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DEVELOPMENT OF THE AUTONOMOUS ANTHROPOMORPHIC WHEELED MOBILE ROBOTIC PLATFORM

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ABSTRACT

This article presents the intelligent autonomous anthropomorphic wheeled mobile robotic platform motion control in unstructured environments. The fuzzy control of a wheeled autonomous anthropomorphic mobile robotic platform motion in unstructured environments with obstacles is proposed. Outputs of the fuzzy controller are the angular speed difference between the left and right wheels of the autonomous anthropomorphic robotic platform and the robot velocity. The simulation results show the effectiveness and the validity of the obstacle avoidance behaviour in the unstructured environment and velocity control of autonomous anthropomorphic mobile robotic platform motion of the proposed fuzzy control strategy. Wireless sensor-based remote control of autonomous anthropomorphic mobile robotic platform motion in unstructured environments is proposed.

KEYWORDS

autonomous anthropomorphic wheeled mobile robotic platform, unstructured environments with obstacles, fuzzy control strategy, wireless sensor-based remote control

CLASSIFICATION

ACM: D.1.1.

JEL: Z00

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INTRODUCTION

Currently, research in robotics, deals with different problems of motion of wheeled mobile robots and the motion control of wheeled mobile robots in unstructured environments. Autonomous navigation is an important problem in mobile robotics. Fuzzy logic approaches to mobile robot navigation and obstacle avoidance have been investigated by several researchers. Many application works of fuzzy logic in the mobile robot field have given promising results.

In recent years, there has been a growing interest in autonomous anthropomorphic mobile robotic platform motion control [1, 2]. This article presents autonomous anthropomorphic wheeled mobile robotic platform motion control in unstructured environments.

The article deals with the fuzzy velocity control of an autonomous anthropomorphic mobile robotic platform in motion in an unstructured environment with obstacles. For the wireless, sensor-based remote control the Sun-SPOT-based remote control is utilised. Conventionally, autonomous anthropomorphic mobile robotic platforms are equipped by ultrasonic sensors and a stereo-vision system. The wheeled mobile robot must be capable of sensing its environment. It is supposed that the autonomous anthropomorphic mobile robotic platform has groups of ultrasonic sensors to detect obstacles in the front, to the right and to the left of the platform, that the model of the autonomous anthropomorphic mobile robotic platform has two driving wheels and that the angular velocities of the two wheels are independently controlled. When the anthropomorphic mobile robotic platform [1, 2], is moving towards the target and the sensors detect an obstacle or slope an avoiding strategy is necessary (Fig. 1). While the anthropomorphic mobile robotic platform is moving it is important to compromise between avoiding the obstacles, slopes and moving towards the target position.

The fuzzy control of a wheeled anthropomorphic mobile robotic platform motion in unstructured environments with obstacles and slopes is proposed. Outputs of the fuzzy controller are the angular speed difference between the left and right wheels of the platform and the platform velocity.

Figure 1. The autonomous anthropomorphic mobile robotic platform.

The simulation results show the effectiveness and the validity of the obstacle avoidance behavior in unstructured environment and velocity control of a wheeled mobile robot platform motion of the proposed fuzzy control strategy. The wireless sensor-based remote control of anthropomorphic mobile robotic platforms motion in unstructured environments using the Sun SPOT technology is proposed. The proposed method has been implemented on the wheeled anthropomorphic mobile robotic platform that is equipped with sensors and the free range Spot from the Sun Spot technology. Finally, the effectiveness and efficiency of the proposed sensor-based remote control strategy are demonstrated by experimental studies and good experimental results of the obstacle avoidance behavior in unstructured environments.

The article is organized as follows. In Section 1 introduction to the topic is given. In Section 2 the strategy of autonomous anthropomorphic mobile robotic platform control in unstructured environments is proposed. Section 3 illustrates the simulation results, while in Section 4 the wireless robot-sensor networked systems are illustrated and the Sun-SPOT-based remote control of autonomous anthropomorphic mobile robotic platform is proposed. Finaly, in Section 5 conslusions are given.

STRATEGY OF AUTONOMOUS ANTHROPOMORPHIC WHEELED MOBILE ROBOTIC PLATFORM MOTION CONTROL IN UNSTRUCTURED ENVIRONMENTS

In this section fuzzy control is applied to the navigation of the autonomous anthropomorphic mobile robotic platform in unstructured environments with obstacles and slopes. It is supposed that: the autonomous mobile robotic platform has two wheels driven independently and groups of ultrasonic sensors to detect obstacles in the front, to the right and to the left of the autonomous mobile robotic platform.

When the autonomous mobile robotic platform is moving towards the target and the sensors detect an obstacle, an avoiding strategy is necessary [3-13]. While the autonomous mobile robotic platform is moving it is important to compromise between [13]:

- avoiding the obstacles and
- moving towards the target position.

With obstacles present in the unknown environment, the autonomous mobile robotic platform reacts based on both the sensed information of the obstacles and the relative position of the target [13]. In moving towards the target and avoiding obstacles, the autonomous mobile robotic platform changes its [13]:

- orientation and
- velocity.

When an obstacle in an unknown environment is very close, the mobile robot slows down and rapidly changes its orientation [13]. The navigation strategy has to come as near as possible to the target position while avoiding collision with the obstacles in an unknown environment [13].

The intelligent autonomous mobile robotic platform reactive behaviour is formulated in fuzzy rules [14-25]. Fuzzy-logic-based control is applied to realize an autonomous mobile robotic platform in an unknown environment with obstacles.

Inputs to the fuzzy controller are:

- the obstacle distance p,
- the obstacle orientation θ_1 (which is the angle between the mobile robotic platform moving direction and the line connecting the robot's centre with the obstacle),
- the target distance l,

- the target orientation θ_2 (which is the angle between the robot platform moving direction and the line connecting the platform's centre with the target).

Outputs of the fuzzy controller are:

- the angular speed difference between the left and right wheels (wheel angular speed correction) of the vehicle: $\Delta\omega = \omega_r - \omega_l$ and
- the vehicle velocity.

The block diagram of the fuzzy inference system is presented in Figure 2.

The obstacle orientation θ_1 and the target orientation θ_2 are determined by the obstacle/target position and the robot position in a world coordinate system, respectively. The obstacle orientation θ_1 and the target orientation θ_2 are defined as positive when the obstacle/target is located to the right of the platforms direction of movement; otherwise, the obstacle orientation θ_1 and the target orientation θ_2 are negative.

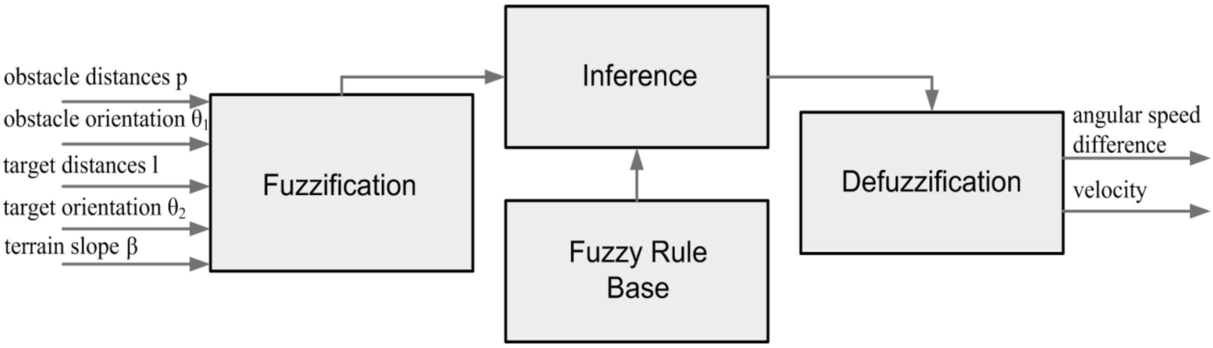

Figure 2. The block diagram of the fuzzy inference system [13].

For the proposed fuzzy controller the input variables for the obstacle distance p are simply expressed using two linguistic labels – Gaussian membership functions – near and far ($p \in [0, 3$ m]).

The input variables for the obstacle orientation θ_1 are expressed using two linguistic labels – Gaussian membership functions – left and right ($\theta_1 \in [-\pi, \pi$ rad]).

For the proposed fuzzy controller the input variables for the terrain slope β is simply expressed using three linguistic labels – Gaussian membership functions sloped left, flat and sloped right ($\beta \in [-\pi, \pi$ rad]), β is the average slope value.

The input variables for the target distance l are simply expressed using two linguistic labels – Gaussian membership functions – near and far ($l \in [0, 3$ m]).

The input variables for the target orientation θ_2 are simply expressed using three linguistic labels – Gaussian membership functions – left, target direction and right ($\theta_2 \in [-\pi, \pi$ rad]).

The fuzzy sets for the output variables of the wheel angular speed correction $\Delta\omega = \omega_r - \omega_l$ (turn-right, zero and turn-left) of the mobile robot are shown in Figure 3. The output variables are normalized in the interval: $\Delta\omega$, rad/s $\in [-20, 20]$.

The other output variable of the fuzzy controller is vehicle velocity. The output variables are normalized between: Velocity, m/s $\in [-10, 20]$. The fuzzy sets for the output variables Velocity (low and high) are shown in Figure 4.

The rule-base for mobile robot fuzzy control is:

R1: If θ_2 is right and β is sloped left then $\Delta\omega$ is turn-right
R2: If θ_2 is left and β is sloped right then $\Delta\omega$ is turn-left
R3: If p is near and l is far and θ_1 is left and β is sloped left then $\Delta\omega$ is turn-right

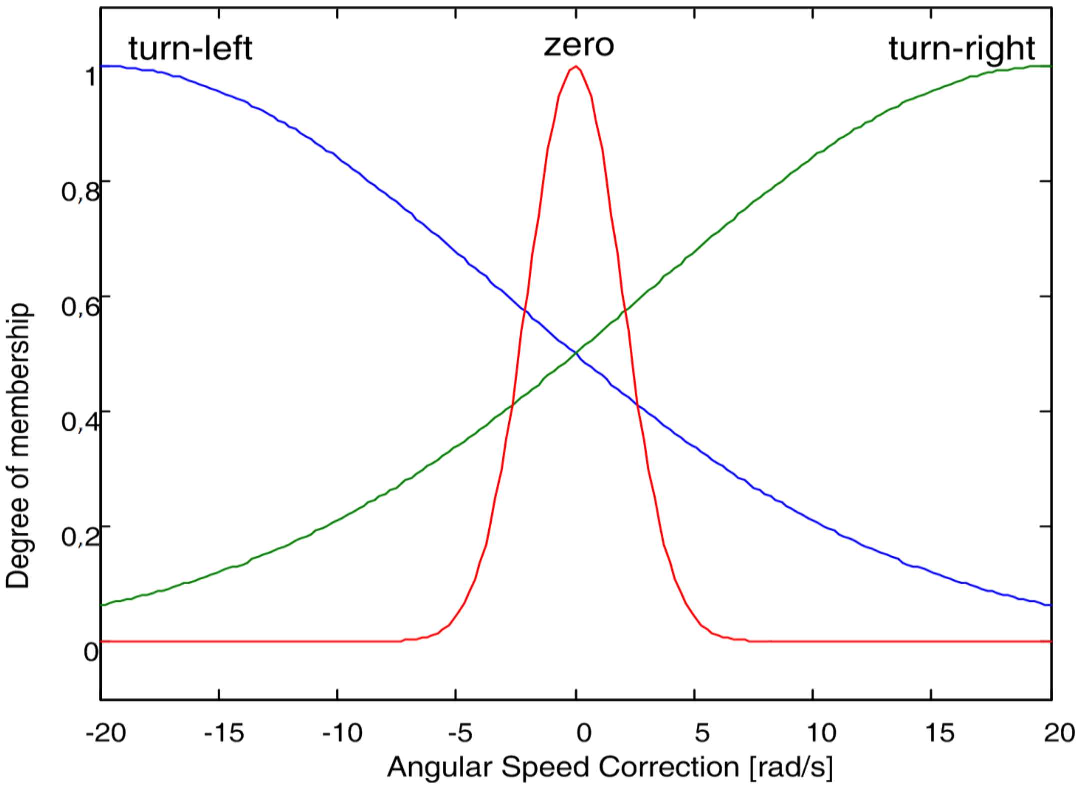

Figure 3. The Membership functions of the angular speed difference $\Delta\omega$.

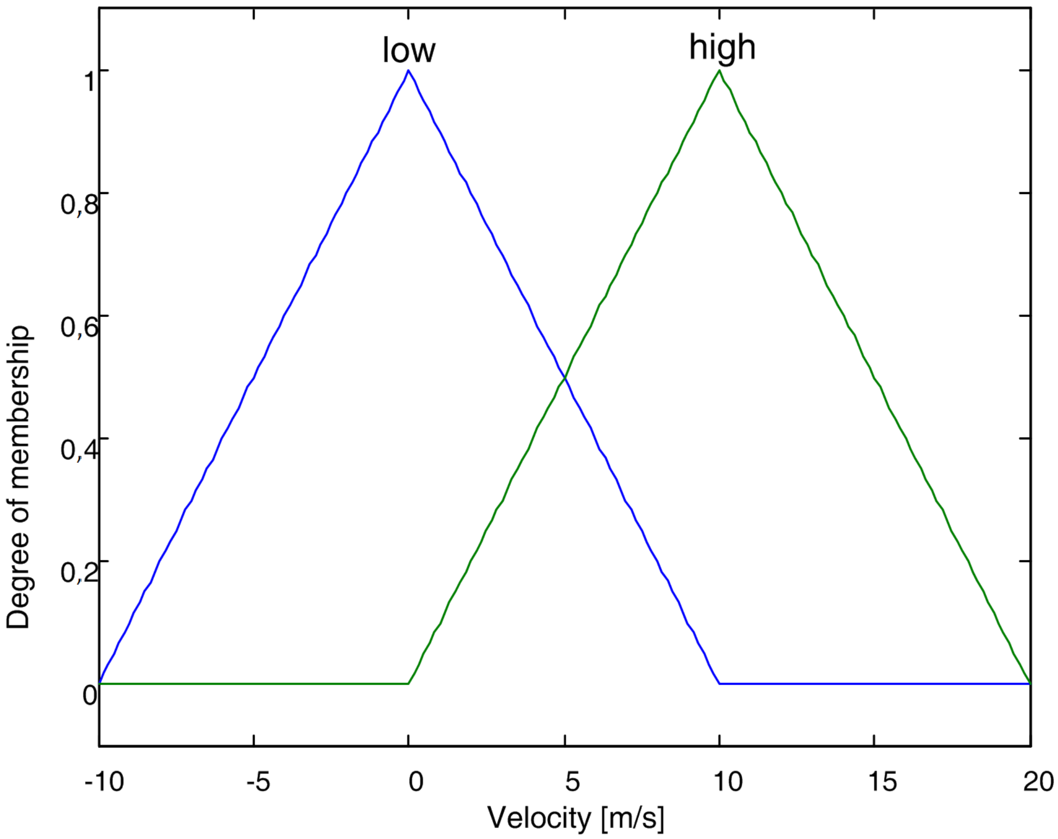

Figure 4. The Membership functions of the velocity of the mobile robot platform.

R4: If p is near and l is far and θ_1 is right and β is sloped right then $\Delta\omega$ is turn-left
R5: If θ_2 is target direction and β is flat then $\Delta\omega$ is zero
R6: If p is far and θ_2 is target direction and β is flat then $\Delta\omega$ is zero
R7: If p is near and l is far then velocity is low
R8: If p is far and l is far then velocity is high
R9: If p is far and l is near then velocity is low.

In the present implementation of the fuzzy controller the Center of Area method of defuzzification is used.

SIMULATION RESULTS

The author applied the proposed fuzzy controller to the autonomous anthropomorphic wheeled mobile robotic platform moving in an unstructured environment with obstacles. A simulation example of a wheeled autonomous anthropomorphic mobile robotic platform is presented in Figure 5. The corresponding fuzzy control is implemented to perform tasks of obstacle and collision avoidance. The results of the simulation are shown in Figure 5 regarding the goal seeking and the obstacle avoidance mobile robot paths.

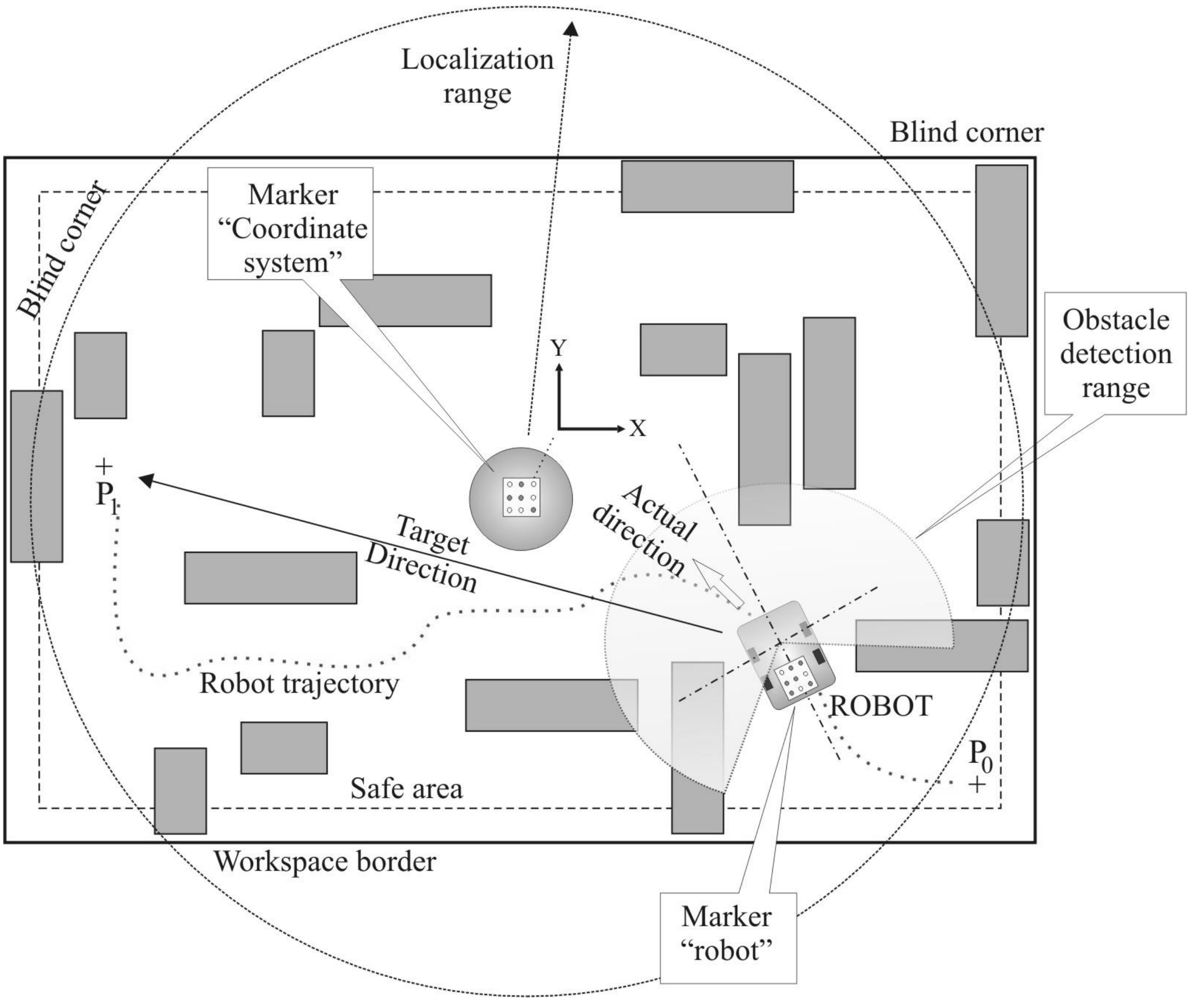

Figure 5. Example of an obstacle avoidance scenario, obstacle avoidance trajectory of autonomous anthropomorphic wheeled mobile robot platform.

WIRELESS ROBOT-SENSOR NETWORKED SYSTEMS

This article presents a wireless sensory control for mobile robot navigation. Wireless Robot-Sensor Networked systems refer to multiple robots operating together in coordination or cooperatively with sensors, embedded computers, and human users [26-33].

Communication between entities is fundamental to both cooperation and coordination and hence the central role of the networked system. Embedded computers and sensors are now ubiquitous in homes and factories, and increasingly wireless ad-hoc networks or plug-and-play wired networks are becoming commonplace.

Robots are functioning in environments while performing tasks that require them to coordinate with other robots, cooperate with humans, and act on information derived from multiple sensors. In many cases, these human users, the robots and sensors are not collocated, and the coordination and communication happens through a network.

In this article Sun SPOT-s (Small Programmable Object Technology) have been used to creat remote control over a autonomous anthropomorphic wheeled mobile robotic platform, Figure 6. Sun SPOT is a small electronic device made by Sun Microsystems. The Sun SPOT is designed to be a flexible development platform, capable of hosting widely differing application modules. For this task 2 SunSPOT-s have been used from the development kit (Sun Microsystems, Inc. 2007).

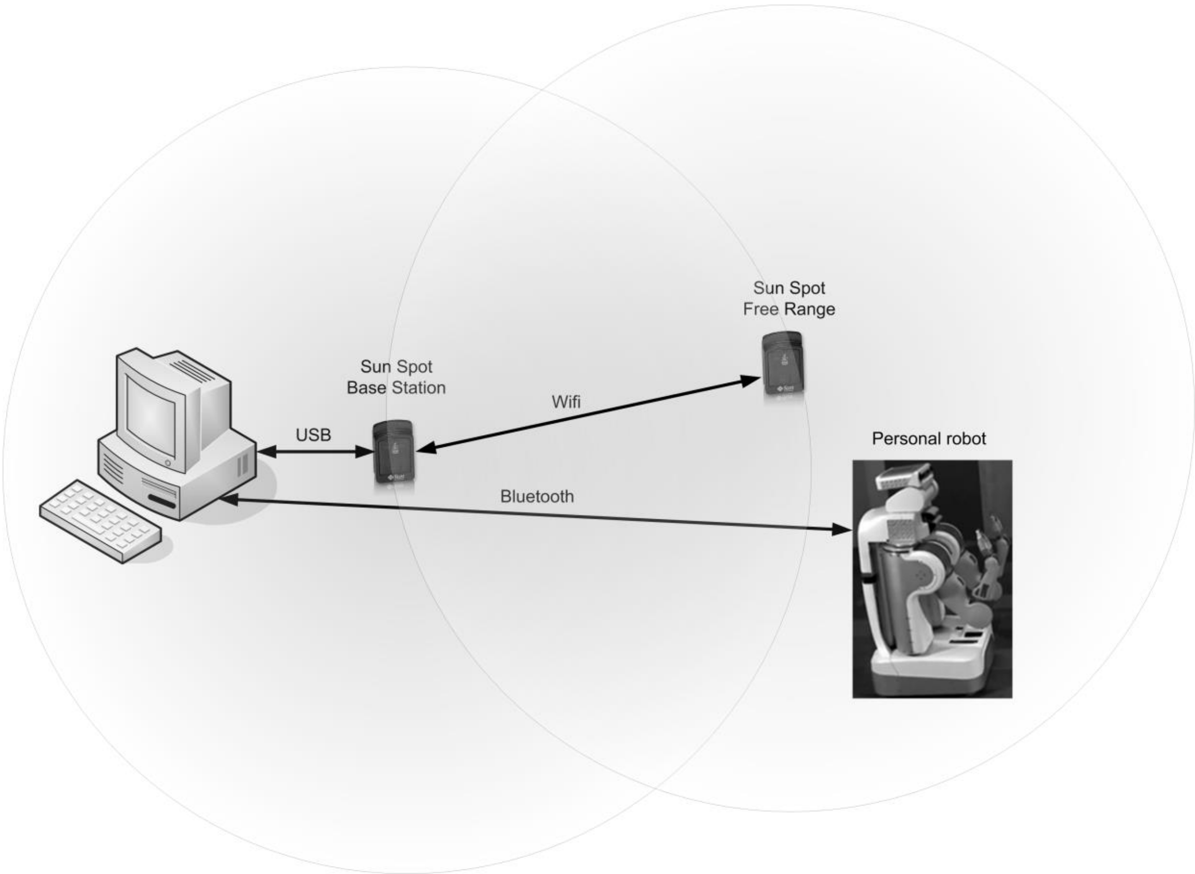

Figure 6. Remote control system.

Sun SPOTs are programmed in a Java programming language, with the Java VM run on the hardware itself. It has quite a powerful main processor running the Java VM “Squawk” and which serves as an IEEE 802.15.4 wireless network node. The SunSPOT’s wireless protocol is Zigbee-based protocol. The Sun SPOT is designed to be a flexible development platform, capable of hosting widely differing application modules. The SunSPOT base station is used to read the data from the free range SPOT and send its contents to the PC. The PC sends via Bluetooth the control signal to the autonomous anthropomorphic mobile robotic platform. Networked robots allow multiple robots and auxiliary entities to perform tasks that are well beyond the abilities of a single robot. Robots can automatically couple to perform locomotion and manipulation tasks that either a single robot cannot perform or that would require a special-purpose larger robot to perform. They can also coordinate to perform search and reconnaissance tasks exploiting the efficiency that is inherent in parallelism. Further they can perform independent tasks that need to be coordinated. Perhaps the greatest advantage of using the network to connect robots is the ability to connect and harness physically-removed assets. Mobile robots can react to information sensed by other mobile robots in the next room. Human users can use machines that are remotely located via the network. The ability to network robots also enables fault-tolerance in design. If robots can in fact dynamically reconfigure themselves using the network, they are more tolerant to robot failures. Finally, networked robots have the potential to provide great synergy by bringing together components with complementary benefits and making the whole greater than the sum of the parts.

CONCLUSIONS

The article deals with the fuzzy control of autonomous anthropomorphic wheeled mobile robotic platform motion in an unstructured environment with obstacles. Further, it presents the wireless sensor based remote control of mobile wheeled robotic platform motion in an unstructured environment with obstacles using the Sun SPOT technology. The simulation results show the effectiveness and the validity of the obstacle avoidance behavior in unstructured environments and the velocity control of a wheeled mobile robotic platform motion of the proposed fuzzy control strategy.

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