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***Abstract*—In this paper, a controlling system is implemented for a wearable walking supporting device so called as Hybrid Assistive Limb. The control circuit is implemented without considering the biological signals of the human body for the knee part, which is based on the knee joint moment from the human body model. The control and a driving circuits are implemented to assistive the knee as for the requirement of knee joint dynamics.**

Keywords— *HAL, Control circuit, Knee dynamics, Driving circuit*

I. Introduction

Till now different types of the walking supporting devices are cranes, caster walks, walking frames etc. has been produced and commercially available. In addition this some actuated walking supporting devices are developed, in which some kinds of motors like DC, stepper and servo motors are used to provide support to the different parts of the human body. The main application of the walking supporting system is to provide free movement of the people who are physically disabled and reducing the load on their muscles. But the main problem with this passive walking support system is, they restrict the daily activities and free mobility of the users.

Some wearable robot systems have been developed so far [1] [2] [3] [4], In most of these wearable supporting systems, supporting muscular force or necessary supporting force/moment of the system is controlled based on the current human muscular force estimated by biological signals or phenomena such as EMG (electromyogram) signals. The output forces of human muscles, however, could not be estimated in real time based on the biological signals, because these biological signals are emitted by the result of the activation of muscles [5].

In this a micro controller-based control circuit is proposed to supporting joint moment without using biological signals and the work mainly concentrates on the knee part of the human body. In the proposed circuit, the human model estimates the knee joint moment. In order to provide support to the knee stepper motors are provided. In the following part of this paper, we first introduce a prototype model of the Hybrid Assistive Limb. This is the wearable supporting device for walking and then proposed a control circuit for Hybrid Assistive Limb. Finally, experimental results conducted on the controlling circuit are illustrated.

II. HYBRID ASSISTIVE LIMB

A. *Introduction:*

Hybrid assistive limb (HAL) systems are having a lot of importance in the area of medical applications. So there exists significant importance in these areas of research, since the human system is the most complicated automatic control system in the universe. HAL expected to be applied in various fields such as rehabilitation support and physical trainee support in medical field. It is also expected that the device gives substantial help for disable people for moving the completion of their daily life activities. It may also provide heavy labor support at factories, rescue support at deserts etc. in entertainment area also some expected. The main parts in the HAL system are,

1. Ankle
2. Knee
3. Hip
4. Shoulder
5. Elbow
6. Rist

But, here the work mainly concentrates on the knee part of the HAL system.

B. *Knee*

The knee joint is the most problematic joint. Common injuries include ligament injuries, meniscus tear and unstable kneecap. Diseases like arthritis at the knee are also a common problem especially among the elderly people. Treatments of knee injuries and diseases will require proper resting of the knee and reducing the pressure acting on the knee joint. This helps to reduce the stress on the ligaments, cartilage, muscles and bones to accelerate the healing process. Current methods to achieve pressure reduction at the knee include the use of crutches, walkers, canes or even wheelchair [5].

C. *Prototype model:*

Figure 1(a) shows the developed prototype of the Hybrid Assistive Limb, and Figure 1(b) illustrates the mechanism of the knee joint of the device. This device is developed taking into account of the knee structure, and has one degree of freedom, that is, rotation around knee joint on sagittal plane, because in walking the motion of the knee joint is only rotation. Hybrid Assistive Limb consists of the geared dual hinges, a stepper motor, and a potentiometer attached to the knee joint of the user.

III. CONTROL CIRCUIT OF HYBRID ASSISTIVE LIMB

A control circuit of Hybrid Assistive Limb is designed in this section. Figure 2 shows the control circuit of the Hybrid Assistive Limb. In this figure, the main parts are potentiometer, Micro controller and the stepper motors. First, each joint angle is measured by considering the kinematics and dynamics of the human knee. By using a potentiometer the joint angle of the human knee is converted to analog signal that is shown in the figure 5 and then it is applied to the micro controller.

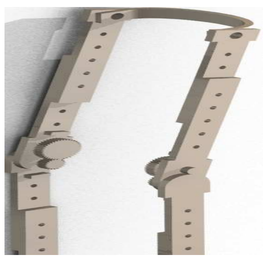

Fig. 1. (a) Hybrid Assistive Limb

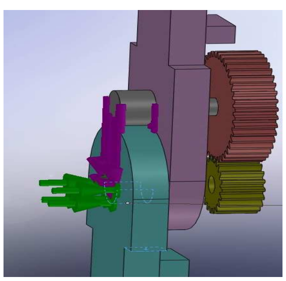

Fig.1. (b) Knee Mechanism

Based on the joint angle the micro controller generates controlling pulses that are shown in figure 6. Finally, the actuator or stepper motor generates the joint moment and help the user to walk.

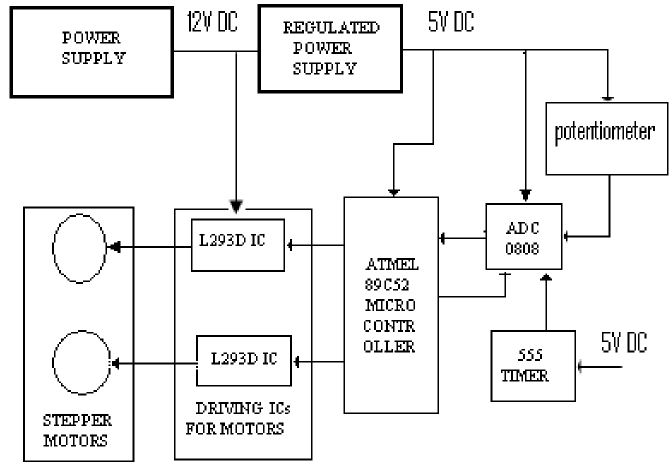

Fig.2. Controller Circuit

The functionally of the ADC 0808 is to convert the Analog signals to digital that are coming form the potentiometer. The driver circuit is provided in order to drive the stepper motors and also used as a isolator for isolating the stepper motor and micro controller unit.

IV. KINEMATICS AND DYNAMICS

Several kinds of wearable robot systems have been developed for supporting walking. These systems generate supporting force/moment for walking based on real-time estimation of current muscular force. In most of these systems, the muscular force is estimated based on biological signals such as EMG signal. How ever, the output force of human muscle could not be estimated by the result activation of the muscles.

In this section the joint angle is measured based the model of human, and we introduced the dynamic equations in order to determine the joint angle.

A. *Human Model:*

Figure 3 shows the simplified model of the human body for calculating the joint moment. The model consists of four links and three hinge joints; a foot link, a shank link, a thigh link, an upper body link, an ankle joint, a knee joint, and a hip joint. The kinematics of the human knee is as follows,

1. Kinematic modeling
2. Dynamic modeling

Steps for kinematic modeling:

1. Assign the frame for each joint. Denote the fixed joint as zeroth frame.
2. Tabulate the DH (Denavit - Hartenberg) parameter table.
3. Formulate the basic transformation matrix and hence find out the final link transformation matrix.

4. Equate the transformation matrix with the position matrix and solve for the unknowns

DH parameter table:

	Θ	d	a	α
0T1	**Θ**	**0**	**1**	**0**

Where,
Θ - Rotation about Z-axis
d - Translation along Z-axis
a - Translation along X-axis
α - Rotation about X-axis

By equating the values from the transformation matrix, the position and orientation of the end effectors can be calculated. The dynamic model of the human knee is based on Lagrange Euler formulation is obtained from the Lagrange equations.

V. EXPERIMENTS

The Hybrid Assistive Limb is controlled by using stepper motors and is controlled by a driving circuit in open loop mode. The stepper motors are mostly used for position and velocity control in the robotic applications, and also it provides torque, which is independent of the load. Stepper motor is controlled in open loop so there is no control over the position of the stepper motor and there should be always an error in the position of the motor shaft.

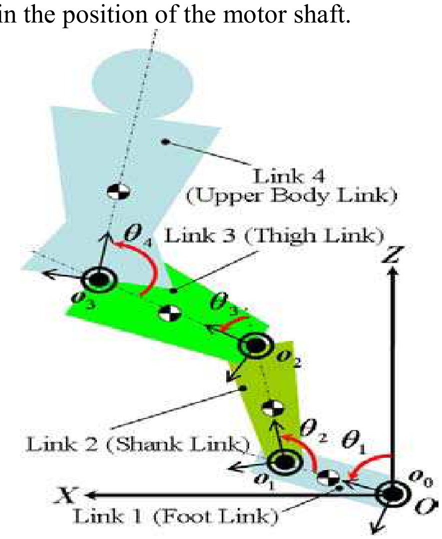

Fig.3. Human Model [5]

So in order to find out the position error, the following circuit arrangement shown in figure 4 is used. For measuring the error a multi turn potentiometer is used and it is coupled to the shaft of the stepper motor by using a shaft coupler.

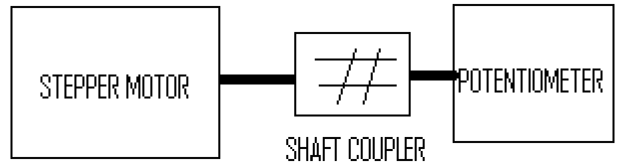

Fig.4. Experimental set up

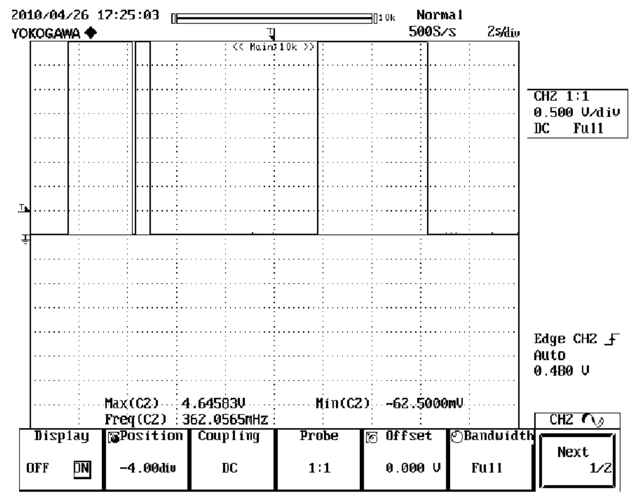

Fig.5. Analog signal of Knee joint angle

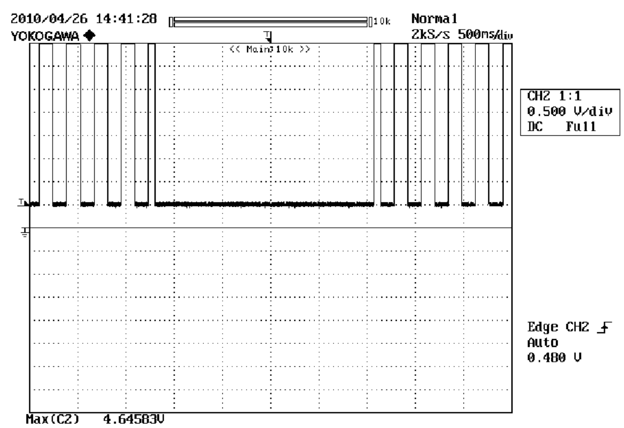

Fig.6. Controlling pulses

The experimental set up consists of stepper motor and a potentiometer. The potentiometer is used to measure the error in the position of the motor shaft. The table I show the experimental results of the above arrangement

VI. SOFTWARE DESCRIPTION

So far the topic mainly concentrates in the detailed description about the hardware, its operation and analysis. But one factor is not at all mentioned anywhere in the previous discussions. It is nothing but the software modules and programming part. It is to be noted that the successful operation of the micro controller mainly depends upon the software. It has to be programmed properly for the successful control of the knee part of the Hybrid Assistive Limb. The detailed description about the software part is considered below. This description is purely about the programming of the micro controller. In this paper, Keil Software (C51) is used to develop the data logger circuit. Keil compiler is a cross compiler which is used to compile that code designed for different chips on host machine and to get the hex code. General procedure in working with Keil compiler as follows:

1. Create source file in 'C' or assembly.
2. Compile or assemble source files.
3. Correct errors in source files.
4. Load the .HEX file into Micro controller Flash Memory with the help of Programmer.

TABLE I
Error Comparison

S.NO.	Measured Voltage (Volts)	Angle Corresponding Voltage (Degrees)	Actual angle (Degrees)	Error (Degrees)
1	0.08	5.76	7.2	1.44
2	0.175	12.6	14.4	1.8
3	0.28	20.16	21.6	1.44
4	0.6	43.2	45	1.8

VII. Summary and Conclusion

In the present work the knee joint angle is measured without considering the biological signals and simplified human body dynamics. A detailed review, presenting the important work going on the Hybrid Assistive Limb area, has been given at the beginning. This has been given with a view to enlighten the reader with the significance of this type of work in the modern medical applications.

A detailed description about the control of the Hybrid Assistive Limb is given next. The type of driving systems, moving mechanism, micro controllers used for the purpose are given.

Suggestions for future work is the knee joint angle can be measured by considering the biological signal i.e. by placing a sensor near the knee joint the angle can be measured.

APPENDIX

Stepper motor parameters:

Type – bipolar winding
Rated voltage – 12V DC
Rated current – 0.6 AMP
Step angle – 1.8 degrees

Acknowledgment

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