Semantic Sketch-Based 3D Model Retrieval

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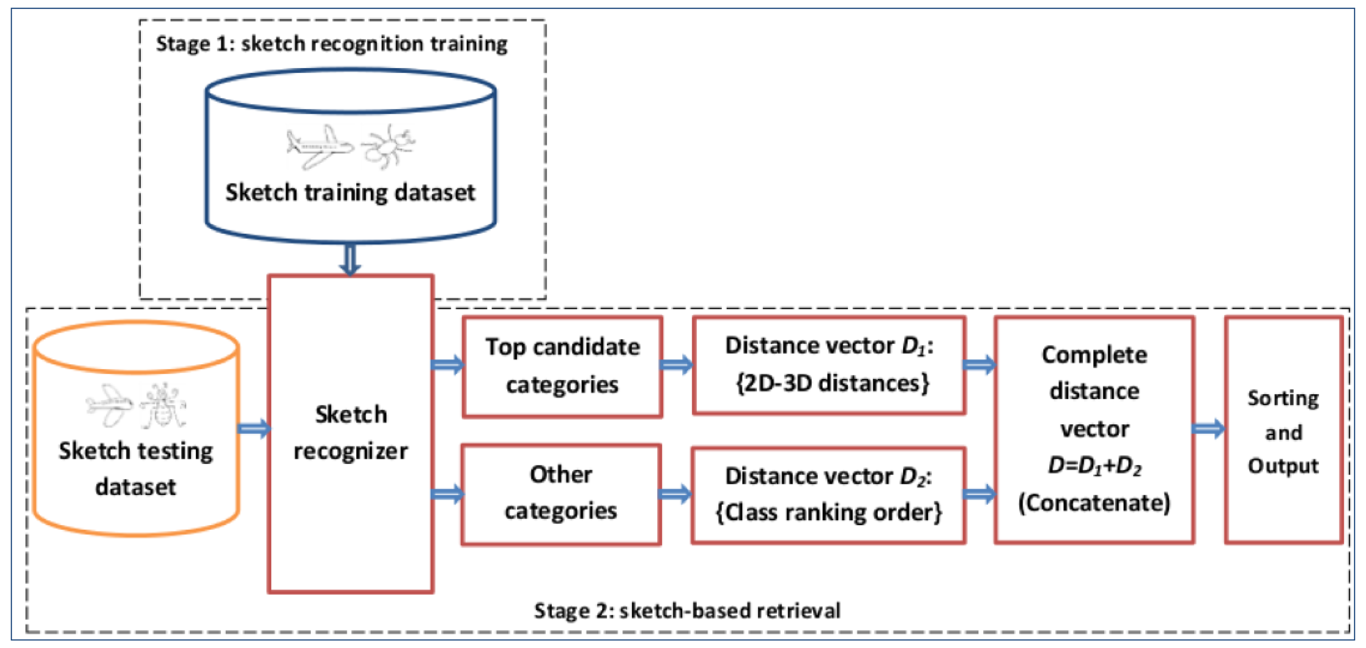
Overview

- **Research Topic:** Query-by-Sketch is an intuitive scheme; promising in game design, 3D animation and human computer interaction, *etc*
- **Problem:** Big semantic gap exists between human-drawn sketches and 3D models
  - ❖ *2D human-drawn sketch*: an iconic representation of an object; several simplified and exaggerated curves; arbitrary styles; high-level abstraction; drastic simplification
  - ❖ *3D model of an object*: accurate representation of the geometry information
- **Consequence:** Such big semantic gap makes the search based on a direct 2D-3D comparison suffer low accuracy and high computational cost
- **Motivation:** Bridge the semantic gap
- **Our Semantic Sketch-Based 3D Model Retrieval Approach:** First recognizing the potential semantic meanings of the user sketch and then performing 2D-3D matching for the 3D models within the predicted categories
- **Overview of Our Results:** Significant improvements in both search accuracy and efficiency

Framework



Algorithm

- **Stage 1: Sketch Recognition Training**
  - ❖ *(1) Sketch feature extraction. Hybrid features:* Eitz et al.'s [2] 500-dimensional *local* feature vector + our proposed 119-dimensional *global* feature vector, which comprises 9 distance histograms:
    - ✓ 5 radial distance histograms of the sketch pixels with respect to 5 selected reference *points/lines*
    - ✓ 2 radial distance histograms of the first *intersection points*
    - ✓ 2 radial angle histograms of the sketch pixels with respect to the two *centers* **C** and **FPC**

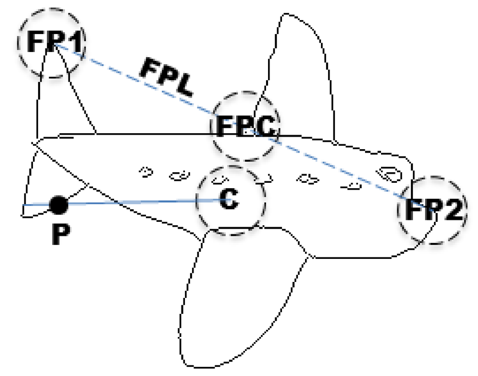


Fig. Illustration of our 5 reference points or lines for the global features: **C**, **FP1**, **FP2**, **FPL** and **FPC**, where **C** is the centroid of a sketch, **FP1** and **FP2** are the two farthest points with respect to the centroid **C**, **FPL** is the line between the two farthest points; and **FPC** is the center of the **FPL** line. **P** is an example of first intersection point.

Algorithm (Cont.)

- ❖ *(2) Sketch classifier training.* Support Vector Machine**:** adopt same parameter settings as [2] including local feature definitions, "soft" kernel-codebook coding choice, vocabulary size, and 3-fold cross-validation selection except for RBF kernel (gamma=0.1 and C=20)

- **Stage 2: Sketch-Based Retrieval**
  - ❖ *(3) Sketch classification.* Predict all the possibilities of the input sketch belonging to all the categories
  - ❖ *(4) 2D-3D matching.* The state-of-the-art sketch-based retrieval approach SBR-2D-3D [4] is applied on all the models in the top ***L*** candidate categories, which makes our approach SBR_SVM-2D-3D. The distances between the models and the input sketch, named D_1, are calculated
  - ❖ *(5) Distance vector generation.* Assign distances between the input sketch and the models in the left categories as the second part of *D*, named D_2: set to be the ranking orders of their respective categories. Concatenate D_1 and D_2 into *D*
  - ❖ *(6) Ranking and output.* All the distances in *D* are sorted and the relevant models are listed accordingly

Experiments

- **SHREC'13 Sketch Track Benchmark:** A large scale sketch-based shape retrieval benchmark
  - ❖ *7200 hand-drawn sketches*: uniformly distributed on 90 classes
  - ❖ *1258 relevant 3D models*: selected from the PSB benchmark, as the target 3D dataset
  - ❖ *"Training" and "Testing" datasets*: randomly selecting 50 sketches per class for training and the rest 30 sketches for testing; while the complete target model dataset is remained as a whole for both training and testing purpose

- **Sketch Recognition Results**

Table 1. Average classification performance comparison in terms of eight metrics. The first two rows are for the SHREC'13 Sketch Track Benchmark; the last two rows (*) are for the Eitz et al.'s [2] complete sketch benchmark.

	TP	FP	P	R	F	MCC	ROC	PRC
Our	0.613	0.004	0.623	0.613	0.614	0.612	0.982	0.664
LSR	0.594	0.005	0.597	0.594	0.593	0.590	0.974	0.637
Our*	0.545	0.002	0.549	0.545	0.544	0.544	0.772	0.326
LSR*	0.520	0.002	0.523	0.520	0.519	0.518	0.759	0.298

- ❖ *Timing*: averagely 0.1 second is needed to classify a sketch

- **Sketch-Based Retrieval Results**

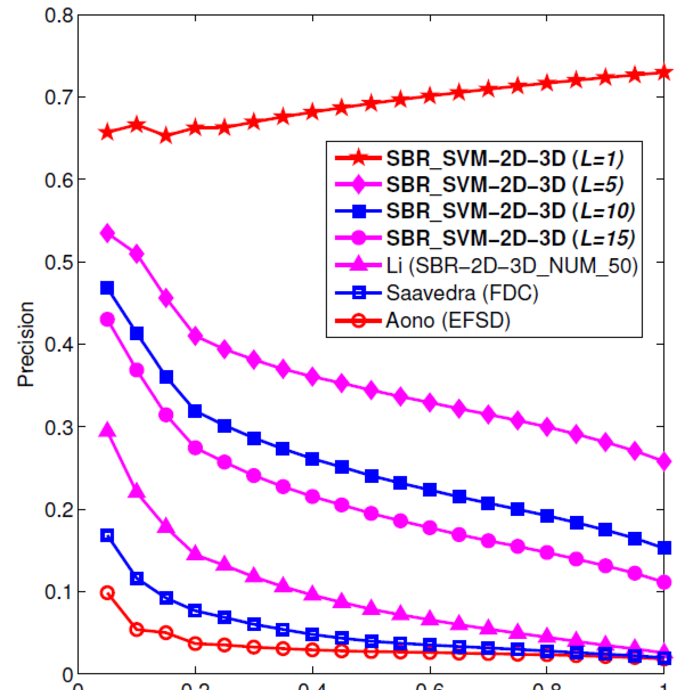


Fig. Precision-Recall diagram performance comparison between our SBR SVM-2D-3D (different L values) method and the participating approaches in the SHREC'13 Sketch Track Contest on the "Testing" dataset.

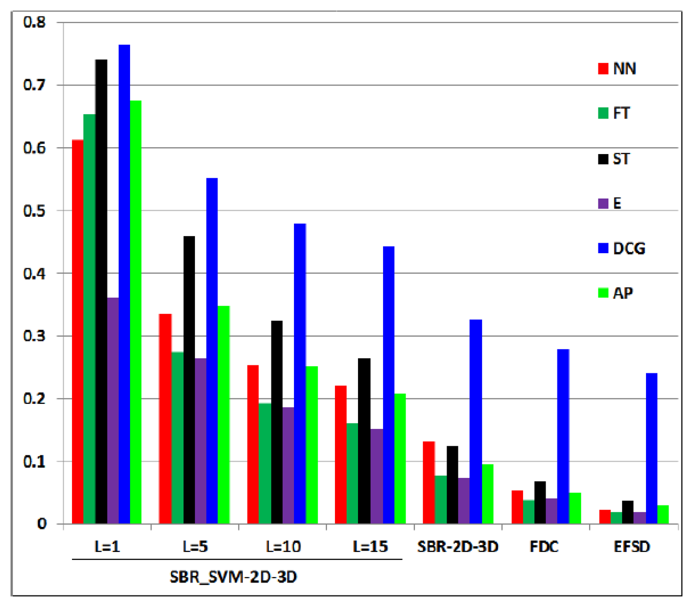


Fig. Other performance metrics comparison between our semantic algorithm SBR SVM-2D-3D (different L values) and the participating approaches in the SHREC'13 Sketch Track Contest on the "Testing" dataset.

Experiments (Cont.)

Table 2. Timing information comparison: ***t*** is the average response time per query based on a modern computer.

Method	SBR_SVM-2D-3D				SBR-2D-3D	FDC	EFSD
	L=1	*L*=5	*L*=10	*L*=15			
t (s)	1.43	4.88	9.32	13.26	43.93	0.02	20.24

- ❖ (1) Our semantic retrieval approach *significantly* improves the retrieval performances (100%~700% better accuracy) than other state-of-the-art sketch-based retrieval algorithms
- ❖ (2) In this experiment, keeping only the top *first* candidate category is the best choice in terms of both accuracy and efficiency. However, for other datasets, the situation may be *varied* due to different sketch recognition performances
- ❖ (3) Sketch-based 3D model retrieval based on semantic information will have broad application *potentials* on the applications which require *real-time* response time

Conclusions

- Our semantic sketch-based 3D model retrieval algorithm is an important improvement to encompass the semantic gap between the sketches and models.
  - ❖ It achieves the *significant* improvements in both retrieval accuracy and computationally efficiency
- *Future work*: study the integration of unsupervised or semi-supervised sketch recognition module when the label information of the target 3D model dataset is not available

References

[1] http://www.itl.nist.gov/iad/vug/sharp/contest/2013/SBR/, 2013.
[2] M. Eitz, J. Hays, and M. Alexa. How do humans sketch objects? *ACM Trans. Graph.*, 31(4):44, 2012.
[3] B. Li, T. Schreck, A. Godil, and et al. SHREC'12 Track: Sketch-Based 3D Shape Retrieval. 3DOR 2012: 109-118
[4] B. Li and H. Johan. Sketch-based 3D model retrieval by incorporating 2D-3D alignment. *Multimedia Tools and Applications*. 65 (3): 363-385, 2012.

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