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FUZZY BASED SELF-TRANSFORMING ROBOT

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ABSTRACT

Self-transforming robot is a robot which transforms its shape according to the hindrance occurring in the path where the robots are being moved. Such robots have been recognized as very attractive design in exhibiting the reliable transformation according to the situations. Military and defense application needs a robot should possess arbitrary movements like human. In some scenarios transformations are made by biological inspired control strategies using Central Pattern Generators (CPG). CPG is used in the locomotion control of snake robots, quadruped robots, to humanoid robots. This paper presents a Fuzzy system for the Self-transforming robot which possess alteration in its original shape to exhibit a human-like behavior while passing over the particular location. Quadrupedal locomotion on rough terrain and un-predictable environments is still a challenge, where the proposed system will provide the good adaptability in rough terrain. It allows the modulation of locomotion by simple control signal. The necessary conditions for the stable dynamic walking on irregular terrain in common are proposed. Extensive simulations are carried out to validate the performance of the proposed Fuzzy system using LABVIEW. Arbitrary parameters such as distance, angle and orientation of the obstacles are provided as input to the fuzzy system which gives the required speed modulation on the motoric module.

Keywords: self-transforming robot, central pattern generators (CPG), quadruped robot, Fuzzy system.

INTRODUCTION

Increase in use of Robot in the modern world lead to afford more attention to the mobile robots. The robots are most commonly used in industries, military, search and rescue operations in hazardous environments and security locations. The major expected requirement of a mobile robot is it should have replaced the human in performing the dangerous and repetitive tasks in outer space or at the bottom of the sea where human could not survive the extreme environment. These requirements can be attained by the different types of modern robots. In order to face the multiple adaptive environments, researchers on robot have established a number of mobile robot prototypes to carry out the required task.

Traditional types of mobile robots are failing to meet out the certain specified requirements. Walking robots possess high mobility, but the lack of stability and size limits the chosen application. Crawler type robot possesses high propulsion but the size limits to use it in the collapsed buildings. Wheeled robots exhibit high velocity, but it cannot possible to climb over the obstacles higher than the radius of its wheel.

A Robot used in the defence should be light-weighted and might have the ability to travel through the minor spaces that the human cannot thinkable to enter. This can be satisfied by the snake-like robot with slim body and has more application for urban search and rescue (USAR). This robot keeps high mobility, light weight, shape-shifting corresponding to the rough ground, but it lags in crossing the big obstacles. [1]. A Novel robot (NEZA-I) is designed with self adaptive mechanism with Two Wheel Track System (TWT) have the ability to transform its configuration among the different terrains by altering the locomotion mode. A TWT unit which driven by the single servo motor was proposed by Zhiqing *et al*. [2]. A general legged locomotion controller with no leg roll joints in the leg have been designed coordination of rhythmic motion of the legs detected, yet without explicit synchronization between the leg controller, allowing to understand dynamic walking in the low-to medium-speed range the method the resistance ability against cross perturbations to some extend proposed by Mafroy *et al* [3].The motion control methods of biped robots by using the nonlinear oscillators are proposed in [4]. The main technical issue in designing a robot is occurring in configuring it device with stair climbing ability. There are different kinds of stair climbing robot. However a number of different robotic structures are designed a new hybrid robotic module called Loper with the ability to overcome the stairs and other obstacles was designed by Herbert *et al* [5]. A linkage type locomotive mechanism was developed for a Wheeled Mobile Robot (WMR) with the passive linkage type locomotive mechanism [6]. The design states transformation to rough terrain and stair-climbing with the absence of active control techniques. The parametric transitions between the motions are stated [7] and the special transition points described without the loss of smoothness.

A kinematic analysis of stair climbing provides the efficient online control method for a transformable tracked robot with isomerism module. The force analysis based stair-climbing and the obstacle avoidance criteria for the motion planning and the recognition for the stair facilitate the robot to predict the climbing capacity [8]. A kinematic model of the wheelchair with the stair climbing ability are described with the defined environmental adaptation, weight balancing and time reduction in climbing ascending and descending obstacle process [9]. Pattaramon *et al* [10] Presents a hybrid model of leg-heel robot with Stair climbing ability. The model includes with normal wheel and leg wheel with different number of

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spokes the analysis of maximum height of the obstacles are considered.

Walking robot is obsessed high mobility, but much consideration of stability [11] and the wheeled robot [12] exhibit high velocity, lags in climbing over the obstacle higher than its radius of wheel. This paper proposes a robotic structure which combines the advantages of both quadruped robot and the wheeled robot. The modular mobile unit is designed with high environment adaptability and big contact area with ground to get enough propulsion. In this work a fuzzy based decision making system is developed using LabVIEW. It is designed mainly for crossing the obstacles like passage and slope along the path with arbitrary movement.

DESIGN CONCEPT

A. Robot model

Mobile platform is planned with the purpose of compactness, weightlessness, high performance and a certain degree of adaptability. A quadruped robotic module built with number of servo motors. Various servo motor provides the proper angular and linear transformations. The quadrupedal structure will combines the merits of wheel and leg modules mechanism. The idea behind the robot design is depends upon the drive system. The system should transform over the altered terrains. According to the drive configuration the system will adapt the movements to provide the modular activities in correspond to the surroundings. Reducing the number of motors should provide high efficiency and reduced weight. Instead higher the number of motor corresponds to the reliable transformation. Increased number of motor includes more flexible multiple operations in a single module.

Based upon these considerations a self-transformable robotic model is proposed with the Self-transformation capability is shown in Figure-1. The system consists of number of servo motors they are controlled by a fuzzy logic controller according to the constraints like length, width and angular distance of the obstacles are measured in accordance to the current location of the system.

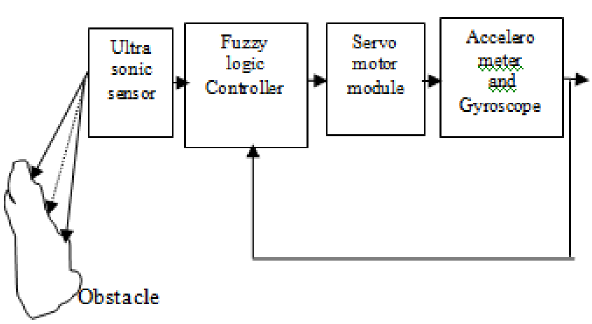

Figure-1. The basic model of the self-transforming robot.

Self-transforming robot model contains the combined motoric structure is shown in Figure-2. Motor structure is chosen in order to accomplish the flexible transformation over normal and rough terrain. Combined servo motor structures provide produces less weight and high initial torque to the low power input. The structure is designed with four units named Position1 (P1), Position2 (P2), Position3 (P3), and Position4 (P4) each position includes the combination of five servo motors which are the hands and legs of the Self-Transforming Robot shown in Figure-2. The limb angular variation with respect to the reference point corresponding to the surrounding ground changes is named as Transformable mode. Both the movements deliver the motion by sensing the obstacle information like length, width, height and the angle. The design will exhibits two work states including the linear state and the parallel state. With the linear state the robot can go through the narrow space, passage

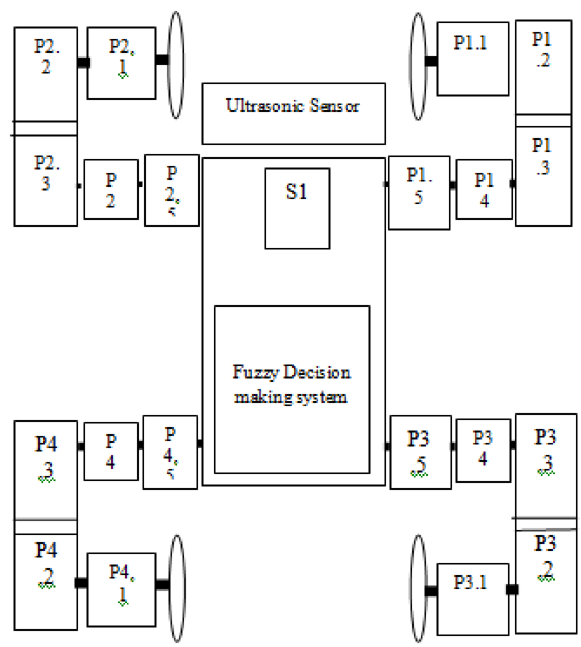

Figure-2. Schematic diagram of self-transforming robot.

The parallel state enables the robot with high mobility on rough ground. The robot travels by wheel mode once it travels on the flat ground. For the robot to have the projecting performances in turning tractability and less energy consumption. Meanwhile, the exchange area will become large between the mobile mechanisms and ground. The force from the environment and the angular variation between the reference points with the environment also considered while planning the transformation towards the destination.

B. Sensor configuration

An ultrasonic sensor is used to access the environmental information. The maximum sensing capability of the module is about 400cm with the 0.3cm of resolution. Overall sensing ability is fixed as ±180 degree with the 10 angular motions in each rotation. The distance information of the object along the path in the both horizontal and vertical planes is observed to process in the fuzzy system. A sensor is used to observe the current position of the each wheel which is achieved by accelerometer and gyroscope. The orientation of the present object is changed by processing the same information in the fuzzy controller unit.

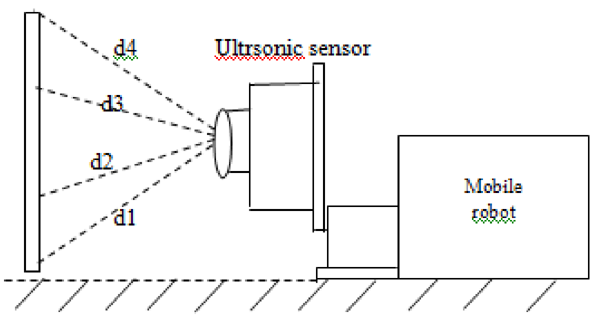

Figure-3. Scheme of distance measurement in ultrasonic sensor.

FUZZY CONTROLLER DESIGN USING LABVIEW

This section describes the LabVIEW implementation of fuzzy logic control methods. The Fuzzy logic controller designed in this paper have the inputs are the obstacle information observed by the ultrasonic sensor and the orientation changes obtained by the accelerometer. The output of the fuzzy controller deliver the control in the form of pulses to servo motor that will lead to proper linear and angular movement of the wheel. Rotational angle and the speed required to obtain the specified result are processed in the fuzzy decision making system.

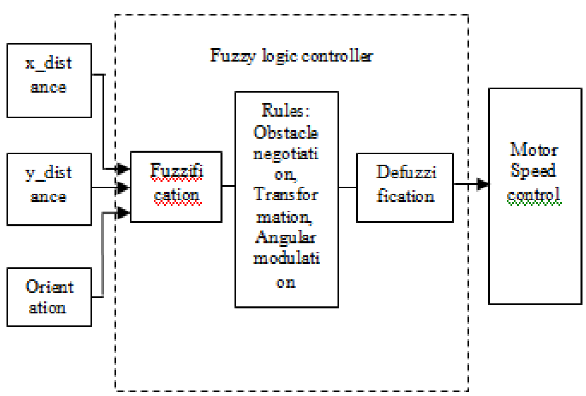

Figure-4. Block diagram of fuzzy logic controller.

The required membership functions are created to process the data obtained by the sensor. x_distance, y_distance, Orientation θ are the membership functions obtained by the ultrasonic sensors and accelerometer respectively. The linguistic variables for each membership functions denote possible variations in each for each movements.

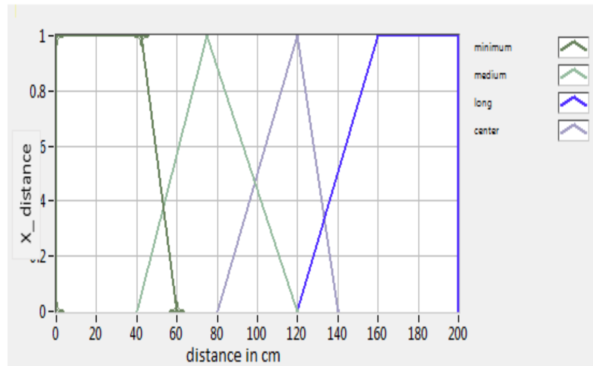

Figure-5. Linguistic terms for x_ distance (Possible variation of distance from the each wheel center to the obstacle along the path).

Figure-5, depicts the different linguistic terms for x_ distance the maximum distance taken into consideration is 200cm about this the measurement range is divided into four linguistic terms. In Figure-6, y_ distance measured by the ultrasonic sensor within the range of 150cm is processed at 4 linguistic terms.

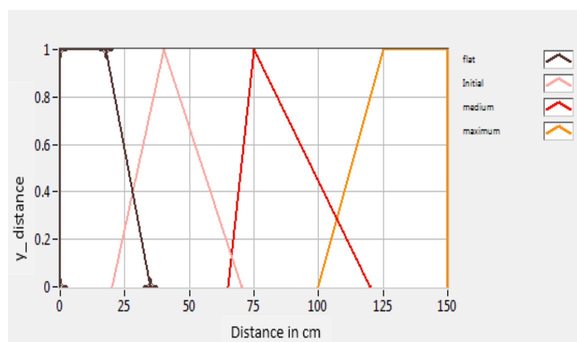

Figure-6. Linguistic variable for y_ distance (Possible variations of vertical distance of the obstacle on the x_ plane).

Figure-7. Indicates the membership functions of the linguistic variable of orientation variations observed by accelerometer and gyroscope.

A. Rule base system design

Rule base system used to built the fuzzy input variable and the corresponding output mapping. The tested system formulated with 54 rules, to obtain the required speed the rules are formulated some of the rules for motor speed control are provided in Table-1.

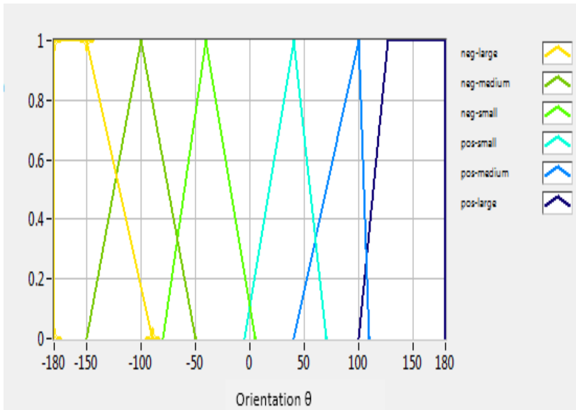

Figure-7. Linguistic terms for angle variations (Possible angle variations of servo motor)

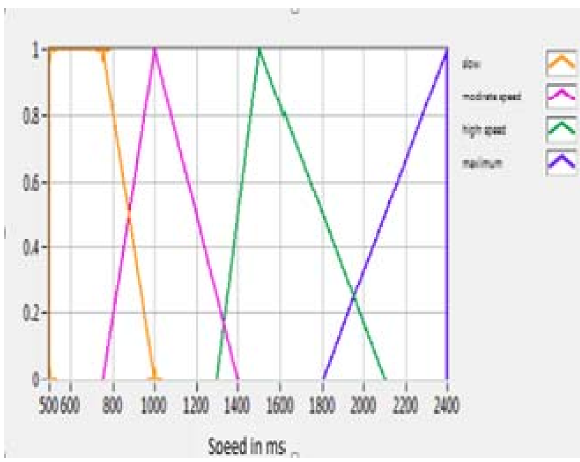

Figure-8. Output linguistic terms.

B. Deffuzification

This paper uses weighted-average defuzzification method to get crisp outputs. The different linguistic terms for the output linguistic variable are depicted on the following Figure-8.

$$x(i) = \sum_{i=1}^{number\ of\ rules} \frac{s(i)*w(i)}{s(i)} \qquad (1)$$

x(i) = defuzzified output
w(i) = weight associated with each rule
s(i) = The member of associated in each rule

The output membership functions for the motor speed control mechanism are pictured in Figure-8. Output variables denoted haves the 3 different linguistic terms which represent the duration control signal given to the servo motor.

Table-1 shows the some of the rules formulated to design the fuzzy system with three input and single output. The distance from the vertical to the reference point are more responsible for the speed variation in movement the orientation takes much consideration while the current system is observed as having large distortion over the specified destination.

Table-1. Rules for angle variations.

If x_distance is minimum and y_distance is Flat and Orientation is neg_small then speed is slow
If x_distance is minimum and y_distance is Initial and Orientation is neg_small then speed is slow
If x_distance is medium and y_distance is large and Orientation is neg_medium then speed is moderate
If x_distance is medium and y_distance is Flat and Orientation is neg_large then speed is slow
If x_distance is medium and y_distance is initial and Orientation is neg_large then speed is maximum
If x_distance is center and y_distance is large and Orientation is neg_large then speed is maximum
If x_distance is center and y_distance is flat and Orientation €neg_small then speed is slow
If x_distance is long and y_distance is initial and Orientation is pos_small then speed is slow
If x_distance is long far and y_distance is large and Orientation is pos_large then speed is high
If x_distance is minimum and y_distance is flat and Orientation is pos_medium then speed is moderate

SIMULATION RESULTS

In the simulation results, each motor speed to overcome the specified obstacles are shown the angular variation needed to reach attain the transformation are analyzed. The path is represented by the motion of mobile robot in each step. Figure-9 shows the overall structure of the FLC system which process and provides the required speed in form of milliseconds to drive the each servo motor connected in the system. Sensor input are calculated and given to the FLC system. The system is designed only for the linear motion.

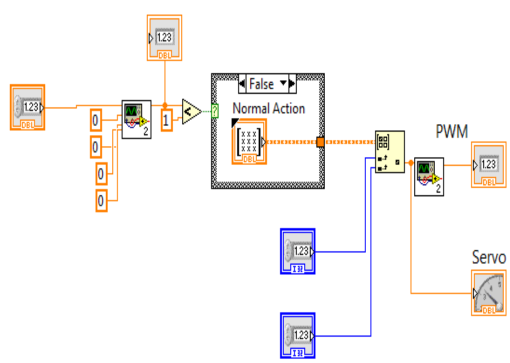

Figure-9. LABVIEW design of FLC.

Figure-10 depicts the motor selection to deliver the normal action with the actual and the reference speed designed in LabVIEW. Number of motors with actual and nominal motion are given the input, the motor which is

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need to drive to reach the specified destination is placed at the output. Required motor to drive is get selected.

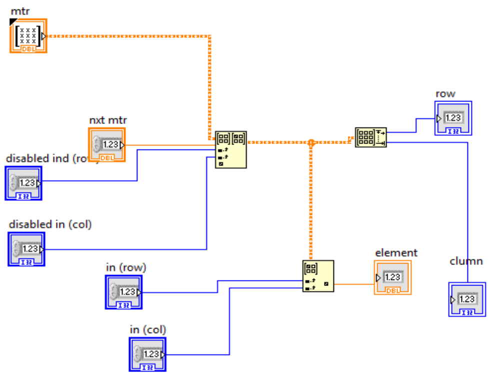

Figure-10. System design of motor selection.

Figure-11 shows the overall FLC output which gives the speed and angular rotation of each servo motor to reach the actual state for normal movement in forward direction with the change in angular motion.

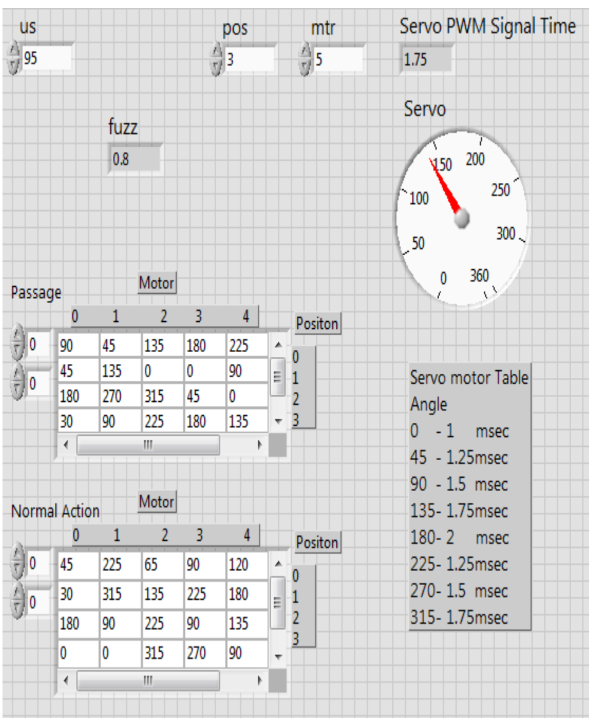

Figure-11. Overall system output.

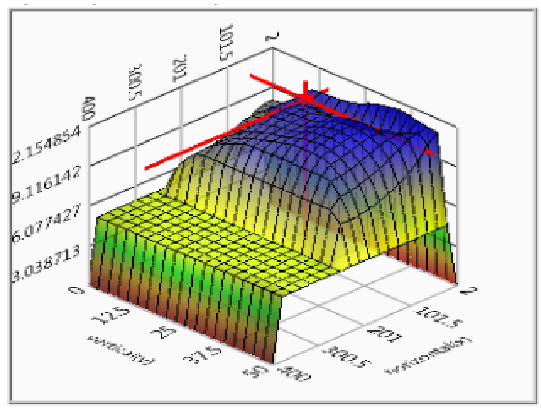

Figure-12. Output FLC surface.

Figure-12 represents the two input and single output system. Initially the FLC is simulated with ultrasonic sensor input i.e., distance of the obstacle in both x and y axis. The system is simulated with 20 samples in each output with 72 rules output specifies the average speed required to Passover the prescribed path. Hardware model of the Self-Transforming robot is shown in Figure-14.

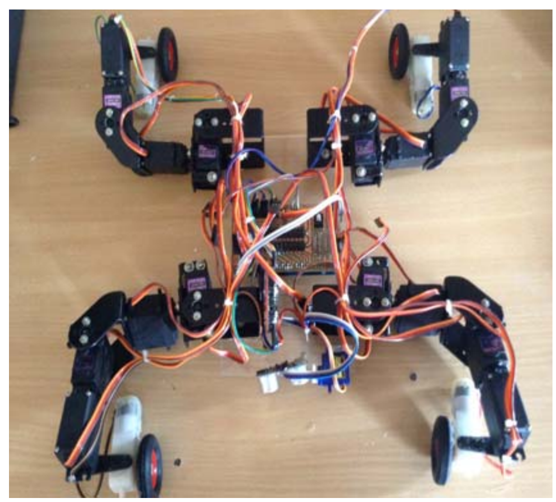

Figure-13. Hardware prototype.

CONCLUSIONS

In this paper Self-transforming robot was designed using Fuzzy logic for linear motion of robot. The purpose of this design is to obtain the required angular motion to provide the transformation which possess shift in the original shape of robot to display a human-like behavior while passing over the particular location. The fuzzy based system will provide a modulation of quadrupedal locomotion on rough terrain by simple control signal. LabVIEW simulations are carried out to validate the performance of the proposed Fuzzy system. Arbitrary parameters such as distance, angle and orientation of the obstacles are provided as input to the fuzzy system which gives the required angular motion the

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motoric module. A Hardware prototype of Self-Transforming robot was developed

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