An Intuitive System for Sketching and Simulating Logic Circuits

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Q: How do you make sketch recognition reliable without restricting the user’s drawing style?

A: Allow the user to draw freely, with no unnatural constraints. Then design the system based on common sketching styles.
INTRODUCTION
DEMO!
Recognition Challenges
Sketch Recognition

Circuit Interpretation

Recognition Correction (User)

Simulation
Sketch Recognition

Circuit Interpretation

Recognition Correction (User)

Simulation

Draw Circuit

Simulation
RECOGNITION OVERVIEW
PREVIOUS RECOGNITION METHOD

- Stroke Classification
- Stroke Grouping
- Shape Recognition
- Shape Connection
RECOGNITION

Stroke Classification

Stroke Grouping

Shape Recognition

Shape Connection
RECOGNITION

- Stroke Classification
- Stroke Grouping
- Shape Recognition
- Shape Connection
RECOGNITION

Stroke Classification

Stroke Grouping

Shape Recognition

Shape Connection
Recognition

Stroke Classification

Stroke Grouping

Shape Recognition

Shape Connection
RECOGNITION

- How does a computer recognize a shape?
- How do you, as a person, recognize a shape?

AND  OR   NOT

Alvarado, Dodds, et al. CS For Scientists and Engineers
RECOGNITION WITH TEMPLATES

AND

OR

NOT

Alvarado, Dodds, et al. CS For Scientists and Engineers
Recognition with Features

- Rather than storing a set of templates, store a set of features that describe the shape!

- Examples:
  - Area
  - Curvature
  - Pen Speed
ROOM FOR IMPROVEMENT

- Recognition can always be improved.
Shape Connection
Stroke Classification
Stroke Grouping
Shape Recognition
Shape Connection
Refining
Recognition Refinement

- Context
- Stroke Steal
- Stroke Shed
CONTEXT REFINING

NAND

NOT
STROKE SHED REFINED

SUCCESS!
STROKE STEAL REFINE

SUCCESS!
REFINEMENT RESULTS

Recognition Accuracy

<table>
<thead>
<tr>
<th></th>
<th>Original Recognition</th>
<th>Context Refine</th>
<th>Stroke Shed Refine</th>
<th>Stroke Steal Refine</th>
<th>Context → Steal → Shed</th>
<th>Context → Shed → Steal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy (%)</td>
<td>86.47%</td>
<td>87.54%</td>
<td>86.56%</td>
<td>86.29%</td>
<td>87.10%</td>
<td>87.46%</td>
</tr>
</tbody>
</table>
PROBLEMS

- Hard to tell...
  - When to refine
  - Which refiner to use
  - Whether it refined correctly
- Draw Circuit
- Stroke Classification
- Stroke Grouping
- Shape Recognition
- Shape Connection
- Refining
- Circuit Recognition
- Recognition Correction
- Simulation
CIRCUIT RECOGNITION
USER INTERFACE
OLD DESIGN – PROBLEMS?

- Modal Interface
- Menus
- Confusing options
DESIGN GOALS

- “Magic Pen”
- No modes
- Avoid menus and toolbars
- Easy to find and correct errors
HOVER ICONS

- **Hover space** – The space directly above the tablet surface
- Based loosely on Hover Widgets (T. Grossman, et.al., 2006)
- Hold pen above tablet surface, widgets pop up
- Lets stylus be used for selection, correction, editing without a menu or modes
SELECTION

- Problems
  - Often requires a separate mode
  - Many types: lasso, drag-box, tapping, others

- Our solution
  - Can begin selection through hover icon or stylus button
  - Can draw again after a selection is made
  - Users liked drag box with tapping
RECOGNITION FEEDBACK & CORRECTION

What is important here?

- Know if errors exist
- Easy to correct errors
- Correcting errors will not introduce more errors
TYPES OF RECOGNITION ERRORS

Incorrect Labeling

Not Connected

Incorrect Grouping
**Incorrect Labeling and Grouping**

- Identified by stroke coloring and tooltips
- Fixed using relabeling and regrouping
- Shapes connected to changed shape are re-recognized
**Incorrect Connections**

- Identified by mesh highlighting and endpoint highlighting
- Fixed by dragging endpoints, drawing over connection
Draw Circuit

Stroke Classification

Stroke Grouping

Shape Recognition

Shape Connection

Refining

Circuit Recognition

Recognition Correction

Simulation
SIMULATION
DEMO!
USER PREFERENCES

- Liked using hover icons over menus
- Liked seeing their sketches “come to life”
- Liked using stylus button for selection
- Tended to use re-labeling over grouping
- Would rather erase and re-draw rather than trace over existing strokes to replace them
Learning From Error Corrections

- How do you use users’ corrections to improve recognition?

Diagram:
- Stroke Classification
- Stroke Grouping
- Shape Recognition
- Shape Connection
- Refining

Axes:
- Area
- Pen Speed
- Curvature
FUTURE WORK

- Learning from error corrections
- In-depth user studies
- CS 5 or CS 42
QUESTIONS?