Fitts' and Hick's law: cognitive modeling methods that could be used to improve usability of the User Interface.

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1.0 Introduction

The interaction between a user and a computer, such as moving a pointer or clicking/touching an icon on the computer's monitor screen, is commonly referred to as Human Computer Interaction (HCI).

Human Computer Interaction occurs at the User Interface (UI). In the context of software component, User Interface is a set of commands, menus, icons, instructions, among other things that allow a user to interact with a computer.

This paper is focusing on two cognitive modeling methods that could be used to improve *usability* of the User Interface: Fitts' law and Hick's law.

2.0 Fitts law

Fitts' law (pronounced Fitzes law) is an empirical model of human *movement* behavior which was theorized by a psychologist Paul Fitts of Michigan University in 1954. The theory has been a subject of numerous studies, especially related to Human Computer Interaction.

Fitts' law has been formulated mathematically in several different ways, one of which is proposed by Scott Mackenzie of York University which is derived from Shannon-Hartley theorem.

2.1 Definition

Fitts' law states that the time it takes to move from a starting point to a final target is proportional to the distance of the target and the size of the target. In other words, the shorter or further the distance to the target and the smaller or larger the size of the target, the slower or faster the moving time will be.

In mathematical expression, Fitts' law can be said that the time required to reach the target is approximately proportional to a logarithmic function of the distance to the target and the size of the target plus 1:

$$T = a + b\log_2(\frac{D}{W} + 1)$$

2.2 Modeling Fitts law

Fitts' law can be mathematically modeled in several different ways. In this paper, we use McKenzie formulation which derived from Shannon-Hartley theorem and Card et al Index of Performance.

In the figure below, the larger the size of the icon and the shorter the distance from the arrow, the faster it would take to move the arrow from a starting position to the icon. Inversely, the smaller the size of the icon and the further the distance from the arrow, the longer it would take to move the arrow from a starting position to the icon.

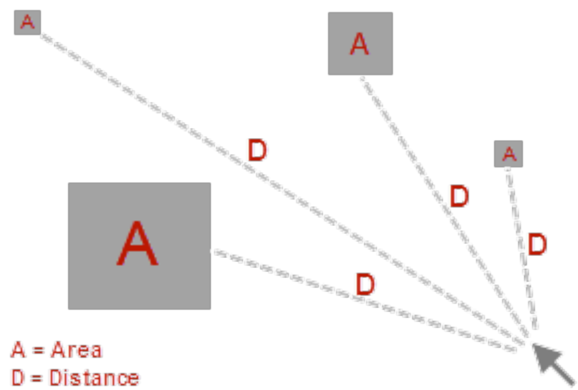

Figure 1

Derived from Shannon-Hartley theorem, various Fitts law equations can be written as follow:

$$T = a + b\log_2(\frac{2D}{W}) \qquad (1)$$
$$T = a + b\log_2(\frac{D}{W} + 0.5) \qquad (2)$$
$$T = a + b\log_2(\frac{D}{W} + 1) \qquad (3)$$

Where:

W = Width (or tolerance) of the target – measured in pixel
D = distance (or amplitude) to the target – measured in pixel
a = speed (or intercept) of the device – measured in bit per second
b = level of difficulty (or slope) of the device – measured in bit per second

The equation (1) is the original Fitts formulation, equation (2) proposed by Welford (1968) and the latter proposed by MacKenzie (1989). Throughout this paper, we are using MacKenzie's formulation because the Index of Difficulty (more on this later) cannot be negative (i.e. when$D < \frac{W}{2}$) and the data from Fitts' experiments yields higher correlations than the other two formulations.

The dependent variables a and b are empirical constants obtained by sampling and applying linear regression analysis. The values are entirely depending on the subjects, input devices and tasks being tested; therefore they vary significantly from different studies.

For mouse in point-select tasks, the dependent variable a represents the speed of the device (i.e. a mouse cursor could be configured to move slower or faster). The dependent variable b represents the level of difficulty of (or using) the device (i.e. a mouse and a joystick maybe used for controlling the system, but a mouse could perform better in some applications, like word processor, than the joystick).

The logarithmic factor of the equation (3) is called the Index of Difficulty (denoted ID), which defined as the index of difficulty to complete the pointing task and it can be denoted as:

$$ID = \log_2(\frac{D}{W} + 1) \qquad (4)$$

From the equation (4) above, the Index of Difficulty increases as the distance to the target increases and the size of the target decreases. Putting together, the reciprocal of the slope coefficient b can be determined:

$$T = a + b\log_2(\frac{D}{W} + 1)$$

$$T = a + b \times ID$$

$$\frac{1}{b} = IP = \frac{ID}{T - a}$$

The reciprocal of the slope coefficient b interpreted as bandwidth or Index of Performance (denoted IP) which gives measure of the information capacity of the human motor system. Using the regression coefficients from Card et al (1978) experiments on a mouse in point-select tasks, the mean of Index of Performance is 10.4 bits/s and the dependent variables a and b are: 1030 ms, 96 ms/bit respectively.

2.3 Applying Fitts law

Since the coefficients a and b of the equation vary heavily on the subjects, input devices and tasks being tested, the examples below are presented using Card et al experimental data obtaining from a mouse in point-select method.

Consider the web-based login dialog (shown in Figure 2): the system does not automatically place the mouse cursor in the "Username or email address" input field. In this case, the subject has to move the mouse cursor from the starting position and place it in the "Username or email address" input field.

Figure 2: without focus

The distance D from the mouse cursor to the "Username or email address" input field is about 170 pixels and the width W of the input field is about 20 pixels, and the time required to move the mouse cursor and place it in the input field is therefore about 1.34 seconds:

$$T = 1030 + (96)\log_2(\frac{170}{20} + 1)$$
$$T = 1341.8\, ms \approx 1.34\, sec$$

Now consider the login dialog in Figure 3 below, the system does automatically place the mouse cursor in the "Username or email address" input field; therefore the Index of Difficulty would be zero – zero time effort (note that, the coefficients a and b are no longer applied here.)

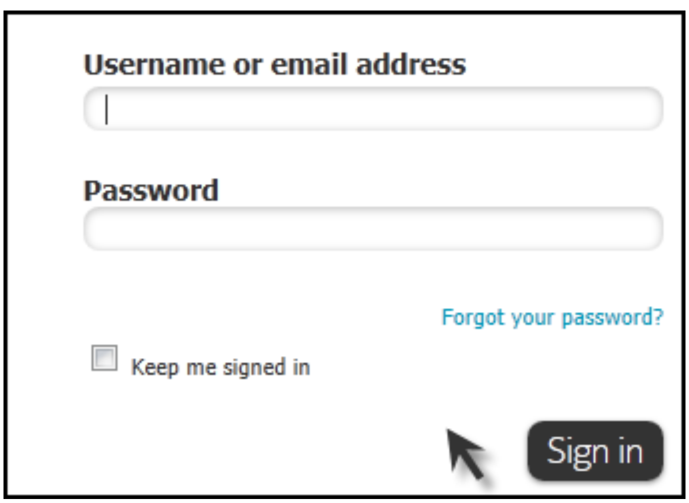

Figure 3: with focus

2.4 Conclusions & Recommendations

Fitts' law is one of the few reliable models in Human Computer Interaction. It is widely used to study the performance of the human movement time.

Following Card et al (1978) experiment data on a mouse in point-select tasks, the mean value of the dependent variable a = 1030 ms/bit and b = 96 ms/bit can be used to determine the linear relationship between the index of difficulty and movement time.

From examples in our section 2.3 above, we can see that the performance of human movement could be improved, if we:

- Reduce or completely eliminate the distance D as much as possible.
- Increase the dimension W of the target area as reasonably large as possible.
- Avoid drag-drop task if point-select task can be achieved in lesser time. The point-select task has lower Index of Performance (IP) than the drag-drop task because it uses less muscle tension.
- Build intelligent systems that can assist users (or predict the behaviors of the users) such that the distance D is reduced or completely eliminated (i.e. automatically put a mouse cursor in the target)

3.0 Hick's law

Hick's law is an empirical model of human *reaction* behavior which was theorized by a psychologist William Edmund Hick of University of Cambridge in 1952. In 1953, Hick's law was modified by a psychologist Ray Hyman of University of Oregon which is known as Hick-Hyman law.

The different between Fitts' and Hick's law is that Fitts' law predicts the human "movement" time whereas Hick's law predicts the human "reaction" time.

3.1 Definition

Hick's law states that a human's reaction time increases as the number of choices increase. In other words, the time it takes a person to make a decision or selection is determined by the number of choices or options available to choose from. As the number of choices or options increase, the time it takes to make a decision or selection also increases.

In mathematical expression, Hick's law can be said that the reaction time is approximately proportional to the logarithmic function of the number of choices plus 1:

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

3.2 Modeling Hick's law

In the Shannon-Weaver information theory concept, Hick's law can be modeled:

$$T = a + bH$$

H is the entropy, defined as:

$$H = \sum_{i=1}^{N} p_i \log_2(\frac{1}{p_i} + 1)$$

So we have:

$$T = a + b \sum_{i=1}^{N} p_i \log_2\left(\frac{1}{p_i} + 1\right)$$

Where:

- Given N choices, ith choice occurs at probability p_i such that the sum of all probability p_i equals to 1.
- a = speed (or intercept) of the device – measured in bit per second
- b = level of familiarity (or slope) of the tasks – measured in bit per second

The dependent variables a and b are empirical data obtained through regression analysis. The dependent variable b represents the familiarity of the tasks being tested. For example, poorly or unfamiliarity icons (like in Figure 4) increases the values of a and b, but highly familiarity icons (like in Figure 5) only decreases b.

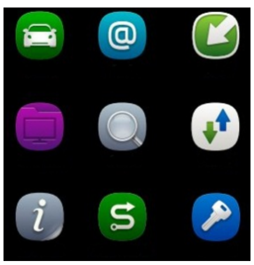

Figure 4

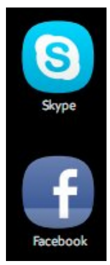

Figure 5

The more icons (choices) and the lesser familiarity of the icons (like in Figure 4), the longer time it takes to make a decision or selection. On the other hands, the lesser icons (choices) and the more familiarity of the icons (like in Figure 5), the shorter time it takes to make a decision or selection.

There are many factors influencing the reaction time such as age, gender, intelligence, personality, etc., but studies suggest that the mean value of the coefficient b is about 150 msec.

3.3 Applying Hick's law

Consider a web menu in Figure 6 below. In its initial state, all menu items are in closing position (hiding all of its sub-menu items), but when a user clicks on any one of the menu item, that menu item will expand and show all of its sub-menu items. If a user clicks on other menu item, that new menu item will expand and the previous opening menu item will be closed automatically. The design idea is to minimize the number choices by showing only the menu items that the user is looking for.

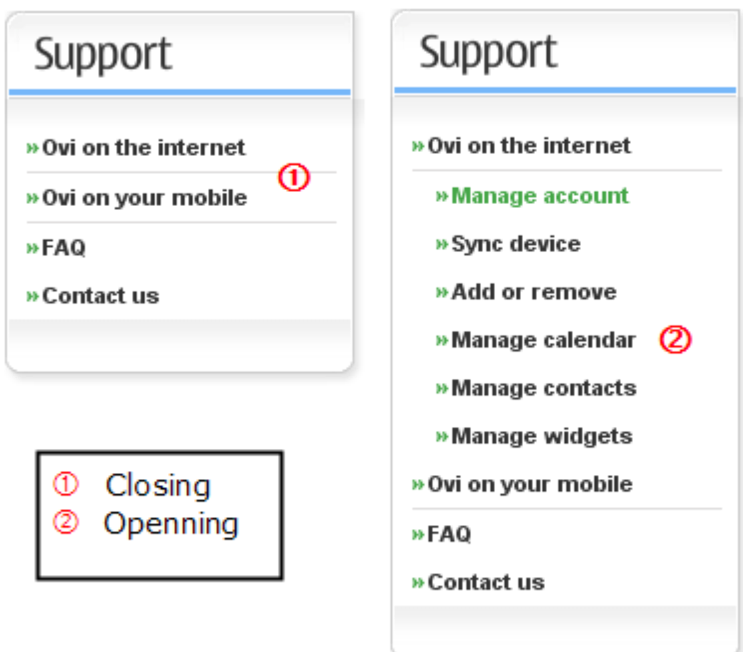

Figure 6

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