Welcome
Sketching as high-level vision
Sketching = Important tool for spatial understanding

- People sketch when they are communicating ideas
  - e.g., maps, diagrams
- People sketch when they are working out ideas alone
  - e.g., designers, students studying
- Needed: Computational models of sketch understanding
  - To model the visual, spatial, and conceptual representations and processes involved
  - To create learning and thinking tools for students and professionals
Computer tutors and learning environments need spatial capabilities

- Intelligent tutoring systems have provided valuable benefits for education
  - Immediate feedback, potentially any time, anywhere
- But not in spatially rich subjects (e.g., geology, engineering)
  - How to create human-like visual processing is a hard scientific question
  - Need to model the spatial & conceptual reasoning involved
- Sketch understanding software could change this

Ultimate goal:
Software that understands sketches as you would
Sketch Recognition Systems

• Focus on object recognition
  – Only works in narrow domains
  – Requires user training
• Doesn’t scale for education

<table>
<thead>
<tr>
<th>System</th>
<th>Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>OrganicPad</td>
<td>Draw 2D molecules, converts to 3D</td>
</tr>
<tr>
<td>Newton’s Pen</td>
<td>Draw free-body diagrams</td>
</tr>
<tr>
<td>Kirchoff’s Pen</td>
<td>Draw resistor networks</td>
</tr>
<tr>
<td>iCanDraw?</td>
<td>Draw human face from reference image</td>
</tr>
<tr>
<td>Mechanix</td>
<td>Draw trusses, get feedback</td>
</tr>
<tr>
<td>LAMPS</td>
<td>Mandarin Phonetic symbols</td>
</tr>
<tr>
<td>Hashigo</td>
<td>Japanese Kanji</td>
</tr>
<tr>
<td>LearnYourShapes!</td>
<td>Simple shapes</td>
</tr>
</tbody>
</table>
Our approach: Open-domain sketch understanding

• **Object recognition is not necessary**
  – People talk when they sketch – they label objects
  – CogSketch enables people to label as they draw, avoiding the recognition bottleneck

• **CogSketch models aspects of human visual and spatial representations and reasoning**
  – Derives rich relational representations
  – Same software operates across many domains
Two Problems in Sketch Understanding

• *Segmentation*: How to break up ink into pieces corresponding to depicted entities?

• *Interpretation*: What is being depicted?
Traditional Solutions

• Segmentation: Heuristics
  – Pen up, long pauses taken as evidence for segmentation
  – Overlapping speech

• Interpretation: *Which-of-N* recognition
  – Fixed vocabulary of entities (10-100)
  – Train system on each user individually
  – Train users via feedback
How people interact with CogSketch

• Draw ink, clicking finish when an object is done
  – Resegment/regroup via lasso if needed
• Label objects via menus
  – Knowledge base provides concepts for labeling
  – 58,000 concepts provide breadth
  – Technical details hidden from users via UI
• Zero segmentation errors
• Zero recognition errors
CogSketch Research Goals

• **Goal:** A cognitive science research instrument.
  – A computational model of spatial reasoning and learning
  – A tool for gathering data in laboratory and classroom studies

• **Goal:** A platform for sketch-based intelligent educational software
  – Helping students learn STEM concepts
  – Helping students learn engineering design

• **Vision:** Sketch understanding software to help students learn could be widely available in 5 years
CogSketch as Research Instrument

- Use cognitive simulation experiments to model visual/spatial processing in CogSketch
  - Constrain via results from multiple experiments
- Gather data in psychology experiments
  - Automatically gathers timing data
  - Automatic scoring of participant responses

Gathering and modeling data in laboratory and classroom experiments
CogSketch in Education

Platform for sketch-based educational software

- Eventually, like a calculator
  - Always available
  - Useful across a broad variety of tasks
- But with more scaffolding
  - Access to intelligent tutors and coaches built in
  - Automated assessment support
Overview

• Introduction to CogSketch
• CogSketch Basics
• Visual processing in CogSketch
• CogSketch in Education
  – Making worksheets, potential for assessment, …
• Using CogSketch for Cognitive Science research
  – Using analogical processing in simulation
• Advanced features
  – Extending the KB, exporting knowledge…
• Wrap-up

Your feedback will help guide CogSketch development