

Design Space and Taxonomy

for Input Devices



Learning Goals

- Understand ...
 - The basic concept of an input device
 - The properties of input devices
 - How input devices can be classified
 - How human capabilities link to input devices
- Know
 - Examples for taxonomies for input device
 - A formal way of describing input devices

What is an Input Devices

Bill Buxton

"...basically, an input device is a transducer from the physical properties of the world into the logical parameters of an application."

http://www.billbuxton.com/input04.Taxonomies.pdf

Taxonomy

"a system for naming and organizing things, especially plants and animals, into groups that share similar qualities"¹

Having a taxonomy for input devices helps to reflect on their properties and helps to answer questions such as:

- What criteria are relevant when looking at input devices?
- How can we organize input devices?
- How to compare input devices?
- Can one input device be replaced by another input device?
- Which input devices is more expressive?

Taxonomy for Input Devices

Bill Buxton

- Criteria to assess input devices
 - continuous vs discrete?
 - agent of control (hand, foot, voice, eyes ...)?
- Dimensions in the Taxonomy
 - what is being sensed (position, motion or pressure), and
 - the number of dimensions being sensed (1, 2 or 3)
 - motor skills to operate (similar motor skills are in sub-columns)
 - touch vs. mechanical intermediary (directly touched vs devices that require a mechanical intermediary between the hand and the sensing mechanism (sub-rows))

http://www.billbuxton.com/input04.Taxonomies.pdf

Taxonomy for Input Devices

Bill Buxton



Buxton, W. (1983). Lexical and Pragmatic Considerations of Input Structures. Computer Graphics, 17 (1), 31-37. http://www.billbuxton.com/lexical.html http://www.billbuxton.com/input04.Taxonomies.pdf

Taxonomy for Input Devices

Bill Buxton

		Number of Dimensions							
			1			3			
Property Sensed	sition	Rotary Pot	Sliding Pot	Tablet & Puck	Tablet & Stylus	Light Pen	lsotonic Joystick	3D Joystick	, M
	Po:				Touch Tablet	Touch Screen			т
	otion	Continuous Rotary Pot	Treadmill	Mouse			Sprung Joystick Trackball	3D Trackball	м
	Σ		Ferinstat				X/Y Pad		т
	Pressure	Torque Sensor					lsometric Joystick		т
		rotary	linear	puck	stylus finger hoiz.	stylus finger vertical	small fixed location	small fixed with twist	

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	Linear	Rotary
Position		
Absolute	P (Position)	R (Rotation)
Relative	dP	dR
Force		
Absolute	F (Force)	T (Torque)
Relative	dF	dT

Card, S. K., Mackinlay, J. D. and Robertson, G. G. (1991). A Morphological Analysis of the Design Space of Input Devices. ACM Transactions on Information Systems 9(2 April): 99-122 https://dl.acm.org/doi/pdf/10.1145/123078.128726

		Linear		Rotary			
	X	Y	Z	rX	rY	rZ	
Р							R
dP							dR
F							Т
dF							dT
	1 10 100 inf						

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Example 1: Touch Screen

	Linear			Rotary			
	X	Y	Z	rX	rY	rZ	
Р	-						R
dP							dR
F							Т
dF							dT
	1 10 100 inf						

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Example 2: Mouse with 3 Buttons and scroll wheel

	Linear			Rotary			
	X	Y	Z	rX	rY	rZ	
Р			3				R
dP	-						dR
F							Т
dF							dT
	1 10 100 inf						

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Mini Exercise: mouse (2 buttons), keyboard with trackpad, joystick

		Linear		Rotary			
	X	Y	Z	rX	rY	rZ	
Р							R
dP							dR
F							Τ
dF							dT
	1 10 100 inf						

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Mini Exercise: Invent a device, that...

...allows simultaneous input of the size of rectangle, the orientation and its position on the screen

- What parameters do we need?
- How could such a device look like?



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A formal view

(M, In, S, R, Out, W)

- M is a manipulation operator,
- In is the input domain,
- **S** is the current state of the device,
- R is a resolution function mapping from the input domain set to the output domain set,
- Out is the output domain set, and
- W is a general-purpose set of device properties that describe additional aspects of how a device works



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Design Space and Taxonomy

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M:	
ln:	
S:	
R:	
Out:	
W:	
Application:	



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Design Space and Taxonomy

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Which manipulation operator is useful?

Some controllers fit better than others

Example: mapping a rotary controller to linear movement



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Effectiveness of Input Devices

Criteria to assess the effectiveness

- Pointing speed (device bandwidth)
- Pointing precision
- Errors
- Time to learn
- Time to grasp the device
- User preference
- Desk footprint
- Cost

Card, S. K., Mackinlay, J. D., & Robertson, G. G. (1990, March). The design space of input devices. In Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 117-124). https://www.cc.gatech.edu/classes/AY2009/cs4470_fall/readings/input-design-space.pdf

Design Space for Input Devices Card,91

- Footprint
 - Size of the devices on the desk
- Bandwidth
 - Human The bandwidth of the human muscle group to which the transducer is attached
 - Application the precision requirements of the task to be done with the device
 - Device the effective bandwidth of the input device



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Bandwidth/Throughput simplified

In bits/s [For more see models and Fitts' law]

- How difficult is it to click the highlighted field?
- How fast can you do it?





Bandwidth/Throughput simplified

In bits/s [For more see models and Fitts' law]

- Throughput is a composite measure
- Takes into account speed and accuracy



$$Throughput = \frac{ID}{MT}$$

 $ID = \log_2\left(\frac{D}{W} + 1\right)$

- ID is index of difficulty
- MT is movement time
- D is the distance from the current position to the target
- W represents the size (width) of the target

MacKenzie, I. S., Kauppinen, T., & Silfverberg, M. (2001, March). Accuracy measures for evaluating computer pointing devices. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 9-16).

Movement time for Different Devices / Muscle Groups

Card,91

- Mouse easiest hard task: click on a character (mouse: 10.4 bits/s)
- It is easier to point with your finger (~25 bits/s)
- It is harder to point with your neck (~4.2 bits/s)



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Did you understand this block?

Can you answer these questions?

- How does Bill Buxton define an input device?
- According to which physical properties do Card et al. classify input devices?
- Draw a trackpoint into the classification of Card et al. How does it differ from a trackpad?
- How can you write the Edge A Sketch user interface in the tuple notification (M, In, S, R, Out, W)?
- Based on which criteria can you assess the effectiveness of an input device?



Reference

- Card, S. K., Mackinlay, J. D. and Robertson, G. G. (1991). A Morphological Analysis of the Design Space of Input Devices. ACM Transactions on Information Systems 9(2 April): 99-122 https://dl.acm.org/doi/pdf/10.1145/123078.128726
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