Design And Development Of Mechanically Automated Renovative Under Transforming Intelligence

Mohammed Aamir Ahmed, Narendra Wadaskar

Department of Mechanical Engineering, Nagpur University, Aradhna Society, Katol Road, Nagpur-440013
ahmedtariqaamir@gmail.com

Abstract: In this paper, a controlling system is implemented for a wearable walking supporting device so called as Mechanically Automated Renovative Under Transforming Intelligence (MARUTI). 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: MARUTI, Control circuit, Knee dynamics, Driving circuit

I. INTRODUCTION

When a person attempts to move their body, nerve signals are sent from the brain to the muscles through the motor neurons, moving the musculoskeletal system. When this happens, small biosignals can be detected on the surface of the skin. The MARUTI suit registers these signals through a sensor attached to the skin of the wearer. Based on the signals obtained, the power unit moves the joint to support and amplify the wearer's motion. The MARUTI suit possesses both a user-activated “voluntary control system" and a “robotic autonomous control system" for automatic motion support 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. 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 MARUTI. 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. BACKGROUND

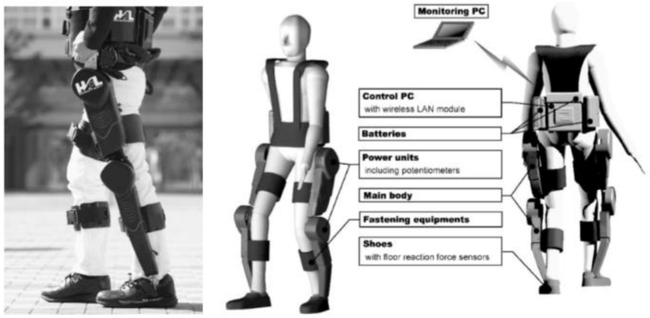


Fig: 1(a)

A.

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. MARUTI

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. Based on this model we have design and developed a model name MARUTI consists of the geared dual hinges, a DC Geared Motor, Microcontroller, Driver, Accelerometer, Flex Sensor, and a potentiometer attached to the knee joint of the user. It working capacity and the load bearing is much more as compare to other artificial limbs developed. The sensors attached with the system will examine the exact stress of the muscle and support the bone for its free movement while walking and also support the user to lift the object easily.

Fig 1(b)

To determine kinematic data, the movement of the half-squat exercises was recorded using the Mac Reflex optoelectronic system (4 cameras) with markers on the left lower extremity at the first metatarsal (Al), the external tibia1 malleolus(A2), the external lateral femoral condyle (A3) and the greater trochanter (A4). A six components force-plate (AMTI) provided kinetic data. Compressive and shear forces acting on the thigh at the knee joint were calculated (Figure 1 (c)).

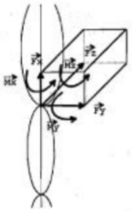


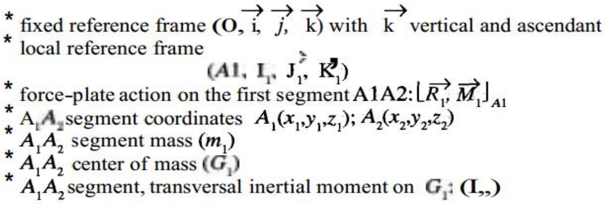
Fig: 1(c)

Figure 1c. Illustration of three dimensional axes defined in terms of anatomical definitions: Fx represents the compressive force; Mx, the external rotatory moment of the thigh; Fy, the medio-lateral shear force; My, the extension moment of the thigh; Fz, the antero- posterior shear force and Mz, the abductor moment of the thighFigure 1(b). Illustration of three dimensional axes defined in terms of anatomical definitions: Fx represents the compressive force; Mx, the external rotatory moment of the thigh; Fy, the medio-lateral shear force; My, the extension moment of the thigh; Fz, the antero- posterior shear force and Mz, the abductor moment of the thigh.

Mathematical model

The following model assumes each limb segment is a rigid segment moving in three-dimensional space. Each segment can be defined by two points (a volume needs 3 points).

Known values



- * fixed reference frame $(O, \vec{i}, \vec{j}, \vec{k})$ with $\vec{k}$ vertical and ascendant
- * local reference frame
  $(A1, I_1, \vec{J_1}, \vec{K_1})$
- * force-plate action on the first segment A1A2: $\lfloor \vec{R_1}, \vec{M_1} \rfloor_{A1}$
- * A_1A_2 segment coordinates $A_1(x_1,y_1,z_1); A_2(x_2,y_2,z_2)$
- * A_1A_2 segment mass (m_1)
- * A_1A_2 center of mass (G_1)
- * A_1A_2 segment, transversal inertial moment on G_1: $(I_{,,})$

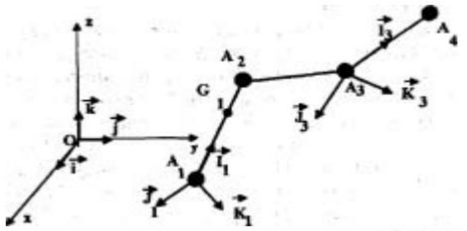


Figure 2. General representation of the model Al=first metatarsal; A2=external tibia1 malleolus; A3=external lateral femoral condyle; I A4=greater trochanter.

Unknown values:

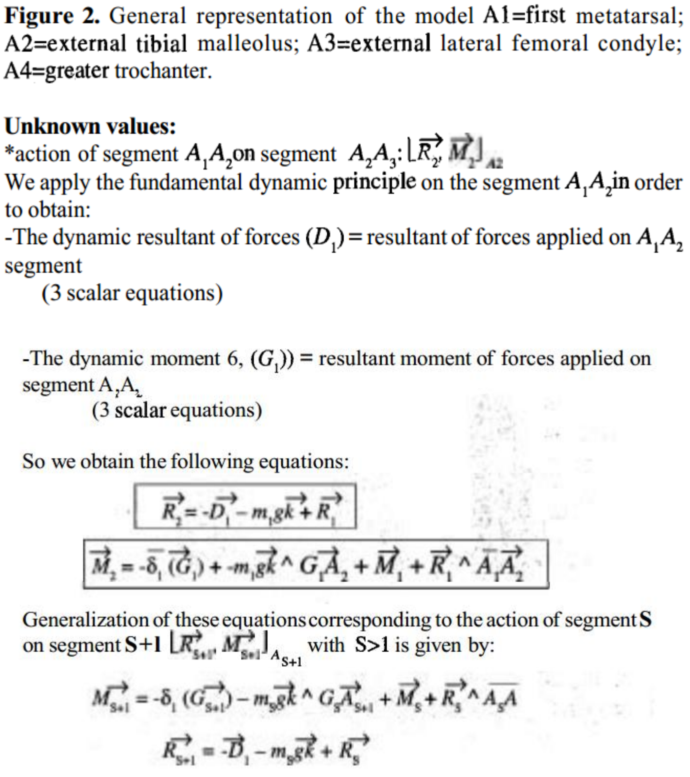


Figure 2. General representation of the model A1=first metatarsal; A2=external tibial malleolus; A3=external lateral femoral condyle; A4=greater trochanter.

Unknown values:

*action of segment A_1A_2 on segment A_2A_3: $\lfloor \vec{R_2}, \vec{M_2} \rfloor_{A2}$

We apply the fundamental dynamic principle on the segment A_1A_2 in order to obtain:

-The dynamic resultant of forces (D_1) = resultant of forces applied on A_1A_2 segment

(3 scalar equations)

-The dynamic moment 6, (G_1)) = resultant moment of forces applied on segment A_1A_2

(3 scalar equations)

So we obtain the following equations:

$$\boxed{\vec{R_2} = -\vec{D_1} - m_1 g\vec{k} + \vec{R_1}}$$

$$\boxed{\vec{M_2} = -\bar{\delta}_1 (\vec{G_1}) + -m_1 g\vec{k} \wedge G_1\vec{A_2} + \vec{M_1} + \vec{R_1} \wedge \overline{A_1}\vec{A_2}}$$

Generalization of these equations corresponding to the action of segment **S** on segment **S+1** $\lfloor \vec{R_{S+1}}, \vec{M_{S+1}} \rfloor_{A_{S+1}}$ with **S>1** is given by:

$$\vec{M_{S+1}} = -\delta_1 (\vec{G_{S+1}}) - m_S g\vec{k} \wedge G_S\vec{A_{S+1}} + \vec{M_S} + \vec{R_S} \wedge \overline{A_S A}$$

$$\vec{R_{S+1}} = -\vec{D}_1 - m_S g\vec{k} + \vec{R_S}$$

WORKING :

The main advantages behind MARUTI is its sensor and smoothness, providing a better facility to the user for walking in a long distance

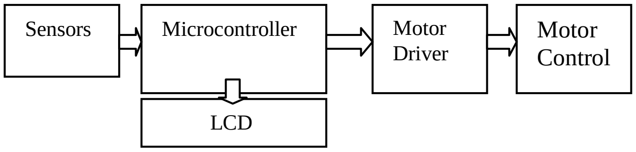


Fig 2(a)

As the per the block diagram Fig 2(b), the model consisting the highly effective sensor like accelerometer, flex sensor, stress sensor etc, which will send the analog signal to the microcontroller for its decision and control of the mechanism by providing a better support to the human limbs. The LCD attached with the system will display all the information related to the limb joint.

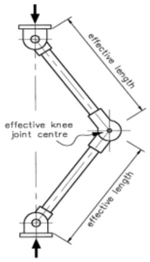


Fig 2(c)

III. 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.

IV.A.

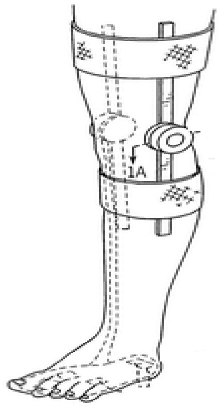
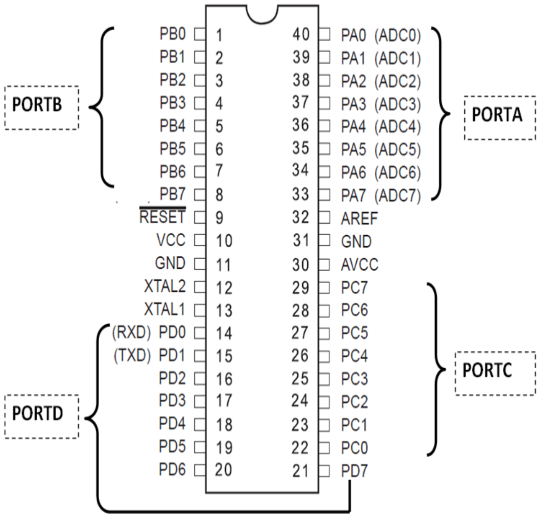


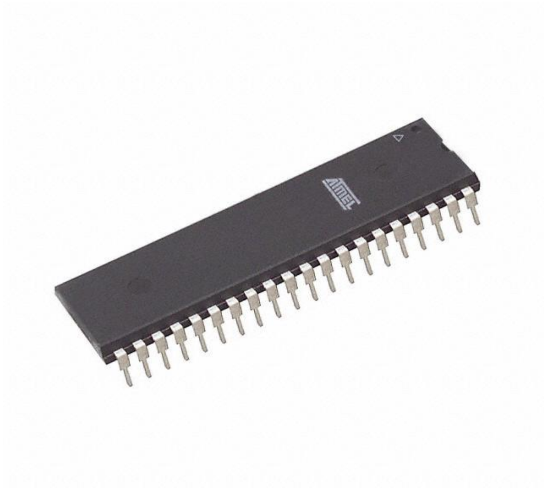
Fig 3

Human Model: Figure 3 shows the simplified model of the human body for calculating the joint moment. The model consists of links and hinge joints; a foot link, a shank link, a thigh link, 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. The MARUTI is controlled by using high torque DC 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. DC motor is controlled in open loop so there is no control over the position of the motor and there should be always an error in the position of the motor shaft.

IV. COMPONENTS REQUIRED:

Microcontroller ATMega16 (Processor)





The ATmega16 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

Pin Descriptions

VCC Digital supply voltage.

GND Ground.

Port A (PA7..PA0): Port A serves as the analog inputs to the A/D Converter. Port A also serves as an 8-bit bi-directional I/O port, if the A/D Converter is not used. Port pins can provide internal pull-up resistors (selected for each bit). The Port A output buffers have symmetrical drive characteristics with both high sink and source capability. When pins PA0 to PA7 are used as inputs and are externally pulled low, they will source current if the internal pull-up resistors are activated. The Port A pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port B (PB7..PB0): Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port C (PC7..PC0): Port C is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port C output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running. If the JTAG interface is enabled, the pull-up resistors on pins PC5(TDI), PC3(TMS) and PC2(TCK) will be activated even if a reset occurs. Port C also serves the functions of the JTAG interface and other special features of the

Port D (PD7..PD0) Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

RESET Reset Input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running. Shorter pulses are not guaranteed to generate a reset.

XTAL1 Input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

XTAL2 Output from the inverting Oscillator amplifier.

AVCC AVCC is the supply voltage pin for Port A and the A/D Converter. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter.

AREF AREF is the analog reference pin for the A/D Converter.

ACCELEROMETER:

Three Axis, X,Y,Z

Fig. 4 Flex sensor

Flex Sensor provides low-cost angular displacement measurement

V.SUMMARY & 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

REFERNECES:

[1]. AKROD, Active Knee Rehabilitation Device Human Trials.

[2]. http://yobotics.com/robowalker/robowalker.html .

[3]. Cybernics Laboratory, University of Tsukuba. 2005. Robot Suit HAL. http://sanlab.kz.tsukuba.ac.jp/HAL/indexE.html .

[4]. Berkeley Robotics and Human Engineering Laboratory. 2003. Berkeley Robotics Laboratory, BLEEX Project. http://bleex.me.berkeley.edu/bleex.htm .

[5]. “Model-based walking support system with Wearable Walking Helper” by Takahiko Nakamura and Kazuhiro Kosuge, Proceedings of the 2003 IEEE International Workshop on Robot and Human Interactive Communication Millbrae, Caliiomia. USA, Oct. 31 - Nov. 2.2003.

[6]. “Providing assistance to knee in the design of a portable active orthotic device” by K. H. Low,

Yuehong Yin and Shanghai Jiao, Proceeding of the 2006 IEEE International Conference on Automation Science and Engineering Shanghai, China, October 7-10, 2006.

[7]. “Realizing a Posture-based Wearable Antigravity Muscles Support System for Lower Extremities” by Takahiko Nakamura, Kazunari Saito, ZhiDong Wang and Kazuhiro Kosuge, Proceedings of the 2005 IEEE 9th International Conference on Rehabilitation Robotics June 28 - July 1, 2005, Chicago, IL, USA.

[8]. “Control Method of Robot Suit HAL working as Operator's Muscle using Biological and Dynamical Information” by Tomohiro Hayashi, Hiroaki Kawamoto and Yoshiyuki Sankai, Graduate School of Systems and Information Engineering University of Tsukuba, Japan

[9]. Stepping Motors Fundamentals, Author – Reston Condit, Microchip Technologies and Dr. Douglas W. Jones, University of Lowa.

[10]. Poumarat, G., Dabonneville, M., Chandezon, R., & Roddier, P. (1989). Les squats: Forces induites sur l'articulation du genou et sur L5 SI enfonction des postures adoptees. Cinesiologie, 69-74. Trafimow J.H., Schipplein, O.D., Novak, G.H., & Andersson, G.B .J. (1993). The effects of quadriceps fatigue on the technique of lifting. Spine, 18,364-367 http://www.technovelgy.com/ct/Science-Fiction-News

[11]. ISPO. Standards for lower limb prostheses (The Philadelphia Report). Copenhagen, Denmark: International Society for Prosthetics and Orthotics; 1978.

[12]. ISO 10328. Prosthetics-Structural testing of lower limb prostheses. Part 5: supplementary structural tests and Part 6: loading parameters of supplementary structural tests. Geneva, Switzerland: International Standards Organization; 1996.

[13]. Day HJB. The assessment and description of amputee activity. Prosthet Orthot Intl 1981;5(1):23-8.

[14]. Berme N, Lawes P, Solomonidis SE, Paul JP. A shorter pylon transducer for measurement of prosthetic forces and moments during amputee gait. Eng Med 1976;4(4):6-8.

[15]. Al-Turaiki MHS. A foot rotary mechanism for the modular below-knee prosthesis. J Prosthet Orthot 1990;2:119-25.