A low cost stabilizing spoon for people with parkinson's disease

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***Abstract*— Recently, the technology for assisting people who are functionally challenged has improved over the recent decades. With today's technology, People with Parkinson's disease can, with a device on their wrist, be able to draw pictures. The main aim of this project is to develop a low cost stabilizing spoon for people with Parkinson's Disease during eating process. This project discusses about the design and development of stabilizing spoon, which are made to be simple and less money consuming by utilizing microcontroller and MPU6050 sensor. The purpose of this project is to analyze how an Arduino microcontroller can be utilized to help people with impaired motor skills during their process. A prototype of a stabilizing spoon was constructed to work under real circumstances and intended to be a complement for people who are in need of assistance during eating process. Design and Implementation of the stabilizing spoon uses acrylic as the material, with 3mm of thickness. The MPU6050 sensor is optimized to detect the sway in axis X, Y and Z or known as roll, pitch and yaw. Gyroscope and Accelerometer provide input to the microcontroller, which will process for output on 3 servomotors that function to stabilize the spoon's position at a specified set point. The results show that MPU6050 sensor can response angle reading error of 9.2° roll, 7.4° pitch and 4.6° yaw. Thus, it can be concluded that smart spoon can work optimally with less money consuming as well as low error.**

Keywords—Stabilizing spoon, parkinson's disease, microcontroller, MPU6050 sensors

I. INTRODUCTION

Parkinson's disease (PD) is known as older person's disease, because it is most often found in individuals over 60. It is found to be only 4 percent of all cases are diagnosed before age 50. Since Alzheimer's, Parkinson is the second most age-related nerve that degenerates. (Parkinson's Disease in the Elderly) Parkinson's Disease is a neurodegenerative disease that occurs in the aging brain but the numbers of midbrain do not decrease significantly in very subjects, arguing strongly that PD is not caused by an acceleration of a naturally aging process. [1] Signs and symptoms of Parkinson's disease can vary for everyone. Early signs could be mild and remain unnoticed. At first, symptoms begin with one side of the body being affected then worsen on the other side which eventually begins to affect the both sides. There are five primary motor symptoms of Parkinson's disease: tremor, rigidity, bradykinesia (slow movement), postural instability (balance problems), and walking gait problems. (Common Symptoms of Parkinson's Disease) Tremor is the one of the visible features of Parkinson's disease. People living with early stage of Parkinson Disease often experience severe embarrassment and difficulties because of their tremor, which limit social interactions and often interfere with the ability to perform daily activities and simple tasks at home and at work. The International Essential Tremor Foundation has gathered information about a number of devices and technologies that may be helpful to people with essential tremor. (Assistive Devices) It is therefore common for people with Parkinson's require assistance from either people or technology.

The medical community is continuously working to improve the lives of those suffering from Parkinson's disease through research and medical advancement; however there is no cure yet for the people with tremor disease. (How is tremor treated?) Botulinum toxin (Botox) injections have shown some promise in relieving froM essential tremor in hands. The function of the injection is to calm the overactive muscles by targeting the specific muscles that are involved in irregular activity and avoiding muscles that are not involved. (Medications for Essential Tremor Disorder)

The ability to perform basic daily living is a vital necessity for every individual. There is a justification which the functions and the structures of the body are disturbed and the capacity may be reduced resulting in impairment. The Rehabilitation Engineering and Assistive Technology Society of North America said that assistive technology has been shown to help people with disabilities to enhance their quality of life. With technology devices specifically designed to meet the needs of the individual, people with disabilities can improve and optimize their day to day functioning so that they can be self-reliant, self-sufficient and self-confident. [2] The main focus of this project is to improve the comfort and usability of existing devices that can help the Parkinson's disease sufferer to eat a meal. Unfortunately, the current device called "Smart" spoon is very costly which the device is manufactured by Liftware. Since the device is very expensive, PD's sufferers cannot afford to buy them which they have to rely on various charities in order to get the devices. For them to get a donated Liftware unit, they have to complete an online application [3].

Most people can live normal lives with condition. Although Parkinson's disease occurs with movements, it affected people with Parkinson's disease while doing daily activities such as eating, drinking or writing. Parkinson's disease usually happens when the hands are stretched as the muscles are opposed to the gravity. It is therefore clear that the Parkinson's disease interferes with the everyday activities. In this research, the case of Essential Tremor produced in hands and palms. The older people feel ashamed to hold their

food in front of other people because of tremor. They become very aware when having their food or drinking water or even writing. That has impact on their conscience. They are feeling very weak. So, the common problems that the old people faced are:

- Intractable tremor which begins while eating
- Hand shivering while writing
- Difficulty in balancing when grasping or holding something
- Emotional activation and stress caused by to tremor
- Worsening of tremor with sudden motion

These problems make the elderly feel embarrassed while doing daily activities such as eating, drinking or writing. The use of stabilizing mechanisms appears in many different fields. There are few examples can be found in air craft, industrial robotics and video stabilization. Many of these mechanisms have a preference for a body's constant and unchangeable location, irrespective of the motion involved. This motion is very important in supporting the people with tremors. People who are affected by this disability can execute certain tasks that occur in everyday life with the help of compensating devices. With the help of the stabilizing spoon, an individual with these problems can eat independently and does not need any helping from another. As been explained earlier, Parkinson's disease is a neurological disease that causes the hands to be shaking and makes eating difficult. Honestly, there is no cure for Parkinson's disease, but there is research and hope for innovative technologies that can help people with the disease to perform their daily activities normally.

To address this issue, various approaches have been created to improve the life of the patients such as pharmaceutical therapies, wearable devices and stabilizing handles. Handheld assistive spoon have been developed by Liftware that can stay stable during eating process. An on-off comparison of patients with mild tremor eating with the assistive spoon has been shown in a study on such product. The devices allowed the patients to feed themselves effective with different kinds of food. The system is non-invasive, user-friendly and effective [4].

There is current no equivalent functional utensil, such as Liftware. However, there are certain solutions for People with Parkinson's Disease and Essential Tremor. First, there are versatile utensils that are intended to eat in a cheap way compared to Liftware. These utensils would cost between $5-100 but it did not help the person with tremors when using these adaptive utensils. Despite using the adaptive utensil, eating condition still remains very difficult. Another alternative way to Liftware is to employ a caregiver to help them during eating but this option would cost around $15-$20 per hour for that option. By this caregiver, it would eliminate the problem of the user's tremor while eating. However, it would eliminate independent eating.

Therefore, the main aim for the project is to build on the existing technology to produce a similarly designed "Smart" spoon, using an open source programmable board like the controller, vibration sensors and servo respectively as input and output. Other main aim is to develop highly efficient prototype with comparable efficiency of tremor stabilization as the current technology but at a smaller budget and thus at a lower consumer cost.

In order to address these challenges, similar research on this assistive device has been carried on to improve the design and more components. Therefore, the main focus of this project is to develop a low cost stabilizing spoon to counter people with Parkinson's Tremor that is cheap and affordable with similar performance as the current technologies. The weight of the system is also light by using light material and sparse. The cost of the overall system is also much less compare to the existing devices.

[5] proposed a design of Two-Axis Stabilized Platform which is used to provide the device with a balanced platform to achieve tracking and guidance efficiency, accurate position and distance angle measurement.[6] proposed a design to compensate for the motions and maintain the stability of platform for landing and take-off of the helicopter. The design consisting of three layers, top layer, where the helicopter lands, actuating layer and bottom layer which lies on the base of the ship. [7] proposed a design using a gyro stabilized optical detection platform, which can provide panoramic range detection and tracking. It mainly composed of a biaxial rate integrating gyroscope, azimuth and height of the DC torque motor, azimuth and height of the solver, half strip transmission mechanism, a supporting frame, and electromagnetic locking device and light reflector. [8] proposed a design of self-stabilizing platform using MPU6050 to reduce accidental death during transporting the patient to the hospital. Mostly problem occurring during transportation are the stability of the patient which are not satisfied due to the continuous movement of the vehicle which can cause a problem for a doctor or nurse to perform minor medical procedure/operation in the moving vehicle which might cause the patient dead on arrival at the hospital. [9] proposed a design of a two-wheeled self-balancing robot for an application to carry object from one place to another. For this design, two controlling sub-system are used for the application of object carrying and preventing the system from falling down when it moves in forward or backward direction. [10] proposed a design of self-stabilizing mobile platform with 2 degree of freedom using low cost material which can be used for various medical, military application and logistic device and is objective suitable for working in outdoor where the ground surface is not flat or uneven. [11] proposed a design of stabilizing platform which is used in ship borne remote sending stabilized platform which serves as an important role in ship borne remote sending system.

II. SYSTEM IMPLEMENTATION

A) Overall Block Diagram

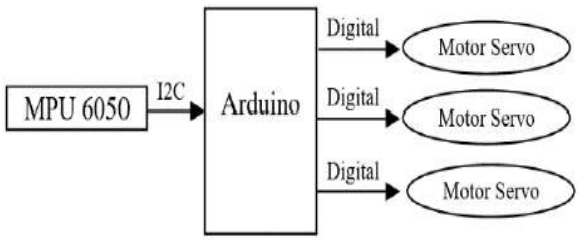

Fig. 1. Block diagram system

The system consists of MPU6050 which inside of the sensor consisted of accelerometer and gyroscope in order to

detect the Parkinson's disease hand and follow the orientation over the gravity. Arduino Nano is used as a microcontroller for data processing and decision which it will sends the data to the three servo motors. As shown in the figure above, the working principle for this project started from the input coming from MPU6050 which it will read the data when it is being tilt or shake. Then, it will send the data and being processed by Arduino Nano which acts as microcontroller and will drive the servomotor as the output of the device to stabilize the assistive device.

B) Hardware Wiring

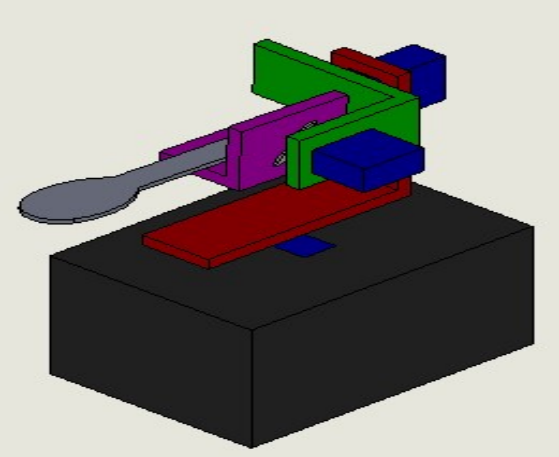

Fig. 2. Prototype design

The prototype is designed using 3D modelling software known as Solidworks. As been mentioned before, it consists of three servo motors for 3-axis control movement and base on which the MPU6050 sensor is place, Arduino Nano and Power Bank are used instead of battery.

Actually the prototype needs to be built using 3D printer. A few problems have been encountered during building the prototype due to limited facilities available. Due to Covid-19 situation, the facilities that are provided by University cannot be used. Nevertheless, the prototype is done with the material and facilities available in the Brunei. Therefore, the housing and the support is made up of acrylic due to the material easily available in the marker and the price is cheap in order to achieve the first objective which is building up the prototype using a sustainable materials. Assembling the prototype is quite easy, as all the supports for the servomotors are attached to the housing using screw. This method is repeated for three times as there are three servomotors using in this project. All of the servomotors need to be secured up to the support which specifically designed to easily fit SM-S2309S servo motors. In order to keep the servo wires organized a holes is made up beside the housing so that the wires can enter through the hole which it connected to the pins of Arduino Nano which the connection of the servomotor will be explained later on.

For powering up the project, Power bank is used instead of battery which is placed outside the housing. This is due to not enough power supply provided by Arduino Nano to power up the three servo motors during testing the prototype. A power bank with 2 slots is used so that it can supply 5V power which one slot is used to power up the Arduino Nano and the another slot is to power up the three servomotors.

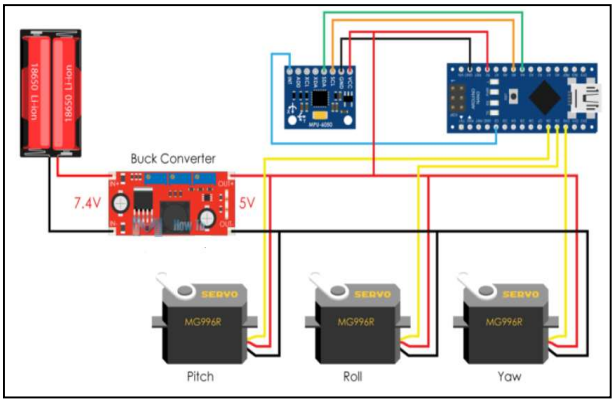

Fig. 3. Circuit connection of whole System

As seen the figure above, the wiring for the prototype should be connected and looking similar like this. A power bank with two slots is used instead of battery as it can supplied 5V power to the Arduino Nano and three servomotors and does not need buck converter. From the figure above, the reds colour represents the wire that needs to be connected to the ground and the red colour represents the wire that needs to be connected to the power supply. For MPU6050, there are five wires need to be connected to the Arduino Nano. As mentioned before, the red colour need to be connected to power supply and the black colour need to be connected to the ground. For SCL and SQL, the wire needs to be connected to Arduino pins 4 and 5. For interrupt pin, the wires need to be Arduino pins 3. For servomotors, there are three colours connected to the servomotor. The yellow represents the wire that need to be connected to the Arduino pin to define the pin for the servomotor, red colour represents the wire that need to be connected to the power supply and lastly, brown colour represents the wore that need to be connected to the ground. All the pins that are connected to the Arduino Nano need to be defined in the programming code according to the wire connected to the Arduino pins to make the prototype functioning very well.

C) Working Principle

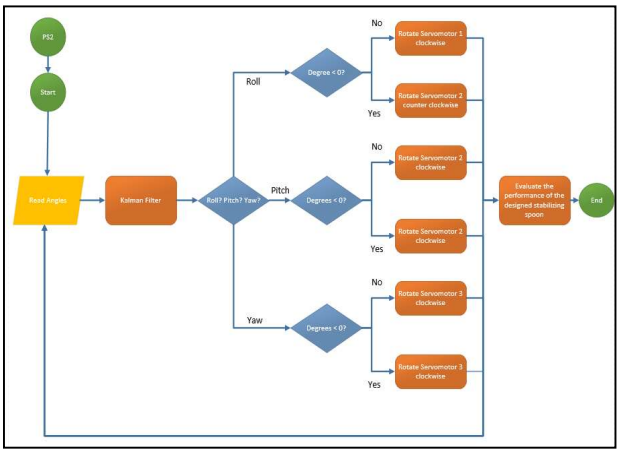

Fig. 4. Flowchart of the entire system

Fig 4. shows the overall block diagram of the entire system. The entire system is control with the power bank as

the power supply to the Arduino Nano and three servomotors so that the MPU6050 sensor can discover the roll, pitch and yaw angle of the vibration of the Parkinson's Disease hand. Then, a microcontroller will take the readings from the angle through an I2C. From a microcontroller, a PWM flag is given to the servo motor through motor driver so that the spoon can be stable in an original position. Servo motor includes a feedback so that a microcontroller can give information the servo motor to move according to Parkinson's Disease hand. This will help to set the angle for adjusting the spoon.

As seen the figure above, the code that was developed divided into three parts. The first part is about declaration of each parameter which is used later in the code. This is important also in the wiring the prototype as the declaration of the pins that are already declared in the code need to be following according to the code set to make it work. The second part is the initial setup, establishing communication between the microcontroller, servomotor and the IMU. The third part is retrieving the outputs value from the IMU which it provides commands to the servomotors to rotate accordingly through a Kalman filter. Then, the performance of the stabilizing spoon can be analysed through GUI to evaluate the performance of the stabilizing spoon during the eating process of the impaired person as an assistive device.

III. HARDWARE RESULTS

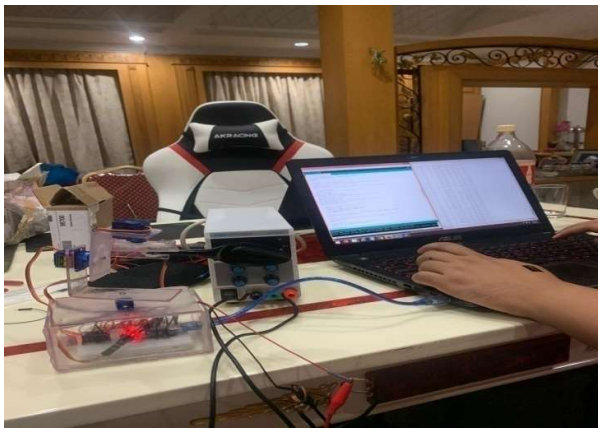

Fig. 5. Hardware testing

It was very clear that the project needs to be tested for a few times as a few problems have been encountered during building up the prototype and also the pseudocode programming for the prototype to working and achieve the desired objective. With the help of tutorials and circuit diagram, learning could be possible on how to use MP6050 with the Arduino Nano. A few steps need to be taken in order to achieve the desired objective.

It was started with building up the prototype. The prototype was built with the materials available, and it was made up from scratch. The real prototype should be designed using 3D printing but due to COVID-19 situation, the facilities in the University cannot be used and need to find other option to build the prototype. To build the prototype, acrylic was used instead of using 3D printing which the final design shown in Figure above. Acrylic was used because the material is easily available in the market and it is also cheap as the main objective of the project is to build the prototype using low cost and sustainable material.

A few problems have been encountered during building up the prototype due to facilities available due to cannot go back to Kuala Lumpur because of COVID-19 situation. The first option is to borrow workshop from University Technology Brunei which have to wait for the official letter from Project supervisor. Unluckily, the University cannot let me to borrow the facilities as they need a fee for student to borrow the workshop after receiving letter from Asia Pacific University. This might be costly as the main objective for this project is to develop a low cost stabilizing spoon for People with Parkinson's disease. In order to achieve the objective, the other option is to build the prototype with the facilities available at home.

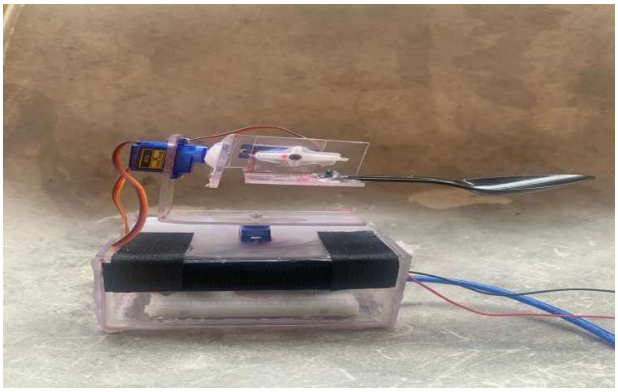

Fig. 6. Final design of the prototype

The building up of the prototype started with cutting the acrylic material according to the design and dimension that are already designed using solidworks. The cutting part is divided into two parts which is for housing and the support for the three servomotors. Then, all the acrylic part was then assembled using glue gun in order to assemble the prototype according to the final design of the prototype.

For programming, need to include all the Arduino libraries before doing the code which are already explained before. This is because the libraries need to be included in order to be able to read the code and understand the code to make the prototype working properly. Before building up the programme, need to check the three servomotors first whether it is in good condition by connecting it to the power supply.

A simple circuit set up is necessary to test the functionality of the MPU6050 and understand how the Arduino being able to talk with MPU6050. MPU6050 need to be calibrate in the programming code due to the position is not suited as the normal suited is not suited to the fixed position of MPU6050 which already been set up in the breadboard. Using the set up and codes given in Arduino, the raw values can be seen in the serial monitor as it automatically applies the filters to the gyroscope and MPU6050 to get the output. Numerous modifications have been made in order to make the code work for the spoon application. After a numerous modifications, it was necessary to see how the MPU6050's could be processed and given an output. A serial print is used to shows the values of the variables.

The serial print from Arduino will show the rotation of roll, yaw and pitch rotation occurs around the X-axis, Y-axis and Z-axis respectively. The screenshot is taken during the testing of MPU6050 which it is being mounted onto the breadboard. The result show that the angle of MPU6050 in the

roll, yaw and pitch direction according to the rotation of the MPU6050 which the direction is being restricted to +-90°

The code uses a "map" function to map the Kalman values on the servomotor. The map function fits the value of one measurement into the range of required output. In this case, Kalman filter angle is set up from a range of -90° to 90° which is the full range of 360. These values are measured in microseconds which it recognised by the servo library and provides greater accuracy when moving the servo. Then, for testing the variables, the code itself will display the data to Arduino IDE serial monitor.

That concludes for the hardware and software simulation results. The testing of thee prototype will be explained later under the testing stages. The code may continue to be used and altered after the submission of this report for further tuning.

IV. TESTING OF THE PROPOSED DESIGN

A) Servo Motor Testing

This testing is carried out to find out whether the servomotor can be move according to the turning angle as an input. This test uses an Arduino which acts a microcontroller to send the input data to the servomotor. After the test is performed, a table is made to identify that the servomotor functions properly or not.

TABLE I. THE RESULT OF ROLL ANGLE TESTING

No	Angle (°)	Data of Sensor reading (°)	Error (°)
1	0	0	0
2	30	22	8
3	45	40	5
4	60	55	5
5	90	85	5
Average			4.6

Based on the result above, it is shown that the servomotor can be move according to the turning angle. Based on the result, it can be seen that the servomotor can do the angle movement in line with the set point, with the average of error for the pitch is 4.6 degree. This value is still in a normal range and can be use. Other main finding is that the servomotor return to its original position when it is being rest after being turn to a certain angle which might cause higher value in the average of error for the pitch.

TABLE II. THE RESULT OF PITCH ANGLE TESTING

No	Angle (°)	Data of Sensor reading (°)	Error (°)
1	0	0	0
2	30	30	0
3	45	45	0
4	60	60	0
5	90	88	2
Average			2

Based on the result above, it is shown that the servomotor can be move according to turning angle in line with the set point, with the average error for the roll is 2 degree. This value still in a normal range and can be use. From the result also, it is found that there is no error when the servomotor is being moved from 0° to 60°. It is found that the servomotor for the roll is more stable compared to pitch and yaw servomotors. Other main finding during testing the servomotor is that when the servomotor for roll is being moved to a certain angle, the pitch and yaw servomotors also move to a certain angle which it should be in rest position when the servomotor for the roll is being moved.

TABLE III. THE RESULT OF YAW ANGLE TESTING

No	Angle (°)	Data of Sensor reading (°)	Error (°)
1	0	0	0
2	30	25	5
3	45	37	8
4	60	50	10
5	90	83	7
Average			6

Based on the result above, it is shown that the servomotor can be move according to turning angle with a set point, with the average error for the yaw is 6 degree. As seen in the table, it is shown that the average of error for yaw is slightly higher compared to pitch and roll error value due to the yaw return to its original position after being titled to a certain position which might cause error during the testing. The servomotor should be remaining in a certain angle when it is being tilted to a certain angle and follow according to the angle that the prototype is being moved. This might result in slightly higher average error value compare to the pitch and yaw as the servomotor should be follow the input from MPU6050 and follow the movement of the MPU6050 after being move according to a turning angle.

B) System Mechanism Testing

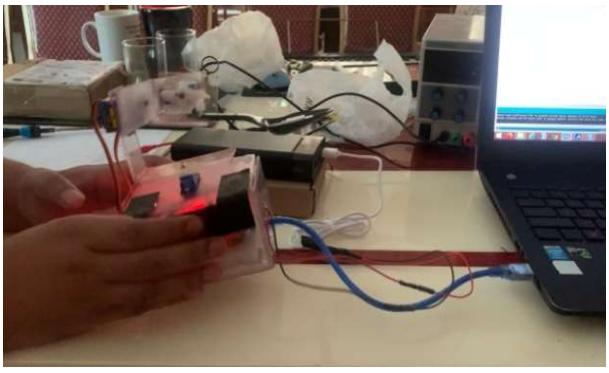

Fig. 7. System mechanism testing

As can be seen in the figure above, the assistive device known as stabilizing spoon were powered up using Powerbank which will produce the power around 5V which is a suitable power to power up the Arduino Nano and the servos. A Powerbank is used instead of Li-on batteries due to Li-on batteries produce power around 7.4V which it needs a buck converter that can convert from 7.4V to 5V in order to make it suitable for voltage references.

System Mechanism testing is carried out by monitoring the movement of the device when it moves to the right and left. A few problems have been encountered to make it work efficiently and achieved the desired object which is to build a low cost stabilizing spoon for People with Parkinson's Disease. Based on the test, it is seen that the spoon is able to stabilise the object that are put into the spoon when it is being tilted to the right and left. It is shown that the assistive devices gave achieved the desired objective which is to help People with Parkinson's Disease during eating process without any

helping hands from others. Assembling the prototype might be quite easy but it must be carefully connected according to the pseudocodes that are already set up before building up the prototype.

Overall, with a low cost, the prototype is working efficiently and achieved the desired objective which to help People with Parkinson's disease during eating process. Although the device is a low cost, but it is reliable and affordable due to it is cheap that the existing devices on the market. The prototype is done, and it works well as expected.

C) Steady Spoon Testing

The Steady Spoon is the unique method in feeding of a person who is unable to perform the eating activity by himself/herself especially for the People with Parkinson's Disease. In order to test the stability of the spoon, the stabilizing spoon should be able to bring food of any kind from their plate or tray towards their mouth. Therefore, it is important to test stability of the spoon whether it can be use by People with Parkinson's Disease or not. This testing is important as one of the main aim and objective of the project is to develop a low close loop control system to reduce more than 70% tremors using sensor and actuators. In order to achieve objective, the stability of the spoon need to be tested during eating process by People with Parkinson's disease. During the testing, the prototype or known as stabilizing spoon should helps to reduce and stabilizes the movement of the spoon to make eating much easier for the patients without any helping hands from others. Below show the table for the testing of the stability of the spoon:

Abbreviation used in Table I:

PRS (Parkinson Rating Scale) Scoring Results:

- 1 = very much improved, minimal symptoms
- 2 = much improved
- 3 = minimally improved
- 4 = no change
- 5 = minimally worse
- 6 = much worse
- 7 = very much worse, severe exacerbation of symptoms

TABLE IV. THE PRS SCORING RESULT

Subject	Age	Sex	Dominant hand	Positive Family History	PRS feeding score	PRS drinking score
1	50	F	R	Yes	2	3
2	45	M	R	Yes	1	2
3	63	M	L	Yes	3	4
4	61	M	L	No	3	4
5	40	M	R	Yes	1	2
6	35	F	R	Yes	1	2
7	68	F	R	No	3	4
8	55	M	R	Yes	2	3
9	60	F	L	Yes	2	2
10	48	F	L	No	1	2

Based on the result in Table IV, it is shown that the stabilizing spoon is proven to be more effective in which 10 patients were made to perform a task such as holding, eating and transferring objects.

V. CONCLUSION

To develop a light-weight stabilizing as an assistive device using sustainable materials, the prototype has been designed and the program has been programmed successfully using an Arduino microcontroller and simulated using a GUI developed using the LABVIEW. The prototype also known as the stabilizing spoon or "Smart" Spoon is quite heavy compare to the existing device known as Liftware which might be uncomfortable for the People with Parkinson's disease to wear it during eating process. The servomotors do not respond as quickly as would be required. This may also be used due to the code being used and processing capability of the Arduino. The "smart" spoon project can counteract movement but fails to eliminate tremors due to limitations of the hardware and the signal processing algorithm used.

Due to the technology has been improved, nowadays, there are many options that become available and creativity which allows us to expand further and create better projects that in turn to satisfy the increasing demand of the future generations. The proposed satisfied all the objectives stated; however with more time, variation of the hardware and more research on the "smart" spoon project, it can be further improve and produce a quality product. To produce a quality product, need to perform the research required, learn the programming language and filtering techniques as this might be time-consuming and need constantly focus on building up the project.

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