Analyzing Users' Performance Interacting with a Digitized Traditional Game on Multi-Touch Display Using Fitts's Law

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***Abstract*—This paper presents an analysis of digitalizing traditional games by using multi-touch digital tabletop through Fitts's law. The objectives of this paper are to study the accuracy of the user aiming performance using the Fitts's Law towards the application, and to determine the movement time with different index of difficulty of the application. Besides, it's to determine the appropriate size of the shooter marble and the target marble for the game design on the multi touch digital tabletop based on traditional games. The development encourage the collaborative works among the children to communicate with each other for increasing their social skills. The conducted experiment concludes the suitable size of the object in the application with the size of tabletop in guiding the user interface (UI) development.**

***Index Terms*—Digitizing Game; Fitts's Law; Multi-Touch Digital Tabletop; User Performance.**

I. INTRODUCTION

Traditional games exist in almost every culture in the world. The games bring people together. They show the values of collaborative, competitiveness and socialized among the players. It is one the ways for filling people's pastime [1]. In Malaysia alone, there are many traditional games that can be explored. Among them include kite flying, the martial arts collectively known as silat, top-spinning, congkak, marble games, and sepak takraw. Unfortunately, these games are no longer popular as pastime activities as they used to be especially among the younger generation. One of the reasons is due to the effect brought by new technology such as computer games, video games, and remote control machine.

Indeed modern technology is impacting many aspects of our life [2] but it is not necessarily all negatives. With the availability of gadgets such as tablet, computer, mobile phone, tabletop display allow users to access information easily as everything is at their fingertips. It encourages innovation and creativity from the users. An initiative has been found to combine traditional and modern games in order to attract the interest of young generation. The research has begun to venture into new game platforms such as tabletops and whole body interaction [3]. This digital tabletop is able to offer unique experience in terms of supporting collaborative works among the players.

Advances in technology have led to an increased manifestation of modern games as a consumer products in recent years. Still, many difficulties remain that designers need to face when outlining for collaborative interaction which involved multiple players. As multi-touch interfaces are becoming more pervasive it is significant to explore not only their performance for certain tasks, but also the user experience of interacting with such interfaces. This gives users a stronger sentiment of having control over their interactions as opposed to being controlled by the system. Another part of direct interaction is that it makes interacting with advanced interfaces open to an expansive range of users. Besides, the innovation empowers concurrent co-located collaboration, particularly on bigger surfaces that give physical bearing which will lead to higher performance [2].

This paper presents a study on the user aiming performance using the Fitts's Law towards the application for designing the user interface (UI) for the interface design, to determine the movement of time with different index of difficulty. Finding the right size for the object that will be used in the interface design to be played on the tabletop for multi-touch digital tabletop based on traditional games. The idea is to combine the traditional games with the existing new technology. It is to study on the collaborative works that can be performed on the tabletop for the digital traditional games. The developed prototype is used to determine the accuracy of the user aiming performance based on the size and distance of the object towards the interface design on the multi-touch digital tabletop based on the Fitts's Law.

II. LITERATURE REVIEW

A. Digital Games

Digital games are interactive games that can be played on computer, tabletop, console and mobile phone or tablet and is either individually or many players. According to Iversen et al. [4], a digital game is an interactive program for one or more players, meant to provide entertainment at the least, and quite possibly more. It is an adaptation of 'traditional' game systems, with rules, player representation, and environment managed through electronic means. Digital games have becoming a trend because of the development of technology in term of mobile devices as well as others. Players tend to install game application in their mobile device as entertainment. Zülfü and Emrah [5] highlighted that digital games present a form of interactive, relational, experienced-based learning that uses instructional technologies such as simulation and multimedia presentations. They are also fun, particularly for children and young people, and therefore, highly motivating. These games basically will give them enjoyment and satisfaction when they are experiencing the environment of playing games.

Tabletop technology encourages group interaction around one interface in a way that other computer workstations and video gaming systems do not [6]. This digital tabletop can be used for medical purposes, education, manipulating photos

and documents, communication as well as gaming that need to have the collaborative works. Research has demonstrated that tabletop displays are useful for gaming and entertainment. Multi-touch digital tabletop is the recent technology that is use for collaborative work. Characteristics of multi-touch tabletops, for example, a substantial intuitive surface and concurrent multiple user input can be exploit in the design of interactions that encourage positive social association among kids amid synergistic exercises [7]. According to Antle et al.[3], digital tabletop offer unique opportunities to facilitate collaborative learning interactions. The digital tabletop will be useful for learning as the user will able to interact with the device via hand gesturing that will increase the user interest.

B. *Fitts's Law*

To design application for the IT device such as tablet, tabletop, smartphone, the human computer interaction (HCI) need to be considered to prevent flaws in term of user performance. The movement element to be considered consists of speed and accuracy of the user performance towards the application. In this project, in designing the application on the tabletop, the size of the game elements is crucial because the tabletop itself is large. The size of the object in the game does matter because it will determine the accuracy of the user's aiming performance. According to Meena, and Sivakumar [8], users will find it more difficult to manipulate small objects. Targets should generally be as large as possible and the distance to be moved as small as possible. However, it depends on the screen size because the size of the screen will give different impact on the accuracy of the user and also it depends on the game itself.

In this project, the Fitts's Law will be applied to study the accuracy of user's aiming performance towards the game. The game is about aiming the target by using the main marble. Fitts's Law is used to check if the size of the marble is suitable for the games because the game will be played on the multi touch digital tabletop with the size of the 40 inch tabletop. Thus, the design of the marble need to be suitable to the size of the tabletop. The Fitts's Law has been known as the performance model. According to Mizuhara, Hatano, and Washio [9], Fitts' Law is a mathematical model that predicts how long it will take to "point" at a target. Meanwhile, Bi, Li, and Zhai [10], stressed that without Fitts' law, performance scores for pointing or tapping times are only meaningful under a set of specific experimental conditions that referred to target sizes and distances.

III. THE EXPERIMENT

Figure 1 shows the marble games or digital traditional game called Guli. The user will need to start the game, then the user will redirect to the main menu which is divided by three parts; start, option and quit. To set the audio, control and the display, the user needs to go to the option part so that the changes can be made. If the user would like to quit the game, the user may click the quit button. The user may click the start button to start the game and need to choose either to play individual which is known as solo or choose cooperative if the user wants to play with many players.

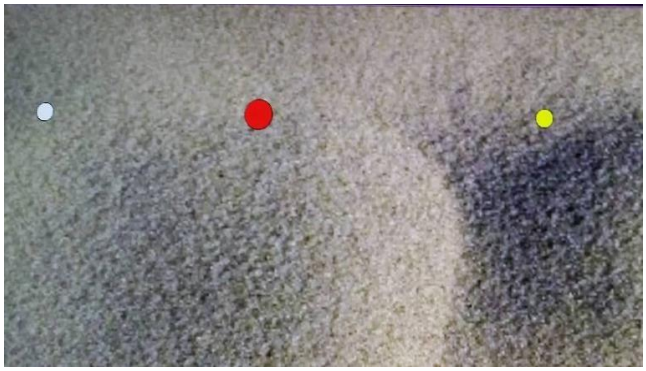

Figure 1: Marble games interface

A. *Experimental Design*

The experiment has been divided into four types which depends on the target size and the distance and has been labeled with experiment A, B, C and D. There are two hypothesis that will be proven in these experiments which are the higher the index of difficulty, the longer the movement of time, and the larger the shooter marble, the smaller the target marble, the higher the index of performance of the accuracy of the user aiming. There are 6 participants who involved in the testing of the accuracy of user aiming performance towards the application. The participants have three trials to test the application for each Index of Difficulty (ID) which consists of ID = $\log_2$ (A/W+1) consists of the distance (A) and the size (W). Formula that will be applied to calculate the Index of Performance (IP) is:

$$MT = a + b\ log_2\ (A/W + 1) \quad (1)$$

$$\text{IP} = \text{ID/MT} \quad (2)$$

In which later the value of b is to be obtained from the graph that is projected from the data. The higher the IP then, the size of the target and the shooter is more suitable for the UI design for this application. The Table 1 shows the result of the experiment with the size of marble 30 pixels and 50 pixels for difference distance which are 750, 1000, and 1500 in pixels. The experiment require users to pull and released the force game simulation as shown in Figure 1. The force is fixed to 10cm in the setting for entire experiment in which the user needs to pull the force 10cm from the center of the shooter marble.

B. *Result*

This experiment is based on different size of the shooter is either larger than the size of the target or vice versa as shown in Table 1 to 4. In overall experiment, its shows that when the ID increases, the movement of time (MT) also increases. However, the ID is different as compare to each table because of the size of marble and width of the target is different. The ID started from 4 bits when the size of Target Marble (W) set as 50 pixels while change to 4.7 bits when the size of Target Marble is set to 30 pixels. As for the Index of Performance, each experiments produces 0.000308 bits/ms, 0.000329 bits/ms, 0.000307 bits/ms, and 0.000271 bits/ms accordingly. The experiments shows that when the size of the object is the same and the size is smaller produced the lowest index of performance as compare to the other three.

Table 1
Experiment A: Shooter Marble: 30; Target Marble: 50; Distances 750, 1000 and 1500.

A	Shooter Marble	Target Marble (W)	ID (bits)	MT (ms)
750	30	50	4	826.667
1000	30	50	4.392317	2098.889
1500	30	50	4.954196	2269.444

Table 2
Experiment B: Shooter Marble: 50; Target Marble: 30; Distances 750, 1000 and 1500.

A	Shooter Marble	Target Marble (W)	ID (bits)	MT (ms)
750	50	30	4.70044	763.889
1000	50	30	5.101538	1983.333
1500	50	30	5.672425	2262.778

Table 3
Experiment C: Shooter Marble: 50; Target Marble: 50; Distances 750, 1000 and 1500.

A	Shooter Marble	Target Marble (W)	ID (bits)	MT (ms)
750	50	50	4	825.5556
1000	50	50	4.392317	2104.444
1500	50	50	4.954196	2313.333

Table 4
Experiment D: Shooter Marble: 30; Target Marble: 30; Distances 750, 1000 and 1500.

A	Shooter Marble	Target Marble (W)	ID (bits)	MT (ms)
750	30	30	4.70044	800
1000	30	30	5.101538	2278.889
1500	30	30	5.672425	2723.889

IV. DISCUSSION

The objective of this project is to determine the accuracy of the user aiming performance using the Fitts's Law towards the application. The result of the accuracy will be used to design the UI of the application to make sure that the size of the object in the application is suitable with the tabletop. From the experiments as shown in Table 1 to 4, the hypothesis is accepted where the higher the index of difficulty (ID) produces the longer movement of time (MT). However, we can see that the ID is different in the experiment. When the width of the target is 30 the lower ID is 4.7 while when the target width is 50, the ID will start at 4 bits. This can be said that the smaller the size of the target marble, the higher the index of the difficulties. It is difficult for the user to aim the target which lead to the lower index of performance and the accuracy of the user aiming performance will be less.

In order to support the experiment's result, analysis of variance (ANOVA) is used to analyze the data to verify that both of the hypothesis are accepted. The ANOVA calculation is divided based on the experiment to find the higher F is able to reject the null hypothesis and find the best result among all the experiments. An F statistic is a value return form ANOVA test which give a meaning between two populations is either significant or not. Table 5 shows sample ANOVA test results which gather form the experiment where its produces larger value of F compare to the F critical value. Thus, the null hypothesis is rejected and the hypothesis of the experiment set in the experimental design is accepted.

Table 5
ANOVA table for the experiment

Experiment	F	F Critical Value	Remark
Shooter Marble = 30 Target Marble = 50	67.62	3.68	F > F CRITICAL VALUE = 67.62 > 3.68. Thus, the hypothesis is accepted
Shooter Marble = 50 Target Marble = 30	89.85	3.68	F > F CRITICAL VALUE = 89.85 > 3.68. Thus, the hypothesis is accepted
Shooter Marble = 50 Target Marble = 50	73.80	3.68	F > F CRITICAL VALUE = 73.80 > 3.68. Thus, the hypothesis is accepted
Shooter Marble = 30 Target Marble = 30	84.38	3.68	F > F CRITICAL VALUE = 84.38 > 3.68. Thus, the hypothesis is accepted

Furthermore, Table 2 shows the larger the shooter marble, the smaller the target marble, the higher the index of performance of the accuracy of the user aiming. It is proven where the sequence of F value is experiment B > experiment D > experiment C > experiment A, whereby experiment B has larger shooter marble, smaller target marble and the higher index of performance. Thus, the second hypothesis is accepted with higher index performance it shows that the larger shooter marble will have higher accuracy towards the smaller target compare to the other condition.

In addition, the second hypothesis is concerning the size of the shooter marble, target marble and the index of performance. This is because size and distance from the most common interactions should be considered when designing any UI element with which the user interacts [11]. From the experiment, we can see that the index of performance for the same size marble is lower than the different size of marble. This can be proof by calculate the index of performance using the Fitts's Law $T = a + b\ log2\ (A/W + 1)$; MT/ID = a + b; Index of Performance (IP) = 1/b. Thus, the result of the experiment that test the same size marble is not accepted which this statement refer to the experiment C and D. However, when the size of the both marbles are different, the index of performance is high. The higher index of performance, the higher the accuracy. These can be proof from the experiments A and B. From the experiment A we can see that the IP is 0.000308 while the experiment B the IP is 0.000329. The highest IP produced by experiment B where in this experiment B the shooter marble is larger compare to the target marble. Thus, the suitable size of the marble for the designing the UI of the application is to have a larger shooter marble, 50 pixels and a smaller target marble, 30pixels. With the highest index of performance gave higher accuracy as compare to the other condition of the size of marbles.

V. CONCLUSION

The traditional games tend to be forgotten by the young generation due to development of the new game technology. The development of digital traditional games using on multi-touch digital tabletop could motivate that the young generation not to forget the traditional games and to play the game in a modern way. By using the multi-touch digital tabletop, the user will have to collaborate among the players. The designing of the UI for this application have no issues on

the accuracy of the user aiming performance. The experiments concluded that the accuracy can be achieved if the size of the shooter marble is larger than the target marble which can be proof from the Fitts's Law.

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