Experimental Review of Fitts' Law

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1 Introduction

In Human-Computer-Interaction (HCI), a widely researched topic is the arrangement, distance and size of Graphical User Interface (GUI) elements and their possible influence on the achieved User Experience. There are different theoretical ways of mathematically calculating the so-called human performance when using a software.

1.1 Fitts' Law

One of these approaches is Fitts' Law. This paper discusses a review of it, which has been taken place in an experimental setting. You will read more about it in Chapter 2 on page 4, but let me first give you a rapid insight into some necessary theoretical aspects.

Fits' Law describes a dependency between the *movement time* (MT) and the *index of difficulty* (ID). Commonly, it is represented in the form of a linear regression:

$$MT = a + b * \log_2 (\frac{2 * A}{W}), \tag{1}$$

with $ID = \log_2 (2 * A/W)$ where A is the distance, e.g. of the mouse pointer and W, the width of the object, i.e. a button, a is the intercept an b is the slope.

Paul Fitts idea is based on the *Shannon entropy*. Fitts assumed, that when solving movement tasks, the information is transmitted through a channel ("human channel"), like in a system in information theory. He refered to Shannon's Theorem 17 (MacKenzie, 1992):

$$C = B * \log_2 (\frac{S + N}{N}), \tag{2}$$

where C is the effective information capacity in bits/s, B is the bandwidth in Hz, S the signal power and N the noise power. Therefore, the noise reduces the theoretically possible capacity.

Fitts conveyed Equation 2 to:

$$IP = \log_2 (2 * A/W)/MT \iff MT = \log_2 (2 * A/W)/IP, \tag{3}$$

where IP is the index of performane. Compared with Equation 2, MT matches 1/B, IP matches C and the log-term is completely replaced by ID. By using linear regression, the right-hand part of term 3 may be transferred to Equation 1.

1.1.1 Alternative Forms. There are several variations of Fitts' Law, especially with different ways to calculate the ID. One approach, which looks more like Shannon's Theorem in Equation 2 is:

$$ID = \log_2 \frac{A+W}{W} \tag{4}$$

2 Experimental Review of Fitts' Law

Being based on Fitt's law, an easy testing environment has been created. For calculating the ID, an alternative formula, compare Equation 4, has been used. Regarding the theory of Chapter 1 on page 3f. the following hypothesis is proposed:

Hypothesis 1 *The higher the ID gets, the higher the MT is.*

2.1 Testing Environment

2.1.1 Describing a Test Run. A self-written piece of software has been used as a testing environment. At first when starting it, there is only a GUI with a centered red rectangle and a label with instructions visible for the test person (compare Figure 1). As soon as the user moves its mouse pointer to the rectangle and hovers it, both a new button and a belonging instruction will appear (see Figure 2). He or she is asked to click the button. A counter will track the timespan between leaving the red rectangle and clicking the button. The procedure of navigating the mouse pointer to the rectangle and then clicking the button will be repeated for ten times. While the rectangle stays centered, the position and width of the button changes in each iteration.

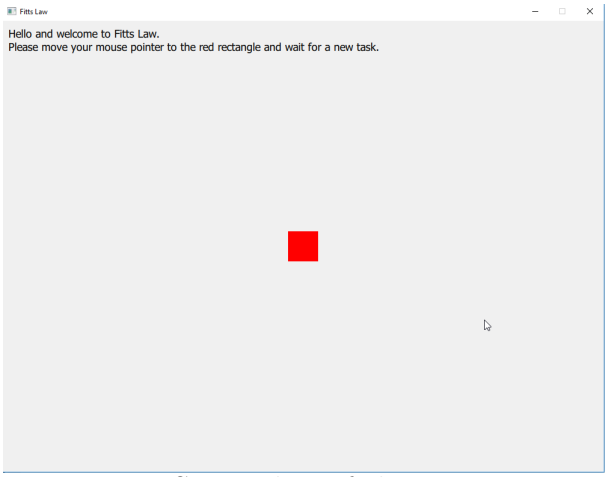

Figure 1. Screenshot of the start screen

Clicking the button triggers the software to write a new dataset containing the *Test Person ID*, the *Button ID*, the *distance between the rectangle and the*

button, the *width of the button*, the *recorded time* and the *Index of Difficulty* to a comma-separated file (*.csv).

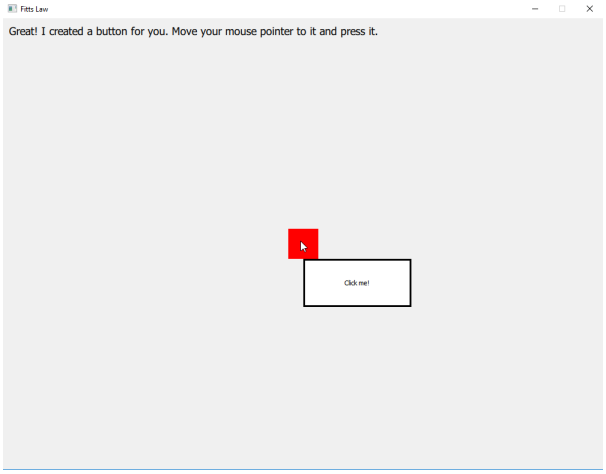

Figure 2. Software waits for a button click.

2.1.2 Explaining the Source Code. The software is written in QML, which is part of the C++ library Qt. The code for writing to and reading from the CSV-file is directly written in C++.

Every time the user clicks the button, a Javascript function `calculateResults()` will be called. Its return value will be passed to a C++ method `writeToFile`, which then adds a new entry to the CSV file.

```
function calculateResults(start, target, time){

    var distance = getDistance(getCenter(start), getCenter(target));
    var realwidth = getRealWidth(getCenter(start), target);
    var difficultyIndex = getDifficultyIndex(distance, realwidth);

    var string = testPerson + ", " +
    testCounter + ", " +
    distance + ", " +
    realwidth + ", " +
    time + ", " +
    difficultyIndex;

    return string;
}
}
```

The ID is calculated in the function `getDifficultyIndex()`.

```
function getDifficultyIndex( distance, objectWidth ) {
    var iod;
    iod = Math.log(distance/objectWidth+1)/Math.log(2);
    return iod;
}
```

It receives the distance as a parameter, which has been calculated previously using the function `getDistance()` (using Pythagorean theorem):

```
function getDistance( startPosition, targetPosition ) {
    var distance;

    distance = Math.sqrt(Math.pow(startPosition.x - targetPosition.x, 2) +
    Math.pow(startPosition.y - targetPosition.y, 2));

    return distance;
}
```

`getRealWidth()` calculates the angle dependend width. For details of code documentation, please refer to the inline style comments.

2.2 Test Realization

The experiment has been carried out using a 13.3" notebook and its built-in touchpad with a size of about 9.7 x 6.5 cm. A sample of $N = 26$ test persons have been part of the experiment.

2.3 Evaluation

To evaluate the measured data, the mean MTs of all 26 test persons has been calculated for each button, compare Table 1. There is a high positive correlation of r = .744 (p < .001) between ID and MT. Thus, the proposed Hypothesis 1 can be confirmed.

Button-ID	Difficulty Index	Time / ms
0	0.8579809951	1106.269231
1	2.584962501	1547.846154
2	1.938599455	1170.192308
3	3.14974712	1324.038462
4	3.247927513	1564.423077
5	3.491853096	1220.615385
6	3.68182404	1319.153846
7	0.5849625007	706.2692308
8	4.14974712	1514.153846
9	2.68182404	1077.653846
r = .744 (p < .001)		

Table 1

Overview of the difficulty index and mean time.

However, the measured time is about 3.3 times higher than the expected value, assuming a = 50 ms and b = 150 ms. Linear regression (see 3) yields a slope value of about 165 and an intercept value of about 820. The r^2 value is just 0.553.

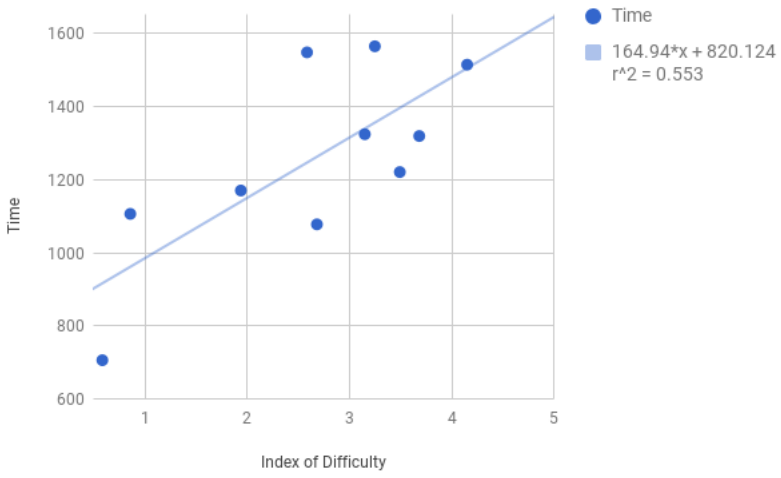

Figure 3. Index of Difficulty and Mean Time

To achieve both a higher correlation and a higher r^2, in a second step instead of calculating the mean values, the medians have been used for each button. It is a good choice to even out skewed values. As you can see in Table 2, using the median generates a strong, even higher positive correlation of r = .869 (p < .001). In this case, the measured time is about 2.9 times higher than the expected value, assuming a = 50 ms and b = 150 ms.

Button-ID	Difficulty Index	Time / ms
0	0.8579809951	994.5
1	2.584962501	1301.5
2	1.938599455	1028
3	3.14974712	1291
4	3.247927513	1410
5	3.491853096	1266
6	3.68182404	1213.5
7	0.5849625007	624
8	4.14974712	1370
9	2.68182404	1133
r = .869 (p < .001)		

Table 2

Overview of the difficulty index and median time.

Now r^2 = .755, the new slope is about 171, the new interference about 711 (compare Figure 4). There are different possible explanations for the relatively high MT values in both versions (mean and median), e.g. the use of a trackpad instead of an external mouse or the changing places, where the tests have been accomplished.

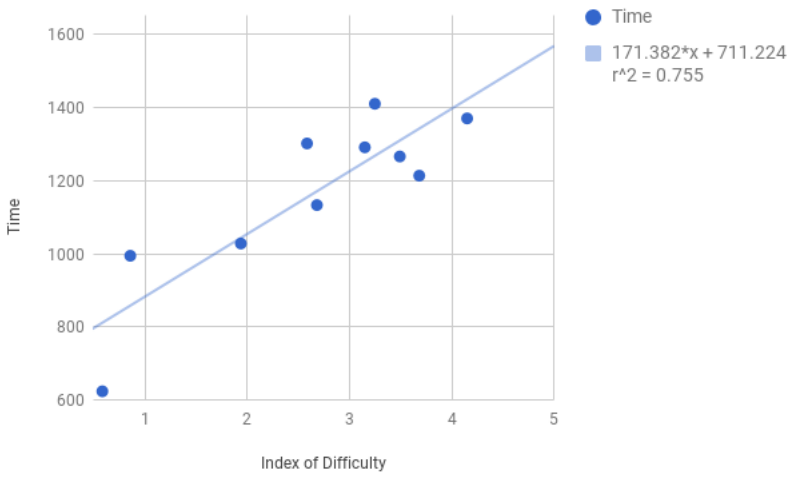

Figure 4. Index of Difficulty and Median Time

3 References

MacKenzie, I. S. (1992). Fitts' law as a research and design tool in human-computer interaction. *Human-computer interaction*, *7*(1), 91–139.