# 3D Sketch-Based 3D Model Retrieval

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## Overview

- **Research topic:** Sketch-based 3D model retrieval
  - An *intuitive* visual search scheme
  - *Promising* in: game design, 3D animation and human computer interaction, etc
- **Motivation:** Big semantic gap exists between **traditional** human-drawn **2D** sketches and **3D** models
  - *2D sketch*: an iconic representation of an object
  - *3D model*: accurate representation of the geometry information
  - *Constraining* a sketch to two dimensions limits the 3D information that can communicate:
    - Creates a huge semantic gap between 2D sketch and 3D model
    - Makes 2D sketch-based 3D model retrieval very challenging
- **Proposal: 3D sketch-based 3D model retrieval**
  - 3D sketch
    - Encodes 3D information, depth and features of more facets of the object
    - Includes the salient 3D feature lines of its counterpart of 3D models
  - Make an initial study on 3D sketching
  - Propose a novel 3D sketch-based 3D model retrieval system
- **Research results**
  - Promising retrieval performance has been achieved in experiments based on
    - 300 collected 3D sketches (Kinect300)
    - A recent large scale sketch-based 3D shape retrieval benchmark (SHREC13STB)
- **Contributions**
  - A novel **3D sketching virtual drawing "board"** (software) is proposed and implemented
    - Allows users to freely draw 3D sketches in the air (a real 3D space)
    - Based on it the first human 3D sketch dataset is collected
  - A **3D sketch-based 3D model retrieval system** is introduced for the first time to solve the matching problem between 3D sketches and models

## 3D Sketching

- **Considerations:**
  - Target: a smart, user friendly, and inexpensive 3D sketching virtual drawing "board"
  - Using **Microsoft Kinect**
    - A popular and low cost motion sensing input device
    - Offers a built-in color VGA video camera, depth sensor, and multi-array microphone
  - Supporting a **voice-activated** Kinect-based 3D sketching Graphical User Interface (GUI)
    - Facilitates sketching and retrieval
- **Functionalities:**
  - Not only tracks the movement of a user's hand, but also supports voice commands
    - e.g. start, left/ right (hand), pause, resume, front/side view, search, and reset
  - A Kalman filter is applied to combat the noise due to shaking of hand

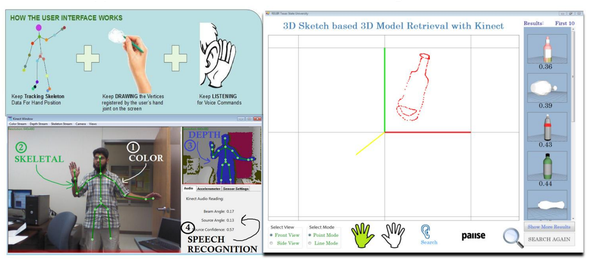



**Fig.** System Graphical User Interface (GUI)

## Retrieval System

- **An efficient 3D sketch-based 3D model retrieval system**
  - Contains both online and offline processes
  - Consists of three major components: data processing, feature extraction, and matching

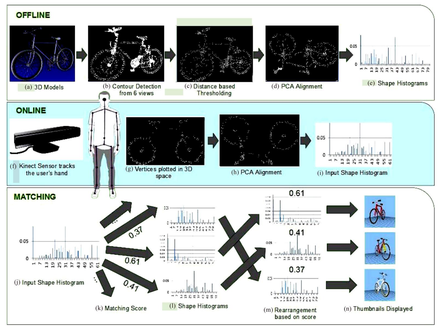
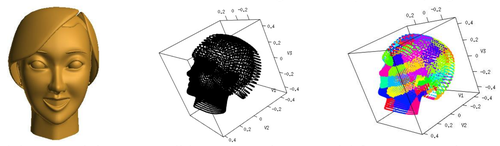



**Fig.** System framework

- **(1) Data processing:** generate 3D outlines of 3D models via
  - PCA-based 3D alignment
  - Contour generation
  - Distance thresholding
- **(2) Feature extraction:** important for effective and efficient sketch-model matching and retrieval
  - Using the 3D shape histogram [1]
    - A representative feature for 3D models and sketches considering its descriptiveness, high efficiency, and simplicity



(a) 3D model (b) point mode (c) feature visualization

**Fig.** A visualization example of the **3D shape histogram feature** based on the spider web model: 20 shells, 6 sectors, 120 bins

- **(3) 3D sketch-3D model matching**
  - Sort the Euclidean distance between the histogram of the 3D sketch and those of all the 3D outlines of the 3D models
  - List the 3D models accordingly in real-time on the right side of the GUI
  - Browse the next 10 results by saying the voice command "Show more results"

## Experiments

- **Kinect300 dataset collection**
  - Based on the drawing "board", we have collected a 3D sketch dataset named **Kinect300**:
    - 300 sketches in 30 object categories, each with 10 sketches
    - Collected from 17 users (4 females and 13 males) with an average age of 21 years

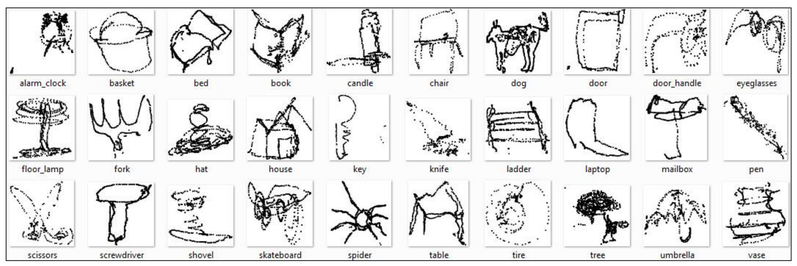



**Fig.** Example 3D sketches (one example per class, shown in one view) of our Kinect300 dataset

## Experiments (Cont.)

- **Evaluation using six commonly used evaluation metrics:** Nearest Neighbor (NN), First Tier (FT), Second Tier (ST), E-Measure (E), Discounted Cumulative Gain (DCG) and Precision-Recall (PR)
- **Three types of experiments**
  - **Outline-model retrieval**: query is a 3D outline generated from a 3D model; targets are 3D models from the same dataset
    - *Objective*: evaluate retrieval using a perfect 3D outline
    - *Query and target datasets*: SHREC13STB benchmark [2] (target dataset only): 1,258 target 3D models of 90 classes
  - **Sketch-sketch retrieval:** query is a 3D sketch; targets are 3D sketches from the same dataset
    - *Objective*: evaluate retrieval using a hand-drawn 3D sketch
    - *Target dataset*: Kinect300
  - **Sketch-model retrieval:** query is a hand-drawn 3D sketch; targets are 3D models of real objects
    - *Objective*: evaluate retrieval using a human 3D sketch
    - *Query set*: Kinect300
    - *Target dataset*: SHREC13STB benchmark (target dataset only)
- **Performance:**
  - **Efficiency:** only **1.22 sec** to perform a 3D model retrieval given a hand-drawn 3D sketch
  - **Accuracy:**

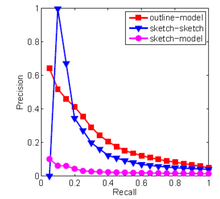
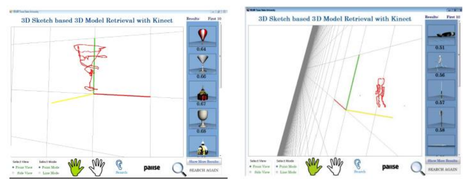



**Table.** Other performance metrics

| Benchmark | NN | FT | ST | E | DCG |
|---|---|---|---|---|---|
| outline-model | 0.391 | 0.156 | 0.238 | 0.121 | 0.486 |
| sketch-sketch | 0.167 | 0.087 | 0.139 | 0.092 | 0.360 |
| sketch-model | 0.029 | 0.021 | 0.038 | 0.021 | 0.254 |

**Fig.** Precision-Recall performance




(a) Simple (b) Complicated

**Fig.** Two retrieval examples

- Sketch-model retrieval is the most challenging task
- Still much room left for further improvement in this challenging task
- More descriptive shape descriptors are deserved for further exploration

## References

[1] M. Ankerst, G. Kastenm¨uller, and et al. 3D shape histograms for similarity search and classification in spatial databases. In SSD, pages 207–226, 1999.

[2] B. Li, Y. Lu, and et al. SHREC'13 track: Large scale sketch-based 3D shape retrieval. In 3DOR, pages 89–96, 2013.

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