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Development of A Knee Orthotic to Prevent Falling Due to Buckling Among Elderlies

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Abstract: Many elderlies are living alone in their home. If an elderly falls due to buckling, it may cause severe bone injuries and maybe be difficult to request help. A mechatronic orthotic is designed and developed to lock the knee movement during the detection of buckling. A ratchet mechanism is deployed to lock the knee orthotic from moving during fall occurs. Data is obtained from all the axis of an Inertia Movement Unit (IMU). To differentiate the normal walking pattern angle and falling pattern angle from the IMU sensor X, Y and Z axis reading are monitored between the range of the Upper Falling Threshold (UFT) value and Lower Falling Threshold (LFT) value which are used to identify falling during walking phase.

Keywords: Knee Buckling, Knee Orthotics, IMU Sensor

1. Introduction

Elderly can be referred as elderly or senior citizens [1] will be taken to mean people over the age of 65. Arthritis is an inflammation of the joints where Malaysia. It's most common joint pain among older people may affect one joint or multiple joints. There are more than 100 different types of [2] arthritis, with different causes and methods of treatment that can be focused on knee buckling among the elderly because 80 percent of the ageing population faces the same problem around the world.

In several patients a programmable knee actuated orthosis may direct and promote the treatment through retraining sessions of a more effective and medically appropriate gait pattern. Lower-extremity robotic systems have been developed for gait retraining to provide an opportunity for intensive rehabilitation [4], but their use is restricted to the clinical setting for relatively brief training sessions. Patients may use a wearable training orthosis during everyday activities, with the desired gait pattern being continuously reinforced. In a real-world scenario, this continual reinforcing of gait retraining has the ability to offer more successful gait retraining, increasing one's capacity for patients with outpatient knee and hip osteoarthritis [5] to implement distinct biomechanical compensatory techniques when walking.

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Patients with unilateral hip osteoarthritis usually build the gait of a Trendelenburg. Throughout the gait stance process on the affected side, the pelvis on the opposite site is rotated downwards to reduce the load on the affected side. Therefore, there is no longer a change from the center of gravity to the stance leg which leads to instability. Reduction of joint flexion and extension due to discomfort, deformity, or muscle weakness can occur as a result of worsening knee arthritis osteoarthritis, resulting in increased balance control deficits. Buckling and symptoms [4] of imminent fall may be treatable or at least avoided, but avoiding buckling precipitating behaviors may restrict operation. Buckling can cause falls and fractures and can help to explain the increased risk of hip fracture in patients with osteoarthritis who are of higher bone density than others of their age and who should therefore be at lower risk of fracture.

2. Research Methods

2.1 System Overview

The knee orthotics and can be used for regular routine as well, by that we can prevent the falling among elderly because of knee buckling. The IMU sensor will analyses the raw accelerometer and gyroscope value will be send the data to Kalman filter to filter out the drift and unstable accelerometer reading in the IMU reading after the filtration, the values will enter are fall detection algorithm that predict buckling or falling going to occur or not. Next, the electrical solenoid plunger will be work to lock the gear system in the exoskeleton when the fall or buckled was detect that will install at knee exoskeleton entre of the entre locomotion joint of the exoskeleton. Finally, this entire component will be connected with Arduino Uno that will analyses and predict the UFT and LFT the overall system design of the Knee Orthotics for Elderly as shown in Figure 1.

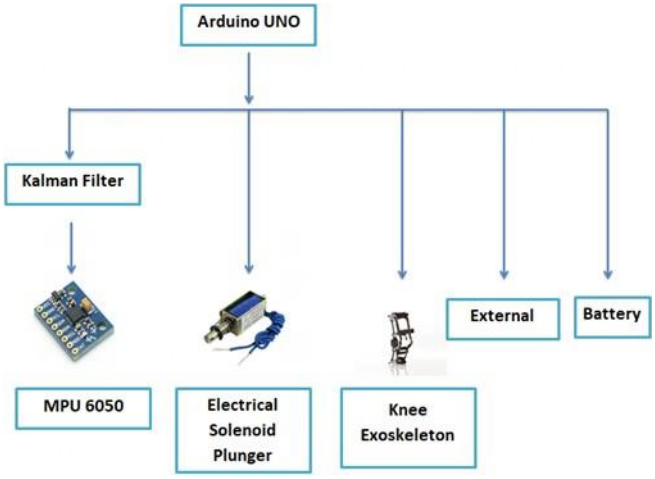


Figure 1: Overview System of the Knee Orthotics

2.2 Mechanical Design

Mechanical design of the knee exoskeleton will be done by using Sketch and SolidWorks to design the orthotics. The mechanical design of knee orthotics for elderly has been sketch the skeleton and dimension. Knee orthotic design have been draw using SolidWork and divide the part into gear, upper link, lower link, 16 mm shaft with key way and 10 m left skeleton shaft. Figure 2 shows the overall knee orthotics design that has been sketch. Beside that the designs divide into three main part upper link, lower link and gear housing.

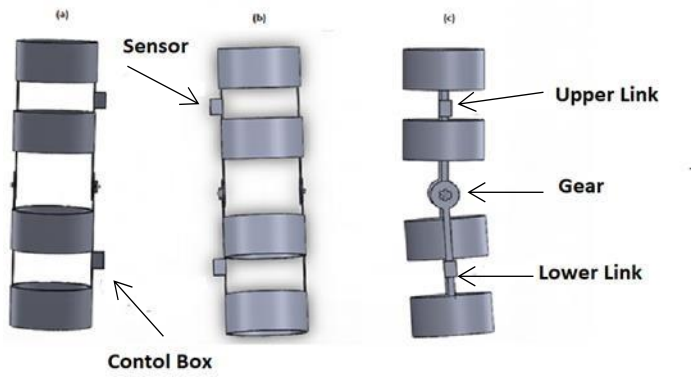


Figure 2: Overall Knee Orthotics Design – (a) Front view, (b) Back view, and (c) Side view

Beside that the pressure point of the gear will design 30 degrees from pitch to another gear pitch because the human knee rotation angles are from 0 to 140 degree and the thickness of 8mm. The design of the key have been done using are rectangular shape design with the dimension of 3mm for all the side. Figure 3 illustrates gear dimension that allows the rotation in one direction and prevents movement in opposite direction that can lock the gear and prevent any type of backward falls during walking and buckling stage.

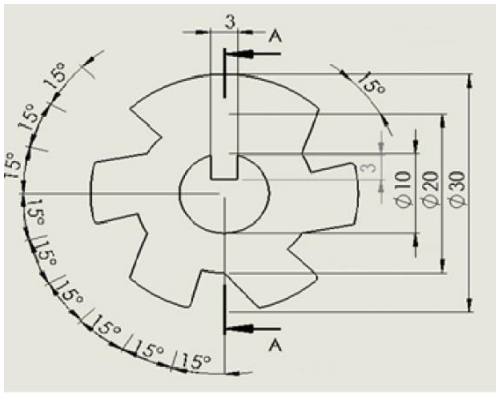


Figure 3: Gear dimension

2.3 Electrical Design

Electrical design of the knee orthotics system the components that use are resistor 270k Ω, diode 1N4001, transistor 2N2222, 9V battery, Arduino Uno, IMU sensor and Electrical Solenoid plunger. Arduino Uno R3 is an embedded microcontroller module as shown in Figure 4. This module was built in with USB connecter and assortment of pins out. Since the system uses both acceleration and angular velocity (gyroscope) to detect falls and buckling pattern, the 6-DOF module was used with small size and power requirements. The 2N2222 is the NPN bipolar junction transistor (BJT) used for applications for typically low-power amplification or switching. It is designed for low-to - medium-current, low-power, medium-voltage and can work at moderately high speeds. A resistor performs electrical resistance as a circuit segment. It is a passive two-terminal. Resistors are used to reduce current stream, alter signal levels, to detach voltage, inclination dynamic parts, and end transmission lines among various job. The dc motor will be replaced with electrical solenoid plunger will convert electrical energy to mechanical energy by that it will be easy to work as lock mechanism system at the skeleton.

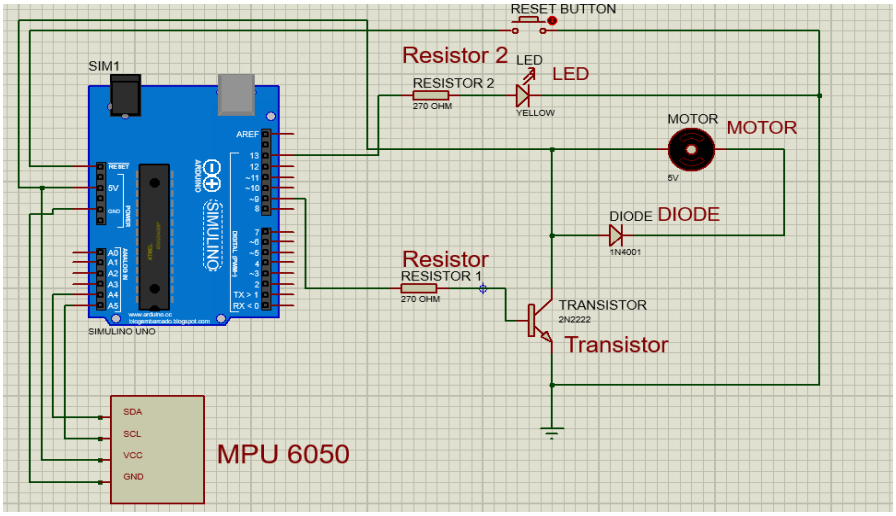


Figure 4: Electrical design of the Knee Orthotics

2.4 Fall Detection Algorithm

The parameters used in analyses are close to those suggested in previous studies [9,10]. Acceleration or Acc, the total vector of acceleration for both static and components of dynamic acceleration are calculated from data sampled using Eq. 1. Where Ax, Ay, and Az are accelerations (g) in directions x, y, and z. Similarly, angular velocity is calculated on the basis of sampled data as shown in Eq. 2.

$$Acc = \sqrt{Ax^2 + Ay^2 + Az^2} \qquad Eq.1$$

$$\omega = \sqrt{\omega x^2 + \omega y^2 + \omega z^2} \qquad Eq.2$$

The acceleration magnitude, Acc, is constant +2 g from the triaxial accelerometer when stationary, and the angular velocity is 500 degrees per second. When falls occur the acceleration changes rapidly and angular velocity generates a variety of signals along the direction of fall.

2.5 Load Analysis

From the scenario the weight of the person is 100kg times with the acceleration a = 9.81 the new weight value is 1000 N (Newton). The motion range of leg is 0 to 90 degree and earlier to calculated the torque at knee during heel strike position during stance phase. Eq. 3 is the formula used for torque. Figure 5 shows the increase of torque at knee when the angle increases during heel strike.

The formulae for torque is $\tau = W \times l \sin\theta$ $\qquad Eq.3$

where, τ = Torque

W = Weight of person change to F

l = length of the thigh

θ = angle at W and Gravity line

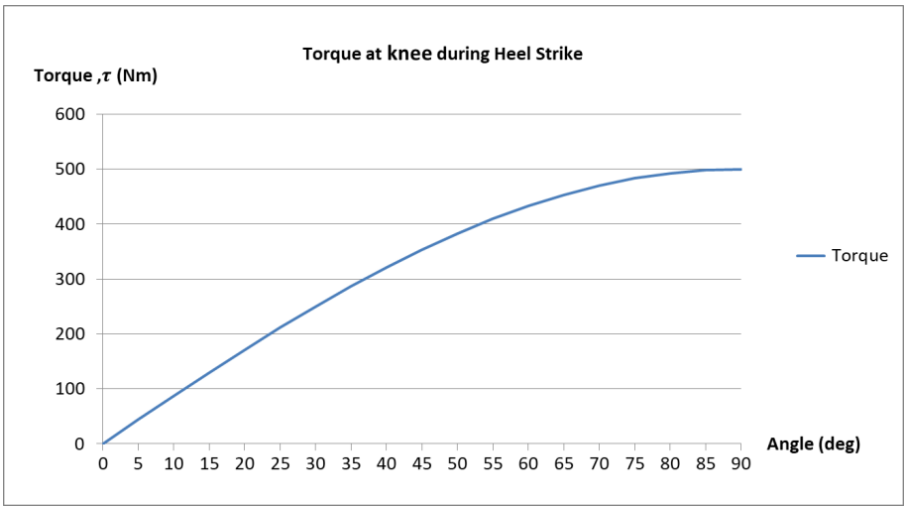


Figure 5: Show the graph of torque verses angle

2.6 Hardware Assembly

The design of knee orthotics is a product to provide convenience to the elderly and at the same time could help elderly in prevent fall due to knee buckling. The elderly can easy the monitor and control the knee orthotic with the touch of hand. An Inertia Movement Unit (IMU) sensor is used to detect the LFT and UFT of the walking and falling phase so that we can control the gear mechanism. Figure 6 shows the complete Develop a Knee Orthotic to Prevent Falling Due To Buckling among Elderly of the project.

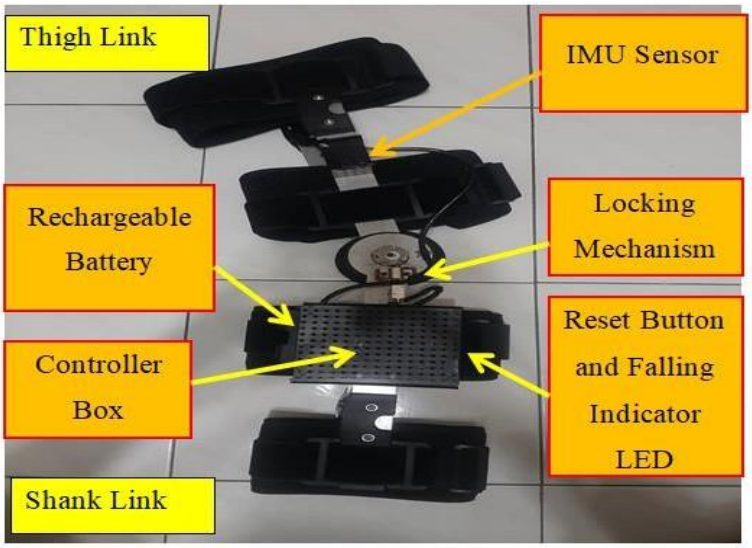


Figure 6: Completed hardware assembly and specifications

3. Results and Discussion

The proposed knee orthotics is a product to provide convenience to the elderly and at the same time could help elderly in prevent fall due to knee buckling. The elderly can easy the monitor and control the knee orthotic with the touch of hand. An Inertia Movement Unit (IMU) sensor is used to detect the LFT and UFT of the walking and falling phase so that we can control the gear mechanism. This system also uses a light weight skeleton design and easy assembly process than can easily to maintain the cost of repairing the skeleton with the style of plug and play. The connection the IMU, it will send data and analyses the buckling stage data for the elderly. Figure 11 shows the Develop a Knee Orthotic to Prevent Falling Due To Buckling among Elderly of the project. Then Figure 7 shows the circuit connection of the system.

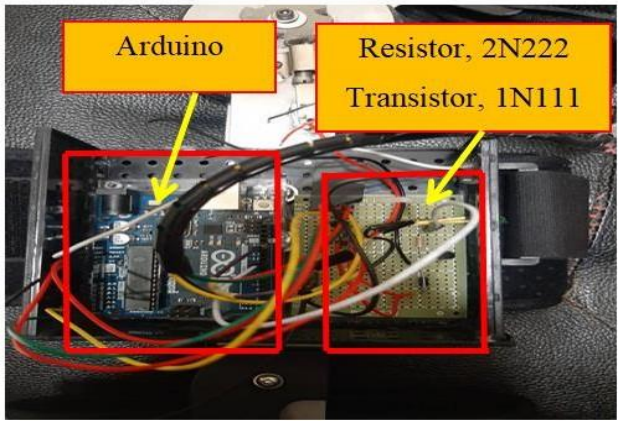


Figure 7: Circuit Connection of System

Inertial measurement units (IMUs), measure the acceleration and angular velocity around their own three-dimensional local coordinate system. With proper calibration, the axis of this local coordinate system represents an orthonormal basis that is usually well aligned with the outer casing of the sensor. From Figure 8 show the IMU sensor axes direction at the knee orthotics and Table 1 shows the function of each axes direction of the IMU sensor.

Table 1. Remark of each IMU axis

Axis	Remark
Y	Direction to be vertical and measure the angular velocity about 10 degrees
X	Direction to be horizontal and measure the angular velocity about 90 degrees
Z	Direction to be Lateral rotation and measure the angular velocity about 5 degrees

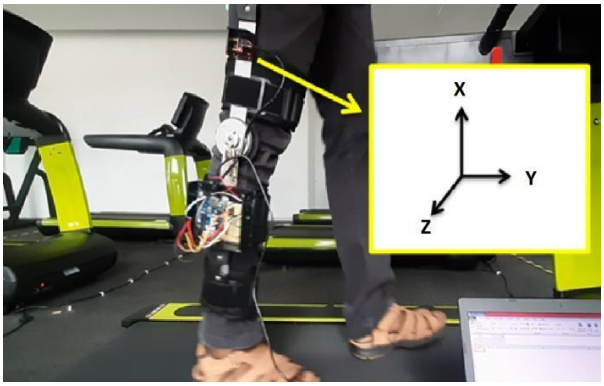


Figure 8: IMU Axis direction at Knee Orthotics

During collect all the axis value from the IMU sensor, that the value of X, Y and Z will be substituted into the fall detection algorithm that have done research previously. All the value have filter at the first stage of the walking phase to prevent drift. After all the axis value is substitute the system will recognize the falling stage easily without a difficulty as shown in Figure 9 shows the normal walking angle pattern of a user without a fall were the value is maintained at the below LFT threshold value, that can help to find the w (omega) value. Finally, the buckling or falling can be identify when the w value exceeds the UFT threshold value that shown in Figure 10. All this finding will be applied at the solenoid coding to make the solenoid extend during w exceed the UFT value.

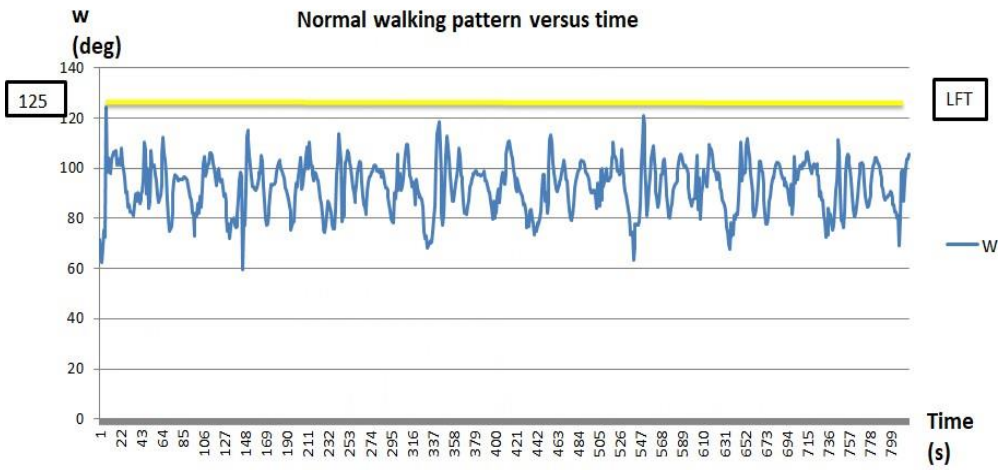


Figure 9: Normal walking pattern reading versus time

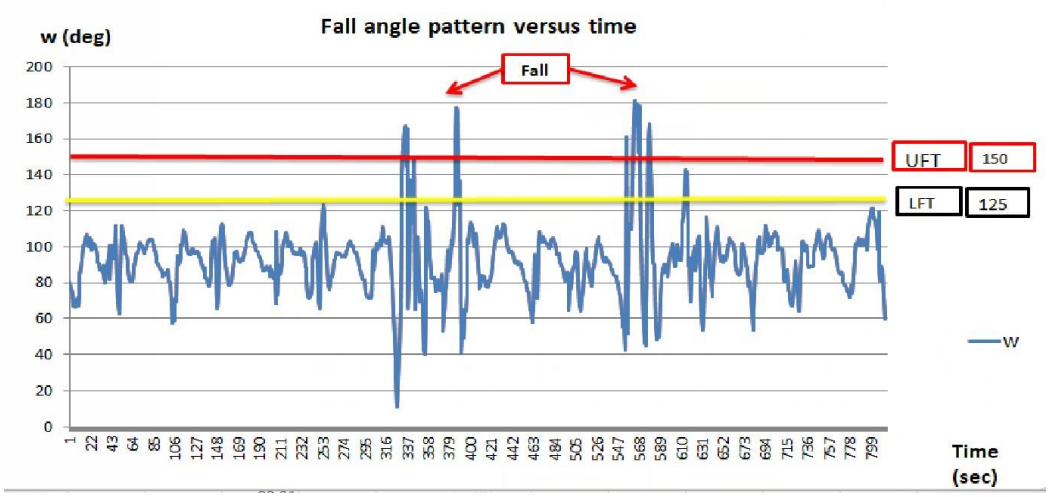
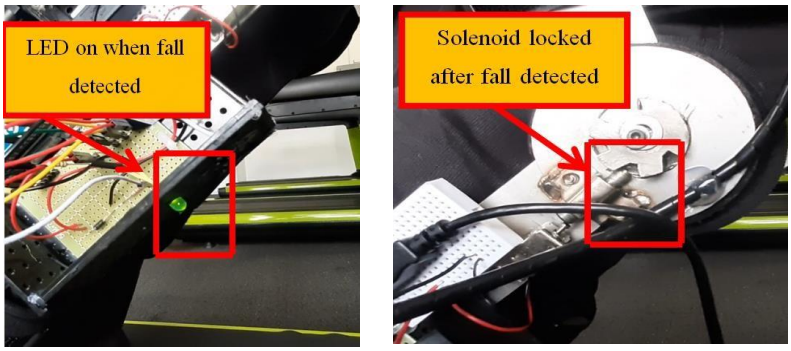


Figure 10: Falling walking pattern versus time

Locking system lock the gear whenever the threshold values exceed the UFT value the solenoid start to push the shaft. Last but not least, the LED will help the elderly to find out when the buck or fall due to buckling was happen. After the elderly gain balance from the fall, elderly can use to reset button to de-energizer the solenoid as shown in Figure 11.



(a) (b)

Figure 11: LED lit-up knee locked during detection of falling due to buckling

4. Conclusion

In conclusion, the paper presented the design and implementation of a knee orthotics that can detect falling and prevents fall due to buckling during walking phase. The design is useful for the elderlies that will encourage them to walk with confident without the fear of fall due to buckling, in which the system will lock during the Heel Strike position to prevent falling among elderlies. One able-body was invited to perform this experiment 10 times to collect the normal and falling reading from the IMU sensor. The finally product showed the effectiveness of the fall detection algorithm and the locking phase that can prevent falling due to buckling during the walking phase.

Acknowledgement

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