Week 3

• Email 2 photographs to Jay by Thursday 1:55pm
  – Your own photographs (not downloaded from Internet)
  – You give us permission to use these photographs in this class, and for any projects, promotional materials, publications etc. that may occur in the future.
  – 1 photo contains >1 face
  – 1 photo contains no faces
How Well Do Line Drawings Depict Shape?

Slides courtesy Forrester Cole
Line drawings

[US Patent 378,973]

[Flaxman 1805]

[Matisse 1932]
Line drawings

Occluding Contours

Sharp creases
Line drawings

- Occluding Contours
- Sharp creases
- Ridges and Valleys
- Suggestive Contours [DeCarlo et al 2003]
- Apparent Ridges [Judd et al 2007]
Assessing Line Drawings

• Goals
  – Artistry, abstraction, etc.
  – Leads to accurate perception of shape
Assessing Line Drawings

• Goals
  – Artistry, abstraction, etc.
  – Leads to accurate perception of shape

• Methodology
  – Qualitative (examples, comparison to artists)
  – Quantitative comparison to artists’ drawings
Comparing models

Suggestive Contours

Ridges and Valleys

Apparent Ridges
Comparing models

Suggestive Contours

Ridges and Valleys

Apparent Ridges
Comparing models

Suggestive Contours

Ridges and Valleys

Apparent Ridges
Comparing models to artists

“Golf Ball” [Lichtenstein 1962]
© Estate of Roy Lichtenstein

Suggestive contours and suggestive highlights [DeCarlo and Rusinkiewicz 2007]
Comparing models to artists

• Argument for ridge-like features [Judd et al. 2007]

[Matisse 1932]  [Brancusi 1910]
Comparing models to artists

• Comparisons to drawings made under controlled conditions [Cole et al. 2008]

apparent ridges

suggestive contours

artist drawing
Comparing models to artists

• Comparisons to drawings made under controlled conditions [Cole et al. 2008]

\[ d_{line}(\text{rendering}, \text{artist drawing}) \]

apparent ridges
suggestive contours
artist drawing
Comparing shapes

\[ d_{3D}(\text{perceived shape}, \text{original shape}) \]
Measuring perceived shape

Local measurements of shape geometry

- Gauge figure adjustment
  [Koenderink et al. 1992]
Measuring perceived shape

Local measurements of shape geometry

• Gauge figure adjustment [Koenderink et al. 1992]
• Studied shaded surfaces and one artist line drawing [Koenderink et al. 1996]
Questions

Do artist and CG drawings effectively convey shape?
   – how accurate are they?
   – how do they compare to a shaded rendering?
Do different viewers perceive the same shape?
When are particular line types most effective?
Study Methodology

1. Measure percepts
   - Both artist and CG drawings
   - Range of models
   - Many participants

2. Compare against ground truth
   - 3D shape and shaded image
   - Accuracy and precision
Orienting a Gauge
Example Session
Study Setup

All 12 models from [Cole et al. 2008]
# Study Setup

6 styles x 12 models  -  2 duplicates

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Study Setup

6 styles x 12 models x 2 duplicates = 70 prompts

Artist’s

R. and V.

Sug. C.

App. R.

Contours

Shaded
Study Setup

70 prompts
× 90 gauges / prompt
× 8 opinions / gauge
× 2 settings / opinion

≈ 100,000 settings
Study Setup

70 prompts
× 90 gauges / prompt
× 8 opinions / gauge
× 2 settings / opinion

≈ 100,000 settings
× 4 seconds / setting

111 hours
So Much Data…

• Amazon Mechanical Turk to the rescue!
• Turker sets 60 gauges, gets paid $0.20
• Efficient even after throwing away garbage
  – “Garbage” is inconsistent data
  – About 80% of data is consistent
  – >70% of the duplicate gauges are set to within 30 degrees of each other
    • these parameters were found during pilot testing
Data Collection

- 275,000 gauge settings
- 4 models x 180 gauges + 8 models x 90 gauges
- Each gauge 9 to 29 opinions, average 15
- 560 different people
Global Accuracy

Error from ground (accuracy)
Global Accuracy

Error from ground (accuracy)

Distribution of errors for shaded
Finding:

On average, turkers did a good job
Aggregating Per-Gauge Data

What is the most representative direction?
– “Mean” is most obvious choice
– “Median” more robust to outliers
Global Accuracy and Precision

Error from Ground (Accuracy)

Error from Median (Precision)
Results:

- Precision greater than accuracy
- Accuracy varies with style, precision does not
Finding:

Peoples’ interpretations of shape are similar, even when those interpretations do not match ground truth.
Question:

Where are the errors?
Accuracy by Model

Cubehole
Rockerarm
Flange
Twoboxcloth
Screwdriver
Femur
Pulley
Lumpcloth
Bumps
Tooth
Cervical
Vertebra

Avg. Error (degrees)
Gauge Visualization:

Artist’s Drawing

Contours Only

180 gauges
Local Errors: Screwdriver

Artist’s Drawing

Contours Only

15 gauges, 5 pixel spacing

Error (deg.)
Curvature: Screwdriver

Artist's Drawing

Contours Only

Zero Curvature

Ground Truth

Artist's Drawing

Contours Only
Future Work

- More analysis of collected data
  - Towards interpretation model for lines
- Further investigation of study

Data available at:
http://lineshape.cs.princeton.edu
What have we learnt

• Question: How well do line drawings represent shape?
  – Accuracy + Precision

• Method: Gauge figure task + Crowdsourcing

• Analysis:
  – Error from ground truth (accuracy)
  – Error from median (precision)
  – Shapes that were easiest and hardest to interpret
  – Gauge lines to try and localize the error in percepts

• Conclusion:
  – People are quite consistent
  – Some drawings almost match shaded images
  – Some styles work for some shapes ... no clear winner
• Each group gets one paper
• 15 minutes to create 4 slides -- “I’m doing a literature survey for my project. Should I read this paper in detail or not?”
• Email the slides to Jay -- this is the end of the time you have to prepare
• Each person presents one slide for the group
• Perceiving human motion variety (APGV 2011)
• The Perception of Finger Motions (SIGGRAPH Asia 2012)
• Perceptual Metrics for Character Animation (SIGGRAPH 2003)
• Obscuring length changes during animated motions (SIGGRAPH 2014)
• Perceiving alterations in trajectory while throwing in a virtual environment (APGV 2011)
• Slide 1: Question/Hypothesis + Background
• Slide 2: Method
• Slide 3: Analysis
• Slide 4: Conclusion + Future work
What have we learnt

• Experiments as a progression: e.g., first check JND for simple finger motions, then if noticeable, move on to a complex scenario

• Techniques to collect data from humans: Questions (two-alternative, rating), Response times, Add cognitive load or a distraction (a task unrelated to the question)

• Span the range: e.g., small, medium, large errors in latency/gravity
Global Accuracy and Precision

Before bas-relief fitting

Error from Ground (Accuracy)

Error from Median (Precision)
Global Accuracy and Precision

After bas-relief fitting

Error from Ground (Accuracy)

Error from Median (Precision)
Bas-Relief Ambiguity

Ambiguity in perception of shaded shapes [Koenderink 2001]
Line Drawing Ambiguity

Line drawings are even less constrained