Input: pointing devices, input-output mappings, CD gain, mid-air interaction, problems of direct input and solutions
Input devices vs. Finger-based input
**Indirect vs. Direct pointing**

**Indirect**: The position of the cursor is controlled by the device

**Direct**: Fingers manipulate visual objects directly on the screen
Absolute vs. Relative pointing

**Absolute:** 1-to-1 mapping between input and output space

**Relative:** Input controls the relative position of the cursor (always indirect)
Hovering mode

Tracking the position of the pointing device (e.g., the pen) or the finger from distance

Hover widgets http://www.youtube.com/watch?v=KRXfaZ8nqZM
Absolute pointing

Direct input
- Hovering feedback is not indispensable as there is a clear mapping between pen/fingers and the screen
- Main drawback: occlusion problems

Indirect input
- “Hovering” is indispensable: users must know the position of the cursor before starting drawing
Relative pointing

Common devices: mouse and touchpad

« Clutching » instead of « hovering » mode
- Lift the mouse or finger to « re-calibrate » movement
- Use of smaller input space to traverse a larger output space
How would you map the input space of the tablet to the output space of the wall?

Smarties: [https://www.lri.fr/~chapuis/publications/CHI14-smartiestk.mp4](https://www.lri.fr/~chapuis/publications/CHI14-smartiestk.mp4)
Buxton’s 3-state model (1990)

A. Two-state model for mouse
Buxton’s 3-state model (1990)

B. Two-state model for a touch tablet
Buxton’s 3-state model (1990)

C. Three-state model for a graphics tablet with stylus
Relative pointing: Mappings

**Position control**: maps human input to the position of the cursor (or object of interest)
- Examples: mouse, touchpad

**Rate (or velocity) control**: maps human input to the velocity of the cursor (or object of interest)
- Examples: joystick, trackpoint
Isotonic vs. Isometric devices

**Isotonic** (iso-tonic = equal tension/force): Absence of resistance, free movement
- Mouse, pen, human arms, etc.

**Isometric** (iso-metric = equal measure): Absence of movement, resistance as we press
Isotonic vs. Isometric devices

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- Mouse, pen, human arms, etc.

**Isometric** (iso-metric = equal measure): Absence of movement, resistance as we press

**Elastic**: Resistance increases with movement
- Joystick, trackpoint
Elastic/Isometric devices

There is a neutral position

As we apply force, an opposing force develops

**Self-calibration:** If we free the device, the opposing force bring the device to its neutral position.
General principles

Isotonic devices (e.g., mouse) most appropriate for position control

Elastic/isometric devices (e.g., joystick) most appropriate for rate (velocity) control
Mixed control (Casiez et al., 2007)

How can we increase the input space of a trackpad to reduce clutching: trackpad + trackpoint

RubberEdge  [Video](http://www.youtube.com/watch?v=kucTPG_zTik)
Mixed control

The wrist as a mixed-control device (Tsandilas et al. 2013)
position control around the neutral wrist position
rate control near extremes angles

No need for clutching
Output resolution

Dots per Inch (DPI)

For screens where dots are pixels, we use the term Pixels per Inch (PPI)
Input resolution (isotonic devices)

Input resolution often measured in **counts per inch (CPI)**
- Also referred to as Dots per Inch (DPI)

A modern mouse: 400 to 10000 CPI
- Detection of displacements between 64µm and 2.54µm (about the size of a bacterium)
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« Useful » resolution: 200-400 CPI (Aceituno et al. 2013)
- Maximum resolution that users can benefit from
Control-Display (CD) gain

\[ \text{CD}_\text{gain} = \frac{V_{\text{pointer}}}{V_{\text{device}}} \]

- \( V_{\text{pointer}} \): velocity of cursor
- \( V_{\text{device}} \): velocity of input device
Control-Display (CD) gain

\[ \text{CD}_{\text{gain}} = \frac{V_{\text{pointer}}}{V_{\text{device}}} \]

- \( V_{\text{pointer}} \): velocity of cursor
- \( V_{\text{device}} \): velocity of input device

\text{CD}_{\text{gain}} = 1 \\
When the mouse moves 1cm, the cursor also moves 1cm

\text{CD}_{\text{gain}} < 1 \\
The cursor moves slower than the mouse: Better precision

\text{CD}_{\text{gain}} > 1 \\
The cursor moves faster than the mouse: Faster, less clutching
Range of usable CD gains

from Casiez et al. (2008)
Pointer acceleration

The CD gain is not constant but changes as a function of the speed of the device
  - The faster I move the device, the faster the cursor (acceleration)
  - Slow movements cause the CD gain to decrease: better precision
Acceleration functions

Also known as transfer functions

from Casiez and Roussel (2011)
Nancel et al. (2013) found that with a good acceleration function, users could be very accurate and fast acquiring targets on a large high-resolution display even when the available input space was very small.
Laser pointing – RayCasting

Main strength: Natural, as the device or hand points directly to the target

Drawback: Sensitive to hand tremor and tracking precision. Depending on the distance of the user, small hand movement can cause large displacements, inappropriate for accurate pointing from distance
Solutions

Relative Pointing + Clutching (Vogel & Balakrishan, 2005)
Solutions

Hybrid Control (Vogel & Balakrishan, 2005)

http://www.youtube.com/watch?v=j26JQxMhBog
Direct input

**Strengths:** The user interacts directly with the objects as in the real world

**Drawbacks:** Lower accuracy due to occlusion, parallax, limited input resolution of the human limbs
The parallax problem

Incorrect perception of where the target is
Occlusion problems

The finger covers the object of interest. Here, the letter under the finger grows and moves upwards to reduce the problem.

Occlusion problems

Sliding Widgets (Moshovich, 2009)
Replacing push buttons by sliding ones to reduce ambiguity due to occlusion or parallax problems (crossing-based selection)

http://www.youtube.com/watch?v=Pw5nmLSYrvE
Hand occlusion
Occlusion-Aware Interfaces
(Vogel & Balakrishan, 2010)

http://www.youtube.com/watch?v=j-b9q4ZjLHo
Other clever solutions

PhantomPen (Lee et al, 2012)

http://www.youtube.com/watch?v=r62wxK3Rma4