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# Faculty Summit 2010

## Hands-On Math

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Thanks to...

Lee Dirks, Bill Buxton, Ken Hinckley, Daniel Wigdor, Michael Haller...

**Researchers:** Andrew Bragdon, Donnie Kendall, Bob Zeleznik

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Two Projects:

HandsOnMath

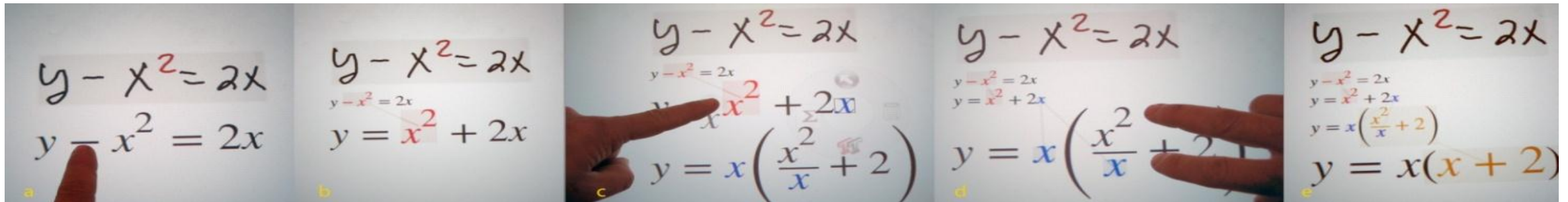
Garibaldi on the Surface

# Hands-On Math

- CAS tools are underutilized for problem solving [Bunt, et al CHI'09]
  - Too rigid and formal
  - Need transparent explanations of computations
  - Must support free-form 2D input
- Hands-On Math
  - Combine best aspects of physical paper and CAS
  - Hypothesis: physical manipulation enhances cognitive processing, both for learners and practitioners
  - Disclose reasoning chains through interactivity
  - Pen and touch gestures make CAS as accessible as doodling

# Math Interaction

- Write math anywhere
  - Calculate with extended notations
  - Create graphs with a gesture
- Manipulate recognized math with multi-touch



Drag  $-x^2$

Annotated  
result

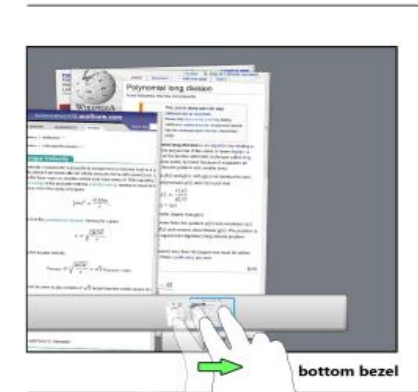
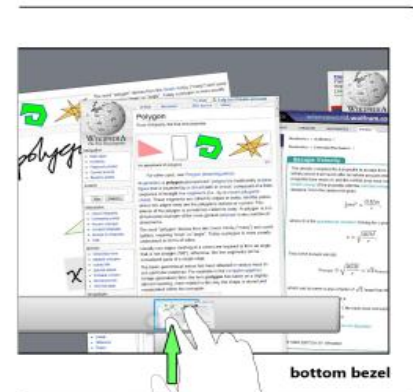
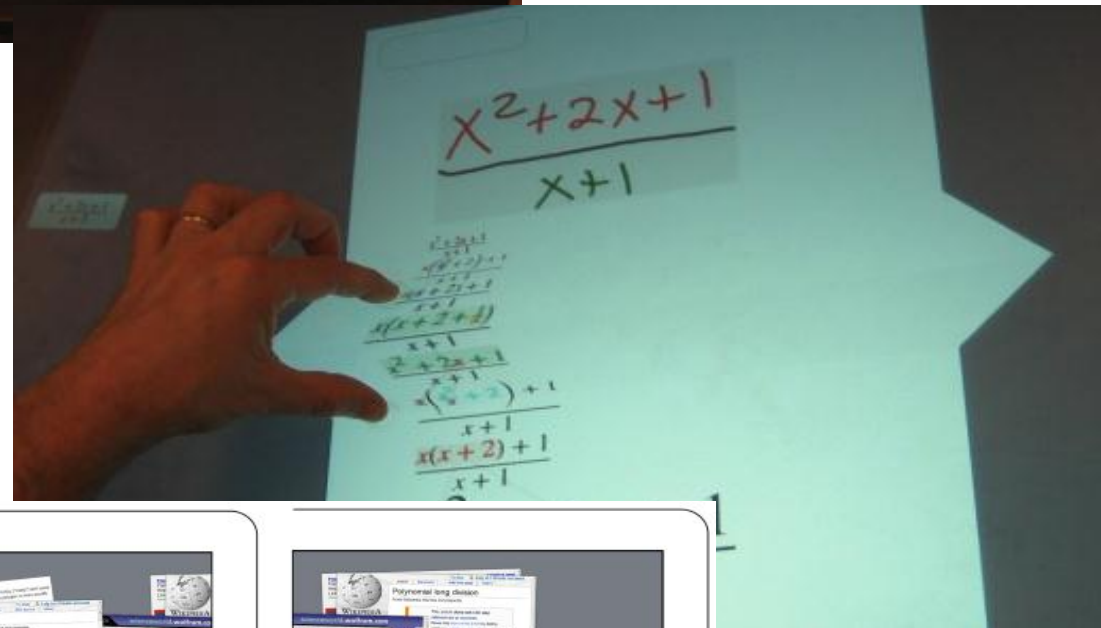
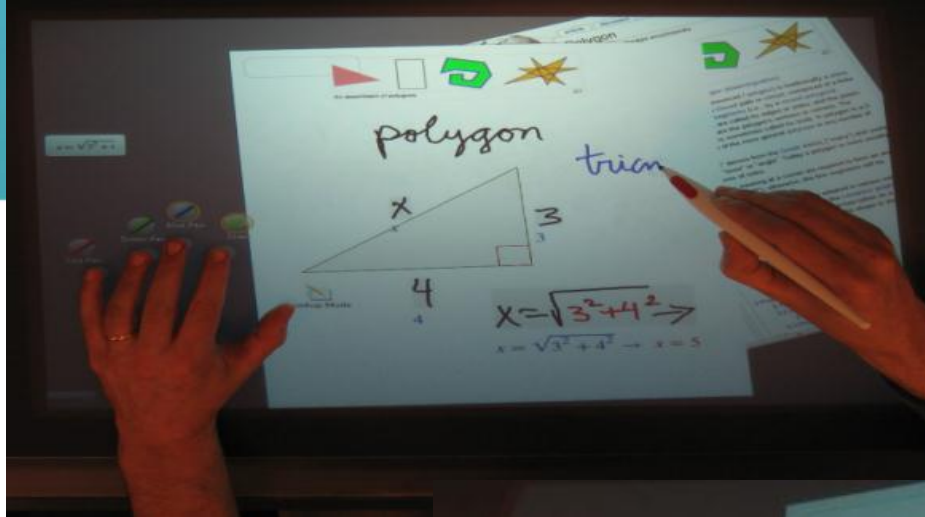
Drag  $x$  (from  $2x$ )  
Interactively factors  
Updating results  
below

Squeezing  $x^2/x$   
simplifies it

Final expression

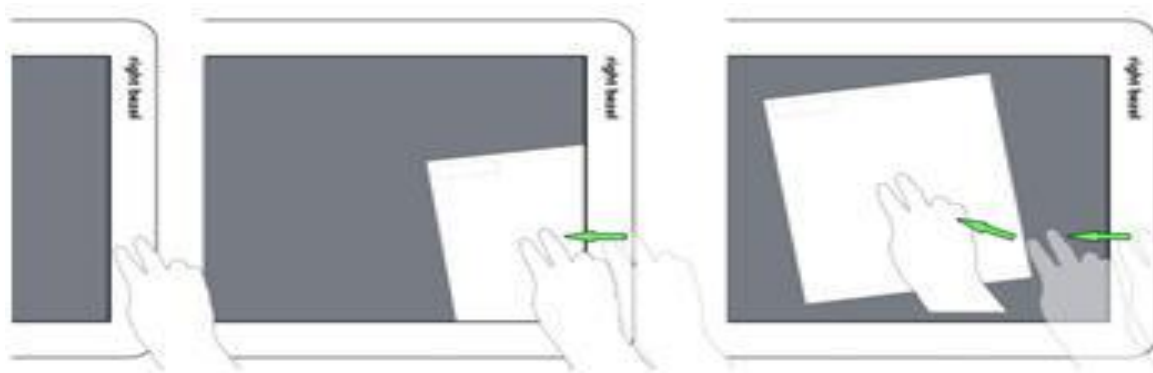
# Hands-On Math UI

- Page-based metaphor
  - Virtual "pages"
    - Used for organization
    - Provide a "scope"
    - Facilitate multi-user scenarios
    - Foldable to make space
    - Web page integration
  - Large pannable desktop
    - Pannable workspace
    - Reference docs

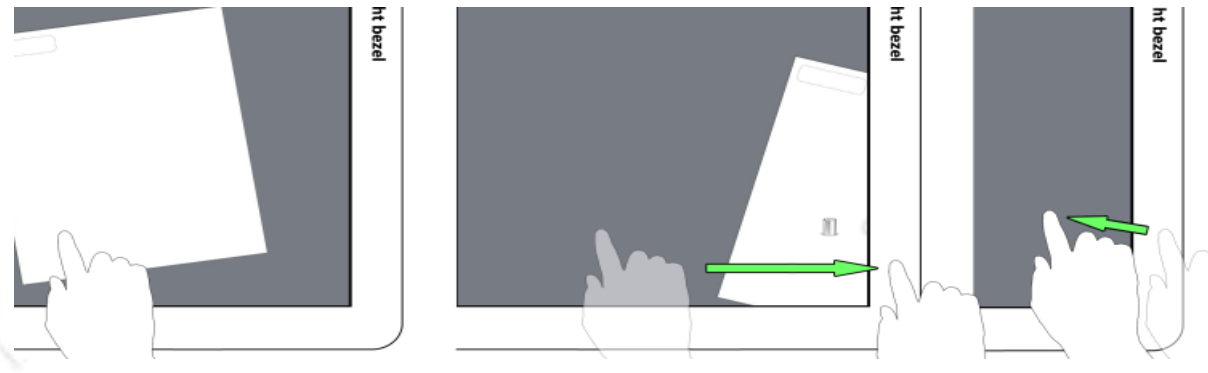


# Page Management

- Can trash single pages
- Bezel gesture actions based on:
  - two fingers to avoid fine-grain targeting
  - which bezel (bottom for panning bar, sides for pages)



Two-finger swipe to create a page



Deliberately harder cross-through-bezel-trashcan to delete a page

# Interactive Math Manipulation

**reorder**

$abx = 1$   $xab = 1$

$ab + x = 1$   $x + ab = 1$

**factor out**

$a^3 = 1$   $xx^2 = 1$

$ab + x + c = 1$   $x\left(\frac{ab}{x} + 1\right) + c = 1$

**transposition**  
drop below '='

$ab + x = 1$   $x = 1 - ab$

$ab + x = 1$  drop below '='  $1 + \frac{x}{ab} = \frac{1}{ab}$

**split as division**

$ab + a = 1$   $ab + \frac{x^m}{x^{m-1}} = 1$

**join factors**

$3x + 2x$   $5x$

**simplify**

$y = \frac{10x}{5}$   $y = 2x$

$\sin^2 x + \cos^2 x$   $1$

**distribute**

$(x + 1)(x + 2)$   $x^2 + 2x + x + 2$

**substitute**

$x^2 + 2x + 1$   $x = 3$   $3^2 + 2 \cdot 3 + 1$

**split fractions**

$\frac{3x + 2y}{9} + \frac{2y}{9} = 1$

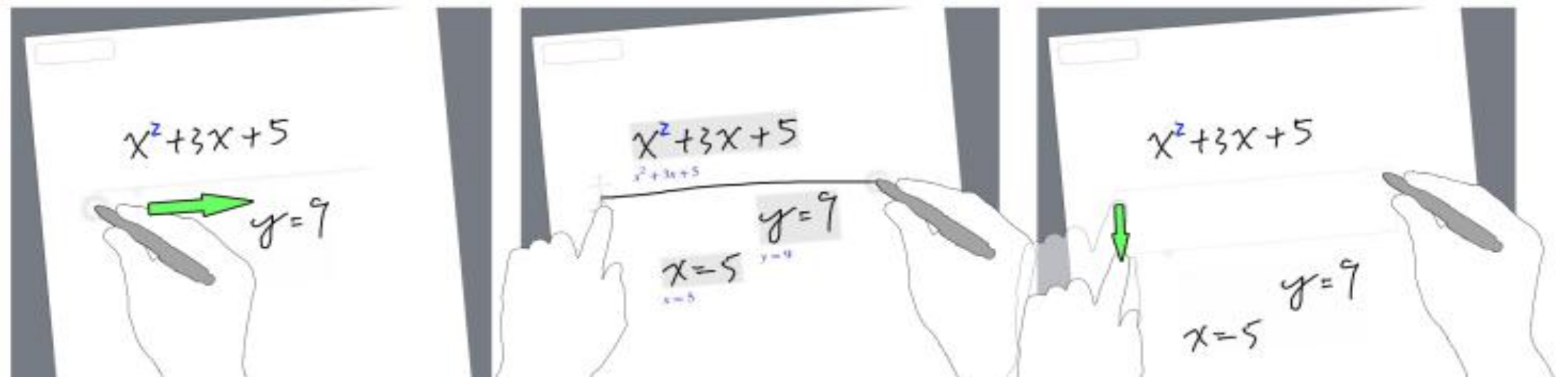
**split into sum**

$2x + 1$   $(m + (2 - m))x + 1$



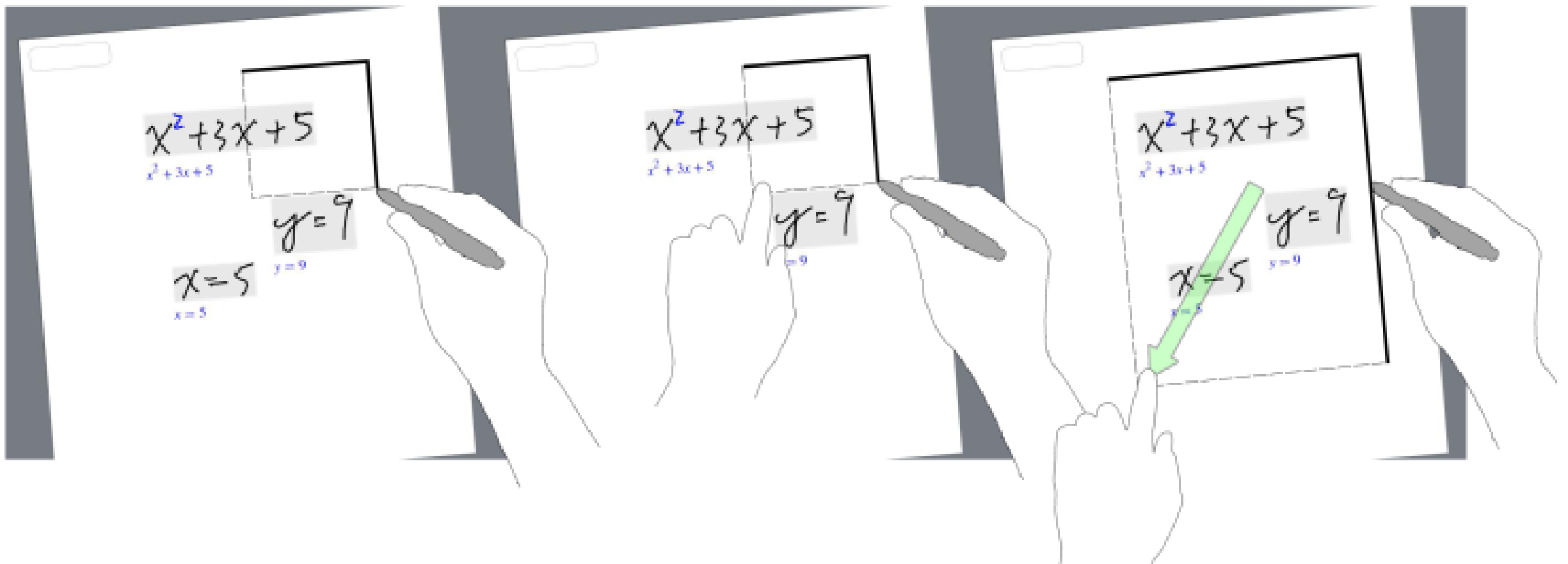
# Working in 2D with TAP gestures

- Touch-activated Pen Gestures (TAP) vs. digital ink
- Bi-manual interaction pattern
  - pen draws something
  - feedforward widget(s) appear
  - touch of widget confirms gesture and specifies additional



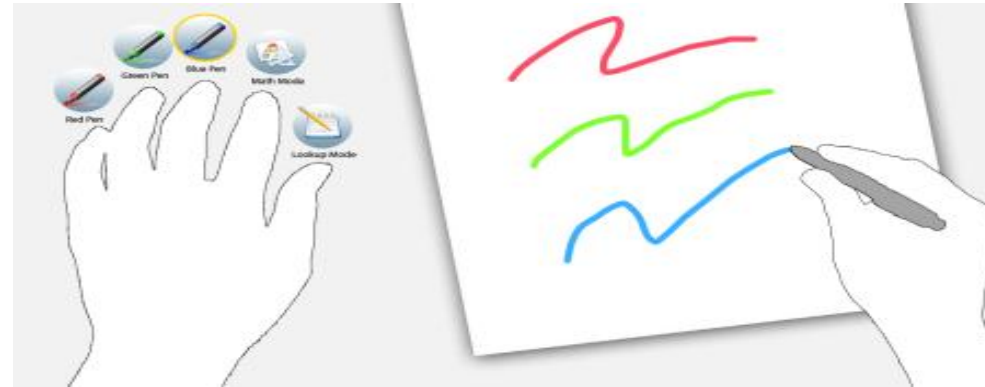
# Working in 2D with TAP gestures (cont)

- Less likely than punctuation to be accidentally activated
- More scalable than pen-only because gesture stems can be "shared" to provide choices



# PalmPrint – virtual chording keyboard

Register PalmPrint by placing palm and five fingertips on surface



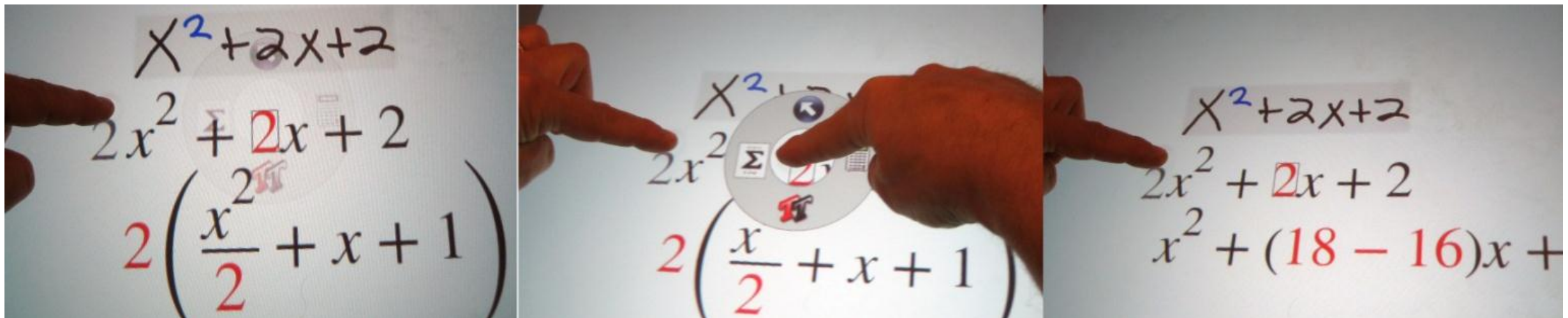
Change drawing modes with a release/press

Customizable function mappings



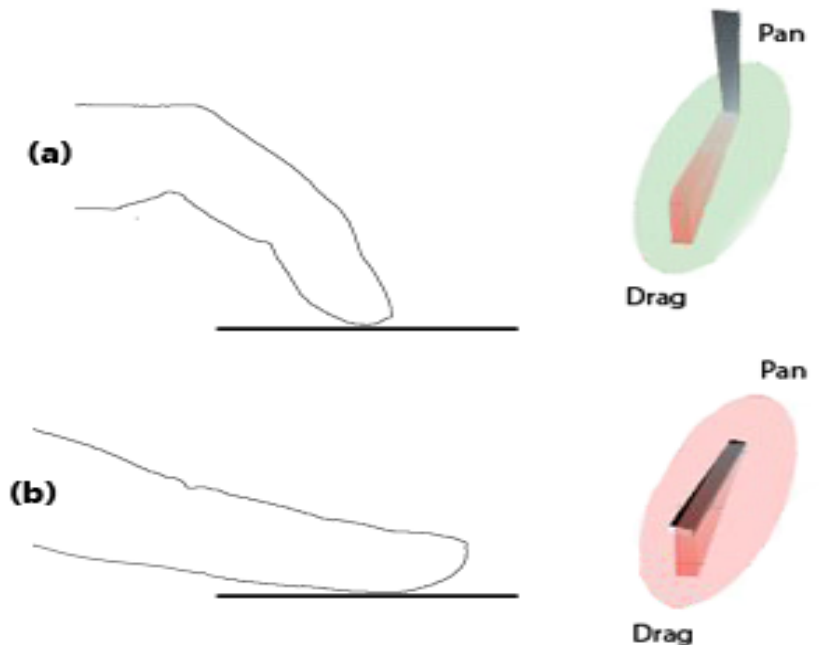
# Under the Rock Menus

- Move the rock (object) to find its UI
- Makes math manipulation scalable
  - Dragging math terms can mean different things...
  - Select non-default dragging behaviors on the fly
- Doesn't clutter the screen
- Develop physical skills (a la marking menus)



# Finger Area & Finger Pose interactions

- Selecting math terms uses fingertip contact area
  - Orient fingertip to touch only desired terms
  - Tightly integrates selection with manipulation
- Dragging windows vs. content based on angle of fingertip
  - Augments two+ finger dragging modes
  - Consistent with finger area interactions
    - Tip of finger grabs "smaller" things (pan graph contents)
    - Pad of finger grabs "bigger" things (move graph window)
  - Disclosed on pause with finger pose widget
- Mac users preferred two vs. one finger



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***video***

# Evaluation

- Users want this kind of math and free-form markup functionality
- Page metaphor appears broadly appealing
- Techniques need refinement
  - better recognition techniques (*e.g.*, surface contacts are not reliable for robust PalmPrint recognition)
  - disclosure techniques are required (*e.g.*, Bragdon's Gesture Bar)
    - to know what gestures exist
    - to know *how* to perform a gesture (*e.g.*, efficient finger posture needs to be learned)
- "Sandwich Problem" of bi-manual interaction
  - perceived benefit needs to outweigh the perceived cost

- Framework for building gesture-driven pen-centric applications
  - Library of pen gestures (graphing, delete, undo, etc.)
  - GestureBar
  - Math recognizer
- Extended to support multi-touch
  - Library of multi-touch interactions
  - Web browser
  - Abstraction layer on Surface SDK for portability
  - Input device framework (*e.g.*, for adding Anoto pen)



# Summary

- Extends StarPad SDK
  - supports multi-touch and pen-and-touch commands
  - makes some Surface interactions portable to desktop
- Also actively used by Michael Haller at Technical Institute of Austria
  - adapted to front projection with Anoto pen
  - added a component architecture for plug-ins, e.g., 3D math visualization
- To be presented at UIST 2010
  - *Hands-On Math: A Page-based Multi-touch and Pen Desktop for Technical Work and Problem Solving. Robert Zeleznik, Andrew Bragdon, Ferdi Adeptura, Hsu-Sheng Ko. To appear in: Proceedings of the 23rd Annual Symposium on User Interface Software and Technology (UIST 2010)*

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## Garibaldi on the Surface

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# The Garibaldi Panorama – 1860's



The panorama in the process of being scanned

## **Size:**

scroll approximately the length of a football field,  
and 4.5 feet tall

## **Medium:**

Watercolor on thin paper similar to wallpaper

## **Rarity:**

The only copy of this artifact to exist

These items combine to make the Panorama essentially inaccessible. To allow scholars and the public to interact with it, it has been scanned and an application for the Surface has been developed to provide the needed interactive capabilities.

# Current Hardware

- Large external display aids in teaching and collaboration
- Microsoft Surface as primary interaction tool enables tactile interaction with a virtual copy of the physical Panorama



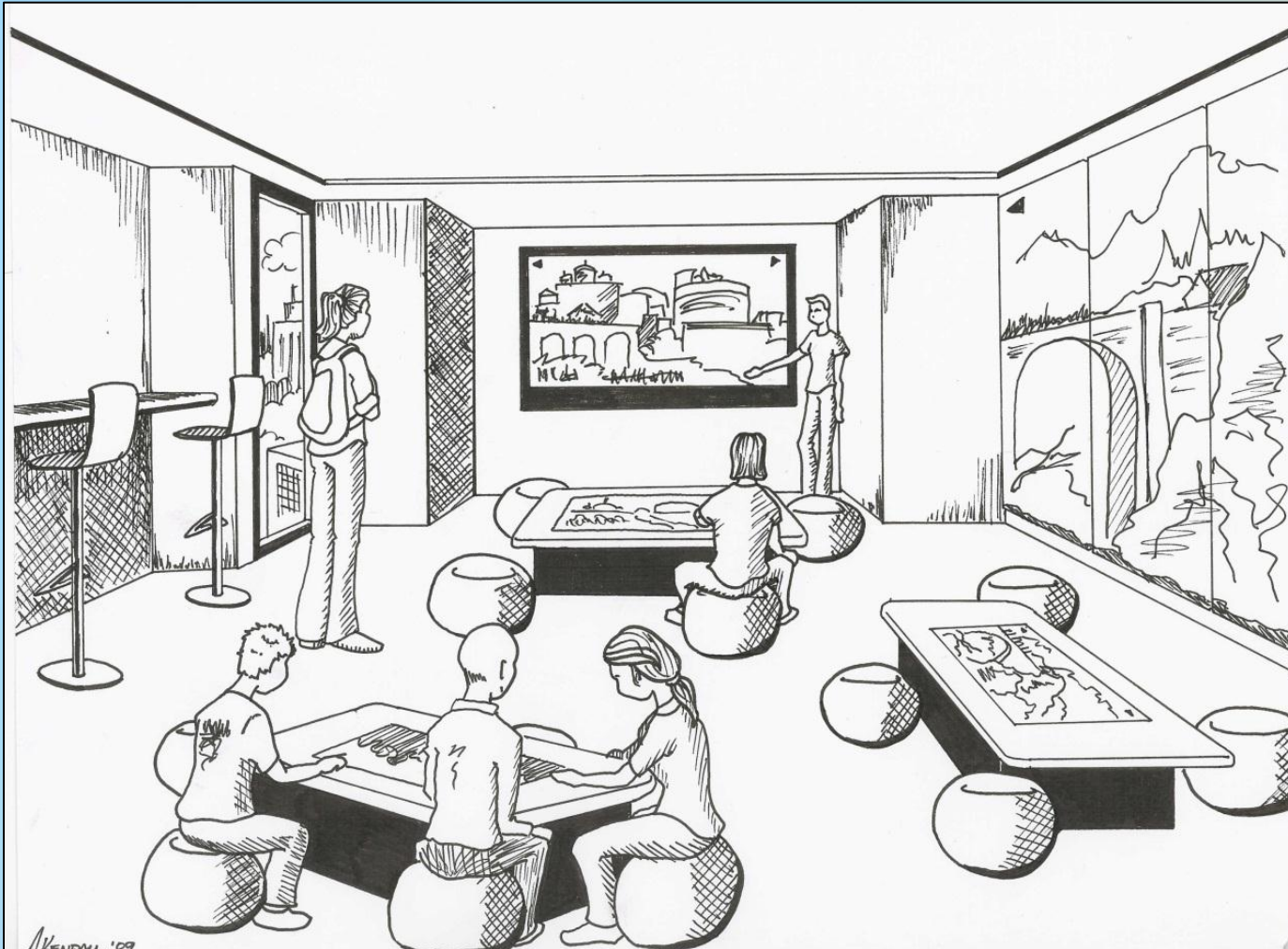
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Garibaldi on the Surface Demo

***video***

# Our Plan for a Digital Scholarship Lab



Sketch by Amy Kendall

- **Experimental** lab for the humanities (and sciences)
- Dedicated **collaborative** work and teaching space
- **Touch+pen**-enabled walls and tabletops to allow full collaboration from all participants – export/import to other form factors
- Access to large store of digital **assets**
- Interest in understanding and supporting the “**scholarly workflow**”

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