Individual Models of Human Factors - II

Objective

- In the previous lectures, we got introduced to the Fitts' law
  - The law models human motor behavior for rapid, aimed, error-free target acquisition task
- The law allows us to measure the task difficulty using the index of difficulty (ID)

Objective

- Using ID and task completion time (MT), we can compute throughput (TP), which is a measure of task performance

$$TP = ID/MT$$

Unit of ID is bits, unit of MT is sec

Thus, unit of TP is bits/sec

Objective

- We saw how TP helps in design
  - We estimate the user performance under a test condition by estimating TP
  - The TP is estimated by taking mean of the TP achieved by different persons tested with varying task difficulty levels under the same test condition

Objective

- In this lecture, we shall extend this knowledge further and learn about the following
  - How TP can help in comparing designs?
  - How the Fitts' law can be used as a predictive model?
- Also, we shall learn about the Hick-Hyman law, another model of human factor (models choice-reaction time)

Throughput – Design Implication

- In the previous lecture, we discussed about one design implication of throughput in HCI
  - That is, to estimate user's motor performance in a given test condition
- We can extend this idea further to compare competing designs

Throughput – Design Implication

- Suppose you have designed two input devices: a mouse and a touchpad. You want to determine which of the two is better in terms of user performance, when used to acquire targets (e.g., for point and select tasks). How can you do so?

Throughput – Design Implication

- You set up two experiments for two test conditions: one with the mouse and the other with the touchpad
- Determine throughput for each test condition as we have done before (i.e., collect throughput data from a group of users for a set of tasks with varying difficulty level and take the overall mean)

Throughput – Design Implication

- Suppose we got the throughputs TP1 and TP2 for the mouse and the touchpad experiments, respectively
- Compare TP1 and TP2
  - If TP1>TP2, the mouse gives better performance
  - The touchpad is better if TP1<TP2

Throughput – Design Implication

- Suppose we got the throughputs TP1 and TP2 for the mouse and the touchpad experiments, respectively
- Compare TP1 and TP2
  - They are the same performance-wise if TP1=TP2 (this is very unlikely as we are most likely to observe some difference)

Predictive Nature of Fitts' Law

- The throughput measure, derived from the Fitts' law, is descriptive
  - We need to determine its value empirically
- Fitts' law also allows us to predict performance
  - That means, we can "compute" performance rather than determine it empirically

Predictive Nature of Fitts' Law

- Although not proposed by Fitts, it is now common to build a prediction equation in Fitts' law research
- The predictive equation is obtained by linearly regressing MT (movement time) against the ID (index of difficulty), in a MT-ID plot

Predictive Nature of Fitts' Law

- The equation is of the form

  MT = a + b.ID

  a and b are constants for a test condition (empirically derived)

- As we can see, the equation allows us to predict the time to complete a target acquisition task (with known D and W)

Predictive Nature of Fitts' Law

- How we can use the predictive equation in design?
  - We determine the constant values (a and b) empirically, for a test condition
  - Use the values in the predictive equation to determine MT for a representative target acquisition task under the test condition

Predictive Nature of Fitts' Law

- How we can use the predictive equation in design?
  - Compare MTs for different test conditions to decide (as with throughput)
- In the next lectures (case studies), we shall see an interesting application of the predictive law in design

A Note on Speed-Accuracy Trade-off

- Suppose, we are trying to select an icon by clicking on it. The icon width is D
  - Suppose each click is called a “hit”. In a trial involving several hits, we are most likely to observe that not all hits lie within D (some may be just outside)
  - If we plot the *hit distributions* (i.e., the coordinates of the hits), we shall see that about 4% of the hits are outside the target boundary

A Note on Speed-Accuracy Trade-off

- This is called the speed-accuracy trade-off
  - When we are trying to make rapid movements, we can not avoid errors
- However, in the measures (ID, TP and MT), we have used D only, without taking into account the trade-off
  - We assumed all hits will be inside the target boundary

A Note on Speed-Accuracy Trade-off

- We can resolve this in two-ways
  - Either we proceed with our current approach, with the knowledge that the measures will have 4% error rates
  - Or we take the effective width D_e (the width of the region enclosing all the hits) instead of D
- The second approach requires us to empirically determine D_e for each test condition

The Hick-Hyman Law

- While Fitts' law relates task performance to motor behavior, there is another law popularly used in HCI, which tell us the "reaction time" (i.e., the time to react to a stimulus) of a person in the presence of "choices"
- The law is called the Hick-Hyman law, named after its inventors

Example

- A telephone call operator has 10 buttons. When the light behind one of the buttons comes on, the operator must push the button and answer the call
  - When a light comes on, how long does the operator takes to decide which button to press?

Example

- In the example,
  - The “light on” is the stimulus
  - We are interested to know the operator’s “reaction time” in the presence of the stimulus
  - The operator has to decide among the 10 buttons (these buttons represent the set of choices)
- The Hick-Hyman law can be used to predict the reaction times in such situations

The Law

- As we discussed before, the law models human reaction time (also called *choice-reaction time*) under *uncertainty* (the presence of choices)

  - The law states that the reaction (decision) time T increases with uncertainty about the judgment or decision to be made

The Law

- We know that a measure of uncertainty is entropy (H)

  Thus, $T \alpha H$

  or equivalently, $T = kH$, where k is the proportionality constant (empirically determined)

The Law

- We can calculate H in terms of the choices in the following way

  let, p_i be the probability of making the i-th choice

  Then, H = $\sum_{i} p_i \log_2(1/p_i)$

The Law

- Therefore,

$$T = k\sum_{i=1} p_i \log_2(1/p_i)$$

- When all the probabilities of making choices becomes equal, we have $H = \log_2 N$ (N = no of choices)
  - In such cases, $T = k \log_2 N$

Example Revisited

- Then, what will be the operator's reaction time in our example?
  - Here $N = 10$
  - A button can be selected with a probability 1/10 and all probabilities are equal
  - Thus, $T = k \log_2 10$

    $= 0.66$ ms (assuming $a = 0$, $b = 0.2$)