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Gait Generation in ManobGari- A Reconfigurable Transformer Robot

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Abstract*- This paper describes the design, prototyping and gait generation of a reconfigurable robot platform, ManobGari. It is capable of changing its configuration from humanoid to car due to multiple degrees of freedom in its structure. It is controllable both wired and wirelessly using RS 232 or USART protocol. The proposed gait generation algorithm enable ManobGari for reconfiguring its shape to pass through an obstacle placed in front of it. It can move on wheels. Rolling, yawing and pitching motions of different parts of human body has been observed and the gaits of the robot has been designed and simulated in Solidworks accordingly. Different types of gait patterns have been integrated with it so that it gets different level of balance while in motion. Several designs have been tested in Solidworks and the improved one with auto-static balancing has been finalized as prototype. Structural analysis and simulation validates its efficiency and performance.*

Keywords: Humanoid, Mobile Robot, Reconfigurable, Robot, Gait-Generation

1. INTRODUCTION

Self-reconfigurable robotics has become a popular topic of research in academia. The world of 21st century is undergoing severe resource limitation. Researchers are now trying to utilize, recycle and reuse same material for various purposes. The resource utilization concept is now a crying need of this century. Under the gravity of the situation, Roboticists are trying to embed this resource utilization concept through designing self-reconfigurable modular robots. The structures of these robots are such designed and constructed that these robots can have multitasking capabilities. Reconfigurable robots can alter their morphology to perform several activities. They are exactly opposite to fixed morphology robots that are used to perform specific tasks in one certain morphology. For example, when the need is to pass through a narrow passage, the reconfigurable robots will transform themselves to a snakelike structure or when the need is to pass through an irregular surface, the same robot will transform itself to a spider-like structure and when the need is to pass a plain surface, the robot will transform itself into a car .These robots can be controlled autonomously or by using computer softwares by RS 232 port or can be operated wirelessly using reliable modules supporting USART protocol. The first reconfigurable robot was CEBOT. It was developed by Fukuda in 1988 [1]. In it, each of the modules had dimensions 8×9×15 cm. The cells consisting of the robot had separate processor, actuators and capability to communicate to connect and disconnect the modules. Baca et al. introduced a realtime distributed configuration discovery approach for MSR’s that enables each module to build the structure simultaneously, and they could detect changes of robot connections in real time [2]. Another reconfigurable robot was PolyBot [3], which was designed at PARC. Necessary parts of the robot were segments, nodes and connection plates. PolyBot has demonstrated various configurations like snake-like gait, four-legged spider gait, rolling-tread motion, climbing porous materials/chains and driving a tricycle etc. SUPERBOT [4], a distributed and scalable robot has been developed at University of Southern California.The goal was to develop a self-reconfigurable robot that can work in real life conditions rather than laboratory environments. In [5], authors present M-TRAN, which combines the benefits of chain-like and lattice structured self-reconfigurable robots. At discrete positions, it reconfigures its structure as a lattice using reconfiguration algorithm. However, it executes its motion in a chain-like structure, that’s how it maintains versatility. Its each module consists of a cube which can rotate from -90◦ to +90◦. Independent servo motors are used here for actuation. Reconfigurable robotics is a growing field. Several of the key directions for the future of this growing field has been written by M. Yim [6]. Principles of self-reproduction have been exploited in machine design by V. Zykov [7]. They created some simple machines which are actually autonomous modular robots having the capability of physical

self-reproduction by the use of set of cubes. In [8], B.Piranda proposed a 2D modular and self-reconfigurable Robots. They are composed of sliding blocks which are centimeter-scale and embed their own actuators and control electronics. They presented the linkage and of the traveling system and developed an algorithm for reconfiguration of the blocks. In [9], the authors presented the challenges of building modules for self-reconfigurable robots and the controlling of these robots.
B.Dong [10] have developed modular and reconfigurable robot modules having power supplies, processing systems, actuators and sensors. The modules are so designed that the robot can perform variety of tasks with a complex working environment.
Variety of tasks has been performed before and several reconfigurable robots have been developed. But reconfiguration from humanoid to car has rarely or not been covered by researchers. This paper presents the design and reconfiguration mechanism of ManobGari, a reconfigurable humanoid robot. Arduino Mega 2560 micro-controller has been used as the brain of the robot. Own developed 18 channel servo controller board has been developed as ManobGari's gait controller. It has been assembled using aluminium brackets. For communicating wirelessly with ManobGari, an Xbee pair has been integrated. The battery juice has been supplied using 2 cell Lipo battery.

2. MECHANICAL DESIGN

2.1 BODY

The body of ManobGari has been constructed using servo motors and aluminum brackets for holding the motors with the robot base. A hip bracket has been placed at the mid portion of the body as the main support of the robot. With the hip joint is attached the main power supply. Also the Arduino Mega 2560 board along with the Xbee Transceiver module has been attached there.

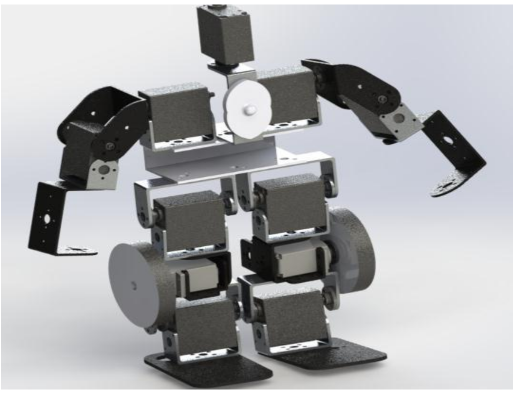

Figure 1: SolidWorks Design of ManobGari

2.2 Servo Motors

Actuating servo motors have been selected using the following algorithm.

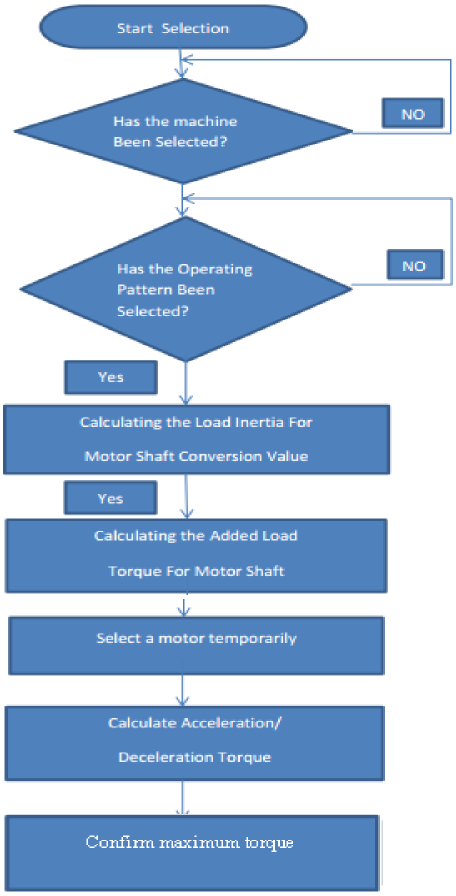

Figure 2: Flowchart of Motor Selection Technique

The robot is actuated using 11 digital robot dc servo motors. 9 of the motors can rotate from an angle of 0° to 180°. 2 full rotation servo motors DS 3115 has been used for differential driving while the robot is at car form. Specifications of robot digital servo motors and full rotation servo motors have been given in the following tables:

Table 1: Specifications of Robot Digital Servo

Size	40cm*20cm*40.5cm
Weight	60 gm
Wire length	320mm
Speed	0.16sec/60 degree at(5v) 0.14sec/60 degree at (6.8v)
Torque	15kg.cm.at(5v) 17kg.cm.at(6.8v)
Voltage	4.8v-6.8v
Dead Zoon setting	3 Microseconds

Table 2: Specifications of Full Rotational Servo DS3115

Size	40cm*20cm*40.5cm
Weight	60 gm
Wire length	320mm
Speed	0.14sec/60 degree at(6v) 0.16sec/60 degree at (7.2v)
Torque	14kg.cm.at(4.8v) 15kg.cm.at(6v)
Voltage	4.8v-8.4v
Dead Zoon setting	4 Microseconds

2.3 Position of Servo Motors

The robot has 11 motors. The motor at top of the robot is termed as m1, m2 and m3 motors are at shoulder, m4 and m5 motors are at arm, m6 and m7 are at hip, m8 and m9 are at knee and m10 and m11 are at ankle. An illustration of the positions of these motors has been depicted in Figure 3.

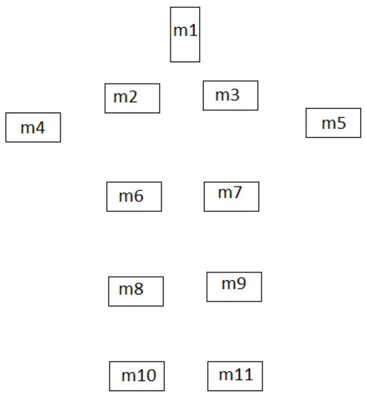

Figure 3: Servo Motor Positions

2.4 Aluminium Servo Brackets

In order to place the servo motors for reconfiguration at their place aluminum servo brackets were used as jackets for the servo motors. The robot is composed of the following types of aluminum servo brackets namely:

(a) Multi-Purpose Servo Bracket
(b) Long U servo bracket
(c) Short U servo bracket
(d) Big Foot
(e) Robot servo tilt U bracket
(f) Robot Servo Arm Round type Disc
(g) Hip Link

These brackets were joined to the servo motors with the help of nuts, bolts and bearings. The design of the brackets have been illustrated in Fig. 4

Figure 4: CAD of Aluminium Brackets

3. ELECTRICAL DESIGN

Electrical design of the robot has several parts. These have been shown in Figure 5.

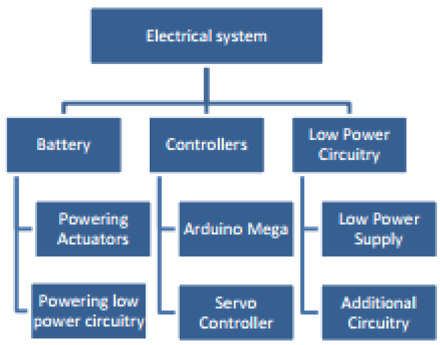

Figure 5: Electrical Design

3.1 Controller

The Arduino Mega 2560 is a micro-controller board based on the ATmega 2560. It has been used in the robot as the main controller.

3.2 Servo Controller

It is the controller for the servo motors connected to the arduino. It receives serial input from arduino and acts accordingly. The SSC32 from Lynxmotion is best suited for this transforming robot. But it is an expensive one.

That’s why, for successfully performing the tasks of the transformer, own developed servo controller board which successfully complies with the ssc32 servo controller board has been used. It has the least jittering problem which is the prime problem in moving servos. It has bit banging feature which gives it an outstanding control for software pwm. It is very good for handling digital servo motors.

Figure 6: Own Developed 18 Channel Servo Controller

3.3 Xbee

Xbee radios are great in wireless communication. They are such devices which are very very handy. These can be used upto 100m range in open space. They need a PAN ID to talk to each other. They also need a AT ID. Here in my transformer robot, 2 XBee radios have been used for communication between robot and the central command pc.

Figure 7: Xbee Radio

3.4 Power

One Lipo Battery of 7.2V 4000mAh has been chosen due to its high current driving capability.

Table 3: Power Budget for the robot

Parts`	**Allotted Power***	**Observed Consumption****
Wheel Motor x 2	6Wh	1.2Wh (6V*.5A*0.20hr)
Actuator x 11	10Wh	7.92Wh (6V*.6A*0.2hr)
Low Power Circuitry	6Wh	3Wh (5V*5A*0.2hr)
Total	**22Wh**	**12.12Wh**
Battery Capacity	**28.8Wh**	

4. COMMUNICATION AND CONTROL

The bot is teleoperated with XBee Series 1 comes standard with 802.15.4 firmware for point to point or star topology. This mature firmware offers ADC (analog-to-digital conversion) inputs, nand digital and analog I/O line passing. The 802.15.4 XBee is significantly faster than ZigBee; RF latency can generally be calculated in 802.15.4. Throughput is also much higher; a practical maximum throughput is around 80kbps. According to the nature of teleoperated robots, most of the decisions are taken by the operator. So, the usage of processing power of the computer is. This module is very small and runs at 3.3 V, making it very low power consuming. It is also easily interfacable with arduino boards. Simply connecting the transmitter and receiver pins of the UART module of the devices makes them work and thus it was found that the device is most suitable for such application considering budget and power consumption.

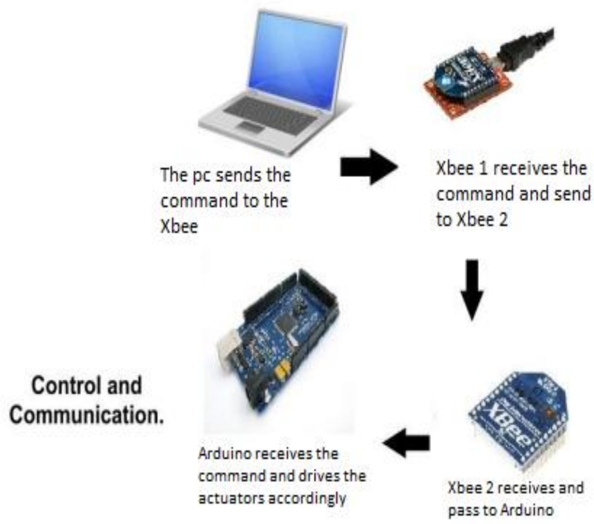

Figure 8: Communication between PC to ManobGari

5. GAIT GENERATION

5.1 Convention

In order to construct the gait control tables, a convention for motor position and corresponding angles was adopted. As shown in Fig. 9, if the reader holds the servo motor in one hand with the motor shaft side towards the reader, the clockwise rotation is denoted by -90◦ and counter-clockwise rotation is denoted by +90◦.

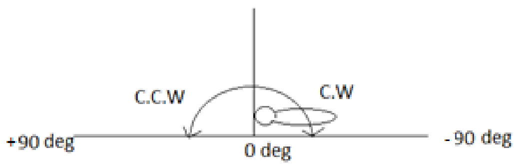

Figure 9: Angles of Servo Motors

5.2 Reconfiguration

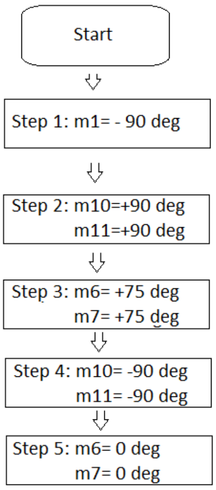

Figure 10: Flowchart for Transformation from Humanoid to Car

At certain character command received from the remote wireless transceiver, the servo controller performs group commands. At first the top motor rotates to 90 degree clockwise. After that the two motors at the ankles rotate 90 degrees counter clockwise. At this stage the robot is in flat position from humanoid. Only ankles need to be rotated for frictionless locomotion. Then the motors at knee joints need to rotate 75 degrees clockwise for uplifting the ankles. This is the position where the motors in the ankles can be rotated in a perfect position. Here those motors are rotated at 90 degrees clockwise. Finally the knee motors have to come back to 0 degree for completing the car shape.

5.3 Movement on Wheels

The two full rotation servo motors help the wheel to be differentially driven. Thus ManobGari has been able to move rightward, leftward, backward and forward.

5.3 Auto-Static Balancing

All the servo motors have been set initially in 0 degree position. The program includes algorithm of retrieving all the motors at initial mean position. This gives the robot auto-static balancing capability.

6. RESULT

Different angles were set at different level to find out the gait generation technique of the robot. Experimentally the generated algorithms were verified and the finalized shapes have been depicted in Figure 11 and Figure 12.

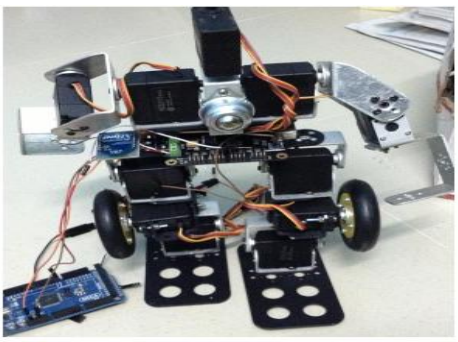

Figure 11: Humanoid Form of Real Robot

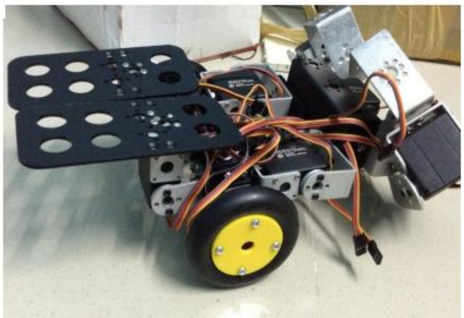

Figure 12: Car form of the Real Robot

7. CONCLUSION AND FUTURE WORK

This paper presented the design, gait generation and reconfiguration of a reconfigurable mobile robot ManobGari. It consists of a centralized control using Arduino Mega 2560. It can transform its shape from humanoid to car using different level of structural modularity. Control commands is sent to the robot using wireless module Xbee supporting USART protocol. Group commands of several servos are performed using own developed 18 channel servo controller. This PWM servo motor controller has been developed with a view to integrating more gaits in future for different morphology.

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