American International University-Bangladesh (AIUB)

Comparing Usability and Efficiency of Graphical and Tangible Interaction Devices: Mouse, Touchpad, and Stylus-Pen in a 2D Environment.

A Comparative Study of User Performance and Preferences in a Graphic Manipulation Software

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Abstract

This purpose of this study is to evaluate the usability and efficiency comparison between mouse, touch-pad and pen-tablet integrated in a 2D graphical environment for completing a specific task in a graphical application or a software. This comparison will give a strong insight and to better understand the graphical and tangible devices and their performance and efficiency for an existing interaction technique. This graphical user interface or WIMP interfaces has become a standard paradigm for interaction styles in the past decades and people have been using it for more than 50 years. But Tangible interfaces have received a huge attention in recent years as the response of the people have named it "more intuitive". In our study we took, mouse as a graphical device and touch-pad and pen-tablet as a tangible device. So, our study will cover up both devices for 2D software manipulation and the comparison will indicate the probable most efficient device that is also easily adaptable. To compare these devices, we developed a python program to take the time to complete a task that is evaluated for all the device with different users. For overall calculation that is discussed in details in the methodology section, we applied Fitts law. For the precise performance evaluation, we took users with different levels of understanding and skills with these devices and some of them had a very little knowledge about all of the devices. The outcomes showed that, the users who already have good skills with the mouse, have performed better with the mouse but the touch-pad and pen-tablet weren't too tough for them to work with. On the other hand, the users with less experience using these devices or no experience at all have performed better with the touch-pad for the small distance. We've also discussed the overall performance and efficiency in time and the user's preferences in details in the results and findings section.

Declaration by author

We hereby declare that this research is composed of our original work that contains nothing that has previously been published for any degree or diploma for any educational institute and not deprived anything from another person's work. Information gathered from published or unpublished work has been acknowledged in the paper and the references has been given. We have clearly stated all the original work that has been done and reported in our paper.

We declare that the work has been done completely from the scratch and does not reveal any content that might disclose any secrets of any organizations or related parties. Anyway, if any of these cases might arrive, American International University-Bangladesh (AIUB) will not be held responsible.

Approval

(All candidates must edit this page)

The thesis titled **"Comparing Usability and Efficiency of Graphical and Tangible Interaction Devices: Mouse, Touchpad, and Stylus-Pen in a 2D Environment"** has been submitted to the following respected members of the board of examiners of the department of computer science in partial fulfilment of the requirementsfor the degree of Bachelor of Science in Computer Science on **(date of defence)** and has been accepted as satisfactory.

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No animal or human subjects were involved in this research.

Contributions by authors to the thesis

List the significant and substantial inputs made by different authors to this research, work and writing represented and/or reported in the thesis. These could include significant contributions to: the conception and design of the project; non-routine technical work; analysis and interpretation of researchdata; drafting significant parts of the work or critically revising it so as to contribute to the interpretation.

	Habib, MD. Tahsinur Rahman	**Shil, Diponkor Chandra**	**Sakib, MD. Sajid Al**	**Kibria, Rasel**	**Contribution (%)**
	18-37837-2	*18-37790-2*	*18-38085-2*	*18-37797-2*	
Conceptualization	20%	30%	20%	30%	100 %
Data curation	25%	25%	25%	25%	100 %
Formal analysis	30%	30%	20%	20%	100 %
Investigation	35%	25%	20%	20%	100 %
Methodology	20%	40%	20%	20%	100 %
Implementation	25%	30%	20%	25%	100 %
Validation	30%	30%	15%	25%	100 %
Theoretical derivations	20%	15%	35%	30%	100 %
Preparation of figures	25%	30%	20%	25%	100 %
Writing – original draft	25%	20%	30%	25%	100 %
Writing – review & editing	20%	20%	30%	30%	100 %

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Keywords

tangible, tangible user interfaces, graphical user interfaces, usability, adaptability, human-computer interaction, interactivity, haptic feedback, graspable user interface

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List of Abbreviations and Symbols

Mention all the abbreviations and the different symbols that is used in this document.

Abbreviations	
CS	Computer Science
CSE	Computer Science and Engineering
NN	Neural Network
HCI	Human Computer Interaction
NLP	Natural Language Processing
TUI	Tangible User Interface
GUI	Graphical User Interface
I/O	Input/Output
UI	User Interface
etc.	*etc.*

Symbols	
$\hat{\rho}$	Density operator
®	Convolution
etc.	*etc.*

Chapter 1

Introduction

1.1 Your thesis topic

Tangible User Interface (TUI) has become one of the most powerful mediums of user experience among all the other user interfaces and as an interaction medium for the people living in this digital world of technology. In this era, we are heavily dependent on digital devices and therefore, getting used to, with mostly used user interface like Graphical User Interface (GUI). Though from the very root of the humans, we have developed skills to sense and manipulate physical environment and objects, that has not been totally grasped in information technology as of yet. As a result, the interaction with digital devices is largely confined with GUI [1]. Therefore, as GUI became the most used interaction model till now, it has established itself as a standard paradigm for the interaction model in Human Computer Interaction [1]. This GUI representation is heavily manipulated by the I/O devices or remote controllers like keyboard, mouse etc. So, the interaction with GUI was also defined as, WIMP interface (Windows, icons, menus, pointer) [2]. Though WIMP interfaces can directly manipulate 2D graphical form [2], this interface has been capable enough to control almost everything that we meant to do with these devices. But as for the humans, our skills for manipulating physical environment doesn’t really cop with this WIMP devices [1]. Though people can do almost everything with these WIMP interfaces, the fact that these remote-control systems have traditionally been used to manipulate 2D objects, restores some certain limitations in executing this approach, like, the motor skills needed for manipulate a WIMP interface or efficiently use a keyboard and mouse are not really intuitive to learn and takes considerable time and practices to get used to it [3]. So, the idea of manipulating physical objects and integrating them in digital information has emerged. To overcome the limitations of WIMP interfaces, The Tangible Media Group at the MIT Media Laboratory moved from GUI to TUI in the mid-1990s [1]. Fitzmaurice, Buxton, and Ishii together took the innovative initiatives towards describing the new conceptual framework with their discussion of “graspable user interfaces” [4]. The main concept of TUI was to manipulate objects physically rather than graphically with our sophisticated human cognitive skills, that’d fit into the physical environment of a user and take haptic feedback to get the work done [1]. Another goal of this post-WIMP interface was to lesser the gap between a user’s motive to perform an action and the execution of that action [5]. Moreover, for interacting with the 3D environment TUI pushed the boundaries of traditional UIs [8] , including the direct manipulation of 2D graphical interfaces [6] , the use of gesture [5] and 3D space [5]. A TUI (initially referred to as “graspable user interface”) is defined as “… a UI in which a person interacts with digital information through the physical environment … taking advantage of the human ability to grasp and manipulate physical objects and materials” [3].

By the time, Tangible user interface (TUI) has recently become very intuitive among the users and got their attention as an alternative approach to the other UIs for some specific application domains [7]. Moreover, some recent developments of interaction models have led to this newly available tangible interaction into implementing it into some specific application [1], [8]. Recent studies have found that participants or users expressed a very keen interest in using TUI based interaction styles and they found that interaction style more enjoyable. That implies the encouraged interpersonal interactions with the tangible interfaces [2].

TUI brings more potentiality to manipulate objects with proper accuracy that is more affordable and adaptable in terms of user experience which is the main focus of our study. Our aim is to compare three TUI devices (mouse, touch-pad, pen-tab) that is integrated in a graphical environment and to variate them in terms of efficiency, accuracy, adaptability and usability in terms of engagement, which we will be addressed as affordance in a whole. To check the affordance for these devices we choose AutoCAD 2023 as all of these devices can be used in this software to perform a particular task. We took several sizes and shapes to evaluate the work pattern and the time takes to perform an action by using these devices separately. We developed a program to determine the time to perform an action. As for the users, we selected some participants to individually work on the three devices separately and calculate the index of difficulty for further calculations. The aim is not to evaluate the flexibility of engagement but the accuracy, efficiency and adaptability of the devices. This experiment may help us develop a better understanding that which of the devices would be better in the perspective of adaptability and efficiency in terms of time taken to perform the action properly. Nevertheless, the three devices that we'll be using for this study are not identical in characteristics and they all have some advantages and disadvantages depending on the given task or goal for the respective application. And the output of the devices may vary depending on the skills of the participants and the application domains. For other applications, among these three devices, the least performing one from this study may work better and might be the most affordable and efficient one. In summary, our contributions for this study will comprise

- In depth analysis of people's understanding of the usage of mouse, touch-pad and pen-tablet as a tangible device integrated in graphical environment,
- Compare these devices and the difference of their performance in a particular application. Outcome in efficiency and usability,
- Discussion of people's preferences and in which they performed better.

Some projects have started to implement and evaluate the usability of TUIs. However, there remains more aspects and more research are needed on this domain for proper and complete understanding of TUI. [9]

Chapter 2

Literature review

2.1 Introduction

Since the first implementation of TUI, it has been investigated from several angles like, designing for different application domains and then the comparative studies with GUIs, as GUI is already the largest interaction model that has long proved its value and practical adaptability for almost any application [10]. That was the main motivation for our work on this domain. To evaluate the performance between the TUI devices that is integrated in a graphical environment, against a mouse-based UI which is been used in a graphical user interface. The comparative studies between a TUI device and a GUI device has been going on for long to understand the performance of TUI against GUI that will indicate the future of TUI devices if emerges. Both categories will be used to manipulate 2D objects on a screen and the data will be taken to evaluate the performance. The whole process of choosing the domain and the devices to setting the environment, specify the workload, collecting the related work, work methodology, writing the program to take the time to perform an action, calculations and finally plotting the performance of each device will be discussed elaborately in the Methodology section. The result is discussed elaborately in the result and findings section.

As, the comparison between TUI and GUI has been going on since the first TUI applications, there is still a lot going on between these two interaction models and their adaptability.

Zuckerman and Gal-Oz examined TUI and GUI forms of a simulation and modeling system that were identical [11] . The results revealed that most users chose the TUI version compared to the GUI version, despite the fact that the TUI version was less usable than the GUI version and that both versions were comparable in time for the completion of tasks and performance quality. The users preferred the TUI version for the interaction style that uses physical manipulation, rich feedback and the realism it provides due to its physical interaction which is proved to be more enjoyable. Besançon et al. [12] researched on comparative performance evaluating the usability and adaptability of mouse-based, touch-based and a tangible interaction for manipulating 3D objects. Melcer et al. [13] compared the effectiveness of mouse and tangible design techniques for boosting key learning aspects in educational programming games. The results showed that, again tangible versions were more enjoyable and interesting to use than GUI, but both versions were successful to improve programming self-beliefs. Similarly, there are many more research approaches that have been done on TUI to improve learning capabilities based on the fact that TUI can provide hands on experience. That may have some positive learning outcomes [14]. For example, learning heart anatomy [15] and many research used TUI for chemistry to manipulate chemical molecules. Another comparative study of Sapounidis and Demetriadis on children's preferences on using Tangible and Graphical interfaces revealed that tangible interfaces were more attractive and fun to use specially among girls. Also, the other children have found TUI more enjoyable and easier to use. But on the other hand, older children, who are already more experienced with computers, have found graphical version easier and more usable [16].

A study of Nathoo et al. on the use of tangible user interfaces for teaching and learning process associated to IoT (internet of things) was to find out the usability and adaptability focused on the learning effectiveness [17]. The results showed that the students who used TUI-based system for learning, have a positive score on the usability of TUI and the knowledge gained from the system were considerably higher than the other learning processes. For another study Nathoo et al. evaluated a prototype using the system usability scale (SUS) to examine the usability of a TUI-based system for teaching Java programming principles [18]. Results showed that, though there were some limitations to the system, the developed prototype was satisfactory and learning effectiveness was much higher than previously used conventions. Koushik et al. developed a design of block-based game that allows blind programmers to learn the fundamentals of programming by producing audio stories [19]. According to the design, to create audio stories for learning basic programming for blind programmers, a group of teachers and students worked together, and their work presents a futuristic process of using tangible tools to learn programming.

There were more studies and research that were previously done on the TUIs learning and teaching capabilities. In most of the cases TUI showed better performance and most importantly the usability and adaptability were much more engaging than the general teaching and learning approaches.

Additionally, TUIs have also been studied in the gaming industry. As TUI uses physical haptic feedback, it emerges in the gaming industry as well due to its intuitiveness and interaction through the physical object manipulation. Several studies on TUI in the gaming industry which experimented on users showed that, users find it easier and enjoyable to use in TUI-based gaming environment. There were also some studies that showed otherwise. People who are already used to using graphical interfaces, performed better and have found it easier with the GUI, though they claimed that TUI was interesting and enjoying to go with. Some direct comparative studies on GUI vs TUI in gaming domain implies that, tangible interaction in gaming provides high and rich feedback, did great in competitive gaming environment and most importantly brings positive experience among the users. Another notable aspect was that, circulation, competitive environment, negative affect, and fatigue were not significantly impacted.

TUI has also been used in enhancing museum exploration experience. Comparative studies on the behaviors of museum visitors using tangible interaction or the physical controls shows better exploration experience to the users than the visualized distribution of the objects because of physical manipulation of objects afforded better physical controls to explore the environment and the experience was on another level according to the visitors.

There are still so many domains, that are yet to be explored, in which TUI has been implemented on. But in exploration of usability and intuitiveness TUI performed better according to the users but in efficiency the results are versatile as a large number of users are already used to using the graphical interaction model like computers. But for neutral users, tangible interfaces show improved efficiency that implies navigation time, accuracy and user satisfaction [3]. But in some cases, despite of better efficiency, there was some lacking in accuracy. In order to acquire a deeper understanding of the user experience, Lucignano et al. contrasted a real tool with a GUI implementation using eye-tracking data [20]. They came to the conclusion that TUIs provide more cognitive advantages since they take less mental effort. According to the domains explored, tangible user interfaces outperformed touch interfaces in efficiency and usability specially for the new users or inexperienced users as TUI takes less mental effort and practices.

In this study, our main purpose is to evaluate 3 devices (mouse-based, touch-pad, pen-tab) that have been implemented in a graphical environment, in terms of usability, adaptability and efficiency. For evaluating the usability and efficiency of our system we chose different users of different skill levels. Some of them were already good at using graphical interfaces like keyboard and mouse-based system, some of them were new users. Finally, to evaluate we choose some shapes to hit a specific target and that to evaluate efficiency from different users measured by a python program.

Chapter 3

Methods

3.1 Subjects

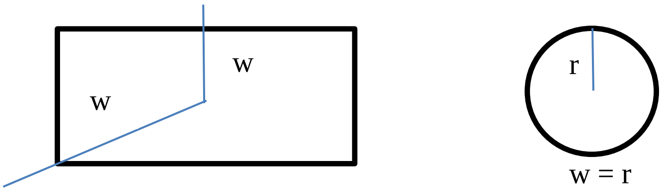
In the experiment for identifying result, thirty-six datasets were collected from twelve subjects (all male). Each subject participated in the experiments in which mouse, pen-tablet and touch-pad were tested. All the users are right-handed. Most of subjects had previous experience using mouse & touch-pad and continuously seven of them were using mouse & others were tested using touch-pad. Among the 7 mouse users, 5 of them had extensive skills and previous experience using mouse. But none of subject had previous experience using pen-tablet. Every user had to go through with three experiments. The instructions of the experiments were declared properly for their better understanding, they continuously monitored during the time of the experiment and the data were collected. Some of the subjects were new users and underaged but the age range of the experienced subjects were between 23 to 25 and they were using mouse and even touch-pad for some instance for their work or educational purposes for at least five years.

3.2 Apparatus

In this experiment, we used three different input devices which were integrated in a graphical environment. Four computers were used as the graphical I/O device to take inputs from the subjects. One of the computers was build-pc or desktop and the other three were laptops. And for the three devices we used Huion H640P Graphics Tablet, one A4tech Bloody 9 button Gaming Mouse & Build-in touch-pad of the three laptops were used as an input device for collecting data from different subjects. Beside this, some tools were used to design and some software were used to measure, calculate, store and compare the data. We used Microsoft Excel Sheet to store data and to generate the graph for better understanding the performance and compare own subject for iterating data & the variation of the data from one subject to another. As for the work environment and design purposes AutoCAD 2022 was used. To understand the efficiency of the tools, the measurement of time was an important part for the experiment. For that, a time measurement software was developed using Python programming language, which detected the time taken to successfully complete a task. The output of the program was shown in console.

3.3 Design

Two different design patterns were chosen to get the datasets for experiment. A design pattern was a toggling menu bar, as we use this feature everyday while using computers which is also used in any software provided for a specific OS. And another design pattern was a circle. The idea of using a menu in this research actually came from the operating system itself and different type of software. For this experiment, the menu holds two sub-menus. Each design pattern was taken twice for experimental requirement. For first menu, first sub-menu had amplitude of 8.1055 inches with width of 5.5 inches & second sub-menu had amplitude of 5.8719 inches with width of 2 inches. Moreover, this menu was selected to get the data of time from subjects. In second menu width was similar to the first menu, only difference was in amplitude. For second menu, first sub-menu had amplitude of 5.9267 inches & second sub-menu had amplitude of 5.8719 inches.



This experiment is based on time which depends on main object & target distance. Initial intention is to hit from point A (Object) to point B (target). Target object can be varies such as square, rectangle, etc. except circle other design pattern W varies according to the path. For example, when a rectangle is selected, the diagonal maximum W can be obtained. If the path doesn't hit diagonally, then the value of W will be less. Since a circle has fixed radius, that's why the circle is chosen as target to avoid error probability. For first circle, target amplitude was 7.2467 inches with width of 2.9845 inches and second circle, target amplitude was 5.4979 inches with width of 2.9845 inches.

3.4 Procedure

First thing, the objective is to enhance Tangible User Interface through human cognition. Fitts' law is applied because from its time measurement, it can be mathematically or graphically visualizing the data calculation if it is adaptable by human or not.

Fitts' Law:

Time T_{pos} to move the hand to target size W which is the distance D away is given by [21],

$T_{pos} = a + b \log_2 (D/W + 1)$

Tangible User Interface is such an interface where technical information collects from physical object [22]. For analysis, three different devices, mouse, touchpad and pen-tablet are selected. To test the equipment's that it is adaptable for human or not, some design patterns needed that make Affordance.

As looks doesn't mean anything, so for researching purpose these two patterns were designed for a realistic and logical data. The reason for choosing this two-design pattern was already mentioned earlier. AutoCAD 2022 was used to perform the task and calculate data perfectly. It helped to measure length of object properly.

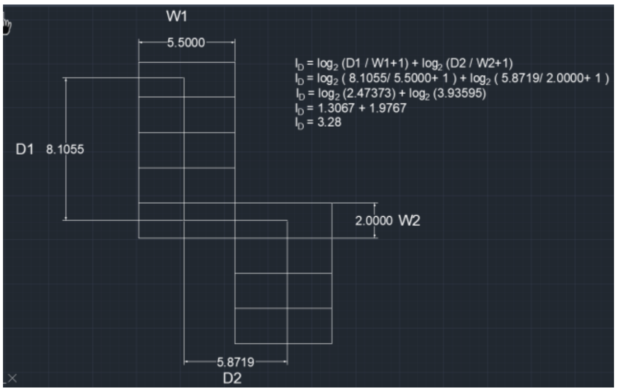


Figure 2 Sum-menu (Using Auto Cad)

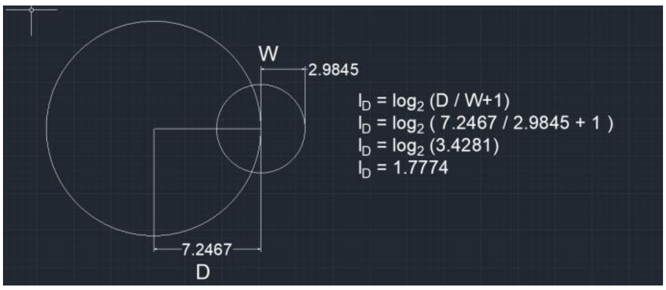


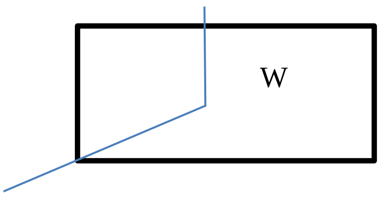
Figure 1: Circle (Using Auto Cad)

The above two images can clearly convey the design model and the calculation with figures talks about Index of Difficulties. It comes from the fitts' law.

$I_D = \log_2 (D/W + 1)$

D

A B



D = Distance from A to B

W = The distance between the center of object and the point of intersection along the path. W varies according to the path. (Diagonally w is max) [23]

Since the target object for both designs were known, the distance was set to hit the target. Using this data, Index of Difficulties can be calculated. This part of the calculation can generate a visible part of data graphically from which the affordance of the system can be discussed.

For calculating Fitts' Law, two diagrams are generated for one design pattern. Different distance is set for two diagrams. Since D1 and D2 for the two diagrams are different, ID1 and ID2 is obtained [24] [25].

Tpos1 = a + b ID1
Tpos2 = a + b ID2

After calculation:

b (ID1-ID2) = Tpos1 – Tpos2
⇨ b = (Tpos1- Tpos2) / (ID1 – ID2) ---------------------- (1)

a = (Tpos1 + Tpos2) / b (ID1 + ID2) --------------------(2)

Now, it is necessary to know when the first iteration will take place in order to generate the values for "a" and "b".

For Menu:

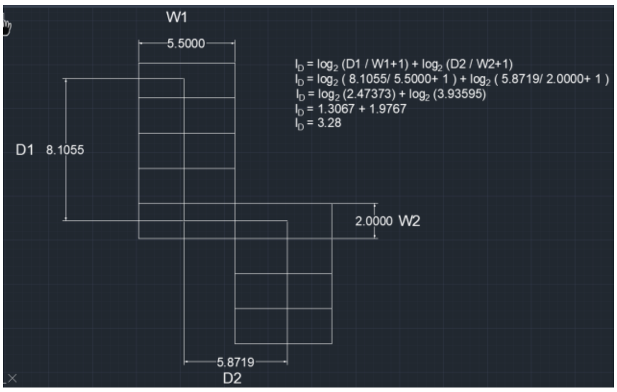


Figure 4: Menu 1

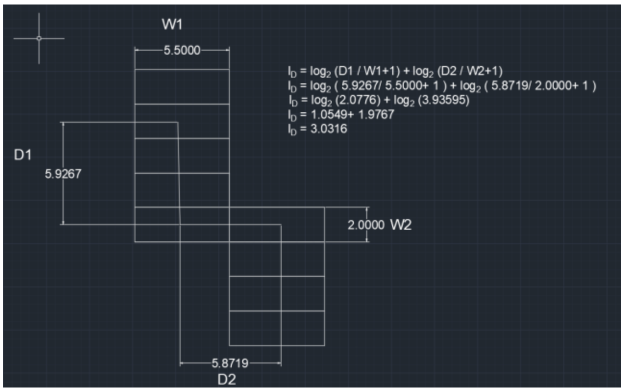


Figure 3 : Menu 2

Menu 1:

D1 = 8.1055 inches
D2 = 5.8719 inches
W1 = 5.5 inches
W2 = 2 inches

ID1 = log2 (D1/ W1+ 1) + log2 (D2/ W2+ 1)
= log2 (8.1055 / 5.5 + 1) + log2 (5.8719 / 2 + 1)
= 3.28

Menu 2:
D1 = 5.9267 inches
D2 = 5.8719 inches
W1 = 5.5 inches
W2 = 2 inches

ID1 = log2 (D1/ W1+ 1) + log2 (D2/ W2+ 1)
= log2 (5.9267 / 5.5 + 1) + log2 (5.8719 / 2 + 1)
= 3.0316

Calculate time listening from mouse or pen-tablet in python

```
import time
from pynput.mouse import Listener

def on_click (x, y, button, pressed):
    global start
    if pressed and button == button.left:
        start = time.time()
    elif not pressed and button == button.left:
        end = time.time()
    print("Calculated time = {:.2f} seconds ".format(end - start))
start = None
with Listener(on_click=on_click) as listener:
    listener.join()
```

Now, time calculation was needed for these two different diagrams. Above program was used to calculate the time which was written in python. Mouse Listener was used to tack the mouse activity and an on_click function was written where two variables were set, one was starting time and another was ending time. The code only listens to the left button of the mouse. Testing equipment to measure the data were Mouse, pen-tablet and Touchpad. Time for two sub-menu diagrams were measured.

For Mouse:

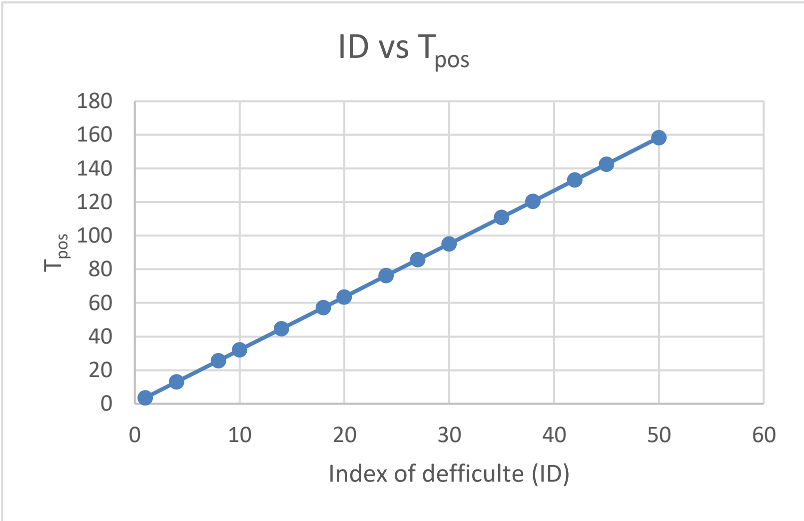
Tpos1 (Sub-menu 1) = 4.46 sec
Tpos2 (Sub-menu 1) = 3.67 sec

b = (Tpos1- Tpos2) / (ID1 – ID2)
= (4.46 – 3.67) / (3.28 – 3.0316)
= 3.16

a = (Tpos1 + Tpos2) / b (ID1 + ID2)
= (4.46 +3.67) / (3.16 * (3.28 + 3.0316))
= 0.4076

T_{pos} = 0.4076 + 3.16 ID -----------------------------(3)

ID	T_{pos}
1	3.5671
4	13.0471
8	25.6871
10	32.0071
14	44.6471
18	57.2871
20	63.6071
24	76.2471
27	85.7271
30	95.2071
35	111.0071
38	120.4871
42	133.1271
45	142.6071
50	158.4071



Equation (3) was calculating mathematical time from which could be possible to different time for different ID. The above table and graph represent different time for different ID. This equation helped to generate time and it indicate for different measurement of the design as ID varied [25] [26].

For Pen-tablet:

Tpos1 (Sub-menu 1) = 4.07 sec
Tpos2 (Sub-menu 2) = 3.43 sec

b = (Tpos1- Tpos2) / (ID1 – ID2)
= (4.07 – 3.43) / (3.28 – 3.0316)
= 2.57

a = (Tpos1 + Tpos2) / b (ID1 + ID2)
= (4.07 +3.43) / (2.57 * (3.28 + 3.0316))
= 0.4623

Tpos = 0.4623 + 2.57 ID -----------------------------(4)

For Touchpad:

Tpos1 (Sub-menu 1) = 2.54sec
Tpos2 (Sub-menu 2) = 2.01 sec

b = (Tpos1- Tpos2) / (ID1 – ID2)
= (2.54 – 2.01) / (3.28 – 3.0316)
= 2.13

a = (Tpos1 + Tpos2) / b (ID1 + ID2)

= (2.54+2.01) / (2.13 * (3.28 + 3.0316))

= 0.3384

Tpos = 0.3384 + 2.13 ID -----------------------------(5)

This three Equation is mathematically generated from two different shapes with one design pattern. Now form this equation, n^{th} time for n^{th} ID for the design of sub-menu can be obtained [25] [24] [27].

For circle:

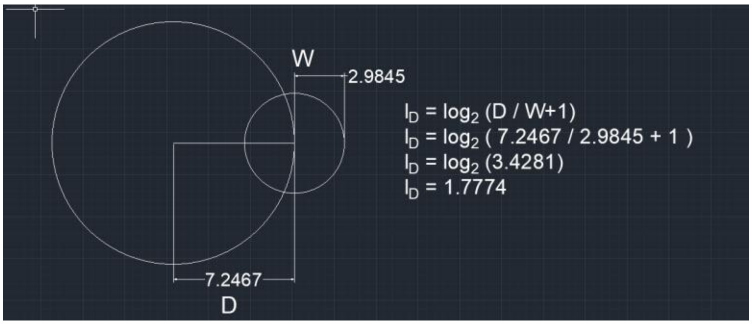


Figure 6: Circle 1

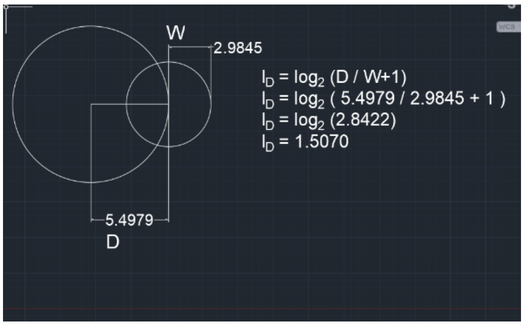


Figure 5: Circle 2

For circle 1:

D1 = 7.2467 inch

W1 = 2.9845 inch

ID1 = log2 (D1/ W1+ 1)

= log2 (7.2467/2.9845+ 1)

= 1.774

For Circle 2:

D2 = 5.4979 inch

W2 = 2.9845 inch

ID2 = log2 (D2/ W2+ 1)

= log2 (5.4979/2.9845+ 1)

= 1.5070

For mouse:

Tpos1 (Circle 1) = 1.38 sec
Tpos2 (Circle 2) = 1.24 sec

b = (Tpos1- Tpos2) / (ID1 – ID2)
= (1.38 – 1.24) / (1.774 – 1.5070)
= 0.5323

a = (Tpos1 + Tpos2) / b (ID1 + ID2)
= (1.38 + 1.24) / (0.5323 * (1.774 + 1.5070))
= 1.501

Tpos = 1.501 + 0.5323 ID -------------------------------(6)

For pen-tablet:

Tpos1 (Circle 1) = 1.22 sec
Tpos2 (Circle 2) = 1.19 sec

b = (Tpos1- Tpos2) / (ID1 – ID2)
= (1.22 – 1.19) / (1.774 – 1.5070)
= 0.1124

a = (Tpos1 + Tpos2) / b (ID1 + ID2)
= (1.22 + 1.19) / (0.1124 * (1.774 + 1.5070))
= 6.5349

Tpos = 1.501 + 0.5323 ID -------------------------------(7)

For Touchpad:

Tpos1 (Circle 1) = 0.92 sec
Tpos2 (Circle 2) = 0.81 sec

b = (Tpos1- Tpos2) / (ID1 – ID2)
= (0.92 – 0.81) / (1.774 – 1.5070)
= 0.412

a = (Tpos1 + Tpos2) / b (ID1 + ID2)
= (0.92 + 0.81) / (0.412 * (1.774 + 1.5070))
= 1.28

Tpos = 1.28 + 0.412 ID -------------------------------(8)

Some iterated time was measured for checking device was adapted or not by human. For this calculation the same code was used for time tracking which was coded in python and this time the menu-1 & circle-1 was taken. Firstly, time was taken for Fig: menu-1 with mouse, pen-tablet & touchpad. Time was measured for different pattern with different equipment from all twelve subjects. A comparison was made to select the best data-set for mouse, pen-tablet & touch-pad from all subjects. From the best dataset 15 iterations were taken to test, if it is adapted or not. From the collected data, a graph was generated from which decision can be made for adaptation [22] [23] [28].

Chapter 4

Results or findings

The experiment informed about two individual categories on the design which depends on Tangible User Interface (TUI). In Method section, design had been shown already. So, subjects performed task into this design and the dataset were collected from tasks [22]. Affordance is the main concern in modern world. When some technology arrives user reviewed products by affordance and adaptation. For adaptation, method section design pattern required datasets to analysis [26] [14].
For adaptation analysis of the design pattern, all subjects were individually testing both designs with three devices. That's how dataset collected and total dataset for each design pattern were thirty-six. Also, each dataset had fifteen iterations for one subject. So, total iterations were 36 multiplies 15 which was 540. For one device, total iterations were 12 multiplies 15 which were 180. Now it's so difficult to experiment the adaptation for all the subjects. Here, a comparison had been run to get the best data for analysis adaptation [29] [26]. From three devices, each one dataset compares to each. Comparison held by last iteration of each dataset for same device means for mouse had 12 datasets. From these 12 datasets every 15th iteration was taken, and selected dataset was the smallest value of 15th iteration. Reason for selecting 15th iteration to compare, as small the time it's best for adaptation. By processing datasets, the lastly selected total datasets were 3 for all devices. One for mouse, one for pen-table and one for touch-pad. Now, graphically compare between one to another which was more adapted for the selected design [17].

Table 1- Selected Dataset (Menu):

Mouse				Pen-tablet				Touch-pad		
Time Taken (S)										
D1	D2	Sum		D1	D2	Sum		D1	D2	Sum
2.56	1.9	4.46		2.9	1.17	4.07		1.1	1.4	2.54
2.42	1.9	4.32		1.97	1.17	3.14		1.1	0.7	1.79
2.05	1.36	3.41		1.3	1.21	2.51		1	0.9	1.93
1.89	1.18	3.07		1.54	1.1	2.64		1	1	1.9
1.78	1.12	2.9		1.28	1.08	2.36		0.9	0.7	1.67
1.89	1.13	3.02		1.29	1.09	2.38		0.9	0.8	1.68
1.77	0.94	2.71		1.26	0.99	2.25		1	0.7	1.63
1.34	1.23	2.57		1.15	1	2.15		0.9	0.9	1.76
1.38	0.9	2.28		1.1	0.93	2.03		0.9	0.7	1.62
1.19	0.9	2.09		1.16	0.85	2.01		0.8	0.6	1.38
1.1	0.8	1.9		1.05	0.87	1.92		0.6	0.7	1.2
1.18	0.84	2.02		1	0.88	1.88		0.7	0.6	1.34
1.06	0.78	1.84		0.94	0.84	1.78		0.7	0.6	1.24
1.02	0.74	1.76		0.93	0.83	1.76		0.6	0.6	1.13
0.98	0.6	1.58		0.78	0.74	1.52		0.6	0.5	1.12

These were the selected dataset from subjects. Now, from every iteration, sum column was taken to compare mouse, touch-pad & pen-tablet.

Iteration	Mouse(sum)	Pen-tablet (sum)	Touch-pad (sum)
1	4.46	4.07	2.54
2	4.32	3.14	1.79
3	3.41	2.51	1.93
4	3.07	2.64	1.9
5	2.9	2.36	1.67
6	3.02	2.38	1.68
7	2.71	2.25	1.63
8	2.57	2.15	1.76
9	2.28	2.03	1.62
10	2.09	2.01	1.38
11	1.9	1.92	1.2
12	2.02	1.88	1.34
13	1.84	1.78	1.24
14	1.76	1.76	1.13
15	1.58	1.52	1.12

Table 2: Dataset for menu

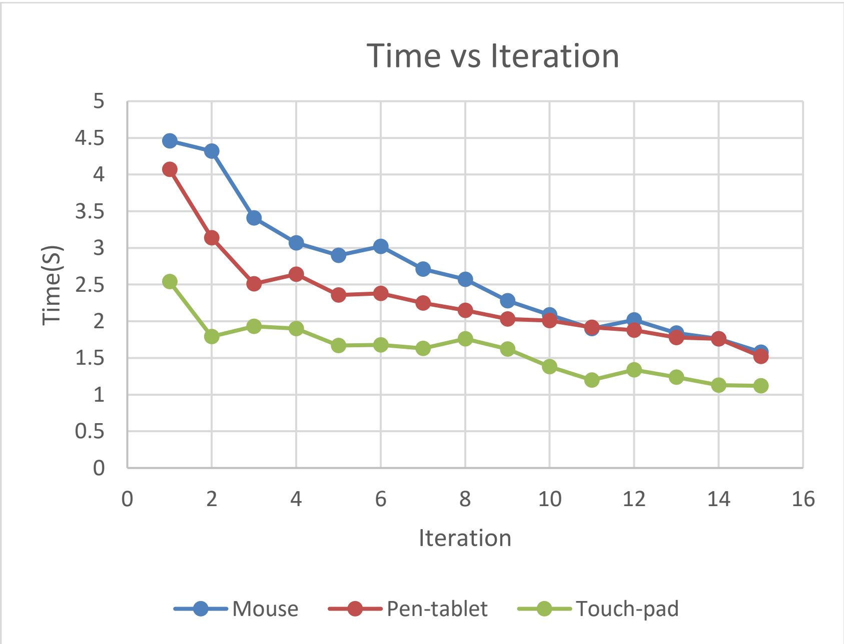


Figure 7: Graphical visualization of dataset for menu

Iteration	Mouse	Pen-tablet	Touch-pad
	Time Taken(S)		
1	1.38	1.22	0.92
2	1.31	1.13	0.82
3	1.32	1.08	0.86
4	1.3	0.98	0.86
5	1.18	0.88	0.71
6	1.2	0.97	0.83
7	1.16	0.99	0.7
8	1.11	0.92	0.79
9	1.02	0.93	0.7
10	0.88	0.87	0.76
11	0.91	0.79	0.68
12	0.88	0.78	0.6
13	0.82	0.8	0.57
14	0.73	0.68	0.47
15	0.68	0.62	0.49

Table 3: Dataset for circle

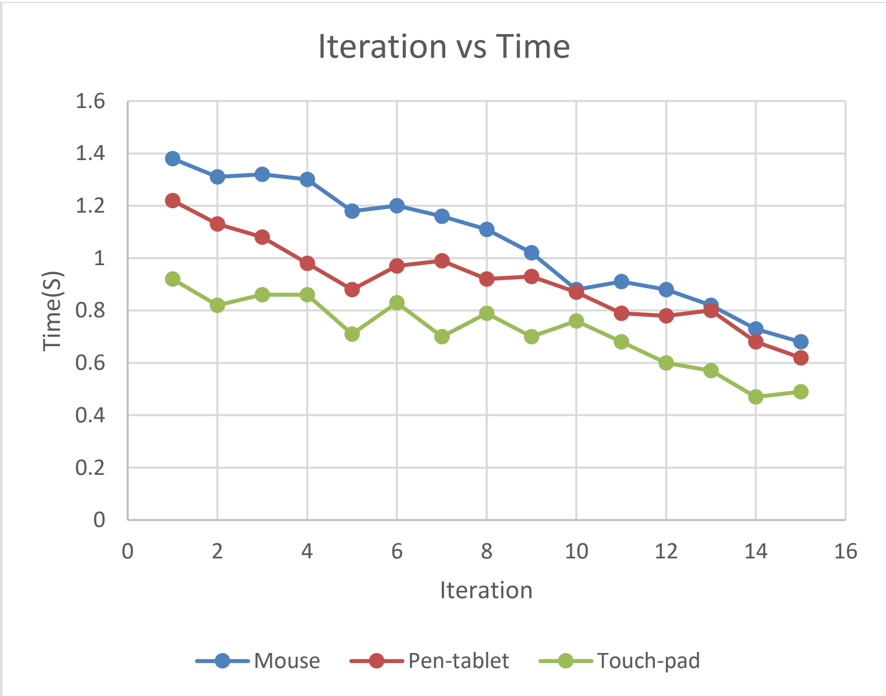


Figure 8: Graphical visualization of dataset for menu

This experiment represents of mouse, pen-tablet & touch-pad comparison. As per data & graphical view this experiment allowed to take decision which device was adapted faster. But, as this experiment depended a lot of technology, subjects, tools etc. error must occur [25]. So, error calculation is necessary for making proper decision. For this time, in this experiment error was ignored and as per the graphical view, experimental results went with touch-pad. For both design pattern, touch-pad was faster than both mouse and pen-tablet. But one thing must be remembering, this experimental result depends on subject [17]. When a subject used one device in long time, subject's cognitive behavior helped to perform better result [30].

Chapter 5

Discussion

One of the very few reliable and precise laws that may be used in the study and design of human-computer interaction is Fitts' law. Numerous studies have been carried out. The design of interactive items in graphical displays is subject to by Fitts's Law [31]. The time it takes to make a selection lower as an item's size grows, and it also does so as the distance between the user's starting point and the object becomes closer. On the other hand, selecting little things that are far from the user's starting point takes the longest. As a result, Effort has been made to build items that, when utilized in the same sequence chain, are as close to one another as possible. Additionally, an effort was made to enlarge the interactive screen elements as much as possible given the available area. Selecting little, dispersed components takes the longest; stay away from this confluence of design elements as much as possible can. To validate and use Fitts' law, Fitts' law's spirit has been advanced by looking into the possibility of additional strong regularities in movement tasks. From the perspective of consistency in widget size & distance design modifications, Fitts' law's index of difficulty formulation was assessed [49]. Since two designs were used to create three distinct experiments, it was discovered that ID might not accurately reflect the actual difficulty [49]. This study's results were confirmed by the exceptional performance of the touchpad for pointing tasks, even though the performance when using a pen tablet and mouse were comparable. And the time consumption of all devices to hit the target point is not the same. It can clearly be witnessed from the graph that what has been calculated is variable. 36 data sets from 12 subjects were gathered. Each participant generates 3 data sets for the mouse, pen tab, and touch pad. There are 15 iterations in each data set. Based on the user's engagement speed, the top 3 data set out of 36 were chosen.

The testing revealed an obvious distinction between using devices for tasks like circle and submenu pointing. Movement times are quicker and more precise when using the device touchpad. The movement times and mistake rates are greater for the other two devices. Across devices, the degradation between states varies. These two performed poorly in both tasks and had a high rate of dragging errors. The degree of muscle and limb involvement necessary to perform state transitions and maintain the movement of the design can be used to explain this [32]. Therefore, the mouse and pen tablet take significantly longer than a touchpad. This experiment confirmed the finding of the superb performance of the touchpad for pointing tasks, although the performance was comparable using mouse and pen tablet. However, these calculations suggested that users' increased familiarity with the mouse was the only factor in explaining the difference in pointing time between a touchpad, pen tablet, and a mouse. The assertion is demonstrably false because learning impacts Fitts' law's intercept more so than its descent. Spending more time using such tools for pointing can lower the difficulty index and make the user a skilled user. This is necessary to become an expert with those devices [50].

The final hypothesis at least attempted to deal with a more realistic context for the design of user interfaces. The layout of the input devices has a significant impact on how usable an interface is. Bigger, closer objects are accessed more quickly than smaller, farther away objects. The influence of task difficulty, according to the current findings, reduced over time for novices but remained unchanged for experts [33]. The latter demonstrated consistent performance with a virtually stable impact of decreasing task difficulty. This was the same for all input methods, however the touchpad had the best performance in general. The findings suggest that novices may have trouble allocating tasks. Novices' performance increases generally (total time decreases), but not particularly in response to the demands of the assignment. In the case of the experiment's last block, this becomes quite clear. The distribution of resources between simpler and more complex jobs is remarkably similar. This indicates that beginners at this stage of skill development mastered the pointing task generally and enhanced cognitive performance for the entire response to stimulus task [17].

Three multiple regression models were assessed in light of this result. The time t to point a target at a distance A and size W was estimated by these models [14]. It was found that the models could accurately represent how, in the instance of the small screen touch UI device, W affected the difficulty index more so than A. The huge screen device, however, required further investigation in this subsequent study, and the models did not perform as well in that situation. The study's potential weaknesses are discussed in some concluding considerations.

- The models however did not work so well in the case of the large screen device, which remained to be investigated in our future work. In further investigations, this needs to be carried out more methodically.

- Self-reported judgments of experience and practice using computers and input devices were used in the current study for evaluating and regulating participant proficiency.

- Concrete measurements, such a pre-test using standardized evaluation tools of fine psychological skills or input job, would have been a significantly more reliable approach than personal ratings.

However, the researcher is still developing the ability to optimize resource allocation to correspond with the distinctive characteristics of task complexity, in contrast to experts in the field [31]. In the final analysis, it can be said that the touchpad is quite efficient and is therefore a useful laptop input device for both beginners and specialists. The handling is quite easy to pick up, and good software design can further increase device operation efficiency.

Chapter 6

Conclusion

A key idea in human-computer interaction is Fitts' law. Fitts' law has been used to simulate how people engage with various input devices under various circumstances. These three are frequently used input devices, and numerous researchers have studied how people interact with them [33]. However, We demand additional Fitts' law-based research on screen interface. The results of such studies will help in enhancing the software usability of computer devices. Studies of Fitts' law applications to models of movement time using input devices take distance into consideration because it is a factor in the equation for the ID [28]. It makes sense that selecting targets that are farther away from a target than those that are closer should take longer. The current study found that movement time increased with target distance and reduced with target size. For distinct horizontal text object sizes, this effect has been documented in numerous investigations, which show orderly increases in input device duration for movement as distance increases. The distance variable's similarity in both procedure and result contributes to the generality and dependability of other outcomes that are similar across investigations. However, the remaining data analysis in the current study revealed that Fitts' law was a superior predictor of movement time at the closest ranges and most significant target sizes [34]. This effect may be partially explained by how respondents moved the cursor in relation to various target sizes and distances. Many subjects were seen to move initially down a slope away from the beginning point before turning and moving in a circle toward the target itself [35]. Other subjects were found to move the cursor first in the direction of the target that was just before it before co rrecting the motion to point at the target that was displayed in accordance with Fitts' law 493 and the Angle of Approach. The Fitts' law model (Fitts', 1954), which is meant to account for motions in a line along a horizontal plane, is obviously complicated by these motions, albeit ballistic movements of a stylus also helped the original model's effectiveness.

Our findings about the users' performance demonstrated that the neuromuscular reactions varied based on the action exerted on a touchpad, mouse, and pen tablet (i.e., the direction of movement), although the performance at a behavioral level was affected only a little [31]. The real input devices present similar regardless of the direction of the pointing action since HCI designers only take behavior into account [36]. Therefore, in order to facilitate their usage, future ergonomics devices must be designed to match the requirements of the fundamental system. The user's needed wrist reach should be one of the other factors that is investigated [37]. It would also be interesting to investigate how performance is impacted by the needed path's shape. Unlike our experimental assignment, when the path is not straight, the gesture may superimpose finger movements on the hand movement, increasing the difficulty of steering. Understanding this might potentially lead to the development of a generic model for navigation through tubes or routes in unrestricted 3D space [29]. In conclusion, we have made a first step toward understanding how people navigate through layers of above-surface contact. We have put up a number of models and tested them in various experiments. Our research will make a substantial contribution to the field of HCI as above-the-surface layer interaction techniques continue to advance.

We conclude that Fitts' law in its complete form should be used in characterizing input performance, as has been done, because these parameters are theoretically and mathematically fundamental to the input system studied and thus applicable beyond the target parameters used in experiments. Alternatively, through regression through the origin, we can force Fitts' law into a one-parameter model if and only if we can safely create procedures that omit all information independent components in the measurement of movement time.

It is clear that more effort needs to be done to address concerns like expanding Fitts' law to take into consideration for approach perspective [8]. We feel that the results of this study serve as a starting point for additional study in this area with an eye toward the creation of more beneficial gadgets. Additionally, they will make it possible for designers to create stylus input devices for portable devices that will provide users with more comfort and efficiency [38]. Future research will face various obstacles in completing this type of investigation. A different set of circumstances should be used for experiments. We want to underline that the design we produced served as the basis for the conclusions regarding of the devices. Once the designers examine multiple factors about we anticipate varied outcomes.

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Appendix A

Appendix

Write your appendix here. Following two are examples.

A.1 Name of Appendix-1

A.2 Name of Appendix-2

Appendix B

Example of Citations

This text is only for Bibliography testing purposes.

Dr. Dip Nandi currently works as an Associate Professor and the Director of Faculty of Science and Technology in American International University-Bangladesh (AIUB). His research area includes: Software Engineering, E-Learning Technologies, Data Mining and Information systems and has produced several publications in these domains [Nandi et al., 2012, Nandi et al., 2011].

Dr. Tabin Hasan primarily focuses in the research Domain of Human Computer Interaction. He is been a active researcher for more than a decade and produced many high quality journals [Hasan et al., 2013], conferences [Hasan et al., 2021] and book chapters.

Appendix C

Example of Equations

The well known Pythagorean theorem $x^2 + y^2 = z^2$ was proved to be invalid for other exponents. Meaning the next equation has no integer solutions:

$$x^n + y^n = z^n$$

The ampersand character & determines where the equations align. Let's check a more complex example:

$$\begin{aligned} x &= y & w &= z & a &= b + c \\ 2x &= -y & 3w &= \frac{1}{2}z & a &= b \\ -4 + 5x &= 2 + y & w + 2 &= -1 + w & ab &= cb \end{aligned}$$

The mass-energy equivalence is described by the famous equation

$$E = mc^2$$

discovered in 1905 by Albert Einstein. In natural units ($c = 1$), the formula expresses the identity

$$E = m \tag{C.1}$$

Some random examples ...

$$\infty \quad 1 \qquad\qquad 1$$

Appendix D

Example of Figures

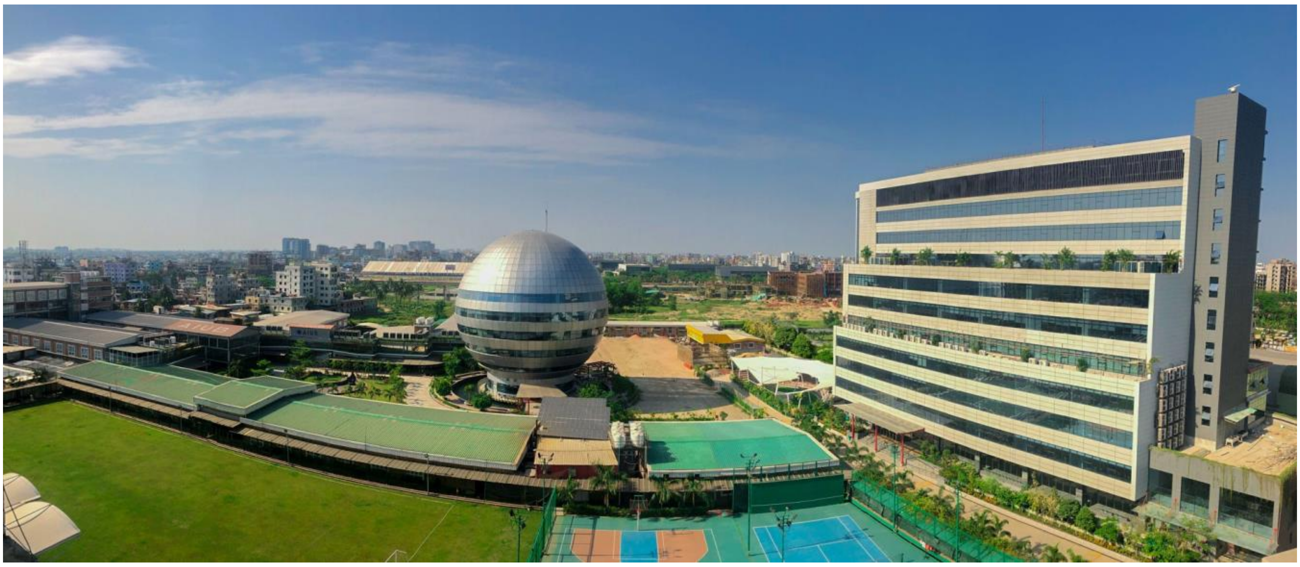

Figure D. 1 : American International University-Bangladesh (AIUB)

The Figure D.1 represents beauty of the AIUB campus.

Appendix E

Example of Tables

Here is a really simple table E.1.

Table E. 1: AIUB currently operates under four distinct Faculties x

Number	**Name**
1	Faculty of Science and Technology (FST)
2	Faculty of Engineering (FE)
3	Faculty of Business Administration (FBA)
4	Faculty of Arts and Social Sciences (FASS)

Here is another example of table row merged E.2.

Table E. 2: Row span example

<table>
<tr><td>col1</td><td>col2</td><td>col3</td></tr>
<tr><td rowspan="3">Multiple row</td><td>cell2</td><td>cell3</td></tr>
<tr><td>cell5</td><td>cell6</td></tr>
<tr><td>cell8</td><td>cell9</td></tr>
</table>

Here is another example of controlling table width E.3.

Table E. 3 : Test Table

One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven	Twelve	Thirteen	Fourteen
1.111	2.222	3.333	4.444	5.555	6.666	7.777	8.888	9.999	0.000	1.111	2.222	3.333	4.444

Appendix F

Example of algorithm procedure

Algorithm 1: Example code

```
/* Now this is an if...else conditional loop                    */
if Condition 1 then
    Do something                        // this is another comment
    if sub-Condition then
        Do a lot
else if Condition 2 then
    Do Otherwise
    /* Now this is a for loop                                   */
    for sequence do
        loop instructions
else
    Do the rest
/* Now this is a While loop                                     */
while Condition do
    Do something
```

Example of writing algorithms is shown here 1.

Appendix G

Example of Code

G.1 Find the greatest number from a list of numbers in *Python*

```
a=[1,2,3,4,6,7,99,88,999]
    max= 0
    for i in a:
        if i > max:
            max=i
    print(max)
```