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Upper Limb Post Stroke Rehabilitation Performance Monitoring Tools using Optical Mouse

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Abstract – Stroke is one of the deadly disease in Malaysia; one of top five major causes of death and one of the top ten causes for hospitalization in Malaysia. Every year 40,000 people diagnosed with this deadly disease. Stroke occurs when blood flow to the brain is blocked. Blood supply essential nutrient and oxygen to the brain. Insufficient blood supply will cause brain cell damages and lead to lose control of human body. Weakness or lost ability to upper limb or arm is one of the main symptoms for the stroke patients. Normally only one part of the body will affected. Upper limb post stroke rehabilitation objective is to help stroke survivor to move their hand and arm as effective as their non-affected hand. Arm/ hand skate is one of the popular equipment used to help the stoke survivor to regain their upper and/or forearm limb strength and endurance of the patients. The main movement direction was horizontal from left to right and reversed. In order to get the benefit of this exercise, stroke survivor has to repeat this exercise for several time, this will lead to boredom and motivation lost. Another disadvantage is there is no indicator for showing degree of the rehabilitation. Objective of this study is to design a computer application using combination of C++, Open GL and optical mouse which can be used to evaluate the stroke survivor hand and arm speed movement. Information obtain from this application can used by the therapist and stroke survivor to monitor their rehabilitation activity progress and effectiveness.

Keywords: Stroke rehabilitation, Optical mouse, Virtual reality

1.0 INTRODUCTION

Stroke is one of the deadly disease in Malaysia; one of top five major causes of death and one of the top ten causes for hospitalization in Malaysia [1-4]. Every year 40,000 people diagnosed with this deadly disease [3]. Hospital Kuala Lumpur record show that 30% to 35% from 1000 patient treated for stroke will end with death [5-8]. Even though in Malaysia most of the stroke patient age are between 54 to 65 year [1]; everybody has potential to get stroke, including children and babies. Considering all this fact, research regarding stroke prevention and rehabilitation is very crucial.

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Stroke occurs when blood flow to the brain is blocked. Blood supply essential nutrient and oxygen to the brain. Insufficient blood supply will cause brain cell damages and lead to lose control of human body. Stroke effect varies from one person to the others depending on the location and degree of brain tissue damage, stroke survivors are likely to suffer cognitive, visual and motor losses. Stroke is divided into two type as shown in **Figure 1**:

- Ischemic strokes; caused by blood clots.
- Haemorrhagic strokes; caused by bleeding in or around the brain.

Ischemic strokes account for 87 percent of all strokes. Ischemic stroke happens when there is a blood clot that blocks blood flow to a part of the brain. Ischemic stroke occurs when:

- Plaque reduce the blood flow to neck or brain. Plaque is a combination of fat, cholesterol and other substances that build up in the inner lining of the artery walls. This condition is often referred to as atherosclerosis, or "hardening of the arteries."
- In some situation the plaque origin is from some other part of the body. When this plaque breaks, the fragments may travel to the brain and disrupt the blood flow. This is called embolism.

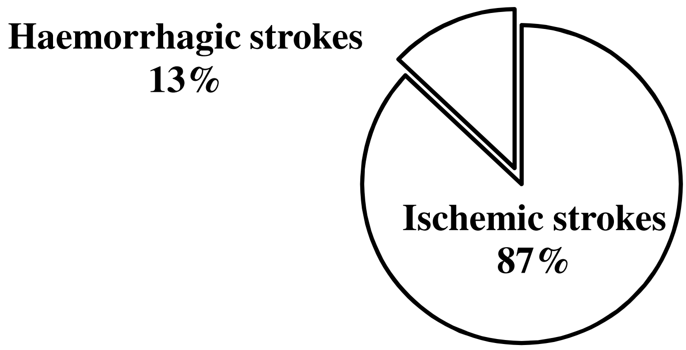

Figure 1: Type of strokes

Haemorrhagic strokes occur when a weakened blood vessel in the brain breaks and bleeds into surrounding brain tissue. This puts too much pressure on blood cells in the surrounding tissue, cutting off their blood supply and causing damage. About 13 percent of all strokes are haemorrhagic strokes.

The effects of a stroke depend primarily on the location of the obstruction and the extent of brain tissue affected. Human brain is divided into two hemisphere; right brain and left brain. Right brain control the left side of human body and the left brain is responsible for right side of human body.

As one side of the brain controls the opposite side of the body, a stroke affecting one side of the brain will result in nerve system problems on the side of the body it affects. For example, if the stroke occurs in the brain's right side, the left side of the body and the left side of the face will be affected, which could produce any or all of the following:

- Paralysis or weakness on certain part of the side of the body such as hand, arm and leg.
- Vision problems.
- Quick, inquisitive behavioural style.
- Memory loss.

If the stroke occurs in the left side of the brain, the right side of the body will be affected, producing some or all of the following:

- Paralysis on the right side of the body.
- Speech/language problems.
- Slow, cautious behavioural style.
- Memory loss.

Stroke can affect both sides of the body or may leave someone in a ‘locked-in’ state. Stroke patient with locked-in state will lost their ability to speak or achieve any movement below the neck. The effect of stroke varies depending on the severity of human brain damage.

2.0 POST STROKE UPPER LIMB REHABILITATION

Weakness or lost ability to upper limb or arm is one of the main symptoms for the stroke patients. Normally, arm movements are the result of different muscle groups working together. Researchers have termed this collaboration between muscles as “synergies”. The brain has the delicate task of coordinating these movements. After the stroke has occurred, muscles will become weak due to the lack of coordination between the brain and body. This causes the muscle synergies to move in abnormal patterns. Normally only one side of the body will be affected. Stroke can affect stroke patient arm in several ways:

- Weakness.

Stroke survivors may completely paralyzed or their shoulder, elbow wrist and/or hand may be weak. This condition will lead to difficulty in reaching, picking things up or holding onto things.

- Coordination problems.

Stroke survivor may have difficulty to plan or coordinate the movements of their arm; arm doesn’t move in the way that they want it to.

- Changes in muscle tone.

Stroke survivor with high tone known as hypertonia or spasticity will suffer stiff or tight muscles. Stroke survivor with low tone called hypotonia, will suffer floppy or loose muscles.

- Subluxation.

Weakness or low tone may allow the top of stroke survivor arm to drop out of the shoulder socket slightly. This makes arm movements difficult and can be painful.

- Contracture.

Weakness or high tone may make stroke survivor muscles shorter or joints less flexible. This makes movements difficult and can be painful.

Based on observation made at Hospital Sultan Ismail rehabilitation unit activity such as cone stacking (Figure 2), picking up small objects such as marbles and transferring it into to another place and arm skating; moving the affected arm on table top using the affected arm (Figure 3) is used to help stroke survivor to regain their hand and arm movement ability [9-12]. In order to get the benefit of this exercise, stroke survivor has to repeat this exercise for several time, this will lead to boredom and motivation lost. Another disadvantage is there is no indicator for showing degree of the rehabilitation.

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Figure 2: Cone stacking

Figure 3: Arm skating

3.0 JDS HAND MOVEMENT SPEED CALCULATION TOOL

JDS hand movement speed calculation tool as shown in Figure 4 is design to measure hand movement speed. User can use information from this application to compare the hand movement speed between the affected limbs and the unaffected limbs, the rehabilitation goal is to train the affected limb so it can move as fast as the unaffected limb.

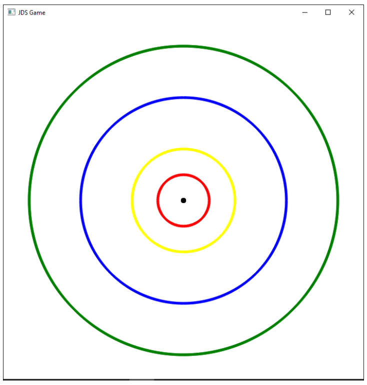

Figure 4: JDS hand movement speed calculation tools snap shot

In this application mouse click location is used to determine the distance between two points. New location will be recorded based on mouse button state (up or down). Every state will produce a new location. Figure show the JDS hand movement speed calculation tool pseudocode.

JDS hand movement speed calculation tool application windows size is set to 700 x 700 pixel. This create a coordinate system ranging from 0 to 700 in x axis and 0 to 700 in y axis. All mouse click location detected by JDS hand movement speed calculation tool will be recorded in log a file. Besides recording the cursor location, this program also record the time duration taken to move for initial point to end point. This data will use by the program to calculate the hand movement speed using the formula shown below

$$Speed, v = \frac{length\ (pixel)}{movement\ duration\ (second)} \tag{1}$$

where *movement duration* = *time stop* – *time start.*

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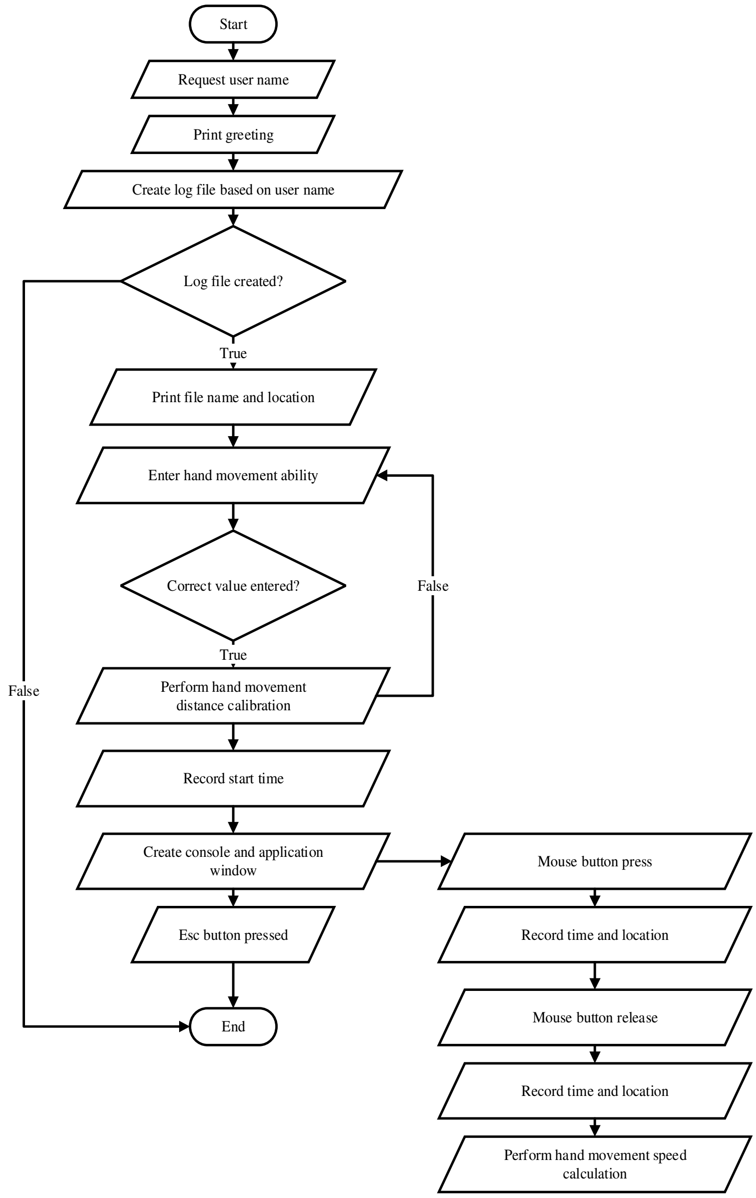

Figure 5: JDS hand movement speed calculation tools pseudocode

4.0 RESULTS AND DISCUSSION

Experiment result show that mouse hardware DPI and in games sensitivity setting value has direct influenced to hand movement distance to move cursor from one point to the other point.

4.1Relationship between mouse hardware DPI and hand movement distance

This test is done using Logitech G502 Proteus Core Tuneable Gaming Mouse, this mouse has the pointer setting option as shown in **Error! Reference source not found.** which allow user to change the mouse DPI setting from 200 DPI to 12 000 DPI. The objective of this experiment is to validate the effect of different mouse DPI to the hand movement distance required to move from one point to other point. In this experiment the hand movement distance to move from the centre of the screen to certain location is recorded in Table 1

Table 1: Mouse DPI Vs Hand movement distance

Mouse model: Logitech Proteus core G502

	Distance from centre of the screen (pixel)			
Mouse DPI	50	100	200	300
1200	4	8	16	24
1000	5	10	20	30
800	6	12	24	36
600	8	16	32	48
400	12	24	48	72
200	27	54	108	162

Chart in Figure illustrates the relationship between the mouse DPI and hand movement distance. Using the chart, we can conclude that user has to move his hand further to move from one point to other point when using a mouse with lower DPI for example to move 300 pixel on computer screen with 200 DPI mouse the user must move his hand for 162 mm, on the other hand the user only need to move 28 mm to move the same distance on screen with 1000 DPI mouse. Relationship between hand movement distance and cursor movement distance is govern by equation in Figure . This study show that mouse hardware DPI value will influence the hand movement distance to move cursor from one to another point.

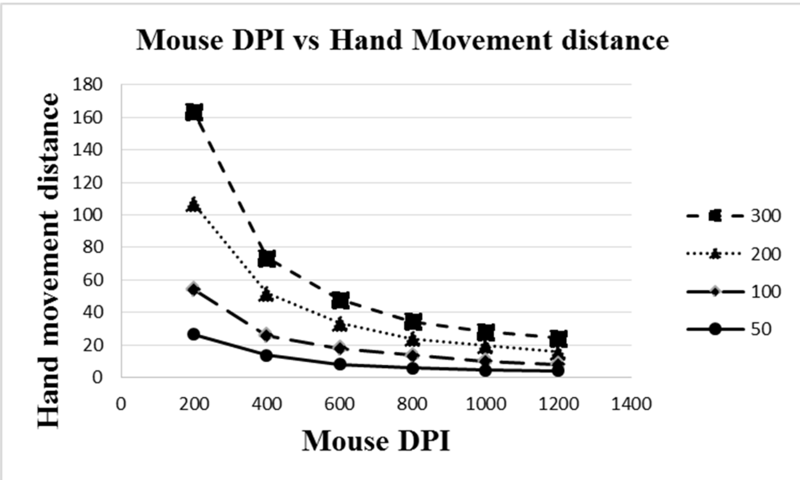

Figure 6: Mouse DPI vs hand movement distance

$$1200\ DPI : hmd = cmd \times 0.08$$
$$1000\ DPI: hmd = cmd \times 0.1$$
$$800\ DPI: hmd = cmd \times 0.12$$
$$600\ DPI: hmd = cmd \times 0.16$$
$$400\ DPI: hmd = cmd \times 0.24$$
$$200\ DPI: hmd = cmd \times 0.24$$

Figure 7: Relationship between mouse DPI and hand movement distance

4.2 Effect of single DPI mouse and multiple DPI mouse to hand movement distance

This section will study the effect of single DPI and multi DPI mouse to the accuracy of hand movement distance calculation using JDS hand movement calculation tools. Objective of this section to choose a mouse which will provide a better accuracy during the measurement process

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using JDS hand movement calculation tools. According to manufacturer mouse DPI is defined as the number of pixel that a mouse can count in one inch. For example, to move 1000 pixel on screen will required the user to move their hand for 1 inch. Using this relationship formula as shown below

$$Hmd = \left(\frac{Cmd \times 2.54}{Mouse\ CPI}\right) \tag{2}$$

where

Hmd = hand movement distance measured in cm
Cmd = cursor movement distance measured in pixel

In this study the hand distance taken to move from one point to another point using two type of mouse; single DPI mouse, Logitech M 325 and Logitech M502, gaming mouse with variable DPI setting is recorded and compared. Measurement will be carry out using 1000 DPI setting.

Table 2 shows the hand movement distance required to move the cursor along to 4 different locations from the centre of the screen using location variable DPI mouse. The relationship the mouse and hand movement distance as shown in Figure is governed by equation (3).

Table 2: Hand movement distance using Logitech Proteus Core G502

Mouse model:		Logitech Proteus core G502		
Cursor distance (Pixel)	Hand distance actual (mm)	Hand distance theory (mm)	Different (mm)	Error percentage (%)
50	5	1.27	3.73	294%
100	10	2.54	7.46	294%
200	20	5.08	14.92	294%
300	30	7.62	22.38	294%

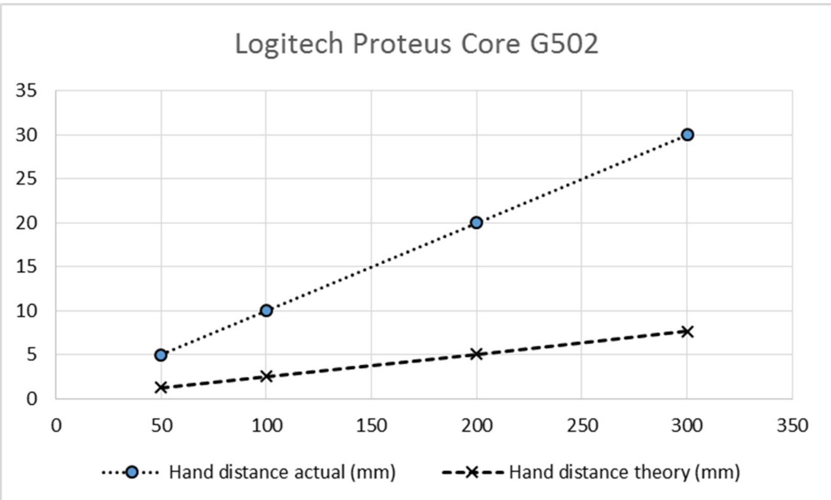

Figure 8: Comparison between actual and theoretical hand movement distance using Logitech M502 mouse

$$Hand\ distance = 0.1 \times cursor\ movement\ distance \tag{3}$$

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Table 3 shows the hand movement distance required to move the cursor along to 4 different locations from the centre of the screen using location single DPI mouse. The relationship the mouse and hand movement distance as shown in Figure 5 is governed by equation (4).

Table 3: Hand movement distance using Logitech M325 mouse

Mouse model: Logitech M325

Cursor distance (Pixel)	Hand distance actual (mm)	Hand distance theory (mm)	Different (mm)	Error percentage (%)
50	1.2	1.27	-0.07	-5.51%
100	2.5	2.54	-0.04	-1.57%
200	5.0	5.08	-0.08	-1.57%
300	7.5	7.62	-0.12	-1.57%
Average				-2.56%

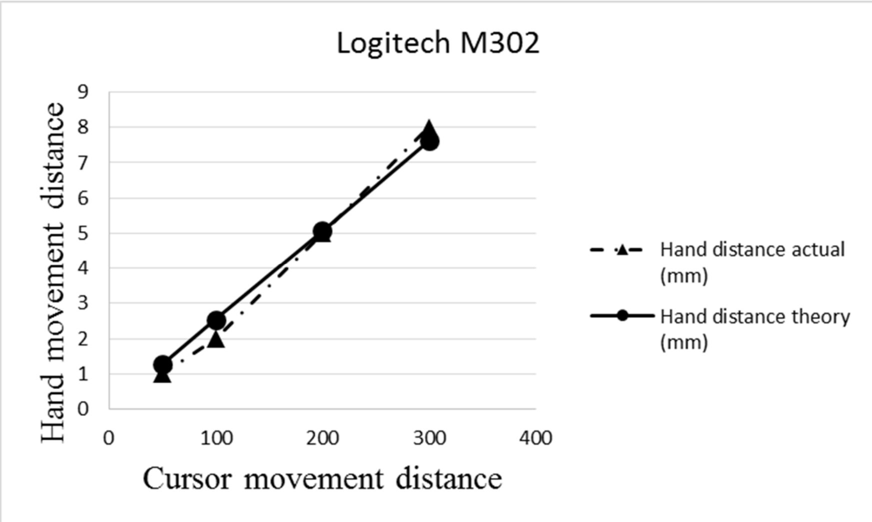

Figure 5: Hand movement distance using Logitech M325

$$Hand\ distance = 0.025 \times cursor\ movement\ distance \quad (4)$$

Error between theoretical and actual hand movement distance required to move from one point to the other point using G502 mouse is 294%, on the other hand the error between theoretical hand movement and actual hand movement distance required to move from one point to the other point using M325 mouse is 2.56%, this result show that single DPI mouse will produce a better accuracy to measure the hand movement distance.

4.3 Effect of in game sensitivity

This section will study the effect of in game mouse sensitivity setting to the hand movement distance while playing the JDS rehabilitation games. In games sensitivity setting is used to adjust the hand movement distance required to move cursor from one to other point while playing the JDS rehabilitation games. Relationship between hand movement distance and in games mouse sensitivity setting is given by equation (5).

$$Hmd = \left(\frac{Cmd \times 2.54}{Mouse\ CPI \times Igs}\right) \quad (5)$$

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where

Hmd = hand movement distance measured in cm
Cmd = cursor movement distance measured in pixel
Igs = In game sensitivity setting

Table 4: Effect of in games sensitivity value to hand movement distance

Cursor movement (Pixel)	50	100	200	300
In game sensitivity	Hand movement distance (mm)			
0	1	2	5	8
0.1	25	50	100	150
0.2	12.5	25	50	75
0.3	8	16	32	50
0.4	6	12	25	38

Experimental result is shown in Table 4. Relationship between the in games sensitivity and hand movement distance required to move from one point to other point in shown in Figure 6; lower in games sensitivity value will force the hand to move further compared to high in game sensitivity value for the same cursor movement distance.

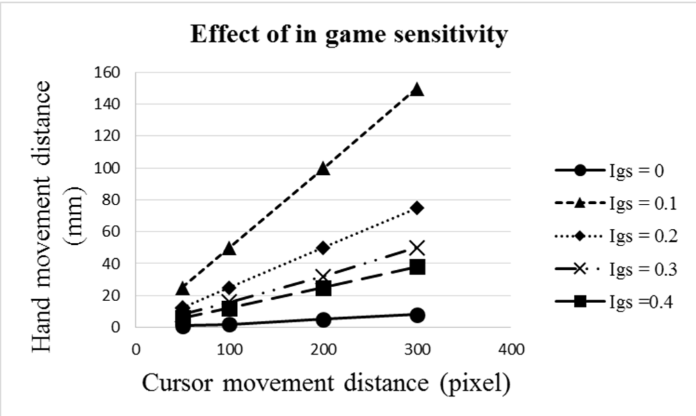

Figure 6: Effect of hand in games sensitivity setting to hand movement distance

5.0 CONCLUSION

This study provides a clear evidence that combination of C++, OpenGL and optical mouse can be used to produce a hand and movement speed calculation tools [13-22]. The accuracy of the measurement is depending on the optical mouse sensor accuracy. Data provided by this application can be use by therapist to evaluate their rehabilitation activity effectiveness [23-29]. This data can also be converted into a progress chart which can use by the stroke survivor to monitor their achievement.

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