DESIGN AND DEVELOPMENT OF MOTORIZED HEIGHT ADJUSTABLE WALKING CRUTCH WITH ENHANCED STABILITY

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ABSTRACT

In our research project, we aim to resolve some of the problems in the walking crutches commercially available in the market. These problems include manual height adjustment, lack of stability, bulky size, etc. After several rounds of discussions and some intensive online research, the team decided to focus on the two major problems of the walking crutch – height adjustment and stability. Due to time constraint and limited resources available, a scaled-down model of the modified walking crutch was designed and developed. In order to achieve the two proposed functions, electric motors and gears have been used to allow the height of the upper part of the walking crutch to be adjustable, as well as to extend and withdraw three additional extendable legs to ensure the stability of the crutch. The electric motors are powered by six AAA batteries; four batteries are used for linear motion and another four batteries are used for rotational motion. We have connected the circuit in such a way that two batteries are used for both rotational and linear motion. After completion of the prototype, it was found that there are still several areas in the motorized walking crutch that can be further enhanced. For example, intelligence features such as addition of a fall detection sensor system, to sense and warn the user when he/she is going to tumble, could be implemented in the future.

INTRODUCTION

Walking crutches are widely used as a tool to assist people who have minor legs or feet injuries to walk. They help lessen the burden of the weight from the upper body and hence encourage the disabled people to walk more often. The crutches have been designed to be light in weight and compact in size for convenient usage. As such, most people would tend to choose walking crutches over wheelchairs to aid their movements.

Crutches and other walking aids have been used for over 5,000 years and they have not changed much over this period of time [1]. There are two basic designs – the axillary crutches and the elbow crutches, that most people use. Axillary crutches are a type of crutch that have a handgrip as well as a pad that rests against the side of the body just under the armpit. This type of crutch is used mostly by temporary crutch users [2]. Elbow crutches are also known as forearm crutches. Like axillary crutches, they have a handgrip, but elbow crutches only extend to the elbow. There is no bar under or near the axilla. This type of crutch is used mostly by permanent crutch users [2]. Dounis, Rose, Wilson and Steventon [3] [4] found that oxygen uptake was less for ambulation with axillary crutches than for ambulation with elbow crutches. They concluded from their study that walking with axillary crutches required less energy than walking with elbow crutches. In our project, the crutch design is that of the axillary crutch.

It is clear that crutches have many physiological and psychological benefits by allowing users to walk instead of using wheeled mobility to get around. However, they also have many drawbacks that may sometimes deter individuals from using them. The drawbacks of the commercially available crutches in the market are that the height of the crutches is fixed and difficult to adjust when using, lack of stability when standing or when walking on wet and slippery ground, bulky in size, etc. There are many ways to overcome the drawbacks and make improvement to the existing crutches. Among these drawbacks, the team has identified two of the more significant problems to research on and develop solutions for.

Although the height of the present manual walking crutches is adjustable, it requires manual effort to do so. Furthermore the manual crutch has only several specific slots located on the crutch that may not perfectly fit some of the users' heights. Another problem is that when the user is using the crutch, manual selection of the height is almost not possible because the weight of the user is pressing on the latch of the slots. To overcome these problems, motors and gears are used in the new design to allow for electrically motorized adjustment of the height to suit every user. At the same time, the feature of manual height adjustment of the crutch has been retained so that the users can still adjust the height of the crutch when the batteries are drained or when minute height adjustment is required. This new design of the manual adjustment also allows for much easier adjustment than the current design of having several slots on the crutch. This is because the new design depends on the turning of gears to adjust the height of the crutch and using gears requires lesser manual effort.

The other problem that the team tried to resolve is the stability issue of the existing walking crutches. It is found that the crutches are not stable enough and especially so during rainy days or when the user is supporting himself with the crutch while standing stationary. The reason is because the existing crutch has only one leg to provide support for the whole weight of the user. The total weight of the user is concentrated at the only point of contact with the ground and this rubber contact is quite minimal (and rubber may be slippery when it is wet). In the research project, three extra legs were added in addition to the existing main leg to enhance the stability of the crutch. Doing so will increase the surface area of the base and the number of contact points with the ground. An electric motor is used to drive the main leg to move linearly – stretching out and pulling back. This in turn would extend or withdraw the three additional legs together. With this function, the user who is resting on the crutch in the stationery position would have better stability while standing up or sitting down.

MATERIAL AND METHODS

The project started off with a lot of effort spent on brainstorming and on drawing of the scaled-down model of the original manual walking crutch with proportional scaling factor of 2.5 times. This was done to aid the team to better visualize how the crutch can be designed. The drawing was further extended to construct a paper model. The paper model was made of construction paper which was easy to roll and fold into the design of the walking crutch. This is an important step, as mentioned by our NUS mentors, because the basic idea of how the new functions of height adjustment and the extension of the extra legs can be clearly illustrated. In addition, analyzing the paper model helped to simulate the design for the team to identify potential problems and come up with better and more practical solutions. The scaled down walking crutch was then constructed in the workshop using PVC solid and hollow pipes. The height of the walking crutch was made adjustable either by manual effort or by electric motors. The extendable legs of the walking crutch also depended on electric motors. The details about the motorized height adjustment and enhancement of stability features of walking crutch would be discussed in the subsequent parts of the report.

Height adjustment of walking crutch – mechanical structure of crutches

The photograph of the top part of the walking crutch was shown in Figure.1. It can be observed that there are several components in the walking crutch that enable the motorized height adjustment features.

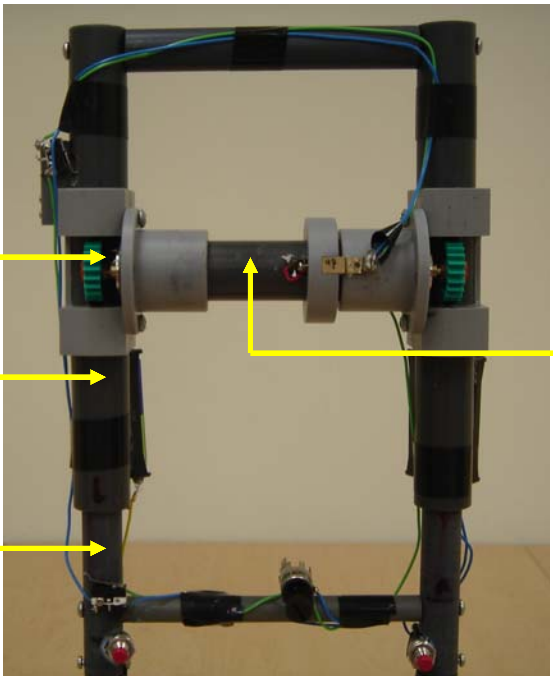

Figure 1: Photograph of top part of walking crutch

The basic components required to fulfill the adjustment of the height of the walking crutch are: two motors, two gears and 2 tracks for the gears to run on. When the electrical circuit is closed, the batteries are connected to the electric motors and the motors will start to rotate. As the motors rotate, the shafts of the motors which are coupled to the gears will turn the gears to generate linear upwards or downwards movement. The track for the gears to climb is mounted on the inner solid tube as shown in Fig. 2. The track does not move, hence the gears will then be able to move up/down the track, thereby adjusting the height of the crutch. The mechanical structure of the top part of the walking crutch is described in Figure 2 and 3. It consists of a solid inner tube with a track mounted on it. This inner tube is pushed into an outer hollow tube. There is a gap in the outer hollow tube, where the gears of the motors can sit in. This gap serves as a guide for the gear so that it does not run off the track.

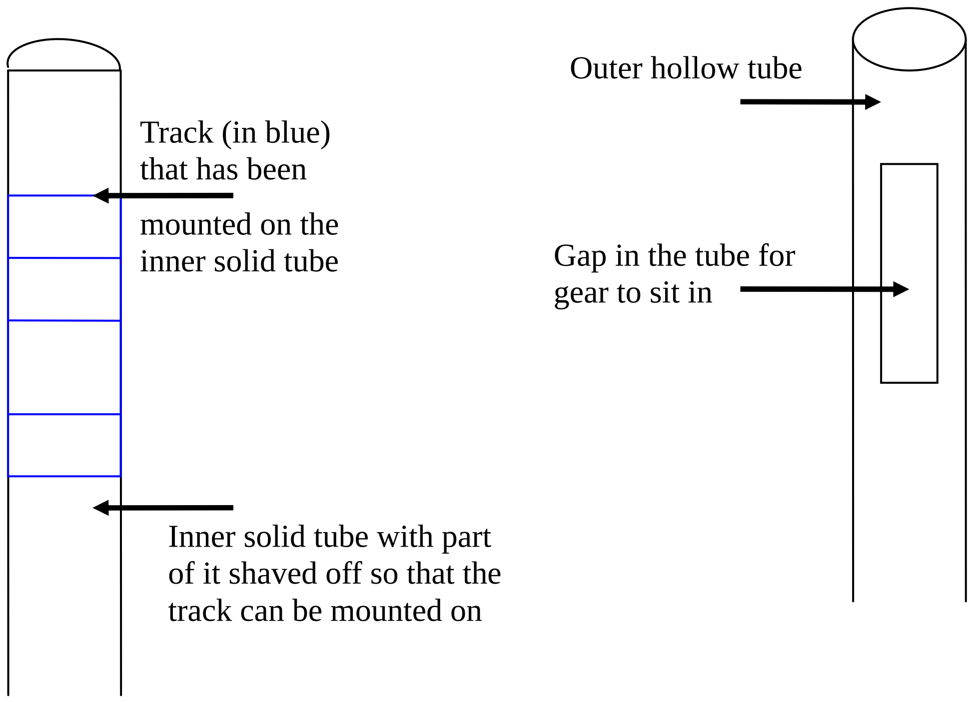

Figure 2: Sketch diagram of inner solid tube and outer hollow tube

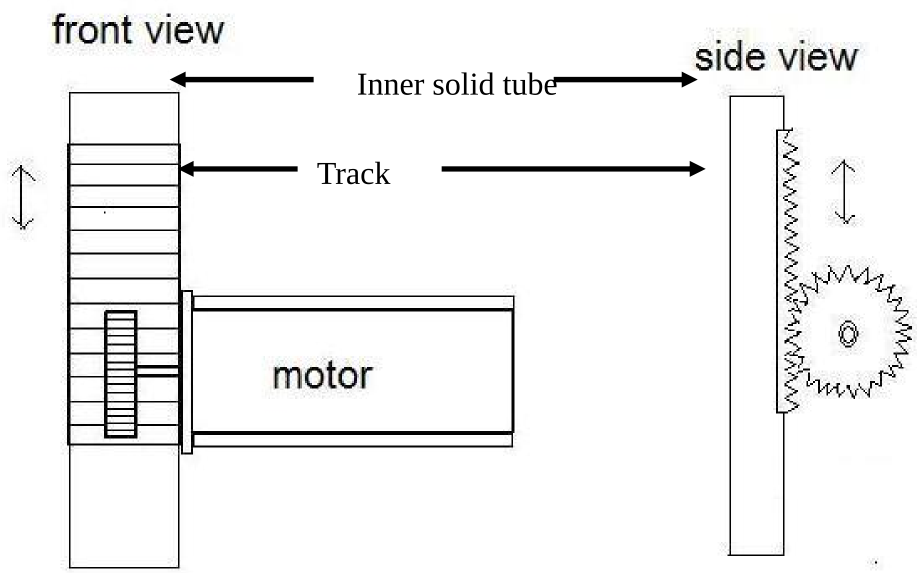

Figure 3: Sketch of front and side view of motor, gear, track and inner solid tube

Manual adjustment of height

When the walking crutch is in manual mode for height adjustment, the turning of the axel will cause the motors hidden inside it to turn (refer to Figure 4). This results in the rotational motion of the gears, which will then move up or down, depending on the rotational direction of the axle. Hence, the height of the crutches will be adjusted manually.

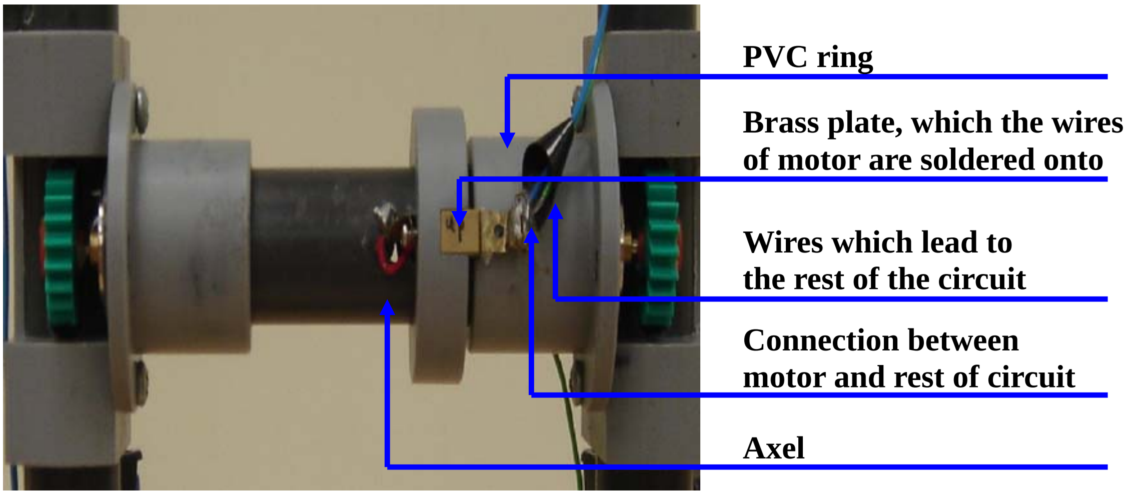

Figure 4: Close up photograph of the axel

Electrical adjustment of height

It can be seen in figure 4 that the wires of the motors are soldered on to a brass plate which is on a PVC ring. When the ring is slotted to the right, there will be a connection between the brass plate and the rest of the circuit. It will also create a "lock" such that the axel cannot be turned manually (The ring has to be slotted to the left when manual adjustment is desired.). The purpose of having the PVC ring design is to resolve the issue related to the wiring. If the electrical wires from the motors are connected directly to the electrical wires leading to the rest of the electrical circuit, the connection wires will all be tangled when the motors turn. Hence, the proposed design arrangement solves the wiring problem.

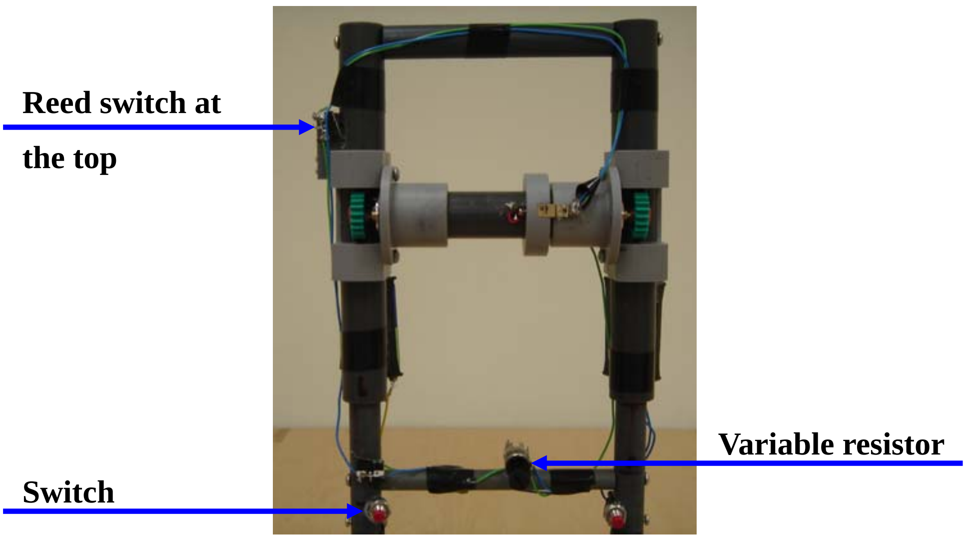

Figure 5: photo of the top part of crutch

There are 2 switches located on the upper part of the walking crutch (refer to figure 5). When the switch is pressed individually, it will complete the circuit and cause the height of the crutch to increase or decrease. In addition, there are reed switches at the highest and lowest point of the crutch. The reed switches has three contact points, of which, two are connected when the switch is in neutral position (i.e. not pressed). When the switch is pressed, these two contact points are not connected, instead, the connection is between another pair. Electrical wires are soldered to those two points which would be connected when the switch is in neutral position. When the crutches are at the maximum/minimum height, they will press against the switch. This breaks the circuit and the crutch will no longer continue its motion. There is also a variable resistor inserted to the electrical circuit so that to control the motion speed of the walking crutch. This is especially important when lowering the height of the crutch because the weight of the user would add force to cause the downward motion to increase speed.

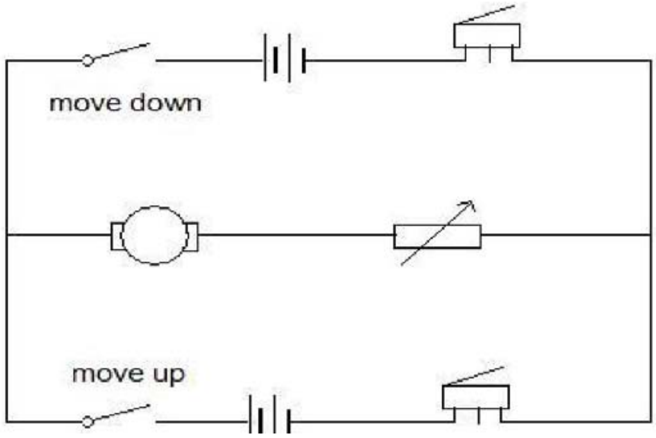

Figure 6: Circuit diagram for the adjustment of height of the crutches

Adjustment of the legs of crutch

Figure.7 shows the walking crutch with three addition legs extended.

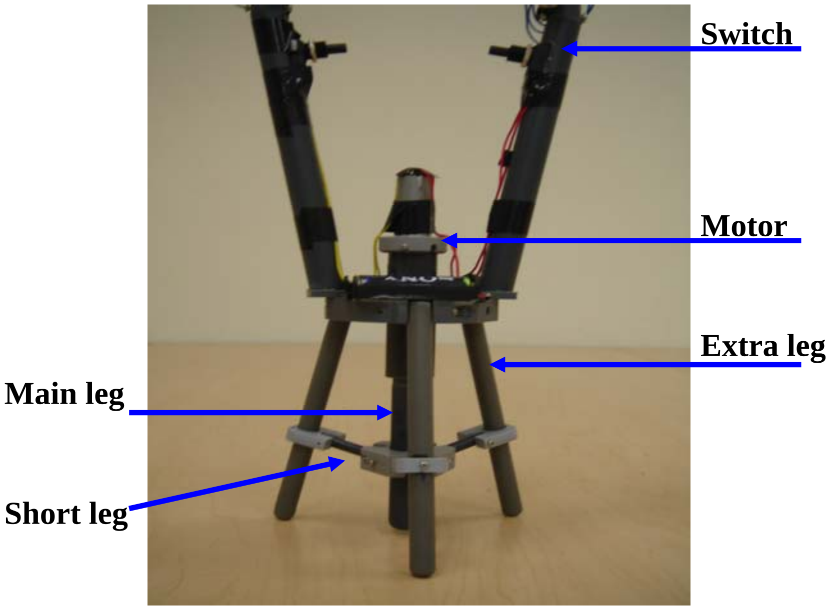

Figure 7: Photograph of the walking crutch with three addition legs extended

When the motor turns, the motor shaft and the lead screw turns as well. However, the lead screw is fixed in place and only experiences a rotational motion. Hence, the main leg acts as a "lead-screw nut" and the rotational motion is converted to a linear one. The main leg then moves up and down and this movement will stretch out or pull back the extra legs.

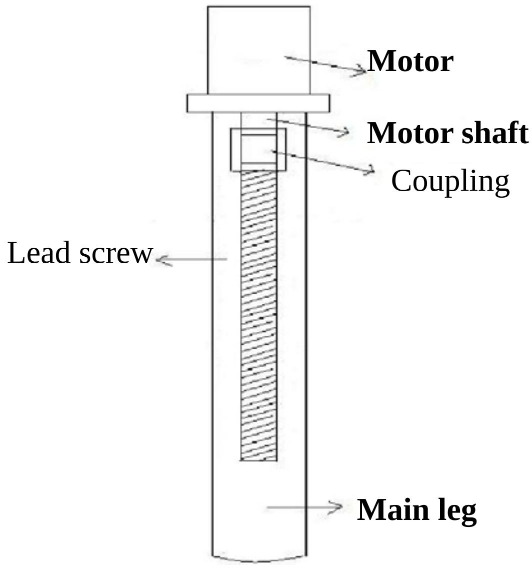

Figure 8: Sketch diagram of the cross sectional view of main leg of crutch

In the electrical circuit (shown in Figure.9) for extending the legs of the walking crutch, we made use of two batteries from the circuit that is used for adjusting the height, and 2 additional batteries. This is so as to save space and reduce the total numbers of batteries used in the whole system. Similarly, there are two on/off switches used here, one allowing the main leg to move up, and the other resulting in the main leg to move down.

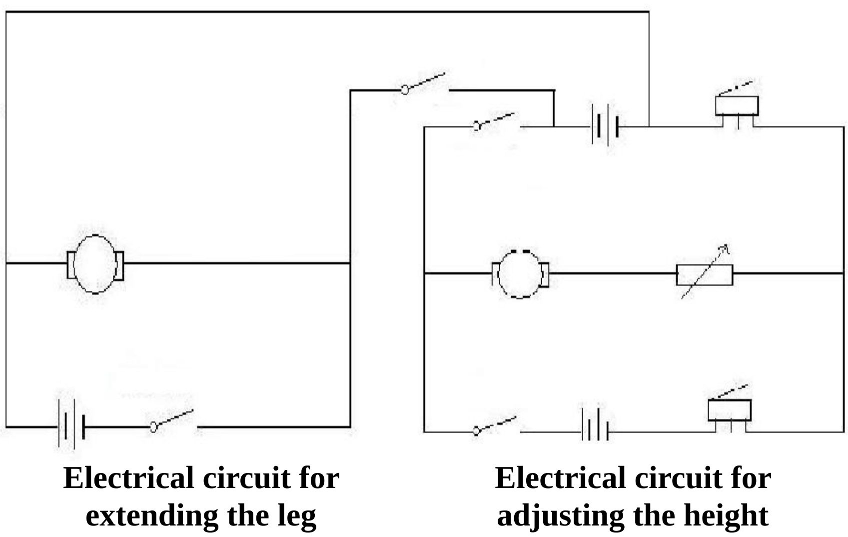

Figure 9: Electrical circuit diagram of the walking crutch

RESULTS

After the mechanical construction of the crutch is completed, four AAA batteries are used as the power source and supply for the function of the height adjustment. There are two on/off switches attached on either side of the crutch as shown in Figure.10 that are responsible for the increasing and decreasing of the height of the crutch. The maximum height that the crutch can raise is around 2.7 cm. The PVC ring can be rotated manually to adjust the height for the crutch as illustrated in Figure.11. For the crutches to move electrically, the PVC ring has to be slotted in place to be in contact with the brass plate as illustrated in Figure.11 so as to complete the whole electrical circuit. It also acts as a "lock" and prevents accidental rotational movement which may result in unintended height adjustment.

Figure 10: Walking crutch at its minimum height (left) and maximum height (right)

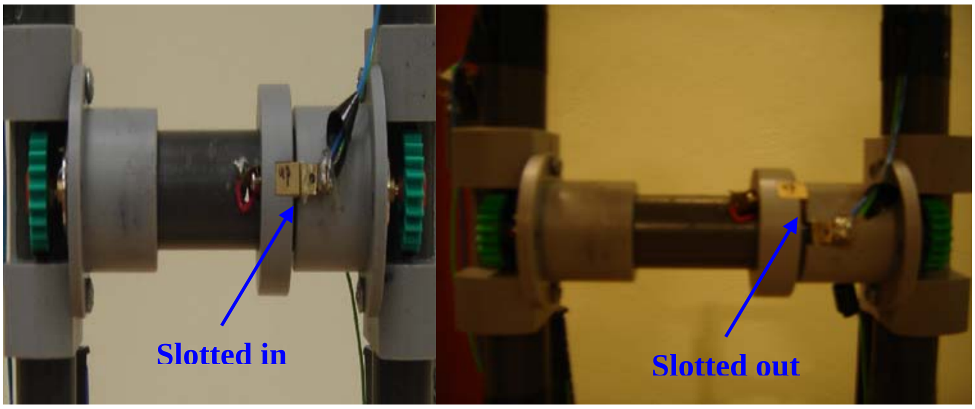

Figure 11: Photos of PVC Ring slotted in and in contact with brass plate (left) and slotted out to allow for manual adjustment (right)

From several experiment tests conducted, it is recorded that the speed at which the crutch extends upwards is around 0.89 cm/s while that for moving downwards is around 2.16 cm/s. As for the extension of the legs, four AAA batteries have been used to power the electric motor. Similarly, there are two on/off switches that will complete the electrical circuit to move the main leg up and down. When the main leg moves down, it will pull the ends of the short legs as shown in Figure.7, causing the short legs to become more perpendicular to the ground. This reduces the angle between the extended legs and the main leg as illustrated in Figure.7, thereby withdrawing the legs.

The walking crutch will then be able to stand on the main leg. When the main leg is pulled upwards, the short legs will be pushed outwards such that they become more parallel to the ground. Hence, this extends the 3 additional legs and the crutch can then stand upright on them, unsupported by any external help. The extension of the three additional legs has demonstrated the stability enhancement of the crutch. In summary, the proposed design of the motorized walking crutch requires minimum effort from the user to bring the two useful and practical features to users. Manual height adjustment is made easier in the proposed design as compared to the walking crutch available in the market. On top of that, the electrical height adjustment has been incorporated into the design to improve the whole design to be more user-friendly and attractive. This attractiveness is further enhanced with the legs extension feature which results in better support for the user when needed.

DISCUSSIONS

Overall, we feel that we have achieved our main objectives. Our model has successfully demonstrated the two targeted functions which we planned at the start of the project. It has allowed greater convenience to the user in terms of making desired height adjustments. However, there are still some areas that we can work on. Firstly, in the real crutches, the amount of energy needed to drive the motors will be very great. This means that more batteries will be needed. This implies that more space will be taken up, and the crutches will weigh heavier. Hence, this defies the purpose of having a crutch, as its aim is to bring convenience to the users. Secondly, the speed of linear motion for decreasing the height is much faster than that for increasing the height. This may pose a danger for the users, and further research must be carried out to solve this problem.

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