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Fabrication of a six-legged robot with crank and slotted lever mechanismusing RF communication

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Abstract- The legs movement of a walking robot has been widely studied to solve mobility problems on such robots. These studies mainly analyze the movement performed by certain animals like mammals, insects, or reptiles, that later will be mimicked by mechanical systems. In the presentwork, a kinematic analysis of crank and slotted lever mechanism attached to legs of a hexapod robot is introduced and RF communication is implemented. Most commercially available robots, capable of making topographic maps and avoiding obstacles have wheels and they do not function well on surface that are not flat and even. This work is carried on different ground surfaces with legs. Consequently the efficiency is increased by incorporating the embedded system.

Keywords:Crank and slotted lever mechanism,RF communication,embedded system.

1. Introduction

Walking robots have been studied in the last three decades in order to reproduce the natural abilities presented in some animals and insects. Nevertheless, locomotion, in these applications [25] is especially challenging in irregular terrains [14] [15]. Legged locomotion allows movement coordination of the mechanism to navigate safely across varied terrain [16]. In such cases it is intended that this type of machines can be independent and autonomous, in other words, do not require human intervention or reduce some restrictions [17].The animals are naturally adapted to different types of surfaces and with the goal of developing a similar mechanism, scientific communities have been inspired in some natural elements present in animals [18][19][20][21][22][23] trying to imitate to some extent in mechanical design, control, navigation and so on [24].These investigations have generated interest about the use of legs or wheels for robot movement. The principal difference between them is that the use of legs is better for motion and adaptation to irregular terrains than wheels which have a limited movement in this type of environments [25] [26]. Therefore, understanding of the behavior of animal locomotion is of main concern for the research community. One of the main challenges in the development of robots is the locomotion system design, which involves the interaction of structures composed of prismatic or rotational joints which emulates the motion functions existing in nature, allowing adapting to uneven terrain [27]. It also needs to deal with problems like the mechanical complexity existing in legs, the mechanism stability, power consumption, synchronization of the links in each of the robots joints and the control of number of degrees of freedom that is requiring. In case of a quadruped robot with three degrees of freedom per leg it is required to synchronize twelve degrees of freedom and for a hexapod robot eighteen angles in total. The legs location regarding the displacement surface is important in the robot's stability, the same way as the observation ofthe center of gravity, owing to that if these do not have a proper synchronization and do not provide the necessary support to the system base, it will lose balance and will fall or its movements will be inefficient causing perhaps a greater energy consumption [28]. This synchronization will depend of the mobility control of the legs for its displacement, because if the robot moves within the established limits, collisions between the links will be avoided and therefore the system will not be affected [29]. The length and design of the legs is essential in robot locomotion, because the trajectory that is implemented in each of the articulation depend on them. If we have the trajectory that allows a smooth movement, we will not see the robot stability affected by a hard movement and we can determine the progress of the movement in a given time. Also, if the robot moves within the established limits, the collision risk is avoided and the system will be safe. The old tradition to solve the problems mentioned above and to test the hypotheses, a prototype has been developed, with the disadvantage of loss of time and resources. The currently progress in programming and graphical environments, allows thedevelopment of tools such as simulators, which provide a validation of the physical system for trajectory selection to get a successful behavior, as well as the control algorithms developed [30] [31] [32].

2.Kinematic Model

2.1.Problem Definition

The system has a rigid body with six flexible legs and a crank and slotted lever mechanism attached to middle legs.The legs are very small compared to the body mass to withstand the deformation and bear required subsystems, such as an on-board computer, electronics, drivers and batteries.[4]Inorder to actuate the system, independent resistors, capacitors, diodes, switches and push buttons are connected to each hip.

The leg ground interation is very important .The system is operated by wire-less communication by RF Technology. Any RF field has a wavelength that is inversely proportional to the frequency. In the atmosphere or in outer space, if f is the frequency in megahertz and sis the wavelength in meters, the s = 300/f

The proposed mechanism makes contact states. Forinstance, o states that i^{th} leg touch the ground whereas 1 states that i^{th} leg is in flight.

2.2.Technical Specifications are as follows:

Domain : Robotics, Wireless Communication
Microcontroller: AT89S52
Power Supply : +9V, 500mA Regulated Power Supply
Crystal Oscillator : 11.0592MHz
Communication Device : RF Module
Transmitter : STT – 433MHz
Receiver : STR – 433MHz
Battery : 9V
Rechargeable battery : 12V
DC geared motors : 60rpm
RF Encoder : HT12E
RF Decoder : HT12D

2.3. Kinematic equations of crank and slotted lever mechanism

This mechanism is mostly used in shaping machines, slotting machines and in rotary internal combustion engines. In this mechanism, the link AC (i.e. link 3) forming the turning pair is fixed, as shown in Fig. The link 3 corresponds to the connecting rod of a reciprocating steam engine. The driving crank CB revolves with uniform angular speed about the fixed center C. A sliding block is attached to the crank pin at B slides along the slotted bar AP and thus causes AP to oscillate about the pivoted point A. A short link PR transmits the motion from AP to the ram which carries the tool and reciprocates along the line of stroke R1R2. The line of stroke of the ram (i.e. R1R2) is perpendicular to AC produced. In the extreme positions, AP1 and AP2 are tangential to the circle and the cutting tool is at the end of the stroke. The forward or cutting stroke occurs when the crank rotates from the position CB1 to CB2 (or through an angle β) in the clockwise direction. The return stroke occurs when the crank rotates from the position CB2 to CB1 (or through angle α) in the clockwise direction.

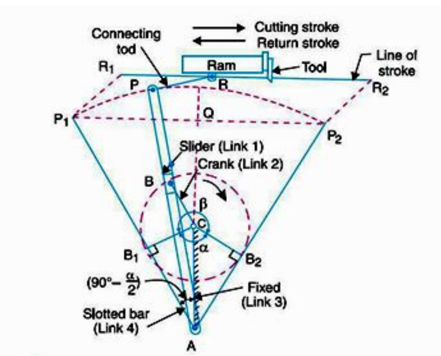

Fig 1:Crank and Slotted Lever Mechanism

3. Position Analysis

For the Crank and slotted lever Quick Return Mechanism shown in Fig above the displacement analysis can be formulated by the following loop-closer equations

$$l_1 + l_2 = l_3 \quad (1)$$

$$l_3 + l_8 + l_5 = l_6 + l_7 \quad (2)$$

Using complex numbers, Equations 1, 2 become

$$l_1 e^{i\theta 1} + l_2 e^{i\theta 2} = l_3 e^{i\theta 3} \quad (3)$$

$$l_3 e^{i\theta 3} + l_8 e^{i\theta 8} + l_5 e^{i\theta 5} = l_6 e^{i\theta 6} + l_7 e^{i\theta 7} \quad (4)$$

where the link lengths l_1, l_2, l_5, l_7 and angular positions θ_1, θ_6 and θ_7 are constants. Angular position $\theta_2$is an independent variable, angular positions θ_3; θ_8, θ_4 and θ_5 are dependent variables.

From figure $\theta_8 = \theta_3 = \theta_4$ and $l_4 = l_3 + l_8$

Substituting and rearranging Equations 1 and 2,

$$l_3 e^{i\theta 4} = l_1 e^{i\theta 1} + l_2 e^{i\theta 2} \quad (5)$$

$$l_4 e^{i\theta 4} + l5\ ei\theta 5 + l6\ ei\theta 6 = l7\ ei\theta 7 \quad (6)$$

As equation 5 has 2 unknowns and equation 6 has 3 unknowns

Utilizing Euler's equation, $e^{i\theta} = \cos\theta + i \sin\theta$ $l_3\cos\theta_4 + i \sin\theta_4 = l_1\cos\theta_1 + i \sin\theta_1 + l_2\cos\theta_2 + i \sin\theta_2$

Separate this equation in real numbers and imaginary numbers.

$$l_3 \cos\theta_4 = l_1 \cos\theta_1 + l_2\cos\theta_2 \quad (7)$$

Also,$\theta_{5a}=\theta_6+\sin^{-1}(l\cos\theta\sin\theta_6 - l\sin\theta\cos\theta_6/l_5)$

By knowing all of the angular positions and the length of l_6, we can find the position of the output slider by using $Pc=l_4+l_5$

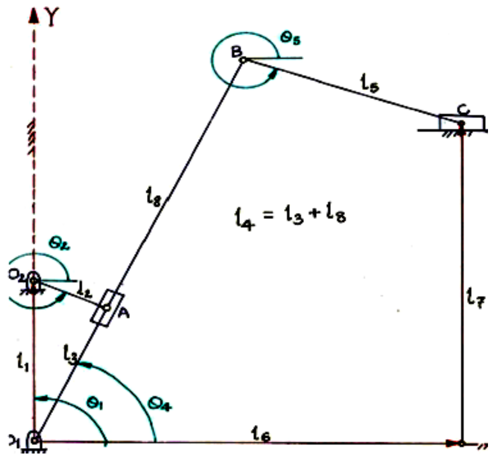

Fig 2: Vector Representation of Mechanism

4.Physical design

The mechanical structure of robot is modeled with mechanical mechanism. We selected this mechanism because of its extraordinary speed and agility [9].We designed the legs of the robot whichintegrated to the mechanism. The middle legs are operated by crank and slotted lever mechanism and the motion is progressed to front and rear legs. The walking servo robot is composed essentially of resistor, capacitor, diodes, LED and Switches and Push buttons. The relation between rotation angle and pulse width is expressed as

$$Y=0.5+0.01X$$

Where Y is the pulse width to be generated in ms, and X is the angle by which the servo is to be rotated. For this RF (Radio Frequency) technology is designed for frequencies ranging from 3HZ to 300GHZ.A RF transmitter STT-

433MHz operating from 1.5-12V supply makes it ideal for battery-powered application. The pin of a transmitter consists of GND, DATA, VCC, and ANT operating voltage for the transmitter VCC should be bypassed with a 0.01uF ceramic capacitor and filtered with a 4.7uF tantalum capacitor 50ohm antenna .The RF encoder used is HT12E for remote control system applications capable of encoding 12 bit of information. The RF receiver (STR-433MHz) receives data from antenna pin with pinouts ANT, GND, VCC (5V)

Fig 3: STT-433MHz Transmitter

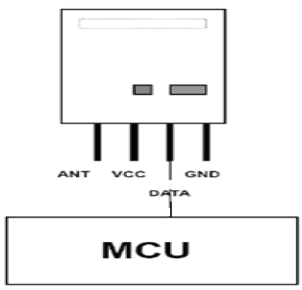

Fig 4: Schematic diagram of RF transmitter

4.1 Features of Microcontroller

Compatible with MCS-51® Products 8K Bytes of In-System Programmable (ISP) Flash Memory Endurance: 1000 Write/Erase Cycles 4.0V to 5.5V Operating Range Fully Static Operation: 0 Hz to 33 MHz •Three-level Program Memory Lock 256 x 8-bit Internal RAM 32 Programmable I/O Lines Three 16-bit Timer/Counters 34 Eight Interrupt Sources Full Duplex UART Serial Channel Low-power Idle and Power-down Modes Interrupt Recovery from Power-down Mode Watchdog Timer Dual Data Pointer Power-off Flag.

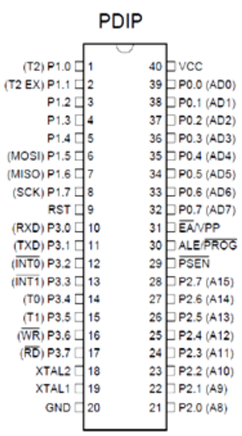

Fig 5:Pin Configuration

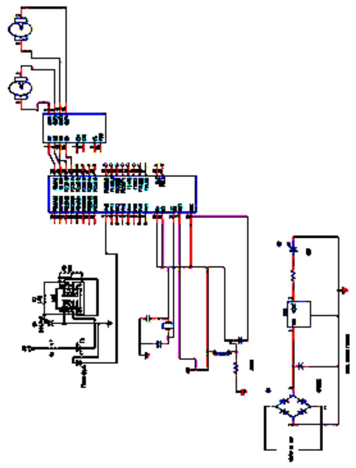

Fig 6: Circuit diagram

4.2Motor Driving Unit

The L293 and L293D are quadruple high- current half-H drives. The L293 is designed to provide bi-directional drive current of up to 1 A at voltage from 4.5V to 36 v. The L293D is designed to provide bidirectional drive current of up to 600-mA at voltage from 4.5V to 36V.both drives are designed to drive inductive load such as relay, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive- supply applications

4.2.1 H-Bridge

H-bride, sometimes called a full bride. The key fact to note is that there are, in theory, four switching elements within the bridge. These four elements are often called, high side left, high side right, low side right and 51 low side left(when traversing in clockwise order). The switches are turned on in pairs, either high left and lower right or lower left and high right, but never both switches on the same side of the bridge.

Table 1: Direction of Motor Rotation

High Side Right	Left High Side	Lower Left	Lower Right	Quadrant Description
On	Off	On	Off	Motor goes Clockwise
Off	On	Off	On	Motor goes counter-clockwise
On	Off	On	Off	Motor brakes and decelerates
Off	On	Off	On	Motor brakes and decelerates

The Device is a monolithic integrated high voltage, high current four channel driver designed to accept standard DTL or TTL logic levels and drive inductive loads (such as relays solenoids, DC and stepping motors) and switching power transistors. To simplify use as two bridges each pair of channels is equipped with an enable input. A separate supply input is provided for the logic, allowing operation at a lower voltage and internal clamp diodes are included. This device is suitable for use in switching applications at frequencies up to 5 kHz. The L293D is assembled in a 16 lead plastic package which has 4 center pins connected together and used for heat sinking The L293DD is assembled in a 20 lead surface mount which has 8 center pins connected together and used for heat sinking.

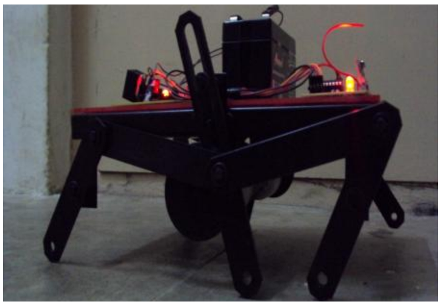

Fig 7: Legs of Robot with Crank and Slotted Lever Mechanism

5. Results and Discussions

In gait analysis the second and fifth legs of robot moves farward and backward with two motor connected by H-Bridge, so that the movement is advanced to first,third,fourth and sixth legs through crank and slotted lever.RF sensing provides simple interface and user friendly motion environment. Remote control of the robot is easily achieved using UP, LEFT and RIGHT KEYS

6. Conclusions

The aim of this study was the development of a low cost robot that is capable of exploring the environment by walking via a RF communication. The hexapod robot described here was designed, with two motors and a crank and slotted lever mechanism. This robot not only moves on smooth surfaces but also on rough terrains. Themotors connected to mechanism are capable of walking, with RIGHTY and LEFTY movements avoids obstacles. It is hoped that this study might find application for the exploration of rough or uneven surfaces and be of considerable use in the future.

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