Chapter 7:
Interaction Design Models

The Resonant Interface
HCI Foundations for Interaction Design
First Edition

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Chapter 7 Interaction Design Models

- Model Human Processor (MHP)
- Keyboard Level Model (KLM)
- GOMS
- Modeling Structure
- Modeling Dynamics
- Physical Models

Predictive/Descriptive Models

- **Predictive models** such as the Model Human Processor (MHP) and the Keyboard Level Model (KLM), are a priori (pre-experience) models
  - They give approximations of user actions before real users are brought into the testing environment.
- **Descriptive models**, such as state networks and the Three-State Model, provide a framework for thinking about user interaction
  - They can help us to understand how people interact with dynamic systems.

Model Human Processor (MHP)

MAXIM

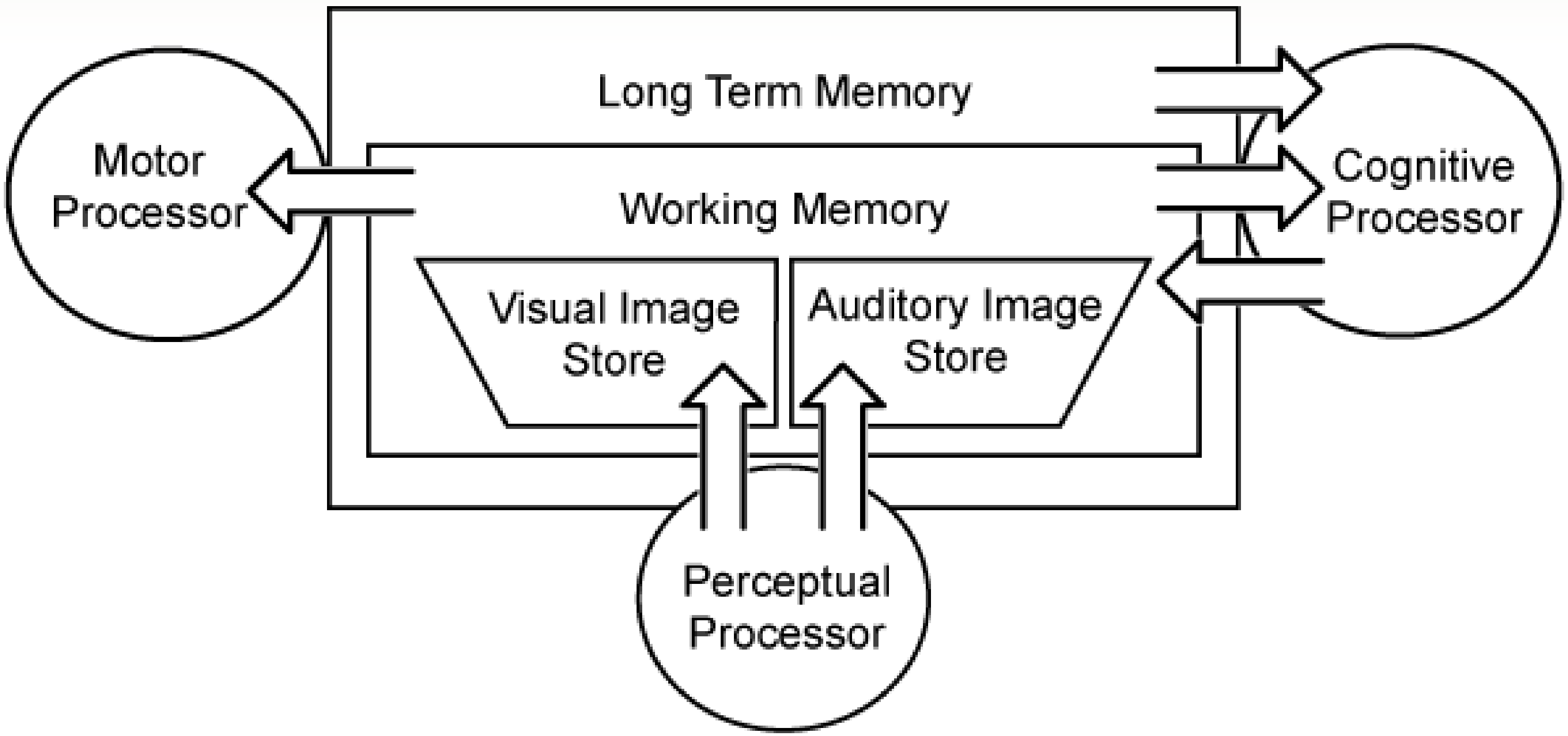
The Model Human Processor can make general predictions about human performance

- The MHP is a predictive model and is described by a set of memories and processors that function according to a set of principles (principles of operation)

Model Human Processor (MHP)

- Perceptual system (sensory image stores)
  - Sensors
    - eyes
    - ears
  - Buffers
    - Visual memory store (VIS)
    - Auditory memory store (AIS)
- Cognitive system
  - Working memory (WM)—*Short-term memory*
  - Long-term memory (LTM)
- Motor system
  - arm-hand-finger system
  - head-eye system

Model Human Processor (MHP)



MHP – *Working Memory*

- WM consists of a subset of “activated” elements from LTM
- The SISs encode only the nonsymbolic physical parameters of stimuli.
- Shortly after the onset of a stimulus, a symbolic representation is registered in the WM

MHP – *Working Memory*

- The activated elements from LTM are called chunks.
  - Chunks can be composed of smaller units like the letters in a word
  - A chunk might also consist of several words, as in a well-known phrase

MHP – *Working Memory*

BCSBMICRA

MHP – *Working Memory*

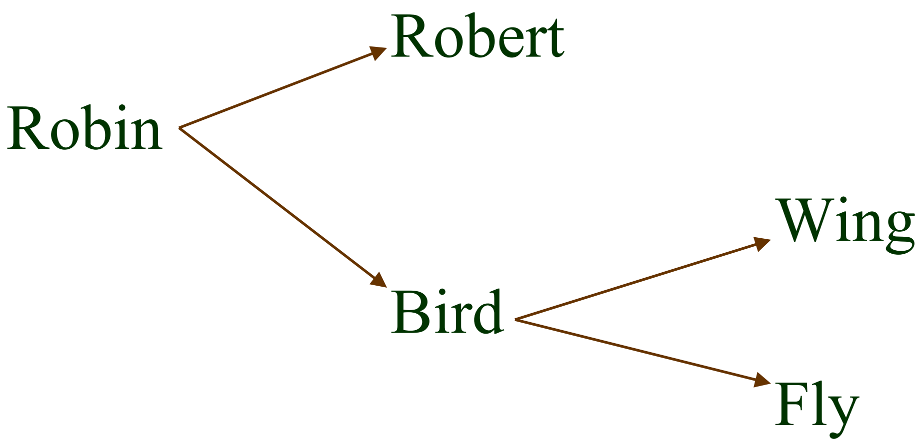
BCSBMICRA

CBSIBMRCA

MHP – *Working Memory*

MAXIM

Chunks in WM can interfere with each other due to LTM associations



MHP – *Long-Term Memory*

- The cognitive processor can add items to WM but not to LTM
- The WM must interact with LTM over a significant length of time before an item can be stored in LTM
- This increases the number of cues that can be used to retrieve the item later
- Items with numerous associations have a greater probability of being retrieved

MHP – *Processor Timing*

- **Perceptual**—The perceptual system captures physical sensations by way of the visual and auditory receptor channels
- Perceptual decay is shorter for the visual channel than for the auditory channel
- Perceptual processor cycle time is variable according to the nature of the stimuli

MHP – *Processor Timing*

- **Cognitive**—The cognitive system bridges the perceptual and motor systems

- It can function as a simple conduit or it can involve complex processes, such as learning, fact retrieval, and problem solving

- Cognitive coding in the WM is predominantly visual and auditory

MHP – *Processor Timing*

- Cognitive coding in LTM is involved with associations and is considered to be predominantly semantic
- Cognitive decay time of WM requires a large range
- Cognitive decay is highly sensitive to the number of chunks involved in the recalled item

MHP – *Processor Timing*

- Cognitive decay of LTM is considered infinite
- Cognitive processor cycle time is variable according to the nature of the stimuli
- **Motor**—The motor system converts thought into action
- Motor processor cycle time is calculated in units of discrete micromovements

Keyboard Level Model (KLM)

- The KLM is a practical design tool that can capture and calculate the physical actions a user will have to carry out to complete specific tasks

MAXIM

The KLM can be used to determine the most efficient method and its suitability for specific contexts.

Keyboard Level Model (KLM)

- **Given:**
  - A task (possibly involving several subtasks)
  - The command language of a system
  - The motor skill parameter of the user
  - The response time parameters

- **Predict:** The time an expert user will take to execute the task using the system
  - Provided that he or she uses the method without error

Keyboard Level Model (KLM)

- The KLM is comprised of:
  - Operators
  - Encoding methods
  - Heuristics for the placement of mental **(M)** operators

KLM - *Operators*

- Operators
  - **K** Press a key or button
  - **P** Point with mouse
  - **H** Home hands to keyboard or peripheral device
  - **D** Draw line segments
  - **M** Mental preparation
  - **R** System response

KLM – *Encoding Methods*

- Encoding methods define how the operators involved in a task are to be written

MK[i] K[p] K[c] K[o] K[n] K[f] K[i] K[g] K[RETURN]

It would be encoded in the short-hand version as

M 8K [ipconfig RETURN]

This results in a timing of 1.35 8 0.20 2.95 seconds for an average skilled typist.

KLM – *Heuristics for M Operator Placement*

- The KLM operators can be placed into one of two groups—physical or cognitive.
- The physical operators are defined by the chosen method of operation, such as clicking an icon or entering a command string.
- The cognitive operators are governed by the set of heuristics

What the KLM Does Not Do

- The KLM was not designed to consider the following:
  - Errors
  - Learning
  - Functionality
  - Recall
  - Concentration
  - Fatigue
  - Acceptability

Applications for the KLM

- Case 1 (Mouse-Driven Text Editor)
  - During the development of the Xerox Star KLMs served as expert proxies
- Case 2 (Directory Assistance Workstation)
  - The KLM clarified the tradeoffs between the number of keystrokes entered in the query and the number of returned fields

GOMS

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Goal/task models can be used to explore the methods people use to accomplish their goals

- Card et al. suggested that user interaction could be described by defining the sequential actions a person undertakes to accomplish a task.

- The GOMS model has four components:
  - goals
  - operators
  - methods
  - selection rules

GOMS

- **Goals** - Tasks are deconstructed as a set of goals and subgoals.
- **Operators** - Tasks can only be carried out by undertaking specific actions.
- **Methods** - Represent ways of achieving a goal
  - Comprised of operators that facilitate method completion
- **Selection Rules** - The method that the user chooses is determined by selection rules

GOMS – *CMN-GOMS*

MAXIM

CMN-GOMS can predict behavior and assess memory requirements

- CMN-GOMS (named after Card, Moran, and Newell) -a detailed expansion of the general GOMS model
  - Includes specific analysis procedures and notation descriptions
- Can judge memory requirements (the depth of the nested goal structures)
- Provides insight into user performance measures

GOMS – *Other GOMS Models*

- **NGOMSL** (Natural GOMS Language), developed by Kieras, provides a structured natural-language notation for GOMS analysis and describes the procedures for accomplishing that analysis (Kieras, 1997)
  - NGOMSL Provides:
    - A method for measuring the time it will take to learn specific method of operation
    - A way to determine the consistency of a design’s methods of operation

GOMS – *Other GOMS Models*

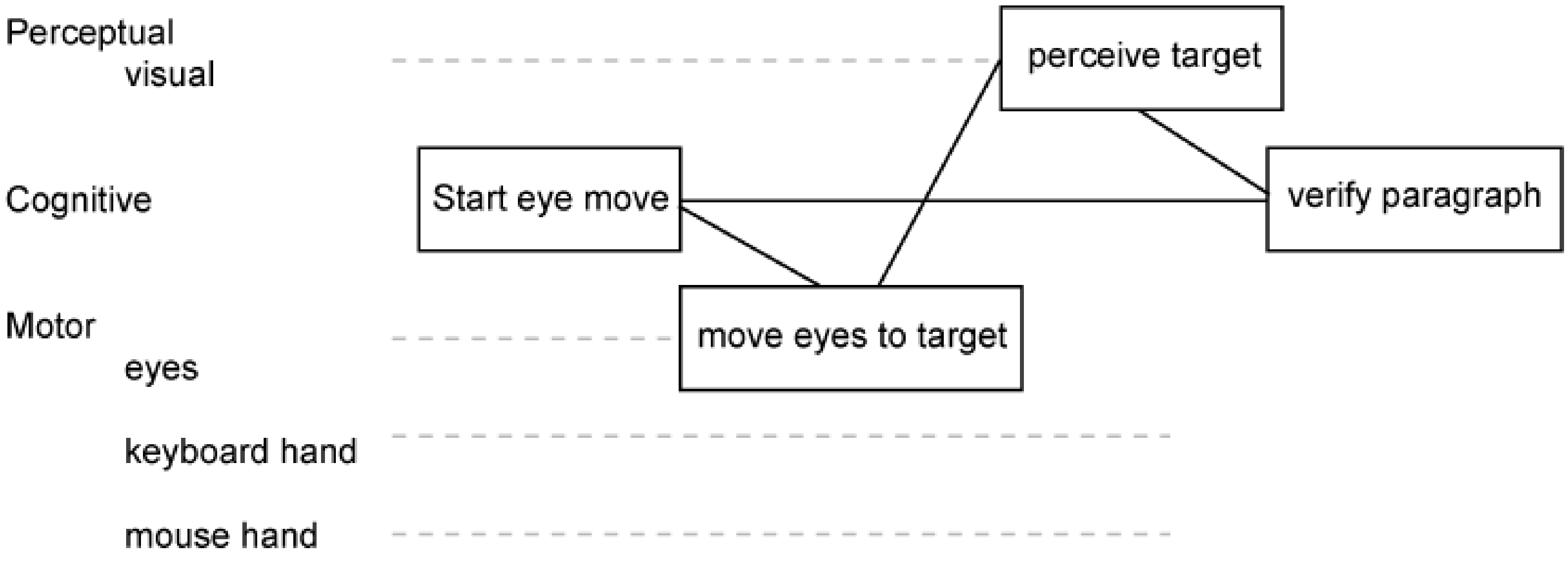
- **CPM-GOMS** represents
  - Cognitive
  - Perceptual
  - Motor operators

- **CPM-GOMS** uses Program Evaluation Review Technique (PERT) charts
  - Maps task durations using the critical path method (CPM).

- **CPM-GOMS** is based directly on the Model Human Processor
  - Assumes that perceptual, cognitive, and motor processors function in parallel

GOMS – *Other GOMS Models*

- Program Evaluation Review Technique (PERT) chart Resource Flows



Modeling Structure

- Structural models can help us to see the relationship between the conceptual components of a design and the physical components of the system, allowing us to judge the design's relative effectiveness.

Modeling Structure – *Hicks Law*

MAXIM

Hick's law can be used to create menu structures

- Hick's law states that the time it takes to choose one item from *n* alternatives is proportional to the logarithm (base 2) of the number of choices, plus 1.
- This equation is predicated on all items having an equal probability of being chosen

Modeling Structure – *Hicks Law*

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

- The coefficients are empirically determined from experimental design
- Raskin (2000) suggests that $a = 50$ and $b = 150$ are sufficient place holders for “back-of-the-envelope” approximations

Modeling Structure – *Hicks Law*

MAXIM

Menu listing order must be logical and relevant

- Menus are lists grouped according to some predetermined system

- If the rules are not understood or if they are not relevant to a particular task, their arrangement may seem arbitrary and random, requiring users to search in a linear, sequential manner.

Modeling Dynamics

MAXIM

Understanding the temporal aspects of interaction design is essential to the design of usable and useful systems

- Interaction designs involve dynamic feedback loops between the user and the system
  - User actions alter the state of the system, which in turn influences the user's subsequent actions
- Interaction designers need tools to explore how a system undergoes transitions from one state to the next

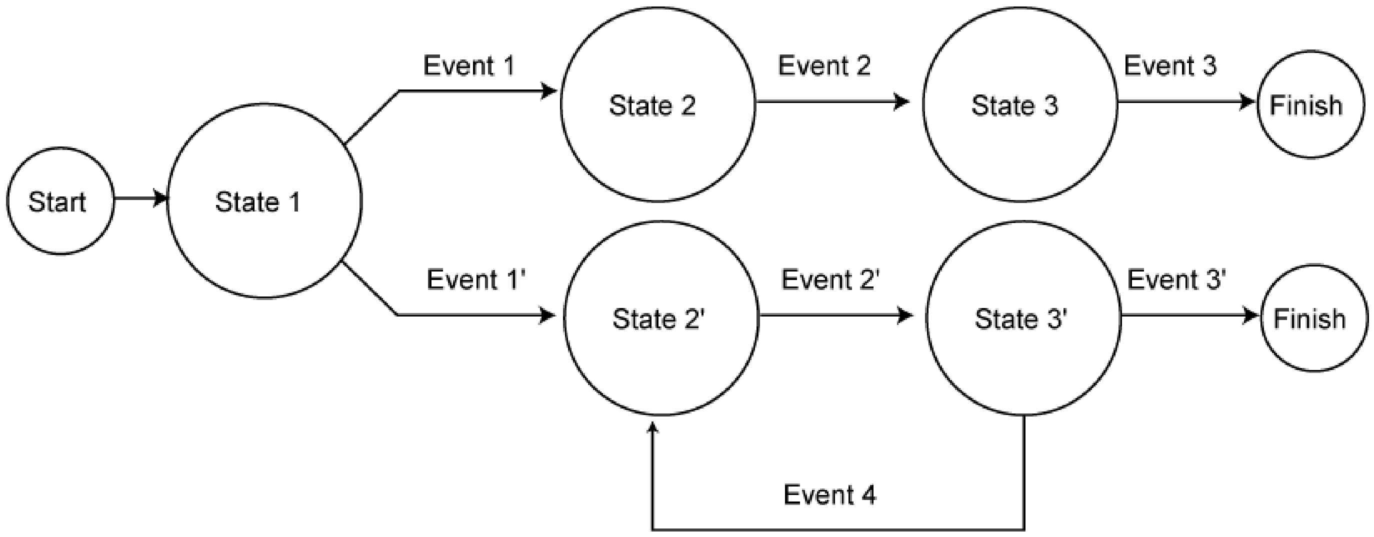
Modeling Dynamics – *State Transition Networks*

- **State Transition Networks** can be used to explore:
  - Menus
  - Icons
  - Tools

- **State Transition Networks** can show the operation of peripheral devices

Modeling Dynamics – *State Transition Networks*

- State Transition Network



- STNs are appropriate for showing sequential operations that may involve choice on the part of the user, as well as for expressing iteration.

Modeling Dynamics – *Three-State Model*

MAXIM

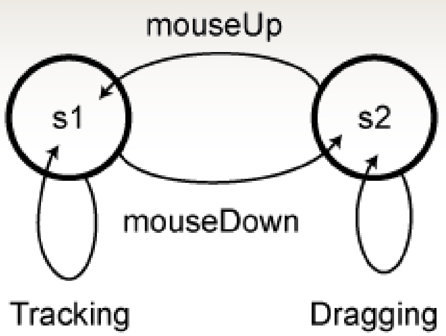
The Three-State Model can help designers to determine appropriate I/O devices for specific interaction designs

- The TSM can reveal intrinsic device states and their subsequent transitions
  - The interaction designer can use these to make determinations about the correlation between task and device
  - Certain devices can be ruled out early in the design process if they do not possess the appropriate states for the specified task

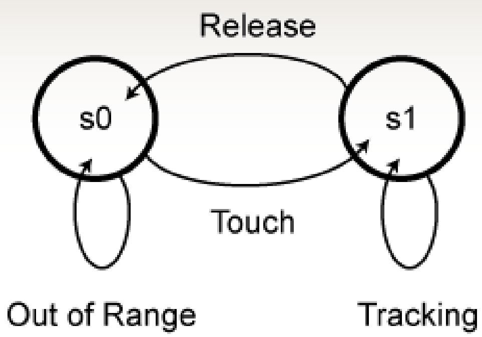
Modeling Dynamics – *Three-State Model*

- **The Three-State Model** (TSM) is capable of describing three different types of pointer movements
  - **Tracked**: A mouse device is tracked by the system and represented by the cursor position
  - **Dragged**: A mouse also can be used to manipulate screen elements using drag-and-drop operations
  - **Disengaged movement**: Some pointing devices can be moved without being tracked by the system, such as light pens or fingers on a touchscreen, and then reengage the system at random screen locations

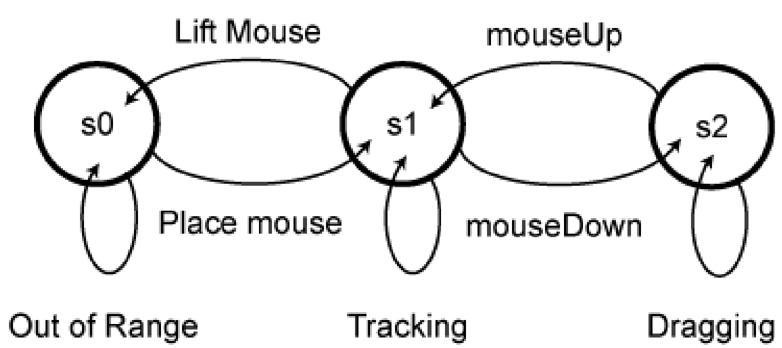
Modeling Dynamics – *Three-State Model*



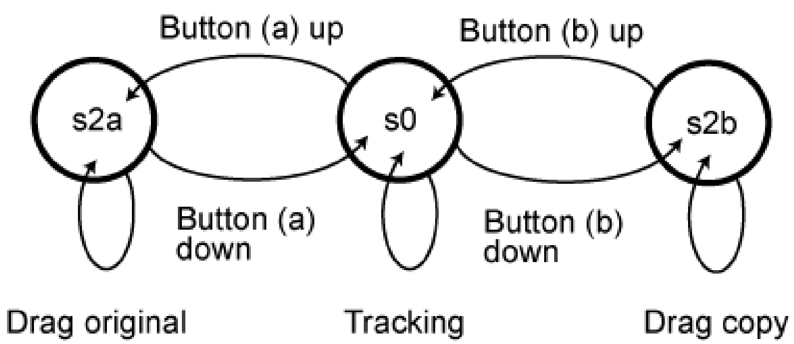
Mouse Three-State Model.



Trackpad Three-State Model.



Alternate mouse Three-State Model.

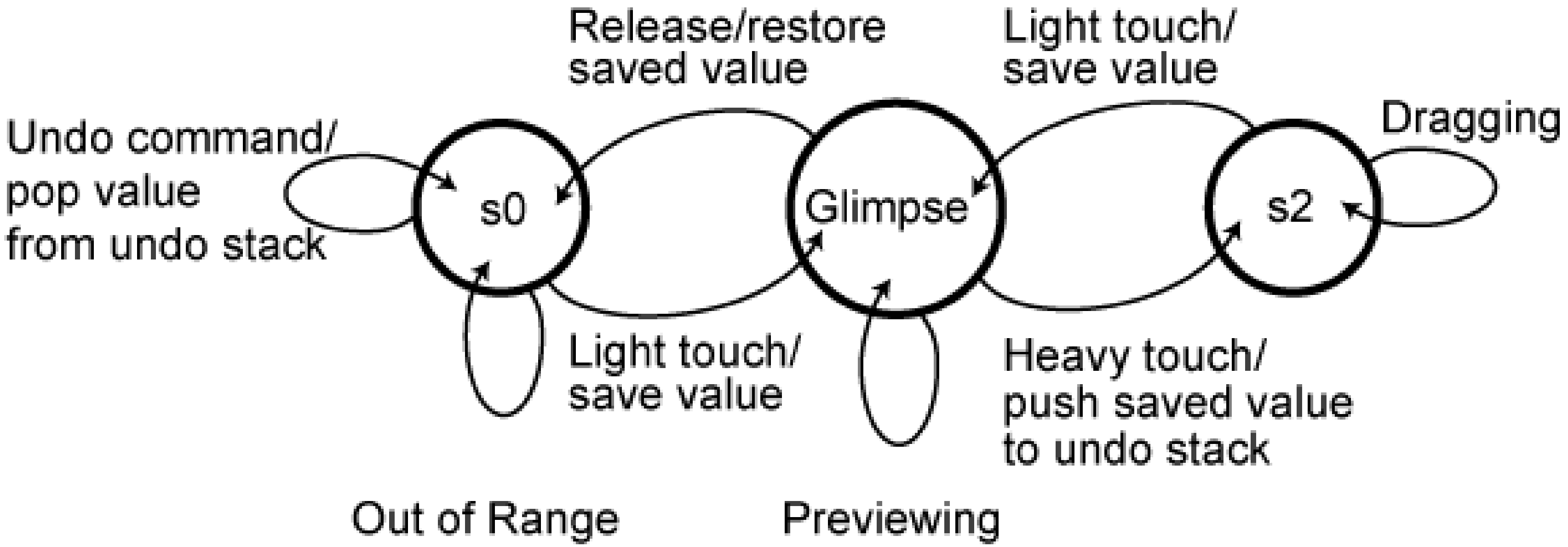


Multibutton pointing device Three-State Model.

Modeling Dynamics – *Glimpse Model*

- Forlines et al. (2005):
  - Because the pen and finger give clear feedback about their location when they touch the screen and enter state 2, it is redundant for the cursor to track this movement
  - Pressure-sensitive devices can take advantage of the s1 redundancy and map pressure to other features
  - Undo commands coupled with a preview function (Glimpse) can be mapped to a pressure-sensitive direct input device

Modeling Dynamics – *Glimpse Model*



Modeling Dynamics – *Glimpse Model*

- Some applications
  - **Pan and zoom interfaces**—Preview different magnification levels
  - **Navigation in a 3D world**—Quick inspection of an object from different perspectives
  - **Color selection in a paint program**—Preview the effects of color manipulation
  - **Volume control**—Preview different volume levels
  - **Window control**—Moving or resizing windows to view occluded objects
  - **Scrollbar manipulation**—Preview other sections of a document

Physical Models

- Physical models can predict efficiency based on the physical aspects of a design
- They calculate the time it takes to perform actions such as targeting a screen object and clicking on it

Physical Models – *Fitts' Law*

- Fitts' law states that the time it takes to hit a target is a function of the size of the target and the distance to that target

MAXIM

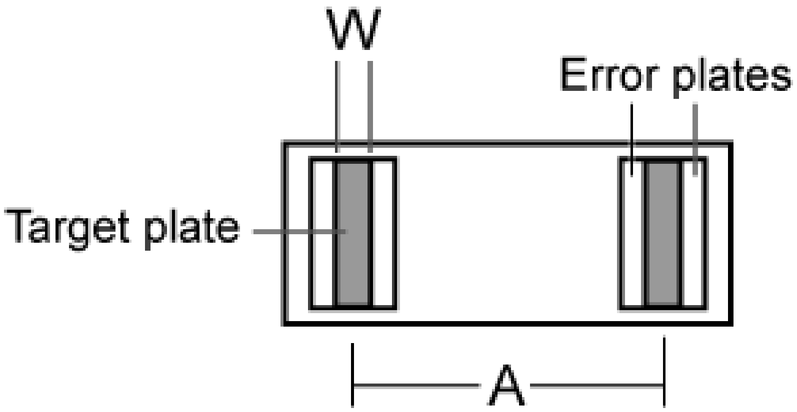
Fitts' law can be used to determine the size and location of a screen object

Physical Models – *Fitts' Law*

- There are essentially three parts to Fitts' law:
  - **Index of Difficulty (ID)**—Quantifies the difficulty of a task based on width and distance
  - **Movement Time (MT)**—Quantifies the time it takes to complete a task based on the difficulty of the task (ID) and two empirically derived coefficients that are sensitive to the specific experimental conditions
  - **Index of Performance (IP)** [also called throughput (TP)]—Based on the relationship between the time it takes to perform a task and the relative difficulty of the task

Physical Models – *Fitts' Law*

- Fitts described "reciprocal tapping"
  - Subjects were asked to tap back and forth on two 6-inch-tall plates with width *W* of 2, 1, 0.5, and 0.25 inches



Physical Models – *Fitts' Law*

- Fitts proposed that ID, the difficulty of the movement task, could be quantified by the equation

$$ID = \log 2(2A/W)$$

Where:

A is the amplitude (distance to the target)

W is the width of the target

- This equation was later refined by MacKenzie to align more closely with Shannon's law:

$$ID = \log 2(A/W + 1)$$

Physical Models – *Fitts' Law*

- The average time for the completion of any given movement task can be calculated by the following equation:

$$\mathbf{MT} = \boldsymbol{a} + \boldsymbol{b}\ \mathbf{log2}(A/W + 1)$$

Where:

MT is the movement time

Constants *a* and *b* are arrived at by linear regression

Physical Models – *Fitts' Law*

- By calculating the MT and ID, we have the ability to construct a model that can determine the information capacity of the human motor system for a given task.
  - Fitts referred to this as the index of performance (throughput)

- Throughput is the rate of human information processing

$$\mathbf{TP = ID/MT}$$

Physical Models – ***Fitts' Law***

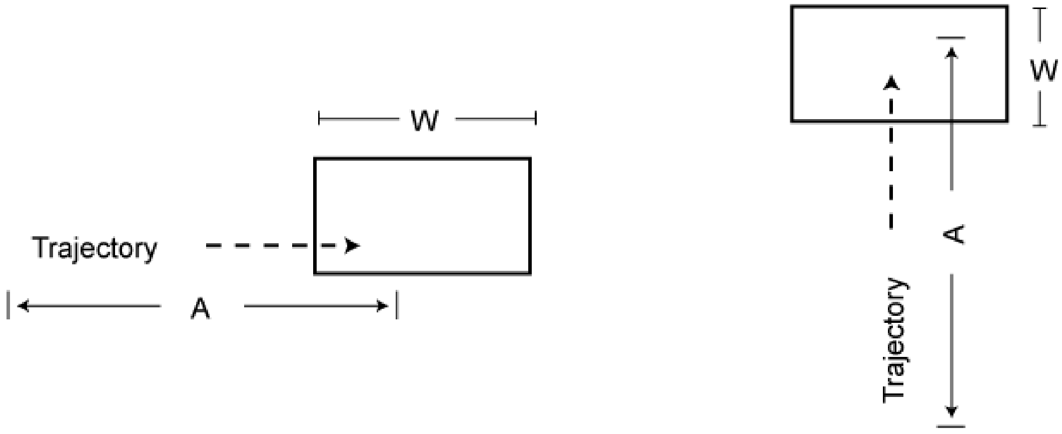
- Implications of Fitts' Law
  - Large targets and small distances between targets are advantageous
  - Screen elements should occupy as much of the available screen space as possible
  - The largest Fitts-based pixel is the one under the cursor
  - Screen elements should take advantage of the screen edge whenever possible
  - Large menus like pie menus are easier to uses than other types of menus.

Physical Models – *Fitts' Law*

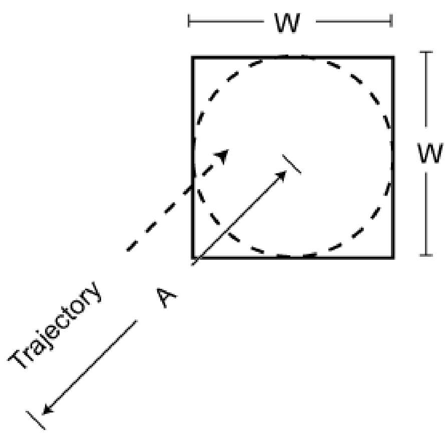
- Limitations of Fitts' Law
  - There is no consistent way to deal with errors
  - It only models continuous movements
  - It is not suitable for all input devices, for example, isometric joysticks
  - It does not address two-handed operation
  - It does not address the difference between flexor and extensor movements
  - It does not address cognitive functions such as the mental operators in the KLM model

Physical Models – *Fitts' Law*

- *W* is computed on the same axis as *A*



Horizontal and vertical trajectories

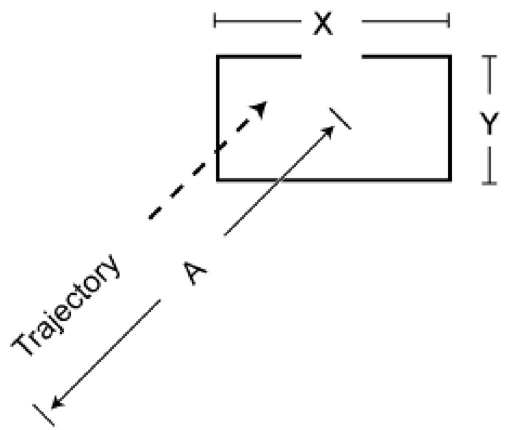


Targeting a circular object.

Physical Models – *Fitts' Law*

- Bivariate data
  - Smaller-Of—The smaller of the width and height measurements:

$$\mathbf{ID_{min}(\mathit{W}, \mathit{H}) = log2\ [\mathit{D}/min\ (\mathit{W}, \mathit{H}) + 1]}$$

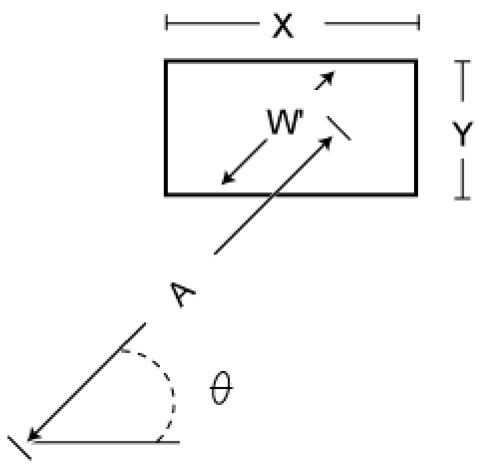


Targeting a rectangular object.

Physical Models – *Fitts' Law*

- *W*—The "apparent width" calculated along the approach vector

$$\mathbf{ID_W = \log2\,(\mathit{D}/\mathit{W} + 1)}$$



Apparent width.

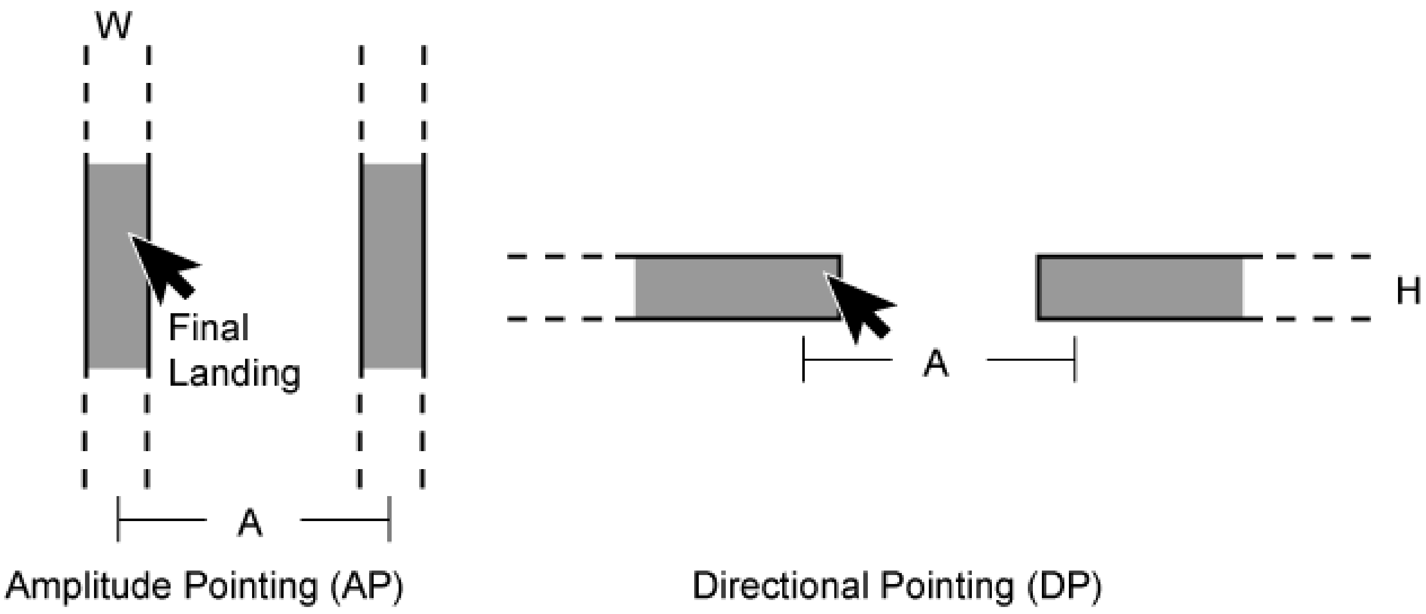
Physical Models – *Fitts' Law*

- **Amplitude Pointing**: One-dimensional tasks
  - Only the target width (whether horizontal or vertical) is considered
  - The constraint is based on *W*, and target height (*H*) is infinite or equal to *W*
  - AP errors are controlled at "the final landing"

- **Directional Pointing:** If *W* is set at infinity then *H* becomes significant
  - The constraint is based on *H*
  - DP errors are corrected incrementally during the pointing movement

(Accot & Zhai, 2003)

Physical Models – *Fitts' Law*



Physical Models – *Fitts' Law*

- Implications for interaction design:
  - Overly elongated objects hold no advantage (W/H ratios of 3 and higher).
  - Objects should be elongated along the most common trajectory path (widgets normally approached from the side should use W, those approached from the bottom or top should use H).
  - Objects should not be offset from the screen edge (consistent with the Macintosh OS).
  - Objects that are defined by English words generally have W H and should be placed on the sides of the screen. (However, greater amplitude measurements may be significant on the normal "landscape"-oriented screens.)

(Accot & Zhai, 2003)