

3 Basic HCI Principles and Models

- 3.1 Predictive Models for Interaction: Fitts' / Steering Law
- 3.2 Descriptive Models for Interaction: GOMS / KLM
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Fitts' Law – Introduction

- Robust model of human psychomotor behavior
- Predicts movement time for rapid, aimed pointing tasks
 - Clicking on buttons, touching icons, etc.
 - Not suitable for drawing or writing
- Developed by Paul Fitts in 1954
- Describes movement time in terms of distance+size of target and device
- Rediscovered for HCI in 1978
- Subsequently heavily used and discussed

Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*, 47, 381-391.

Card, Stuart K., English, William K., Burr, Betty J. (1978). *Ergonomics*, 21(8):601–613
Evaluation of mouse, rate-controlled isometric joystick, step keys, and text keys for text selection on a CRT.

Fitts' Law – History

- **Paul M. Fitts** was an American psychologist and one of the pioneers in improving aviation safety. He went on to lead the Psychology Branch of Air Force Research Laboratory – later renamed, in his honor, to Fitts Human Engineering Division.
- Fitts' Law was his most famous work. It was first mentioned in a publication in 1954, and first applied to Human-Computer Interaction in 1978.
- Fitts' discovery "*was a major factor leading to the mouse's commercial introduction by Xerox*" [Stuart Card]
- Initially derived from a theorem for analogue information transmission

Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*, 47, 381-391.

<http://fww.few.vu.nl/hci/interactive/fitts/>

Derivation from Signal Transmission

$$C = B \log_2 \left(1 + \frac{S}{N} \right)$$

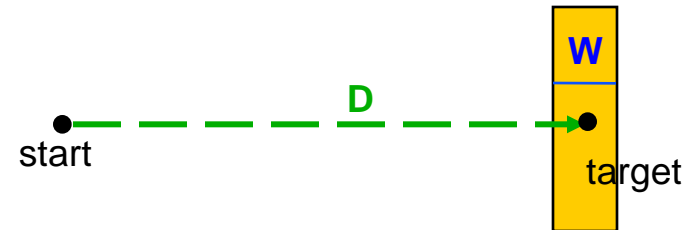
- Shannon-Hartley Theorem
- C is the channel capacity (bits / second)
- B is the bandwidth of the channel (Hertz)
- S is the total signal power over the bandwidth (Volt)
- N is the total noise power over the bandwidth (Volt)
- S/N is the signal-to-noise ratio (SNR) of the communication signal to the Gaussian noise interference
(as linear power ratio – $\text{SNR(dB)} = 10 \log_{10}(\text{S/N})$)

C. E. Shannon (1949). Communication in the presence of noise.
Proc. Institute of Radio Engineers vol. 37 (1): 10–21.

Fitts' Law – Formula

- The time to acquire a target is a function of the **distance** to and **size** of the target and depends on the particular pointing **system**

$$MT = a + b \log_2 \left(1 + \frac{D}{W} \right)$$

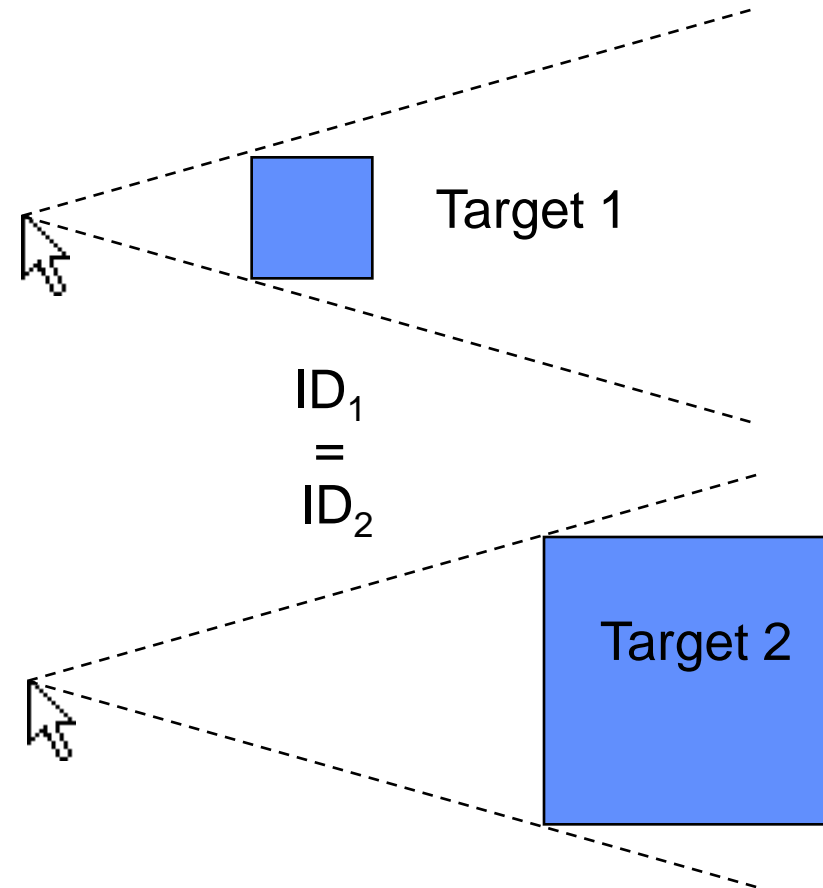


- MT**: movement time
- a and b**: constants dependent on the pointing system
- D**: distance to the target area
- W**: width of the target

Fitts' Law – Index of Difficulty

$$MT = a + b \underbrace{\log_2 \left(1 + \frac{D}{W} \right)}$$

- Index of Difficulty, $ID = \log_2 \left(1 + \frac{D}{W} \right)$
 - $MT = a + b \cdot ID$
 - ID describes the difficulty of the task independent of the device / method
- Units
 - Constant a measured in seconds
 - Constant b measured in seconds / bit
 - Index of Difficulty, ID measured in bits



Fitts' Law – Advanced Topics

- Throughput
 - Also known as index of performance or bandwidth
 - Single metric for input systems
 - One definition: $TP = ID / MT$ ('average' values of ID and MT are used)
 - Another definition: $TP = 1 / b$ (equals ID / MT only if $a=0$)
 - Probably still the best approach:
 - » Use regression analysis to compute a and b
 - » Use $1 / b$ as throughput cautiously
- See detailed discussion in [Zhai 2004]

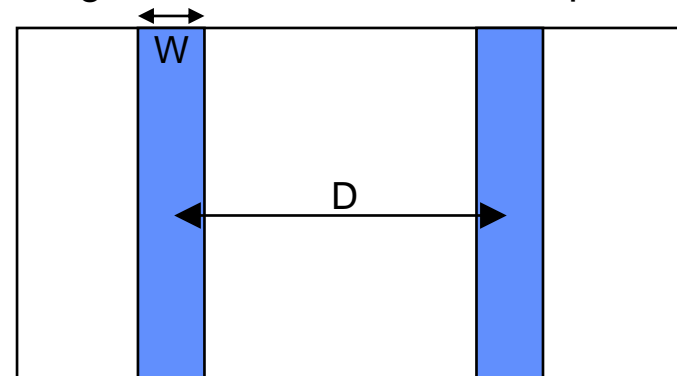
Zhai, S. 2004. Characterizing computer input with Fitts' law parameters: the information and non-information aspects of pointing. *Int. J. Hum.-Comput. Stud.* 61, 6 (Dec. 2004), 791-809

Fitts' Law Experiment

- Extension to 2D
 - “Status Quo”: use horizontal width
 - “Sum Model”: $W = \text{width} + \text{height}$
 - “Area Model”: $W = \text{width} * \text{height}$
 - “Smaller Of”: $W = \text{width}, \text{height}$
 - “W’ Model”: width in movement direction
 - See also [MacKenzie, Buxton 1992] and [Zhai et al. 2004] who refer to

$$ID = \log_2 \left(\sqrt{\left(\frac{D}{W}\right)^2 + \eta \left(\frac{D}{H}\right)^2} + 1 \right)$$

Original Fitts' Law test: 1D repeated tapping



MacKenzie, I. S. and Buxton, W. 1992. Extending Fitts' law to two-dimensional tasks. *In Proceedings CHI '92*. 219-226.

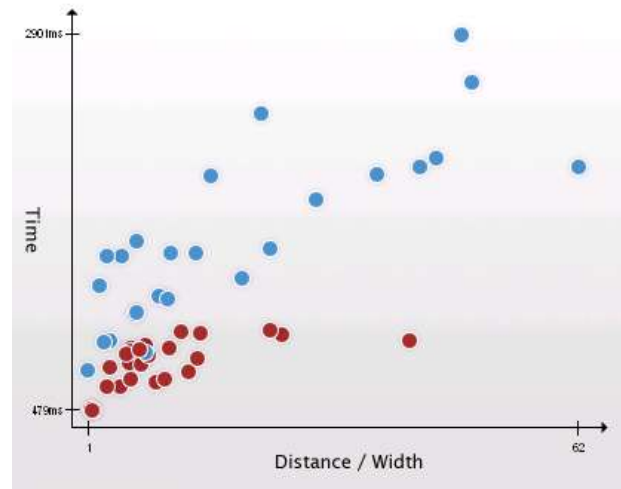
Zhai, S., Accot, J., and Woltjer, R. 2004. Human action laws in electronic virtual worlds: an empirical study of path steering performance in VR. *Presence: Teleoper. Virtual Environ.* 13, 2 (Apr. 2004), 113-127.

(Simple) Linear Regression

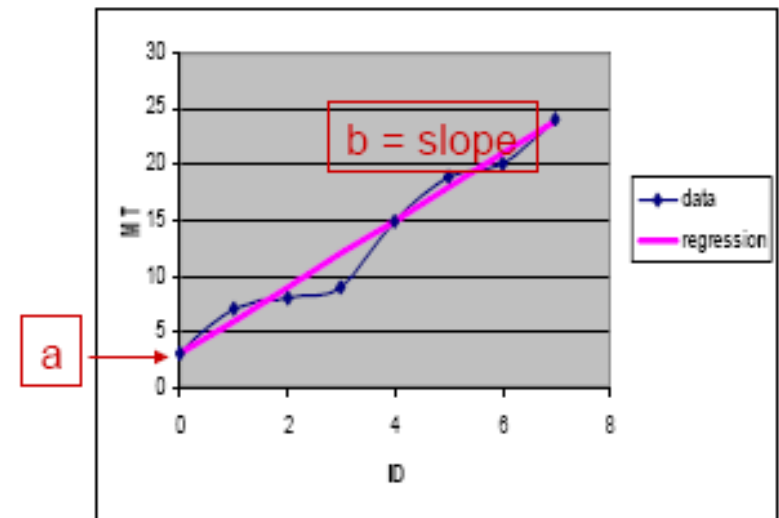
- How to measure a and b for a new pointing device / menu / etc.?

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

- Setup an experiment with varying D and W and measure MT
- Fit a line through the measured points: a = intercept, b = slope



<http://fww.few.vu.nl/hci/interactive/fitts/>



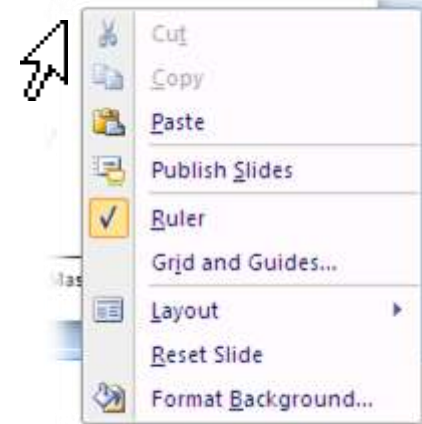
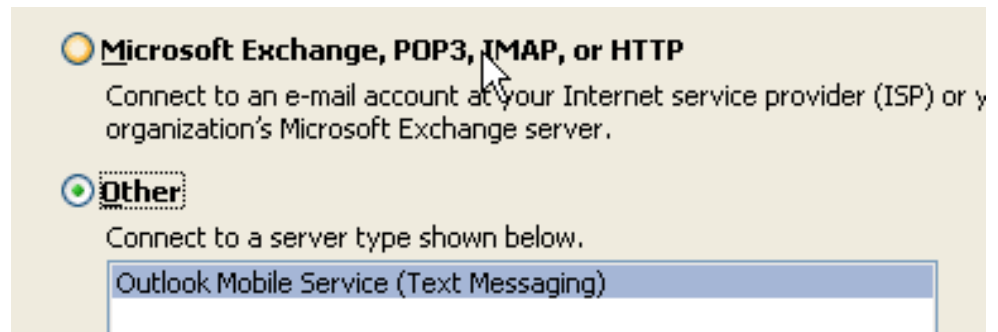
linear regression model

Implications for HCI (1)

- Bigger buttons
 - e.g. web links
 - e.g. check / radio boxes
- Proportional to amount of use?!
 - See principle (and golden rule) of **consistency**!
- Use current location of the cursor
 - distance is close to zero
- Use edges and corners (for examples see next slide)
 - edges of the screen have infinite height or width, respectively
 - corners have infinite height and width



<http://msdn.microsoft.com/en-us/library/ms993291.aspx>



Implications for HCI (1)

Mac OS X

- Edges and corners

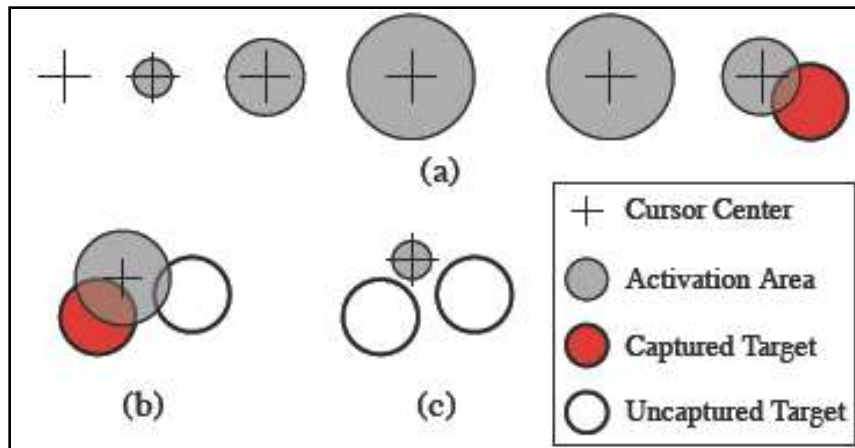


Windows



Implications for HCI (2)

- Compare and evaluate input devices
- Current examples
 - Behind the display cursor
 - Dynaspot



Yang, X., Irani, P., Boulanger, P., and Bischof, W. 2009. One-handed behind-the-display cursor input on mobile devices. *In Proceedings CHI EA '09*. 4501-4506.

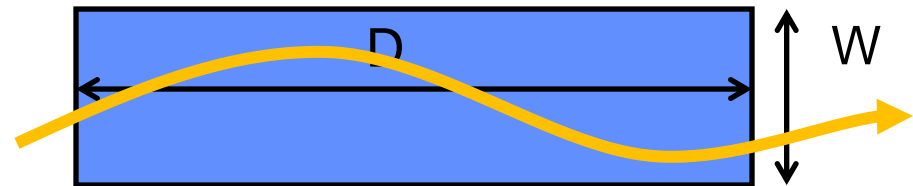
Chapuis, O., Labrune, J., and Pietriga, E. 2009. DynaSpot: speed-dependent area cursor. *In Proceedings CHI '09*. 1391-1400

Additional Literature for Fitts' Law

- A Cybernetic Understanding of Fitts' Law:
<http://www.hcibook.com/e3/online/fitts-cybernetic/>
- Bibliography of Fitts' Law Research
(to get an impression about research in the HCI community):
http://www.yorku.ca/mack/RN-Fitts_bib.htm
- Fitts' Law: Modelling Movement Time in HCI
<http://www.cs.umd.edu/class/fall2002/cmsc838s/tichi/fitts.html>

Steering Law

- Equally early discovery: 1959 by Nicolas Rashevsky
- For HCI rediscovered in 1997 and there sometimes called the Accot-Zhai steering law
- Models the movement time of a pointer through a 2D tunnel
- Can be seen as an extension to Fitts' Law



Rashevsky, N. (1959). Mathematical biophysics of automobile driving.
In The Bulletin of Mathematical Biophysics 21:375-385

Accot, J. and Zhai, S. (1997). Beyond Fitts' law: models for trajectory-based HCI tasks.
In Proceedings CHI '97. 295-302.

The screenshot shows a Windows XP desktop with the Start menu open. The 'All Programs' list is visible, and the '560 Developer Tools' entry is highlighted. A red arrow points from the red box to the '560 Developer Tools' entry in the 'All Programs' list.

Steering Law Equation

- The time to acquire a target through a tunnel is a function of the **length** and **width** of the tunnel and depends on the particular pointing **system**

$$MT = a + b \frac{D}{W}$$

- **MT**: movement time
- **a and b**: constants dependent on the pointing system
- **D**: distance, i.e. length of the tunnel
- **W**: width of the tunnel

Steering Law Equation – Index of Difficulty

- The time to acquire a target through a tunnel is a function of the **length** and **width** of the tunnel and depends on the particular pointing **system**

$$MT = a + b \underbrace{\frac{D}{W}}$$

- ID (Index of Difficulty): $ID = D / W$
- Index of Difficulty is now linear, not logarithmic as in Fitts' Law
 - Steering is more difficult than pointing

Steering Law Extension to Arbitrary Tunnels

- The time to acquire a target through a tunnel is a function of the **length** and **width** of the tunnel and depends on the particular pointing **system**
- The previously shown formula applies only for constant width W

$$MT = a + b \frac{D}{W}$$

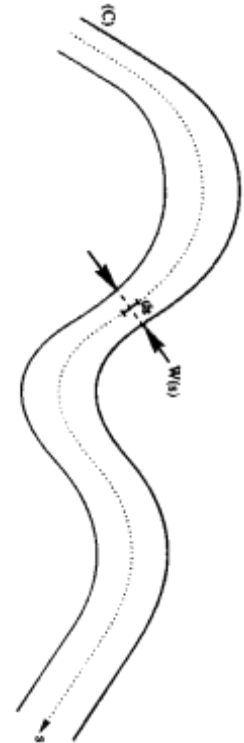
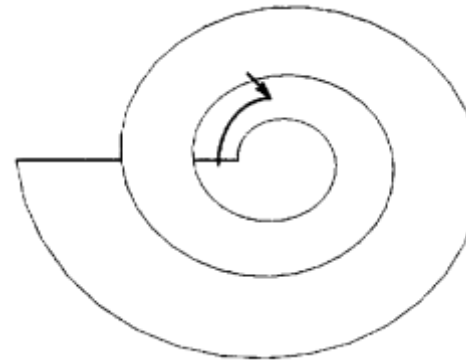
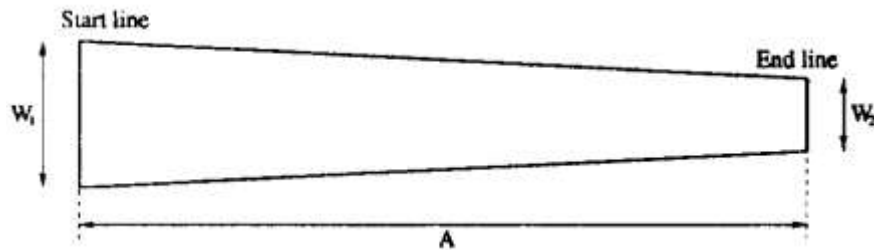
- Let the width $W(s)$ be parameterized by s running from 0 to D

$$MT = a + b \int_C \frac{ds}{W(s)}$$

- **C**: path characterised by s
- **W(s)**: width dependent on s

Steering Law Applied

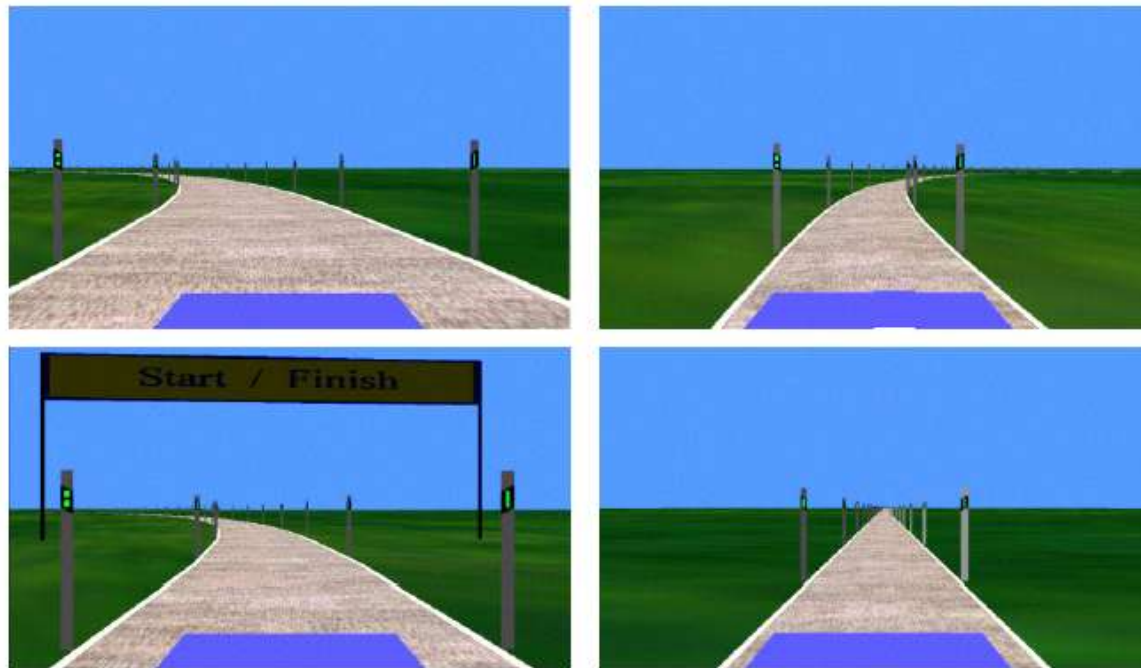
- Early work focused on car driving scenarios and models with straight tunnels
- Various example tunnel shapes have been explored



Accot, J. and Zhai, S. 1997. Beyond Fitts' law: models for trajectory-based HCI tasks.
In Proceedings CHI '97. 295-302.

Steering Law Applied

- Further extension to 3D e.g. virtual reality applications



Zhai, S., Accot, J., and Woltjer, R. 2004. Human action laws in electronic virtual worlds: an empirical study of path steering performance in VR. *Presence: Teleoper. Virtual Environments* 13, 2. 113-127.

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