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# DESIGN OF IRIS MECHANISM FOR FLEXION AND EXTENSION TRAINING IN HAND REHABILITATION

Muhammad Aminuddin Anwar Ali and Norsinnira Zainul Azlan
Department of Mechatronic Engineering, Jalan Gombak, Kuala Lumpur, Selangor, Malaysia
E-Mail: anwarbp91@gmail.com

## ABSTRACT

Rehabilitation therapy is the process to reduce the impairments and disabilities of upper or lower limb that are caused by accidents or stroke. This paper presents the design and development of a new hand rehabilitation device based on iris mechanism with basic Arduino coding to train the flexion and extension of the hand. The iris mechanism is designed using SolidWorks 2015 and the prototype is developed using ABS filament and perspex. The steps to design the iris mechanism is shown in this paper, starting with the first layer (lower body), then the blade, second layer with gear, and third layer (for holding all layers together). The measurement of inside diameter is decided by considering the average size of object can hold by the patient for basic daily life. The inside diameter of the iris mechanism varies from 15 mm to 110 mm to enable the patients to adapt to various object sizes. The device can be used for the right-handed or left-handed person. The preliminary output shows that the designed mechanism is able to perform the opening and closing motion for the rehabilitation of hand function. The holding rod of the mechanism opens to the maximum 110 mm as the second layer with gear is rotated 77°.

Keywords: iris mechanism, mechanical design, rehabilitation, opening and grasping.

## INTRODUCTION

Sports, accidents involving transport, and accident at work place are the common causes to the injury [1]. Effects of the injury to the patient is they difficult to performs basic self-care such as eating, drinking, holding the object, dressing tasks, writing, rising up and down from a chair, and playing with the children.

Through the rehabilitation training, patients have high potential to improve motor function, reduce the impairments and disabilities, and allow regaining movement for upper limb especially fingers. Research has shown that intensive, repetitive, and goal-directed rehabilitation improve motor function [2, 4]. One of the objectives of rehabilitation training is to help patients to regain hand function, since this is important to perform activities daily life [2].

While the traditional or manual treatment for the patients are done by the physiotherapy, researchers from engineering perspective are looking for option or alternative that more efficient and help reduce the cost to both side [3].

Rehabilitation engineering can be explained as the design, development and application of engineering methods and devices to enhance injury patients' recover. Rehabilitation robotics is the area to learn and help the physiotherapist to do treatment process using the application of robotic devices [4]. Rehabilitation robots can potentially provide an automated and portable device, stable, repetitive, monitor progress, precise, provide assessment and training for the patient, and increase the duration and intensity of therapy in rehabilitation settings. Furthermore, rehabilitation robots make it possible for a single therapist to help multiple patients at same time.

Besides that, patient also can train by their own self at home without therapist.

Opening and closing finger is an important hand function and is necessary for grasping and manipulation an object [5]. Because of the injury around the hand, it's very hurt for certain patients to extend the finger to maximum position. For stroke patients, extensor muscle weakness makes their fingers fixed in a flexed position and not able to control finger motion. So, the first task of the robotic robot is finger extension before the robot trained to strengthen the muscles [6].

In order to get functional use of the hand such as grasp and release, series of tasks need to be prepare for the patients. The patients have to face gradual training from initial state (closing) until maximum open. However, training of grasping and carrying items of different sizes, weights, shapes, and textures is based on the level of recovery of the patients.

In these cases, the training is divided into 2 activities. First activity involves passive training and second activity involves active training. Passive training is the training that machine helps the patients while active training is the training that machine give resistance to the patients. At final stages, objective of the rehabilitation is the patients are able to do basic daily activity at home.

At early stages of rehabilitation, physiotherapy exercises focus to improve joint range of motion and muscular activity. Exercise at this stage very important before the patients execute more complex movements [7]. Besides that, passive rehabilitation is a preferred method for reducing pain and swelling and also restoring range of motion.

In rehabilitation engineering, mechanical design is important to decide the part of body for rehabilitation

training either upper or lower limb. Generally, there are two types of rehabilitation robot from the mechanical design point of view: end-effector based robots, and exoskeleton-type robots [8].

For the design of end-effector, it could adapt to different size of body of the patients. For exoskeleton-type robots, it can resemble human anatomy and apply torque to specific joints [8].

Iris mechanism is the new mechanism built in rehabilitation process for upper limb. The unique structure or movement of the iris mechanism is the center can gradually open when any layer is rotating. Different size of center can be designed based on the designer desired. It helps the rehabilitation process for opening, closing, and test power strength for the fingers. The purpose of this expletory study is to design the iris mechanism with electric circuit for rehabilitation process especially fingers.

## IRIS MECHANISM DESIGN

This section presents the process in developing the iris mechanism. There are several ways to construct and design the iris mechanism. In this paper, the iris mechanism consists of the first layer (lower body), blade, second layer with gear (upper body), and the third layer as shown in Figure-1. The iris mechanism has a unique structure, where all the blades travel in a straight line back and forth along the slide which is perpendicular to the angles bisector and it imitates the opening and closing of the fingers in grasping variable sizes of the object. The design of an iris mechanism consists of designing the first layer (lower body), blade, second layer with gear (upper body), and third layer as will be decided in the following subsection.



**Figure-1.** All components in iris mechanism (a) first layer, (b) blades, (c) second layer with gear, (d) third layer, (e) spacer, (f) bolts, (g) nuts, and (h) holder.

### First layer (Lower body)

In order to make sure that the blade can travel in a straight line, the position of Slide A must be in correct position. This is so that the blades can travel smoothly without stuck. Figure-2 shows the design of the first layer of the mechanism. First, the designer needs to plan the

inner diameter for the mechanism. After that, the designer can calculate the outer diameter using Equation (1).
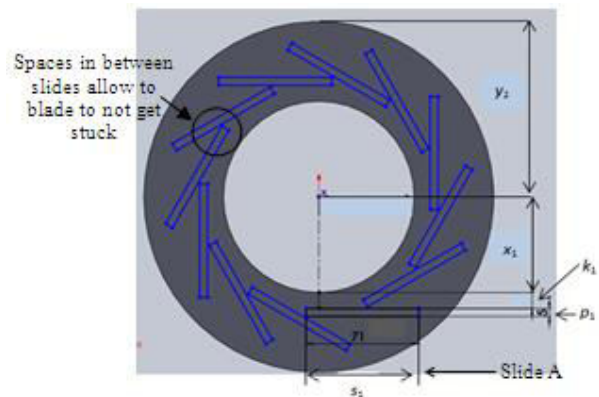


**Figure-2.** Measurement for the first layer.

Referring to Figure-2, the slide on the first layer is denoted by Slide A while the inner radius is represented by $x_1$, outside radius by $y_1$, space between inner diameter and Slide A by $k_1$, height Slide A by $p_1$, and the length of Slide A by $s_1$. Slide A has to be rectangular shape because Slot A on the blade as will be elaborated in the following subsection is in rectangular shape. The outside radius of the first layer, $y_1$ can be calculated as,

$$y_1 = 2x_1 \qquad (1)$$

where $x_1$ can be chosen by the designer.

The length of Slide A, $s_1$ can be calculated as,

$$\text{Length slide A,} \ \ s_1 = x_1 + t \qquad (2)$$

where $t$ is the length Slot A, and can be chosen by the designer.

### Blades

Blade is one of the important parts in this mechanism. Different number of blades can be chosen. Usually, 4, 6, 8 and 12 numbers of blades are used in the mechanism design.
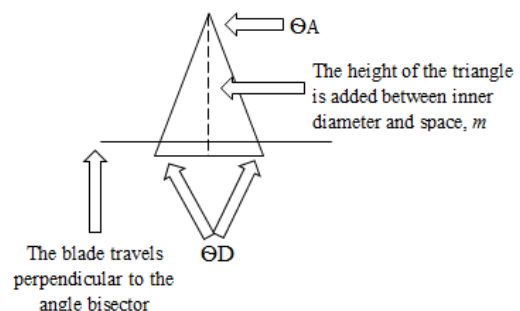


**Figure-3.** Design of the blade.

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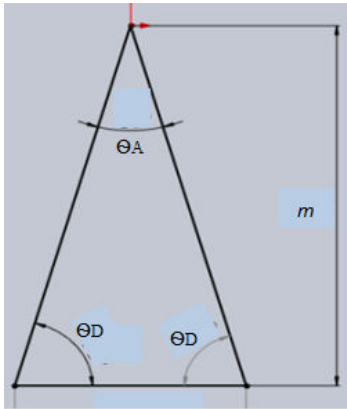
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**Figure-4.** Measurement for the blade.

Each blade should be made of isosceles triangle where 2 legs are same length and the other one is different. Therefore, 2 of the angles will have the same size and the last one will be different. After choosing the suitable number of blades, the designer can determine the value for ΘA. The diagram of the blade can be seen in Figure-3. Let the number of blades be represent by $b$, angle of center triangular by ΘA, angle of side triangular by ΘD, and length Slot A by $t$. The angle of the center triangular, ΘA can be calculated as,

Angle of center tiangular,  $ΘA = 360°/b$          (3)

While the angle of the side triangular by ΘD can be calculated as,

Angle of side trangle,  $ΘD = \frac{180° - ΘA}{2}$          (4)

An example of the angle determination with 12 blades is shown in Figure-4. The height of the isosceles triangle, $m$ is determined by adding the radius of inner radius, $x_1$ with the height of Slide A, $p_1$ and space between inner diameter and slide A, $k_1$.

Height of isosceles triangle,  $m = x_1 + p_1 + k_1$          (5)

where $k_1$ and $p_1$ can be chosen by the designer.

The top view and isometric of a blade is shown in Figure-5. As can be seen in Figure-5, the top surface consists of a pin to be fitted on Slide A in Figure-2 and enable the blade to move along the slide. The blades also consist of holding rods where the patients can hold during the flexion and extension exercise. Figure-6 shows the position of the blade on the first layer.
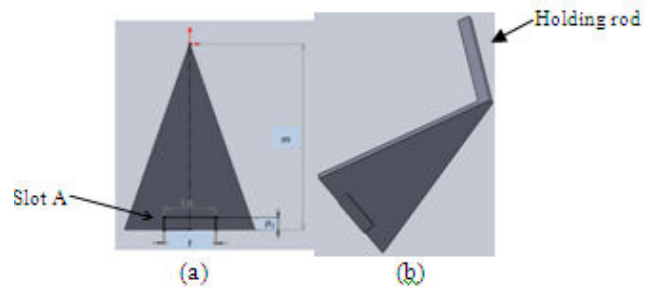


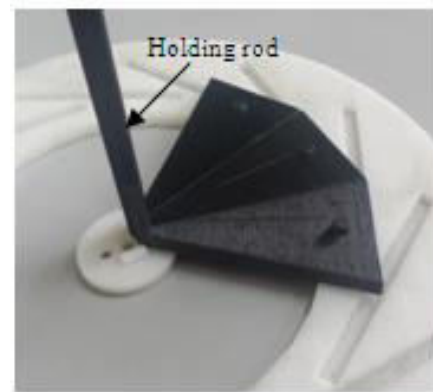**Figure-5.** (a) Top view (b) isometric of the blade.



**Figure-6.** Position for blade and first layer (lower slot).

The bottom view of the blade is shown in Figure-7. An extrusion, named as Slot B is placed at the bottom of the blade to enable it to move in Slide B on the second layer of the iris mechanism as will be described in the following subsection.
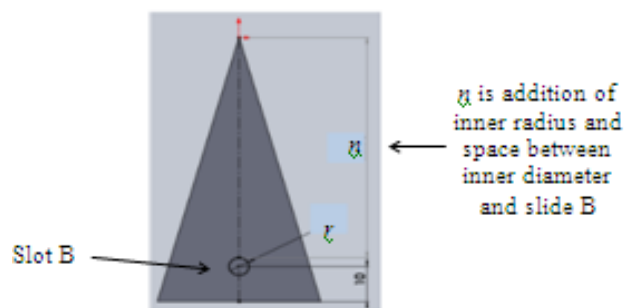


**Figure-7.** Bottom view of the blade.

The diameter for Slot B can be chosen by the designer. However, the position of the Slot B needs to be decided after the inner radius and space between inner diameter and slide B is confirmed. Let the diameter of Slot B represent by $r$, the position of Slot B on the blade can be set as $n$ and it can be calculated as,

Position of Slot B,  $n = x_1 + k_2$          (6)

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## Second layer with gear

The second layer of iris mechanism is another important component because this layer will be attached to the gear from the stepper motor to move the mechanism. The measurement of the gear must be same as the gear attached to the motor, so that; the mechanism can function well without slipping. Figure-8 shows the design of the second layer with gear, while Figure-9 shows the movement of the blade along Slide B to open and close the mechanism.
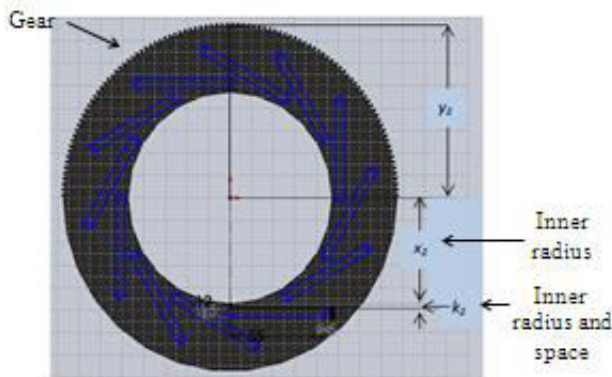


**Figure-8.** Measurement for second layer with gear.

The outside radius for second layer with gear, $y_2$ can be chosen equal or smaller compared to the first layer, $y_1$. The inner radius for the second layer with gear, $x_2$, must be same size as the inner radius of the first layer, $x_1$. It can be simplified as $x_2 = x_1$.

As shown in the Figure-8, Slide B is constructed on the top layer of the second layer with gear. Compared to the Slide A, Slide B has a round edge because Slot B (please refer to Figure-9) has a circular shape while Slot A is a rectangle shape. Referring to Figure-8, the space between inner diameter and Slide B can be represent by $k_2$, height Slide B by $p_2$, and length Slide B by $s_2$. The length of Slide B, $s_2$ can be calculated as,

$$s_2 = x_2 + r \tag{7}$$

where $r$ is diameter of Slot B, and can be chosen by the designer.
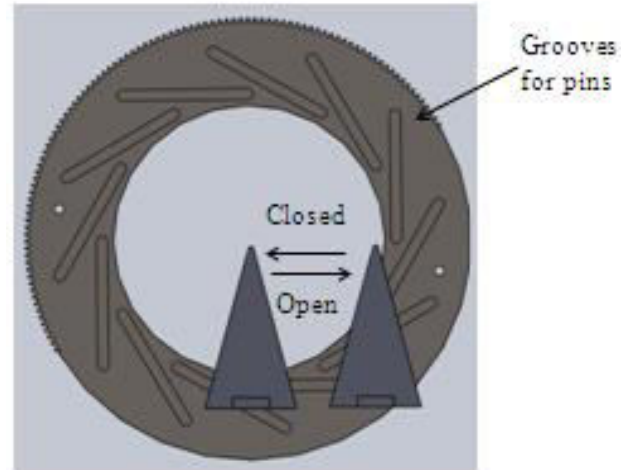


**Figure-9.** Blade travels for open and close.

## Third layer (for holding all layers together)

The function of the third layer of the iris mechanism is basically to hold the first layer, blade and second layer using nuts and bolts together. The inner and outer diameters for this layer are same as the first layer. The holes are built on the third layer to accommodate the nuts and bolts. Let the outside radius for third layer be denoted as $y_3$ and the inner radius as $x_3$. The size of these parameters can be set as $y_3 = y_1$ and $x_3 = x_1$. Figure-10 and Figure-11 show the measurement of inner diameter and outside diameter of the iris mechanism and also the hole for bolts.
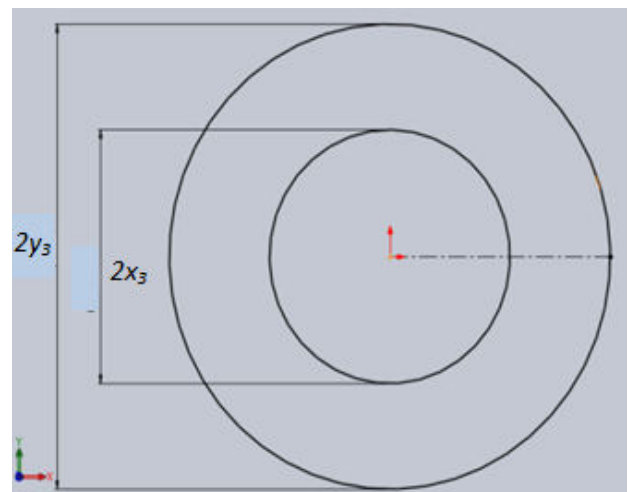


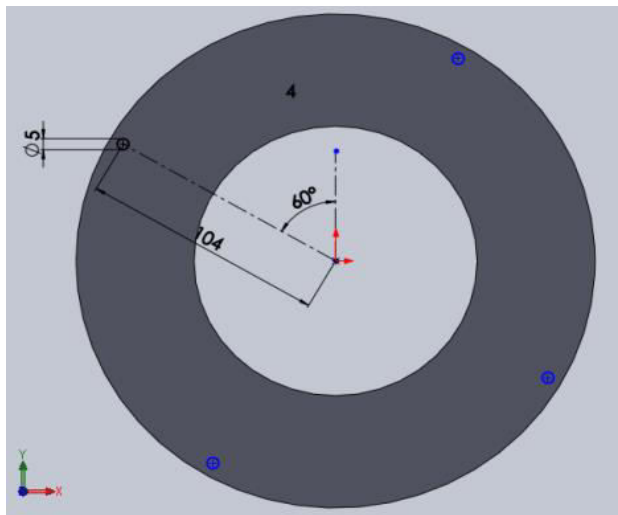**Figure-10.** Measurement for third layer.

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**Figure-11.** Holes for nuts and bolts.

## ELECTRICAL COMPONENTS AND CIRCUITS

### Electric components

Electrical components are very important in every robotic device. In order to have any movement for robotic devices, motor, resistor, microcontrollers are the common components that have been used in the circuit.

### i. Stepper motor

In this design, stepper motor is used because stepper motor can provide accurate movement between their many poles compared to servo and DC motor. Besides that, stepper motors are simpler to commission and maintain the maintenance time by time. In this experiment, speed is not the main concern, but high torque and precision motor are more important. Stepper motor is the most suitable motor for this application since it has lower speeds, which are less than 2000 revolutions per minute and low acceleration. It also has the flexibility for open and close loop operation. Stepper motor is also stable at rest and hold motor position without any fluctuation.

### ii. L293D (motor driver)

The microcontroller that is used in this circuit can supply only 5V voltage while the stepper motor requires voltage up to 24V. The motor driver that is used in this project is L293D and can supply up to 600mA current and 30V voltage.

### iii. Microcontroller (Arduino Mega 2560)

Microcontroller is needed to control all electrical components in this circuit like LED (light emitted diode), switch, stepper motor and variable resistor. Arduino Mega 2560 is one of the microcontroller's boards that are widely used nowadays. It contains 56 inputs and output pins for digital and analog.

**Table-1.** All electrical components.

| Label | Components | Connection |
|---|---|---|
| **IC1** | **L293D** | |
| B1 | 5V DC supply | |
| SW1,SW2 | Normally Open Push Button | |
| R1,R2,R3,R4 | 100 Ω 1/4W | |
| R5.R6 | 10k Ω 1/4W | |
| D1,D2,D3,D4 | Light Emitter Diode (LED) | |
| CN1 | Arduino | pin13 (digital pin) |
| CN2 | | pin12 (digital pin) |
| CN3 | | pin11 (digital pin) |
| CN4 | | pin10 (digital pin) |
| CN5 | Stepper motor | |
| CN6 | Arduino | pin2 (digital pin) |
| CN7 | | pin3 (digital pin) |
| CN8 | | A0(analog pin) |
| CN9 | | Ground pin |
| CN10 | | 5V pin |

### Circuit design

Figure-12 shows the electric circuit is built using the components listed in Table-1. The light emitter diode (LED) shows the direction of the stepper motor to indicate opening and closing of iris mechanism. Figure-13 is shown the circuit built on the breadboard and connected to the microcontroller.
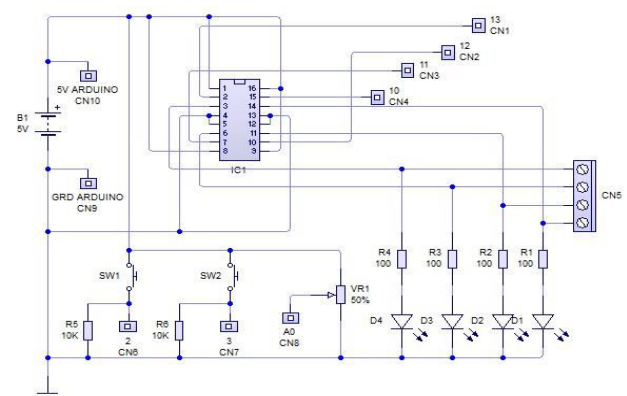
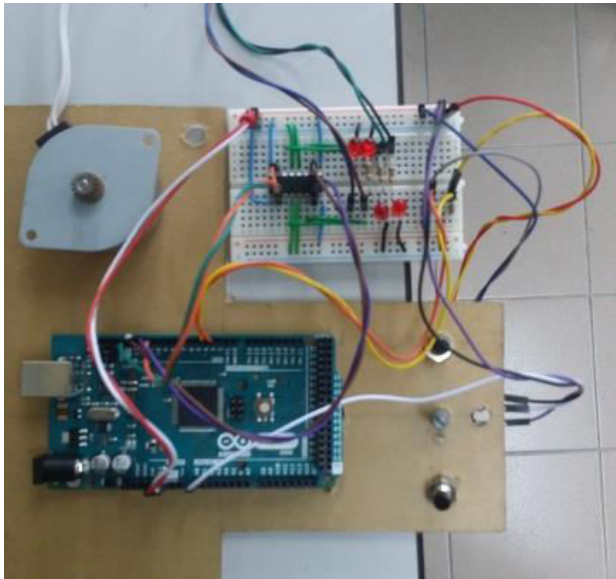

**Figure-12.** An electric circuit.

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**Figure-13.** Picture of components in circuits.

## OPERATIONAL FLOW

Figure-14 illustrates the operational flow of the iris mechanism. The system uses closed loop controller with the simple interaction between the mechanism and patient. Simple coding is implemented in this system to make sure the mechanism function smoothly.

The operation start with the therapist and patients specifies the range of motion and speed of the mechanism for opening and closing the finger. After that, the iris mechanism increases the inner diameter to open the fingers. Next, the iris mechanism return to initial position and the patient's exercise is recorded. This step is repeated until the exercise duration is achieved and the system will display the patient's performance and provide guide for next exercise.
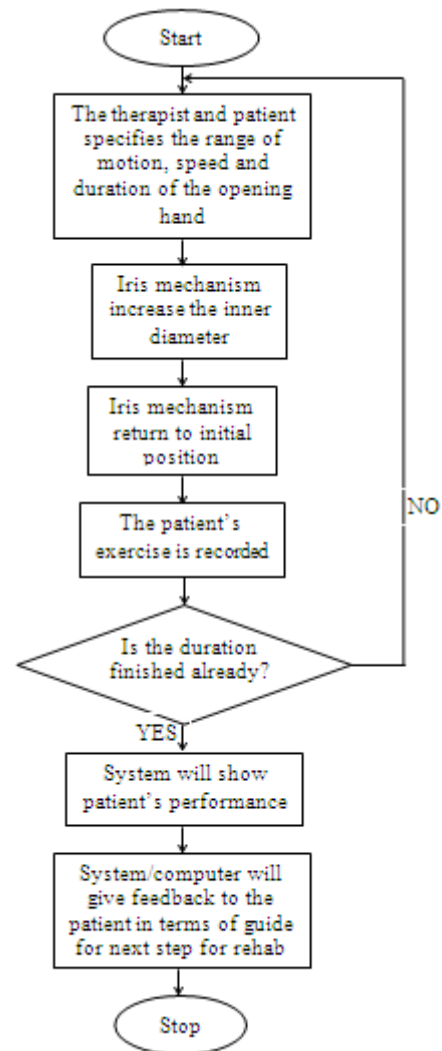


**Figure-14.** Flowchart how the system works.

## RESULT

A prototype of the iris mechanism has been built using ABS filament and perspex. The first layer and blades of the iris mechanism are built using ABS filament while second layer with gear and third layer are constructed using perspex cut by the laser. ABS filament is used for the first layer and blades because this material is easy to be shaped based on the desired design. A holding rod is placed at one end of the triangle. The holding rod is assigned to extend the finger when the inner diameter is opened. For the second layer with gear and third layer, perspex is used because this material has smooth surface, which makes the friction between two layer low and the surfaces smooth.

For this prototype, the inner radius for the first layer, $x_1$ is set by 60 mm. Therefore, the outer radius, $y_1$ will be 120mm based on the Equation (1).The space between the inner diameter and Slide A, $k_1$ is set to be 10 mm and the height of Slide A, $p_1$ is 5mm. Based on Equation (2), the length of Slot A, $t$ is set by 16mm, therefore the length of Slide A, $s_1$ is obtained as76mm.

In this design, the inner diameter for the iris mechanism is set by 120 mm. It shows that the mechanism is able to extend the finger up to 110 mm where many things such as glass for drink have diameter in this range. There is difference by 10 mm between inner diameter and the maximum the finger can extend. It is because the holding bar takes up space. The main focus rehabilitation is to regain hand function and patient is able to perform activity daily life.

In this design, number of blades, $b$ that be chosen is 12. In order to help patient to extend their finger, the suitable number of blade must be chosen. Too low number of blade will cause problem since the distance between blades is too far and not suitable for the rehabilitation process. On the other hand, too high number of blade, the mechanism will stuck and not smooth. For 12 blades, the angle of the $\Theta A$ is 30º and angle of side triangle, D are 75º. Based on the Equation (5), the height of isosceles triangle, $m$ is 75 mm. The space between the inner diameter and Slide B, $k_2$ is set to 2.5 mm, so the position of Slot B, $n$ is 62.5 mm based on the calculation from Equation (6).For the diameter of Slot B, $r$ is set by 5 mm, so the length of Slide B is 65 mm.

For second layer with gear, the gear is cover for 180º. The inner radius, $x_2$ is same with $x_1$, but the outside radius, $y_2$ is a bit smaller. The outside radius, $y_2$ for this design is set by 100 mm. For third layer of the iris mechanism, it is same like first layer where the inner radius, $x_3$ is 60 mm and outside radius, $y_3$ is 120 mm. The full design of iris mechanism is shown in the Figure-15.
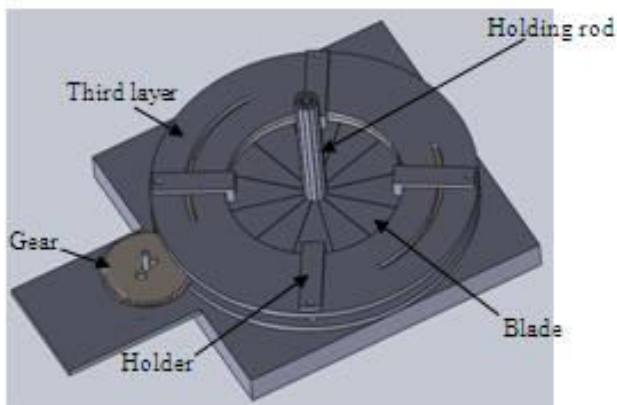
**Figure-15.** Full design of iris mechanism.

Figure-15 shows all blades at the initial state where the iris mechanism is at closed-position. The first layer (lower slot) and third layer (for hold) remain stationary during the whole operation. Only second layer with gear and blade moves while opening and closing the iris mechanism to simulate grasping of object with various sizes. Figure-17 shows the position of blade while the iris mechanism is half opened. In addition, Figure-18 shows the final state where the movement of blades end and the mechanism is fully open to open the patient's hand. In this state, the holding rod is opened to the maximum diameter of the iris mechanism.
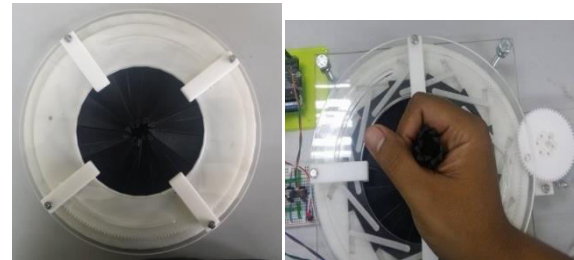
**Figure-16.** Initial state (closed).

**Figure-17.** Half-openediris mechanism.

**Figure-18.** Final state (fully opened).

From this results can be seen that the proposed design has successfully achieved the opening and closing motion for rehabilitation exercise. The blades opens from 15 mm to 110 mm as the second layer with the gear is rotated 77°.

## CONCLUSIONS

This paper presents anew iris mechanism to assist and help injured patient in recovering motor function of the hand especially the fingers. Based on the design, it was developed to focus on training basic hand functions such as opening and closing of the fingers, where it is very important to perform most of the basic activities. The preliminary output for healthy subjects is shown that the mechanism is able to perform opening and closing finger and can used for hand rehabilitation. Future work will be involve the mathematical modelling of the iris mechanism and development of control algorithm.

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## REFERENCES

[1] Mohad, Anizu bin Mohd Nor. 2006. Psychological predictors of injury among Malaysian professional football players. Thesis for Degree of Doctor of Philosophy. pp.xiv-xvi.

[2] Patricia Kan, RajibulHuq, Jesse Hoey, Robby Goetschalckx, Alex Mihailidis. 2011. The development of an adaptive upper-limb stroke rehabilitation robotic system. Journal of NeuroEngineering and Rehabilitation. 8:33.

[3] Younggeun Choi, James Gordon, Hyeshin Park, Nicholas Schweighofer. 2011. Feasibility of the adaptive and automatic presentation of tasks (ADAPT) system for rehabilitation of upper extremity function post-stroke. Journal of Neuro Engineering and Rehabilitation. 8:42.

[4] Nizam Uddin Ahamed, Kenneth Sundaraj, R. Badlishah Ahmad, Matiur Rahman, Asraf Ali. 2012. A framework for the development of measurement and quality assurance in software-based medical rehabilitation systems. In: International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012). Procedia Engineering. pp. 53-60.

[5] Xun Luo, Robert V Kenyon, Tiffany Kline, Heidi C Waldinger, Derek G Kamper. 2005. An Augmented Reality Training Environment for Post Stroke Finger Extension Rehabilitation. In: 9th International Conference on Rehabilitation Robotics. pp. 329-332.

[6] LudovicDovat Olivier Lambercy, Roger Gassert, Thomas Maeder, Ted Milner, TeoChee Leong, and Etienne Burdet. 2008. HandCARE A Cable-Actuated Rehabilitation System to Train Hand Function After Stroke. In: IEEE Transactions on Neural Systems and Rehabilitation Engineering. pp. 582-591.

[7] Eduardo Lopez-Larraz, Luis Montesano, Angel Gil-Agudo, Javier Minguez. 2014. Continuous, decoding of movement intention of upper limb self-initiated analytic movements from pre-movement EEG correlates. Journal of Neuroengineering and Rehabilitation. 11:153.

[8] Rong Song, Kai-yu Tong, Xiaoling Hu, Wei Zhou. 2013. Myoelectrically controlled wrist robot for stroke rehabilitation. Journal of Neuroengineering and Rehabilitation. 10: 52.