Delicate Dance: 
Preferences in Interactive Meshing

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Virtual Event
Munich
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Previously on Polygon Reduction (Polyred)
Previously on Polygon Reduction (Polyred)...
Previously on Polygon Reduction (Polyred)...
Previously on Polygon Reduction (Polyred)...
Representation Learning
(active in ML)

Classic Approach
(well-studied in CO)

Human-in-the-loop
(active in HCI)
(So what?) "I think theses works are between communities, which community to you want to contribute? (Pick a side)"

-- Prof. Schmidt
Essentials
Design Task as Optimization Problem
Design Task as Optimization Problem

\[ f_o(d) \]

Objective function

evaluate
design space
See successful works in keyboard layout optimization by A. Oulasvirta, D. Buschek, etc...
Instantiation: 3D Modeling as Optimization Problem

How to judge a mesh?

Optimizer

\[
\max_{d \in D} \sum_{o \in O} w_o f_o(d)
\]

objective function

How to pick meshes?

generate

evaluate

mesh space

consumer

artists

polygon meshes

consumer

artists
Time Complexity on Interactive 3D Modeling

\[ T = \sum_{a \in A} (DT(x) + P(m)) \]

Total Time Spent

Decision Time to Pick a Design

Single-step Modeling Time

Put

Evaluate

Satisfied?

Bayesian Opt. No

#Attempts
Time Complexity on Interactive 3D Modeling

\[ T = \sum_{a \in A} (DT(x) + P(m)) \]

- Total Time Spent
- Decision Time to Pick a Design
- Single-step Modeling Time

Bayesian Opt.

RUN

Evaluate

Satisfied?

No

Changkun Ou · Delicate Dance: Preferences in Interactive Meshing · 2021.03
Design Optimization Problem Specification

- Design space $\mathcal{X}$ (or say search space) is parameterized by $x \in \mathcal{X}$
- The goal is to search the best parameter settings s.t.
  $$x^* = \arg\max_{x \in \mathcal{X}} g(x)$$
- where $g$ is the user's preference (and expensive to evaluate)
- Bayesian optimization is widely used for hyperparameter search with few queries:
  $$x^* \succ \{x(i)\}_{i=1}^m$$
- Bring reinforcement learning agent strategies
  - Exploration (i.e. How to propose the next parameter settings?)
  - Exploitation (i.e. How to converge as fast as possible?)
A computer graphics artist sits down to use a simple renderer to find appropriate surfaces for a typical reflectance model. It has a series of parameters that must be set to control the simulation: “specularity”, “Fresnel reflectance coefficient”, and other, less-comprehensible ones. The parameters interact in ways difficult to discern. The artist knows in his mind’s eye what he wants, but he’s not a mathematician or a physicist — no course he took during his MFA covered Fresnel reflectance models. Even if it had, would it help? He moves the specularity slider and waits for the image to be generated. The surface is too shiny. He moves the slider back a bit and runs the simulation again. Better. The surface is now appropriately dull, but too dark. He moves a slider down. Now it’s the right colour, but the specularity doesn’t look quite right any more. He repeatedly bumps the specularity back up, rerunning the renderer at each attempt until it looks right. Good. Now, how to make it look metallic...?
Geometry Galleries
Geometry Galleries
Geometry Galleries
Geometry Galleries

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What are the actual preferences among these meshes?

- (Almost) Equal polygon counts
- Preference record from a 3D designer
What are the actual preferences among these meshes?

- Exactly equally reduced polygon counts
- Preference record from another senior 3D designer
A Further Comparison

1 v.s. 4 (zero difference, just z-fighting)
Why?

- Maybe your experiment was not designed properly...
- Maybe your algorithm's output space have no overlap to the desired design space...
- Maybe your participants is not reliable...
- Maybe ...

I don't know! - These results commonly exist in real world cases
Theories
"My arm really hurts."

"How would you rate the pain, from 1 to 10, where 10 is the worst pain you can imagine?"

"One."
Judgement under Uncertainty

by A. Tversky and Kahneman

This Nobel Lecture discusses the microeconomics analysis of choices behavior of consumers who face diverse economic alternatives. Before the 1980s, economists used consumer theory mostly as a tool to test empirically the properties of alternative market organizations. In the early 1980s, however, when a new generation of researchers started to apply the model of choice behavior formulated in the early 1960s by R. Duncan and R. L. Kahneman, it was only of moderate success. To this new generation, the model of choice behavior was thought to be inefficient in the presence of many factors and the need for dynamic decision choices. The model of choice behavior is often used in the study of consumer behavior, but the results of exchange and collaboration with many other scholars in the 1980s and 1990s has improved its empirical testability. For example, in my own work, we have investigated preferences, economics, and cognitive psychology; and in the study of consumer behavior, the model of choice behavior is often used to predict own choices and to test the model of choice behavior.

Daniel Kahneman, Nobel Prize in Economics, 2002

Economic Choices

by Daniel M. Feinberg

Economic Choices

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Thinking, Fast and Slow

by Daniel Kahneman

WINNER OF THE NOBEL PRIZE IN ECONOMICS

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Comparative Judgement by L. Thurstone, R. Luce, R. Bradley

P(choose A over B)
Design Galleries [Marks et al. 1997]

- Seminal work on display representative design options on a two-dimensional screen by low dimensional embedding

- Focused on light placement settings
  - Didn't mention anything on the preference theory :(

- A few follow up works
  - Text editing preview: M Terry et al CHI'02
  - Web design: B Lee et al CHI’10
  - Crowd-powered visual design Y Koyama et al UIST’14
  - Interface design: J Dudley et al CHI’19
  - Input devices: Y Liao CHI' 21 EA
  - ... too many!
Reflections
Cognitive Illusions in Sequential Design Preferences
Cognitive Illusions in Sequential Design Preferences

- **Anchoring**: subjective preferences are dominated by earlier experiences
  - A prompt creates in the subject’s mind, at least temporarily, the possibility that the uncertain quantity could be either above or below the prompt
  - Result in psychophysical discrimination errors
  - **User preference function is a conditional distribution**: $g(x|u)$
Cognitive Illusions in Sequential Design Preferences

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- **Drifting**: subjective preference changes over time in an open-ended design task
  - The mesh optimizer fails to converge to an optimal design because of invalid feedbacks (garbage in, garbage out)
  - **User preference can be time dependent**: \( g(x, t_1|u) \neq g(x, t_2|u) \)
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- **Yearning**: subjects are eager to produce an expected preference or similar
  - Exploration slows the exploitation process down in order to decode the entire design space
  - Preference space and design space may only have small overlaps: \( g(x) \in \mathcal{P}, |\mathcal{P} \cap \mathcal{X}| \approx 0 \)
Sources of Meshing Complexity

1. Well-formulated mathematics that describes continues settings can be inconsistent in discret settings (No-free-lunch: not all properties are preserved, e.g. Laplace-Beltrami)

\[(\Delta f)_i = w_i \sum_{ij} w_{ij} (f_j - f_i)\]

\[w_i = \frac{1}{2A_i}, \quad w_{ij} = \cot \alpha_{ij} + \cot \beta_{ij}\]

\[w_i = \frac{1}{N_i}, \quad w_{ij} = 1\]

\[w_{ij} = \frac{1}{||f_i - f_j||} \left( \tan \left( \frac{\gamma_{ij}}{2} \right) + \tan \left( \frac{\delta_{ij}}{2} \right) \right)\]

\[\sum \theta_i = 2\pi\]

\[\sum \theta_i < 2\pi\]
Sources of Meshing Complexity

1. Well-formulated mathematics that describes continuous settings can be inconsistent in discrete settings (No-free-lunch: not all properties are preserved, e.g. Laplace-Beltrami)

2. Edge cases of geometry processing largely exists and developers failed in handling it well or expensive to give a fix (hard to retrieve the knowledge even for the developer).

"I don't understand your magic here"

"Neither do I 😄"

"I don't have a clear mind about if your implementation works on these cases. Do you still have your code in mind?"

"Sorry for the late reply. Had to re-read my code to get it back in mind^^"
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3. Ground truth expert opinions (labels) does not exists in modeling (or not widely accepted)

Aside: All ML models are limited by the quality of the ground truth used to train and test
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4. Defects exist and slow down the workflow, manual repairing is tedious, but regular users don't care
Sources of Meshing Complexity

\[ \int_{M} |\nabla f|^2 dA \Leftrightarrow \Delta f = 0 \]

Mathematics
Fundamentally about geometry

Computer Science
Discrete computing algorithms on geometry data structure

Data Analytics
Increasing unlabeled dataset and needs of solving problem at scale

Human-Computer Interaction
Software does not produce expected results. Why and how to deal with it???
"(So what?) I think theses works are between communities, which community to you want to contribute? (Pick a side)"

-- Prof. Schmidt
When was your last time to do pixel-level adjustment in Photoshop?
How trivial to adjust a pixel?

When was your last time to do vertex-level adjustment in Blender edit mode?
How trivial to adjust a vertex?
Conclusions

- Apparently, all these problems are in HCI (convinced? If not, where? SIGGRAPH? NeurIPS? :-)
  - I believe solving them requires bottom-to-top understanding in geometry and processing
- 3D modeling is a difficult design task in seating in between open-ended and deterministic
  - To the best of my knowledge: all existing HCI theories are not directly applicable here
- The efficiency of 3D modeling workflow does not only depends on algorithms
  - Upstream producer determines characteristics and defects of outputs
  - Downstream consumer determines the requirements on their inputs
- 3D Modeling user interface influences to user's mental model and impacts the experiment
- **Combining subjective data into an objective computation process is a delicate dance**
  - Huge rooms for improvements and still a big challenge
Join the Hacking 👋

- More works on github.com/changkun and github.com/polyred
- Open-sourced and to be open-sourced (ask me if you are interested and one is not open-sourced yet)
  - changkun.de/s/bo: Bayesian optimization in native Go
  - changkun.de/s/ddd: An efficient 3D rasterizer in native Go
  - changkun.de/s/ray: An efficient 3D path tracer in native Go
  - changkun.de/s/win: A cross-platform window management package in Go
  - poly.red/s/geometry: Geometry processing facilities in native Go
  - poly.red/s/geobench: Geometry processing benchmarking facilities in Go
  - poly.red/s/linalg: Algebra facilities for geometry processing in native Go
  - poly.red/s/formats: Wide range formats support in Mesh loader/exporter in Go
  - poly.red/s/raster: Cross-hardware unikernel for rasterization in Go
  - poly.red/s/pbr: Cross-hardware unikernel ray tracing rendering in Go
  - poly.red/s/tree: A 3D engine in Go
  - … and more!
Discussions

- **Better HCI models**: (Almost) all existing HCI theories are not applicable
  - How to better combine users’ subjective data into an objective algorithm computation process?
  - Are there any more HCI models that describes and learn human preferences?

- **Efficient preference query**: User should always take the lead but ask feedback is (super) inefficient
  - Can user preference be encoded in an open-ended design task?
  - Search a design as quick as possible (machine side)

- **Time-varying preference learning**: The assumption of users’ preference does not change is not valid
  - What can we do about it?

- **Crowdsourcing**: End consumers may not care about high quality mesh
  - How to involve their opinion in real-time? GWAP? [Ou et al 2019]

- **Better coding experience in research**
  - Huge code workload for a simple idea, what can we improve about this?
  - Open-source helps gather crowd wisdom, but I keep doing research as a single coder on a project (almost impossible to communicate low-level details, it is not just calling APIs). How can we improve about this?
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