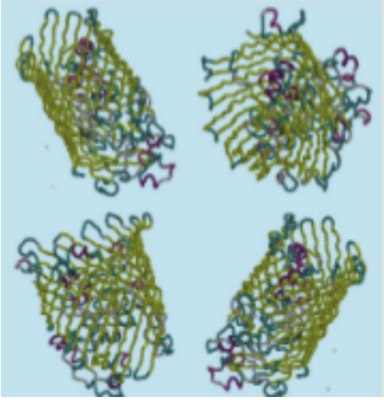
1. Motivation and Scope
2. Problem Statement
3. Objectives
4. Related Works
5. System Model
6. Methodology
7. Implementation
8. Results
9. Conclusions and Future Scope

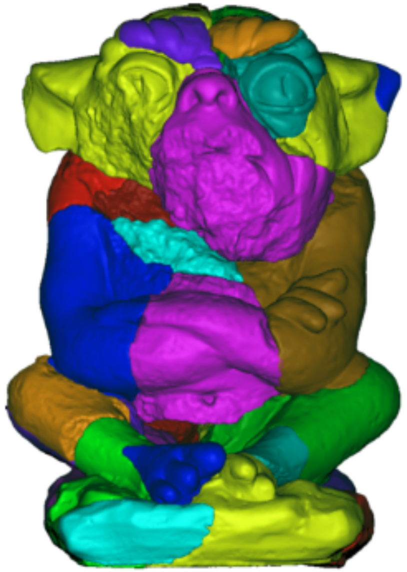
Motivation and Scope

Increasing amount of 3D data.
Ability of capture devices to **produce low-cost multimedia data**.

Applications:

1. Cultural Heritage
2. Archaeology
3. 3D protein retrieval and classification
4. 3D retrieval for museums





Problem Statement

To develop a technique to retrieve the similar objects given a partial query.

Input

Partial Query

Output

Retrieved Objects

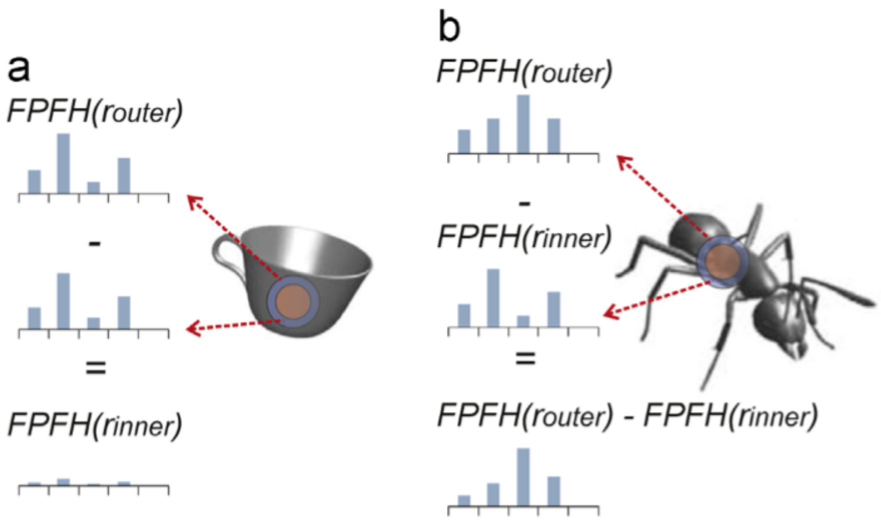
Objectives

1. To extract the features from the given 3D objects.
2. To perform encoding of the extracted features.
3. To match the input query with the dataset.
4. To evaluate the performance of the proposed technique.

Related Works

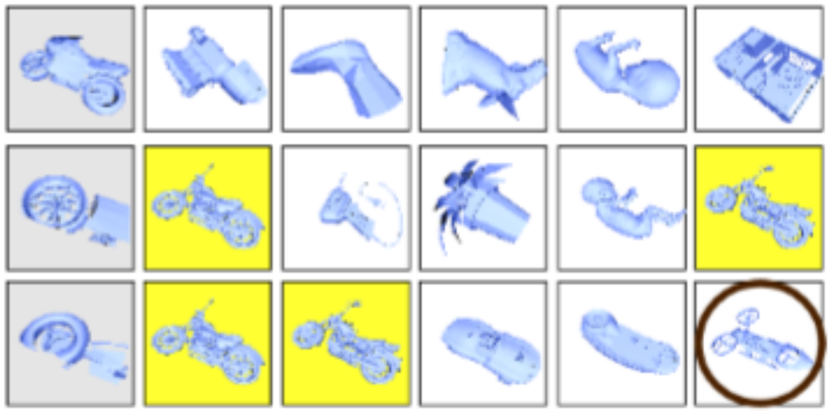
Fisher encoding of Differential Fast Point Feature histograms for Partial 3D Object Retrieval, 2016 [1]
The proposed system is based on hybrid shape matching scheme so as to account for both global and local shape similarities.

- Differential fast point feature histogram
- Fisher vector.

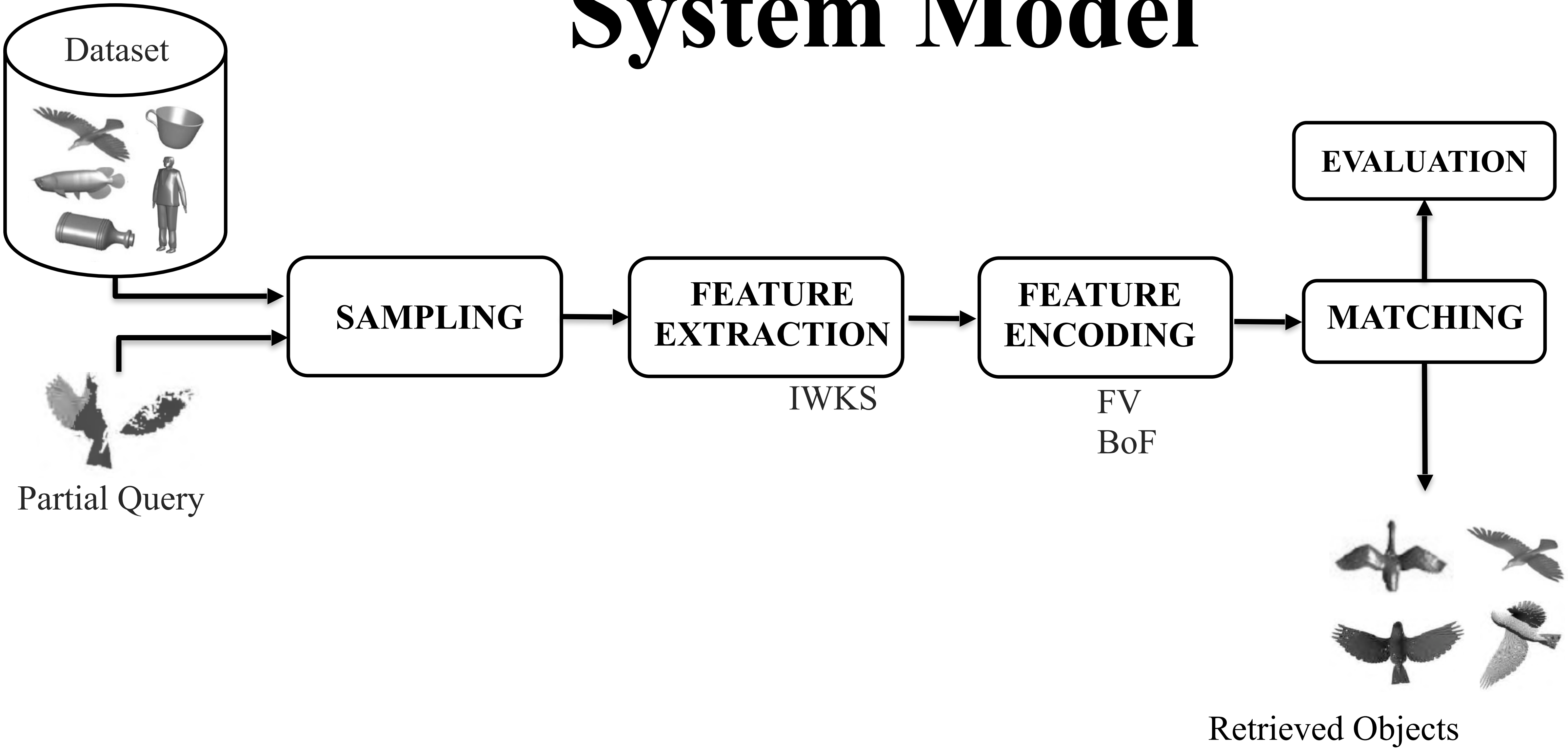


A Query-by-Example Concept and User Interface for Global and Partial 3D Object Retrieval,2009. [2]
It is based on the idea to apply an existing global 3D descriptor on both whole models and model segments.

- Partial similarity - Local to local correspondences
- Model segmentation



System Model



Methodology

1. **Feature Extraction**

   Improved Wave Kernel Signature (IWKS)

   - Characterize a point by the average probabilities of quantum particles of different energy levels.
   - Energies correspond to frequency.
   - Eigen values of the LBO.
   - Cube root scaling.
   - Curvature aggregation.

Methodology

2. **Feature Encoding**
    - **Bag-of-features (BOF)**
        - Convert the descriptors to codewords.
        - K-means clustering
    - **Fisher Vector (FV)**
        - Gaussian Mixture Model used as visual code book.
        - Captures the average first and second order differences between descriptors and the centers of GMM.

Methodology

- For Kth GMM, we define,

$$u_k = \frac{1}{N\sqrt{\pi_k}} \sum_{i=1}^{N} q_{ik} \sum_{k}^{-1/2} (x_i - \mu_k)$$

$$v_k = \frac{1}{N\sqrt{2\pi_k}} \sum_{i=1}^{N} q_{ik} [(x_i - \mu_k) \sum_{k}^{-1} (x_i - \mu_k) - 1]$$

- Fisher encoding of feature vector is given by,

$$f = [u_1^T, v_1^T, ..., u_k^T, u_k^T]$$

Methodology

3. **Matching**

- **Manhattan Distance (L1- norm)**

$$d = \sum_{i=1}^{N} |a_i - b_i|$$

- **Euclidean Distance (L2-norm)**

$$d = \sqrt{\sum_{i=1}^{N} (a_i - b_i)^2}$$

Methodology

- **Cosine Distance**

$$d = \frac{\sum_{i=1}^{N}(x_i y_i)}{\sqrt{\sum_{i=1}^{N} x_i^2}\sqrt{\sum_{i=1}^{N} y_i^2}}$$

- **Earth Mover Distance**

$$d = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} f_{i,j} d_{i,j}}{\sum_{i=1}^{M} x_i^2 \sum_{j=1}^{N} f_{i,j}}$$

Methodology

4. Performance Evaluation

Nearest Neighbor (NN)

- Ratio of objects in the query's class that are present in the top N matches. N=1 is considered.
- **First Tier (FT)**
- Given a query, it is the precision when C objects have been retrieved, where C is the number of relevant objects. $K=|C|-1$ is considered for first tier.

Methodology

Second Tier (ST)

- Given a query, it is the precision when 2*C objects have been retrieved, where C is the number of relevant objects in the 3D dataset. K = 2∗(|C|−1) for the second tier.
- **E-measure**
- F-measure, which is the weighted harmonic mean of precision and recall. F-measure is defined as:

$$F = \frac{(1+\alpha) \times precision \times recall}{\alpha \times precision + recall}$$

Where α is the weight. Let $\alpha = 1$ then,

$$F = \frac{2 \times precision \times recall}{\alpha \times precision + recall}$$

Methodology

E-measure is defined as,

$$E = 1 - F$$

$$E = 1 - \frac{1}{\frac{1}{precision} + \frac{1}{recall}}$$

Discount cumulat

- DCG penalizes the objects which are relevant and appear lower in the result list.

$$DCG_r = relevant_1 + \sum_{i=2}^{r} \frac{relevent_i}{log_2(i+1)}$$

Dataset

SHREC 2011 Range Scan
Classes : 50
Objects per class : 20

Results

Encoding	K	NN	FT	ST	E	DCG
FV	10	0.0000	0.0180	**0.0350**	**0.0223**	0.3085
	20	0.0067	0.0107	0.0303	0.0149	0.3037
	25	0.0067	0.0107	0.0310	0.0162	0.3068
	50	0.0000	0.0097	0.0310	0.0162	0.3037
	100	0.0000	0.0093	0.0293	0.0151	0.3064
	125	0.0133	0.0133	0.0347	0.0200	0.3081
	150	0.0133	0.0117	0.0303	0.0164	0.3079
	200	**0.0133**	**0.0160**	0.0317	0.0179	**0.3102**
BoF	10	0.0000	0.0143	0.0243	0.0164	0.3056
	50	0.0200	0.0217	0.0417	0.0246	0.3170
	100	0.0000	0.0140	0.0317	0.0182	0.3104
	150	0.0200	0.0177	0.0327	0.0205	0.3128
	200	0.0267	0.0257	0.0430	0.0285	0.3209
	300	0.0400	0.0257	0.0437	0.0282	0.3218
	500	0.0533	0.0240	0.0443	0.0290	0.3219
	1000	**0.0600**	**0.0527**	**0.0527**	**0.0333**	**0.3222**

Performance metrics obtained using L1-Norm for matching

Results

Encoding	K	NN	FT	ST	E	DCG
FV	10	**0.0067**	**0.0177**	0.0337	0.0221	0.3086
	20	0.0000	0.0180	0.0350	**0.0223**	0.3085
	25	0.0000	0.0183	**0.0357**	0.0218	0.3078
	50	0.0000	0.0157	0.0310	0.0195	0.3068
	100	0.0000	0.0140	0.0310	0.0187	0.3079
	125	0.0000	0.0140	0.0283	0.0182	0.3077
	150	0.0067	0.0160	0.0287	0.0190	**0.3098**
	200	0.0000	0.0153	0.0287	0.0192	0.3088
BoF	10	0.0067	0.0403	0.0690	0.0446	0.3362
	50	0.0200	0.0200	0.0387	0.0226	0.3171
	100	0.0000	0.0160	0.0407	0.0218	0.3119
	150	0.0067	0.0203	0.0383	0.0231	0.3114
	200	0.0333	0.0247	0.0460	0.0285	0.3187
	300	0.0400	0.0190	0.0450	0.0295	0.3198
	500	0.0333	0.0267	0.0503	0.0313	0.3212
	1000	**0.0533**	**0.0267**	**0.0527**	**0.0333**	**0.3222**

Performance metrics obtained using L2-Norm for matching

Results

Encoding	K	NN	FT	ST	E	DCG
FV	10	0.0133	0.0140	0.0267	0.0167	0.3064
	20	0.0133	0.0137	0.0257	0.0149	0.3073
	25	0.0133	0.0177	0.0307	0.0187	**0.3103**
	50	**0.0133**	**0.0180**	**0.0323**	0.0218	0.3108
	100	0.0133	0.0153	0.0333	0.0195	0.3065
	125	0.0133	0.0167	0.0320	**0.0197**	0.3086
	150	0.0133	0.0140	0.0300	0.0190	0.3090
	200	0.0000	0.0150	0.0320	0.0179	0.3086
BoF	10	0.0067	0.0493	0.0907	0.0569	0.3436
	50	0.0200	0.0243	0.0467	0.0277	0.3243
	100	0.0000	0.0217	0.0397	0.0249	0.3177
	150	0.0000	0.0140	0.0287	0.0172	0.3073
	200	0.0133	0.0273	0.0520	0.0338	0.3239
	300	0.0400	0.0247	0.0447	0.0292	0.3247
	500	0.0267	0.0247	0.0440	0.0277	0.3262
	1000	**0.0400**	**0.0290**	**0.0497**	**0.0292**	**0.0292**

Performance metrics obtained using Cosine Distance for matching

Results

Encoding	K	NN	FT	ST	E	DCG
FV	10	0.0067	0.0157	0.0350	0.0218	0.3096
	20	0.0000	0.0173	0.0427	0.0254	0.3126
	25	0.0000	0.0167	**0.0437**	**0.0269**	0.3119
	50	0.0000	0.0167	0.0417	0.0228	0.3117
	100	0.0067	0.0170	0.0403	0.0236	0.3139
	125	0.0000	0.0160	0.0413	0.0231	0.3134
	150	**0.0067**	**0.0187**	0.0407	0.0251	**0.3163**
	200	0.0000	0.0160	0.0423	0.0241	0.3142
BoF	10	0.0067	0.0167	0.0417	0.0246	0.3136
	50	0.0000	0.0197	0.0397	0.0244	0.3187
	100	**0.0667**	0.0317	0.0633	**0.0418**	0.**3354**
	150	0.0600	**0.0323**	0.0630	0.0390	0.3338
	200	0.0200	0.0153	0.0370	0.0226	0.3134
	300	0.0067	0.0180	0.0347	0.0218	0.3102
	500	0.0067	0.0157	0.0370	0.0215	0.3160
	1000	0.0000	0.0187	**0.0420**	0.02625	0.3144

Performance metrics obtained using EMD for matching

Results

Comparison with state-of-the art technique

Feature	NN	FT	ST
RSI	0.0892	0.0734	0.0713
PSI	0.0933	0.0812	0.0770
SC	0.0861	0.0825	0.0771
FPFH	0.1167	0.0799	0.074

Performance metrics of state-of-the art technique on SHREC’09

Encoding	Distance	K	NN	FT	ST
FV	l_1-norm	200	**0.0133**	0.016	0.0317
	l_2-norm	10	0.0067	0.0177	0.0337
	Cosine	50	0.0133	0.0180	0.0323
	EMD	150	0.0067	**0.0187**	**0.0407**
BoF	l_1-norm	1000	0.0600	**0.0527**	**0.0527**
	l_2-norm	1000	0.0533	0.0267	0.0527
	Cosine	1000	0.0400	0.0290	0.0497
	EMD	100	**0.0667**	0.0317	0.0633

Performance metrics of proposed partial 3D object retrieval technique on SHREC’11

Results

- We observed that the proposed technique using BoFs encoding outperformed FV encoding techniques.
- L1-norm distance out performed other distance measures.

Conclusions And Future Scope

We proposed a partial 3D object retrieval technique comprising five modules, namely, sampling, feature extraction, feature encoding, matching and performance evaluation.

- We demonstrated the performance of the proposed technique on SHREC'11 dataset.
- We observed that the proposed technique using BoFs encoding outperformed other encoding techniques. Also, for matching L1-norm distance performed better.
- As future work the proposed technique can be extended by using other feature extraction methods and matching techniques.
- Also weighting of codewords can be done in BoF.

THANK-YOU

REFERENCES:

[1] Michalis A. Savelonas, Ioannis Pratikakis, Konstantinos Sfikas. Fisher encoding of Differential Fast Point Feature histograms for Partial 3D Object Retrieval, 2016.

[2] I.Pratikakis, M.Spagnuolo, T. Theoharis, and R.Veltkamp. A Query-by-Example Concept and User Interface for Global and Partial 3D Object Retrieval,2009.

[3] Mathieu Aubry, Ulrich Schlickewei, Daniel Cremers. The Wave Kernel Signature: A Quantum Mechanical Approach to Shape Analysis.

Implementation

```
OFF
46622 90161 0
0.345632 -0.989338 -0.226566
-0.063311 0.753159 -0.400532
1.0083 -0.183685 -0.54204
-0.725983 -0.052494 -0.085058
-0.386981 0.021914 0.190186
-0.401598 0.049609 0.176745
-0.411009 0.038168 0.181225
-0.377571 0.033354 0.185706
-0.41137 0.040663 0.183257
-0.387342 0.024409 0.192218
-0.410374 0.044023 0.184144
-0.386346 0.027768 0.193105
-0.408288 0.047346 0.183649
-0.38426 0.031092 0.19261
-0.405669 0.049743 0.181904
-0.381641 0.033489 0.190865
-0.403221 0.050571 0.179377
-0.379193 0.034317 0.188338
-0.367505 0.00965 0.199779
-0.382122 0.037345 0.186338
-0.391533 0.025905 0.190818
-0.358095 0.021091 0.195299
-0.391894 0.0284 0.19285
-0.367866 0.012146 0.201811
-0.390898 0.03176 0.193737
-0.36687 0.015505 0.202698
-0.388811 0.035083 0.193242
-0.364784 0.018829 0.202203
-0.386193 0.03748 0.191497
-0.362165 0.021225 0.200458
-0.383745 0.038308 0.18897
-0.359717 0.022054 0.197931
-0.348029 -0.002613 0.209372
-0.362646 0.025082 0.195931
-0.372056 0.013641 0.200411
-0.338618 0.008828 0.204892
```

Input 3D Point

Feature Extraction

```
1 0.050280 0.051050 0.051972 0.053143 0.054726 0.056962 0.060149 0.064598 0.070571 0.078203 0.087451 0.098063 0.109598 0.121453 0.132929 0.143311 0.151967 0.158453 0.162594 0.164515 0.164631 0.163583
  0.162155 0.161166 0.161363 0.163312 0.167302 0.173294 0.180938 0.189663 0.198832 0.207903 0.216550 0.224720 0.232612 0.240599 0.249110 0.258491 0.268878 0.280108 0.291690 0.302850 0.312642 0.320110
  0.324443 0.325113 0.321956 0.315195 0.305407 0.293443 0.280317 0.267066 0.254630 0.243741 0.234870 0.228215 0.223730 0.221194 0.220282 0.220641 0.221963 0.224026 0.226730 0.230098 0.234247 0.239350
  0.245562 0.252953 0.261442 0.270754 0.280422 0.289827 0.298280 0.305132 0.309868 0.312186 0.312024 0.309545 0.305080 0.299066 0.291974 0.284248 0.276260 0.268288 0.260501 0.252976 0.245722 0.238733
  0.232030 0.225708 0.219944 0.214995 0.211151 0.208685 0.207803 0.208604 0.211071 0.215077 0.220413 0.102731
2 0.042697 0.044213 0.045481 0.046398 0.046928 0.047143 0.047268 0.047709 0.049019 0.051825 0.056716 0.064150 0.074384 0.087446 0.103124 0.120979 0.140382 0.160577 0.180768 0.200208 0.218264 0.234458
  0.248453 0.260025 0.269015 0.275288 0.278722 0.279228 0.276806 0.271602 0.263963 0.254442 0.243771 0.232792 0.222370 0.213293 0.206182 0.201408 0.199046 0.198861 0.200361 0.202896 0.205802 0.208540
  0.210817 0.212627 0.214217 0.215979 0.218281 0.221315 0.224978 0.228847 0.232262 0.234468 0.234801 0.232844 0.228534 0.222201 0.214558 0.206643 0.199717 0.195140 0.194214 0.198002 0.207145 0.221708
  0.241091 0.264037 0.288754 0.313146 0.335108 0.352831 0.365053 0.371206 0.371424 0.366443 0.357410 0.345682 0.332634 0.319534 0.307462 0.297275 0.289600 0.284820 0.283083 0.284294 0.288145 0.294149
  0.301702 0.310163 0.318928 0.327500 0.335525 0.342807 0.349292 0.355036 0.360164 0.364835 0.369209 0.100928
3 0.022735 0.024567 0.027117 0.030519 0.034885 0.040241 0.046473 0.053298 0.060292 0.066970 0.072905 0.077811 0.081584 0.084289 0.086113 0.087315 0.088171 0.088941 0.089852 0.091088 0.092804 0.095145
  0.098252 0.102269 0.107327 0.113500 0.120755 0.128901 0.137563 0.146210 0.154234 0.161067 0.166300 0.169773 0.171618 0.172243 0.172260 0.172384 0.173300 0.175545 0.179413 0.184912 0.191785 0.199576
  0.207735 0.215731 0.223143 0.229725 0.235421 0.240343 0.244716 0.248808 0.252868 0.257099 0.261647 0.266625 0.272122 0.278197 0.284839 0.291908 0.299071 0.305780 0.311293 0.314768 0.315414 0.312657
  0.306290 0.296556 0.284134 0.270045 0.255476 0.241577 0.229276 0.219139 0.211317 0.205575 0.201393 0.198111 0.195083 0.191804 0.187995 0.183622 0.178869 0.174068 0.169609 0.165846 0.163022 0.161224
  0.160371 0.160241 0.160524 0.160882 0.161015 0.160698 0.159805 0.158306 0.156249 0.153733 0.150879 0.104129
4 0.104774 0.100940 0.096745 0.092171 0.087250 0.082113 0.077012 0.072329 0.068549 0.066199 0.065778 0.067698 0.072232 0.079466 0.089252 0.101160 0.114462 0.128156 0.141053 0.151909 0.159569 0.163117
  0.161988 0.156065 0.145724 0.131828 0.115631 0.098595 0.082140 0.067390 0.055019 0.045218 0.037801 0.032362 0.028446 0.025670 0.023796 0.022758 0.022669 0.023802 0.026580 0.031558 0.039398 0.050831
  0.066582 0.087255 0.113168 0.144151 0.179360 0.217162 0.255171 0.290474 0.320019 0.341093 0.351752 0.351113 0.339440 0.318049 0.289049 0.255009 0.218606 0.182311 0.148170 0.117684 0.091801 0.070987
  0.055357 0.044801 0.039092 0.037936 0.040964 0.047673 0.057353 0.069033 0.081486 0.093321 0.103139 0.109741 0.112310 0.110544 0.104680 0.095428 0.083815 0.071003 0.058102 0.046026 0.035414 0.026606
  0.019678 0.014507 0.010844 0.008393 0.006855 0.005972 0.005534 0.005385 0.005415 0.005549 0.005739 0.099635
5 0.030284 0.028884 0.027447 0.026002 0.024613 0.023370 0.022385 0.021783 0.021690 0.022222 0.023477 0.025534 0.028445 0.032219 0.036805 0.042075 0.047817 0.053741 0.059511 0.064777 0.069228 0.072623
  0.074837 0.075895 0.076003 0.075579 0.075240 0.075758 0.077947 0.082526 0.089976 0.100441 0.113692 0.129159 0.146001 0.163206 0.179698 0.194449 0.206590 0.215498 0.220865 0.222719 0.221411 0.217558
  0.211963 0.205531 0.199173 0.193725 0.189864 0.188030 0.188376 0.190749 0.194722 0.199687 0.204970 0.209950 0.214145 0.217260 0.219180 0.219928 0.219612 0.218358 0.216271 0.213411 0.209789 0.205388
  0.200183 0.194178 0.187423 0.180034 0.172210 0.164227 0.156431 0.149211 0.142957 0.138010 0.134612 0.132862 0.132698 0.133890 0.136068 0.138758 0.141439 0.143603 0.144822 0.144800 0.143417 0.140747
```

IWKS features

Implementation

Feature Encoding and Matching

14.620515	14.970101	14.626765	18.742137	14.648453	14.793995	15.336420	17.074759	14.672190
15.071215	16.113056	17.701663	17.698095	19.596749	18.429274	15.756585	17.207922	21.874132
16.664856	15.944921	16.114256	14.346034	14.372935	15.086486	16.499138	24.813869	19.012891
16.809121	15.820039	24.461756	15.316389	15.797004	16.392833	16.034865	17.359610	17.277325
22.359112	17.747075	18.056772	19.572358	15.210226	14.640430	18.920930	17.665648	14.766238
19.969264	15.207854	15.125418	17.475769	21.244660	16.013304	19.765733	16.358264	14.853928
18.298576	16.482294	22.562756	20.953228	20.454971	15.046720	18.544733	19.286704	14.578660
16.717046	15.974663	18.495464	18.620275	17.208055	15.810090	24.928934	16.395471	17.016678
15.741292	20.848572	15.146948	14.687022	16.887125	18.724995	15.381240	15.061201	16.308775
16.776185	19.019627	18.216160	15.238976	18.612929	14.824546	14.536049	15.154107	19.327745
15.190304	14.608425	16.594414	14.798928	18.297127	16.890854	14.946721	21.212264	15.184657
14.690491	16.657235	14.916384	17.587172	16.305881	18.500377	19.341536	17.406914	16.234812
16.515398	15.709943	15.967297	15.845501	16.085257	15.536251	14.525725	17.691798	20.820275
19.251932	14.614850	13.808893	16.482635	16.989161	16.107411	15.859863	27.213714	15.675002
20.806755	16.452433	14.907622	15.254660	15.826778	14.483572	16.692820	14.872060	17.496717
16.764768	15.582310	17.201866	16.253425	15.578367	16.552320	15.090085	18.178024	16.185699
21.219833	17.216389	14.459999	16.252771	13.729901	19.106687	18.257746	17.241214	15.285468
16.062410	15.010480	18.116329	17.139225	15.305158	22.931441	17.582021	17.384139	15.330120
15.857382	16.145354	15.083883	14.721060	18.567730	19.493520	17.594716	17.117788	17.351547
16.507596	15.040100	17.348597	18.756786	16.033034	16.330388	18.068995	17.844276	15.334921
16.951806	15.074666	14.508074	15.812700	15.975489	18.554610	15.250451	19.944289	18.280343
17.298349	15.249938	16.398786	18.235532	15.683504	20.940790	15.023006	19.677004	15.141016
15.967316	14.560880	14.929883	15.689794	16.692097	15.457996	19.236746	15.000969	15.626144
18.784035	22.351981	17.675541	15.458241	17.144284	19.234502	17.634345	14.160555	17.227271
17.851219	14.618129	20.696591	17.308717	20.357454	14.497471	17.761486	19.098530	16.665999
26.175523	17.991816	29.180205	14.226024	14.973580	16.363649	18.168313	19.426279	19.565403
14.988161	18.544091	15.490701	15.985469	16.365934	16.099103	18.872161	22.159959	15.621667
14.718398	16.987271	15.385979	14.690066	16.226250	14.779066	21.589350	14.965812	16.461616
16.661609	17.732022	16.909288	18.521760	17.533926	15.437341	18.726334	13.936519	16.307409
20.312392	19.041746	18.668388	14.708485	16.568877	15.873677	17.730311	14.506933	18.414865
14.962078	16.252771	17.590681	17.230871	17.457804	16.730490	14.307772	16.261599	16.794094
16.544997	20.560552	16.894241	17.453510	15.222383	14.936353	14.814873	16.918622	18.439448
16.610459	23.714509	15.940356	16.719464	15.783190	17.510626	16.825642	15.937560	17.043565
16.521372	18.035684	19.569748	15.667983	13.821432	15.243081	20.219066	20.681037	15.389233

Distance Matrix

Generating Ranked List

RQ0001	
D00325	13.729901000000002
D00263	13.808893
D00665	13.821432000000001
D00568	13.936519
D00915	14.029943
D00478	14.08895
D00156	14.139003
D00468	14.160554999999999
D00873	14.166057
D00051	14.167767999999999
D00921	14.185222
D00953	14.201017000000002
D00198	14.203201000000002
D00173	14.222005
D00504	14.226023999999999
D00676	14.245052
D00577	14.260414
D00889	14.263792
D00310	14.278835
D00631	14.303379000000001
D00607	14.307772
D00781	14.312448000000002
D00946	14.314570999999999
D00860	14.318677
D00654	14.333682000000001
D00044	14.346034
D00836	14.359932
D00933	14.371594
D00045	14.372935
D00789	14.38384
D00359	14.393061999999999
D00458	14.399866000000001
D00053	14.399992999999998
D00881	14.406676999999998
D00747	14.420335000000001
D00951	14.429309
D00901	14.455884
D00323	14.459999
D00978	14.46285
D00837	14.47649
D00158	14.481909

Ranked List