Introduction to Human-Computer Interaction

05. Interaction Elements and Fundamental Design Goals

Instructor: Jaemin Jo (조재민, jmjo@skku.edu)
Interactive Data Computing Lab (*IDCLab*),
College of Computing and Informatics,
Sungkyunkwan University

Interaction Elements

- What are the elements of HCI?
    - HCI researchers' vocabulary (terminology)

- Controls, mapping, degree of freedom (DoF), conceptual model, ...

- These elements are essential to describe the interaction between humans and computers in the real world.

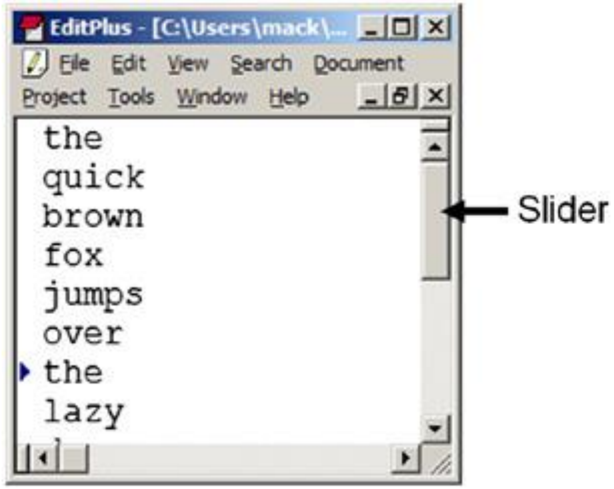
Hard Controls and Soft Controls

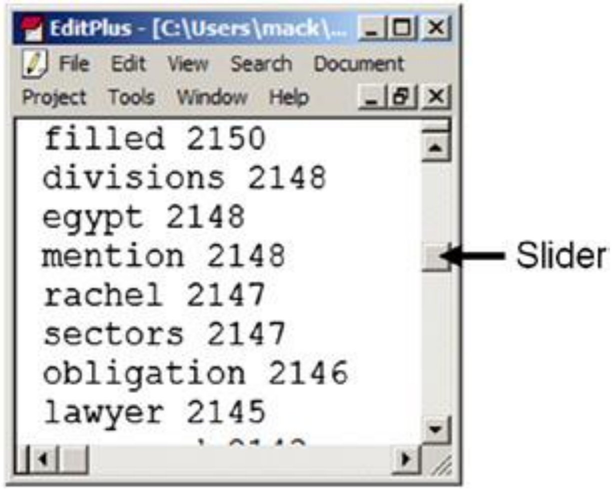
- **Hard controls:** joystick, switches, push buttons, keys, …
  - Once manufactured, their behaviors are constrained.
  - Physical and single-purpose

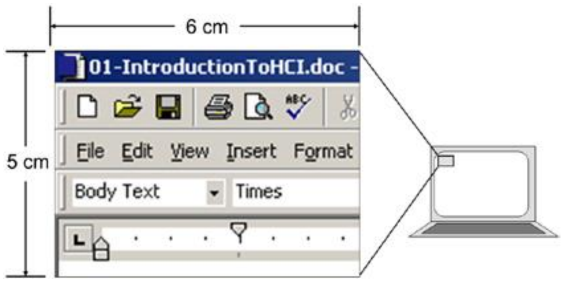
- **Soft controls:** display + pointing device + software
  - “malleability of a display”
  - Bring unlimited possibilities to a relative small physical space

Hard Controls and Soft Controls

- Soft controls blur the distinction between controls and displays
- Soft controls need little space







Control-Display Relationship

- **Control-display relationship**: the relationship between what a user does and what is experienced.

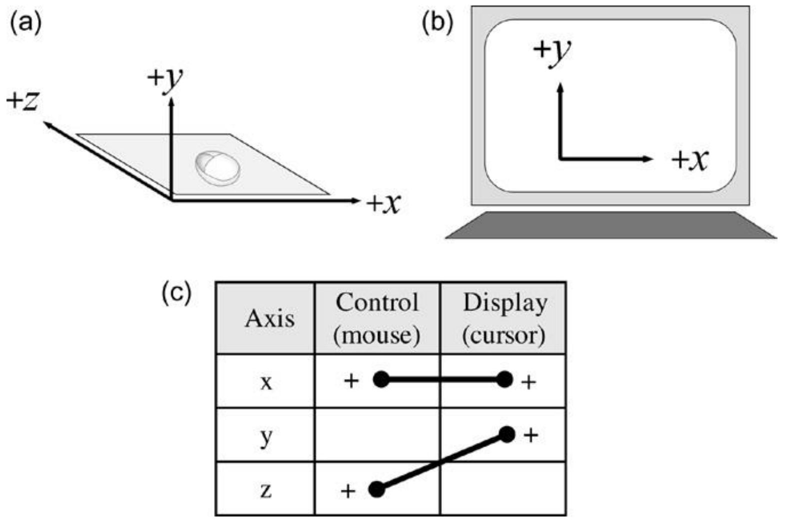
- “Move the mouse to the right” -> “Move the cursor on the system to the right”

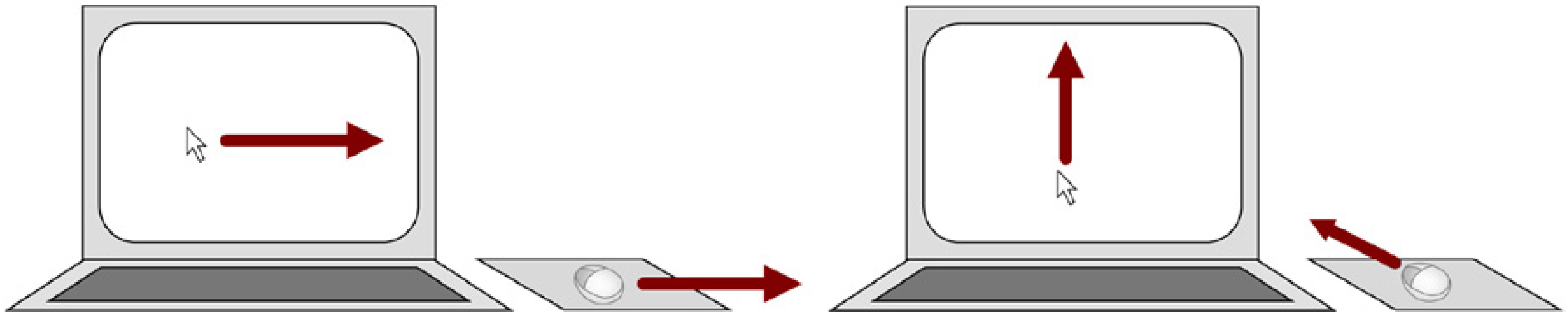
- Should be natural, seamless, intuitive, and efficient

Spatial Relationship

- Move the mouse to the right -> cursor right
- Move the mouse “forward” -> cursor “up”
  - Raising the mouse “up” off the mouse pad?

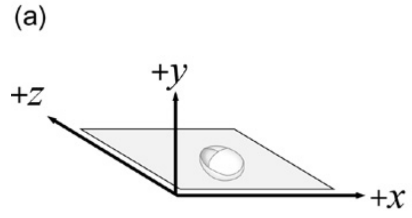
- *Transformed spatial mapping*
  - Even though transformed, the mapping can be quickly learned.

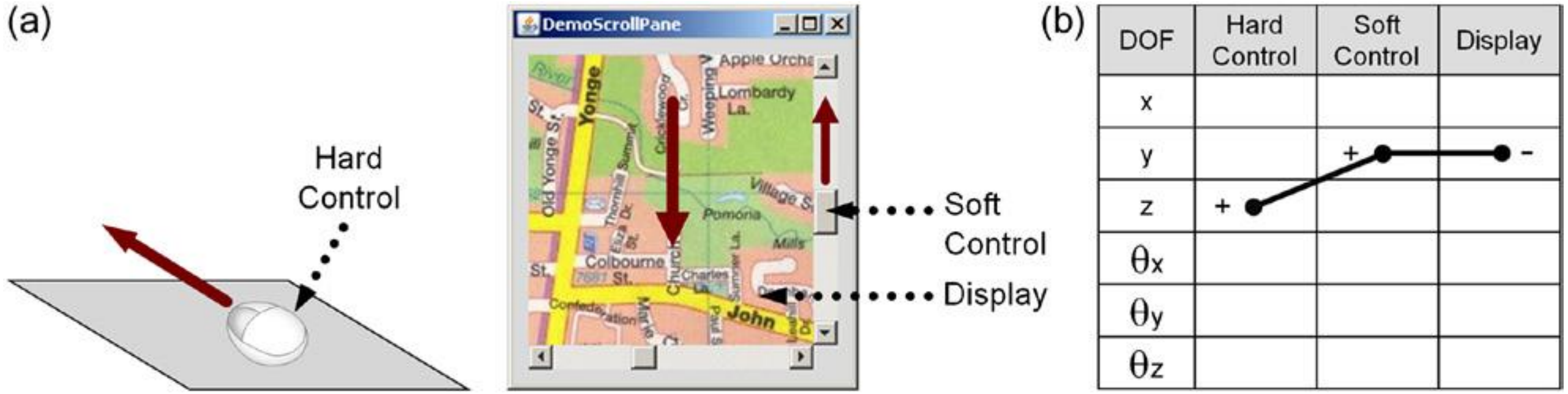




Spatial Relationship

- Scrolling exhibits a three-tier control display relationship.
  - Transformation between the hard and soft controls
  - Transformation between the soft control and the view

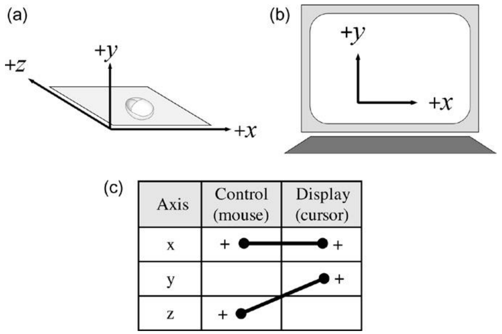


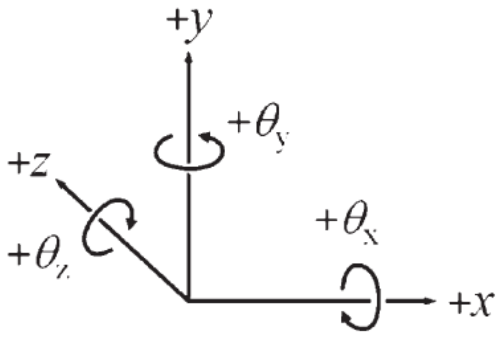


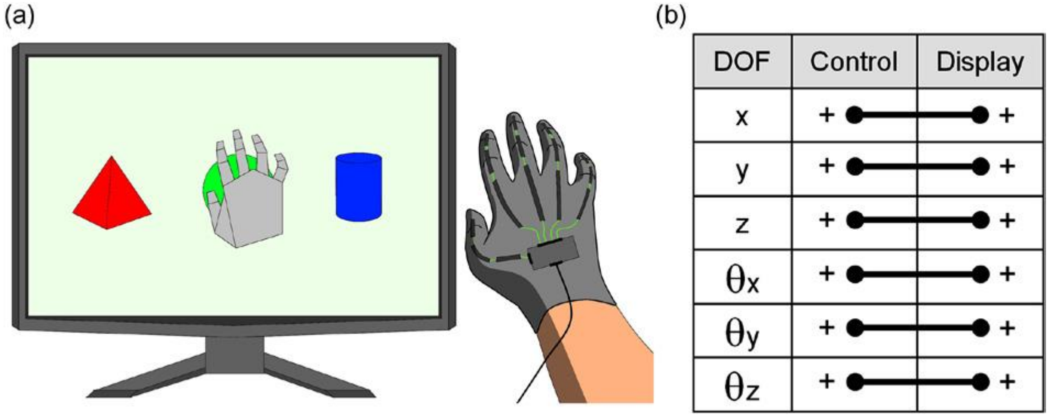
Spatial Relationship

- More degree-of-freedom (DoF)?
  - The number of parameters can be manipulated independently of others.

- Spatial congruence is achieved in (a).







Spatial Relationship

- Interaction (e.g., dragging, see (b)) or soft controls can be used to support manipulation.

- The mapping in (b) look convoluted, but people can quickly learn it.

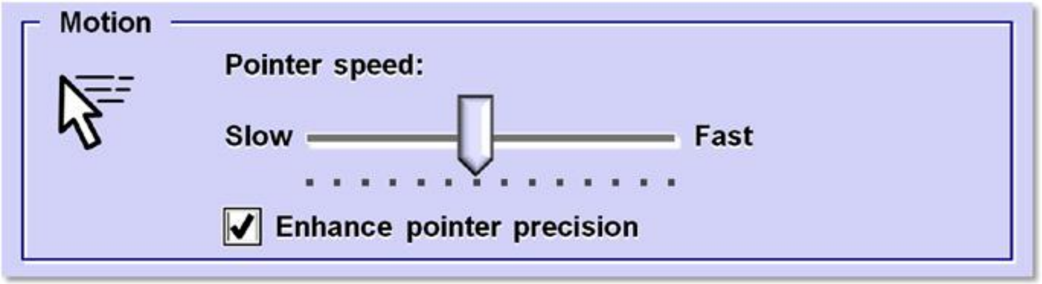
(a)

(b)

DOF	Control	Display
x	+	
y		
z	+	
θx		+
θy		-
θz		

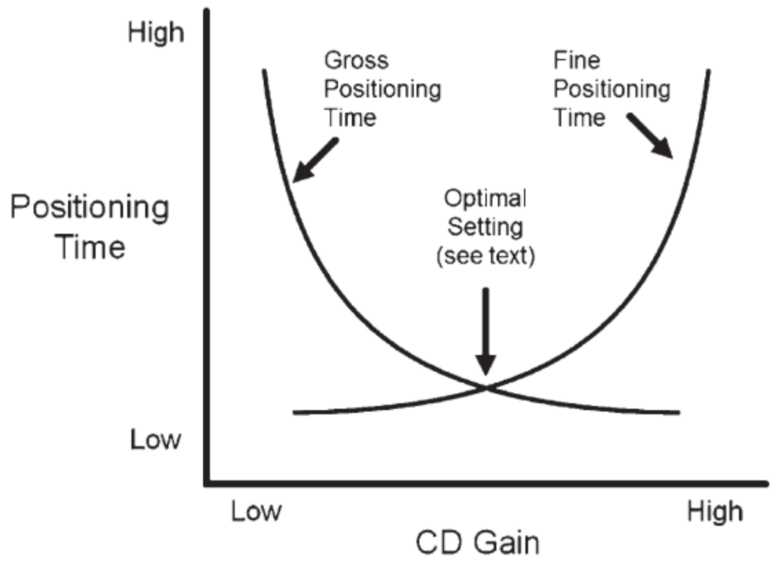
Control-Display Gain

- **CD gain**: the amount of movement in a display object for a given amount of movement in a control.
  - Move mouse 3 cm -> cursor moves 3 cm: CD gain = 3 / 3 = 1
  - Move mouse 3 cm -> cursor moves 6 cm: CD gain = 6 / 3 = 2
- Often the gain is non-linear and uses a power function.
  - Mouse moves slowly -> low CD gain (enhance pointer precision)



Control-Display Gain

- Early research on finding the optimal CD gain (1940s)
- Speed-accuracy trade-off
- Very large display, very small displays, remote pointing, 3D interaction, …



Property Sensed

- Which property of a control is sensed?
  - Position
  - Displacement
  - Force

- **Touchscreen:** absolute position of fingers
- **Mouse**: displacement (the amount of movement)
- **Touchpad on laptops**: absolute position is sensed, but operates in mouse-emulation mode

Order of Control

- What does the sensed property change?
- **Position-control (zero-order control)**: the sensed property controls the position of an object
- **Velocity-control (first-order control)**: the sensed property controls the velocity of an object.

(a)

(b)

Isotonic joysticks (displacement sensing)

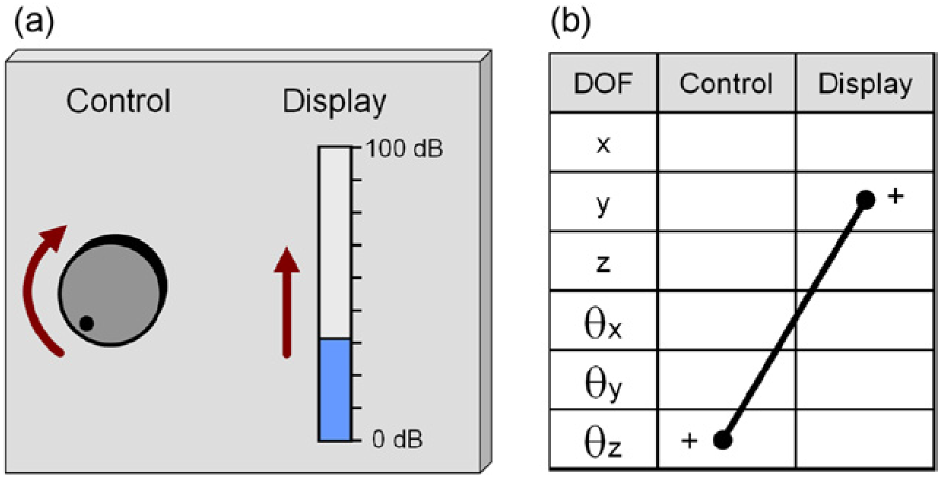
Best when position-control

Isometric joysticks (force sensing) Joystick is fixed

Best when velocity-control

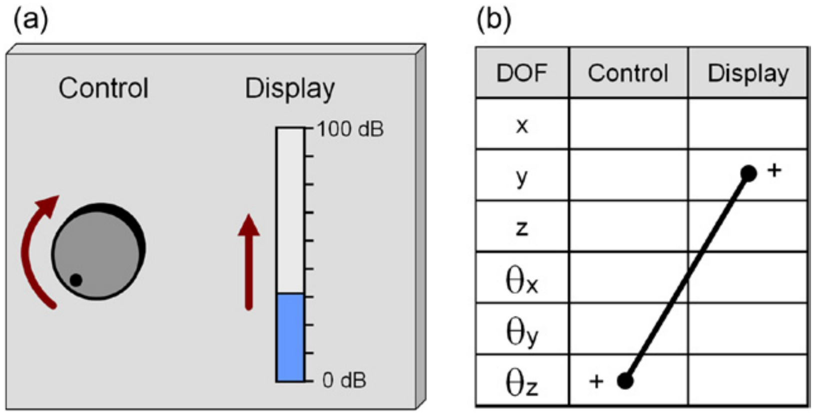
Natural vs Learned Relationship

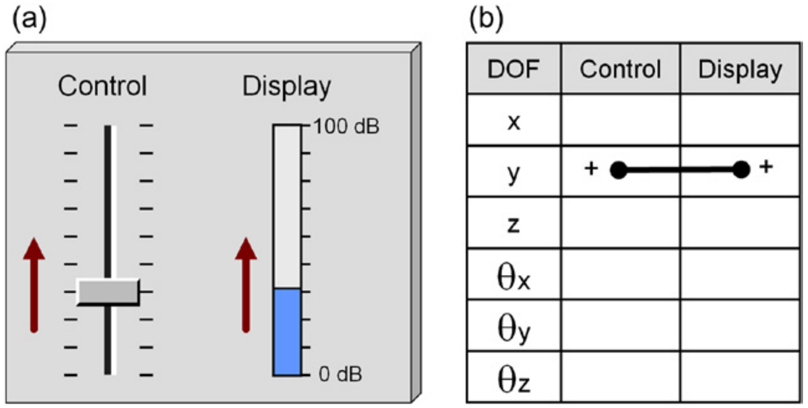
- Is a control-display relationship natural, or must be learned?
- Rotating the knob clockwise → increasing the value
    - Simple, intuitive, and easy



Natural vs Learned Relationship

- But, it is a learned relationship.
  - Think about rotating the knob counter-clockwise
- People with different cultures/ethnicity/geographical groups may have different “*expectation.*”
  - Spatial congruence is important

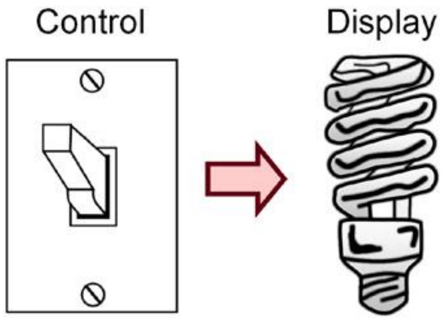


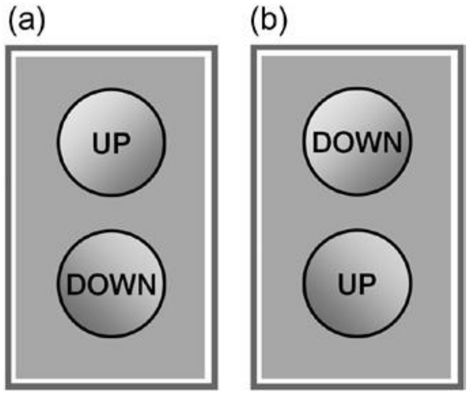


Natural vs Learned Relationship

- Switch-light interaction: no spatial mapping between a switch and a bulb
  - In UK, up → on, but In US, up → off

- Physical contradiction in (b)
  - Universal throughout cultures
  - People will learn but may make more errors.
  - (a) is superior to (b).

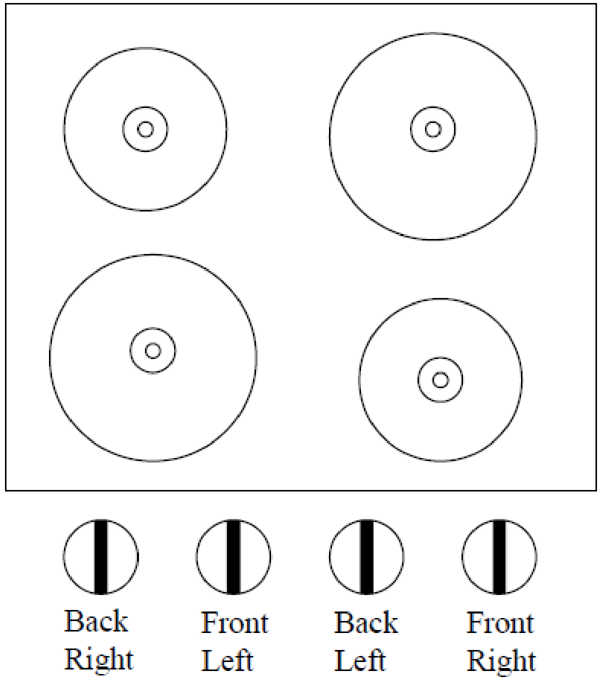




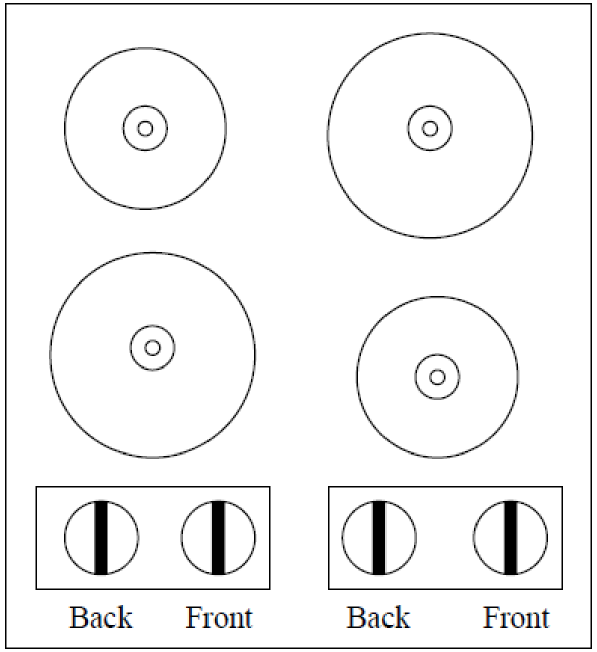
Mapping

- Relationship between controls and actions should be apparent to users.
  - Minimize the need for labels or legends
  - Work by “logical constraints”

Arbitrary

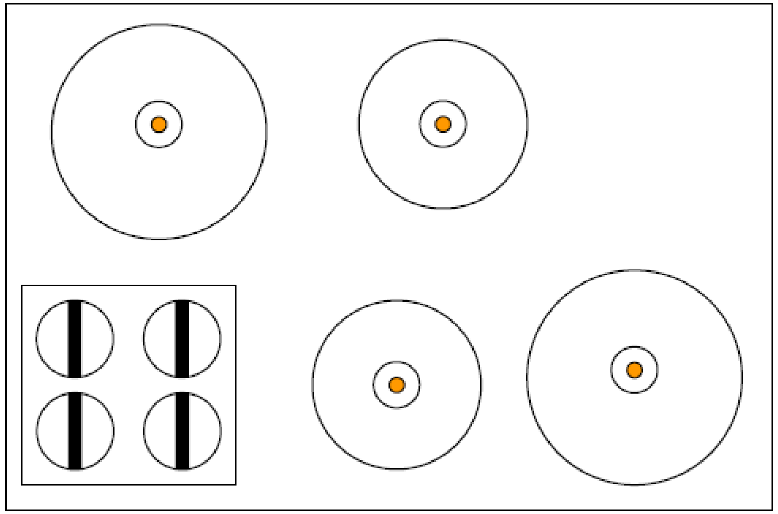


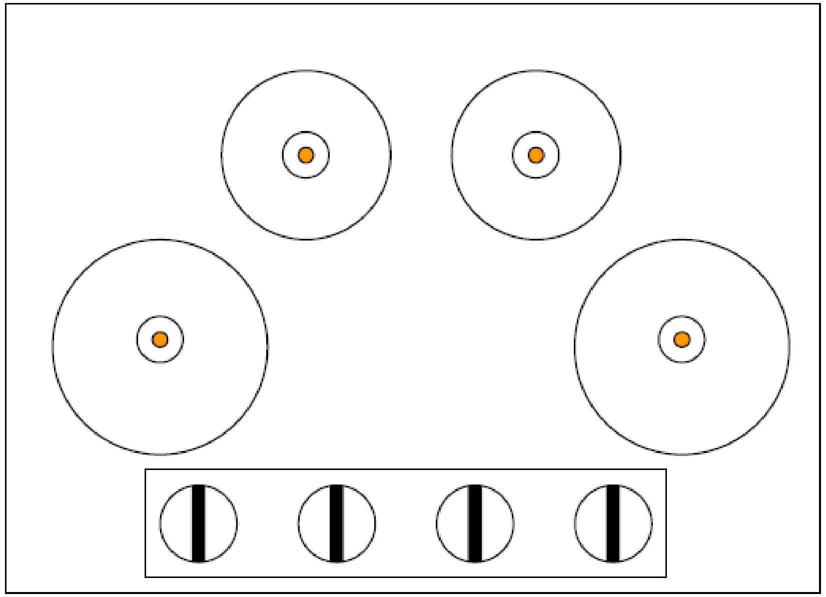
Paired



Mapping

- Full natural mapping between controls and burners
  - No labels!





Fundamental Design Goals

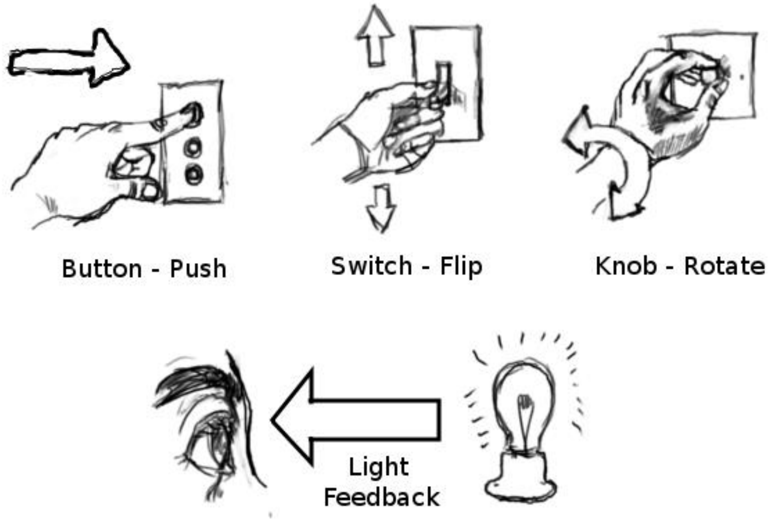
1. **Provide a good mapping between controls and actions**

Affordances

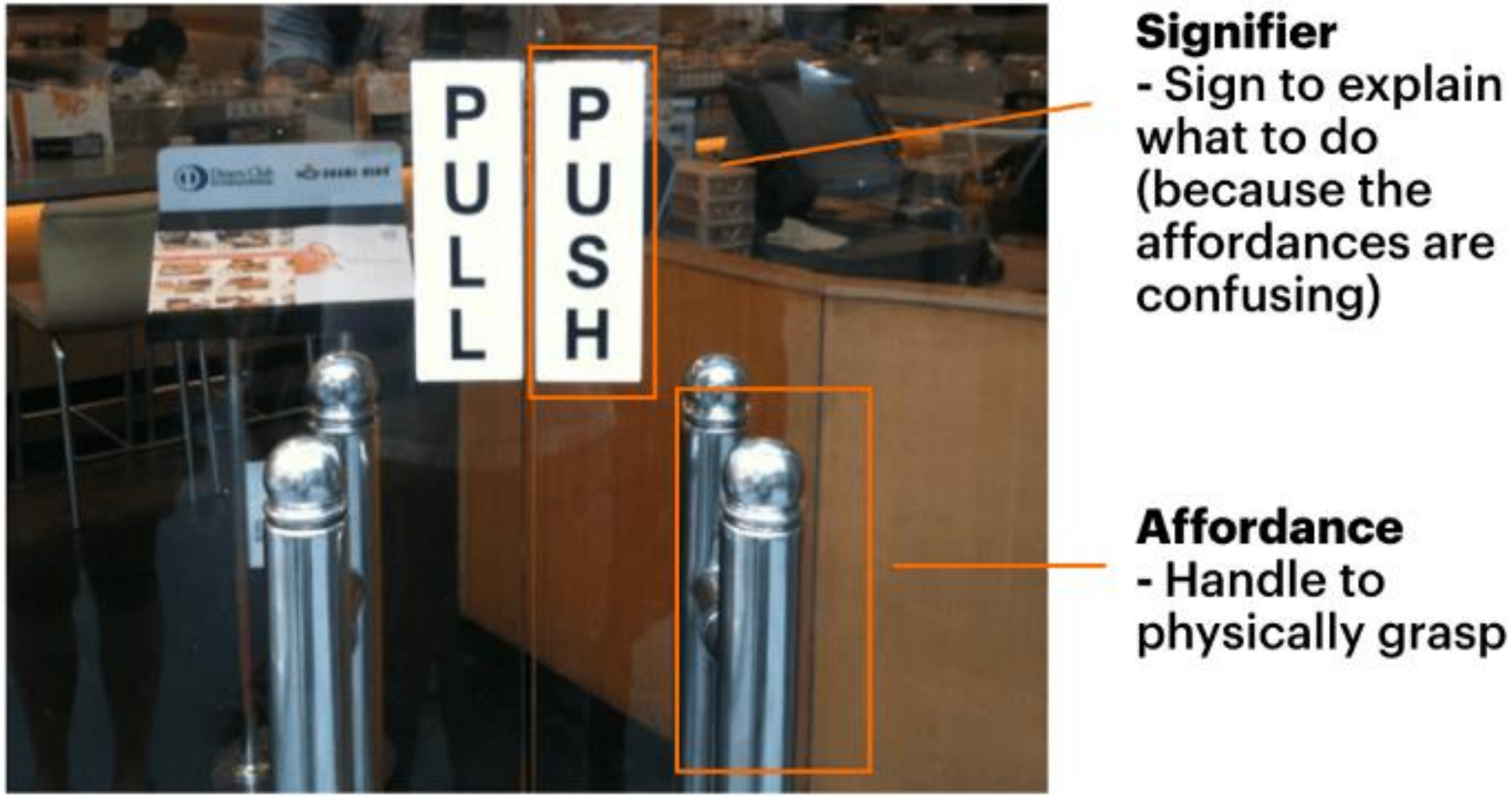
- **Affordances** are properties of objects which show users the actions they can take.
  - Provide strong clues to the operations of things
  - Affordances are everywhere!

- A chair affords sitting = a chair is for sitting
- Buttons for pushing
- Knobs for rotating

- No need for words, symbols, trial and error!



Affordance Example



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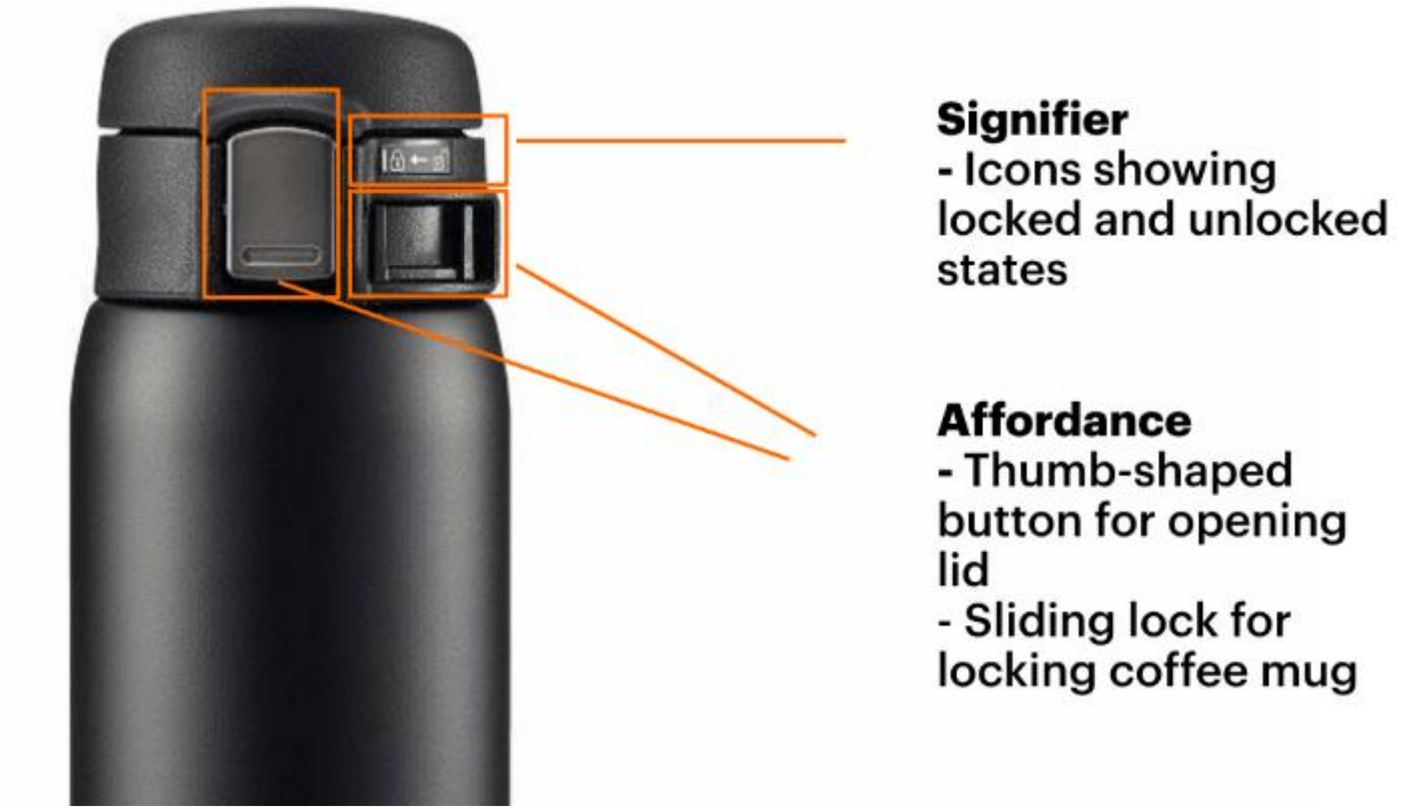
Affordance Example



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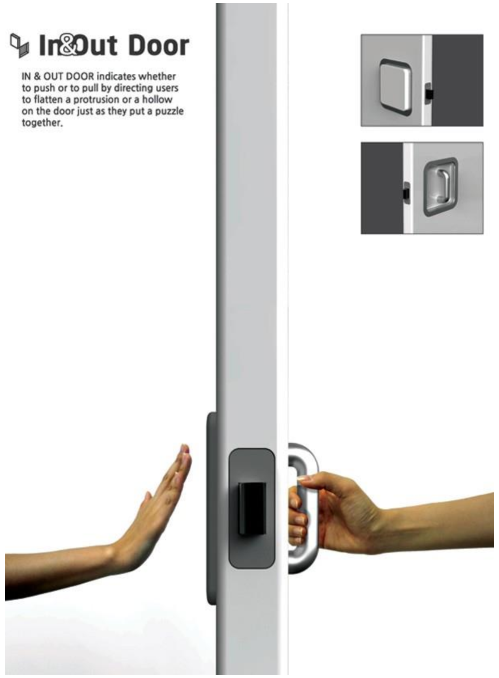
Fundamental Design Goals

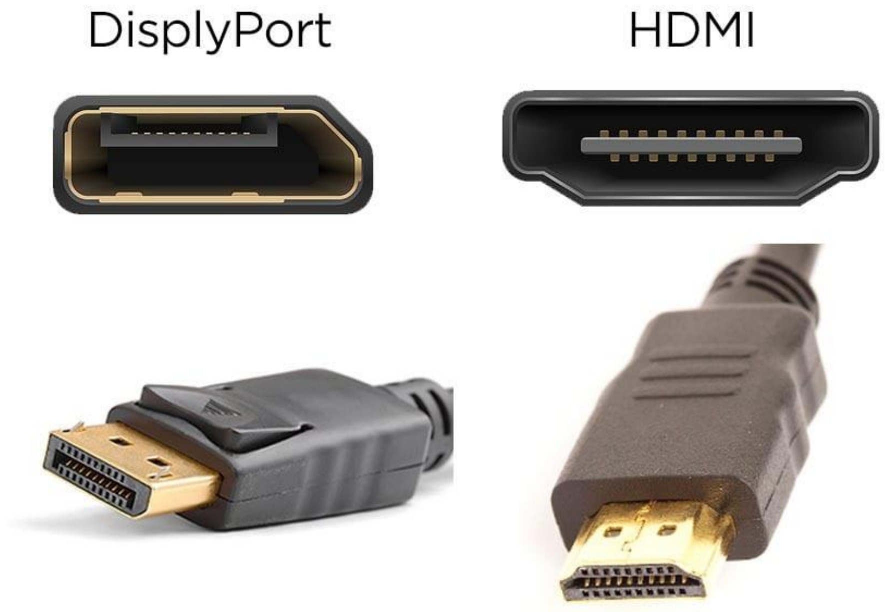
1. Provide a good mapping between controls and actions
2. **Provide the right affordances and signifiers**



Constraints

- **Visible constraints** limit the possible actions by appearance.
- Prevent errors

Types of Constraints



Physical

Semantic

You will choose the most meaningful action considering the situation.

Types of Constraints

Cultural

Logical

Types of Constraints

- **Physical Constraints**: Physical limitations constrain possible operations

- **Semantic Constraints**
  - Depending on our meaning of situation

- **Cultural Constraints**
  - Allowable actions for social situations

- **Logical Constraints**
  - only one piece left, only one possible place to go
  - spatial layout of components
  - “Natural mapping” work by this constraints

Fundamental Design Goals

1. Provide a good mapping between controls and actions
2. Provide the right affordances and signifiers
3. **Use constraints to prevent errors**

Metaphors

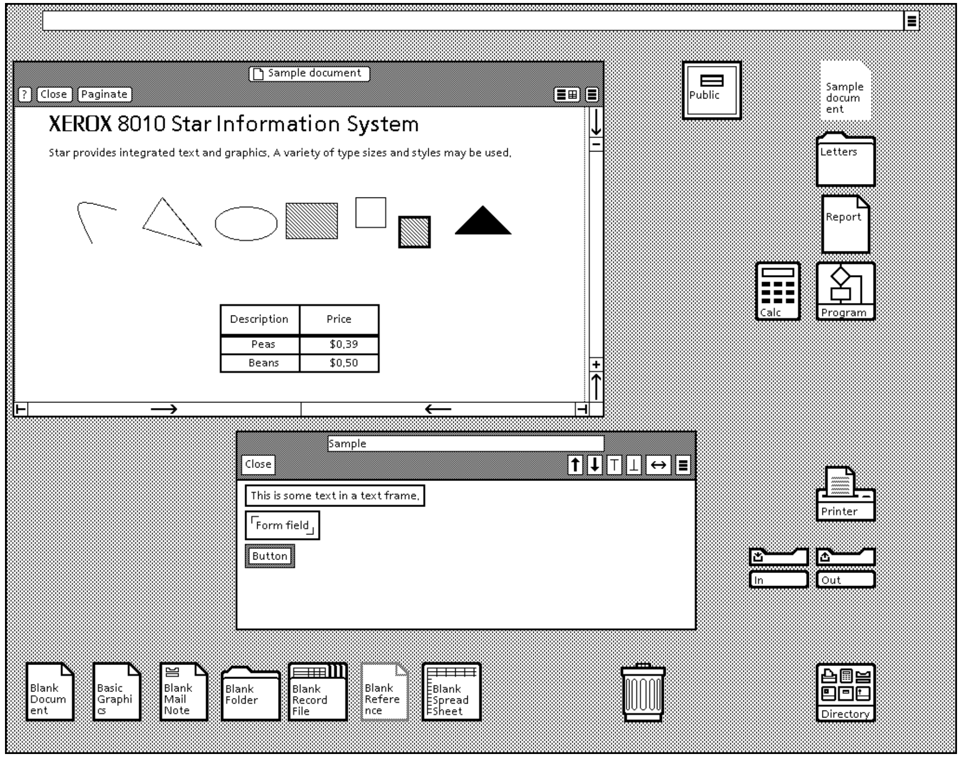
- Do we need to experience a thing to learn how to use it?

- **Physical analogy or metaphor** is one of the most common ways to learn and adapt.

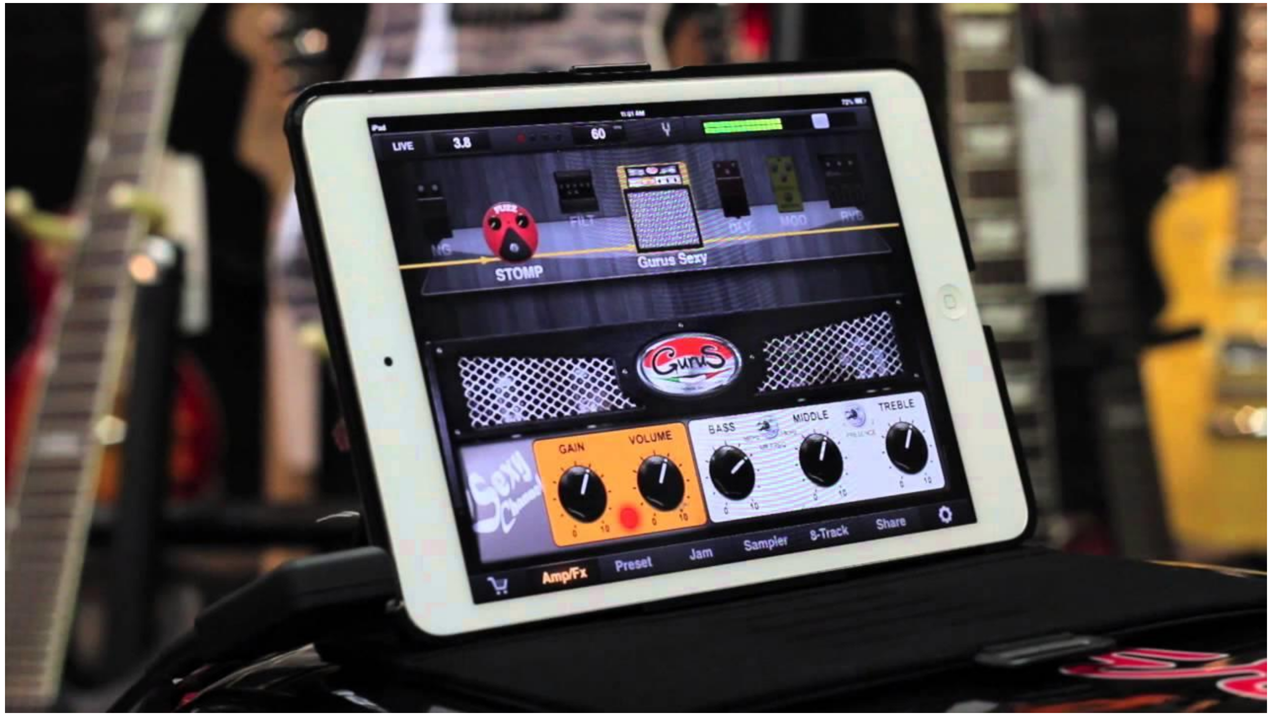
"Desktop" Interface

- In the CLI era, there was no GUI.
- Using GUI required a new way of thinking.

- Designers exploited the metaphor of the office or desktop to give users a jump-start on the interface.
  - Users could work with concepts already understood.
  - Documents, folders, filing cabinets, trashcans, pointing, selecting, dragging, dropping, …
  - "Desktop metaphor"



Metaphor Examples



Metaphors

- Pros
  - Reuse the previous experience to understand the working of a new thing
  - Leverage our knowledge of familiar, concrete objects/experiences
  - Transfer this knowledge to abstract computer and task concepts

- Cons
  - **Too limited**: The metaphor restricts interface possibility
    - You can undo commands in your desktop but not in the reality
  - **Too powerful**: The metaphor makes believe that the system can do things it can't
  - **Mismatched**: The metaphor makes it difficult to carry out the task

Fundamental Design Goals

1. Provide a good mapping between controls and actions
2. Provide the right affordances and signifiers
3. Use constraints to prevent errors
4. **Exploit metaphors**

Mental Models

- Why are metaphors effective?
- Because they help you build your mental model.

- **Mental model**: the user's explanation about how something works in the real world.

Mental Model Examples

Mental Model Examples

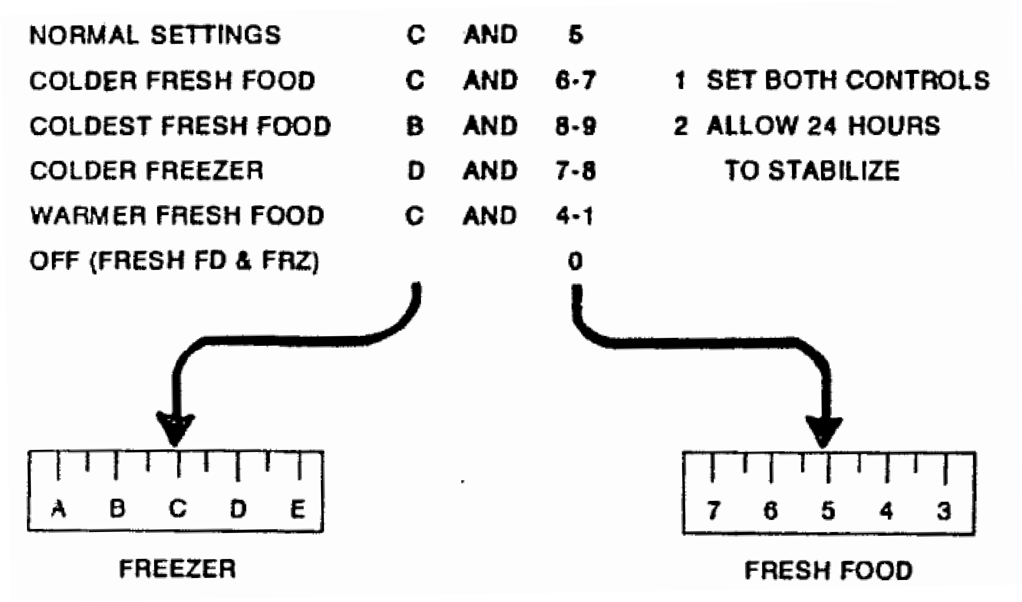
Mental Models

- “The models people have of themselves, others, the environment and the things with which they interact. People form mental models through experience, training and instruction”

- Abstract representation
- Enable people to reason about a system
- Affect the way we see and interpret reality
- Allow people to make predictions

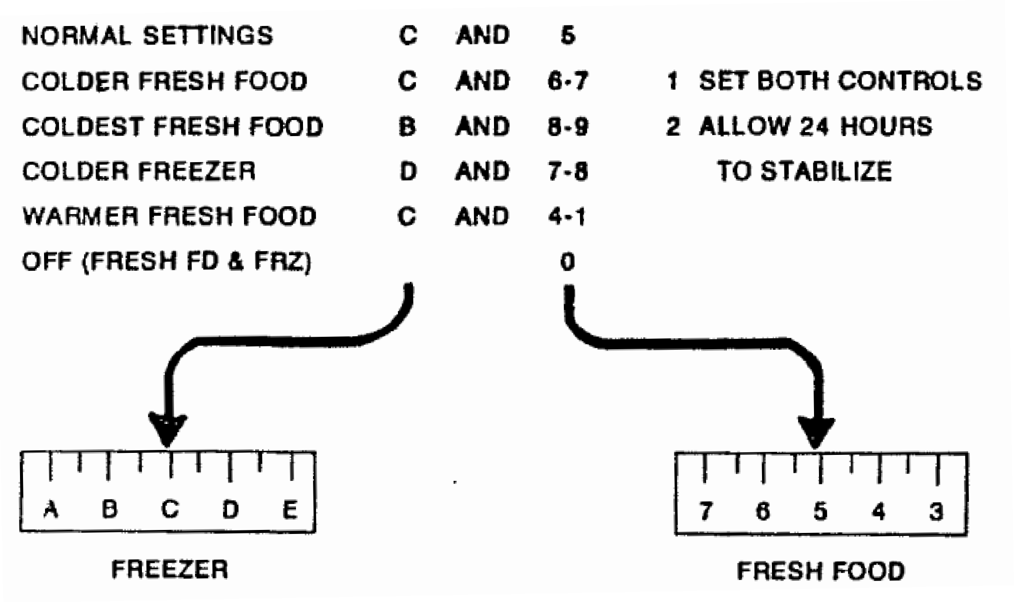
Refrigerator Example

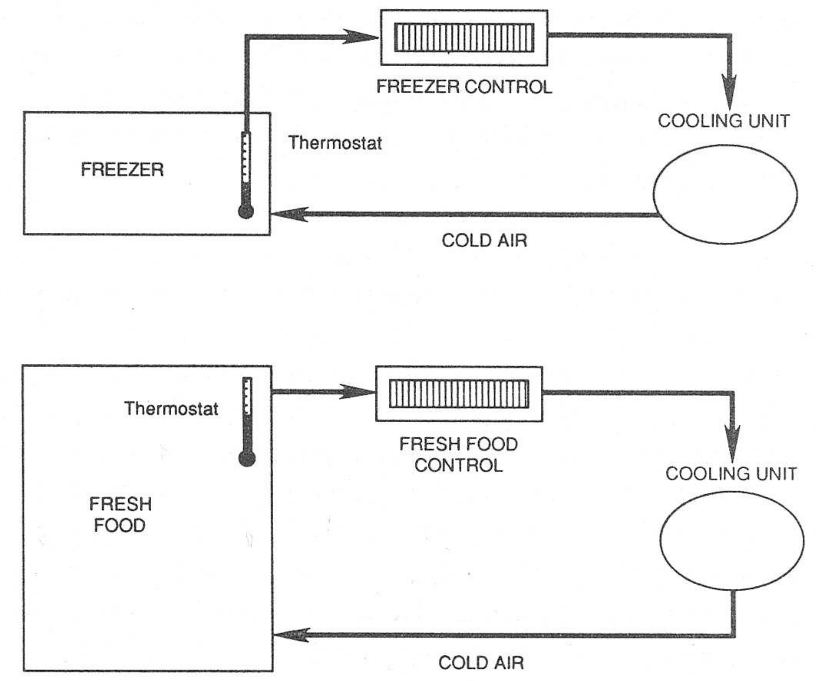
- What will happen if you turn the control for the freezer to E?



One Reasonable Mental Model

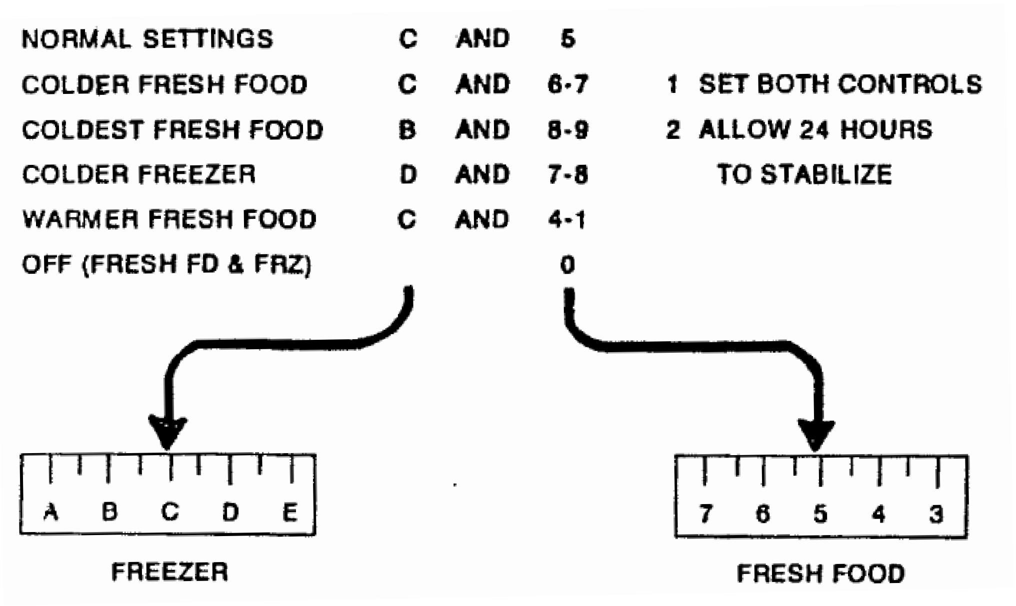
- Two controls and two compartments
- "Okay, one control must be for the freezer and the other for the refrigerator!"

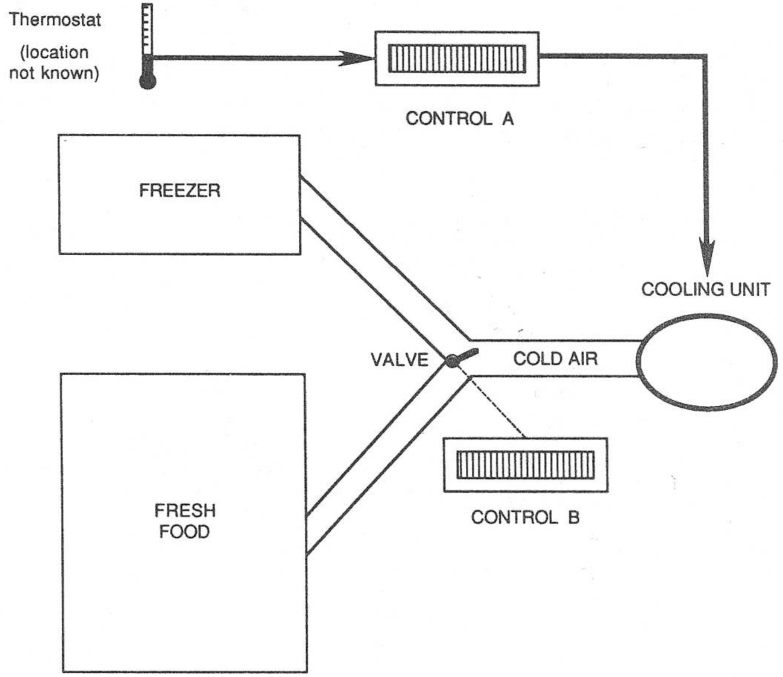




One Reasonable Mental Model

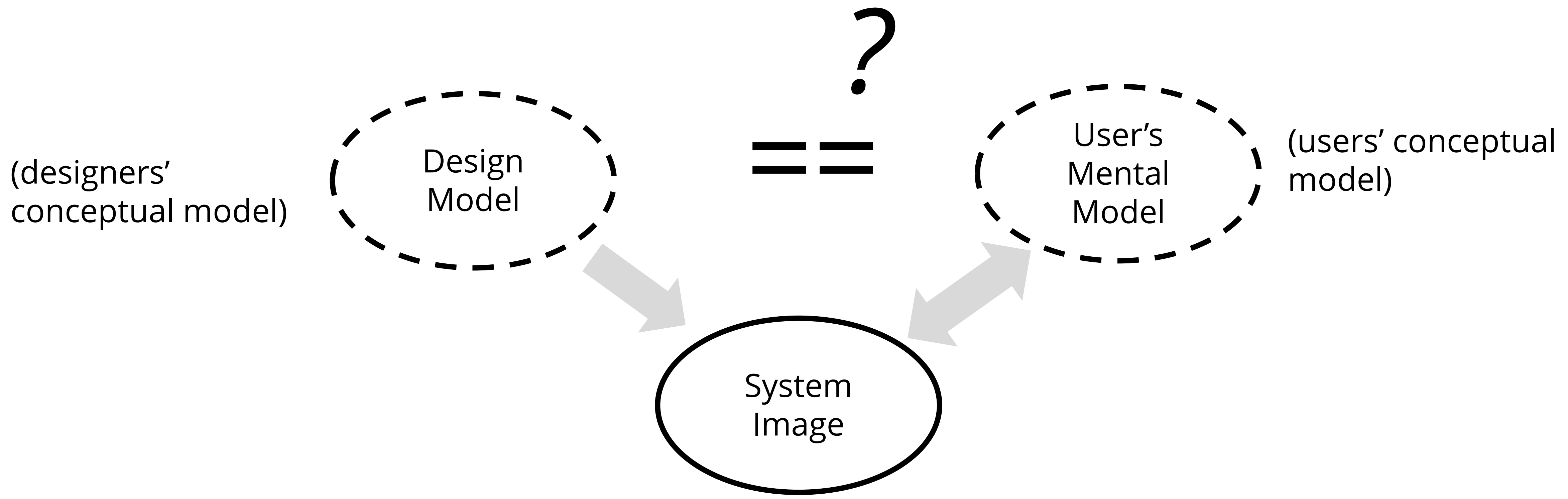
- But in fact, the first control controls the “total” amount of air while the second controls how much of cold air goes to freezer/refrigerator.
- Very hard to make only the freezer colder





Design Model

- **A design model** is generated over the course of a product's development
- No direct interaction!



Design Model

- If the design model doesn't match the users' conceptual model, the user will find the product hard to learn and use.
  - "Why did they design in this way?"

- How to deliver the design model effectively?
  - Manuals?
  - Talking to the user directly?

Conceptual Model

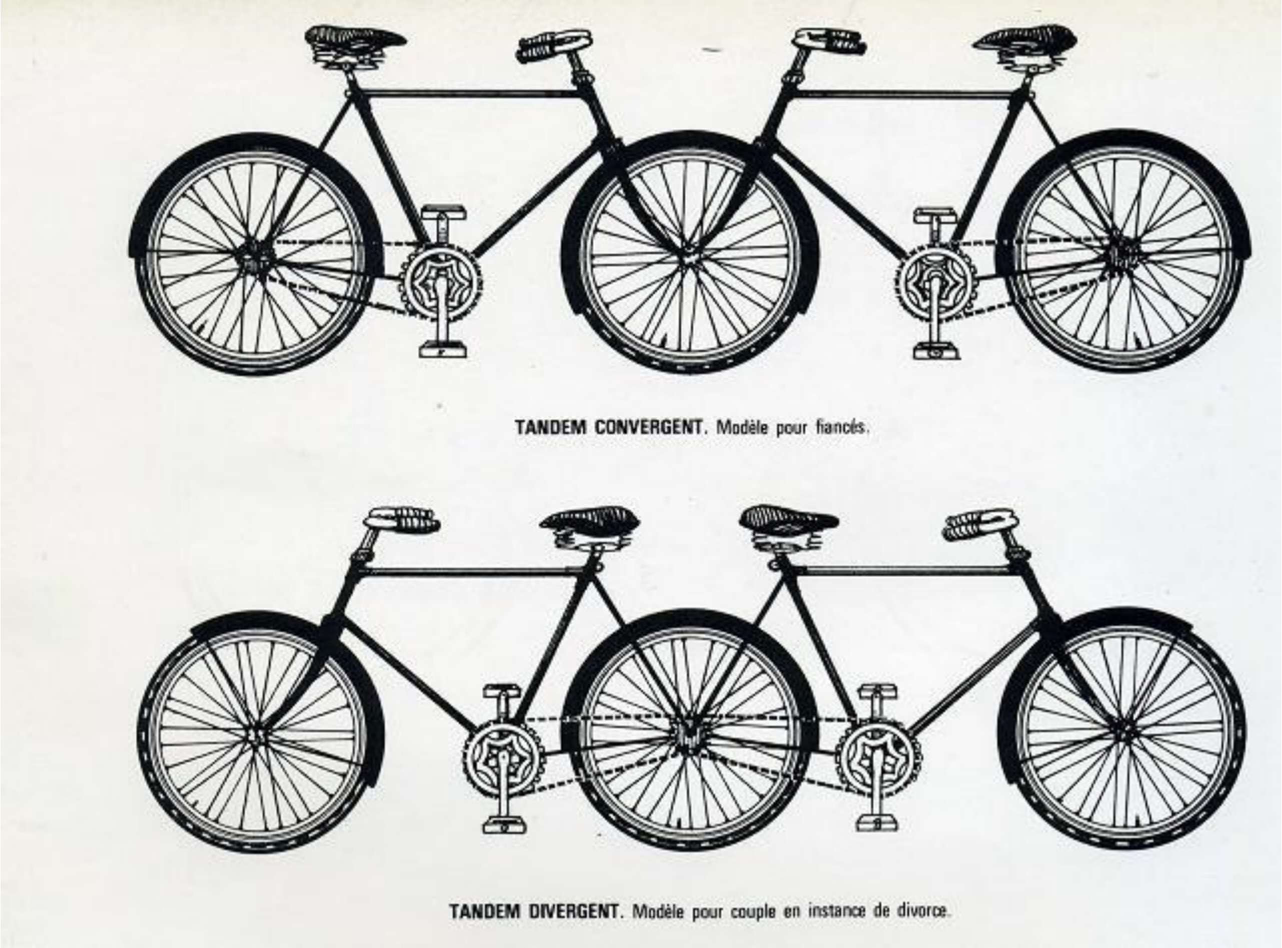
- Formed by

- Affordances
- Constraints
- Mappings
- Feedback the users receive from actions
- The visual cues from the appearance of a product

Conceptual Model Example

- Visibility: all parts visible
- Affordances
  - Handles with holes (putting something into them?)
  - Sharp blades (don’t touch this part!)
- Constraints: only two holes (not many possible actions)
- Mappings: big and small holes
  - Small for the thumb and big for other fingers
  - Transfer effect (learnt mapping from adults)
- = Good Conceptual Model
  - Implication is clear.

Conceptual Model Example

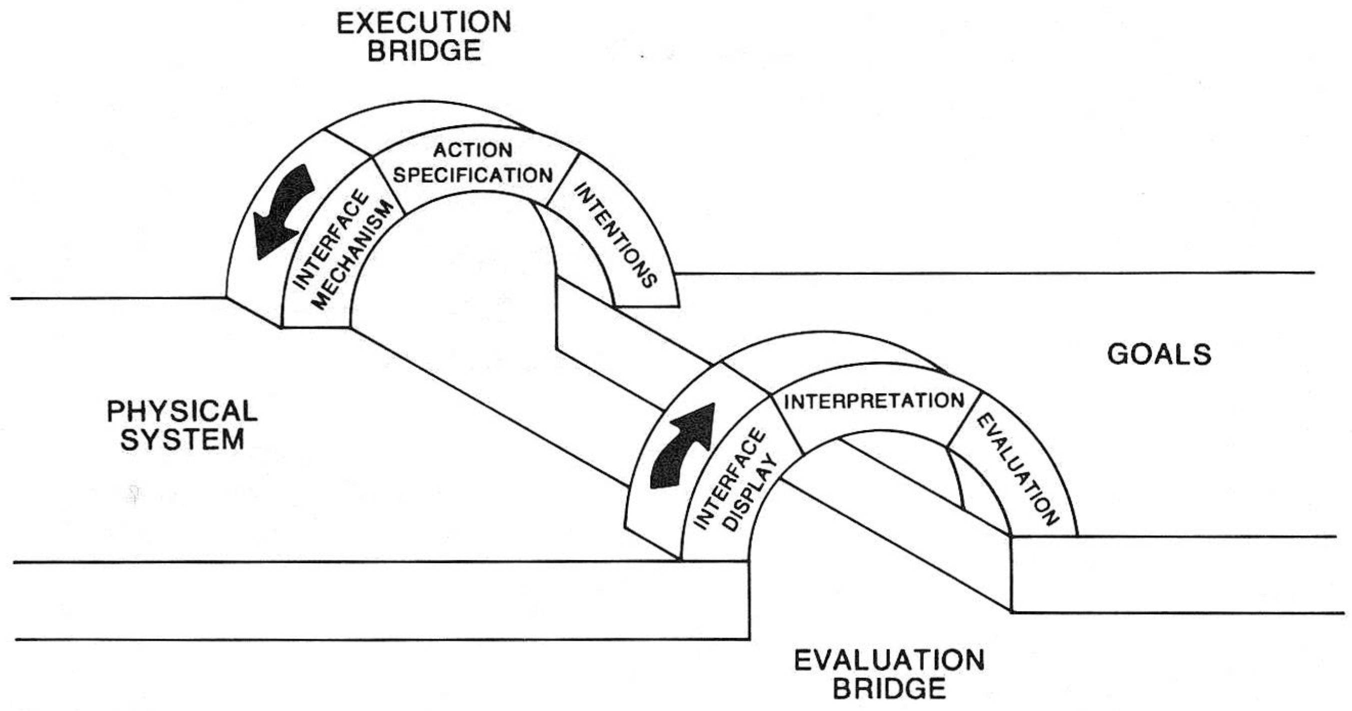


Fundamental Design Goals

1. Provide a good mapping between controls and actions
2. Provide the right affordances and signifiers
3. Use constraints do prevent errors
4. Exploit metaphors
5. **Help users to build the right conceptual model**

Gulf of Execution/Evaluation (Norman, 2002)

- Two gaps between the user and the system

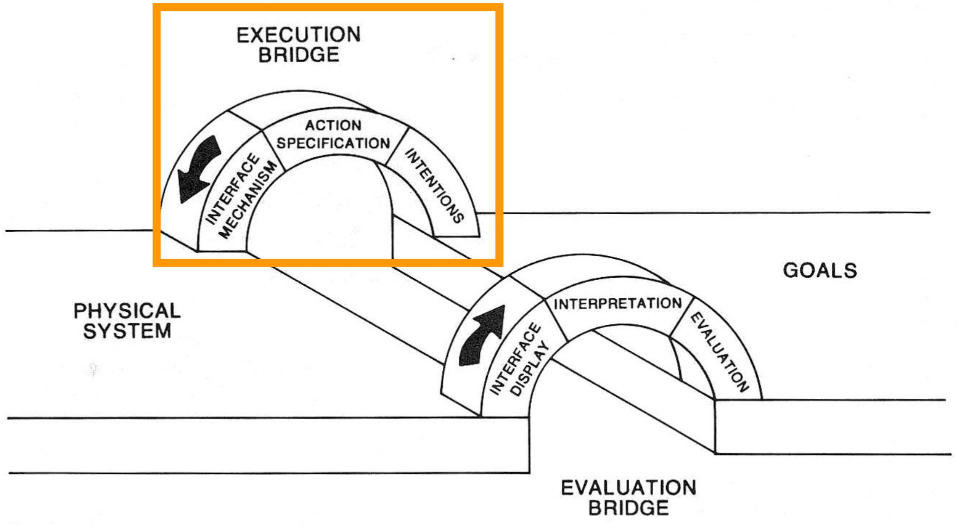


Gulf of Execution

- The difference between **the intentions** and **the allowable actions** in the system

- Measure the size of gulf
  - How well the system allows the person to do the intended actions directly, without extra effort?
  - Do the actions match those intended by the person?

- Related to functionality and usability



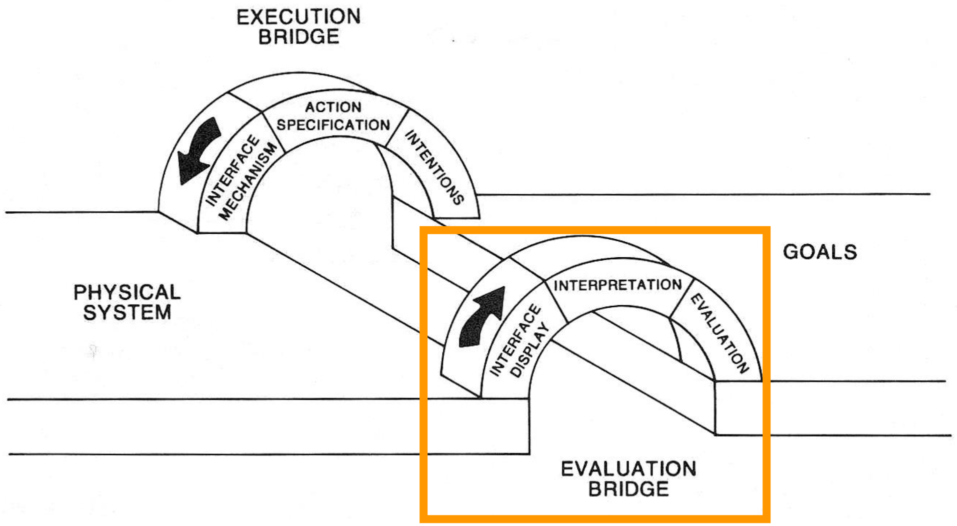
Gulf of Evaluation

The difference between

- **the physical representation** provided by the system and
- **users' interpretation** (in terms of the intentions and expectations)

- Reflects the amount of effort that the person must exert
  - to interpret the physical state of the system
  - to determine how well the expectations and intentions have been met

- Related to feedback and visibility



Gulf of Execution Example

Real World

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<svg>
   <rect width="..."
   transform=".."
</svg>
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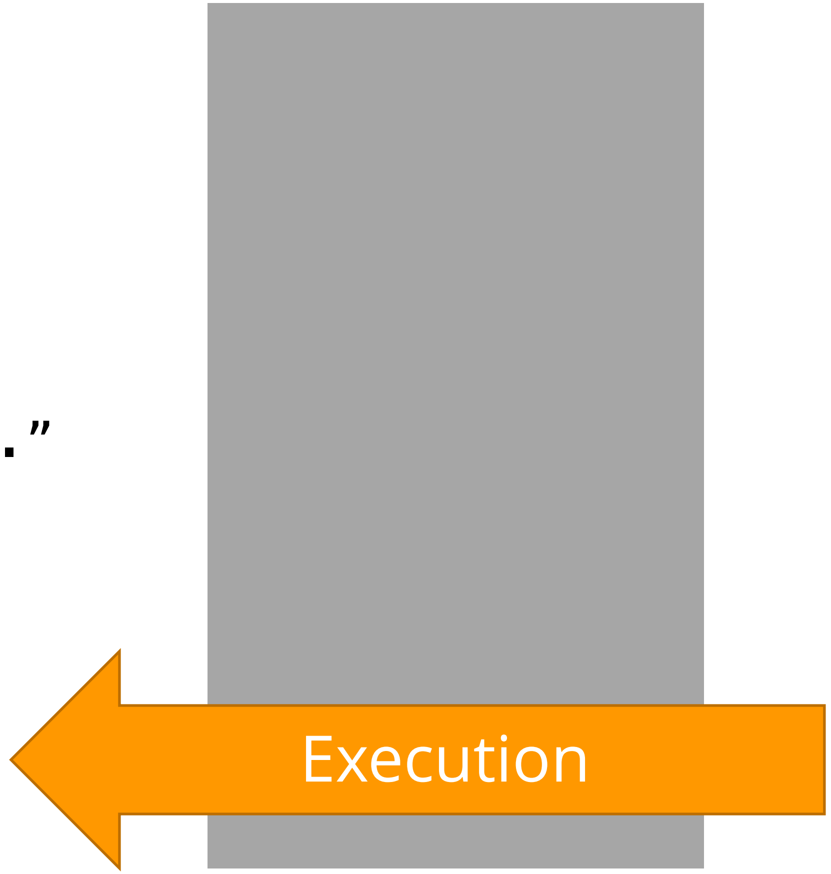
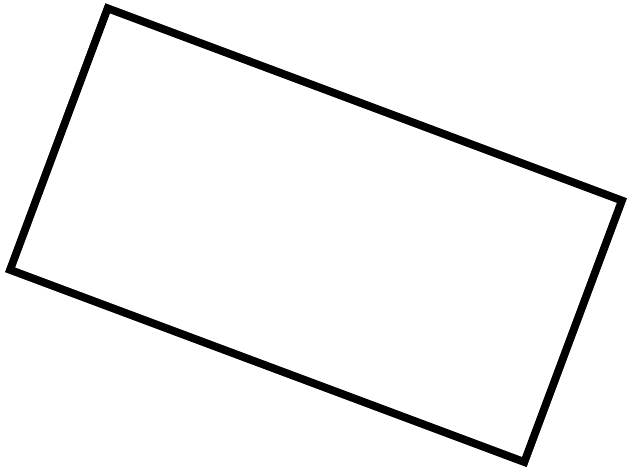


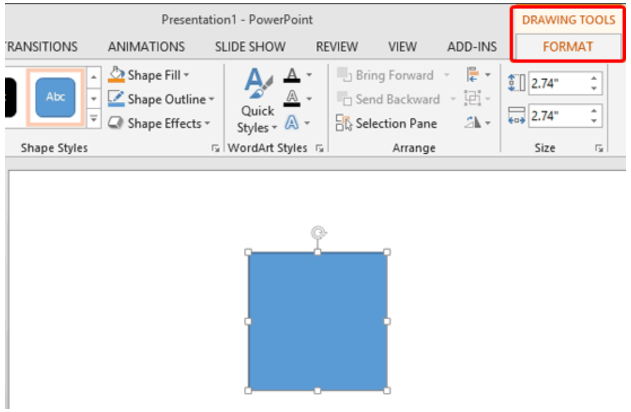
Gulf of Execution

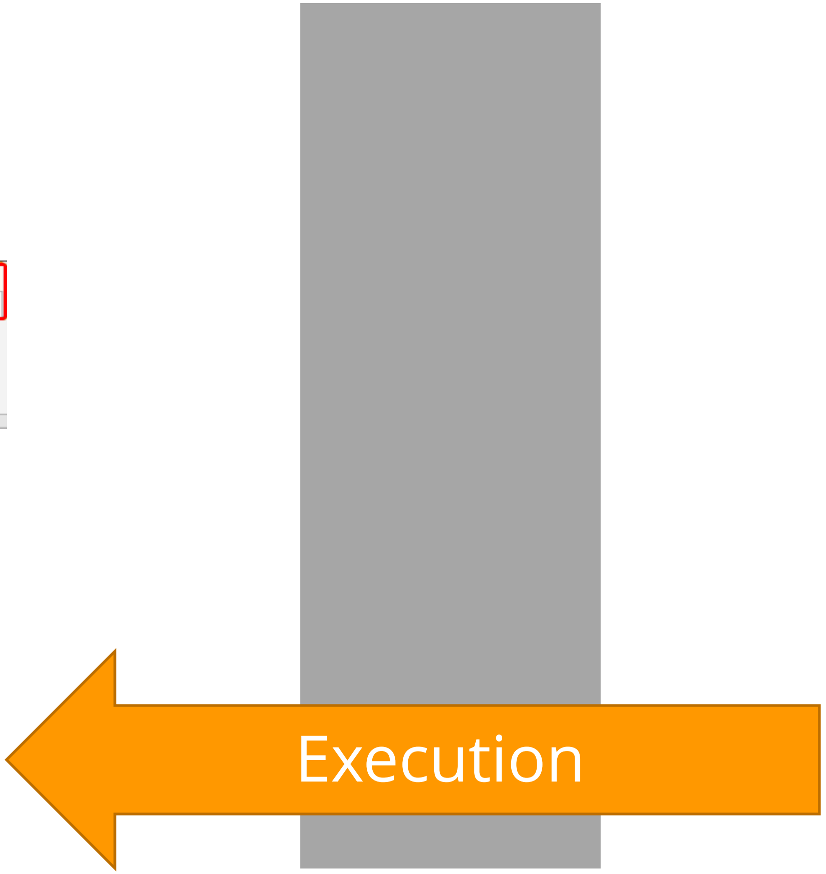
Goal:
Draw a rectangle



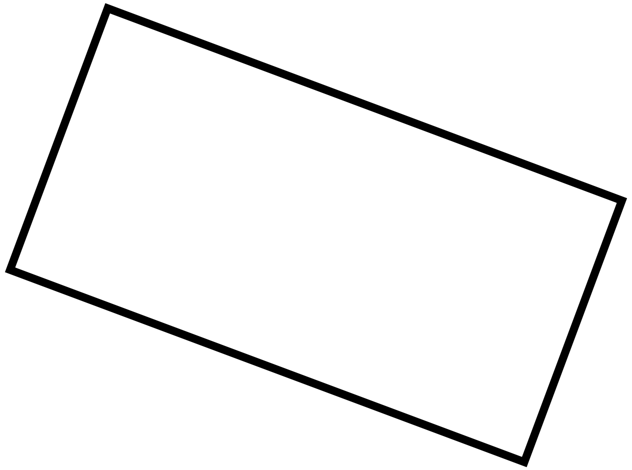
Gulf of Execution Example

Real World





Goal:
Draw a rectangle

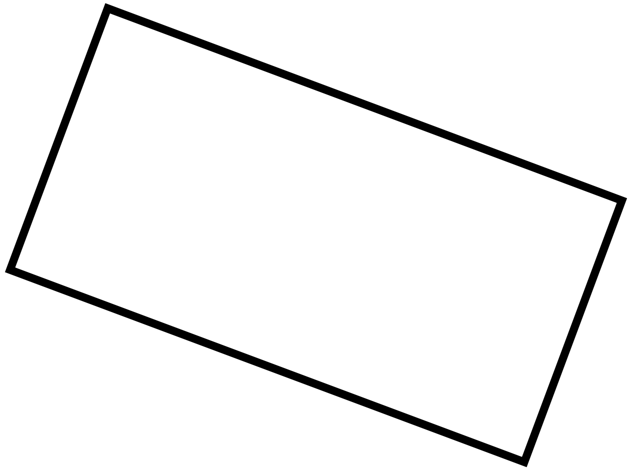


Gulf of Execution

Gulf of Execution Example

Real World

Goal:
Draw a rectangle



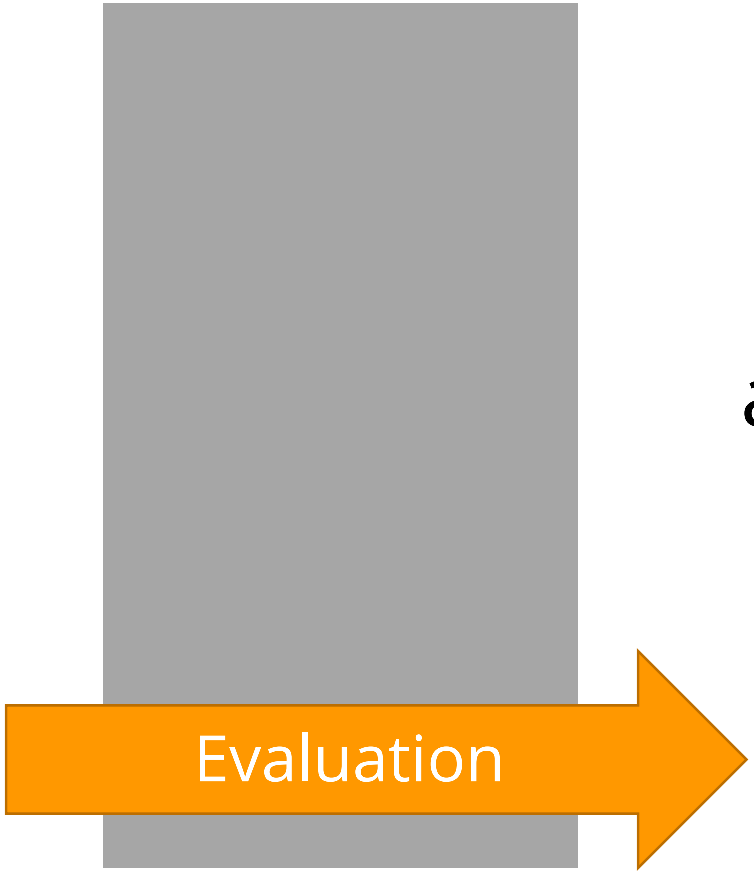
Execution

Gulf of Execution

Gulf of Evaluation Example

Real World

X	Y
0.67	0.79
0.32	0.63
0.39	0.72
0.27	0.85
0.71	0.43
0.63	0.09
0.03	0.03
0.20	0.54
0.51	0.38
0.11	0.33
0.46	0.46

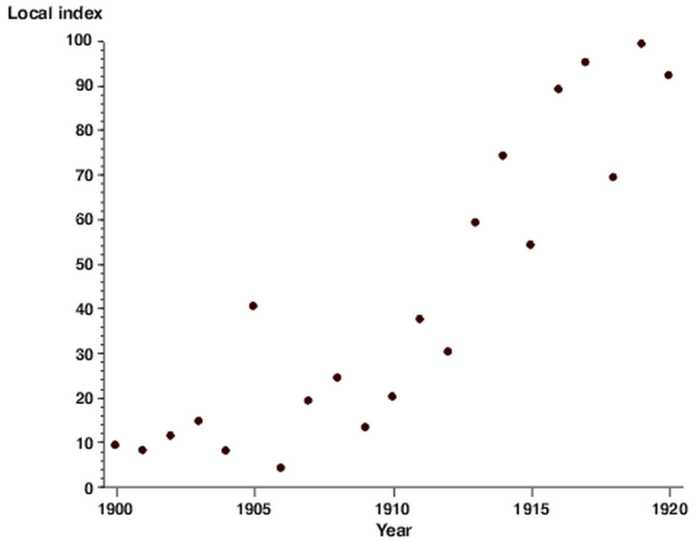


Gulf of Evaluation

Goal:
Identify whether X and Y are correlated

Gulf of Evaluation Example

Real World



Evaluation

Gulf of Evaluation

Goal:
Identify whether X and Y are correlated

Fundamental Design Goals

1. Provide a good mapping between controls and actions
2. Provide the right affordances and signifiers
3. Use constraints to prevent errors
4. Exploit metaphors
5. Help users to build the right conceptual model
6. **Make the commands/mechanisms of the system match the thoughts**
7. **Make things visible**

Credits

- Our textbook (Human-Computer Interaction by I. Scott MacKenzie)
- Ben Bederson, UMD HCIL
- François Guimbretière, Cornell University
- Jinwook Seo, Seoul National University