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ORIGINAL RESEARCH

Implementation and study of a novel approach to control adaptive cooperative robot using fuzzy rules

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Abstract The function of an Independent Robot has demanding conflicts and a perfect balance is required to minimize the conflicts along with a degree of capability. This paper talks about two co-operating mobile robots with a multilayer control system which utilizes Boolean logic to enable the significance of a relative behaviour. Therefore the fuzzy system takes its role as an arbiter that has the ability to control conflicting behaviours. This makes the robots to perfectly move on the near enabled minimum area. The array of vectors has been changed by the adaptive mechanism originated from the online analysis of the fuzzy rule. The strategy of the neural dynamics is employed here which has a control system as an unstable structure and study the system and its adaptability through phase stressed condition. This process is achieved by Suppression rules using Fuzzy Technique which allows the system to move in a steady state. This paper proves that the robots present in the unstructured environment enable an unstable state to a stable condition that increase the probability of Robots reaching its desired stability goal. A model is created using Matlab tool and simulation are performed in Matlab Simulink model. The novelty of work is controlling the robots in uncontrolled environment and also in multitasking environment.

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1 Introduction

Over a past decade, the platform for autonomous robots has improved because of the arrival of reactive and bottom-up methods [1, 2]. These improvements talk about a hybrid approach, that targets on combining both mission scheduling capacity of Artificial Intelligence based traditional designs with the different methods of reactive control [3, 4]. The patterns with control mechanism provide the excellence of control with the task performing capabilities. The capacity of a autonomous robots working as a group can be controlled by hybrid methods such that robot is accommodated to a confined event and thus overall making it as smart handling of its action [1, 5]. Hence a robot is an automated controlled device and the complex animated problem is needed to select a suitable solution [6, 7]. This paper discuss about the ability of the moving control of the robots in the real world with smarter handing and executing task events [8, 9]. Therefore a solution is proposed to enhance the significance of the robot that ensures overall increase their ability to perform task in difficult terrain situations [2, 10]. This paper discusses the role of improving and making an easier independent decision based on Fuzzy adaptive mechanism. It is proposed here two ideas; the first one is whether a FAM adaptive surface can increase the capacity of a robot despite the fact of changing its surroundings, and the second one is whether the proposed scheme can be applied to a mobile autonomous robot. After Introduction Sect. 1 describes the adaptatvity of Robots with the aim of attaining self-directed robots, whereas Sect. 2 explains about the robotics in behaviour methodology. 3 describes about the adaptive controller in uncertainty environment and 4 talks about the simulation results and Sect. 5 covers the implementations part and conclusion part in Sect. 6. In general the unstable robot in an rough terrain or environmental condition shows there is no scope for achieving the desired goal or performing multitasking with accurate control. Seema et al. discussed about single task allocation using distributed computing system in [11]. Himanshu describes TF model with single distribution for electrical discharge problems in [12]. Anuradha banerjee in [13] described only single hop energy efficient structure using fuzzy. In [14, 15] Hybrid control using fuzzy and ANFIS Technique are used to control Robot system individually. But nowhere describes about uncertain multi environment condition. The proposed ideas are simulated and volatile behaviour of a robot is studied using system simulation.

1.1 Robot adaptivity

The self-directed robots have the capability to fit in to the system of operation which is determined by a set of actions that get more properties for selecting appropriate groupings of good performances. For the self-directed agent the necessity of fuzzy logic is to switch group of likely things and benefits. The prior gain is the capability to find the obstructing tracks all over the fuzzy mechanical system, which gives a space onto an representative state as it escapes from a location [16, 17]. Thus the state of Vague systems are critical in allowing the technique of vibrant aspect, allowing to message the robots and get set of required results [3, 18, 19]. This process therefore gives the mechanical device with a terms of predicting and corresponding complex conflicting behaviours and bringing the adaptive in nature with implementation of memory elements [20, 21].

1.2 Disturbed behaviour

The main concept of the proposed scheme is from current proof in neuroscience, that relate idea of a brain as an unsteady system [6, 22], and the neurons as adaptable schemes [23], slightly than the non-active shifts. These move in idea with a method to design a machine and automation system for control and control and getting the desired goal. Now current independent robot ruler arrangements prefer animate style of thinking, with large interpretation of inherited algorithms described in [7, 24, 25]. Capacity of our robots has dynamical ability to modify the base of fuzzy rule in the disturbed condition. The problem scenario is based on the holding plus shifting of damaging materials, particularly for example in using Robots in an atomic plant condition. The general aim of the paper is to design a Robot which has a multiple-agent Collaborative and autonomous in nature and its governing. The process produce the alteration of complex user requests, through a manager plan, which are radio transferred to numerous '*autonomous*' machines. The robot machines will then achieve separately or merging to perform the step of action. Figure 1. Shows the helpful robots 'Fred & Ginger', which existed and reserved as to trial the fuzzy controller system as shown below. The robot works as a single system, and is able to perform equally to any Environmental conditions.

2 Autonomous robot behaviour

The pattern change in automation made by replacement of covered sensitive controller, an existing sum of effort has been established associated on 'Behaviours' focused concept. Nowadays it is required for controlling a Robot a Complex Processes and also it should be reflective one for any directed agents [1]. These two approach has developed significant as it is a 'hybrid' method, and samples in the process by [3, 4, 6, 7, 25]. Another process explains such systems are in need of 'hierarchical' manner and modifies a partition by role of the entire mechanism of the system into distinct levels in each of which is based on the part of slow or sensitive response [22, 26].

When some fusion approaches ensures keys to the entire mission field of independent robots, there exist some explicit problems that needs to be solved. "In Addition, as behaviours remain new to the scheme and the situation of difficulty rises, and the interface of the numerous behaviours often becomes tough to expect as well as repair the autonomous robot system" as mentioned in [7, 24, 27]. Omrane et al. showed trajectory tracking control with design and implementation but lacks the collision behaviour as in [28]. Aouf et al. [29] described robot behaviour in strange environment but no explanation regarding the collision effects and used only single robot. Sabotto et al. [30] showed fuzzy rule control for a single robot with unique patterns. Do Khak Tiep gives in detail about tracking mobile robot with differential drive as in [31]. Thi Thanh Van Nguyen et al. showed multi objective optimization in strange environment in [32]. Sing and Bera

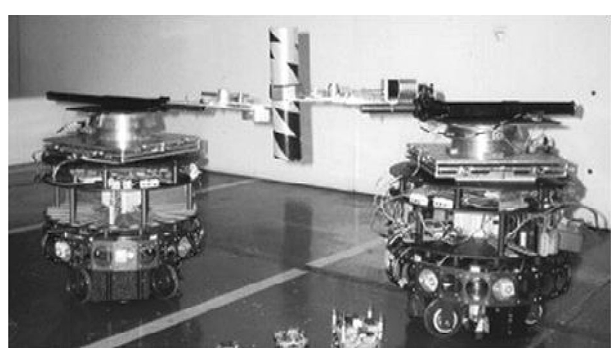

Fig. 1 Fred and Ginger Robots

explained collision avoidance of robots using hybrid alogirthms in [33]. Aggrey SHITSUKANE gives in detal about collision avoidance using sensor fusion technique in [34]. Seyyed Mohammad used AI Technique for Collision avoidance in [35].

2.1 Behaviours synthetic architecture

The first level of controller inside our device is a set of actions, which relates each intellectual device openly with a reaction. The Behaviour Synthesis is an Architecture used as a reaction controller scheme that is well practical to governor of operating with the self-directed plans for a displacement movement [8, 25, 36].

$$B_{pt} = \{R_t = F_r \cdot S_t)\}\{u_t = f_u(S_t)\} \tag{1}$$

In Eq. 1 the specific signal reaction is represented by R_t at a period t and Let F_r be function of a given sensual response, and resultant utility can be defined as

$$uX_t = \sum_{n=1}^{m} u_{t,n} \cdot e^{j \cdot r_{t,n}} \tag{2}$$

and m matches the full amount of leads to utilitor that has many policy stages. The motion response and utility function can be obtained from:

$$uX_t = m \tag{3}$$

$$rX_t = \arg|uX_t| \tag{4}$$

Let X_t resembles to an exact grade of choice, e.g. swap, and the subsequent sensor reply and let rX_t be the movement response performed by the robot. From (2), the essential design is that evolving a resulting response from many behaviours constitutes an idea of preservative fusion. The utility related with each pattern provides an single response which relatively changes an acting supply and then fed to machine information, from the complex regulator level [21, 25, 37]. The complex level identified as damage level without executing the exact performances [36, 38, 39].

3 Controlled fuzzy logic

In the case of the outcome effort by Zadeh [40], and profits by means of a quality merging process to instruct the physical structures of any autonomous system has clearly deliberated in [17, 41]. So Ambiguous controller scheme performed by encrypting an expert's idea into a group of rules are given as inputs and to get a simple actual output for ad defined input. Every rule is stated as either a wedge-shaped trapezoid e.g. gaussian which is associated to quantity of input variable.

$$\text{IF}(y \text{ is } q) \text{ and } (x \text{ is } p) \text{ then } (z \text{ is } t) \tag{5}$$

Let x, y, z as variables demonstrating responses and p, q and t be the outputs of the ambiguous controller. Uncertain guidelines will be communicated by means of a uncertain associative retention matrix. This device measurements denote the contribution variables and individual FAM medium access for any uncertain set with yield. Now utilizing the Law of Least Rule and by reference of FAM definition, the weight for the ith FAM is given by

$$W_i = \Delta \min\{F(i)(y)F(i)(x)\} \tag{6}$$

where y and x are the response function.

Hence by denoting every amount produces uncertain association set defined as:

$$B_i = \text{output fuzzy set} \tag{7}$$

The total crisp reaction for n output association sets is:

$$F_T = \frac{\left(\sum_i w_i \cdot B_i\right)}{\left(\sum_{i=1}^{n} w_i\right)} \tag{8}$$

At a given period of time let n be the total instructions. The entire matrix procedure standards of weight function which is defined as an array and described in next section.

3.1 Fuzzy control and hierarchies

Here the run-down compound job orders needed independent robots into a flow of progressively controller schemes that gives a forceful technique for make best use of a robots grade with its self-rule is considered. This describes the following conversation of order in methodology, with precise relation to the Exact role which is notified by Lorenz. In [42] the behaviour shapes with countless elasticity and adapt to change the ecological situations are described in detail and they proved that all its subordinate systems and the connections between them, are phylogenetically automated and adaptations by learning methods are made [23, 42]. Some internal issues might occur between single or clusters of actions, or among act procedures that can be resolved in later stage. Hence overall behaviour and control are not synchronously.

3.1.1 Behaviour of fuzzy robots

Uncertain intelligence is an effective tool for building difficult multiple-level controller structures in this ground of recent project by several groups, [10, 37, 43]. A Perfect fuzzy controller raises the basic capability level of an autonomous robot by excellently managing the communication of more *primitive behaviours* which can increasingly reduce the performance on a preparation device [43–45].

With the Behaviour Combination order as a foundation Here a model is proposed for uncertain organizer, that gets straight sensory idea and place undesirable response on the value of preferred behaviours. The value to every behaviour is then adapted vigorously to fit the present group of environmental stimuli.

3.2 Fuzzy rule analysis

The set of mass values also involves of background reliant on content if the uncertain system is monitoring the agents first actions.

3.2.1 The Fuzzy space state

As the uncertain controller method gives the entire information about a vibrant illustration on the machines communication with its proper location. The Effort done is represented by considering the agent location message which can help objectives and give preference into the universal sets of systems with difficult problems [11, 46–48].

3.3 Dynamic action surface using fuzzy

3.3.1 Non stable systems.

A detail of the uncertain governor scheme as a lively procedure that exhibit a reason in an ill-defined situation is illustrated in this section and also performing in the place of unpredictable environments with proper on troller arrangement is aim of the section. This process pulls on ethological work that exhibit how response without influential reinforcement takes to the loss of repeated exposure to a conditional and related conditional response [36]. The project on the dynamic forces of neural methods notifies that kind of schemes will give a dynamic instability as a process of stable reaction [11, 26]. Here the agent cause need to be capable to degrade actions that are not elongated preferring a beneficial reply From the robots point of view-making development as we are planning to generate an independent robot as it is inspiration for progress. Therefore if no growth is being complete while developing a fixed group of unsure rules related with those rules is removed. This avoiding instruction is hence needed and is developed on their virtual activity at a particular period of time. Figure 2 shows the simulation behaviour characteristics of two robots under unique parameter that shows instability in its behaviour [49, 50].

Simulation Graph in Fig. 2 shows for unique characteristic with uncertain regulation after 400 iterations yields uncertainty and certainty for group of seconds in matlab environment. The above conditions considered are mass

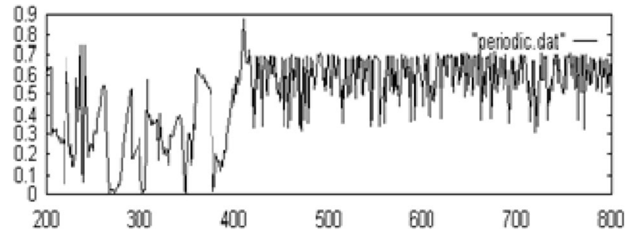

Fig. 2 Simulation Behaviour Charectersitics

and surface area of robots. The above conditions considered as inputs for understanding uncertainty behaviour.

3.3.2 The vectors weight

The method of maximizing the ability of the uncertain system has numerous steps happen to adapt the uncertain controller:

- ascending features of the unsure variable,
- the uncertain groups indicating the sense of language principles,
- To represent the if–then rules, [18].

The perfect tune of self-tuning controller's is first established with Fuzzy set of rules. In the previous step, it alters the instruction value, it is well modelled as a 'self-organizing' manager that always habits an simulated network to exercise a fixed rules as of given input–output data, [24]. The process proposed is 'self-organizing' one and for each unsure rule can be transformed frequently.

In order to consider matrix as a flawless exterior before by associated a course with every FAM weight and the control surface can be multiple one by allowing to the condition to conquer separate guidelines. Hence we can represent the process by the Eq. 9:

$$F_{TA} = \frac{\left(\sum_i w_i \cdot V_i \cdot B_i\right)}{\left(\sum_{i=1}^{n} w_i)\right)} \tag{9}$$

Let V_i of the adjusting vector generates a fuzzy rule action, and F be the uncertain output and adjustable one be FTA. Let the sum for each value is assumed as beginning value and given for each rule in a controller loop the mass w_i is separated for each repetition. If the above rule ends the threshold its weight is reduced as meant for the time of the resulting controller cycle. A fresh action area is generated for degradation, which sends the unstable stream of the robot's communication with the present environment. An empirical study is needed for a given area in order to detect the optimum threshold. A function between degree of degradation and its rules activity is another approach that is based on ethological samples.

4 Implementation

The planning for the research patterns is to custom two B12 movable robots as the base. These robots must have a large set of gesture instructions, and are power operative and are single-directional, manageable via an RS232 interface. The prepared and constructed superstructures are used to house extra sensors, information gaining, communications. A multiple-frequency ultrasonic scheme for interference closeness detection is proposed here. A self-centred uses each automaton to 'feel' the power exhibited by the additional automaton, Shift data is by visual lead encoders which captures XY data automatically. They have to change a battery voltage level sensor and move drive motor position encoders. Then with the help of ultrasound direction sensors is used for finding the active beacons and it is used here with only the frequency for the interference sensors.

4.1 Simulation

An unstable replication in the dual movable robots has produced along with the B.S.A and fuzzy control system. Every simulated robot has a physical robot with sensors, by fluctuating pattern. This virtual reality model does not have of sensor noise, and the aim is to check whether the FAM matrices were simpler and conveyed to the actual robot. The simulation is carried out in Matlab environment.

4.2 Matlab environment

In this paper Matlab R14 is used for implementing the proposed idea. Assuming two robots Fred and Ginger works independently and its dynamic characteristics are defined and together with different iterations their behaviours are studied. For Comparison purpose unique parameter is defined and simulation is carried out for different iteration as shown in Fig. 2. Surface and Mass characteristics are defined and studied along with the proposed fuzzy rules. FAM is defined along with their parameters like vector weight, uncertain output parameter and fuzzy rules. During interaction and collision surface area studied for both the robots from the simulation. Applying Sensor stimuli with single beacon, Virtually studied the behaviour characteristics using FAM Matrix [12, 13].

5 Experimental results

A fixed of relative progress is implemented to derive the two theories given in the paper; the first theory is to use an adaptive flexible and when it is moving over a half structured area, and second theory is that whether this device can openly move onto real movable robots. In order to derive the primary problem the imitation of the mobile robots is to run along an area which has the wall space that gradually decreases for adapted and non-adapted systems. This device will also fit effectively in allocation, 10% less than the non-adaptive case. Therefore testing for any disturbance of the fuzzy action could aid the mobiles overcomes FAM output to random noise from 5 to 10% of the entire value. It is noticed that the robots ability does not change to perform in most difficult area. Figures 3 and 4 shows the behaviour characteristics such as surface of Rigid mass of virtual robot and actual robot.

Figure 3a explains the distorted surface of Rigid mass of a robot and 3b actual robot considered. Figure 4a FAM assisted modulated masses and 4b on real robot with identical surface area. The major challenge encounter here is turning on or sending beacon signal to the robots. Practically the robots only have two forward beacon facing sensors which covers the less space. Thus the real robots often do not improve from the beacon signal though the strong sound acceptance of the uncertain controller was needed in allowing a straight transmission from physical robots to virtual reality assuming with real sensors. Figure 3 shows the space of information state with a crumbling surface. Figure 4 displays the result of summing up the device to that of load selection. The external sets in Fig. 4 we can identify that the adapted device does have a similar outcome from the replicated and physical robots fuzzy surface, where a specific order pour out the threshold for destruction. Thus the associated effort has defined that the suitable controllers would be developed down and

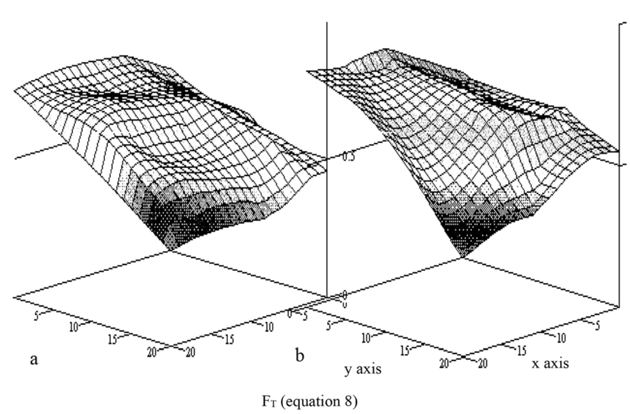

Fig. 3 **a** For virtual robots—surface of rigid mass; **b** for actual robot—virtual surface of rigid mass

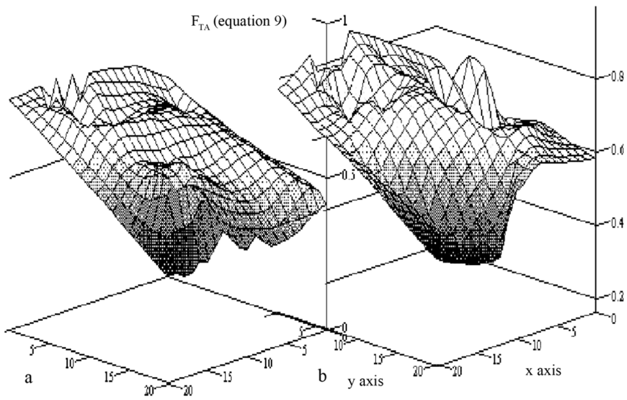

Fig. 4 **a** FAM modulated masses surface area for robots; **b** Identical surface area performing on physical robots

sends to the physical robot using stable inherited algorithms. To analyse the uncertain control mechanism whether it increases the capability of robots to arise from local minimum. A single robot improved to transfer the similar area, with or without an uncertain controller tool. A virtual robot remained used as the communication of only the interference prevention behaviour and beacon behaviour must be separated [15, 28].

From Fig. 5, the uncertain controller level gives the needed output which is detached from the behaviours of the robots. After 300 time steps the robot when it originate into an atmosphere the wall blocked the beacon route, one of the sensors detect the beacon and form detection the swapping of robot towards the beacon device is noted. However the fuzzy system able to produce an extreme response due to the level of the obstructer or wall (dashed line) as in Figs. 5 and 6. Robot moves away from the wall after say 500 time steps in control loop operations and now the beacon is in off condition [14, 15].

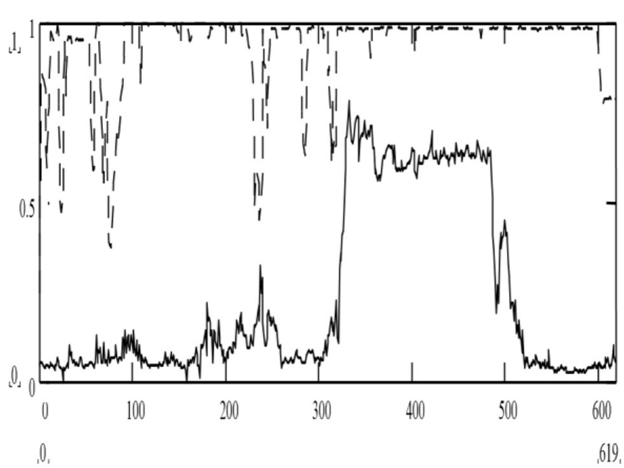

Fig. 5 Design of single beacon sensor stimuli

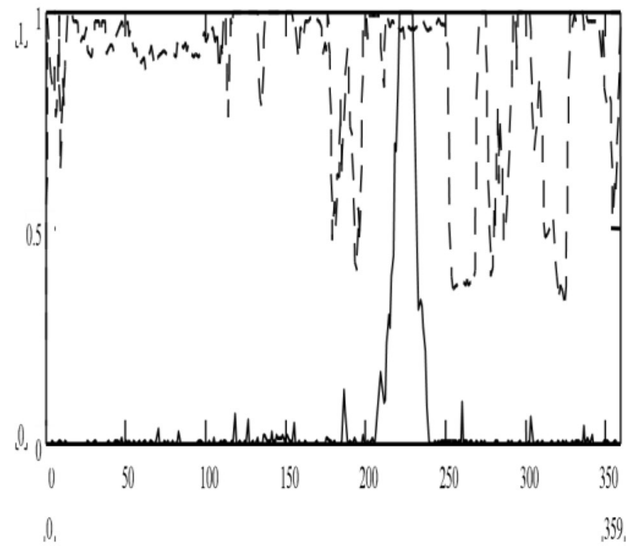

Fig. 6 Crisp production of the FAM matrix

From Fig. 6, the uncertain structure is paired into the certain features. Robot after moving from the exact location identifies the beacon again after 200 steps. However this time the fuzzy output after only 30 time steps degrades the beacon behaviour. At the local minimum in the beacon robot moves away from the wall and successfully identifying the wall or obstacle. The novelty of the work is dynamic adaptive system considered for getting volatile behaviour through which much improvement can be shown. Finally It is proved that ability of robot can be increased using the proposed controller based on Fuzzy techniques. FAM rules using to bring uncertain behaviour in to certain behaviour through on specified area. The behaviour characteristics of two robots such as mass, surface area and control mechanisms proves that its possible to control robot in uncertainty condition.

6 Comparison with exisitng system

The proposed approach in this paper is compared with the reference recently, in [28] collision behaviour is not taken in to consideration. Awataf Aouf etal proposed fuzzy logic with navigation in strange environments but the behaviour properties is not mentioned in [29]. Zein-Sabatto in [30] described fuzzy behaviour with respect to single robot and outcome does not tell about collision. Hussein et al. explained about behaviour for a single robot as in [32]. Singh and Bera gave hybrid collision algorithm for robots but in smooth environment [33].

In [34] Sensor Fusion Technique is used for collision avoidance for two robots but it is complex and by practical more hardware or additional deployment required as compared to our system. Seyyad Mohammad et al. [35] explained same using AI technique but they have not mentioned Collision behaviour nature. By comparing all the proposed system is adaptive in nature and implementation in hardware gives autonomous guiding with collision free stage in complex environment. Adaptive nature and tuning capacity enables to deploy in complex environment. The future scope of the work is to propose the same in Multi collision environment and more uncertainty in navigation and control.

7 Conclusion

The turning capacity ability of robots has been increased by using the controller adaptive system. The indistinct behaviour of robots with certain control is transformed to group of robots with volatile behaviours that improves the ability of robots for relocation over an organized area is proved here. This way of process too variates the additional fuzzy rule of the proposed idea, so here followed by allowing the straight connection of a controller method from a real robot imitation, though it is not designed on the devices or active assets of the actual robot but the simulation is reasonably normal. For such a transmission an essential rule is needed to exchange only the advanced levels of the controller instruction order, thus the sensor and actuator essentially facts available in the method. This is said to be as the single method for uneven controlling of an uncertain logic built on the control surface that may have connected together. However, the greater in dependence logically constrains the charge of decreasing the information of the devices in quick term response. The future scope of the work is employing the Robot in unstable condition and proves the mechanism accurately.

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