ARBIB: Development of an Autonomous Robot based on Intelligent Behavior

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Abstract

The essence of behavior based robotics is to develop robotic systems which can exhibit behaviors normally found in the nature. As a result, such system does not require high performance computational frame work for system control and operation. The sensory measurements in this case will generate direct response from the motor or actuator. Therefore in lieu of classical Sense → Plan → Act paradigm these systems operate on the principle of Sense → Act. Often multiple sensors are mounted on the system according to degree of autonomy required.

Historically Grey Walter's tortoise has been considered as a first attempt in this direction. Subsequently, this area has been further enriched by Brooks, Arkin and many more. The present work emphasizes on the development of behavior based intelligent autonomous robot. The behavioral tasks are controlled by the logical axioms. Multiple experiments have been carried out within a constrained environment, providing large number of disturbances to the system. The system explores the uncertain environment avoiding the obstacles coming in front of it. This work concludes the significance of Subsumption Architecture for behavior based autonomous robots. Work is in progress to implement learning of the system from its past experiences.

Key words: Autonomous robots, Behavior based system, Subsumption architecture.

1 Introduction

The behavior based robotics is developed to build of intelligence systems in terms of avoiding obstacle and finding the proper way. A sensor-based behavior implements a control policy based on external sensing: intuitively, the robot moves with respect to features in the environment, rather than with respect to an internally preprogrammed path. These sensors and software agents provide the high level of intelligence in such systems for prolific environment. Multiple sensors are often mounted on the system according to degree of autonomy required. Sensors receive information within their hypothetical range from the world through their sensing elements. Recent work has been done significantly to improve all aspects of performance and reliability and therefore applications.

The autonomous behavior based robotics mainly depends upon the behavior units. These behavior units make the system reactive. For instance, there is no programming in the robot of what a chair looks like, or what kind of terrain the robot is moving on-all the information is gleaned from the input of the robot's sensors. The robot uses that information to react to the changes in its environment. A BBR (Behavioral Based Robot) often makes mistakes, repeats action, and appears confused, but can also show the quality of tenacity.

The paper is organized as follows; the first phase of the paper describes the system specification and architectural overview of the system with given importance to the behavioral approach and logical approach of the system. The Second phase of the paper depicts the experiments and result and discussion. Some future work and concluding remarks are drawn at the end of the paper.

2 Literature Survey

The word Robot was introduced to the public by Czech writer Karel Capek in his play R.U.R (Rossume's Universal Robot), which premiered in 1921. In 1953, W.Grey Walter created first Autonomous Robot named as Grey Walter's tortoise [1]. In his work he used low ranged analog sensors unlike this project. After Walter in the year 1977 Hilare invented another autonomous robot whose weight was 400kg .This weight is unsuitable for commercial application. Moravec constructed a small cylindrical robot named CMU Rover (An advanced camera-equipped mobile robot is being built at the CMU Robotics Institute to support research in control, perception, planning and related issues. It used initially to continue and extend visual navigation work) in 1983[2].Though the system was moderately reliable, but it was very slow. The cart moves about one meter every ten to fifteen minutes. In 1980 the concept of Subsumption architecture (the current project deals with) was published by Rodney Brooks. In his paper ,Brooks (1986) advocated the use of a layered control system,embodied by the subsumption architecture but layered along a different dimension than what traditional research was pursuing. In 1993 Mataric invented multi tasking robot with behavioral programming language[3]. But the system executed only one rule at a time. In the year 1997 A.Ram, R.C.Arkin, K.Moorman, R.J Clark published the paper regarding Case Based Reactive Navigation for autonomous intelligent agents [4]. They discussed a case based method for dynamic selection and modification of behavioral assemblages for navigational systems. These behavioral assemblages made the system slow which is not acceptable. In 2004 Yang, S.X., Hao Li, Meng, M.Q.-H. , Liu and in 2005 Hansberger, Okon, Aghazarian, Robinson constructed multi behavior autonomous robot [5] using the concept of fuzzy controller. Most of the works described earlier are based on classical robotics; (Sense →Plan →Act) not behavior based robotics (Sense→Act).

The current project aims to address these limitations of preceeding works and implementation of subsumption architecture for behavior based robot. The weight of the system will be within 1.12 kg. Due to reactive architecture it won't slow down the system.

3 System Description

Autonomous Robot Based on Intelligence and Behavior (ARBIB) consists mainly a microcontroller, two IR (infrared) sensors, two DC motors. The peripherals like buffer and the driver circuit are added to drive sensors, microcontroller and motors respectively. The microcontroller will act according to the program in it and produce the outputs to the buffers followed by driver circuit, motors, LED and beeper. The system is connected with 12 volt power supply.

3.1 System Specification

The specifications of the developed system are as follows:
Name: ARBIB
Weight: 1.12 Kg
Size: 16x10x12 cm
Endurance: 25 minutes
Speed: 15 cm/sec
Sensors: 13 cm

3.2 Architectural Overview

Robot architecture refers to the software and hardware framework controlling the robot. The Hardware part deals with sensors, battery, motors, ICs, video camera etc. Software part deals with microcontroller behavioral programming.

In robotics, controlling is a big issue for intelligence, collision free path and autonomous navigation. System collects the input data from the various sensors and then acts accordingly (fig.1). The response of the system depends upon its behavior [6]. The behaviors of the system are predefined by the developer. The inputs from various sensors are used intermediately (parallely) to symbolically represent the environment or action.

Fig1: Basic operational diagram for behavior based robotics.

Now-a-days two types of control models are available. One of them is Classical Control (Deliberative) & the other is Behavior Based (Reactive) control [7]. In the Classical Control Model (fig 2) the inputs of the sensors are collected first and then decision is taken by the system after constructing the world model. Lastly the signals are sent to the end effectors for action. In the Behavior Based Model instead of responding to internal entities, the system responds directly to the perception of real world as shown in (fig 3). It's a spontaneous system and more effective than the previous one. It's a direct relation between the sensors and the end effectors/motors and needs less computational power due to absence of the planning part as in case of classical robotics.

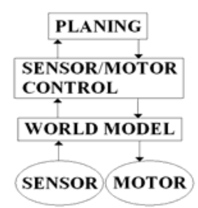


Fig 2: Classical Control (Deliberative) Model.

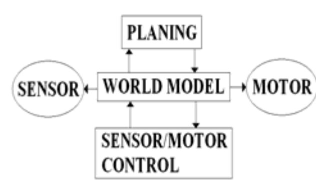


Fig 3: Behavior Based Control (Reactive) Model

The current project deals with Rodney Brook's Subsumption architecture [8]. It consists of three layers as per the priority basis in the (fig 4). Emergency layer deals with urgent purpose. For example robot is avoiding the obstacle making its path; at that time if on board power supply goes down then system will be shut down. That means low battery charge (hunger) is the most important task among all the tasks. So this layer is called Emergency Layer. After this layer there is task layer. This layer presents how the behavioral tasks have been prioritized by the user during the exploration of the system. The last layer of the architecture is motion layer. The speed and direction of the motor for various behaviors are decided from this layer. It regulates motion such a way that the system will either move forward or take a turn .Here turning is obtained by speed difference of the two motors.

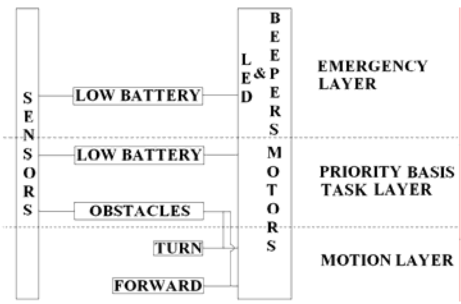


Fig 4: A Three-Layered System Architecture

4 Behavioral Approach

The Subsumption Architecture is motivated by Rodney Brooks. The behaviors exist to take account each of the requirements needed to exploring an autonomous behavior based robot. All the method of behavior based Robotics is to provide a clear idea of behavioral primitives that can achieve the goal of Sense→Act model [6]. The present work is consisted of the following behaviors:

Wandering: the system is exploring the experimental environment.

Obstacle avoidance: Using the logical axioms the system will avoid the obstacle coming in front of it. It inevitably encounters many obstacles [1, 9].

Hunger: When the on board battery is low, the system will shut down indicating a need for recharging.

The actual avoidance maneuvering will depend not only on whether an obstacle is detected but also creates a certainty of its existence [10].

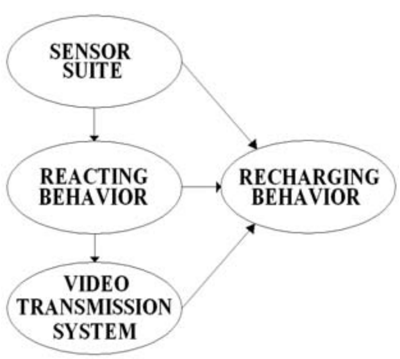


Fig 5: Subsystem Layers.

4.1 Sensor-suite

The system is controlled by the user defined logic/programming. By checking the battery level we can find out the necessity of recharging. Two Infrared sensors are used to detect and avoid the obstacles in its path. When the system is wandering, all the external environmental information is gathered by the system's sensors. The system uses this information to act against the any changes in its environment and simultaneously scans the whole environment in front of it.

4.2 Reacting behavior

When the system falls in the traps of obstacles, it makes its own way to get out from these traps according to the predefined logic. If the obstacles are in the right side, then the right sensor is activated and the left motor stops its movement at the mean time the right motor moves by its usual speed. At the result, the system takes a left turn and vice versa for avoiding the obstacles of the left side. But when the obstacle is totally in front of the system, the two sensors sense it, the system at first moves in reverse direction and then take a short left turn. Thus the system intelligently avoiding the obstacles makes its own path. The two DC geared motors are used to drive two wheels for its movement.

4.3 Video transmission system

A small wireless (RF) video camera, mounted on the front of the system. It is used for monitoring/viewing the whole area in front of its path. The video data was collected to a PC via a frame-grabber card, which is captured by the video camera.

4.4 Recharging behavior

A LED and a Beeper are used to indicate the low onboard battery power. If the onboard battery gets discharged during the exploration, the recharge indication elements (a LED & a Beeper) will indicate for recharging (hunger stage) and the whole system will be shut down automatically. At the recharging state the system needs to recharge its 12v (3 no's of 4 v batteries) rechargeable batteries through external recharging system.

5 Logic Diagram of ARBIB

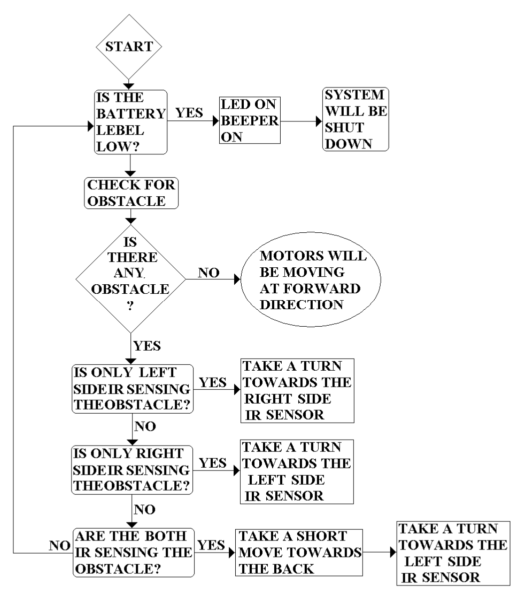


Fig 6: logic diagram

Autonomous Robot Based on Intelligence and Behavior (ARBIB). The logical approach of this system establishes connectivity between the different types of behaviors. When the system is exploring in the environment, it will firstly create the move-forward behavior. Then the obstacle-avoidance behavior will be added to it [11]. The performance of the system is properly done following the logical axioms. These logical axioms implemented in the system using the KEIL software through C programming. The software integration has been done on 89C51X2BN microcontroller. The logical path helps the system to achieve its targeted behavior in the exploring environment.

6 Experiments

To test the performance of the system, an environment in the lab had been created. Some colored boxes which were representing the obstacles, had been used to make different pattern of obstacle to check the reliability and efficiency of the system. At the beginning of the experiment all the behaviors of the system were assigned to zero level.

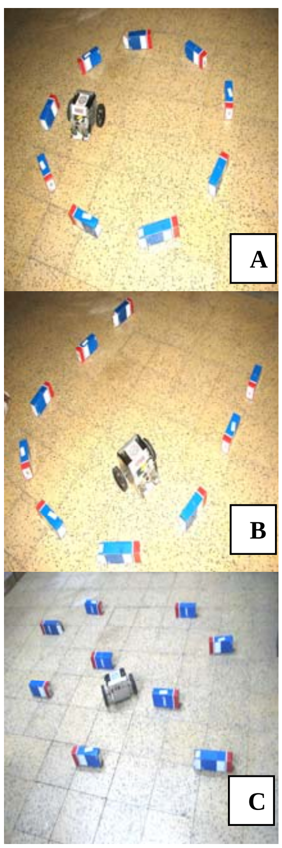


Fig 7: The three types of environment: (A) Round Shape, (B) “U” Shape and (C) Zigzag Shape.

Among the patterns of obstacles, first pattern was Round shaped. In the round shaped [fig 7(A)] pattern of obstacles, the system was avoiding the obstacle with proper deviation and revolving around the perimeter of the circle.

Second pattern was ‘U’ shaped [fig 7(B)] .There the system also successfully avoided the obstacles.

The last experiment was done creating a ‘Zigzag’ shape [fig 7(C)] which was most challenging for the system.

The path of this pattern could prove that how much the system is reliable, efficient and sensitive in autonomous navigation. Here also system worked properly with out any human intervention. The system chose its path accordingly in between the obstacles.

7 Result & Discussion

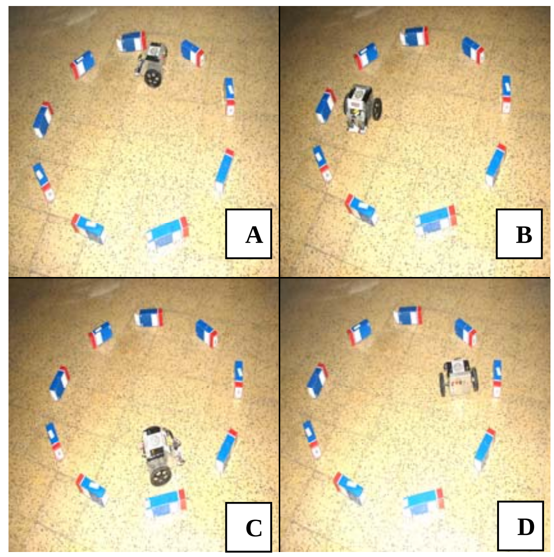
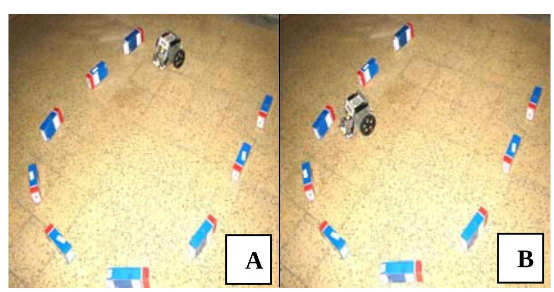


Fig 8: (A) Stage-I: Entering into the circular pattern (B) Stage-II: Sensing the circular pattern of obstacle (C) Stage-III & (D) Stage-IV: The system is moving with an imaginary angle to avoid the obstacle.

This pattern shows (Fig 8) the system is being tested in the “Round” shaped area. It is moving into that trap of obstacles and avoiding the obstacle intelligently. Its automatically forms a particular angle to avoid the obstacles and following the perimeter of the circle.



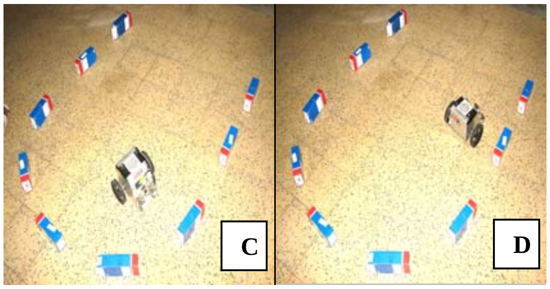


Fig 9: (A) Stage-I: Entering the 'U' shaped pattern (B) Stage-II: Sensing a obstacle (C) Stage-III: avoiding an obstacle (D) Stage-IV: Coming out from 'U' Shaped pattern.

These sequences of pictures (Fig 9) depict ARBIB's actions during moving in the "U" shaped area. The sequence proceeds from left to right avoiding the obstacles to achieve its goal.

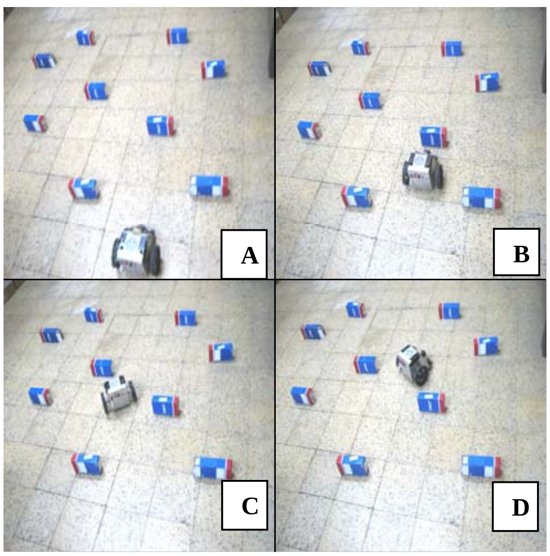


Fig 10: (A) Stage-I: Entering into the Zigzag pattern (B) Stage-II: Sensing one of the obstacles shaped (C) Stage-III: Sensing an another obstacle (D) Stage-IV: Avoiding that obstacle coming out from there

The system is being tested in the "Zigzag" shaped area in the (Fig 10). Though the obstacle is placed in the haphazard sequences, the system can avoid the obstacle easily.

8 Limitations & Future Scope

The current task is the first step of multitasking behavioral robotics. The experiments demonstrate the feasibility of autonomous robot accomplishing simulated tasks. The system is limited to a simple monolithic system [12]. It is having two IR sensors. Sometimes IR sensors could not be able to detect the narrow obstacle comes in between the sensors. So that can be recuperated using bumper switch (in the next phase of work).

The system can be used to prevent the terrorist attack or Maoist attack attaching mine detector in it. Additional sensors make the system more compatible in hazardous areas in every aspect. The next phase of work is related to the development of learning robot with its multi behavior.

9 Conclusions

Autonomous robot up lifted the today's science into a glorious position of progression. It is having simplicity, robustness, and reliability, low cost, capable of intelligent motion. This work attempts to describe the behavioral architecture along with subsumption architecture. Addition of sensory subsystem, video subsystem, recharging subsystem has increased its applicability & versatility. The logical approach relates to the system with the theoretical version. The results were very promising and the knowledge gathered will be used to develop an upgraded version of this system.

10 Acknowledgment

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