Robotic Supporting Leg for Handicapped People

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Abstract:
There are many people who are handicapped by their legs also some aged person can’t move their legs normally because of lack of required power to move the leg normally. Such kinds of people are unable to make movements of their legs by their own effort. To help these people ROBOTIC SUPPORTING LEG can be used. The idea behind this project is as per the program, manually operated switches used to move the leg. There are two motors used to provide external torque for joints of leg. Power supply is given by using two batteries such as 6V and 12V. When switch is on, power supply from battery passes to electronic control device and electronic control device to wiper motor. The electronic control device is used to control the motion of motor such as backward and forward. There are three switches are used. Out of these three switches one switch gives the backward motion and another gives the forward motion. The automatic switch provides the automatic movements of leg. This paper also remarks some challenges that current systems still have to meet in order to obtain a broad clinical and market acceptance.

Key words: Robot, supporting leg, handicapped people, Microcontroller, Wiper Motor, CATIA.

I. INTRODUCTION

The concept of a wearable robotic device that would help people walk or lift heavy objects has been around for decades. Michael Goldfarb, an engineering professor at Vanderbilt University engineering, built one such device in the early 1990s, but it couldn’t be used outside of a laboratory. Its propulsion system was bulky and wasn’t powerful enough to reliably move an adult’s limbs. Mr. Goldfarb experimented with hydraulics and other systems, including one that used small amounts of rocket fuel, but none was sufficiently powerful or safe. A legged vehicle allows locomotion in environments cluttered with obstacles where wheeled or tracked vehicles cannot be used. It is inherently omnidirectional, provides superior mobility in difficult terrain or soil conditions (sand, clay, gravel, rocks etc.) and provides an active suspension. The legs also give the chair versatility and allow it to be re-configured. When stationary, one of the legs can be used as a manipulator Kenta Suzuki et al. developed intention-Based Walking Support for Paraplegia Patients with Robot Suit HAL (Hybrid Assistive Limb). This paper proposes an algorithm to estimate human intentions related with walking in order to comfortably and safely support a paraplegia patient’s walk. A robot suit “HAL” has been developed for an enhancement of healthy person’s activities and for support of physically challenged person’s daily life. Assisting method based on bioelectrical signals such electricity successfully supports healthy person’s walking [1]. Junpei Okamura et al. developed the EMG-based prototype powered assistive system for walking aid. Despite rapid scientific and technological progress in allied disciplines, there has been very little innovation in wheelchair design over the last 200-300 years. The folding wheelchair came in 1933, and powered wheelchairs were developed in the early 1970s. New materials such as plastics, fiber-reinforced composites and beryllium-aluminium alloys have found their way into the design and manufacture of lighter, stronger and more reliable wheel chairs. The wheelchair industry has also benefitted from the development of lighter, efficient, durable and reliable motors, better amplifiers and controllers and most important of all superior batteries [2]. T. Hayashi et al. have developed a robot suit HAL (hybrid assistive limb) as an assistive device for lower limbs. Human can appropriately produce muscle contraction torque and control joint viscoelasticity by muscle effort such as co-contraction. The purpose of this study is to propose a control method of HAL using biological and motion information. In this method, HAL produces torque corresponding to muscle contraction torque by referring to the myoelectricity that is biological information to control operator's muscles. In addition, the viscoelasticities of HAL are adjusted in proportion to operator's viscoelasticity that is estimated from motion information by using an on-line parameter identification method. To evaluate the effectiveness of the proposed method, the method was applied to a swinging motion of a lower leg [3]. Hiroaki Kawamoto and Yoshiyuki Sankai have developed the power assistive suit, HAL (Hybrid Assistive Leg) which provide the self-walking aid for gait disorder persons or aged persons. In this paper, they introduced HAL-3 system, improving HAL-1,2 systems which had developed previously. EMG signal was used as the input information of power assist controller. They proposed a calibration method to identify parameters which relates the EMG to joint torque by using HAL-3. They also obtained suitable torque estimated by EMG and realize an apparatus that enables power to be used for walking and standing up according to the intention of the operator [4]. S. Lee and Y. Sankai described the power assist control for walking aid based on EMG and impedance adjustment with HAL-3 They developed the virtual torque derived from EMG is adopted as a basic control method, and the motion assist control as to operator's intention can be realized by this method. And we suggest the impedance adjustment around knee joint for more effective power assist control. Experiments for simple motion and walking motion were performed to verify the proposed approach, with impedance parameters found by RLS (recursive least square) method. The evaluation of assisted motion was done by a calculation based on EMG in nearly proportion to the operator's muscle force. The results showed the amplitudes of EMG were reduced significantly, the operator was able to swing the leg lighter by reducing the inertia around knee, and
the strain of knee in foot-grounding could be alleviated by adding the stiffness to joint [5]. S. Lee and Y. Sankai also developed the exoskeleton-type powered suit, HAL (Hybrid Assistive Leg)-3 for walking aid. In this research, they considered the operator's leg as pendulum model, identified the physical parameters around human's knee joints, tried to adjust the impedance, and applied that to pendular movement of leg. The effectiveness of adjusting the natural frequency in power assist control can be confirmed through the experiments evaluated with myoelectricity [6]. S. K. Au et al. proposed two control schemes to predict the amputee's intended ankle position: a neural network approach and a muscle model approach. Tested these approaches using EMG data measured from an amputee for several target ankle movement patterns and found that both controllers demonstrate the ability to predict desired ankle movement patterns qualitatively [7]. Two early attempts to develop such systems were the Powered Gait Orthosis (PGO) [8] and the Pneumatic Active Gait Orthosis (PA GO) [9]. Both devices underwent testing on human participants, but they were not commercialized. Currently, the only commercialized system for rehabilitation is the Anklebot (Interactive Motion Technologies, Inc.), an ankle robot developed at the Massachusetts Institute of Technology (MIT) to rehabilitate the ankle after stroke [10]. It allows normal range of motion in all 3 DOF of the foot relative to the shank while walking overground or on a treadmill. Pilot controlled trials with such device were presented in [11, 12], showing a carry over to characteristics of gait with a general improvement in the walking distance covered and time. The MIT also developed an Active Ankle-Foot Orthosis (AAFO) where the impedance of the orthotic joint is modulated throughout the walking cycle to treat drop-foot gait [13]. Another system is the Ankle Foot Orthosis at the University of Delaware (AFOUD) with 2 DOF. The two motions incorporated are dorsiflexion/plantarflexion and inversion/eversion motion [14]. Knee-Ankle-Foot-Orthosis (KAFO) is an orthosis powered by artificial pneumatic muscles during human walking [15]. The authors had previously built a powered Ankle-Foot-Orthosis (AFO) and used it effectively in studies on human motor adaptation and gait rehabilitation. The Robotic Gait Trainer (RGT) developed in the Human Machine Integration Laboratory at the Arizona State University is a walking device meant to be used on a treadmill [16]. It is naturally compliant due to the spring in muscle actuators and has the ability to achieve a more natural gait by allowing the patient’s ankle joint to move in eversion, inversion, plantarflexion, and dorsiflexion. A case study conducted with a female was reported to examine the performance of the system [17]. The patient suffered no disadvantage as a result of the RGT incorporated therapy, where performance indicators either improved or stayed the same. The Yonsei University has developed an active ankle-foot orthosis (Yonsei-AAFO) that can control dorsiflexion/plantarflexion of the ankle joint to prevent foot drop and toe drag during walking [18]. Gait analyses were performed on a hemiplegic patient, and the results indicated that the developed AAFO might have more clinical benefits to treat foot drop and toe drag in hemiplegic patients, comparing with conventional AFOS [19]. Basically partially handicapped people by leg can’t walk naturally. So they has been facing lot of problems regarding walking, running some time standing also even though they have legs, because of insufficient power required to move joints of leg. Naturally as time passes power of human body goes on decreasing. At this particular phase aged people facing lot of problems including walking. They require external efforts for walking, standing, exercising even though for regular vital work. Some times after some minor or major damage human can’t mover their part naturally. So to achieve normal movement they require exercise. While exercising they required another person at starting phase and that is some time difficult due to unavailability.

The main objective behind this project work is:
- To give power at joints of leg to perform naturally.
- To give supplementary torque at joints of handicapped and aged person.
- To provide independency while exercising the affected leg for recovery after any mishaps.
- To make handicapped and aged person independent in the sense of walk and stable stand.

In general, handicapped people and aged person can’t perform their motion of leg naturally because of lack of power in joints (knee and ankle) of leg. If we provide the sufficient power as per calibration of power calculation required to perform for an ordinary person such that natural walk can be achieved within economic constraints.

II. SYSTEM DESIGN

2.1. Design Requirements

As per the human anatomical research the working of the leg is depends upon the following factors:
- Torque at knee and ankle (T).
- Walking speed (V).
- Running speed (v).
- Height of the leg (L).
- Mass of the body (m).

In this Robotic leg human anatomical actuation is going to analog with mechatronic to supply external power to actuate the movement of the leg. The follows is an estimate of the power consumed in walking and in running as a function of a person's mass (m), leg length (L), and running speed (v). The speed at which running becomes more efficient than walking is calculated. An estimate is given for the maximum sustained running speed. The minimum required coefficient of friction is calculated for walking and running.

2.1.1. Walking Model

Make the following assumptions about the walking process:

Each leg is stiff during the time of its contact with the ground like the spokes of a wheel, which thereby rotates without benefit of a rim, and thus each foot leaves contact with the ground at the instant the other touches the ground. The flexing of the knee of the free leg serves only to keep that foot from contacting the ground as its leg swings forward, and such flexure doesn’t consume significant energy or change the natural period of oscillation of the leg. The legs swing with their natural period, assumed to be given by,

\[ t = 2\pi \left[ \frac{2L}{3g} \right]^{1/2} \]

Where, \( g = 9.8 \text{ m/s}^2 \) is the acceleration due to gravity, independent of walking speed.

Energy is consumed in raising the center of mass of the body once per step, and this energy is not recovered when the center of mass is lowered again. Under these assumptions, it is
straightforward to calculate the power (energy per unit time) expended in walking:

\[ P_w = \frac{mg}{\pi} \left[ \frac{3gL}{2} \right]^{1/2} \left[ 1 - \frac{1}{2V^2} \right] \]

2.1.2. Running Model

Make the following assumptions about the running process:

Each foot contacts the ground for a negligible time during which an impulsive force propels the body along a parabolic trajectory until the opposite foot strikes the ground. The upward component of the velocity of the center of mass of the body at the instant the foot leaves the ground is equal to the horizontal velocity of the center of mass so as to achieve maximum range before the opposite foot strikes the ground. Energy is consumed in raising the center of mass of the body once per step, and this energy is not recovered when the center of mass is lowered again under these assumptions, it is straightforward to calculate the power (energy per unit time) expended in running:

\[ P_r = \frac{mgv}{4} \]

2.1.3. Transition Speed

It is easy to calculate the speed \( V_c \) above which running consumes less power than walking at the same speed. This is done by equating \( P_w \) to \( P_r \) and solving for \( v \). The result is

\[ V_c = \left( \frac{12}{5\pi} \right) \left[ \frac{3gL}{3} \right]^{1/2} \]

This critical speed depends only on the length of the leg, and the dependence is weak (square root). The prediction is that a shorter person will begin running at a lower speed than a tall person, as expected. At the critical speed, the person advances forward by \( 8L/5 \) with each step, which seems a bit large. Note that on the moon where \( g \) is about one sixth of its value on the earth, the transition speed is about 2.5 times lower, and thus astronauts would be expected to run even when moving rather slowly, as seems to be the case. The result is independent of the mass of the person, and thus the bulky equipment carried by the astronauts should not alter the results. This prediction could be tested on a treadmill by having the subject carry a heavy backpack.

2.1.4. Maximum Running Speed

As the running speed increases, the legs have to oscillate more rapidly. It is extremely difficult to force them to oscillate faster than their natural resonant frequency. Additional energy, so far neglected, has to be expended to do so. If we take this resonant frequency as the upper limit of comfortable running, the maximum running speed \( V_m \) can be calculated: \( V_m = \pi \left[ \frac{gL}{6} \right]^{1/2} \). The prediction is that tall people can run faster than short people, and that a person with legs 1 m long should have a maximum speed of 4.02 m/s (or 8.98 miles per hour). Sprinters can do somewhat better than this speed, but it is a reasonable upper limit for a marathon runner.

2.2. Friction Requirements

Experience suggests that it is harder to run on ice than to walk on ice. We can quantify this expectation by calculating the minimum coefficient of friction \( \mu \) for which the foot does not slip for each case. For the walking case, the result is

\[ \mu = \frac{V}{\left[ \frac{6gL}{\pi^2} - V^2 \right]} \]

For the running case, the force is impulsive (it occurs over a very short time interval), and it is thus much larger than the person's weight. Furthermore, to launch the person at a 45° angle requires equal vertical and horizontal forces. Running thus requires \( \mu = 1 \) independent of speed. The minimum coefficients of friction required for walking and running are shown in Fig. 2. As expected, the minimum required coefficient of friction occurs for slow walking. However, above a speed of \( V = \left( \frac{3gL}{2} \right)^{1/2} \mu = 0.884 \ V_c \),

It should be easier to run on ice than to walk.

![Figure 1. Graph of speed vs coefficient of friction.](image)

The minimum coefficient of friction required to walk and to run. Note that below a speed of about 2 m/s, it is easier to walk on a slippery surface than to run, but that above that speed it is easier to run, although the minimum coefficient of friction is 1.

1.0. Calculation of Angle

![Figure 2. Extreme condition while walking](image)

![Figure 3. Forward extreme conditions](image)
III. PROPOSED CALCULATIONS

Assumption used in project:
- Length of leg (From knee to ankle) \( L_1 = 500 \text{mm} \)
- Length of leg (From ankle to toe) \( L_2 = 210 \text{mm} \)
- Normal Walking Speed \( V = 0.5 \text{m/s} \)
- Weight of body \( W = 15 \text{ kg} \)
- Coefficient of friction \( \mu = 1 \)
- Acceleration due to gravity \( g = 9.81 \text{ m/s}^2 \)

Calculation of legs swing with their natural period is given by:
\[
t = 2\pi \sqrt{\frac{2L}{3g}} \]
\[
t = 2\pi \times \sqrt{\frac{2 \times 0.5}{3 \times 9.81}} \approx 1.16 \text{ sec}
\]

Calculation of power (energy per unit time) expended in walking:
\[
P_w = \frac{(mg/\pi) \sqrt{3gL/2}}{1 - \left(1 - \frac{\pi^2 \times 0.52}{6 \times 9.81 \times 0.5}\right)^{1/2}}
\]
\[
P_w = \left(\frac{15 \times 9.81}{\pi}\right) \times \left(\frac{3 \times 9.81 \times 0.5}{2}\right)^{1/2} \times \left[1 - \left(1 - \frac{\pi^2 \times 0.52}{6 \times 9.81 \times 0.5}\right)^{1/2}\right] = 5.44 \text{ W}
\]

Calculation of the torque required at knee joint:
\[
T = \frac{P_w \times t}{2\pi} = \frac{5.44 \times 1.16}{2\pi} = 1.004 \text{ Nm}
\]

3.2. Design of Structure

3.3. Selection of Material

These trade terms are often used interchangeably to describe standard carbon steels used for structural purposes, is being AS3679 Grade 250 or Grade 300.

3.4. Microcontroller

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel’s high-density non-volatile memory technology and is compatible with the industry-standard 80C51 instruction set and pin-out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications. The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In addition, the AT89S52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

![Microcontroller Diagram](image-url)
3.5 Wiper Motor

3.5.1 Working Principle

Wiper motor, the power source of the wiper blade is, the core of whole wiper system. Therefore, the quality of wiper motor must be guaranteed to ensure its performance. The wiper motor is a permanent-magnet direct current (DC) one. It is equipped on the front windshield glass with the mechanical parts of worm gear. The worm gear functions to slow down and increase torque. Its output shafts spur four bar linkage, by which the movement is changed from rotary to swing. Three-brush structure is adopted to make speed change more convenient. The intermittent relay, by which the interval controlled, utilizing the return of switch contacts and the charge-discharge function of the resistor-capacitor in the relay, drives the wiper to wipe in a certain cycle. The wiper blade tape, the clean to cool to clean the rainwater and the filth on the glass, presses the surface of glass with springs. Only when the tip of the blade is in a certain angle with the glass, can the required function be realized.

3.5.2 Working of wiper motor

The electric wiper motor is a permanent magnet, rotary electric motor. A worm gear machined on the armature shaft drives the output shaft and gear through an idler gear and shaft. The output shaft operates the output the output arm, which connected to wiper linkage. As the electric motor revolves the output arm, the linkage is forced to move in a back and forth motion. The speed of the electric motor is controlled by resistors controlled by resistors, located on in the controlled switch, and connected to the wiper motor electrical windings. The control switch directs the currents through certain circuits of the motor, as the driver desires.

![Wiper motor diagram](Image)

Figure 7. Wiper motor

3.5.3 Working of wiper motor

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3.6 Fabrication Process

Layout: The end product of the layout designing is pencil sketch Component and conductor drawing; which is called as ‘layout sketch’ and it contains all relevant information for the preparation of the artwork.

Artwork: Minimum spacing specification must also take care of overall precision of the artwork prepared. The following factors contribute to result:
- Artwork method and how many layer involved.
- Dimensional stability of artwork base foil.
- Artwork aids used. Individual accuracy of the artwork designer, Artwork scale.

Bending: Bending is manufacturing process that produces ‘U’ shape in ductile. The U shaped structure is support the body.

Welding: Welding is a fabrication or sculptural process that joins material, usually metal, by causing fusion, which is distinct from lower temperature metal joining technique such as brazing and soldering. Mild steels are eminently weldable using 6013 electrode.

Drilling: Drilling is a cutting process that uses drill bit to cut or enlarge hole of circular cross-section in material.

Mounting of component: Two motors are mounted on this structure. One is mounted at knee to give movement to lower leg and another motor is mounting on waist at upper body. Electronic components such as micro-controller, relay, diode, capacitor, resistor, oscillator etc. are mounted in plastic rectangular box. Batteries are mounted in also plastic rectangular box which consist 6V and 12V.

Soldering: Leads are cut down before soldering so that they are protected and also covered with solder typically followed manual soldering process are:
- Insert-cut-solder
- Insert-cut-clinch-solder
- Insert-solder-cut

If the production volumes are high the use of the automatic wave soldering machine is economically justified.

3.7 Testing of Model

![Testing of model](Image)

Figure 8. Testing of model
3.8. Advantages
- The cost of structure is less as compared to other supporting structures, so it is affordable to ordinary persons.
- No effect of corrosion since corrosion resistant material is used.
- Material is water proof so no leakage or shortage problems.
- Structure is light in weight.
- All the structure can separate and assemble, so any part can be changed as per the requirement.
- As per the requirement the programming can be changed.

3.9. Challenges
Robotic systems are believed to be used as standard rehabilitation tools in the near future. Furthermore, worldwide efforts are being made to automate locomotor training to reduce health care costs. The capacity of robots to deliver training with high intensity and repeatability make them very valuable assistive tools to provide high quality treatment at a lower cost and effort. These systems should also be used at home to allow patients to perform therapies independently, not replacing the therapist but supporting the therapy program. This work has reviewed 43 robotic systems for lower-limb rehabilitation, of which more than half have not yet been marketed. Moreover, those systems available at the market are not developed as yet for application at home. Main reasons are elevated costs, lack of high clinical improvement evidence, and the need for a therapy protocol and assessment criteria. In addition, current systems are somewhat bulky and the mobile systems still lack long duration power supply solutions. The usage of robotic systems allows precise measurement of movement kinematics and dynamics, which should be used for assessing patient recovery ability and progress. However, there is a need to develop standard protocols and procedures to obtain reliable assessment data. Currently, patient recovery of walking ability is usually quantified by employing clinical measures such as the Barthel index [20]. Regarding robotic systems, gait velocity and walking distance, ROM, and many other dynamic measures have been used for assessment. However, there is not an standardized and widely (and clinically) accepted method. Therefore, large clinical trials are needed to determine clinical criteria for its use. Finally, clinical studies conducted still show little evidence for a superior effectiveness of the robotic therapy, although a clear benefit is shown in reduced therapist effort, time, and costs. It has been shown that robotic rehabilitation can be as effective as manually assisted training for recovery of locomotor capacity, but a higher benefit should be desirable to spread its use in clinics worldwide.

3.10. Future Scope
- By changing the material which is lighter in weight having same or more strength the cost can be saved.
- The change in design of structure can be possible or the desired change can be done to enhance its aesthetic and ergonomic features.
- Using optimum motor speed and torque cost can be saved.
- The programming can be done in the point of view to give more ease to that person.
- More switching can give the range of operation.
- Adjustable length will give more proper movement and can be universal.

IV. CONCLUSION
In this research paper, a new robotic supporting leg was developed for the elderly and handicapped people and the following conclusions were drawn.
- Running or movement of model takes place due to the actuation of servo motor.
- The structure supports the handicapped leg of person.
- Motor takes the load of leg only to move it.
- Along -with structure leg is in balanced position.

V. REFERENCES


