Looking Back ...

- Humans
  - Understanding them needs knowledge from many fields
  - Processing information by humans can be modelled
  - Human physiology plays an important role for designing systems
  - Vision
    - eye tracking, eyes can be tricked, preattentive processing
    - Gestalt psychology
  - Hearing
    - audibility, pain threshold, spatial hearing
  - Touch
    - input and output
  - Memory
    - sensorial, short term (working), and long term memory
    - short term memory: 7 ± 2 chunks
    - long term memory: episodic and structural memory
    - generate new information: deduction, induction, abduction

Looking Back ...

- Affordances
  - Attractive things ‘work’ better (i.e. are often perceived as easier to use)
  - Perceived affordance is the perceived possibility for action
    - not only bc learned by conventions, feedback, etc.
- Intuitiveness
  - Do not rely on something to be intuitive, especially with regard to virtual interfaces
  - Providing clear perceived affordances and constraints can help the user
  - Use previous knowledge, e.g. metaphors for interaction
- Signifiers
  - Indicators in the physical or social world that can be interpreted meaningfully
  - Help to make possible actions and states visible
  - Often unconsciously / unintentionally (e.g. are still people waiting for the bus?) but can be applied intentionally (show a scrollbar to indicate length)

Mensch-Maschine-Interaktion 1

Chapter 7 (July 8, 2010, 9am-12pm):

Basic HCI Models

Basic HCI Models

- Predictive Models for Interaction: Fitts' / Steering Law
- Descriptive Models for Interaction: GOMS / KLM

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

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

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.

Derivation from Signal Transmission

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

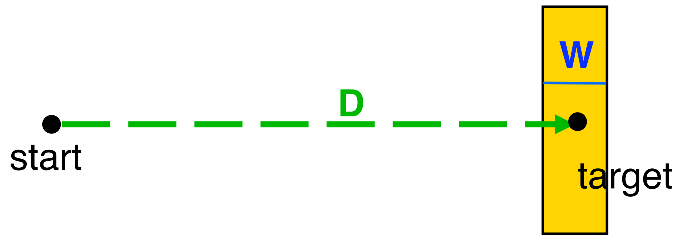
- Shannon-Hartley Theorem
- C is the channel capacity (bits / second)
- B is the bandwidth of the channel (Hertz)
- S is the total signal power over the bandwidth (Volt)
- N is the total noise power over the bandwidth (Volt)
- S/N is the signal-to-noise ratio (SNR) of the communication signal to the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

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**

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

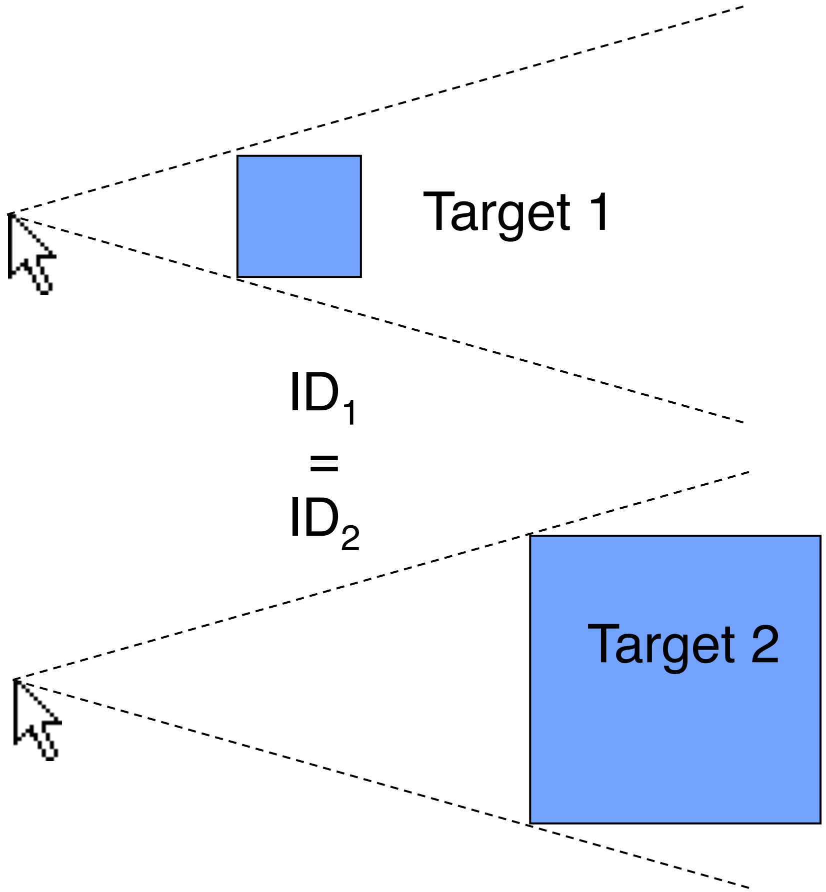


- **MT**: movement time
- **a and b**: constants dependent on the pointing system
- **D**: distance to the target area
- **W**: width of the target

Fitts' Law – Index of Difficulty

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

- Index of Difficulty, ID = $\log_2\left(1 + \frac{D}{W}\right)$
  - MT = a + b ·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]

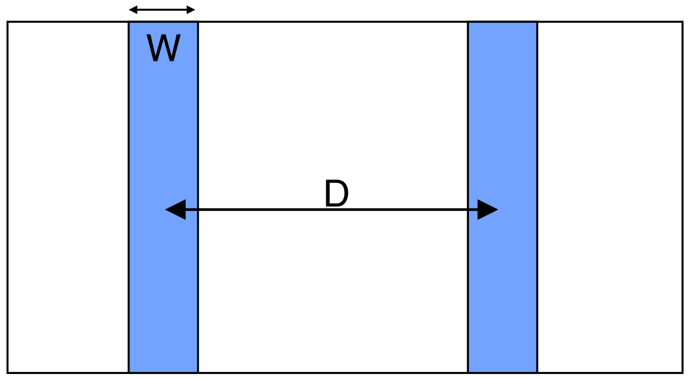
Zhai, S. 2004. Characterizing computer input with Fitts' law parameters: the information and non-information aspects of pointing. *Int. J. Hum.-Comput. Stud. 61, 6 (Dec. 2004), 791-809*

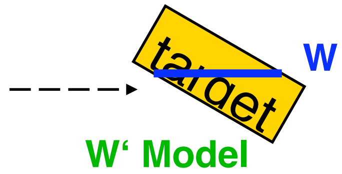
Fitts’ Law Experiment

- Extension to 2D
  - “Status Quo”: use horizontal width
  - “Sum Model”: *W* = width + height
  - “Area Model”: *W* = width * height
  - “Smaller Of”: *W* = width, 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.*

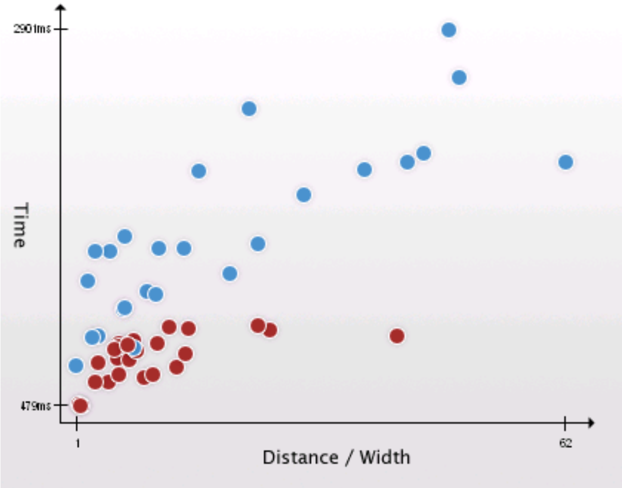
Zhai, S., Accot, J., and Woltjer, R. 2004. Human action laws in electronic virtual worlds: an empirical study of path steering performance in VR. *Presence: Teleoper. Virtual Environ. 13, 2 (Apr. 2004), 113-127.*

(Simple) Linear Regression

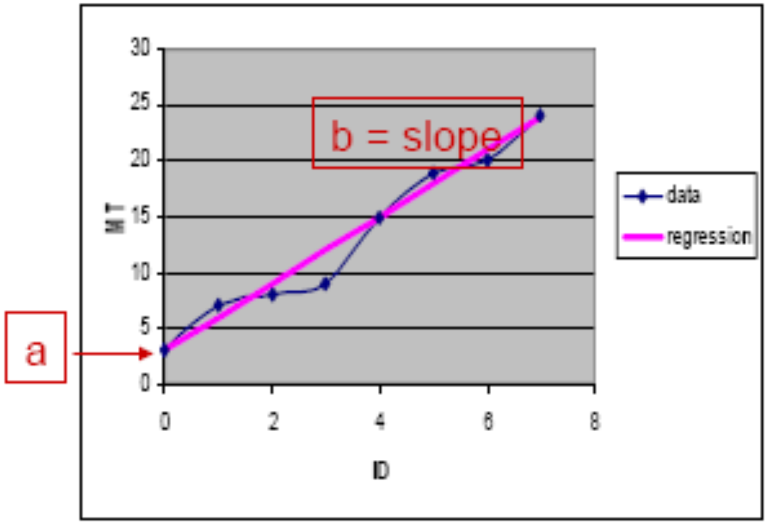
- How to measure a and b for a new pointing device / menu / etc.?

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

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

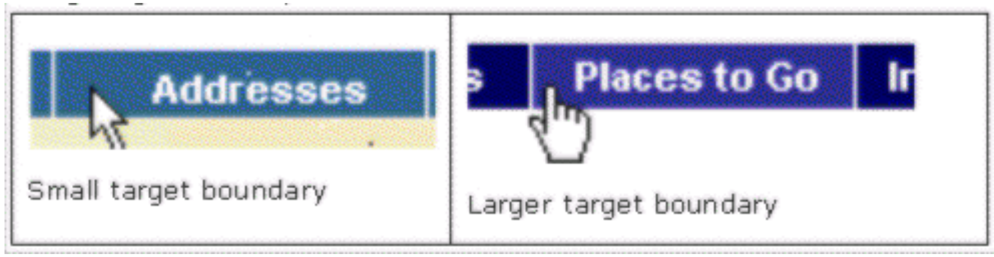


http://fww.few.vu.nl/hci/interactive/fitts/



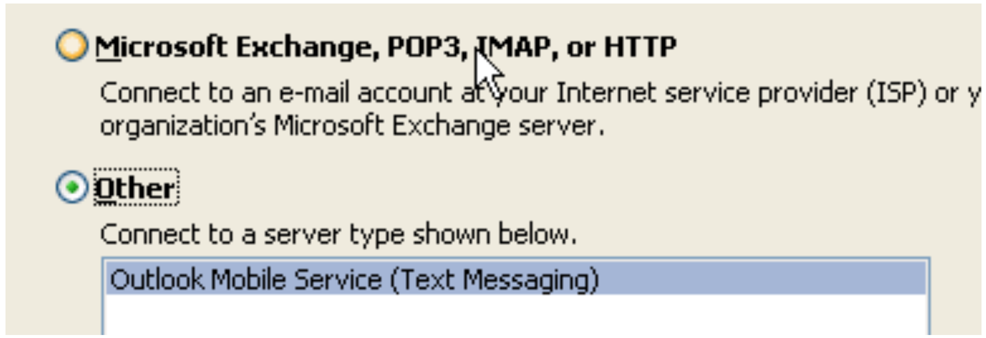
linear regression model

Implications for HCI (1)

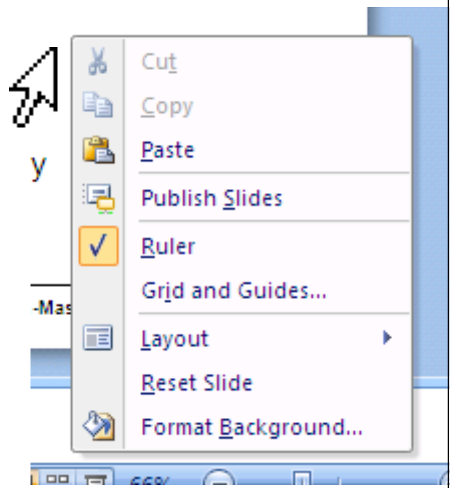


http://msdn.microsoft.com/en-us/library/ms993291.aspx

- 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

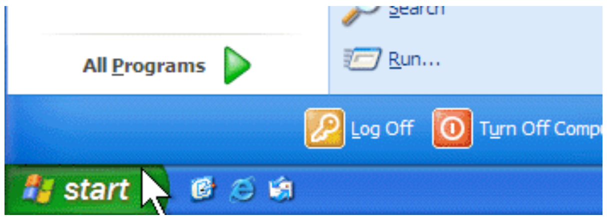


Implications for HCI (1)

Mac OS X

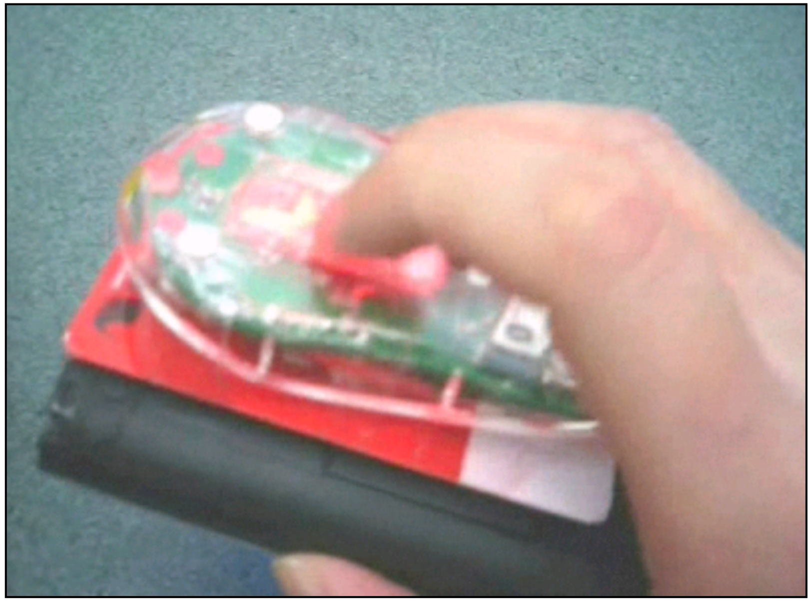
- Edges and corners

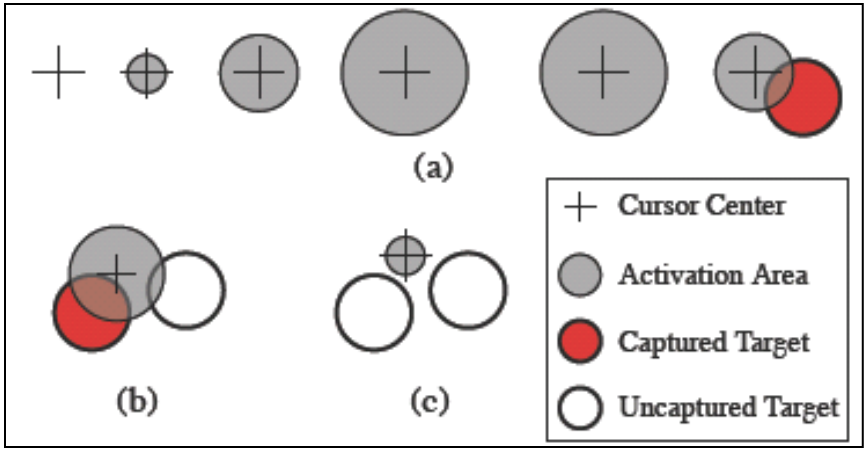
Windows



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*

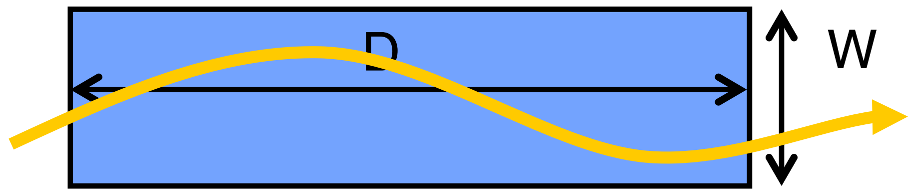
Additional Literature for Fitts' Law

- 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

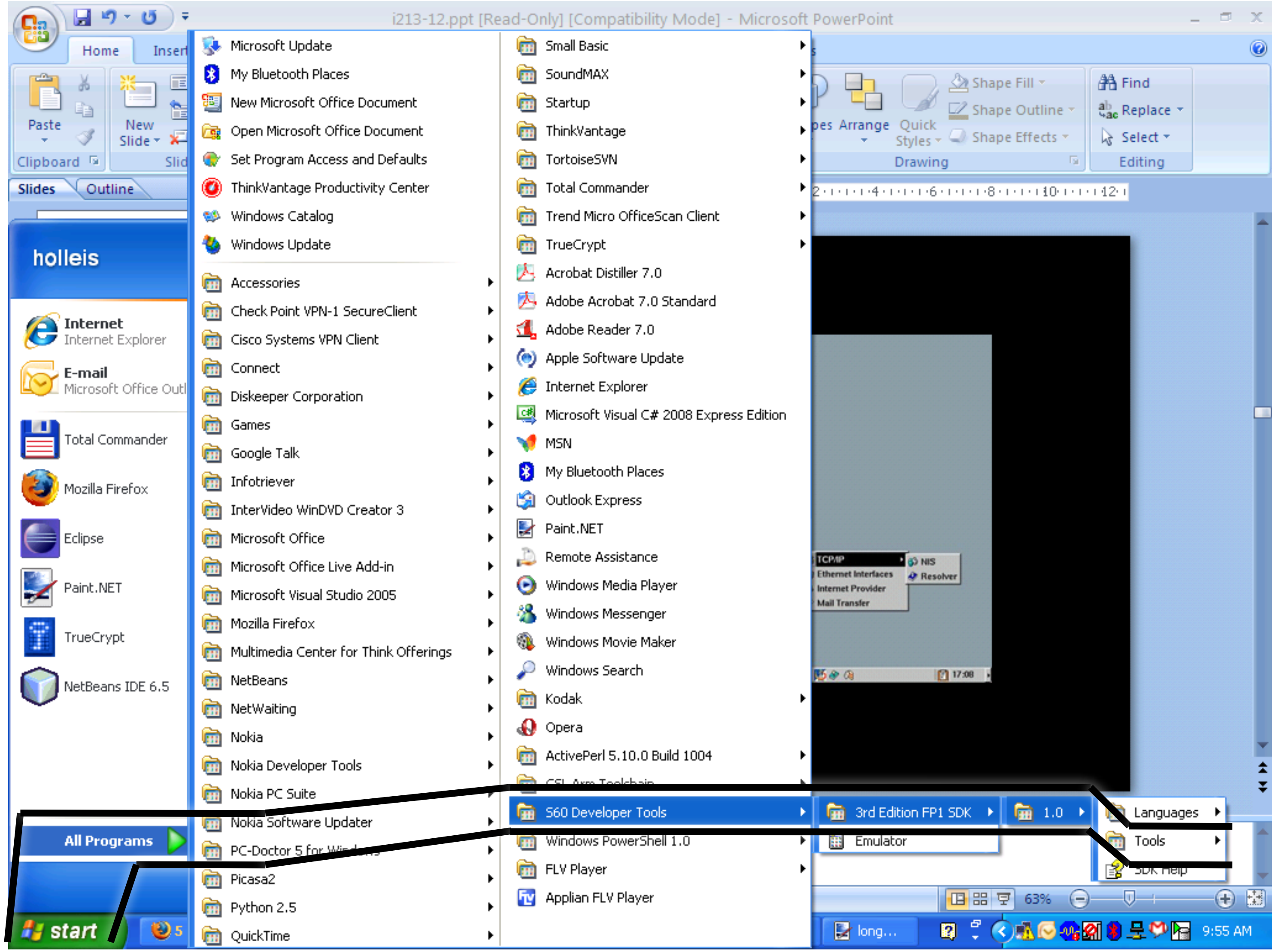
- Models the movement time of a pointer through a 2D tunnel
- Can be seen as an extension to Fitts' Law



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.*

Steering Law in Practice



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 then 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

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

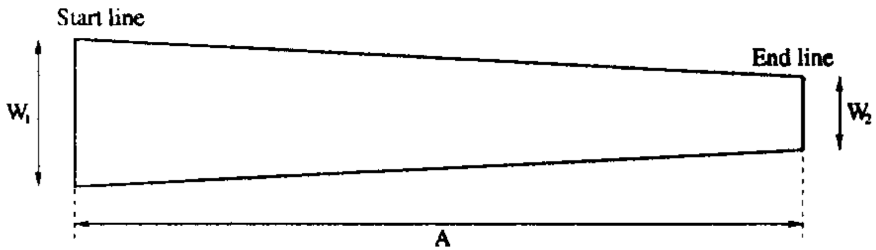
- Let the width W(s) be parameterized by s running from 0 to D

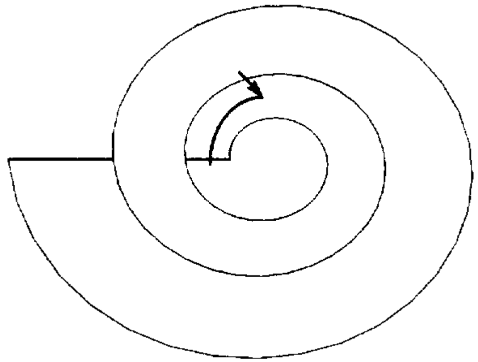
$$MT = a + b\int_C \frac{ds}{W(s)}$$

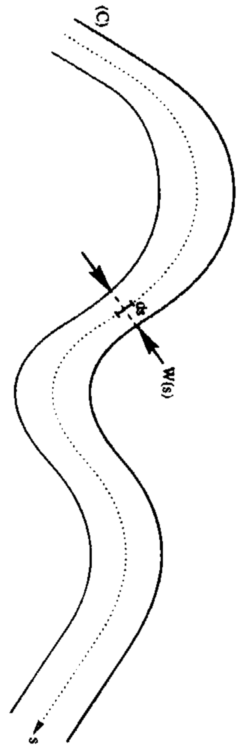
- **C**: path characterised by s
- **W(s)**: width dependent on s

Steering Law Applied

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



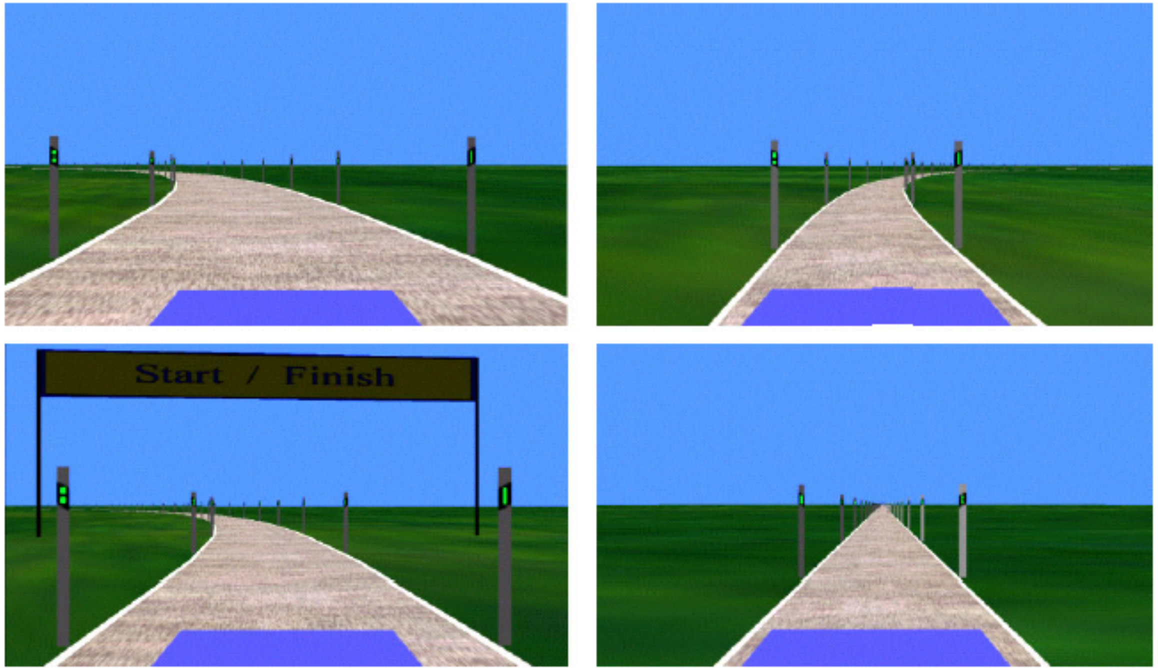




Accot, J. and Zhai, S. 1997. Beyond Fitts' law: models for trajectory-based HCI tasks.
In Proceedings CHI '97. 295-302.

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.*