Input Performance

Recall Butlers-Based Design

- Respect physical and mental effort
- Physical
  - Treat clicks as sacred
  - Remember where they put things
  - Remember what they told you
  - Stick with a mode
- Mental also important, but input performance is about physical effort, primarily clicks and motion

In this lecture

- Models of input performance
  - KLM, Fitts's Law, Steering Law
- UI Techniques to "Beat" Fitts's Law/Steering Law
  - Bubble Cursor
  - Expect-K
  - Enhanced menus

Keystroke Level Model

- Problem: You're designing an interface and would like to model how long it takes to perform different tasks
  – Why?
- Keystroke Level Model
  – Describes a time cost for each action
  – A task is a sequence of actions, so simply sum the time costs involved.

Keystroke Level Model

- Describe each task with a sequence of the following operators. Sum up times to estimate how long the task takes
  - K = Keystroking = 0.35s
  - P = Pointing = 1.10s
  - H = Homing = 0.4s
  - D = Drawing = variable time
  - M = Mental operator = 1.35s
  - R = Response by System = 1.2s

Keystroke Level Model

- Benefits?
  –
  –
  –
- Drawbacks?
  – Some time estimates are out of date
  – Some time estimates are inherently variable
  – Doesn't model:
    - Errors
    - Learning time
    - etc.

Keystroke Level Model

- Drawbacks (cont):
  - Equipment differs (eg: Trackpoint vs. touchpad)
  - All pointing takes 1.10s? *Really?*

Better Estimates

- **Fitts' Law**: Pointing time without path constraints
  - Paul Fitts (1954)
  - Psychologist at Ohio State University
  - Theory based on rapid, aimed movement
  - Most robust and highly adopted model of human hand movement
- **Steering Law**: Pointing time with path constraints
  - Independently discovered three times:
    - Rashevsky (1959)
    - Drury (1971)
    - Zhai and Acott (1997)
  - The last one was in the HCI community; most general mathematical result

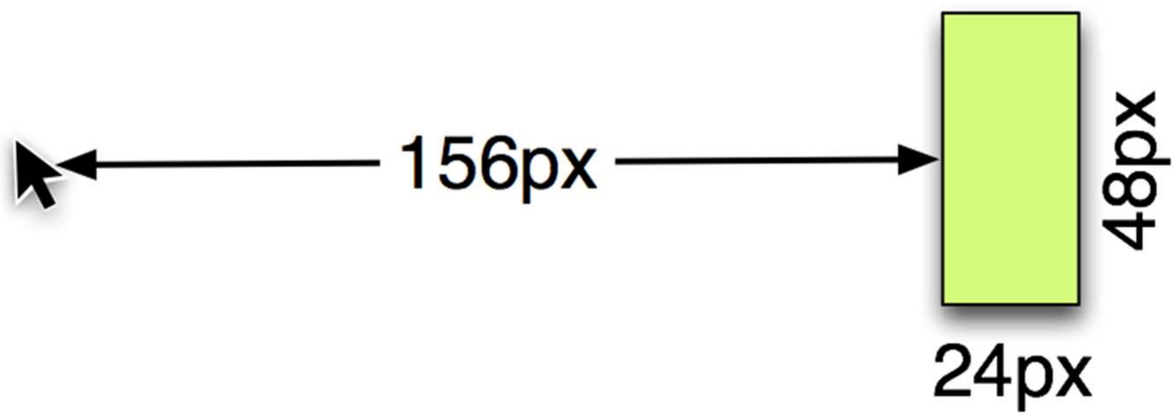
Fitts' Law

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

- T = time
- A = Amplitude of movement (distance between the starting point and the centre of the target)
- W = Constraining size of the target
- a and b are empirically determined based on the device and user

Fitts' Law Examples (1)

- Assume a = 1030 and b = 96.
- What are the values for A and W?



$$T = 1030 + 96 \log_2\left(\frac{A}{W} + 1\right)$$

Fitts' Law Example (1)

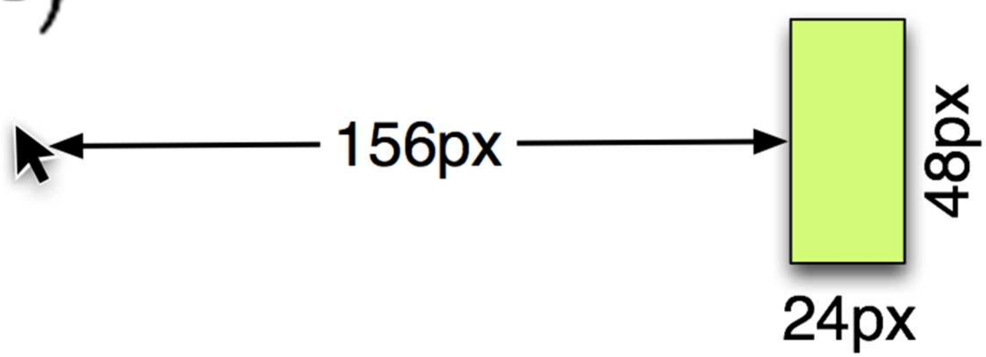
$$T = 1030 + 96\log_2\left(\frac{156 + 24/2}{24} + 1\right)$$

$$T = 1030 + 96\log_2\left(\frac{168}{24} + 1\right)$$

$$T = 1030 + 96\log_2(8)$$

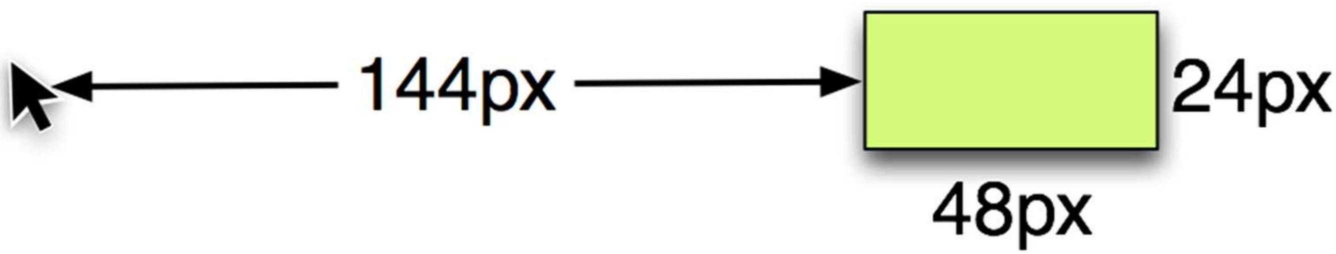
$$T = 1030 + 96 \times 3$$

$$T = 1318ms$$



Fitts' Law Example (2)

- Assume a = 1030 and b = 96.



$$T = 1030 + 96\log_2\left(\frac{144 + 48/2}{24} + 1\right)$$

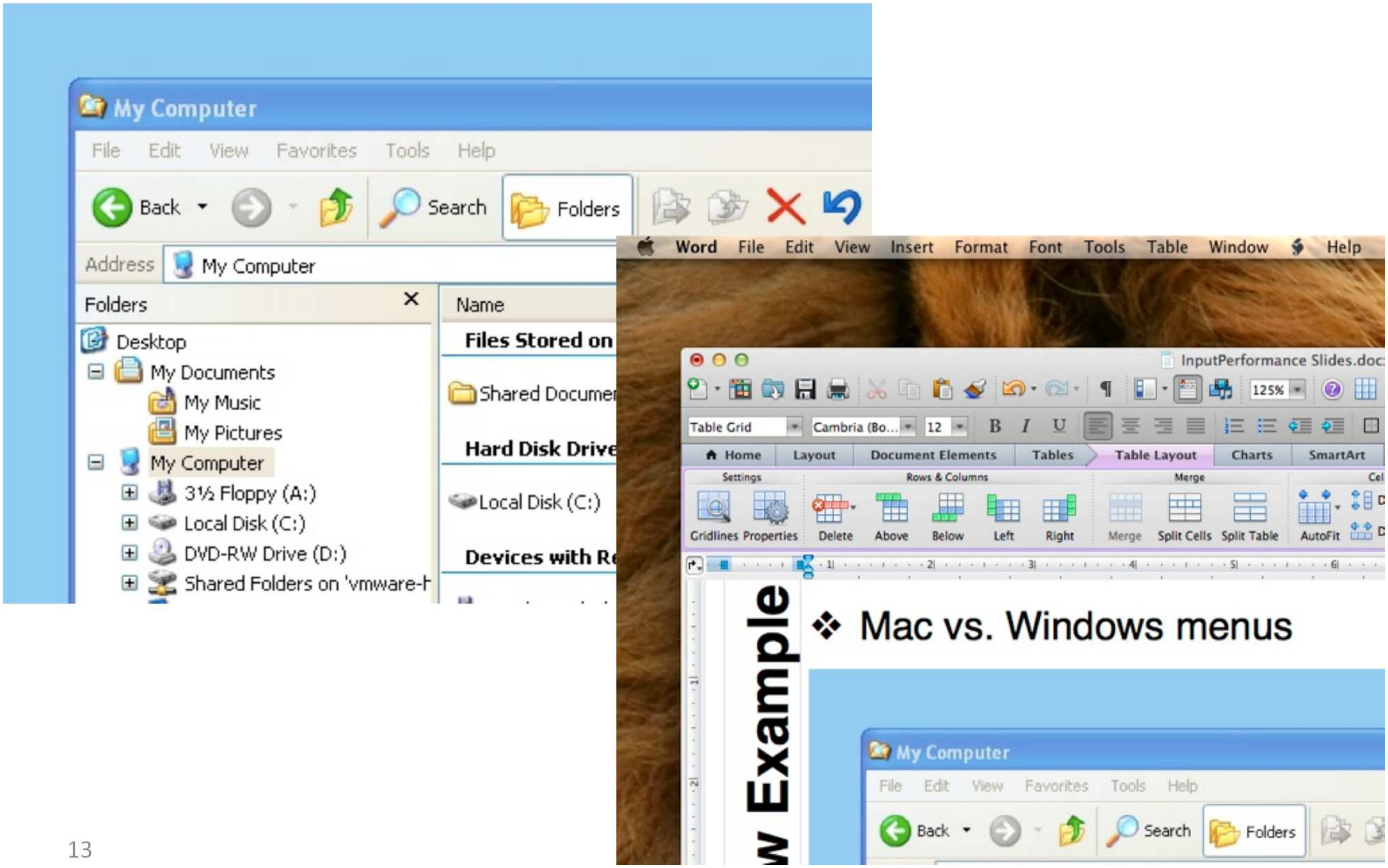
$$T = 1030 + 96\log_2\left(\frac{168}{24} + 1\right)$$

$$T = 1030 + 96\log_2(8)$$

$$T = 1030 + 96 \times 3$$

$$T = 1318ms$$

Fitts' Law: Mac vs. Windows

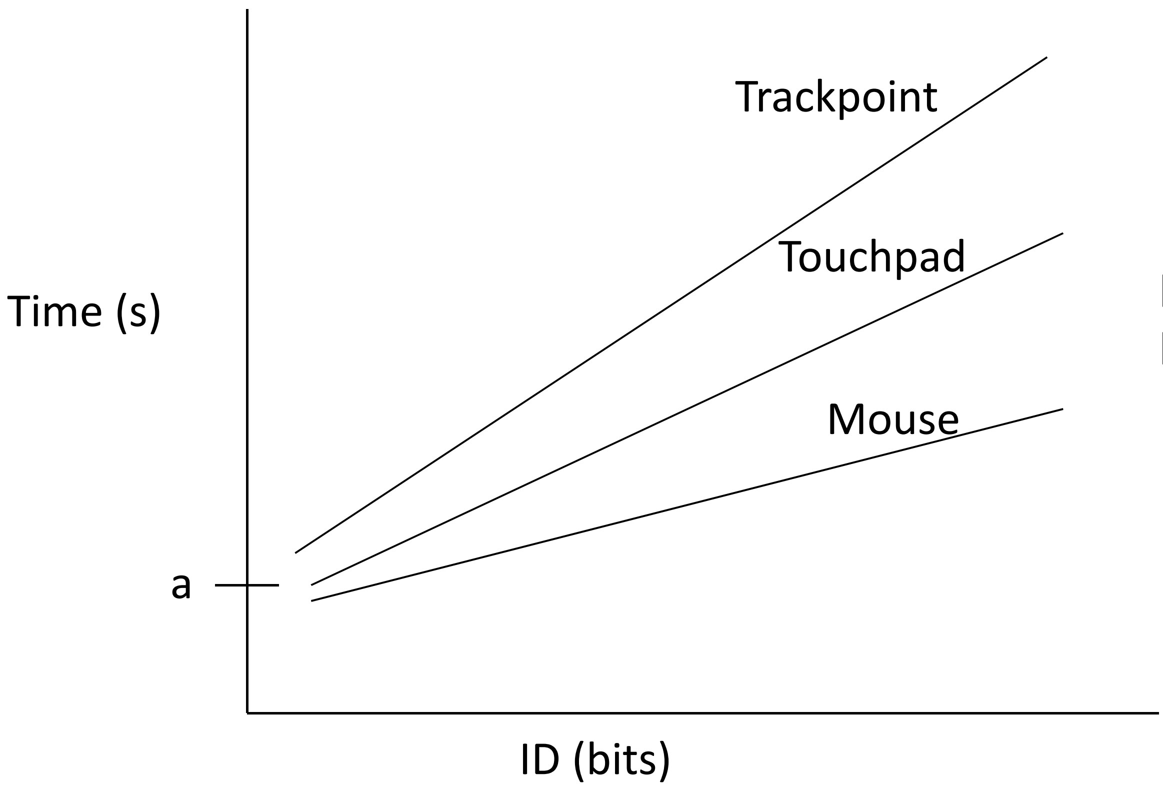


Fitts' Law: Index of Difficulty

- ID = "Index of Difficulty"
- IP = "Index of Performance" = 1/b

$$T = a + b\underbrace{\log_2\left(\frac{A}{W} + 1\right)}_{ID}$$

ID versus IP



Different IP =
Different curves

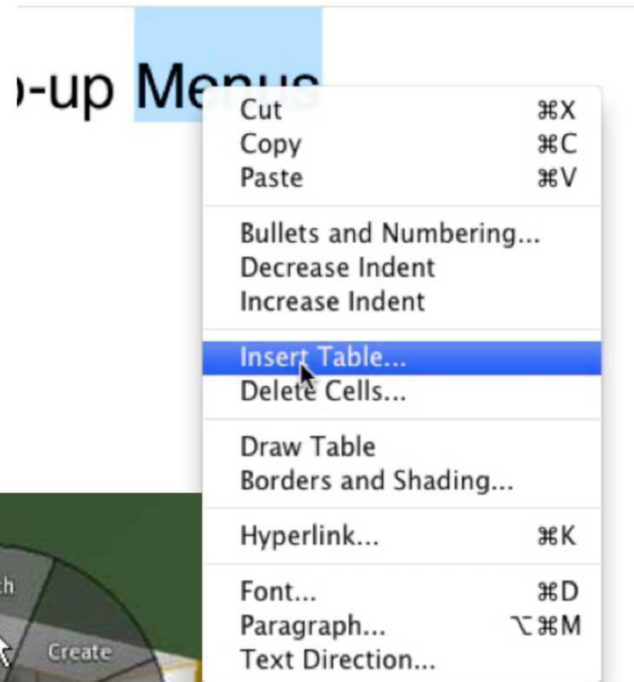
b = slope of line
b = f(device)

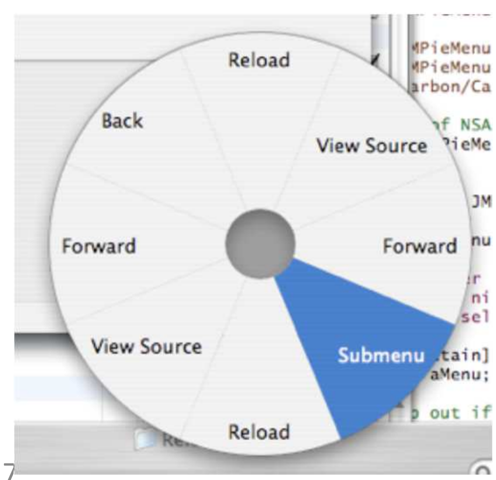
Physical Interpretation

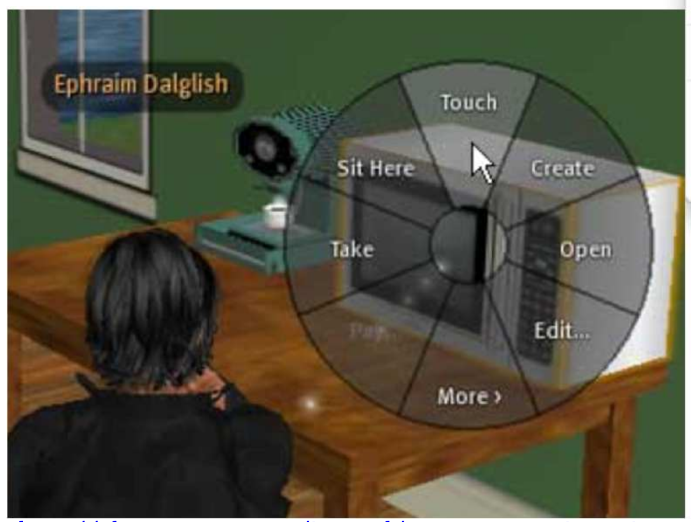
- Larger objects are acquired faster than smaller objects; closer objects are acquired faster than more distant objects
- Gives mathematical rigor to what we already know intuitively:
  - the faster we move, the less precise our movements are
- Assumptions:
  - User is free to choose any path to the target.
  - Ignores the time to locate the target.

Pop-up Menus; Pie Menus; Marking Menus

- Pop-up Menus
  - Customized for action
  - Near mouse, but some items are still far away
- Pie Menus
  - All items are close
- Marking Menus are a special variant of pie menus that work well for expert use



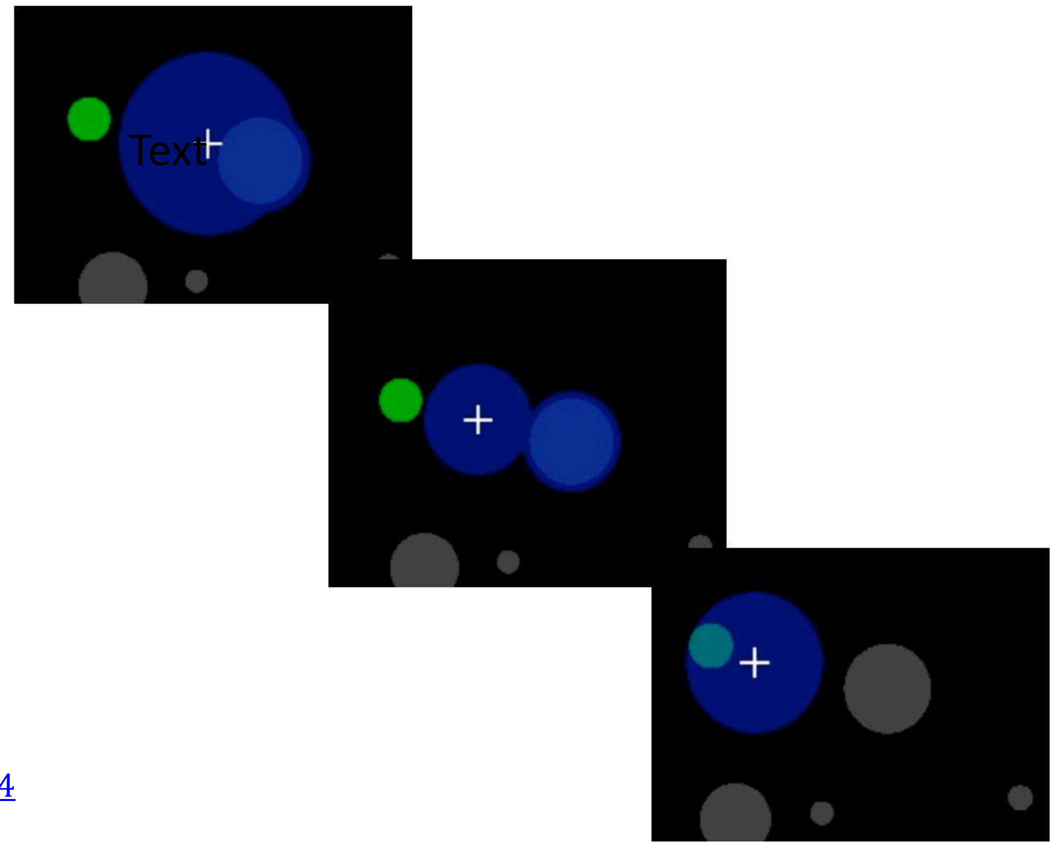




http://elementaryos.org/journal/argument-against-pie-menus
http://instruct.uwo.ca/english/234e/site/secondlife_2.html

Bubble Cursors

- Change the size of the cursor to enclose exactly one nearby target.

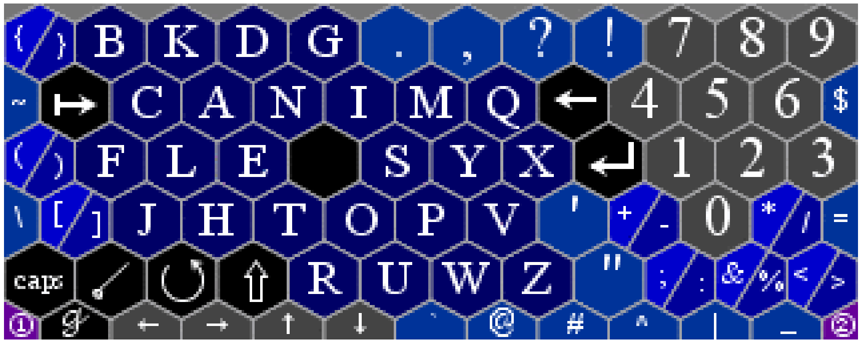


http://www.tovigrossman.com/BubbleCursor/
http://www.youtube.com/watch?v=46EopD_2K_4

Expect-K

- [Video of Expect-K]()

- Atomik keyboard



Motor vs. Screen Space

- How the cursor moves in response to mouse motion is under our control.
  - Making the cursor move more slowly when over the save button makes it larger in “motor space” even though it looks the same size in “screen space”.
  - LOOKS the same on screen, but “Save” button is “sticky”.
  - Faster to click “Save” than Fitts’ Law (in pixels) would indicate.

Steering Law

- Steering Law is an adaptation of Fitts' Law
- Developed by Zhai and Acott
- Choose a paradigm which focuses on steering between boundaries
- Applicability?

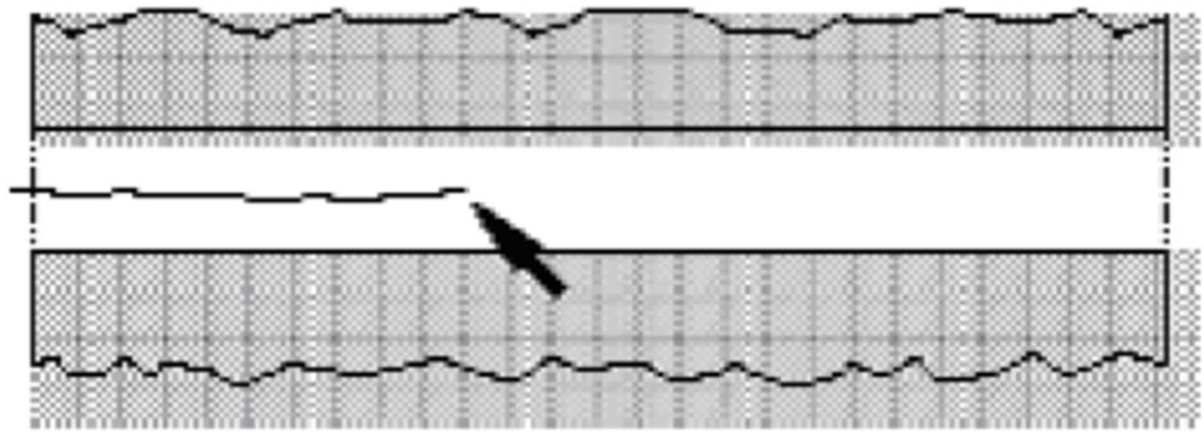
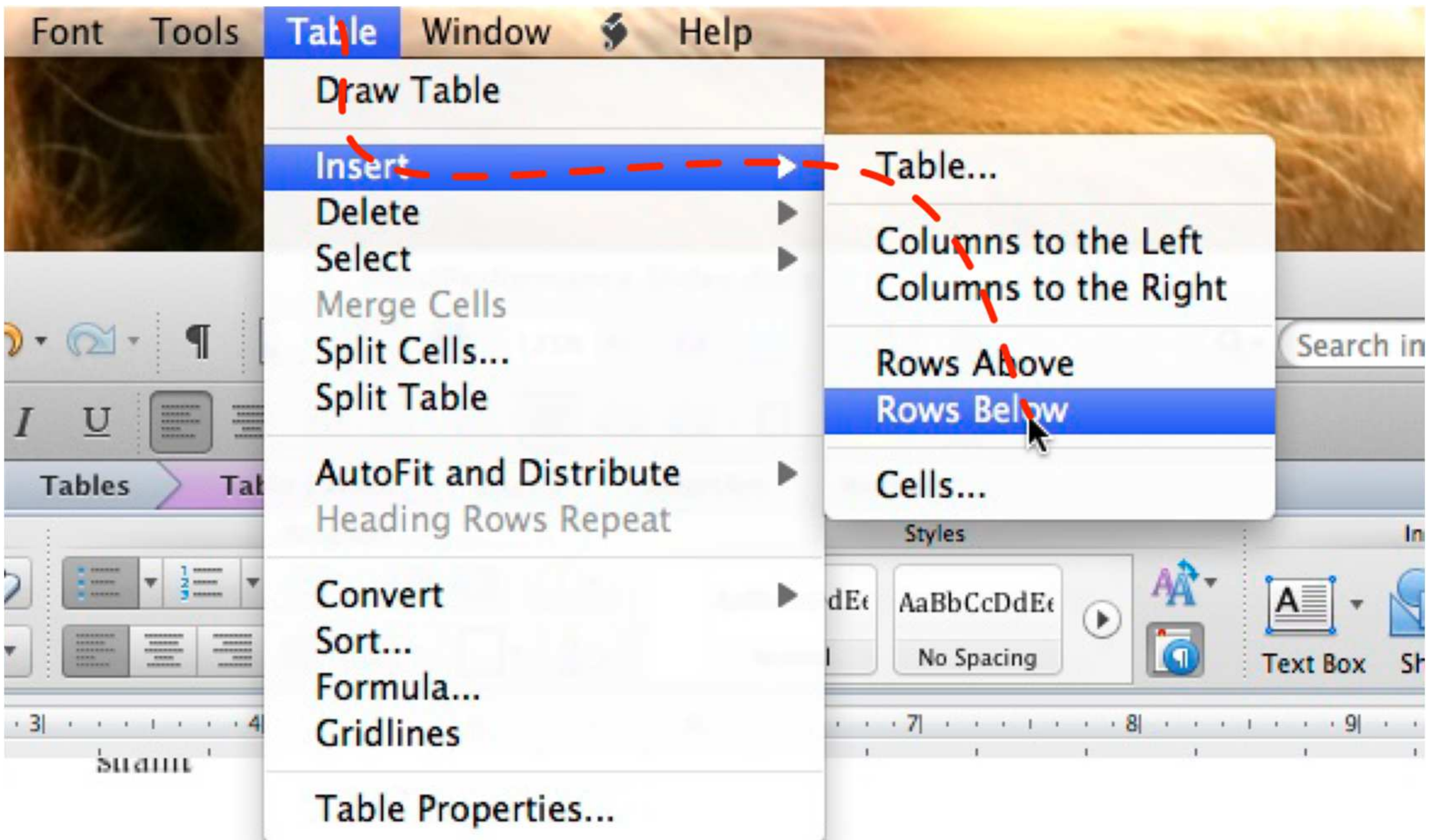


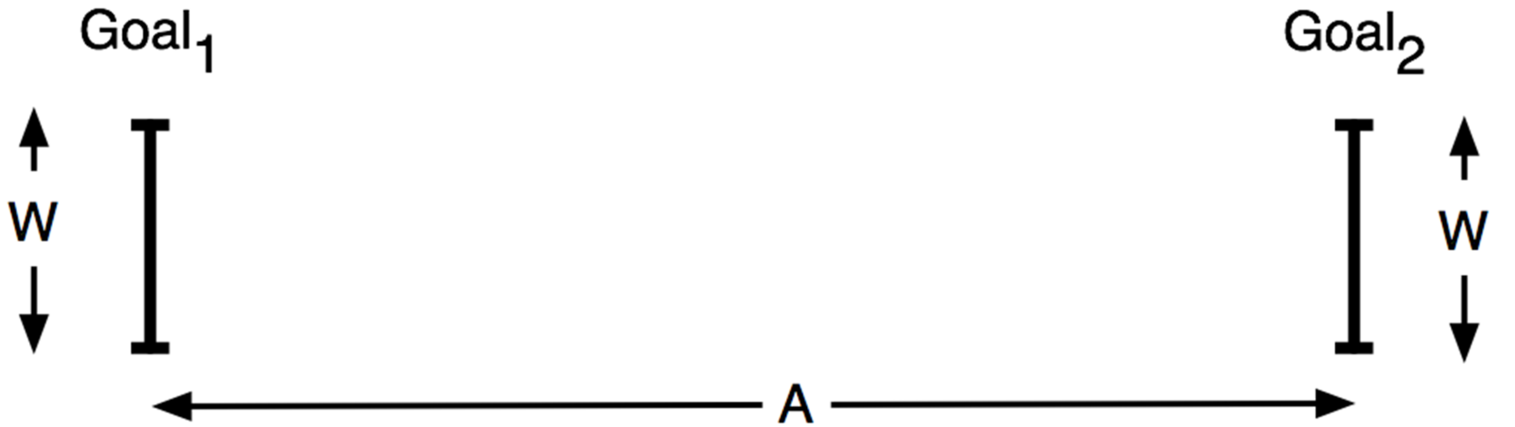
Figure 1: Self-paced movement with normal constraint

Steering Law

- Tracking a constrained path takes longer



Steering Law: Goal Passing



- Subjects passed a stylus from one end to the other
  - As fast as possible
  - Between each goal
  - Several trials with different amplitudes (A) and widths (W)
- Result: Same law as Fitts' tapping task

Steering Law: Goal Passing

- With only goals at the endpoints:

$$ID_1 = \log_2\left(\frac{A}{W} + 1\right)$$

- Adding N goals:

$$ID_N = \log_2\left(\frac{A}{N \times W} + 1\right)$$

- When N approaches infinity, the task approaches steering through a tunnel (hierarchical menu).
- Index of Difficulty:

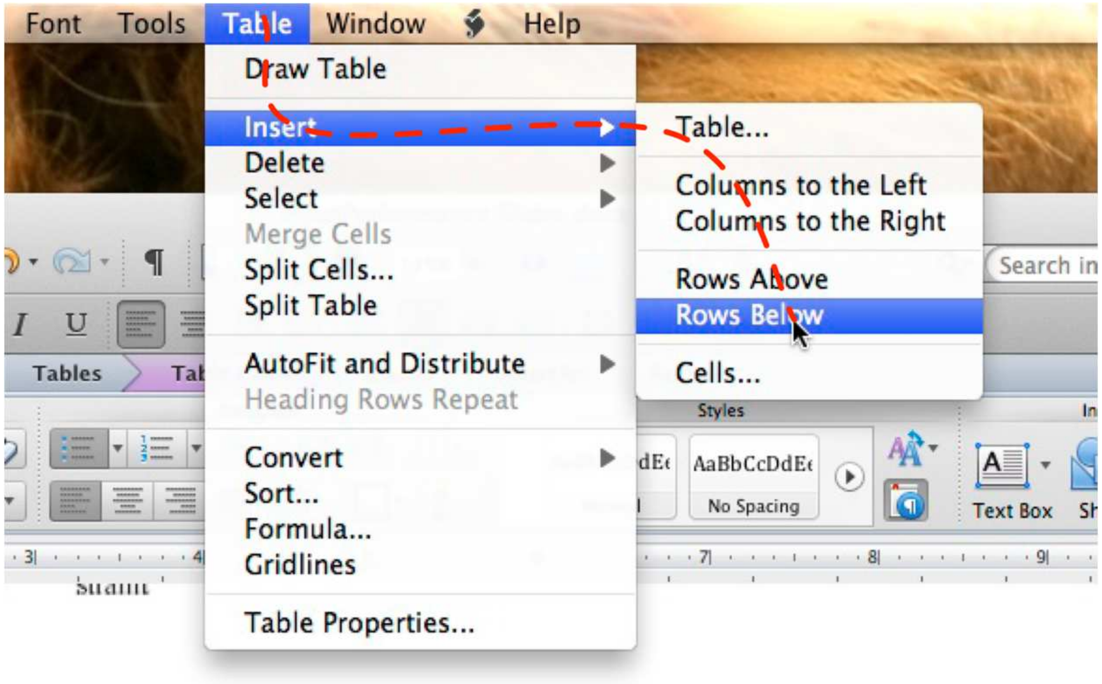
$$T = \lim_{N \to \infty} \sum_{i-1}^{N} b \log_2\left(\frac{A/N}{W} + 1\right)$$

$$T = b\frac{A}{W}$$

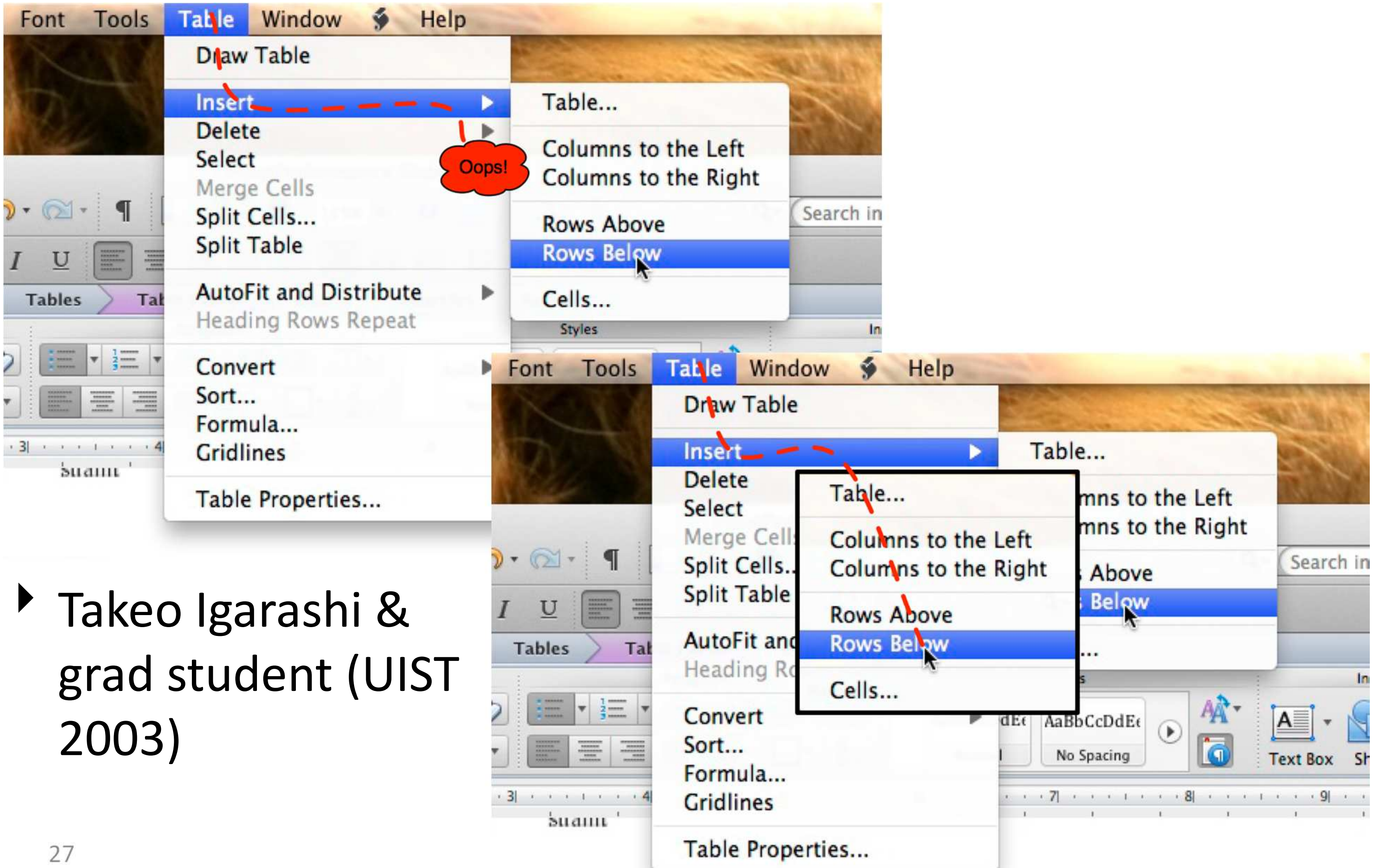
- So difficulty is not related to log(A/W) but just A/W

Hierarchical Menus

- Sum the parts of the path:
  - Wide path (but short stopping distance)
  - Narrow path (but wide stopping distance)
  - Wide path (with short stopping distance)



Improving Menus



- Takeo Igarashi & grad student (UIST 2003)

Variants on Steering Law

- Crossing-based interfaces
  - Uses goal crossing instead of clicking
  - Useful for some paradigms (e.g. stylus, maybe finger, etc.)
  - Mathematical behaviour is same as Fitts's Law, but you can cross two targets in same gesture
    - Avoids down, up, down, up.
  - Becomes almost marking menu style behaviour

Summary

- We have mathematical models for acquiring a target, both when the path is unconstrained and constrained
  - Larger/closer is faster
- Gives some ideas for speeding things up