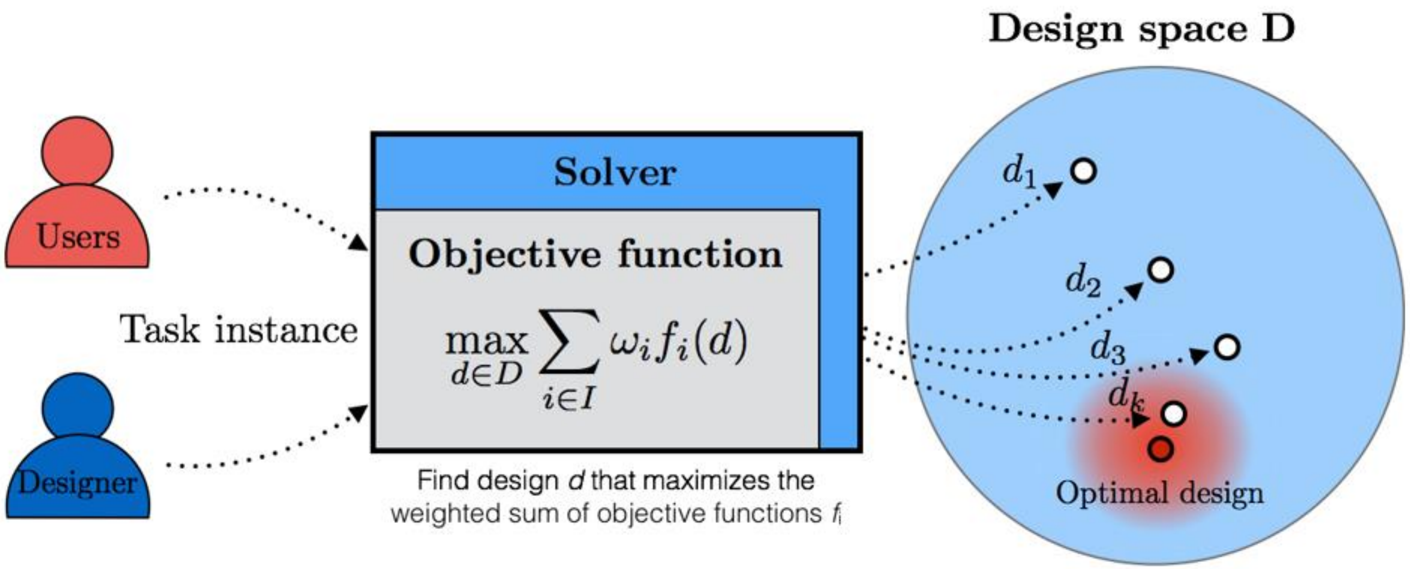
Previous Lecture

Combinatorial Optimization in HCI

Combinatorial optimization refers to algorithmic search for combinations of design decisions that best meet stated design objectives.

Published applications in HCI include keyboards and panels, menu systems, graphical user interfaces, visualizations, and input methods.

Basic Concepts



1.design space (search space; a.k.a. feasible set, candidate set): a finite set of alternative designs;

2.objective function: defines what you mean by 'good' or 'desirable design';

3.task instance: sets task-specific parameters.

Bayesian Optimization

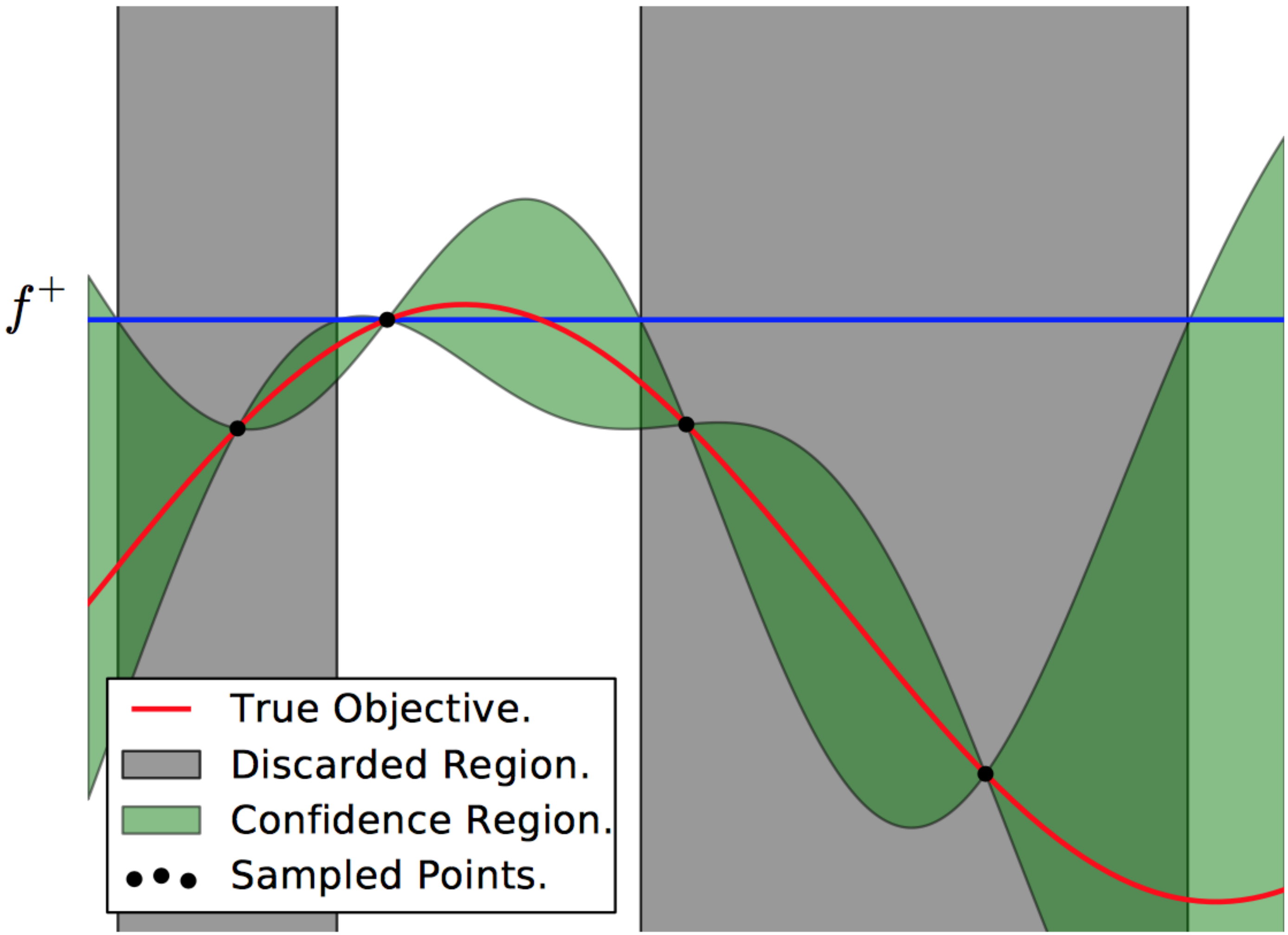
The computational problem

Problem: Find the minimum of a function $f(x)$ within some bounded domain $\mathcal{X} \subset \mathbb{R}^D$:

$$x^* = \arg\min_{x \in \mathcal{X}} f(x)$$

Challenges

- f is a black-box that we can only evaluate point-wise,
- f can be multi-modal,
- f is slow or expensive to evaluate,
- evaluations of f are noisy,
- f has no gradients available (can be used if available).


f^+
True Objective.
Discarded Region.
Confidence Region.
Sampled Points.

Summary

Xiaojun Bi
Stony Brook University
xiaojun@cs.stonybrook.edu

Human Computer Interaction

- What is Human Computer Interaction (HCI)?

A discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them.

ACM SIGCHI Curricula for Human-Computer Interaction
by Hewett, Baecker, Card, Carey, Gasen, Mantei, Perlman, Strong and Verplank
http://old.sigchi.org/cdg/cdg2.html (access 2018)

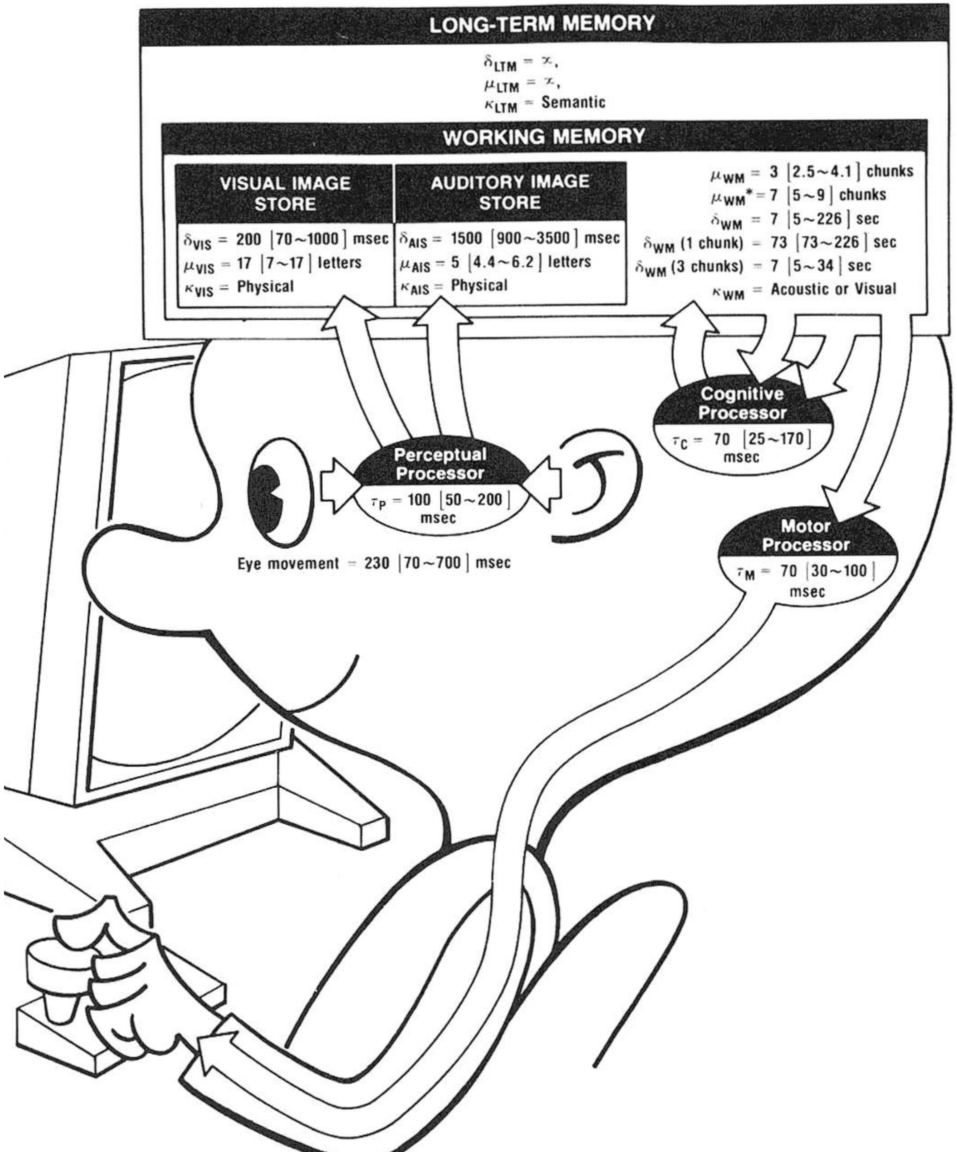
What have we learned?

- **Theoretical Foundations**
  - Human Performance Modeling
  - Evaluation Methodologies
  - Behavioral Science in HCI
  - Design Principles, Affordances
  - Optimization in HCI

- **Practical Topics**
  - Text Entry Technologies
  - Tangible Interfaces
  - Multi-Modal Interfaces
  - Natural User Interfaces (NUI)
  - Human Computation
  - Intelligent User Interfaces (IUI)

Human Performance Modeling

Summary



3 subsystems

- Perceptual
- Cognitive
- Motor

- Each subsystem has its own memories and processors.

- Memory
  μ, storage capacity in items
  δ, decay time of an item
  κ, main code type (physical, acoustic, visual, semantic)

- Processor
  τ, cycle time

- Three subsystems can work in parallel.

Human Performance

- Three Types of Models

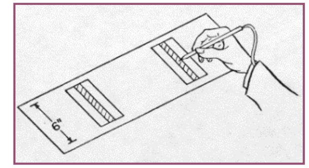
  Best Performance (Fastman)

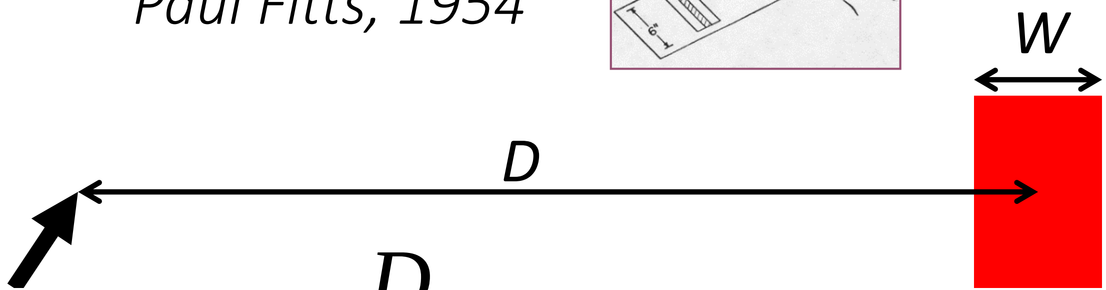
  Worst Performance (Slowman)

  Nominal Performance (Middleman)

Fitts' Law

Paul Fitts, 1954



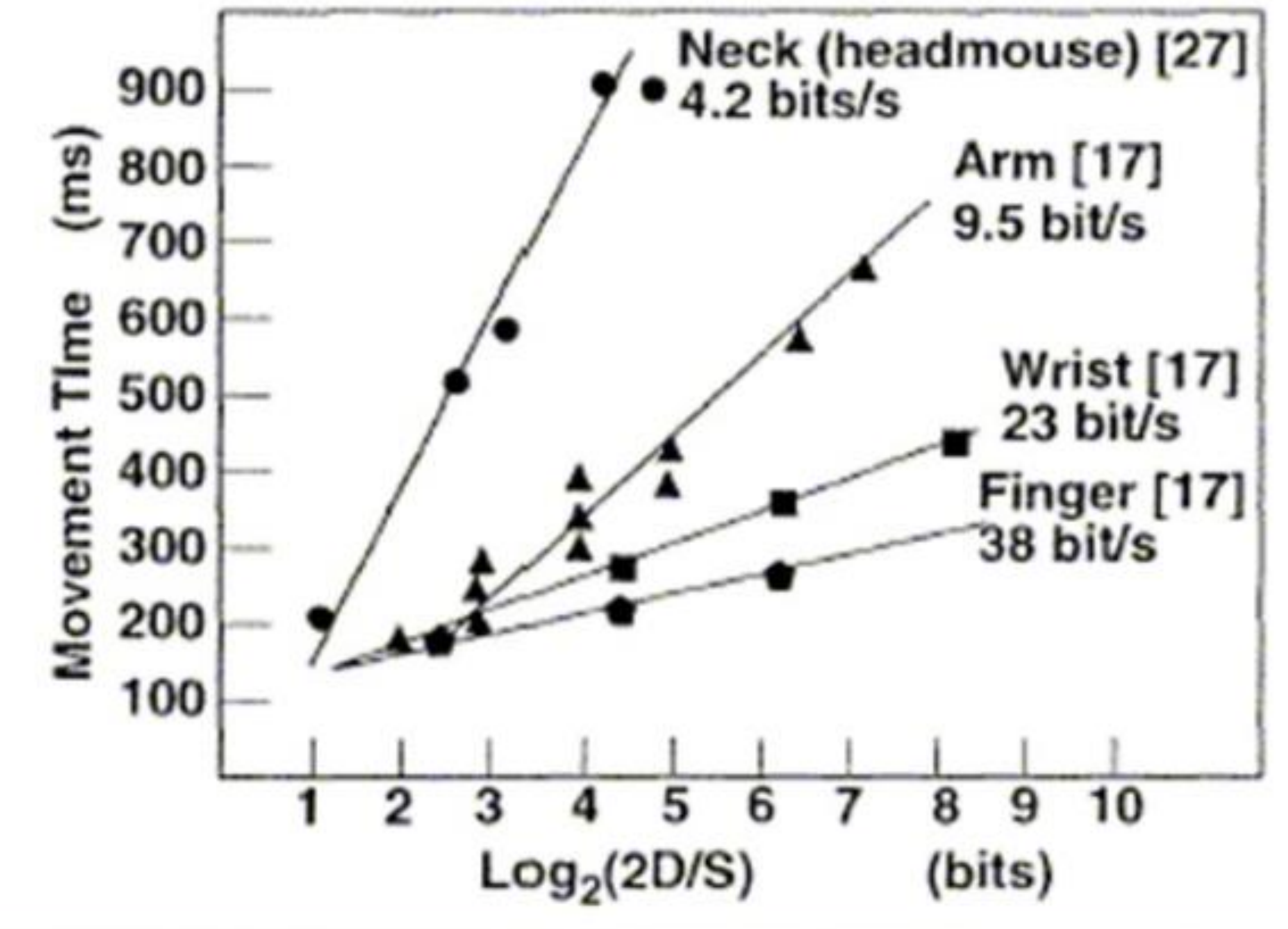


$$\underbrace{MT}_{\textbf{Movement Time}} = a + b\underbrace{\log_2\left(\frac{D}{W}+1\right)}_{\textbf{Index of Difficulty}\ (\mathit{ID\ [bits]})}$$

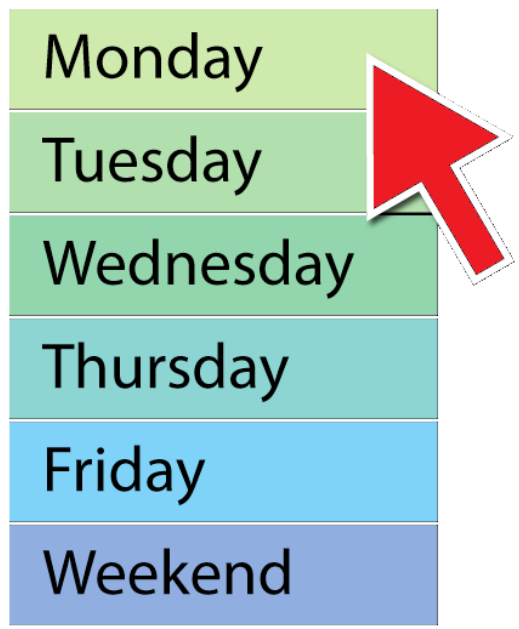
Task difficulty is analogous to information:
→ execution time is interpreted as
human rate of processing information

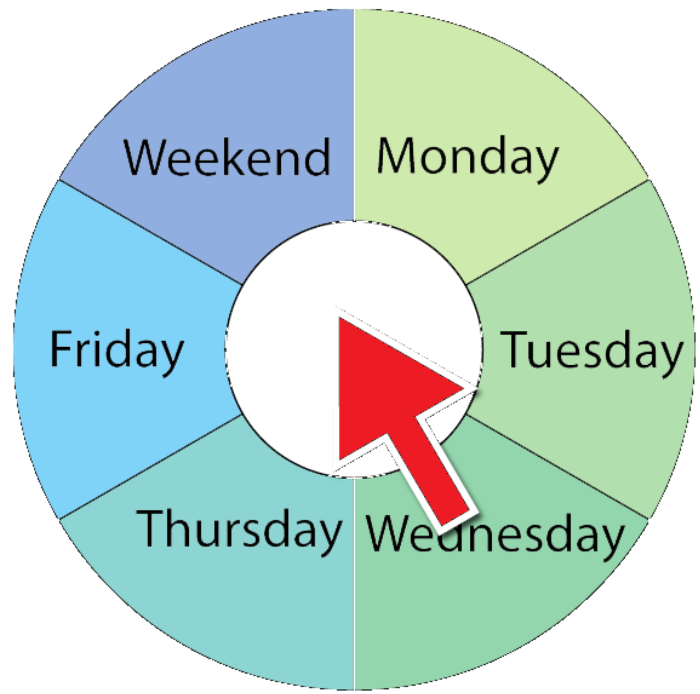
Bandwidth (IP) of Human Muscle Groups

IP = 1/b



Fitts' Law Example





Which will be faster on average?

pie menu (bigger targets & less distance)

Power Law of Practice

- Task time on the nth trial follows a power law

  $$T_n = T_1 n^{-a} + c$$

  where a = .4 [.2 ~ .6], c = limiting constant

  - You get faster the more times you do it!

Applies to skilled behavior (sensory & motor)

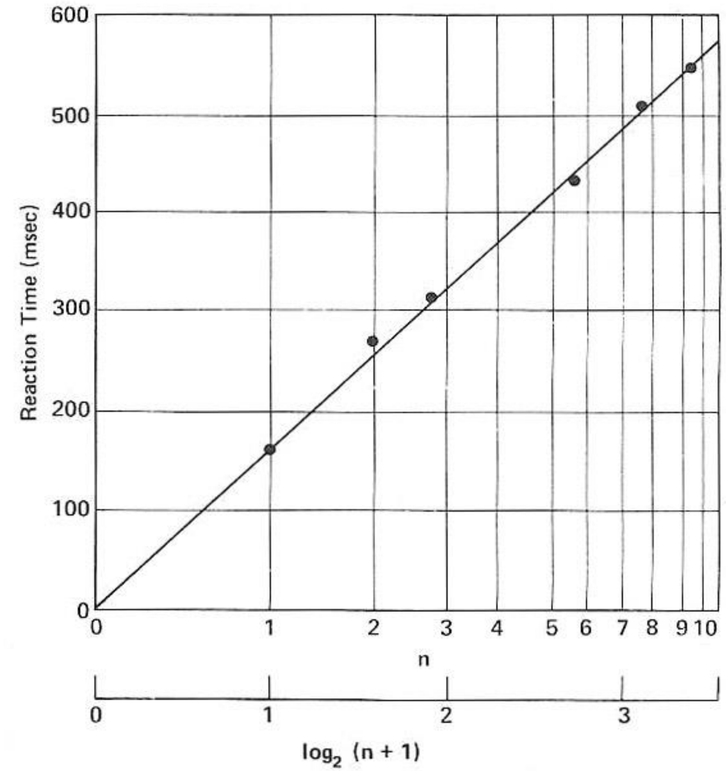
Does not apply to

- Knowledge acquisition
- Improving quality

Hick’s Law

The time it takes for a person to make a decision as a result of the possible choices he or she has: increasing the number of choices will increase the decision time logarithmically.

$$T = b \cdot \log_2(n+1)$$



At the onset of one of *n* lights, arranged in a row, the subject is to press the key located Below the light (After Welford, 1968, p62)

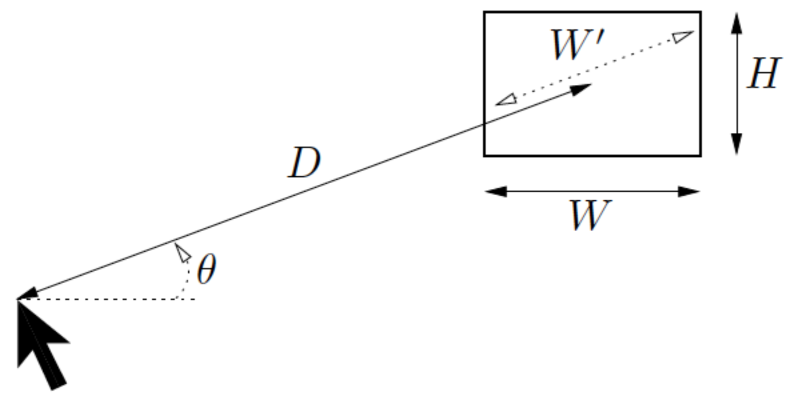
Extending Fitts' law to Two-Dimensional Tasks

- 5 model proposed
  - "STATUS QUO" model
  - "SMALLER OF" model
  - Apparent width W' model
  - Substitute W with W*H
  - Substitute W with W+H

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

$$ID_{\min(W,H)} = \log_2\left(\frac{D}{\min(W,H)} + 1\right)$$

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

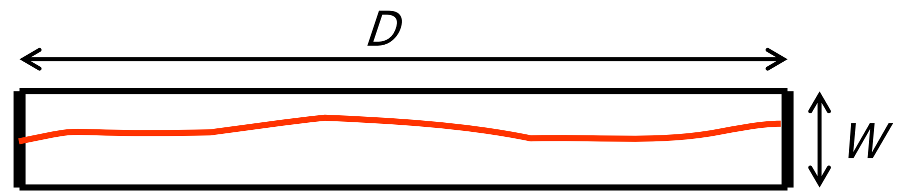


Steering Law *(Accot and Zhai, 1997)*

"Beyond Fitts' Law: Models for trajectory based HCI tasks."
Proceedings of ACM CHI 1997 Conference

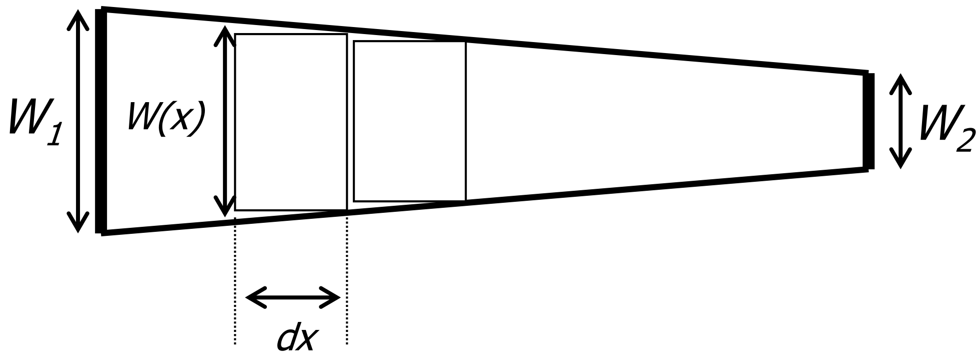
fixed width tunnel:

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



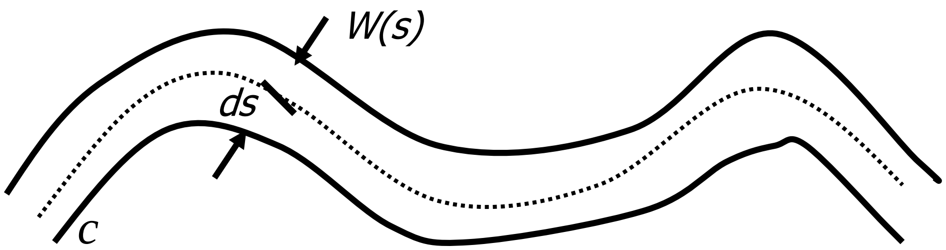
narrowing tunnel:

$$ID = \int_0^D \frac{dx}{W(x)}$$



general Steering Law:

$$ID = \int_c \frac{ds}{W(s)}$$



What is GOMS?

- A family of user interface modeling techniques

- Goals, Operators, Methods, and Selection rules
  - Input: detailed description of UI and task(s)
  - Output: various qualitative and quantitative measures

Evaluation

Qualitative Methods

Discount Usability Engineering

Cheap

- No special labs or equipment needed
- The more careful you are, the better it gets

Fast

- On order of 1 day to apply
- Standard usability testing may take a week

Easy to use

- Can be taught in 2-4 hours

Heuristics

H2-1: Visibility of system status

H2-2: Match system and real world

H2-3: User control and freedom

H2-4: Consistency and standards

H2-5: Error prevention

H2-6: Recognition rather than recall

H2-7: Flexibility and efficiency of use

H2-8: Aesthetic and minimalist design

H2-9: Help users recognize, diagnose and recover from errors

H2-10: Help and documentation

Quantitative Studies

Quantitative

- Use to reliably measure some aspect of interface
- Compare two or more designs on a measurable aspect

Approaches

- Controlled experiments

Examples of measures

- Time to complete a task
- Average number of errors on a task
- Users’ ratings of an interface
  - Ease of use, elegance, performance, robustness, speed,…

Between vs. Within Subjects

Between subjects

- Each participant uses one condition
  - + Avoid carry-over learning effects
  - - Participants cannot compare conditions
  - - Need more participants

Within subjects

- All participants try all conditions
  - + Compare one person across conditions to isolate effects of individual diffs
  - + Requires fewer participants
  - - Fatigue effects
  - - Bias due to ordering/learning effects

Menu selection example: Within-subjects, each subject tries each condition multiple times, ordering counterbalanced

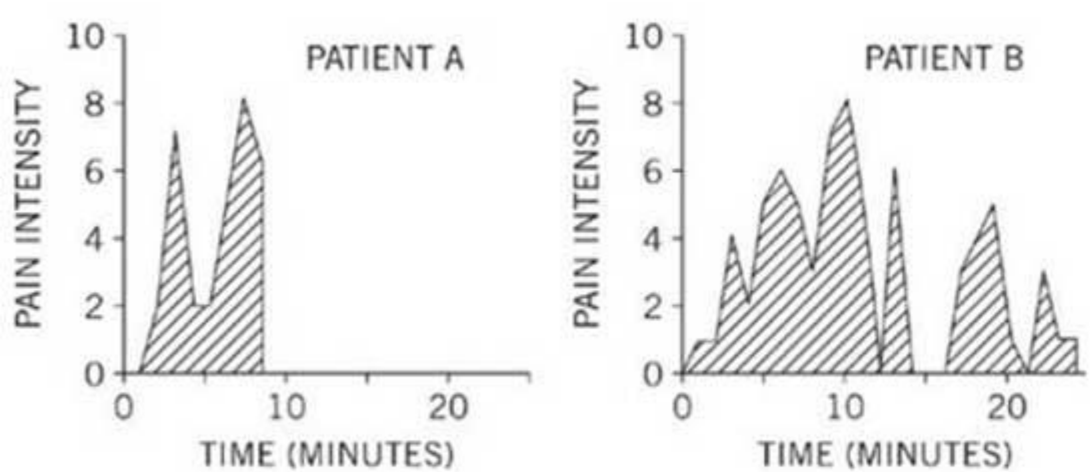
Behavioral Science in HCI

Peak-End Effect

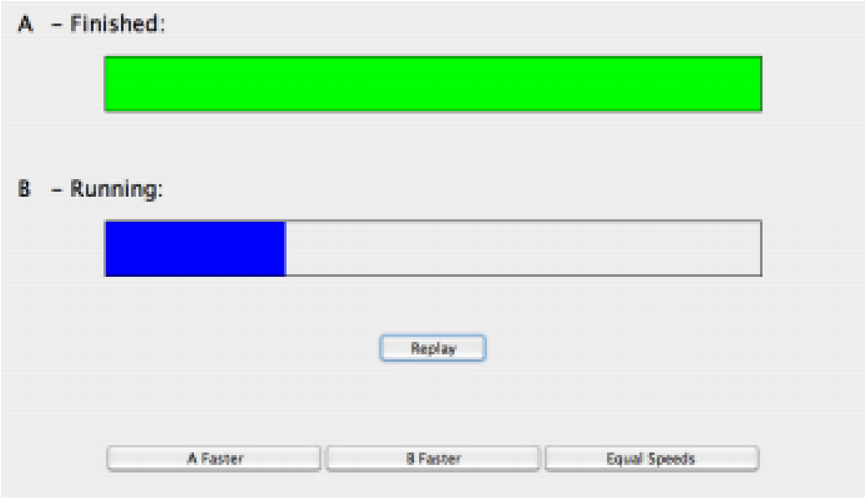
- **Peak-End Rule**
  - The most intensive (peak) and ending moments play a dominant role

- **Judgments of unpleasantness are unaffected by their timespan**

  Experiment . Patients undergoing colonoscopy examination



App #1. Progress Bar Designs

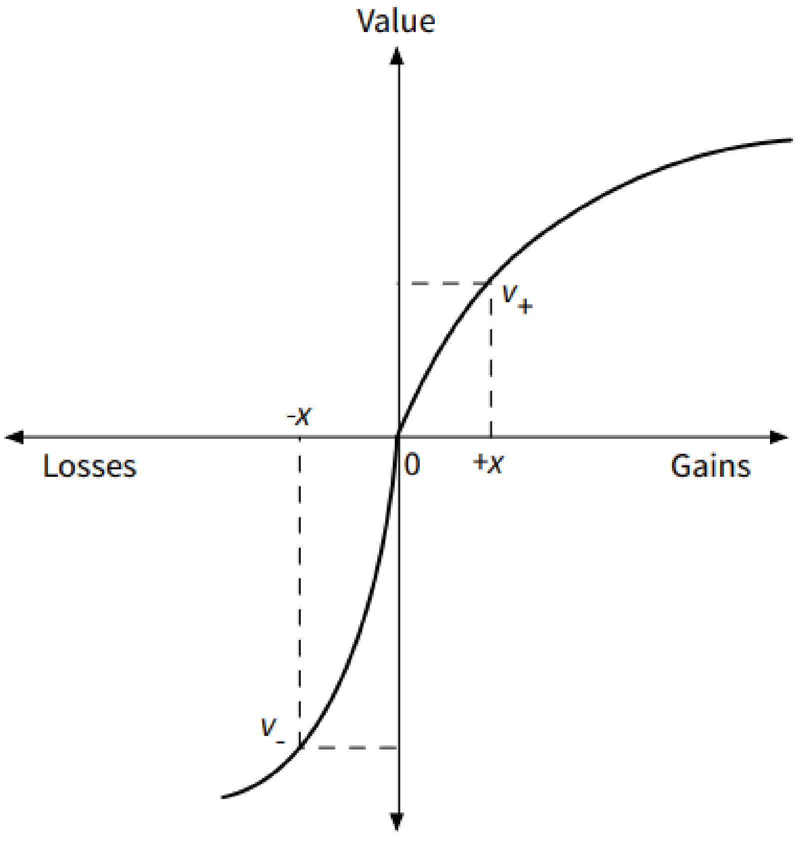


- Each progress bar took 5.5 seconds
- Progress behaviors varied, including
  linear, early pause, late pause, slow wavy, fast wavy
  poser, inverse power, fast power, inverse fast power

Chris Harrison, Brian Amento, Stacey Kuznetsov, and Robert Bell. 2007. Rethinking the progress bar. UIST '07, 115-118.

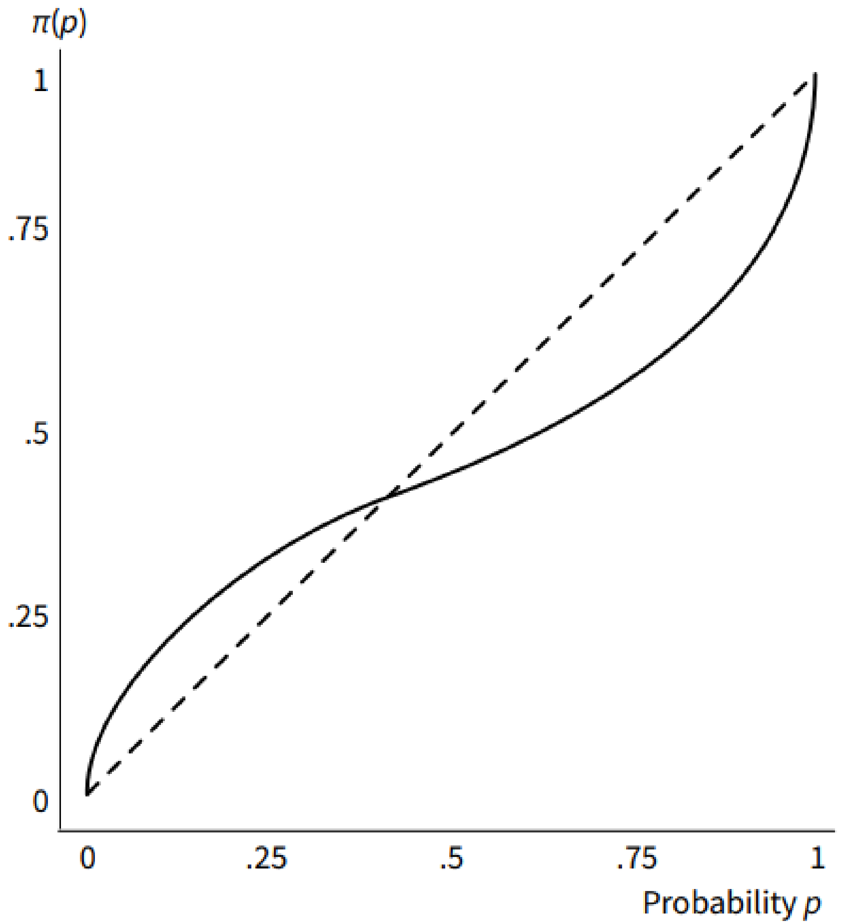
Prospect Theory

- Value function

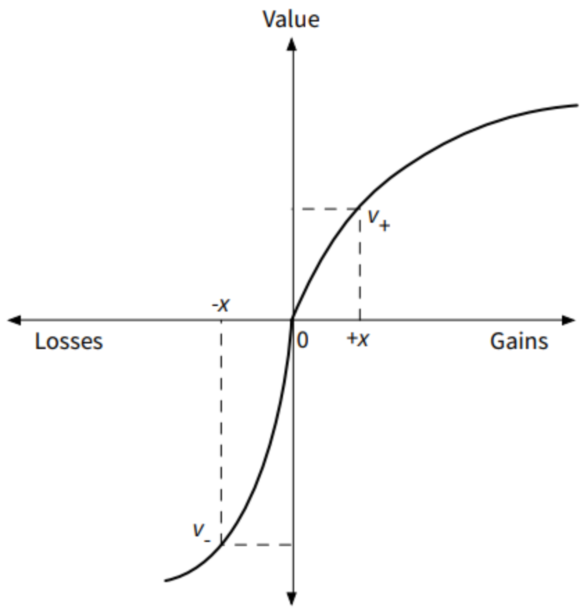


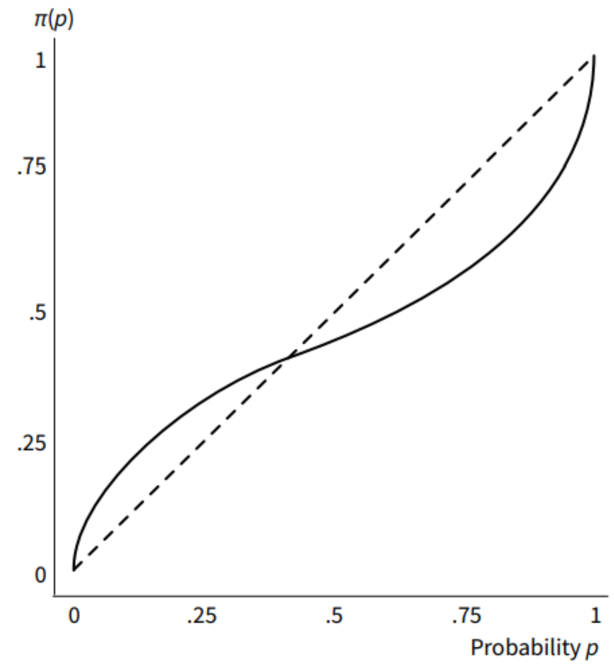
Prospect Theory

- Decision Weighting Function



Prospect Theory

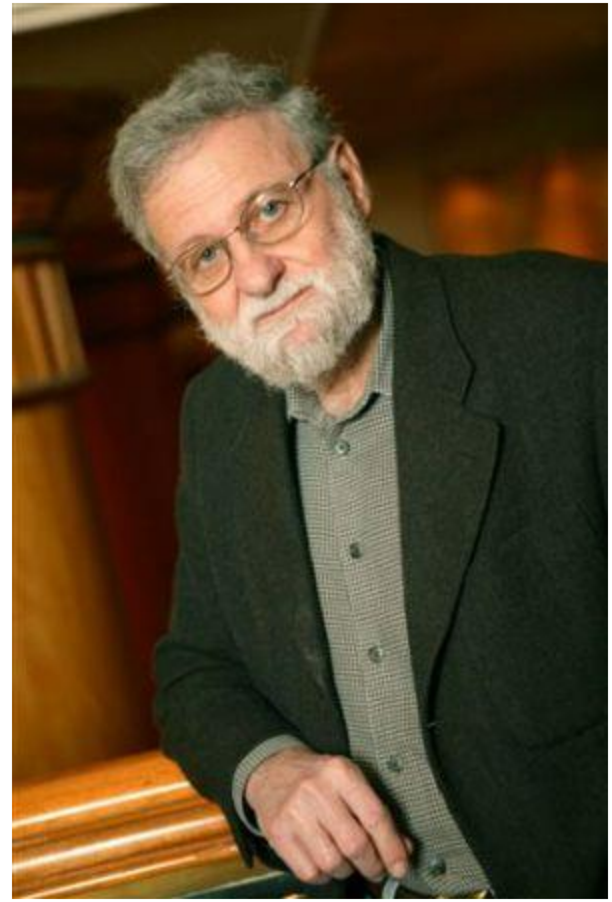




$$V(X,P) = \sum_{i=1}^{n} \pi(p_i)v(x_i).$$

Affordances

"… the term **affordance** refers to the *perceived* and *actual* properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used.



Some affordances obvious

- Knobs afford turning
- Buttons afford pushing
- Glass can be seen through

Some affordances learned

- Glass breaks easily
- Floppy disk
  - Rectangular – can't insert sideways

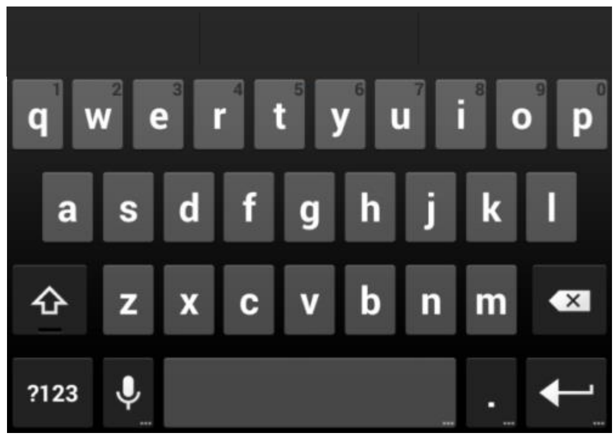
What have we learned?

- **Theoretical Foundations**
  - Human Performance Modeling
  - Evaluation Methodologies
  - Behavioral Science in HCI
  - Design Principles, Affordances
  - Optimization in HCI
- **Practical Topics**
  - Text Entry Technologies
  - Tangible Interfaces
  - Multi-Modal Interfaces
  - Natural User Interfaces (NUI)
  - Human Computation
  - Intelligent User Interfaces (IUI)

Text Entry Technique

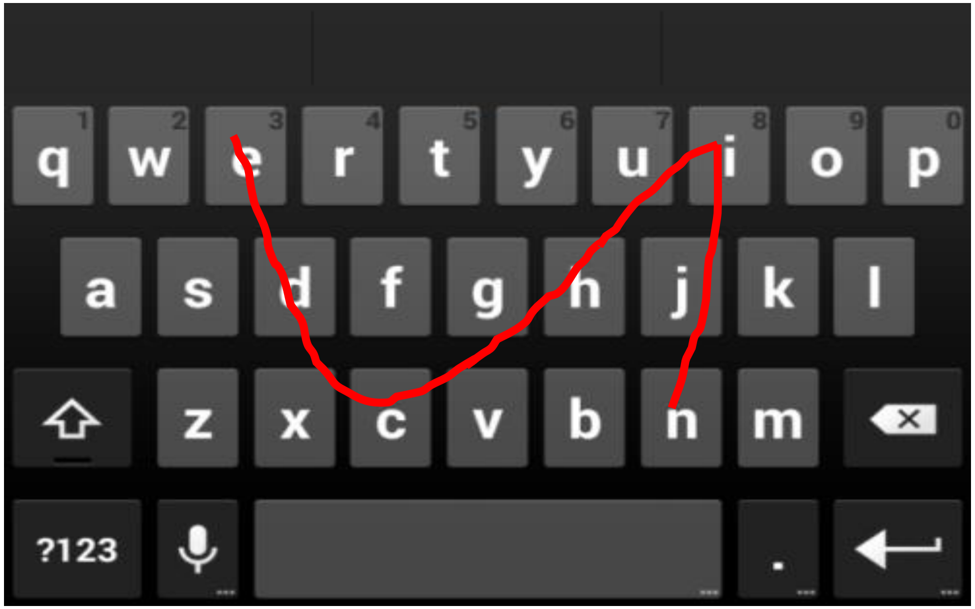
Smart Touch Keyboard

Typed Word		Keyboard Output
agsim	→	again
quivj	→	quick
fav	→	favorite



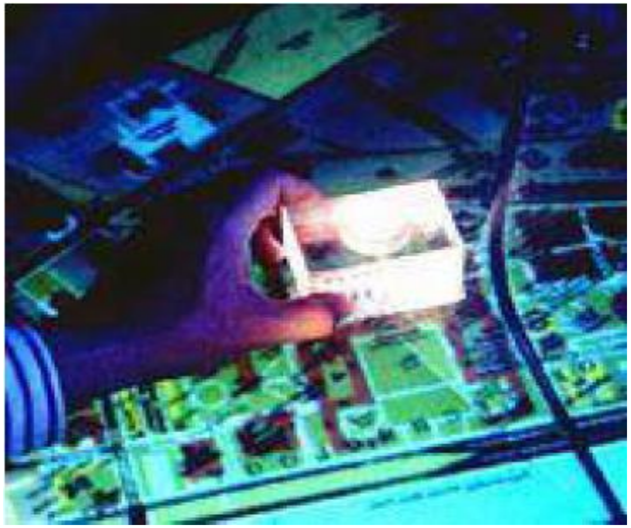
Gesture Keyboard

Entering *nice*



Tangible Interfaces

A tangible user interface is a user interface in which a person interacts with digital information through the physical environment.



Multi-Modal Interfaces

- *Multimodal* generally refers to an interface that can accept input from two or more combined modes

- Input Modalities

mouse

pen

speech

non-speech audio

tangible object manipulation

gaze, posture, body-tracking

Natural User Interfaces

- **Natural user interface**, or **NUI**, is the common parlance used by designers and developers of computer interfaces to refer to a user interface that is effectively invisible, or becomes invisible with successive learned interactions, to its users. The word natural is used because most computer interfaces use artificial control devices whose operation has to be learned.

NUI – Common Interactions

- Multi-touch
  - Mobile Devices, Table-top interactions
- Gestural Interfaces
- Speech Interfaces
- Physiological Interfaces
  - EEG

Human Computation

- **Human Computation** is a technique when a computational process performs its function via outsourcing certain steps to humans.

Intelligent User Interfaces

- Intelligent user interfaces are human-machine interfaces that aim to improve the efficiency, effectiveness, and naturalness of human-machine interaction by <u>representing, reasoning, and acting</u> on <u>models of the user, domain, task, discourse, and media.</u>

- Examples
  - Recommendation systems are ubiquitous
  - Typo & grammar correction
  - Automated bidding
  - Spam filters
  - More, better speech interfaces

What have we learned?

- **Theoretical Foundations**
  - Human Performance Modeling
  - Evaluation Methodologies
  - Behavioral Science in HCI
  - Design Principles, Affordances
  - Optimization in HCI

- **Practical Topics**
  - Text Entry Technologies
  - Tangible Interfaces
  - Multi-Modal Interfaces
  - Natural User Interfaces (NUI)
  - Human Computation
  - Intelligent User Interfaces (IUI)