Evaluation of Virtual Reality based Mesh Saliency Maps

Abschlussvortrag zur Masterarbeit
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Outline

Goal of this work

- Evaluation of differences between automatically computed and through user selections determined important parts of 3D objects
- Gathering data and discussing differences

Background

- Automated complexity reduction of 3D objects for real-time rendering
- Maintain perceived quality and detail as much as possible

Terms

- Mesh Saliency
  - **Prominence** of surface points of objects in 3D space
  - Measure of **perceived importance**, based on fundamentals of human cognition[1]

http://www.digitaleng.news/de/polygonal-mesh-library-for-postprocessing-3d-scan-data/
- visited 07-06-2017

- Immersive Virtual Reality environments
  - Virtual scene is **perceived** as real, actual stimuli are overshadowed

- Spatial indexing structures
  - Allow efficient operations on 3D data
  - Quad- and Octrees, R-trees...

[1] Itti, Laurent, Christof Koch, and Ernst Niebur. "A model of saliency-based visual attention for rapid scene analysis." IEEE Transactions on pattern analysis and machine intelligence 20.11 (1998): 1254-1259.

Related work
Mesh Saliency

- Comparison of vertices to their **surrounding** to determine their perceived importance
  - Critical value: **curvature**
  - Scalable via **radius** determining the surrounding
- Relevant for automatic **complexity reduction** (number of vertices and polygons) in the context of real-time rendering



Chang Ha Lee, Amitabh Varshney, and David W Jacobs. Mesh saliency. In *ACM transactions on graphics (TOG)*, volume 24, pages 659–666. ACM, 2005.

Concept
Major tasks

- Implement **Selection Application**
  - Loading and indexing of 3D data
  - Selection functionality

- Conduct **User study** to collect data
  - Users select **interesting** regions via selection application
  - Selections logged and used as “**user saliency**” values

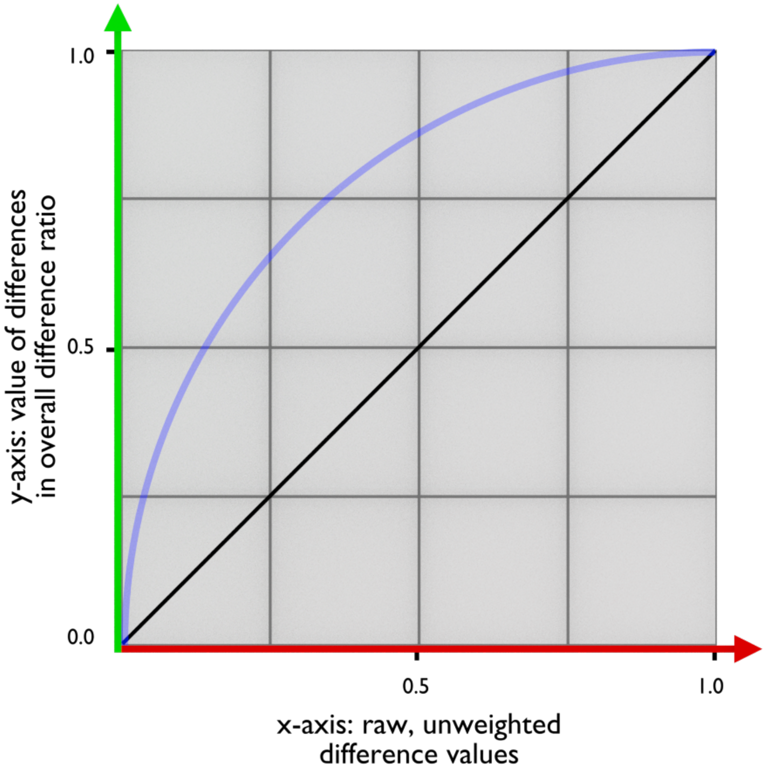
- **Difference evaluation**
  - Use *mesh saliency* to compute **mesh saliency** values
  - Gather data from user study
  - Compare mesh saliency and user saliency values
  - Conceptualize **measure of difference**

[1] http://assimp.sourceforge.net/

Concept
Measure of difference

- $S_M(v_i)$ = calculated mesh saliency value for vertex v_i
- $S_U(v_i)$ = average user saliency value for vertex v_i
- $|S_M(v_i) - S_U(v_i)|$ = (unweighted) difference for vertex v_i
- Sum over differences = **measure of difference**
- All values normalized to range [0.0, 1.0], in relation to maximum values

- Some differences more interesting
  - Mesh saliency values for surrounding vertices of vj high ->
  - $|S_M(v_j) - S_U(v_j)|$ gets weighted
- Goal: First, quick and easy measure of differences



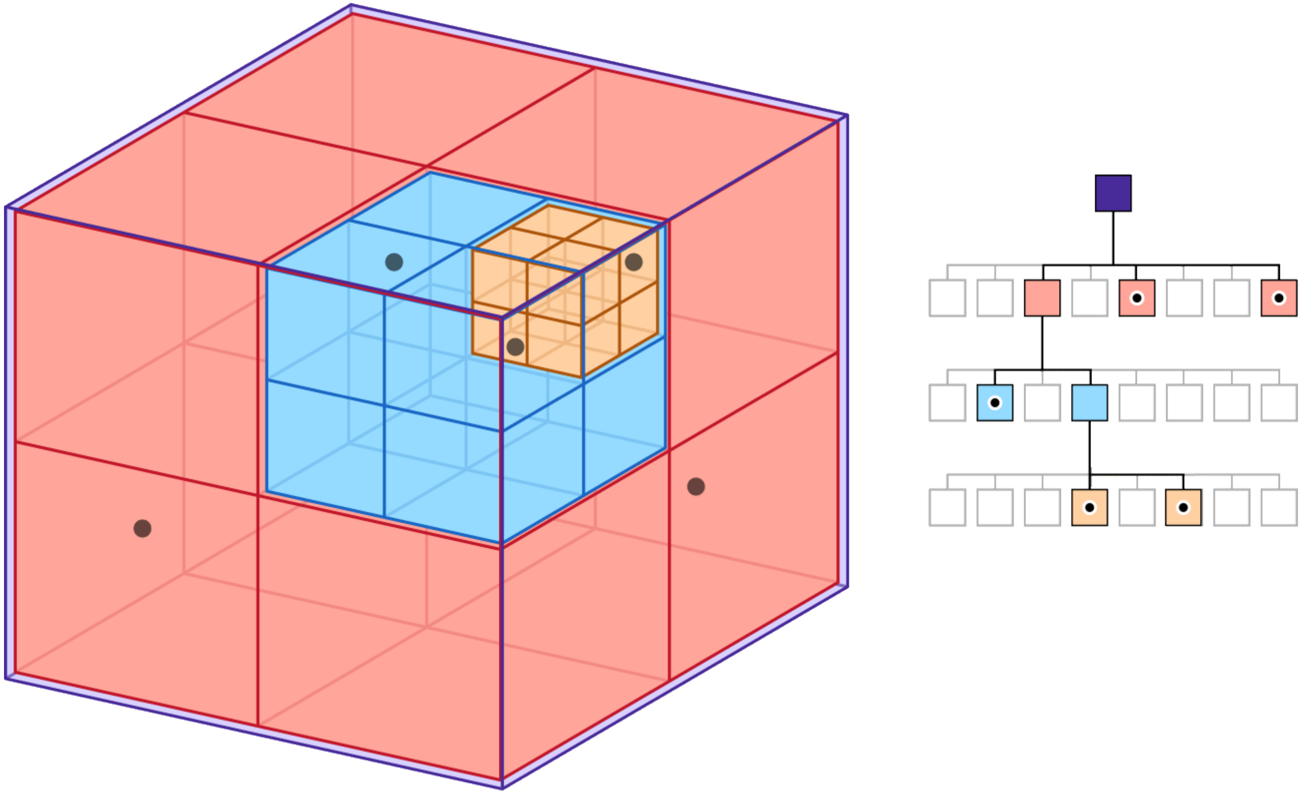
Implementation
High-level tasks

- Spatial **index structure** as basis
  - Octree, implemented in C++
  - Load and render objects
  - Render selection target
- Selection functionality
  - **Select** & **deselect** vertices
  - Visual feedback on **where operations take place**
  - Visual feedback on **what is** currently **selected**
  - **Log** user selections & provide export function
- **Adjust** application for usage at V2C
  - **Distributed rendering** via graphics cluster
  - Ensure **synchronized** rendering

http://assimp.sourceforge.net/

Implementation
Octree

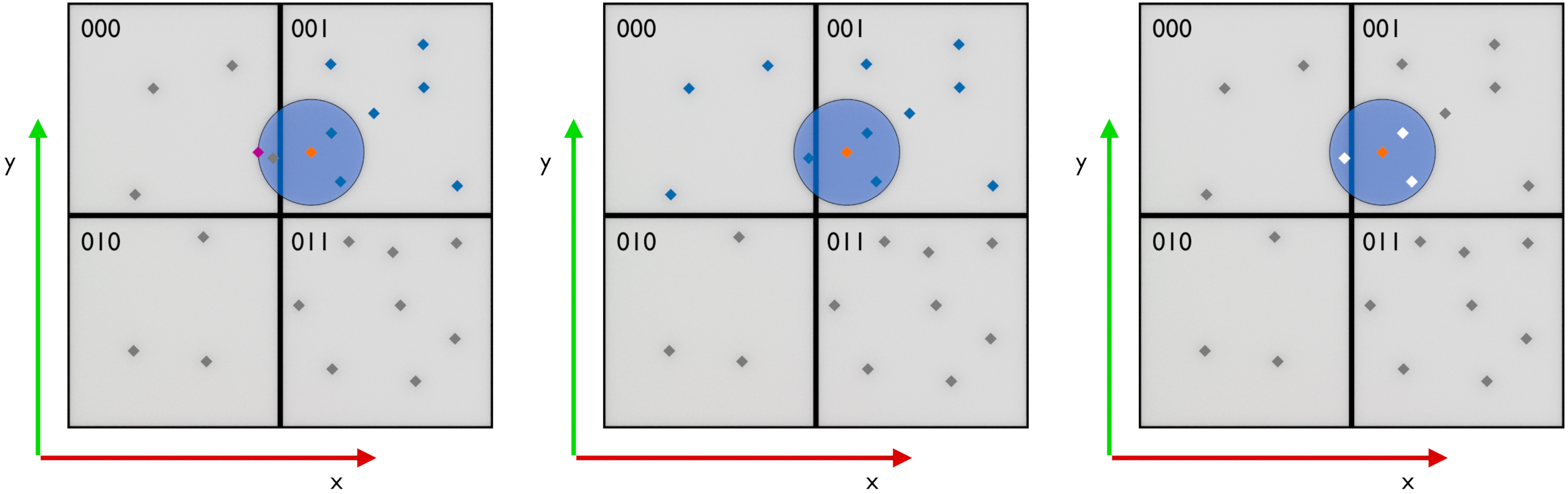
- **Load** objects via ASSIMP[1]
- Spatial **indexing** of loaded 3D data
- Provide **real-time interaction**



https://developer.apple.com/documentation/gameplaykit/gkoctree - visited 08-12-17

Vertex selection

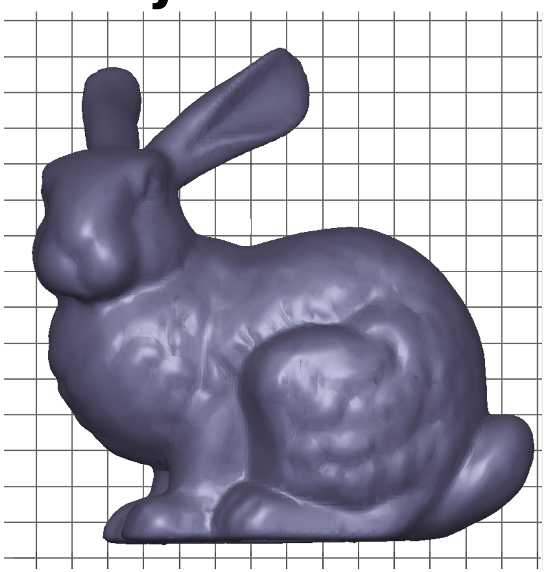
- Add vertices to selection & remove them
- Next-neighbor queries and possible follow-up queries
  - Determine **target subtree** of original query
  - Determine **set of vertices to check**
  - Determine **crossed borders** of target subtree
  - Update set of vertices to check accordingly

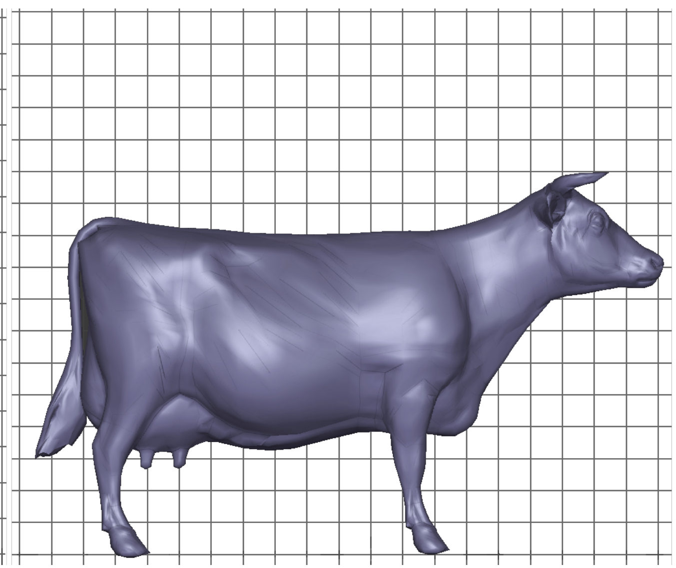


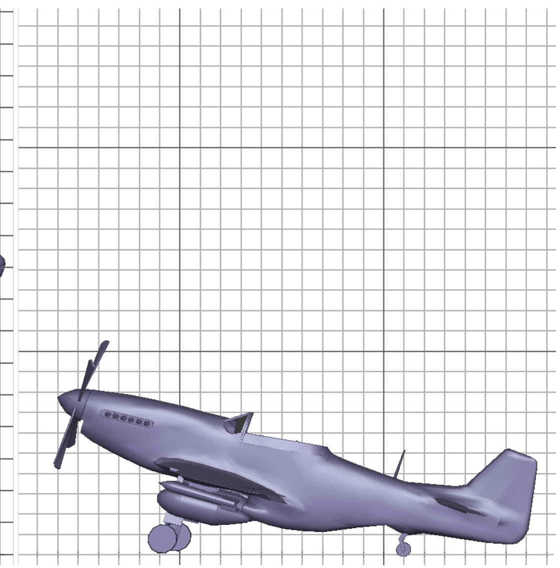
User study

- Users select **parts of objects** considered "**interesting**"
- Selection-radius around input device: **95%** of smallest possible subtree
- "interesting" as interpreted **subjectively**. Suggested hints:
  - *"Parts which are **geometrically interesting** or important"*
  - *"Parts which intuitively attract **attention**"*
  - *"Parts and regions which are **characteristic** for the object"*

Objects

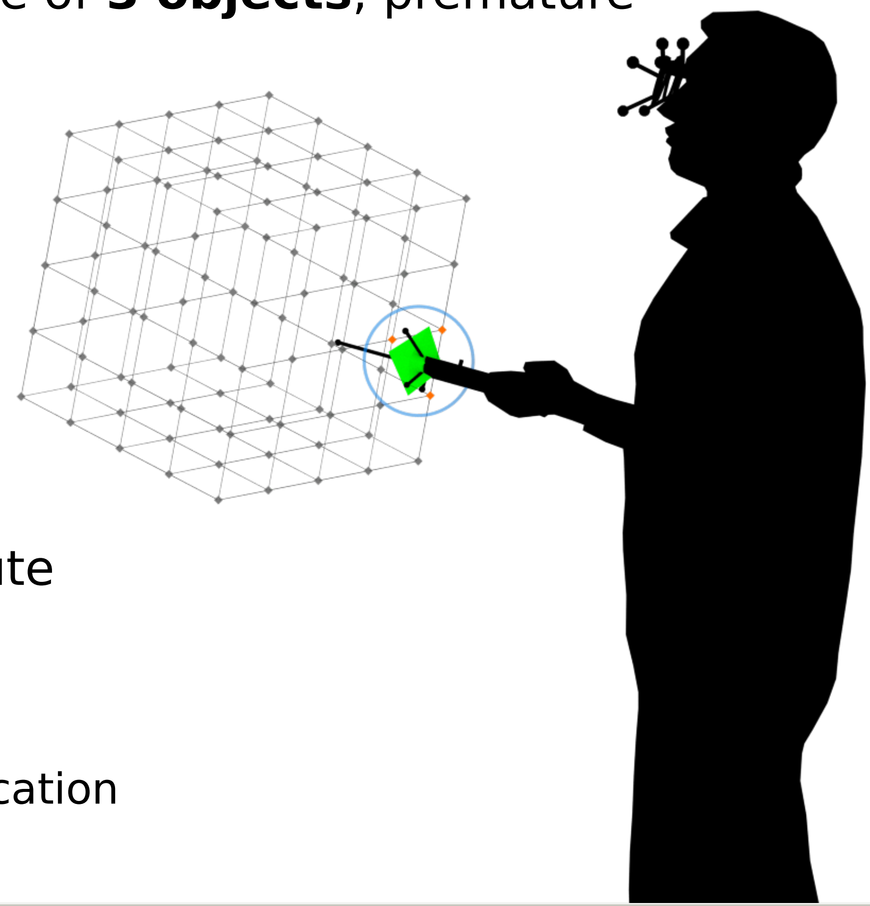

68.754 Vertices


69.648 Vertices


51.708 Vertices

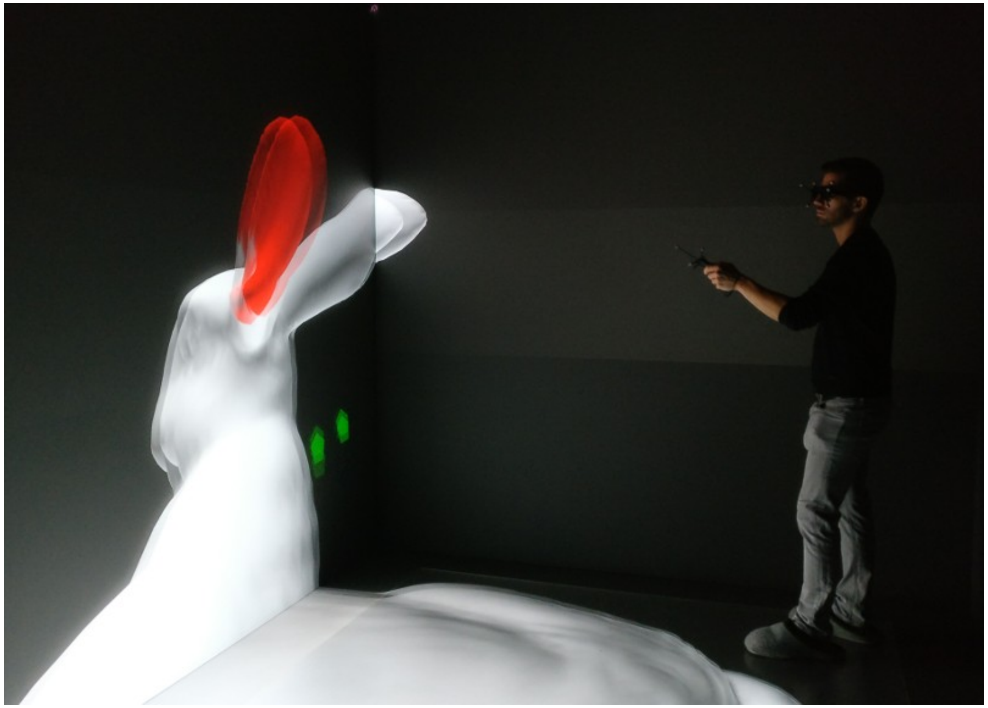
User Study
Instructions

- **Take time** to **get familiar** with the application
- **5 Minutes** maximum for each one of **3 objects**, premature termination by user possible
- Consider **symmetry** in selection
- Select as **precise** as desired
- No “correct” or “incorrect” selection
- Clue at beginning of the last minute
- Questionnaire
  - Demographic information
  - Interests and feedback on the application



User Study
Goals

- 3 **User-selections** per user
  - Vertex-ID & Timestamp logged
  - Saved to logfile

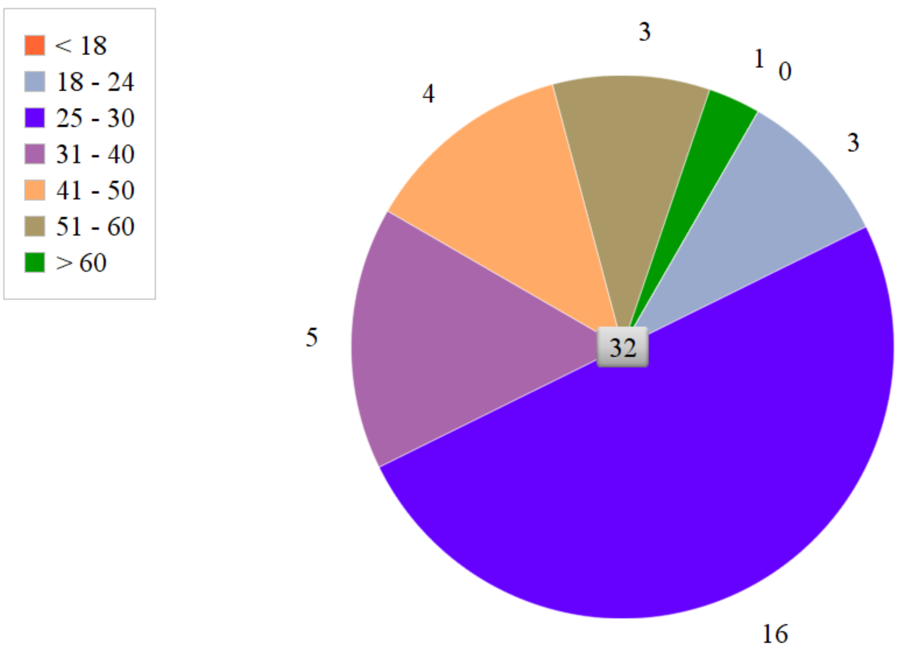


- Get "**User saliency**" values

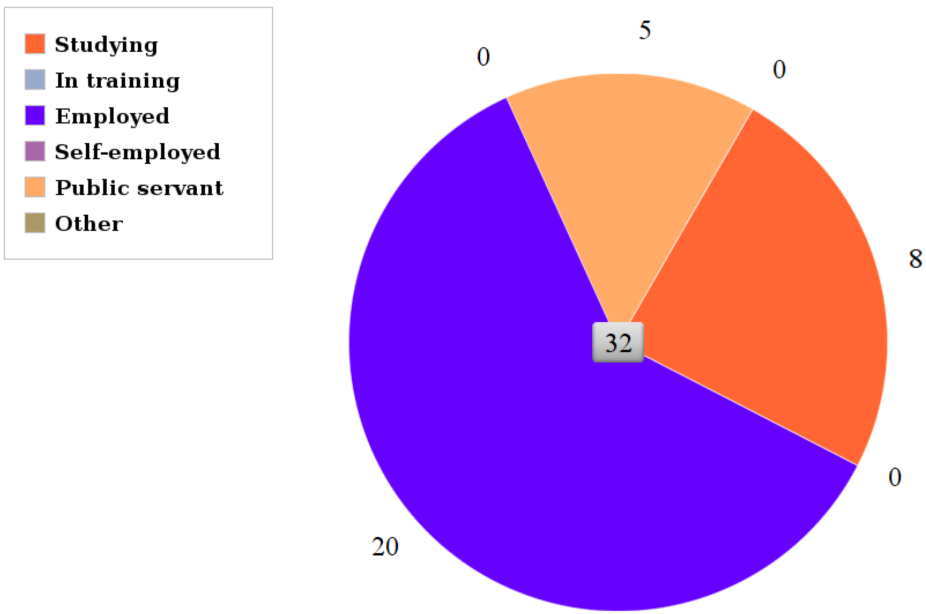
- Basis for evaluating differences between computed mesh saliency maps and average user selections

Results
Demography

- **32 participants total**, 50/50 male/ female
- **14** users **with** prior **experience** with VR; **18** users with **none**
- No strong impairments of vision
- 29 right-, 3 left-handed



Age groups



Working situation

Results
Feedback on application

Average value scores Likert-Scale

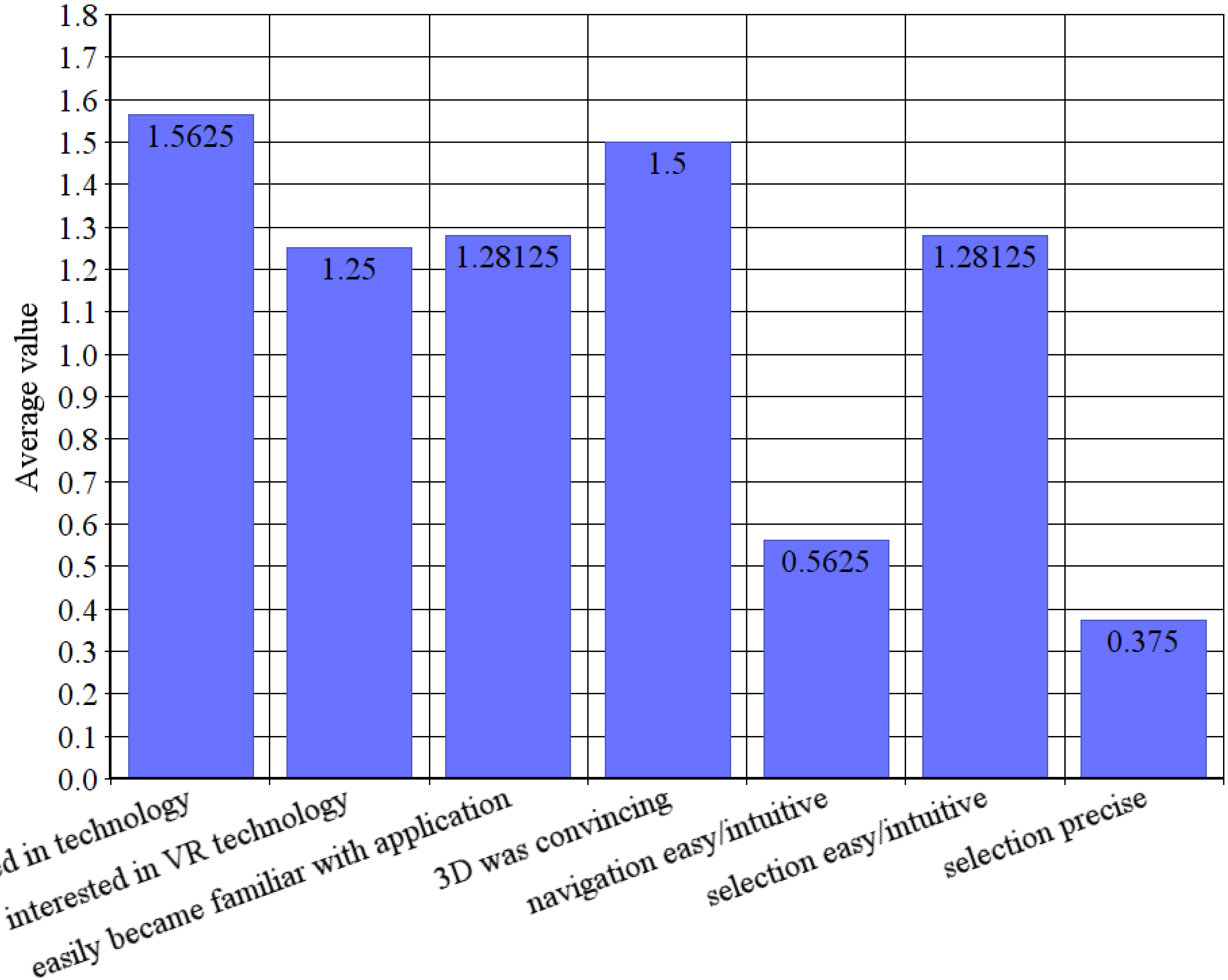
2 = “strongly agree”

1 = “agree”

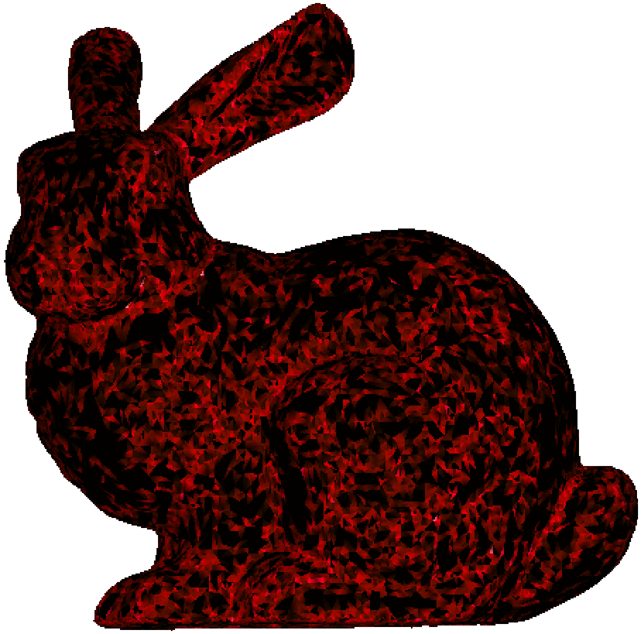
0 = “no statement”

-1 = “do not agree”

-2 = “strongly disagree”



Results
Model “bunny”



Mesh Saliency

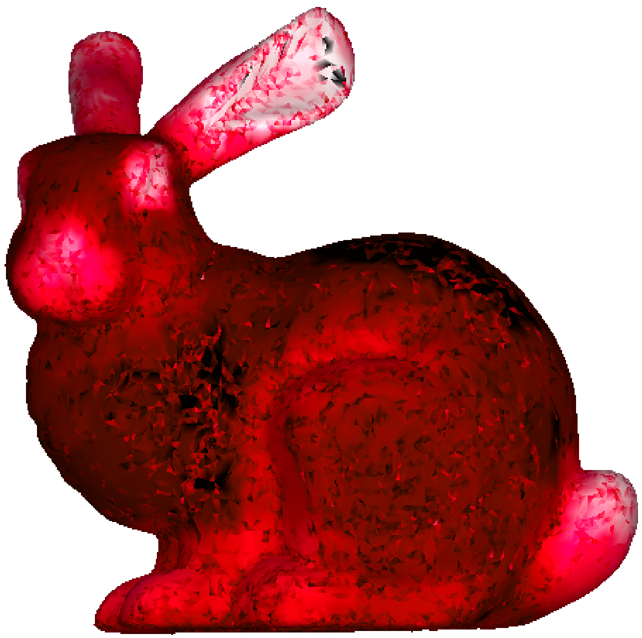
Average User Saliency

Scale

0.0 0.5 1.0

Results
Model “bunny”

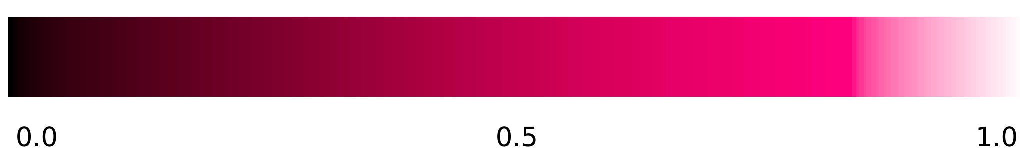
Difference overall (unweighted):	**0.23435**	Vertices total:	**68.754**
Difference overall (weighted):	**0.23455**	Vertices weighted:	**2667**



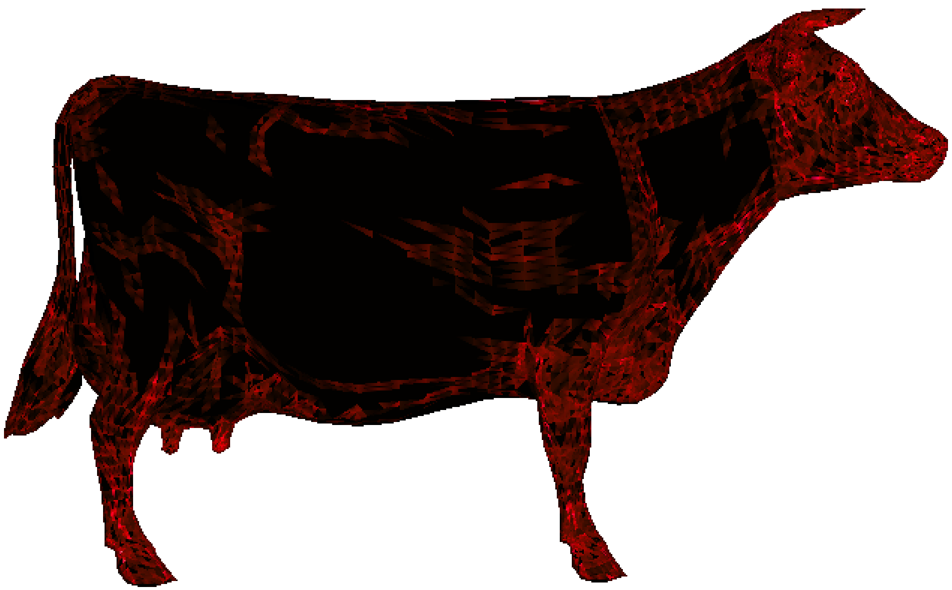
Differences unweighted

Differences weighted

Scale

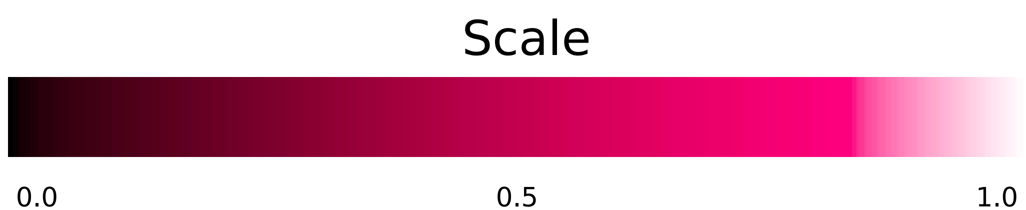


Results
Model “cow”



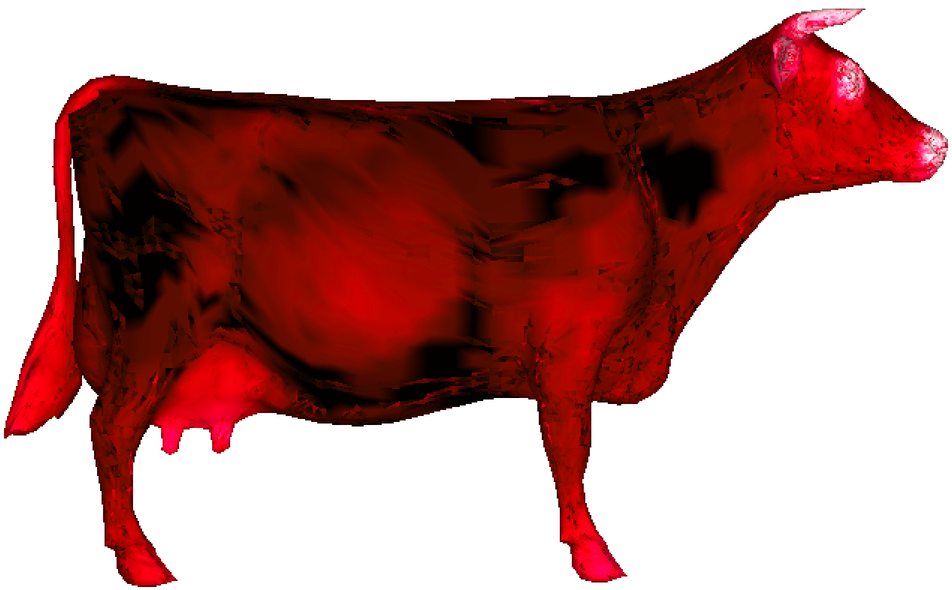
Mesh Saliency

Average User Saliency

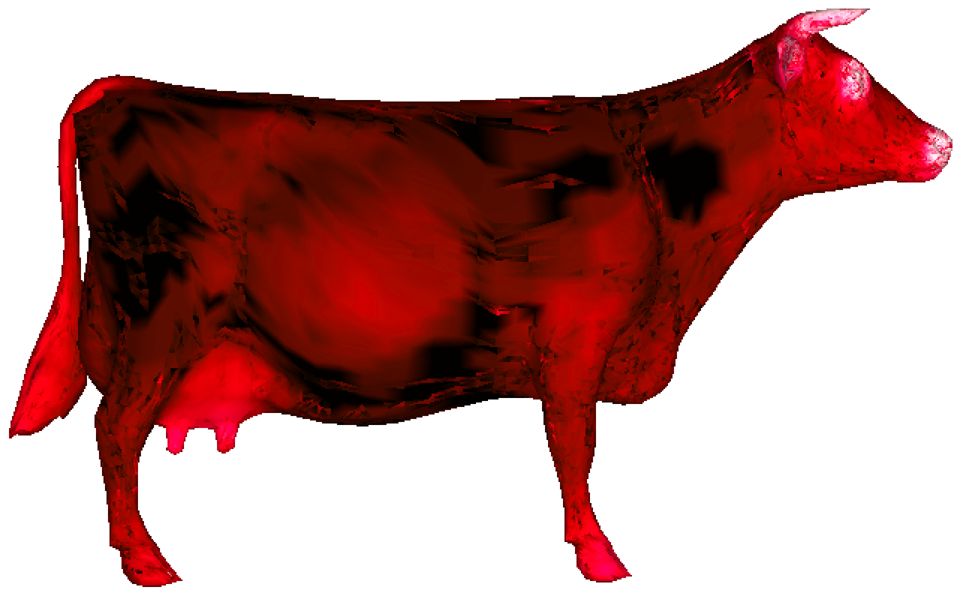


Results
Model “cow”

Difference overall (unweighted):	**0.27431**	Vertices total:	**69.648**
Difference overall (weighted):	**0.26904**	Vertices weighted:	**3200**



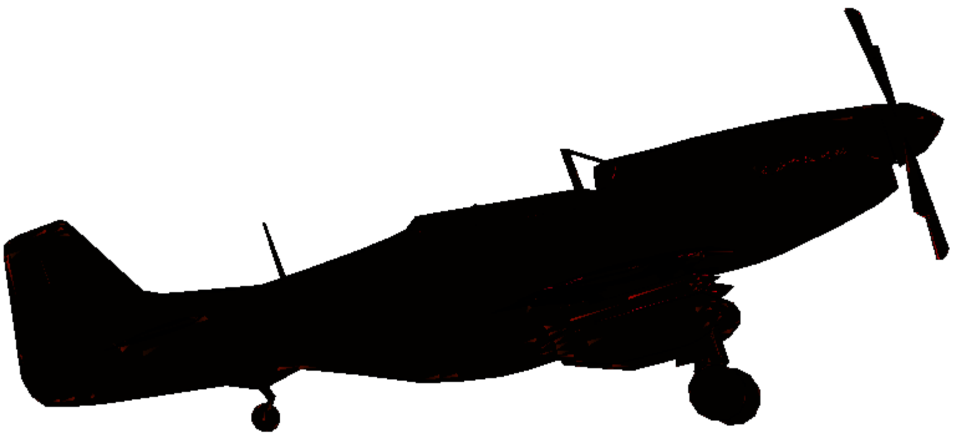
Differences unweighted



Differences weighted

Scale

Results
Model “P51”



Mesh Saliency

Average User Saliency

Scale

Results
Model “P51”

Difference overall (unweighted):	**0.38002**	Vertices total:	**51.708**
Difference overall (weighted):	**0.38002**	Vertices weighted:	**0**

Differences unweighted

Differences weighted

Scale

0.0 0.5 1.0

Measure of difference

- Overall differences between ~0.23 and ~0.38
- Low difference, as expected **but**
  - **Many very low values** “water” overall result
  - Very basic measure of difference

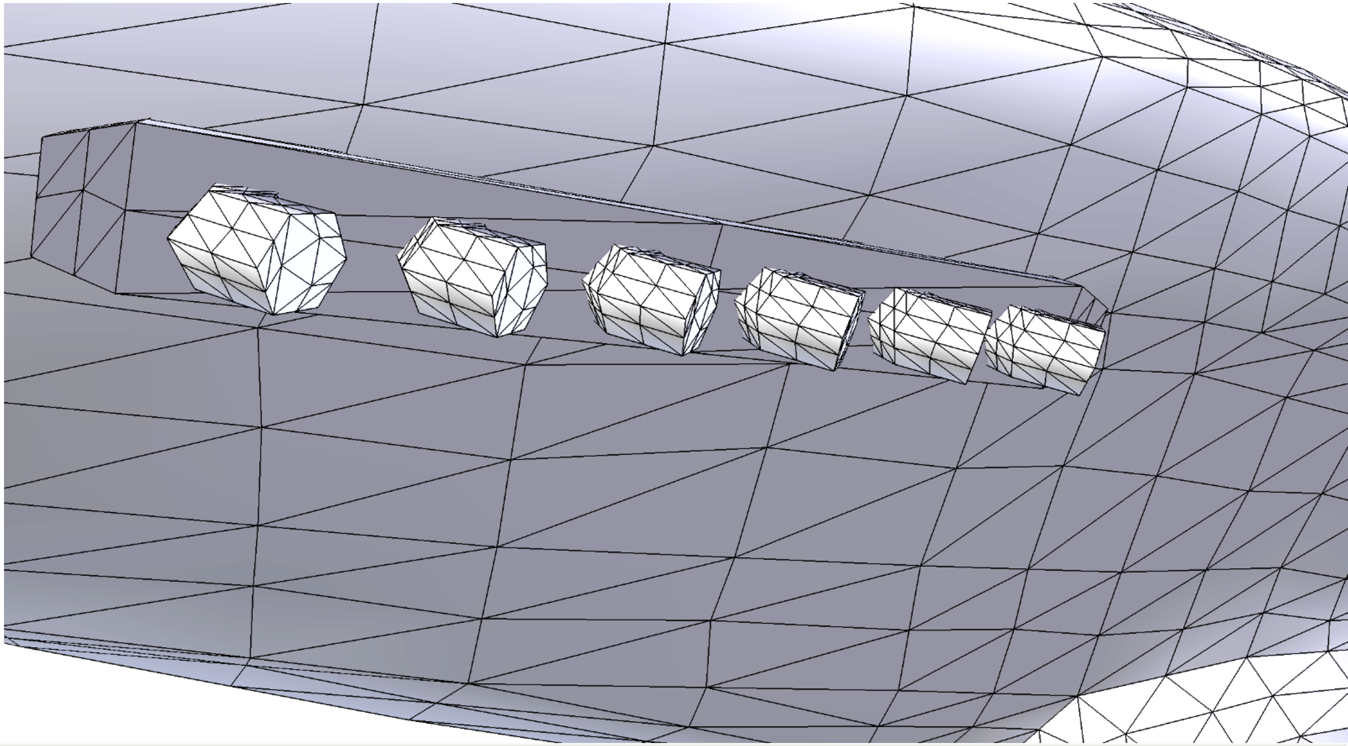
Observations

- Seemingly **zero-values** in the middle of highly “*popular*” regions
- Possible faults in implementation

- Stronger **variation** in user saliency values
- More clearly **distinct patches** in user saliency values
- Clearer values for **both** mesh and user saliency values for non-mechanical objects

Mesh saliency with mechanical objects

- **Normalizing** saliency values to the highest one
  - Very **few**, extremely **high** values
  - **Almost all** values are very **low**
- Weakness of difference measure



Future Work

- Further develop **measure of difference**
  - No normalizing of values
  - Multiple figures expressing differences
- Other values for variables
  - Selection radius
  - Object size
  - Time
- More extensive **user study**
  - More users
  - Other kinds of immersive VR
- Use **additional data** collected
  - Determine influences of VR (feedback)
  - Use logged **time**

References

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- https://developer.apple.com/documentation/gameplaykit/gkoctree - visited 08-12-17
- http://http.developer.nvidia.com/GPUGems2/gpugems2_chapter37.html - visited 07-06-17