University of Basel

3D model retrieval using Constructive Solid Geometry (working-title)

Bachelor thesis

Natural Science Faculty of the University of Basel
Department of Mathematics and Computer Science
Database and Information Systems Research Group
https://dbis.dmi.unibas.ch/

Examiner: Prof. Dr. Heiko Schuldt
Supervisor: Ralph Gasser, MSc.

Samuel Börlin
samuel.boerlin@stud.unibas.ch
16-051-716

Hand-In-Date

Abstract

Table of Contents

1 Introduction

2
Related Work

2.1 3D model/multimedia retrieval

Cineast, spherical harmonics, clusterD2+color, etc.

2.2 Visualization of voxels

Marching cubes, dual contouring, CMS

2.3 (VR) sculpting

3
Concepts and Architecture

3.1 General overview

How all components are connected to each other (cineast, feature module, cottontail, rest api, polygonizer, voxel storage, vr interaction controller, etc.)

3.2 Cineast

What is cineast, how does it work (feature modules, cottontail etc.)...

3.2.1 Extraction Modules

What, how

3.2.2 Queries

What, how, KNN, etc.

3.3 Voxels

What are voxels, purpose, hermite data, etc.

3.4 Isosurface Polygonization

Method for converting voxels into meshes, some common algorithms as examples

3.5 CSG

3.6 Voxelization

3.7 Signed Distance Functions

What are they, why are they relevant for this work

3.8 Virtual Reality

What is VR, use cases

3.8.1 UI design

Windows vs. using 3D space

3.8.2 Sculpting interactions

One hand to grab, other to sculpt, rotating brush with trackpad, etc.

3.9 Unity

What, why

4 Implementation

4.1 Cineast

4.1.1 Cineast core changes

UV + texture support in meshes and OBJ loader

4.1.2 ClusterD2+Color feature extraction

What, why (color support), explain assumptions made that were not covered by the paper

4.1.3 Comparing features for similarity

L2 distance, Jensen-Shannon divergence, χ^2 distance

4.1.4 RESTful API

OpenAPI, swagger codegen

4.2 Voxels

4.2.1 Voxel storage

Chunks, hermite data quantization

4.2.2 CMS

Main algorithm on regular grid

4.2.2.1 Multi-material extension for CMS

Algorithm

4.2.2.2 Lookup table based implementation

Lookup table generator, lookup table based algorithm, limitations (time, multi-material support)

4.2.3 CSG operations on hermite data

How union and difference operations work on hermite data, algorithm

4.2.4 Rendering

Vertex colors encode material (RGB, A=texture id), texture array, triplanar texturing shader

4.2.5 Voxelizer

Purpose, explain method used for voxelization (assigning triangles to bins, patching holes, etc.), use of job system

4.2.6 SDFs

Implementation, arbitrary linear transformations by using the inverse to transform space instead of SDF

4.3 VR Sculpting

4.3.1 Sculpting features

General overview of capabilities and functionality, UIs, SteamVR Plugin, etc.

4.3.2 Brush properties menu

Functionalities, color selection (why HSV: you can see most colors at once, as opposed to RGB sliders)

4.3.3 Custom brush editing menu

Explain custom brush tool, why it exists, etc.

5 Evaluation

5.1 Technical Evaluation

Voxelizer, polygonization, queries, precision vs. recall?, etc.

5.2 User Evaluation

5.2.1 Structure

5.2.2 Results

TBD after evaluation

6
Discussion

6.1 Conclusion

6.2 Lessons learned

6.3 Future work

Performance, LODs/Octrees (SVO)/memory use (e.g. run length encoding), meshes as brushes (using voxelizer), saving/loading sculptures & custom brushes, multiple sculptures at once, splitting sculptures

Bibliography

A
Appendix

A.1 User Evaluation Questionnaire

The purpose of this user evaluation is to gather insight and feedback about the current implementation of the sculpting and querying functionality and the impression it has on users. The results will be helpful in identifying shortcomings and to improve the user experience.
If at any point you feel unwell or nauseous while using the VR headset please let me know. That can be a common reaction when not used to VR or when the program is not responsive enough.
Each time before moving on a next task please press the X button to reset the scene.

Missing: V
ton?

Background

1: not at all, 2: slighty, 3: moderately, 4: very, 5: extremely

1. How experienced are you with Virtual Reality?	1	2	3	4	5
2. How experienced are you with 3D sculpting applications?	1	2	3	4	5

Sculpting

1: very easy, 2: easy, 3: neutral, 4: difficult, 5: very difficult

3. Read the controller hints to become familiar with VR and the control scheme. Disable the controller hints once you're ready. Time limit: 5min.	1	2	3	4	5

Feedback:

_____

_____

4. Select the sphere brush and place it the world to create a shape or simple sculpture using the 'Add' mode.
Time limit: 3min. 1 2 3 4 5

Feedback:

_____

_____

5. Select a brush and create a shape, then select another brush and remove a piece of your sculpture with it using the 'Remove' mode.
Time limit: 3min. 1 2 3 4 5

Feedback:

_____

_____

6. Select a brush and create a shape, then pick another colour and colour a piece of your sculpture using the 'Replace' mode.
Time limit: 3min. 1 2 3 4 5

Feedback:

_____

_____

7. Select a brush and create a shape, then pick another material (i.e. texture) and change the material of a piece of your sculpture using the 'Replace' mode.
Time limit: 3min. 1 2 3 4 5

Feedback:

_____

_____

8. Create your own brush (with at least two primitives) using the custom brush editor and then use your own brush to create a shape.
Time limit: 5min. 1 2 3 4 5

Feedback:

_____

_____

Querying

1: very easy, 2: easy, 3: neutral, 4: difficult, 5: very difficult

9. Select a brush and create a shape, then use the query menu to run a similarity search.
Time limit: 6min. 1 2 3 4 5

Feedback:

_____

_____

10. Select a brush and create a shape, then use the query menu to run a similarity search. After that, pick one of the results and voxelize it into the world.
Time limit: 6min. 1 2 3 4 5

Feedback:

_____

_____

11. Select a brush and create a shape, then use the query menu to run a similarity search. After that, pick one of the results and place it in the world. Using a brush, remove a piece of it and then run a similarity search for the modified sculpture.
Time limit: 8min. 1 2 3 4 5

Feedback:

_____

_____

12. That was all, thank you! If you feel like playing around some more with the program feel free to do so for a couple more minutes. Further below you can give general feedback.
Time limit: 5min. 1 2 3 4 5

General feedback

13. If you have any additional remarks or suggestions for improvements please write them down here.

Declaration on Scientific Integrity
Erklärung zur wissenschaftlichen Redlichkeit

includes Declaration on Plagiarism and Fraud
beinhaltet Erklärung zu Plagiat und Betrug

Author — Autor
Samuel Börlin

Matriculation number — Matrikelnummer
16-051-716

Title of work — Titel der Arbeit
3D model retrieval using Constructive Solid Geometry (working-title)

Type of work — Typ der Arbeit
Bachelor thesis

Declaration — Erklärung
I hereby declare that this submission is my own work and that I have fully acknowledged the assistance received in completing this work and that it contains no material that has not been formally acknowledged. I have mentioned all source materials used and have cited these in accordance with recognised scientific rules.

Hiermit erkläre ich, dass mir bei der Abfassung dieser Arbeit nur die darin angegebene Hilfe zuteil wurde und dass ich sie nur mit den in der Arbeit angegebenen Hilfsmitteln verfasst habe. Ich habe sämtliche verwendeten Quellen erwähnt und gemäss anerkannten wissenschaftlichen Regeln zitiert.

Basel, Hand-In-Date Missing

Signature — Unterschrift