



## Enabling Natural Interaction

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Oskar Breuning, Sonya Cates, Jacob  
Eisenstein, Tracy Hammond, Mike Oltmans,  
Metin Sezgin

MIT CSAIL

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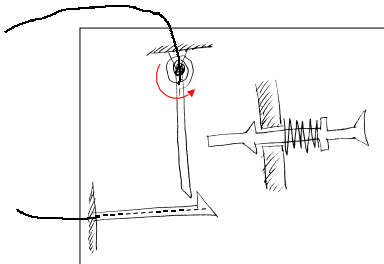
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## Consider This Device...



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## Our Model



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- The designer sketches with pen and paper
- The observer interprets the sketch
- The observer and designer interact

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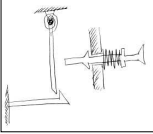
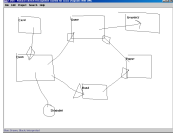
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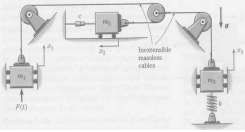
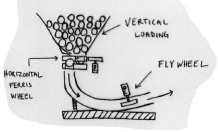
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## Sketches are Ubiquitous

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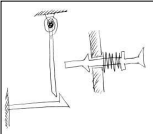
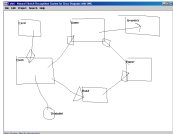
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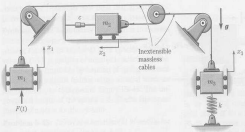
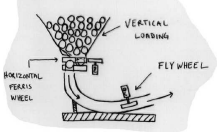
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## Sketches are *Dead*

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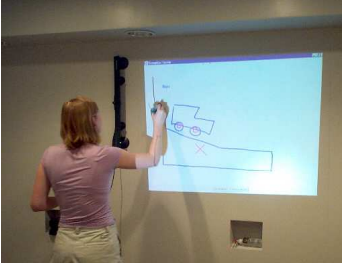
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## Magic Paper



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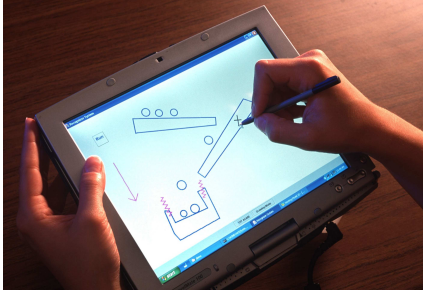
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# Magic Paper



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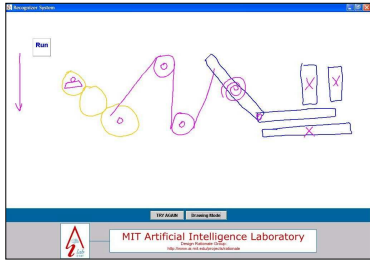
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# More Complex Example



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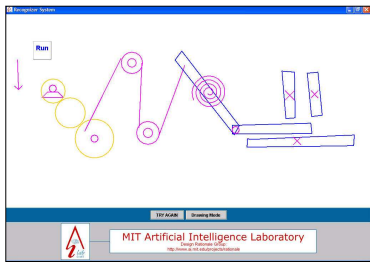
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# More Complex Example



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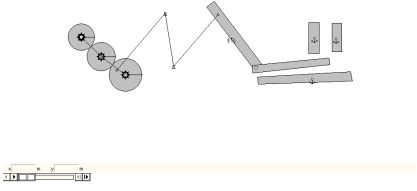
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## More Complex Example



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## Overview

- Architecture
- Early processing
- Learning new symbols from 1 example
- Sketching and talking
- Understanding gestures
- Overcoming error through context
- Other domains
- Reconceptualizing interaction: SKRUIs
- Reinventing desktop computing

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## A Prevalent Theme

Natural interaction is knowledge-based.

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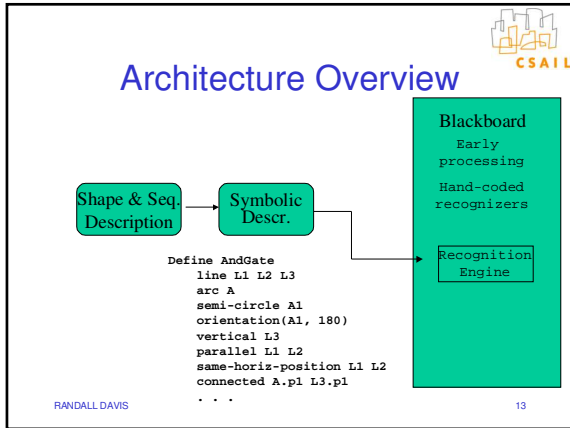
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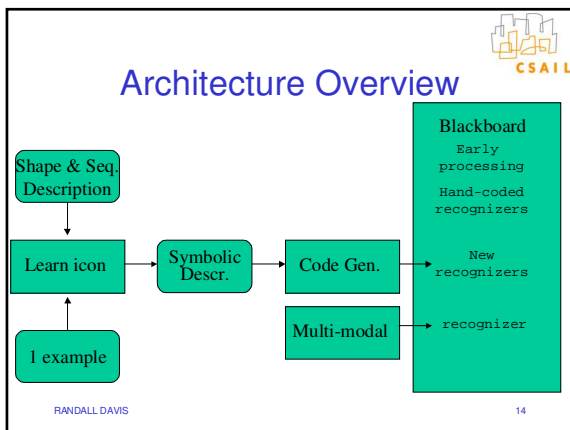
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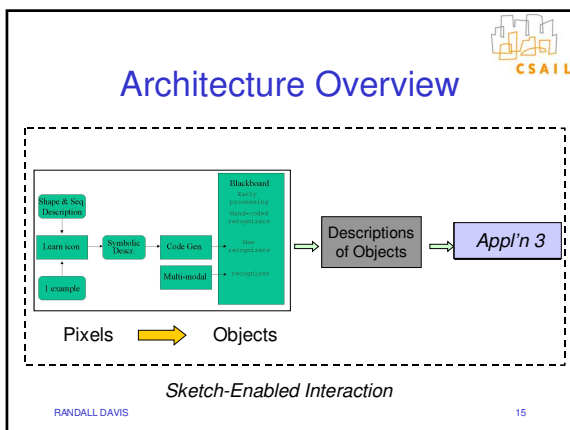
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## Early Processing

- Freehand stroke  $\Rightarrow$  description in terms of geometric primitives (circles, lines, curves)




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## Vertex detection




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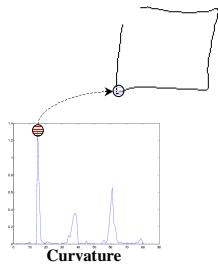
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## Vertex detection




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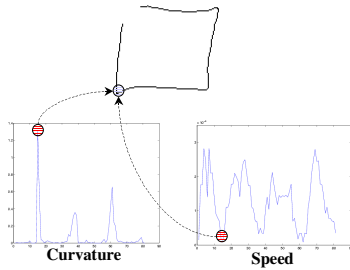
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## Vertex detection



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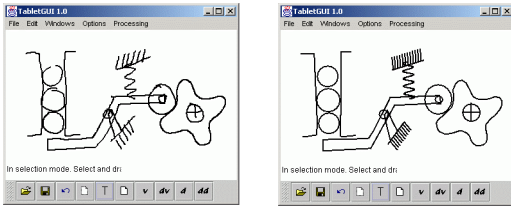
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## Results



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## Learning New Symbols

- From hand-drawn example to a shape description



```
Define AndGate
line L1 L2 L3
arc A
semi-circle A1
orientation(A1, 180)
vertical L3
parallel L1 L2
same-horiz-position L1 L2
connected A.p1 L3.p1
connected A.p2 L3.p2
meets L1.p2 L3
meets L2.p2 L3
```

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## Learning New Symbols

- Goldmeir's *singularities*



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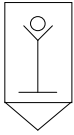
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## The Description Learned



**STATISTICS:**  
*Number of initial relations: 173*  
 93 removed; 15 increased in relevance; 74 decreased in relevance;  
 16 redundant constraints removed  
*Number of final relations: 83*

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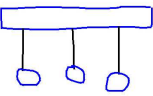
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## Multi-Modal Interaction

Run



"Three identical, equally spaced pendulums..."

- Graphical vs verbal communication:  
What's best said, what's best sketched?

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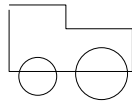
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## Multi-Modal Interaction



- Framework
  - Nouns (*pendulum*)
  - Adjectives as modifying actions to take (*identical, touching, equally spaced*)
- Next step: interactive acquisition of new nouns



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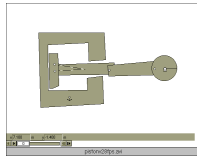
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## Understanding Gestures



- Lexicon: What gestures do people make?
- Depends on task.
- Our task: explaining how something works.



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## Understanding Gestures



- 96% of gestures refer to the diagram.
- Two-handed gestures are common.
- Deixis is more frequent.
- Gesture units are longer.

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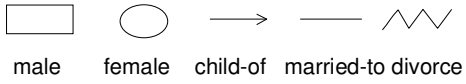
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## Overcoming Error

- Domain: Sketching family trees
- Lexicon



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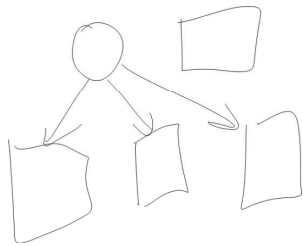
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## Overcoming Error



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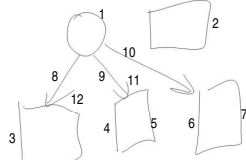
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## What's Hard?



- Task is incremental
- Signal is noisy
- Styles vary
- Segmentation is difficult
- The signal is 2-d, non-chronological

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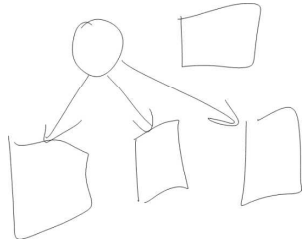
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# What Do We Do?

- Use context



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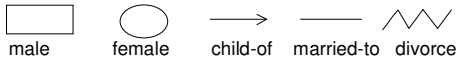
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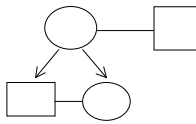


# Context

- Lexicon



- Grammar



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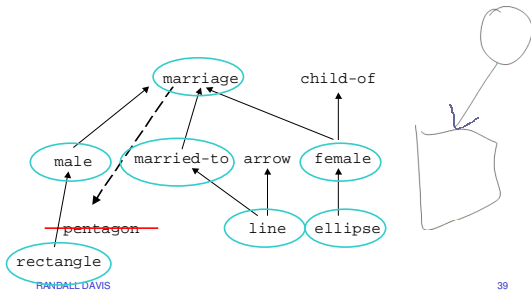
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# Using Context



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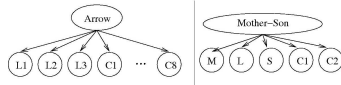
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## Challenges

- Controlling network growth
  - heuristics for deferring, pruning
- Evaluating candidates
  - Bayes' net constructed dynamically from fragments



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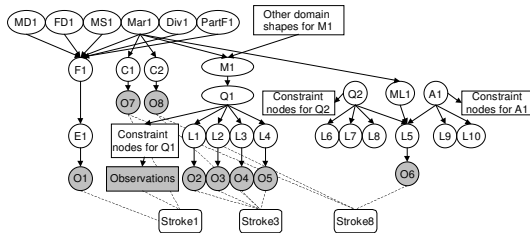
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## Bayes' Net Example



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## Domains

- Mechanical engineering
- Family trees
- Software design
- Circuit design
- PowerPoint: Exploring SkRUIs

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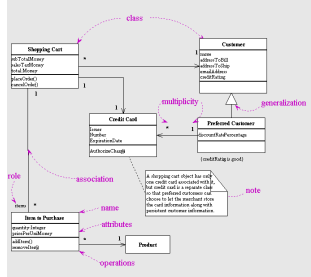
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# Sketching Software

Class Diagram: Electronic Shopping Cart



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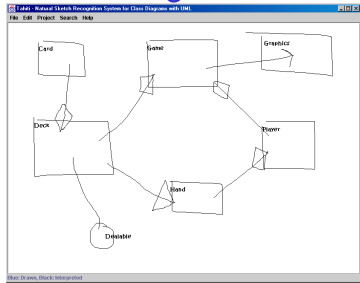
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# Sketching Software



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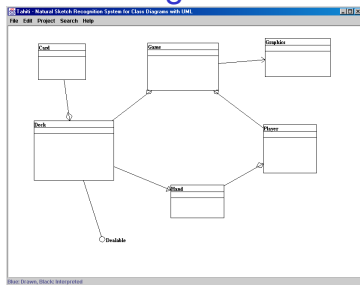
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# Sketching Software



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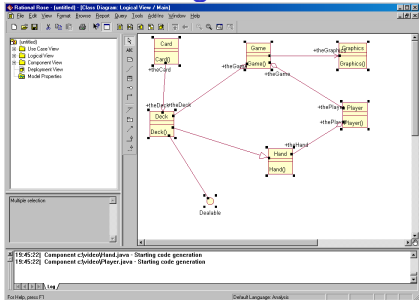
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## Sketching Software



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## Sketching Software



```

//Source file: c:\video\Deck.java
public class Deck extends Hand
implements Dealable
{
    public Card theCard;
    public Game theGame;
    /**
     * @roseuid 3C21348C0257
     */
    public Deck()
    {
    }
}
    
```

```

//Source file: c:\video\Game.java
public class Game
{
    public Graphics theGraphics;
    public Deck theDeck;
    public Player thePlayer;
    /**
     * @roseuid 3C21348C02E3
     */
    public Game()
    {
    }
}
    
```

```

//Source file: c:\video\Dealable.java
public interface Dealable
{
}
    
```

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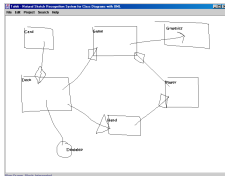
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## Sketching Software



```

//Source file: c:\video\Deck.java
public class Deck extends Hand
implements Dealable
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    public Game theGame;
    /**
     * @roseuid 3c21348c0257
     */
    public Deck()
    {
    }
}
    
```

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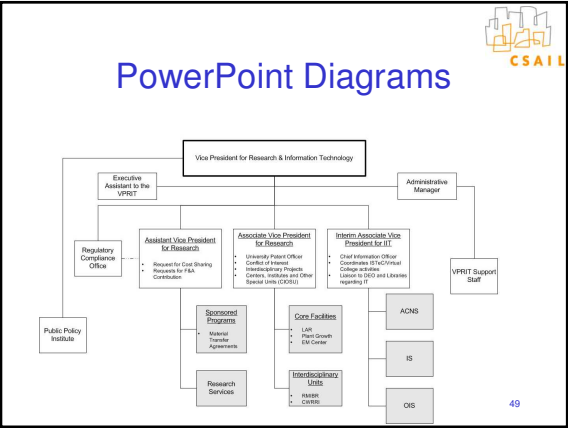
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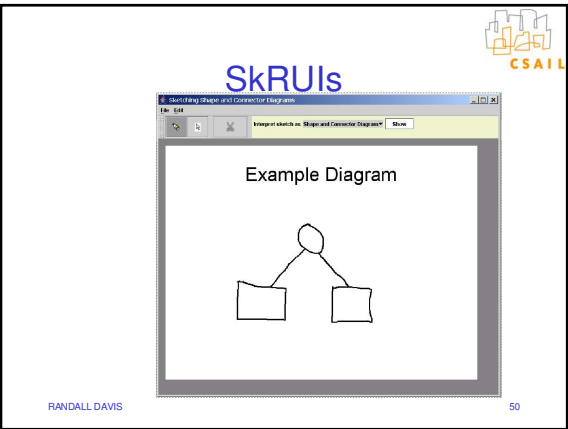
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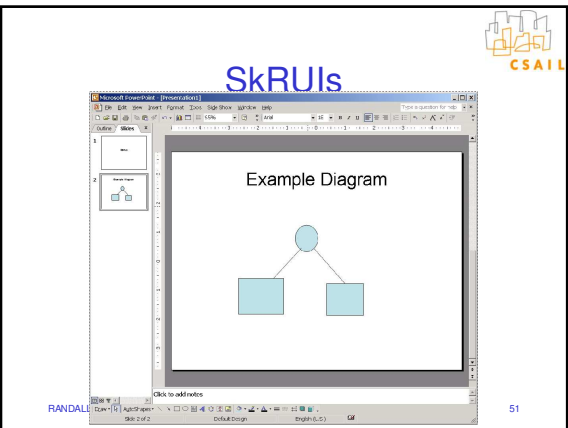
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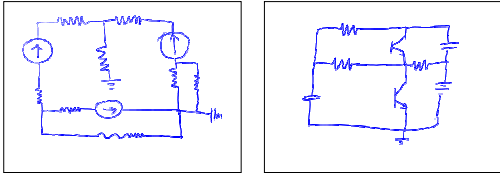
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## Circuit Design



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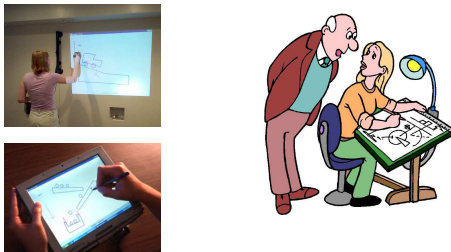
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## Hardware



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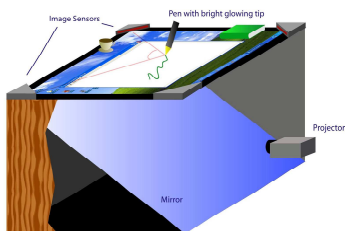
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## Hardware



Kodak KLI-14403 linear image sensors at corners  
Pen: sampled @ 200 Hz, .5mm, pressure sensitive  
Challenges: High data rate, blurred image at the sensor

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## Summary

- Once the sketch is understood, many things are possible.
- Break down the barriers: *eliminate* interfaces
- Natural interaction is enabled by intelligence
  - About sketching, gesturing, speech
  - About the domain
  - About the task

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