252-0538-00, Spring 2017

Shape Modeling and Geometry Processing

Introduction and Overview



Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

February 21, 2018

Course Staff

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http://crl.ethz.ch/teaching/shape-modeling-18/



CRL - Computational Robotics Lab



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Shape modeling





Geometry processing

Signal processing on surfaces



Levy and Zhang, Spectral Mesh Processing, Siggraph Asia 2009 course notes



Spherical cow in vacuum

https://en.wikipedia.org/wiki/Spherical_cow



Geometry processing

Crane et al. Conformal Willmore Flow, Siggraph 2013



Computational fabrication







Course Goals

| Shape | Computational | Geometry |
|----------|---------------|------------|
| modeling | fabrication | processing |

| Theory and | Modeling | Hands-on |
|--------------|-------------|------------|
| applications | competition | experience |



Geometry = Shape = Object = Model





Applications



Product design and prototyping



Medicine, prosthetics



Architecture





Cultural heritage



Applications







Geographical systems









Boyer et al. 2012











Manufacturing, 3D Printing



Animation





Fabrication





Digital Geometry Processing

- DGP!
- Processing of discrete
 (polygonal mesh) models
- Why discrete?
 - Simplicity
 - Efficiency
 - Output of most scanners
 - Input to most simulators





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Interactive Shape Modeling

- Tools for design, editing and animation of digital shapes
 - Interactive = fast
 - Intuitive = predictable



http://youtu.be/EMx6yNe23ug



Interactive Shape Modeling Modeling is difficult!



https://youtu.be/ALbt17LLH54

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Interactive Shape Modeling Modeling is difficult!





Interactive Shape Modeling Modeling is difficult!





Interactive Shape Modeling Modeling is easy?



https://youtu.be/nUe2IHN_isU

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Tools of the trade

- Use techniques from both CS & Math
 - Numerical Optimization
 - Discrete differential geometry
 - Linear algebra
 - Graph theory
 - • •
- Coding!





Organization

- Communication through course website: <u>http://crl.ethz.ch/teaching/shape-modeling-18/</u>
- Mailing list
- Weekly lectures and exercise sessions
- Prerequisites:
 - Intro to Computer Graphics or Computer Graphics (252-0543-01L) - somewhat soft condition
 - Knowledge of C++ programming firm condition



Course Materials

- No book covers all topics
 - Many of the topics are recent research results
 - The following book might be helpful: Polygon Mesh Processing, Mario Botsch, Leif Kobbelt, Mark Pauly, Pierre Alliez, Bruno Levy, AK Peters, 2010. <u>http://www.pmp-book.org/</u> Several copies available in the CS library.
- We will **link** to some relevant papers in the **course slides**
- Lecture slides available on the website shortly after the class
- Papers from: ACM SIGGRAPH, Symposium on Geometry Processing (SGP), Shape Modeling International (SMI), EUROGRAPHICS, see <u>http://kesen.huang.googlepages.com/</u>



Grading

| Homework assignments | 80% |
|--|-----|
| Basic mesh modeling | 10% |
| Surface reconstruction | 14% |
| Parameterization | 14% |
| Mesh deformation | 14% |
| Finite Element Method | 14% |
| Geometry Optimization | 14% |
| | |

• Exam (last tutorial of semester) - 20%



Policy

- Homework assignments to be done individually.
 You may consult but may not collaborate. More details in the exercise section.
- Assignment are evaluated mostly based on a written report. This report should be GOOD.



Shape representation

Digital geometry processing Shape acquisition 3D printing Finite element method Surface parameterization Discrete differential geometry Editing and modeling Shape optimization Architectural geometry **Digital fabrication** Topology optimization



Shape representation

A little about

Parametric curves/surfaces

Implicits







Shape representation

But mostly about Polygonal meshes







Shape acquisition

Scanning





Shape acquisition

Reconstruction



"Reconstruction and representation of 3D objects with radial basis functions", Carr et al., ACM SIGGRAPH 2001



Differential geometry Continuous and discrete Powerful tool to analyze and model shapes





Digital geometry processing Denoising, smoothing, simplification, remeshing, parameterization, compression





Parameterization





Parameterization





Shape creation and editing





Shape creation and editing





Shape creation and editing



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Animation









http://www.mit.edu/~ibaran/autorig/



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http://youtu.be/P9fqm8vgdB8

Shape optimization



http://igl.ethz.ch/projects/spin-it/ Spin-It: Optimizing Moment of Inertia for Spinnable Objects", Bächer et al., ACM SIGGRAPH 2014



Shape optimization



Bharaj et al., "Computational design of metallophone contact sounds", Siggraph 2014



Topology optimization



Lu et al., Siggraph 2014 Stava et al., Siggraph 2012Wang et al., Siggraph Asia 2013

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Topology optimization



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