SMI'11
June 22 - 24, 2011
Shape Modeling International
The Interdisciplinary Center, Herzliya, Israel

# A Comparative Evaluation of Foreground/Background Sketch-based Mesh Segmentation Algorithms

Min Meng  Lubin Fan  Ligang Liu

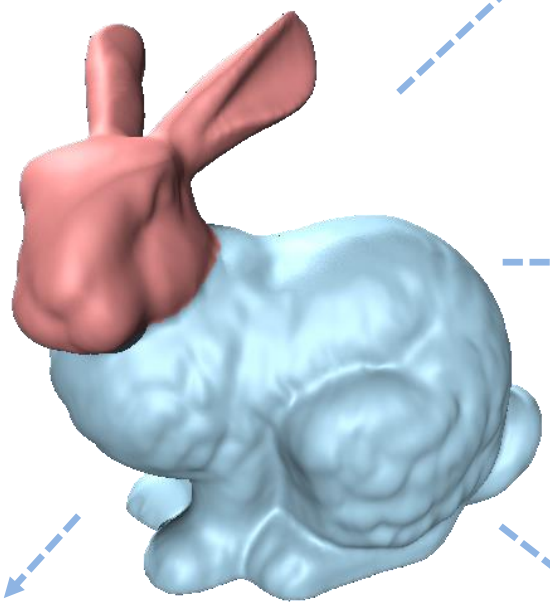
*Zhejiang University, China*

# Mesh Segmentation

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

Modeling

Deformation



Morphing

Texture Mapping

Shape Editing

Shape Retrieval

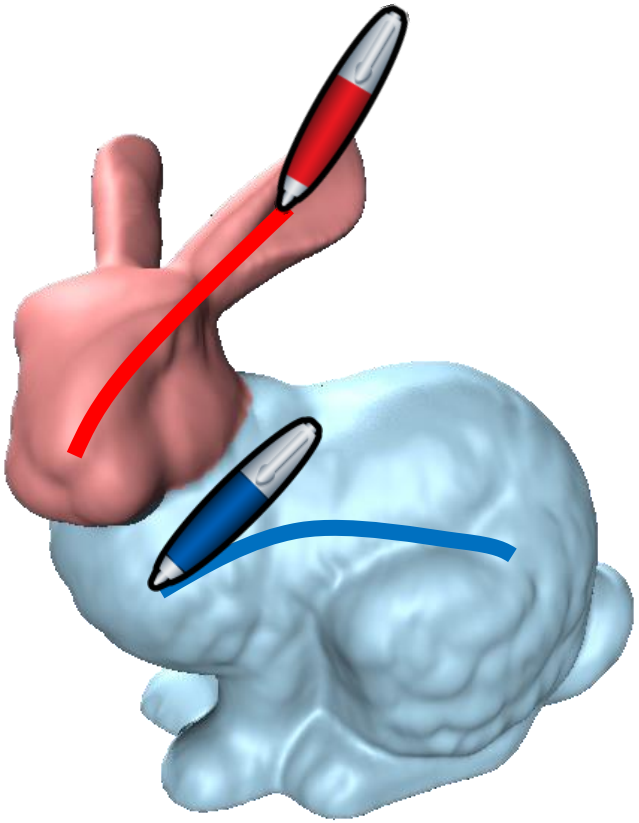
"I want to cut out the head part of the bunny model"

.....

# Foreground/background Sketch-based UI



- **User Interface**
  - Easy mesh cutting [Ji et al. 2006]
  - [Wu et al. 2007]
  - [Lai et al. 2008]
  - [Xiao et al. 2009]
  - …
- **Easy to use**

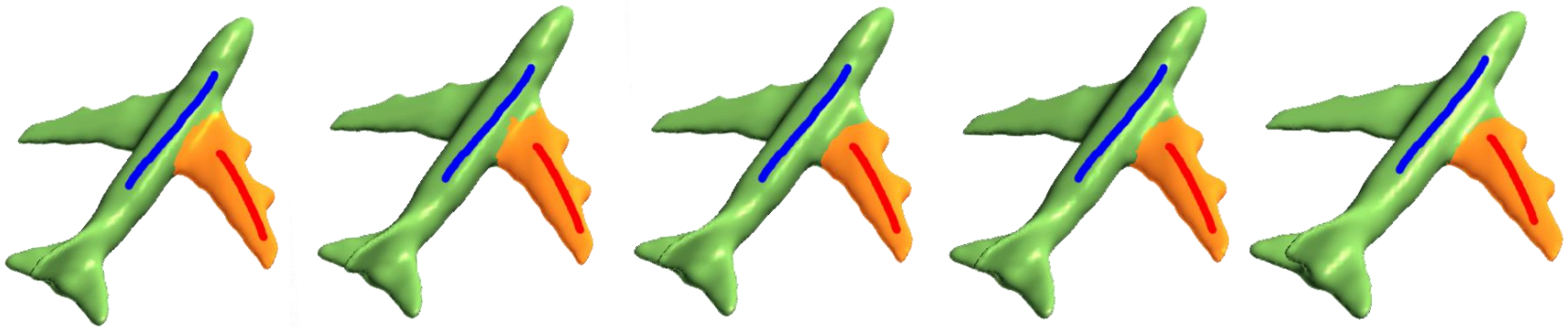


# Motivation



- **Current State**
  - Lots of algorithms
  - Different results and performance levels
  - No work on the quantitative evaluation

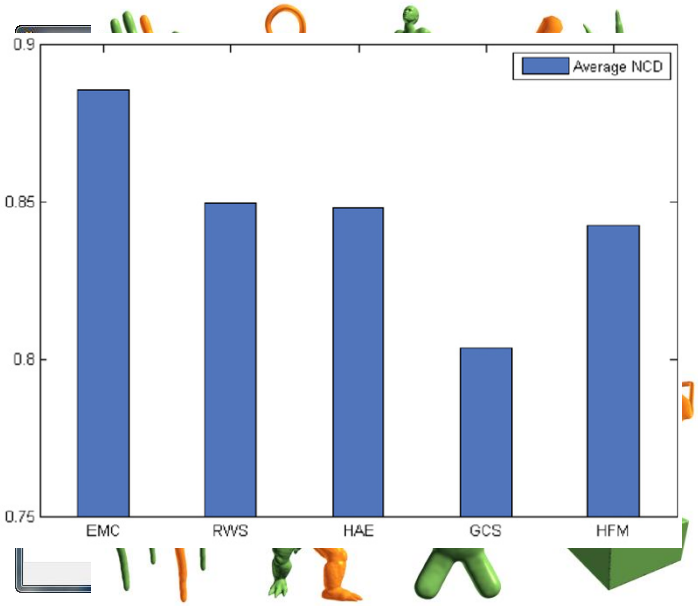
**How well the approaches perform?**



# This Work

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

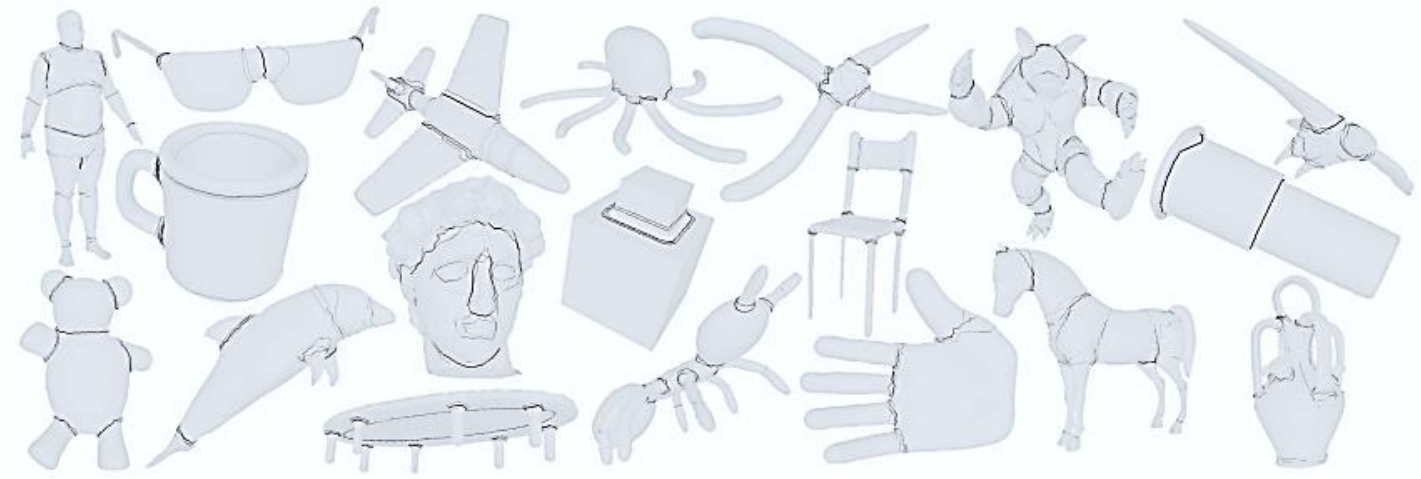
- **The first evaluation of sketch-based mesh segmentation algorithms**
  - 5 state-of-the-art algorithms
  - 100+ participants
  - A software platform
  - A ground-truth segmentation data set
  - Extensive analysis
  - Valuable insights



# Related Work on Evaluation



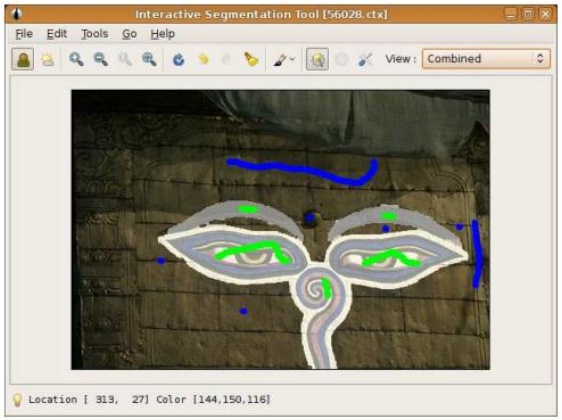
- **Automatic Mesh Segmentation**
  - Mesh segmentation - a comparative study [Attene et al. 2006]
  - A survey on mesh segmentation techniques [Shamir 2008]
  - A benchmark for 3D mesh segmentation [Chen et al. 2009]
    - 7 automatic mesh segmentation algorithms
    - Publicly available data set & software



# Related Work on Evaluation

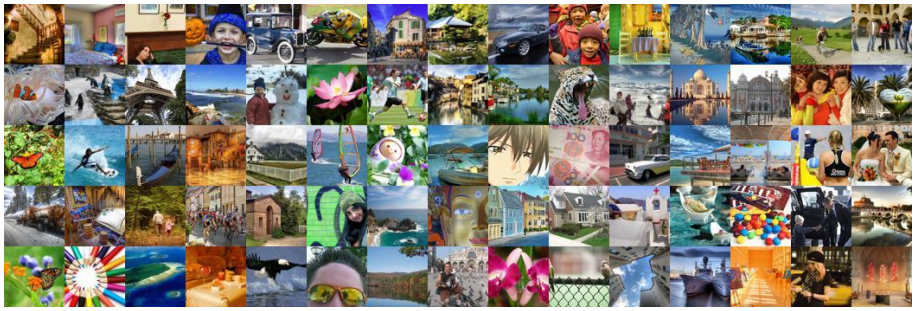
SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- **Image**
  - Image Segmentation
    - A comparative evaluation of interactive segmentation algorithms [McGuinness et al. 2010]




  - Image Retargeting
    - A Benchmark for Image Retargeting [Rubinstein et al. 2010]

RetargetMe



# Outline

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- **Evaluated Algorithms**
- **Date Set**
- **Evaluation System**
  - Training Mode
  - Evaluation Mode
- **Experiment**
- **Analysis**
- **Conclusion**

# Evaluated Algorithms



| Method | Algorithms | Abbreviation |
|---|---|---|
| Region growing | [Ji et al. 2006] * [Wu et al. 2007] | EMC |
| Random walks | [Lai et al. 2008] * | RWS |
| Bottom-up aggregation | [Xiao et al. 2009] * | HAE |
| Graph-cut | [Brown et al. 2009] * | GCS |
| Harmonic field based | [Meng et al. 2008] * [Zheng et al. 2009] | HFM |

*Note:*

- The evaluated algorithms are marked by *
- For further details, please refer to the original papers.

# Constructing the Data Set

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- **Our Data Set**
  - Based on the Princeton database [Chen et al. 2009]
  - 18 categories

*Princeton segmentation database [Chen et al. 2009]*

# Constructing the Data Set

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- **Our Data Set**
  - Based on the Princeton database [Chen et al. 2009]
  - 18 categories
  - 5 models in different poses from each category
  - One part for each model

*Princeton segmentation database [Chen et al. 2009]*

# Constructing the Data Set

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

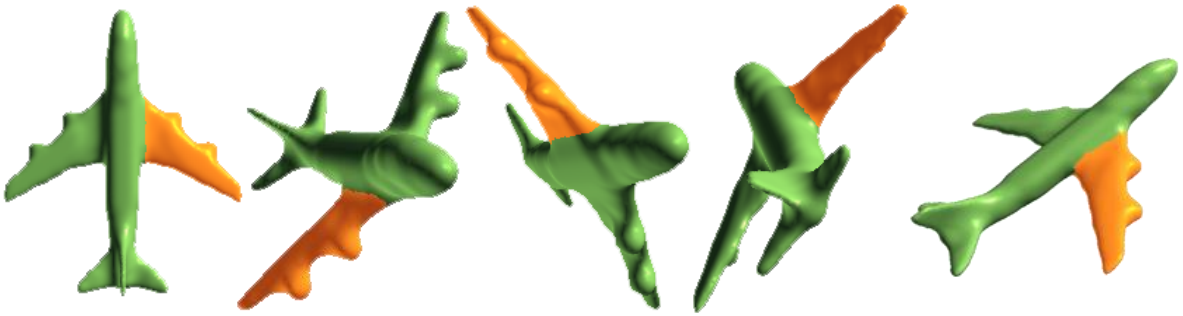
- **Our Data Set**
  - Based on the Princeton database [Chen et al. 2009]
  - 18 categories
  - 5 models in different poses from each category
  - One part for each model

*Models in our ground-truth corpus*

# Constructing the Data Set

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- **Our Data Set**
  - Based on the Princeton database [Chen et al. 2009]
  - 18 categories
  - 5 models in different poses from each category
  - One part for each model
  - Assistant images

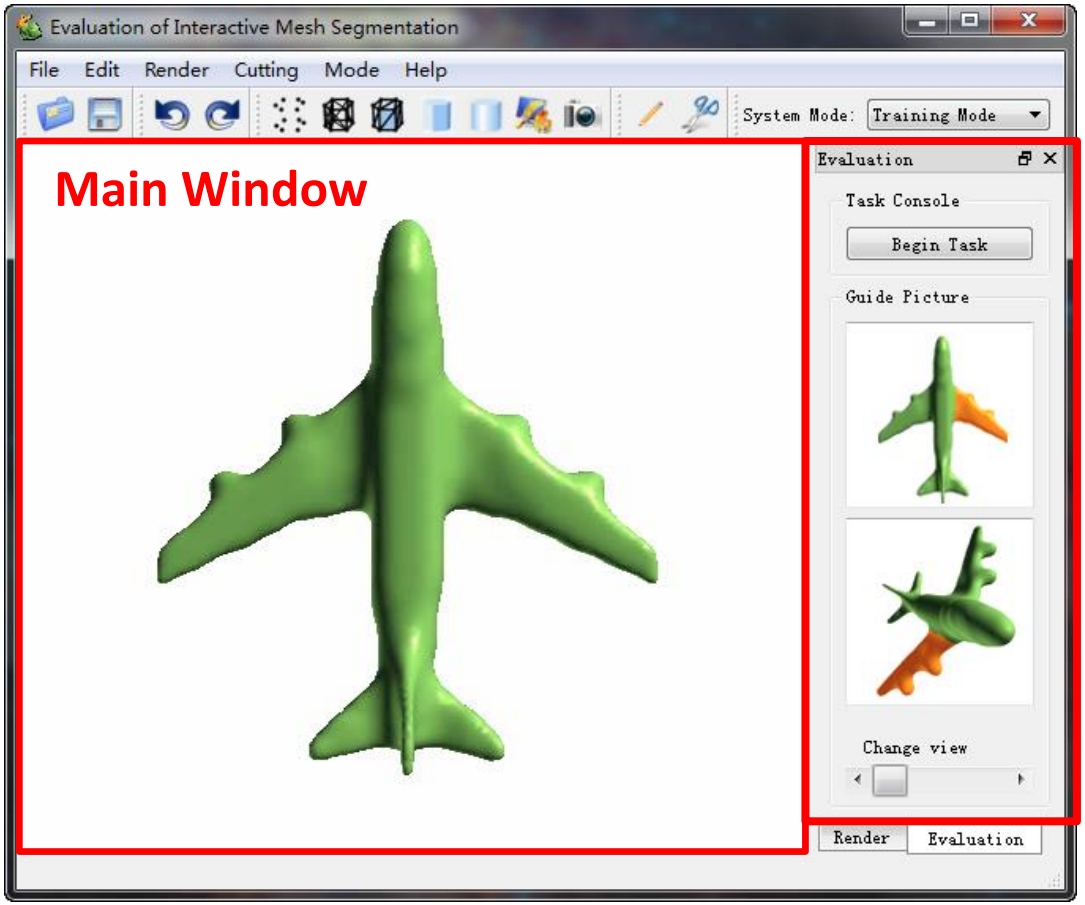


*Assistant image of model "airplane"*

# Evaluation System

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

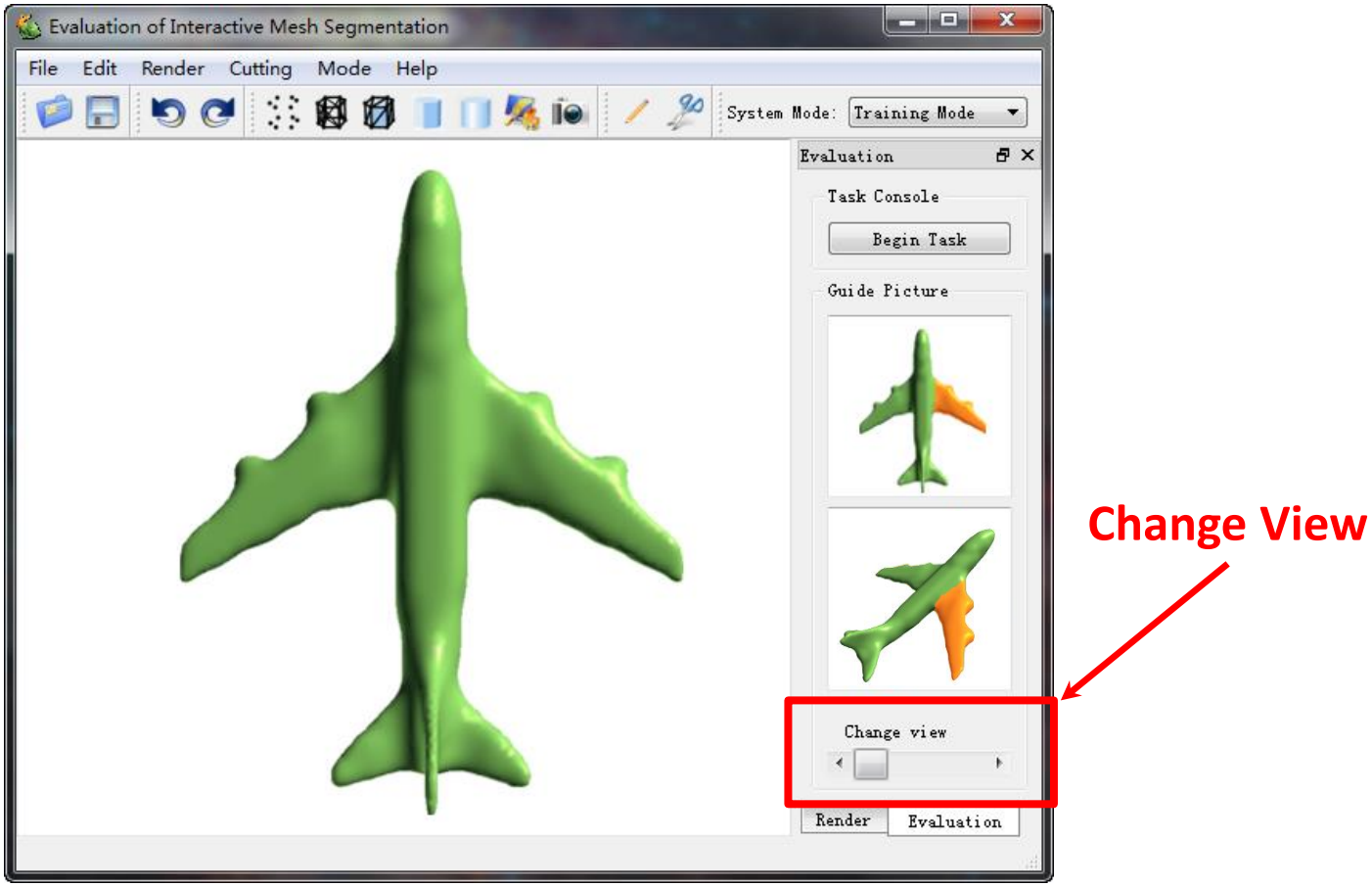
- System Overview



# Evaluation System

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

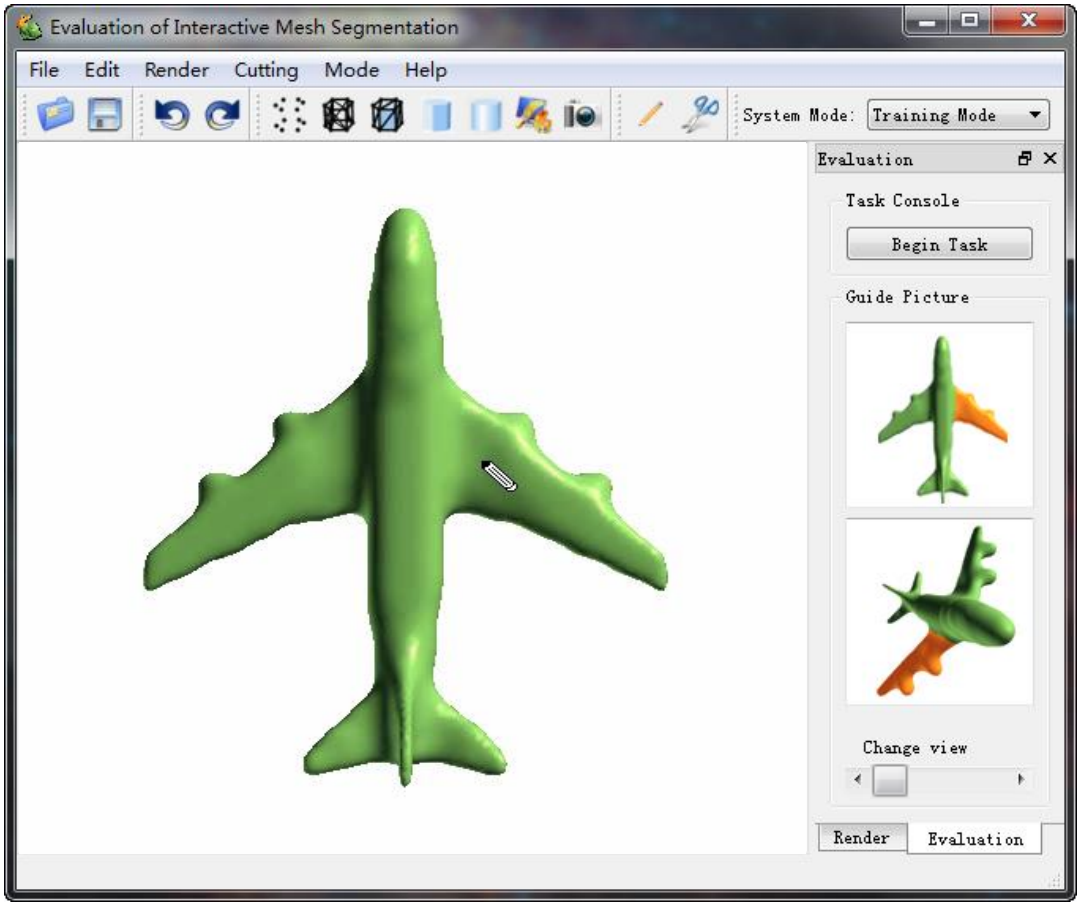
- System Overview



# Training Mode

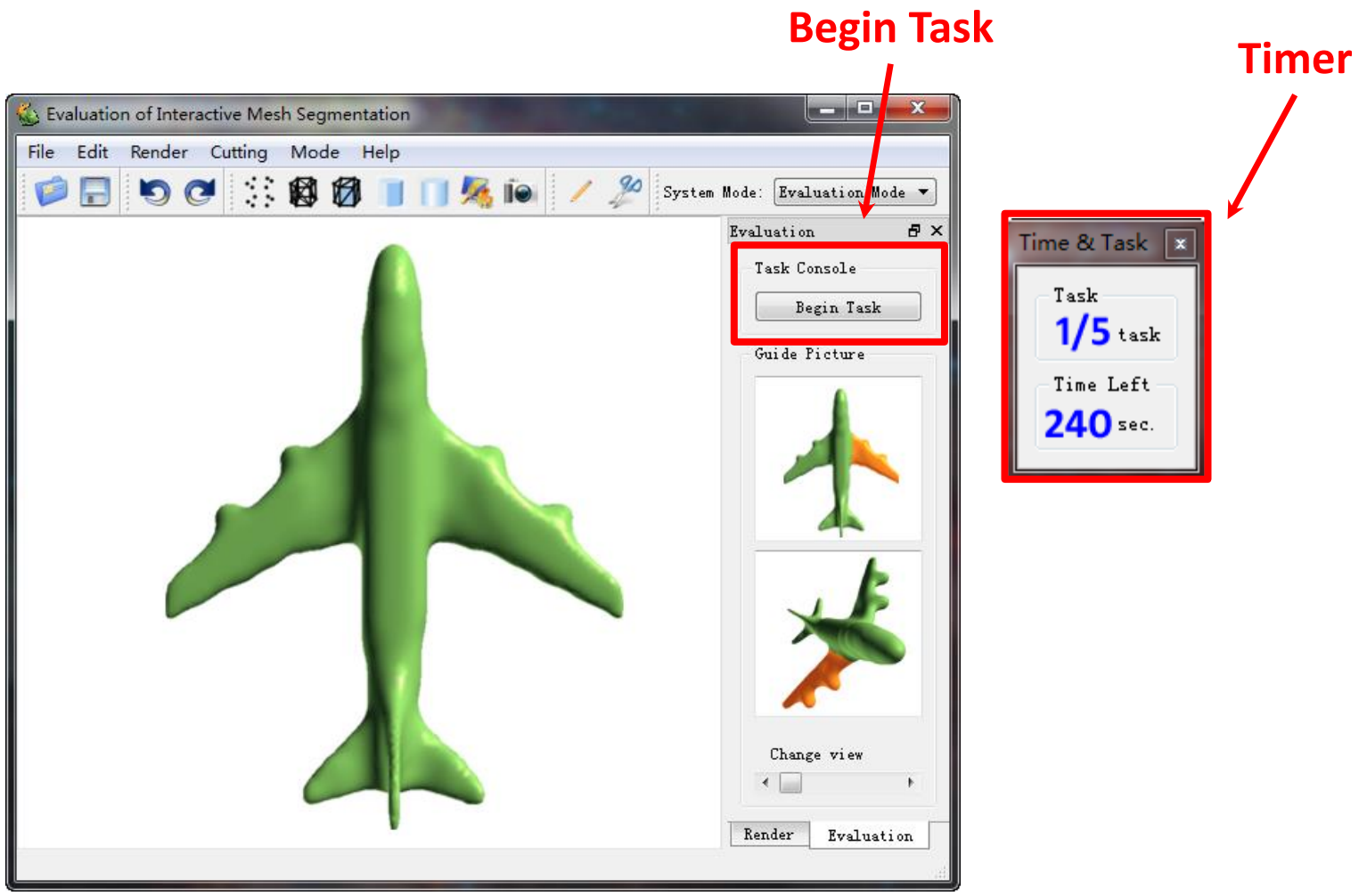


- Training Process



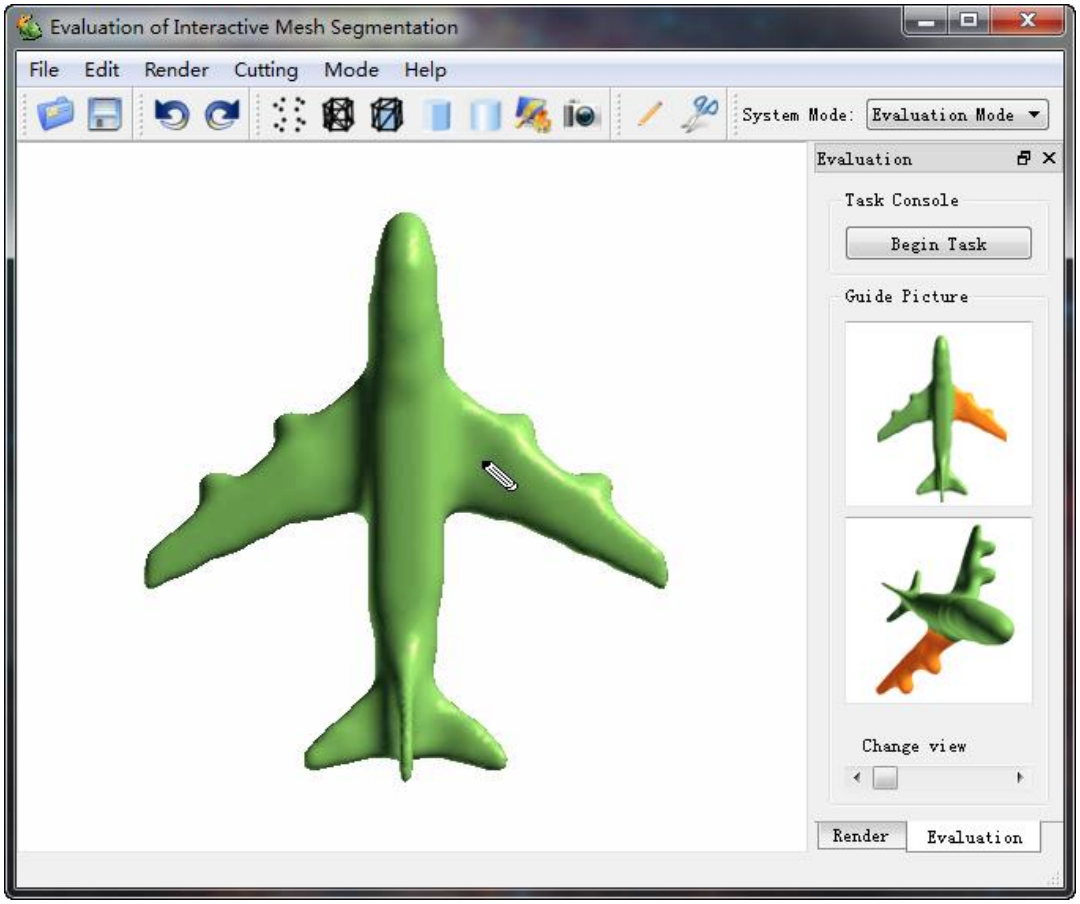
# Evaluation Mode





# Evaluation Mode

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

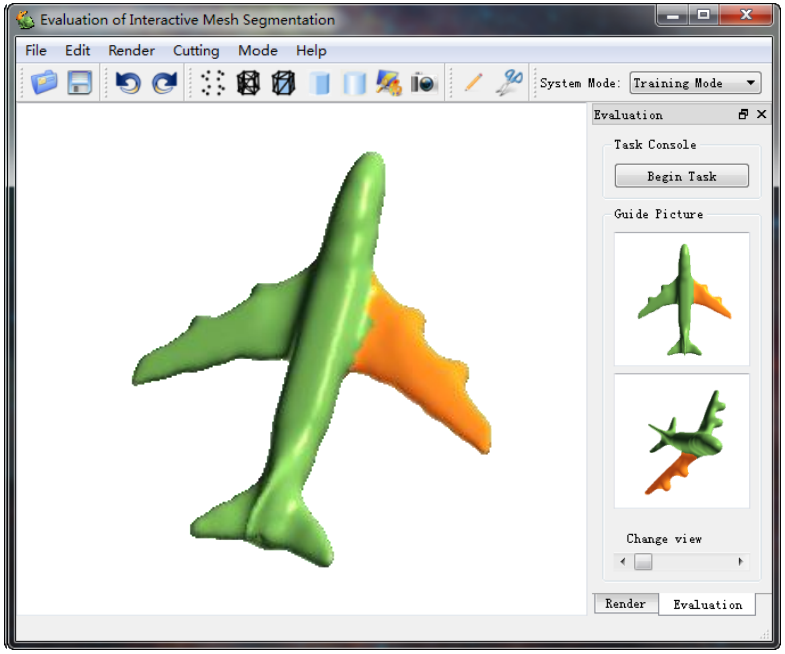



- **Rec**
  - Algorithm's name
  - Users' interactions;
  - Segmentation results;
  - Time of interaction;
  - Run time of the algorithm.

# Experiment



- Task for each participant




Training

Participant

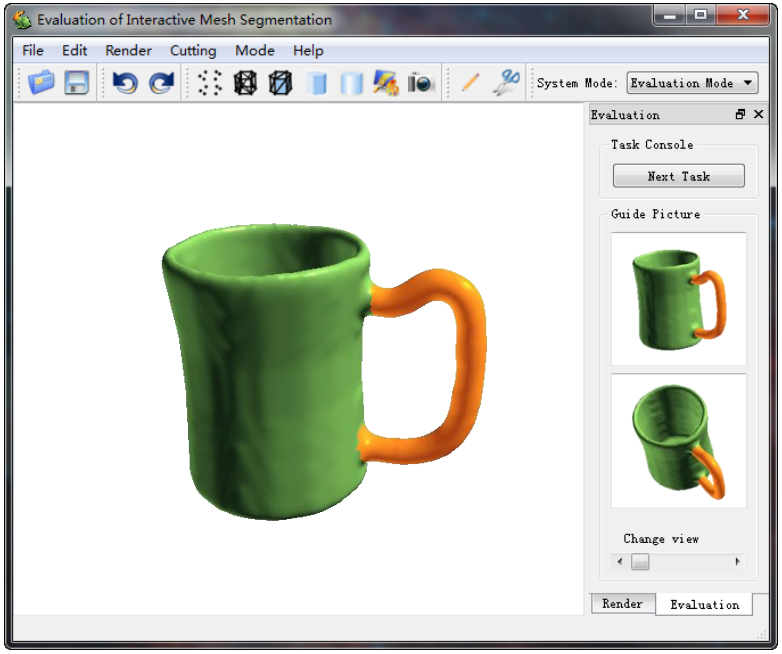
Data Pack

Test model

# Experiment



- Task for each participant




Finish task with 5 segmentation algorithms in unknown order.

Questionnaire

Participant

Record

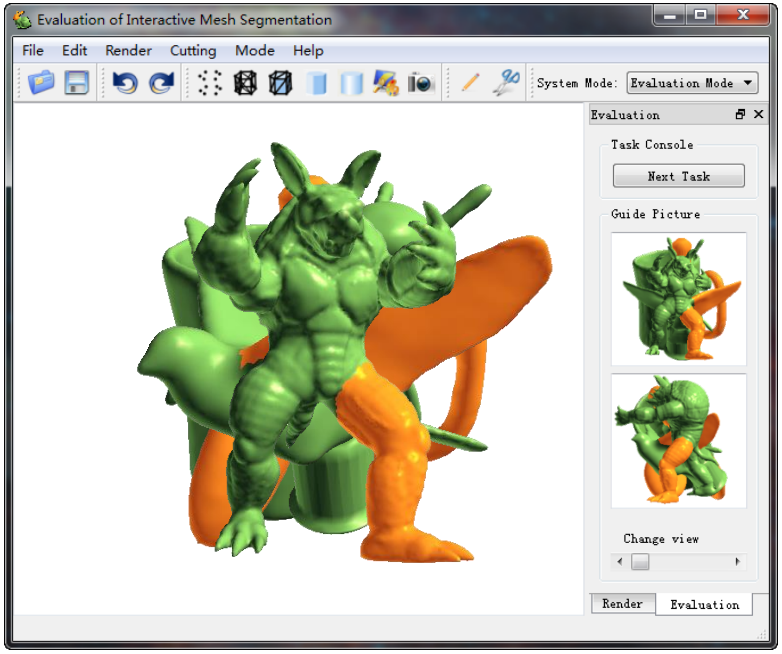
**Data Pack**

Test model

# Experiment

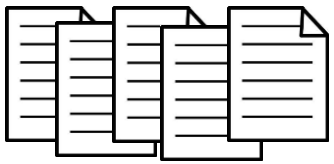


- Task for each participant




Segment all models.

Participant



Data Pack

# Experiment

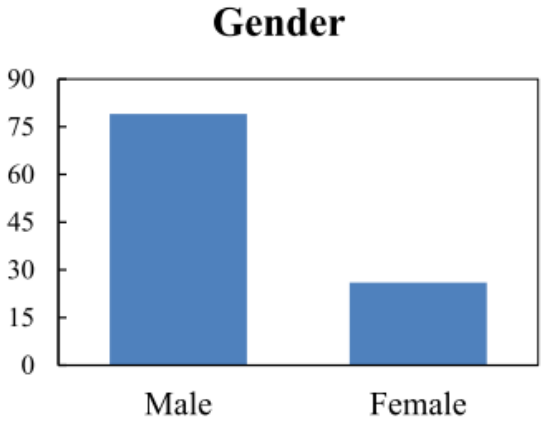


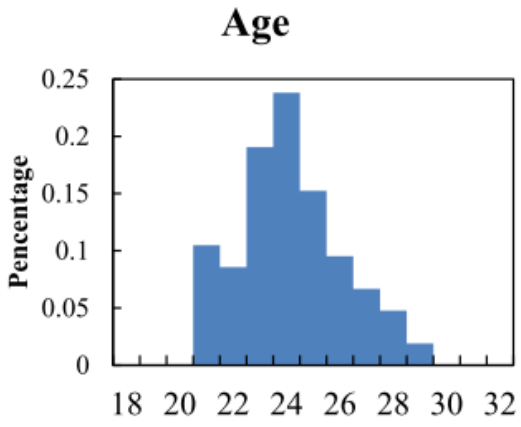
- **Questionnaire**
  - Personal information part
    - Gender, age, education background, experience on geometry processing
  - Algorithm part
    - How easily the users specified the segmentations?
    - How fast they carried out their initial segmentations?
    - How accurate they considered their initial segmentations?
    - How fast they refined their segmentations?
    - How accurate they considered their final segmentations?
    - How stable is the method?
    - Rate the algorithm by considering the general performance.

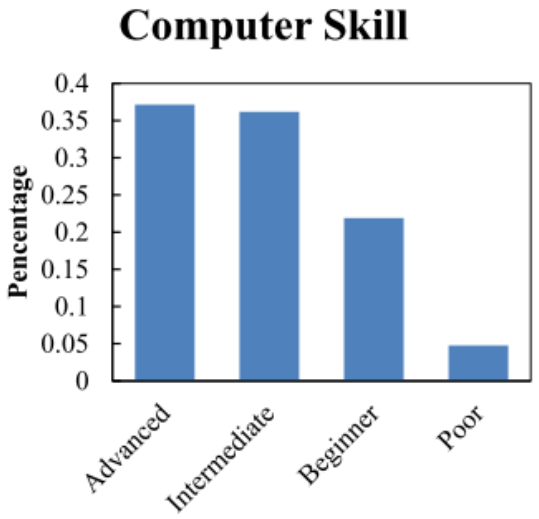
# Experiment



- **User statistics**
  - 105 participants.
  - 30 participants have experience in geometry processing,
  - 40 participants are familiar with human-computer interaction.
  - Most of them are computer science graduates.



# Experiment

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- **Collected experiments**
  - One month.
  - 2625 segmentations collected
    - 2310 accepted
    - 315 discarded
  - Each model was segmented an average of 5 times by each algorithm

# Criteria of Evaluation

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- **Accuracy**
  - The degree to which the extracted part corresponds to the ground-truth
- **Efficiency**
  - The amount of time or effort required to perform the desired segmentation
- **Stability**
  - The extent to which the same result would be produced over different segmentation sessions when the user has the same intention

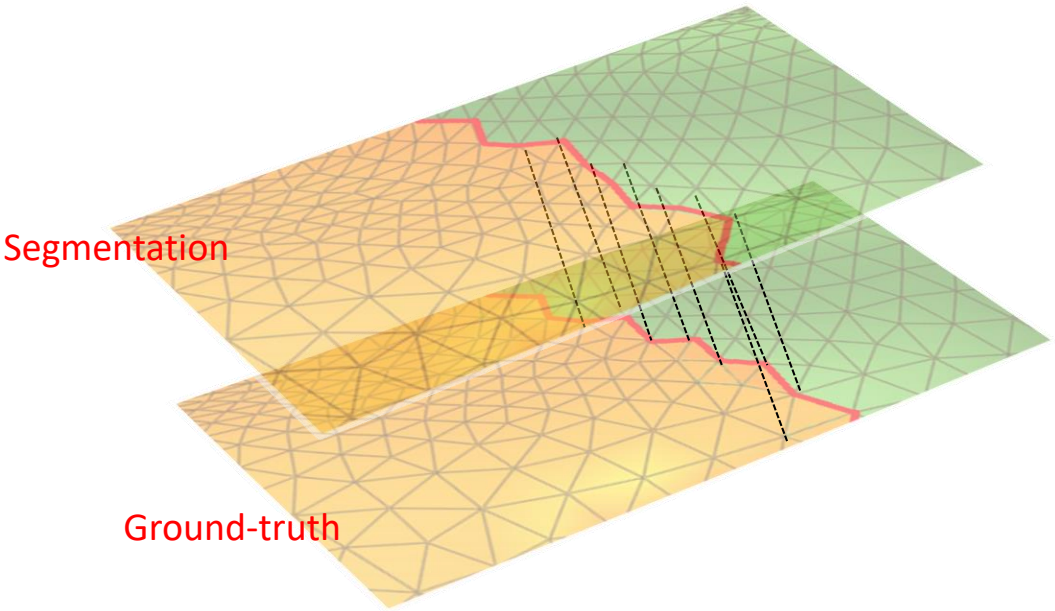
# Accuracy Measurement



- **Boundary Matching**

  The matching degree between the cut boundaries of two interactive segmentations

  – Cut discrepancy (**NCD**) [Chen et al. 2009]



# Accuracy Measurement

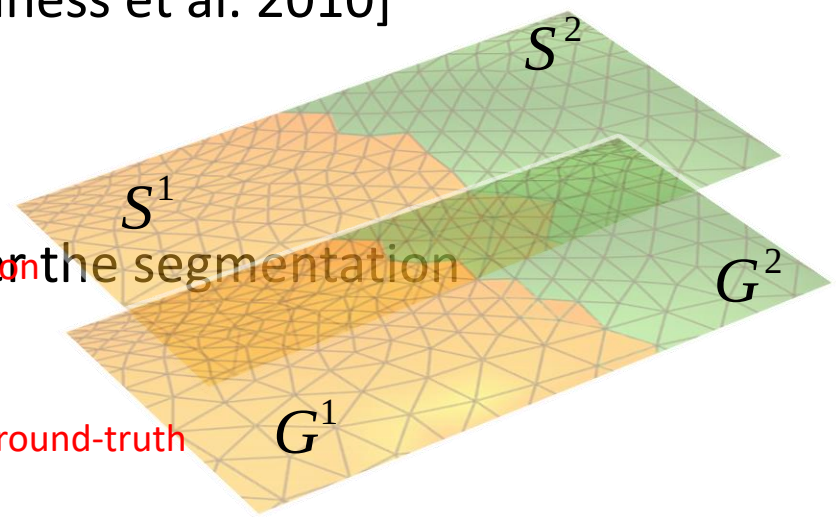
SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- **Region Difference**

  The consistency degree between the parts of interest produced by interactive segmentations in our study

  - Hamming distance (**NHD**) [Chen et al. 2009]
  - Rand index (**RI**)
  - Global/Local consistency error (**NGCE**, **NLCE**)
  - Binary Jaccard index (**JI**) [McGuinness et al. 2010]

- **Normalized Measures**
  - the higher the number, the better the segmentation



# Analysis

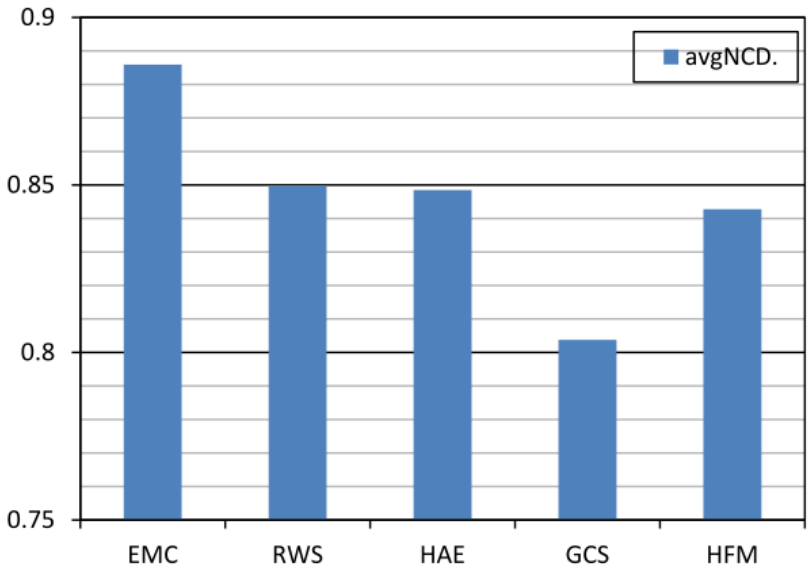
SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- **Accuracy**
  - Boundary Matching
  - Region Difference
- **Efficiency**
  - Interactive time
  - Updating time for new sketches
  - Number of interactions
- **Stability**
- **User feedback**
- **Comparison with automatic algorithms**

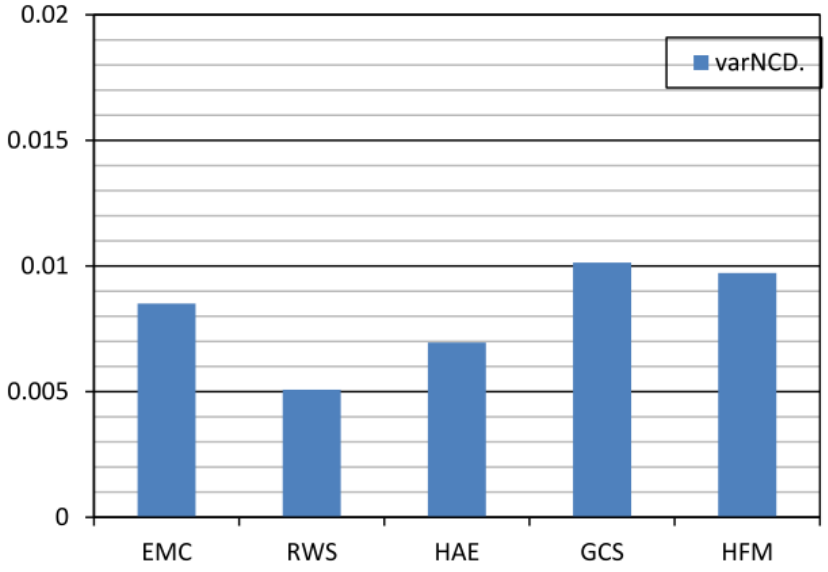
# Accuracy



- **Boundary Accuracy**




Boundary Accuracy

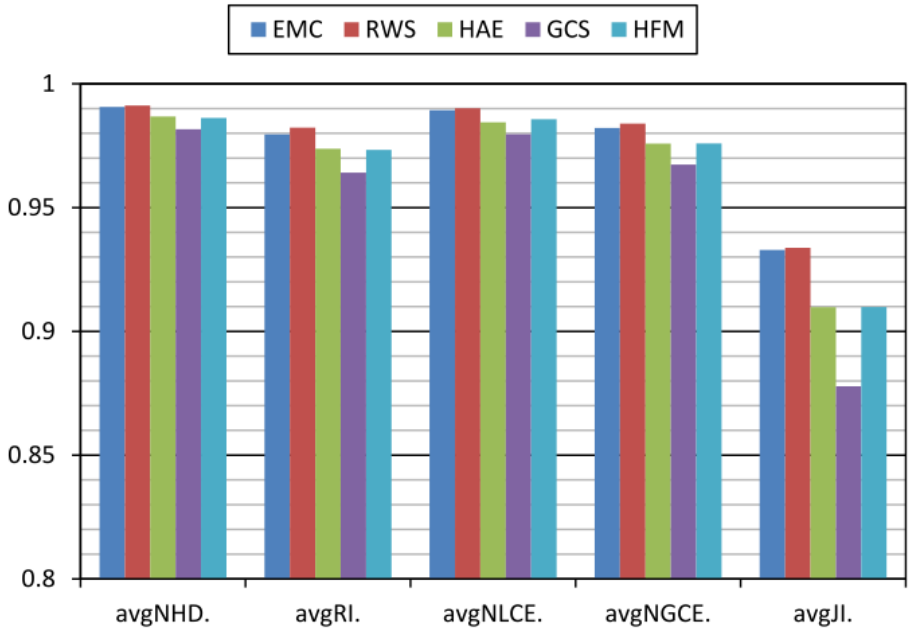



Variance of Accuracy

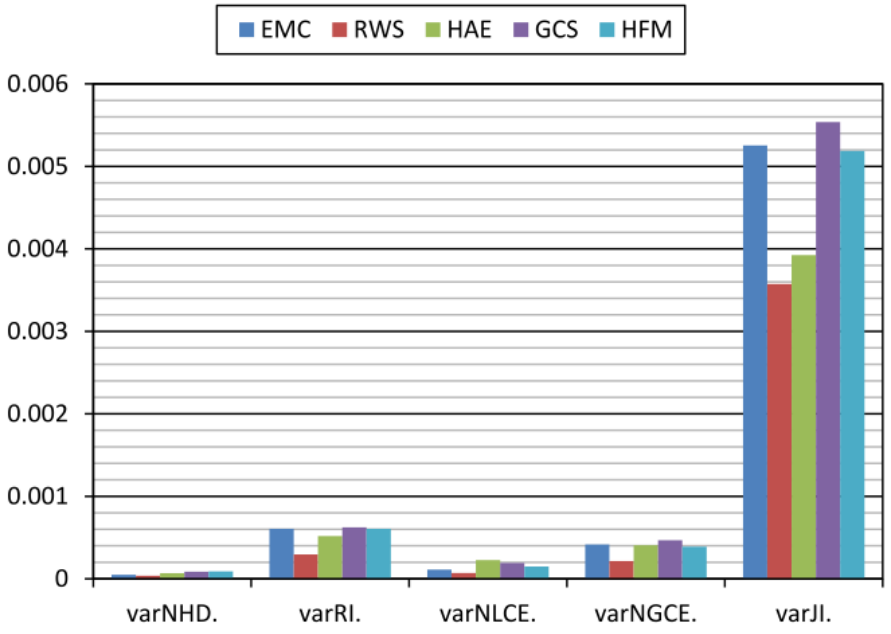
# Accuracy

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- Region Accuracy




Region Accuracy

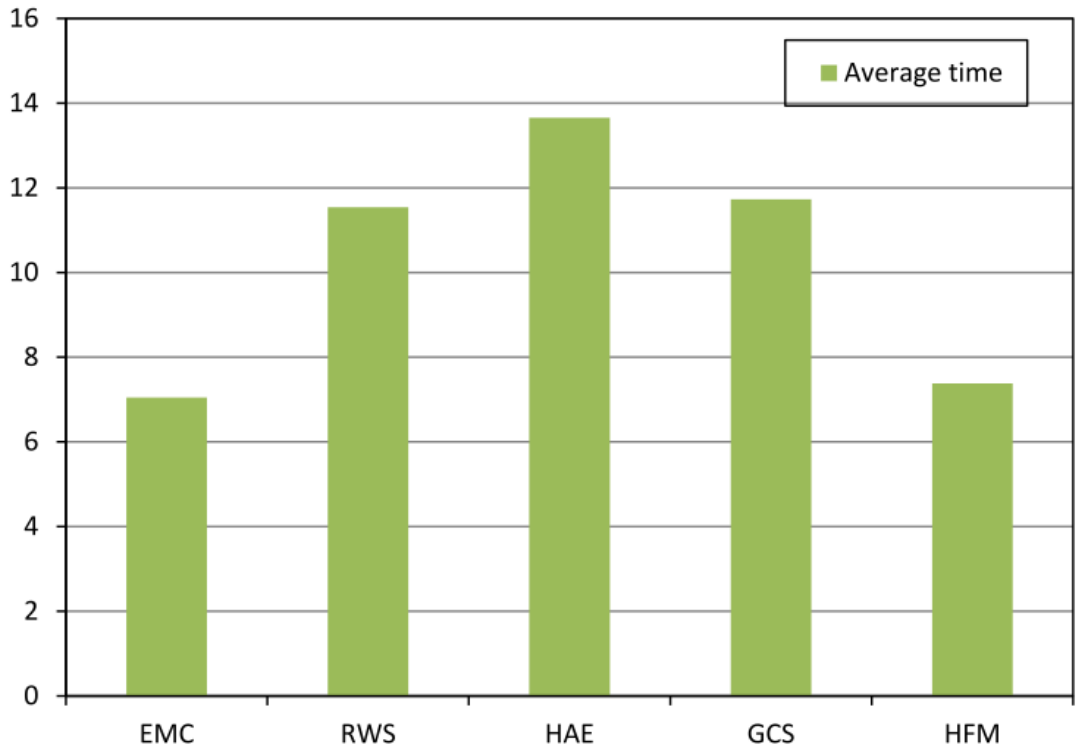



Variance of Accuracy

# Efficiency



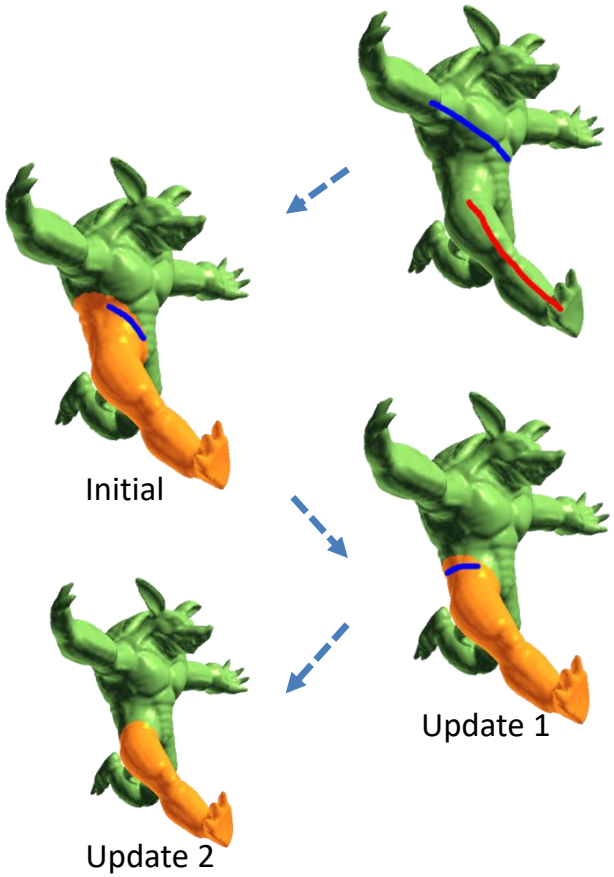
- Interactive time

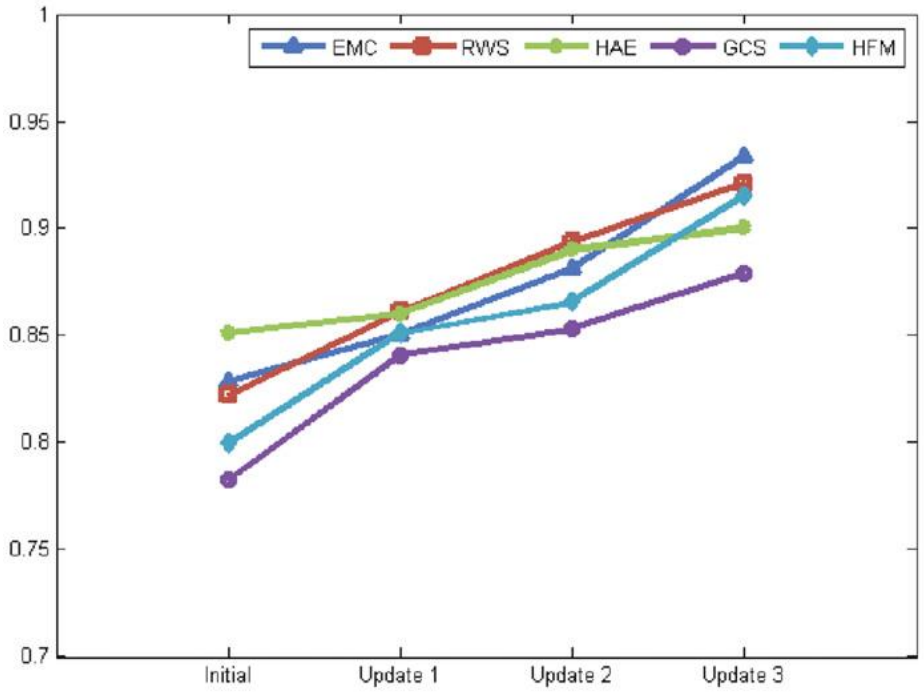


# Efficiency



- Updating time for new sketches



# Efficiency



- **Number of interactions**

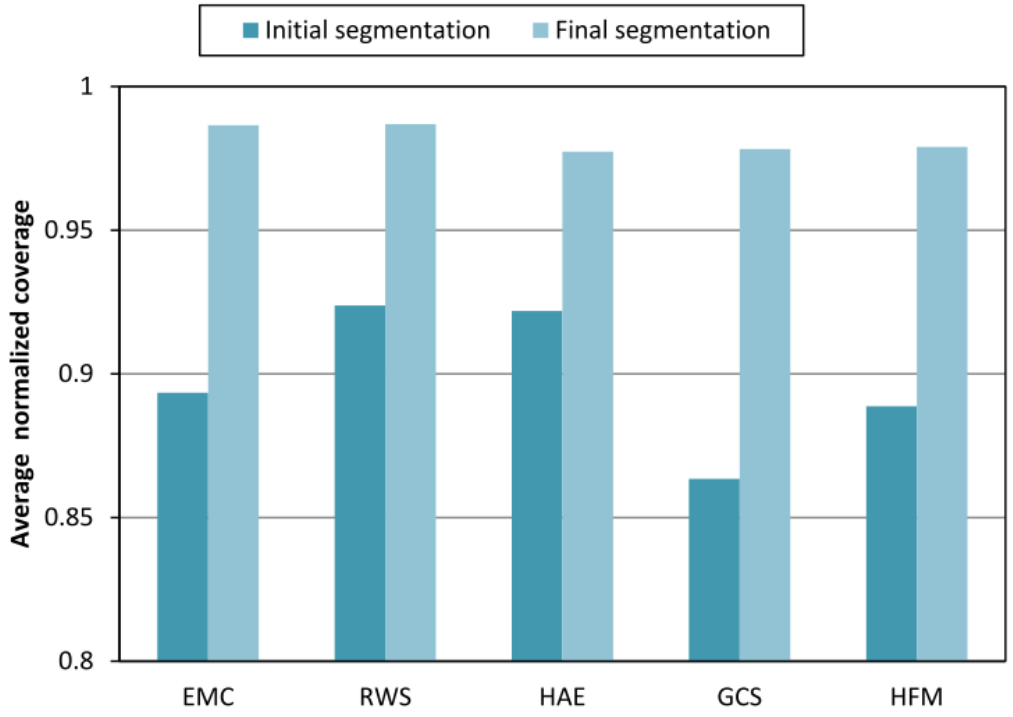

Average number of interaction

# Stability



- **Averaged normalized coverage**

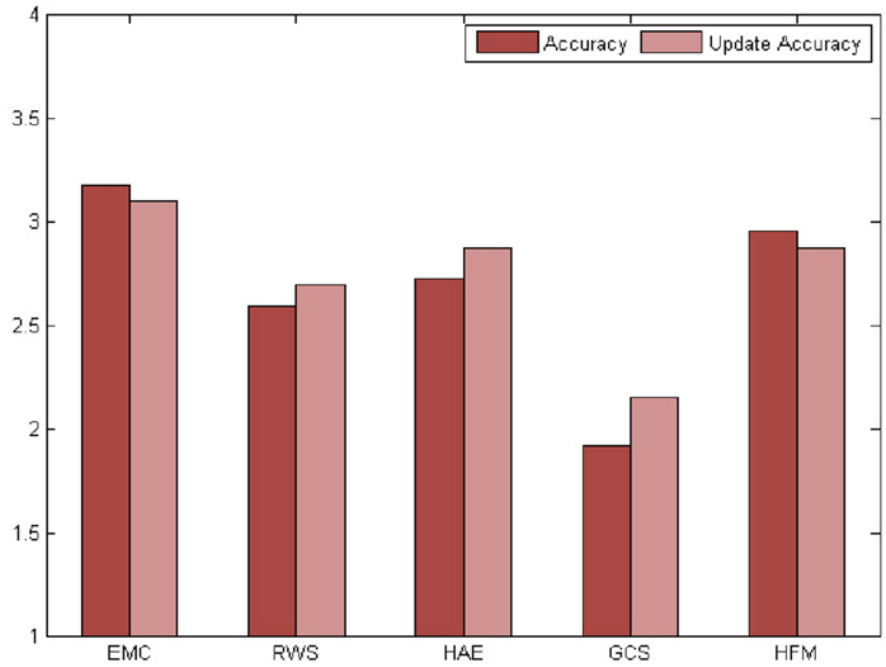
The percentage of triangles with the same labels (foreground or background) found when using different user inputs per model, averaged across all models for each algorithm.

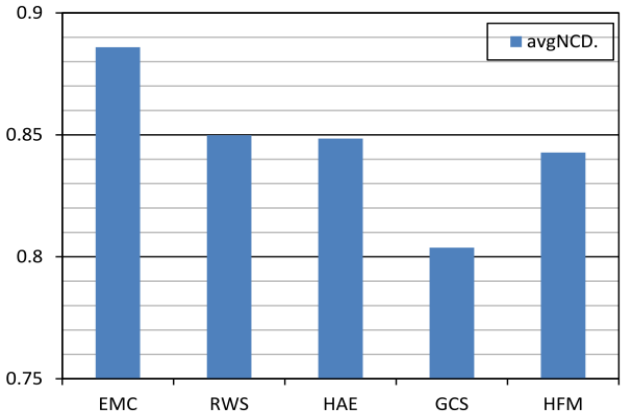


# User Feedback

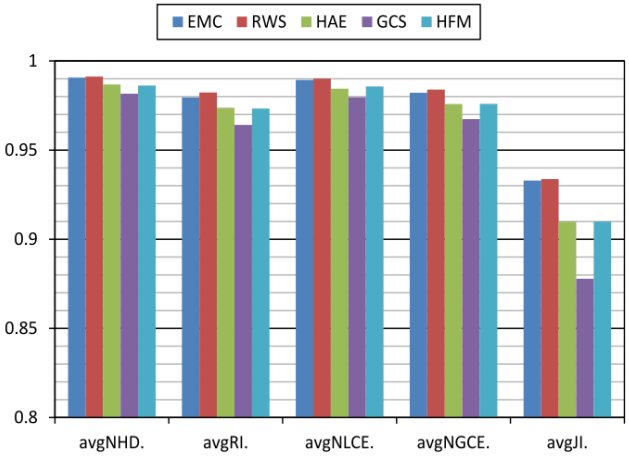
SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- Perceived accuracy




Boundary Accuracy

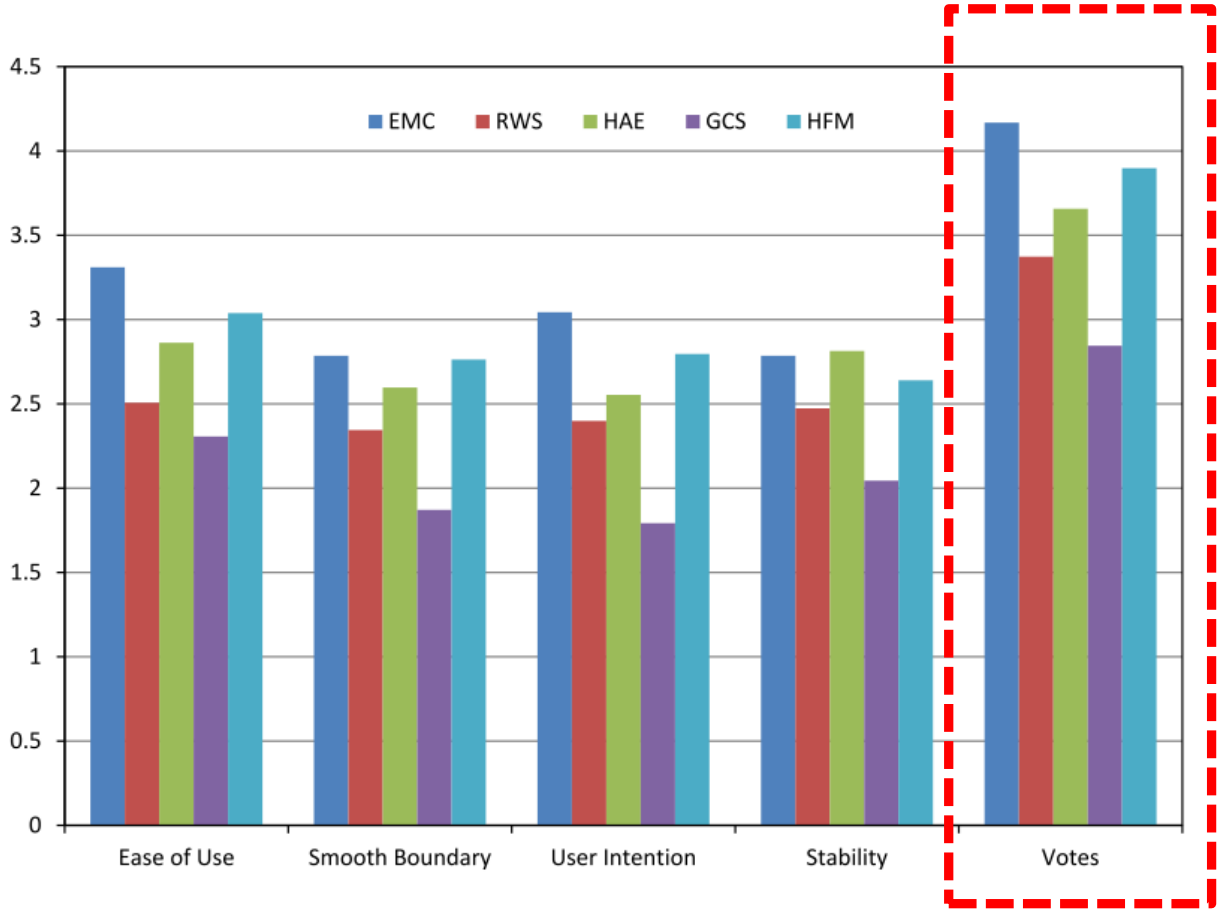



Region Accuracy

# User Feedback

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

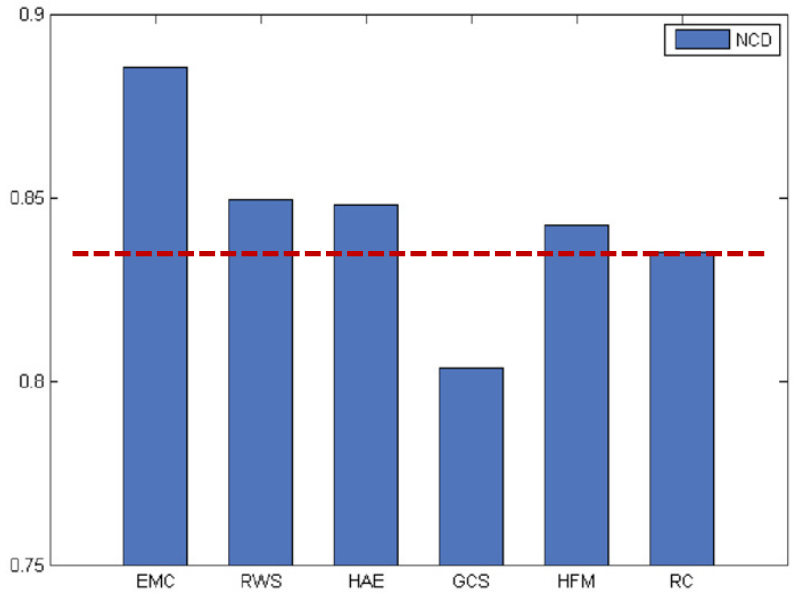
- Feedback for Each Algorithm

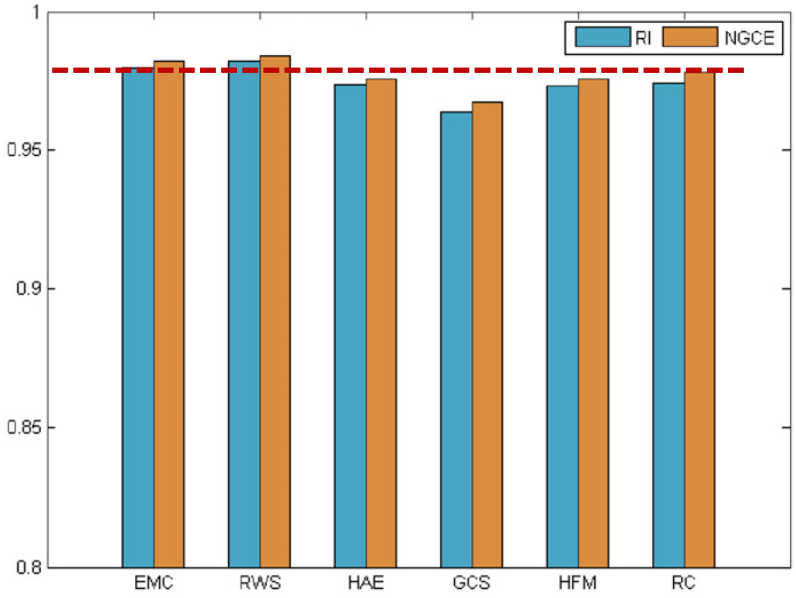


# vs. Automatic Algorithms



- **Automatic Algorithms**
  - Randomized cuts algorithm (**RC**) [Golovinskiy et al. 2008]
  - Segmentation results are from the Princeton segmentation database [Chen et al. 2009]



# Summary



## Object

- No interactive algorithm is better than all the others.
- EMC performs better:
  - The region growing scheme is very efficient.
  - Capture the geometry features
  - Quick  feedback

## Subject

- Efficient refinement
- Few interactions
- Instant feedback

Fast feedback and quick update process are more important than accuracy.

# Conclusion

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- Evaluation methodology for foreground/background sketch-based interactive mesh segmentation algorithms
- A software platform for evaluation
- Extensive user experiments
- Thorough analysis
- Valuable insights

## Future Work

- Expand corpus and ground-truth
- Different sketch-based user interfaces

# More details

SMI'11
IDC, Herzliya, Isael
June 22 - 24, 2011

- **Webpage:**

  http://www.math.zju.edu.cn/ligangliu/CAGD/Projects/SketchingCuttingEval-FB/default.htm

- **Supplementary file**
- **Share the data (soon!)**
  - Data set
  - Segmentation tasks and assistant images
  - User data
  - Analysis data

SMI'11
June 22 - 24, 2011
Shape Modeling International
The Interdisciplinary Center, Herzliya, Israel

# A Comparative Evaluation of Foreground/Background Sketch-based Mesh Segmentation Algorithms

Min Meng  Lubin Fan  Ligang Liu

*Zhejiang University, China*