Intelligent Robot: Chaotic Exploration and Goal Finding

Jin-Shig Kang

Dept. Telecommunication and Computer Eng. Cheju Nat'l Univ.
Ara 1, Jeju, Korea, 690-756
Tel: +82 064 754-3637
Email: shigkj@cheju.ac.kr

***Abstract*:** In this paper, an agent based intelligent approach of chaotic exploration and goal finding algorithm is presented. An reactive type robot control structure is considered. To give learning ability, the robot consisted of multi sub-agents such as sensor sub-agent, behavior computation sub-agent, action selection sub-agent, etc.. Learning algorithm, considered, is simple reinforcement learning. Finally, the simulation result shows better learning ability and fast goal finding.

I. INTRODUCTION

Recently, there are some studies related the intelligent robot as an intelligent agent. Intelligence for robot to grow and evolve can be observed both through growth in computational power, and through the accumulation of knowledge of how to sense, decide and act in a complex and dynamically changing world. Intelligent systems are required in knowledge engineering, computer science, mechatronics and robotics. Fukuda and Hasegawa [1] discusses the machine(system) intelligence from the viewpoints of learning and adaptation of creatures and they introduced computational intelligence including neural network, fuzzy system, and genetic algorithm. Kondo et. al[2] presented a learning method for autonomous mobile robots operating in unknown environments, where not only a learning mechanism for sensorimotor mappings but also an extraction/re-use mechanism of the schemata (i.e. constraint rules for learning) is implemented. Nehmzow and Walker[3] present a method to describe the behavior of a mobile robot quantitatively, using methods from dynamical systems theory, time series analysis and deterministic chaos theory. They showed experimental results obtained with a Pioneer II mobile robot demonstrate the use of the method, and robot behavior exhibits deterministic chaos, and is substantially influenced by the control program executed by the robot, while changes to the environment have far less influence. Also, Nehmzow and Walker[4] present experiments on the application of chaos theory to describe a robot's behavior quantitatively. And computing the Lyapunov exponent of robot trajectories observed in a number of experiments, they showed a change in task of robot behavior far more noticeably than a change in environment.

In this paper, an intelligent approach of chaotic exploration and goal finding algorithm is presented. An reactive type of robot control structure is considered. To give learning ability, the robot consisted of multi sub-agents such as sensor sub agent, behavior computation sub-agent, action selection sub-agent, etc.,. Learning algorithm, considered, is simple reinforcement learning[5].

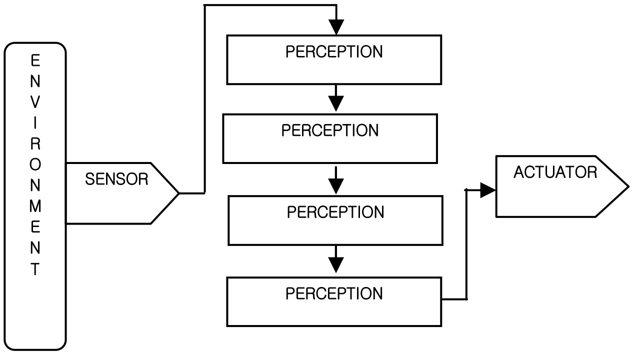
II. ROBOT STRUCTURE

2.1 Robot control structure

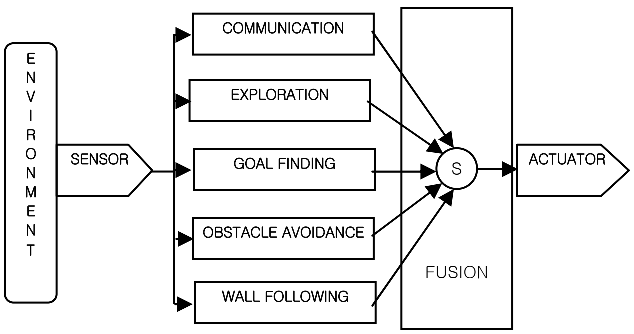
The basic structure of agent consisted of environment, perception and action. The ability of agent can be stated as: perceive environment and act to change environment. But, the environment of real world in which a robot act is unknown, very complex, highly unstructured and there exists uncertainties. By these reason, the intelligent agent(robot) must have learning ability and adaptability. The intelligent robot as an agent must have properties such as: autonomy, reactivity, pro-activeness, social ability, rationality, versatility, adaptability, mobility.

The robot control structure can be categorized as hierarchical, behavior based control structure and hybrid one. Fig. 1 (a) shows the hierarchical control structure. It had good properties as: good predict ability and good accuracy, but the speed of response is very slow. The behavior based control strategy, which originated Brooks's sub-sumption algorithm shown by Fig.1. (b), shows fast response but it have low-level intelligence. Most of researchers concentrate their efforts on this point: fast response, good predict capability, good accuracy. In other words, most of the researches are focused on: how can we give intelligence the reactive structure, not affecting the speed of response.

This paper, focused on this point, present agent based robot structure consisted of multiple sub agents such as: sensor sub-agent, goal planning sub agent, goal level, action sub-agent, etc.,. We give intelligence and learning ability via reinforcement learning ability of the action selection sub-agent and knowledge based goal planning ability of goal planning sub-agent.



(a) The hierarchical control structure



(b) Brooks's subsumption control structure

Fig. 1. The hierarchical and subsumption structure

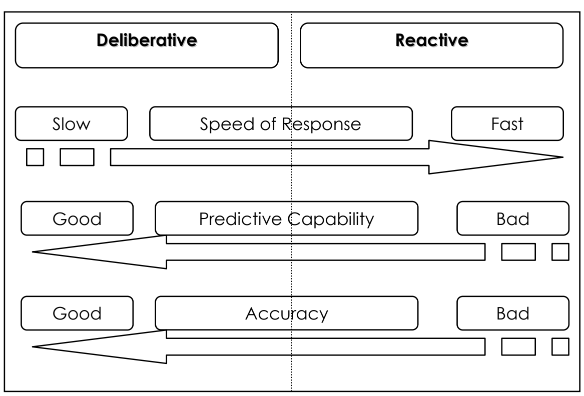


Fig. 2. Control strategy: deliberative vs reactive

2.2 Robot structure

A robot structure, presented this paper, is shown Fig. 3 consisted of multiple subagents as: sensor sub-agent, goal level sub-agent, action selection sub-agent, goal planning sub-agent, action sub-agent. Each sub-agent have their own functions described as follows:

Sensor sub-agent: consisted sensor elements. It perceive environment and its output supply appropriate goal.

Goal level sub-agent: consisted multiple level of goals. It supplied environment signal by appropriate sensor element and compute robot action.

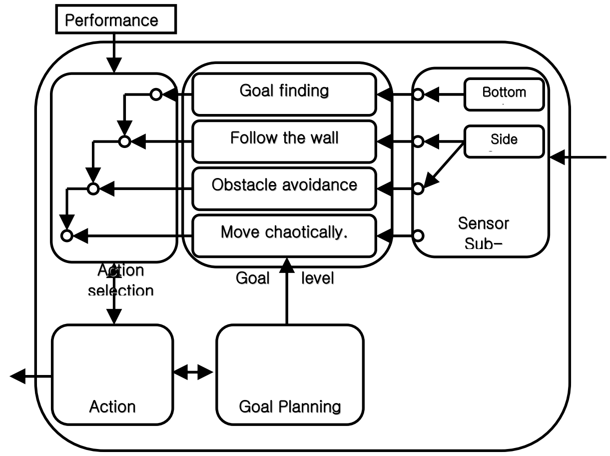


Fig. 3. Robot structure

Action selection sub-agent: it have three input sources: the one from goal level sub-agent, the 2nd from action sub-agent which is penalty or reward, and 3rd performance.

Goal planning sub-agent**:** it have two basic functions one of which is plan a new goal and other is extract a knowledge and preserve.

Action sub-agent**:** it is consisted actuators and reinforcement learning algorithm.

III. OBSTACLE AVOIDANCE, GOAL FINDING and LEARNING

In this paper, the differential drive two wheeled mobile robot(DDWMR) is considered. The structure of DDWMR is shown in Fig. 4. Let V_R and V_L be the right and left wheel velocity, and v be the linear velocity, then the kinematics equation be described by

$$\varpi = \frac{V_R - V_L}{L}, \quad v = \frac{V_R + V_L}{2}$$
$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v \\ \varpi \end{bmatrix} \tag{1}$$

where, ϖ is rotational velocity of the robot and D is a distance between the center of the right wheel and the left wheel.

Goals of the robot are: ① chaotic exploration, ② goal finding, ③ obstacle avoidance, ④ wall following.

Chaotic exploration**:** In order to achieve chaotic movement of robot, velocities of left and right wheels are selected as:

$$\begin{aligned} V_R^{CH} &= (40 + 5\sin(4\pi(rand(1) - 0.5))) \\ V_L^{CH} &= (40 - 5\sin(4\pi(rand(1) - 0.5))) \end{aligned} \tag{2}$$

Because of random number, sine term, 3rd order differential equation, and reactivity of the robot, eq. (2) guarantees chaotic behavior of the robot.

***Goal finding*:** The second object of the robot is goal finding. Inherently, because of the environment is unknown and dynamically changing and no information is available, the goal finding object seems to be hard to achieve. But, during the exploration, the information required to finding goal is gathered and the robot can use these information to finding goals. The goal finding procedure is summarized as: if there is no information available then explore chaotically otherwise follow directions computed by using gathered information.

$$V_R^{GF} = \{\text{computed by gathered information}\}$$
$$V_L^{GF} = \{\text{computed by gathered information}\} \quad (3)$$

***Obstacle avoidance and Wall following*:** Obstacle avoidance and wall following goal can be achieved by using sensor data and velocities to achieve it must be computed by reactively. The only difference is the desired direction of robot moving in obstacle avoidance and wall following. In table. 1, the desired Angle of robot movement for each detected sensor is showed. In order to avoid the limit cycle and oscillation of vector field method, the velocities of the wheels are computed by weighted sum of the desired angle as

$$\theta_d = \frac{\sum_{i=1}^{n} sen_i w_i \theta_i}{\sum_{i=1}^{n} sen_i w_i}$$
$$V_R^{OB} = \{\text{computed by } \theta_\text{d}\}, \quad V_L^{OB} = \{\text{computed by } \theta_\text{d}\} \quad (4)$$
$$V_R^{WF} = \{\text{computed by } \theta_\text{d}\}, \quad V_L^{WF} = \{\text{computed by } \theta_\text{d}\}$$

Action selection: The action selection sub-agent selects an action one of (2~4) by using performance. Also, in this sub-agent, a new velocity of left and right wheel is computed as the weighted sum of current velocity and previous one. The action selection procedure is summarized as:

$$V = \alpha V_{\text{Prev}} + (1-\alpha)\,\text{sel}\{V^{CH}, V^{GF}, V^{OB}, V^{WF}\}$$

where, α is a learning parameter computed by reward and penalty. If previous selection of action is rewarded then decrease α and if previous selection of action is penalty then increase it, otherwise no change.

IV. SIMULATION

Simulation environment, shown by Fig. 5, is assumed 120×200 square area, two robots are working together with and finding each goals. In Fig. 5, small square box in the left side of the figure is moving obstacle and two small square boxes in the right side is goals for each robot. And the black boxes are obstacles such as walls.

Fig. 6. shows the initial movement of robot and moving obstacle. The 1st exploration is shown in Fig. 7. In the 1st exploration, we give no information about the simulation environment. During 1st exploration simulation, sensed data is gathered and by using these data, the goal finding speed becomes faster. The gathered data is sensed location and classification type. The data type is

(x-coord, y-coord, classification).

For example,

(5, 15, corner)
(82, 107, moving obstacle)
(5, 116, corner)
(36, 104, moving obstacle)
(48, 48, moving obstacle)
(42, 7, wall)
(53, 89, moving obstacle)
(56, 65, moving obstacle)
(6, 83, wall)

Table 1. The desired Angle of robot movement

sensor	Obstacle avoidance	Wall following
0	- π	π/2
1	π/4	π/4
2	π/6	0
3	π/9	-π/6
4	0	π/2
5	-π/9	π/6
6	-π/6	0
7	-π/4	-π/4

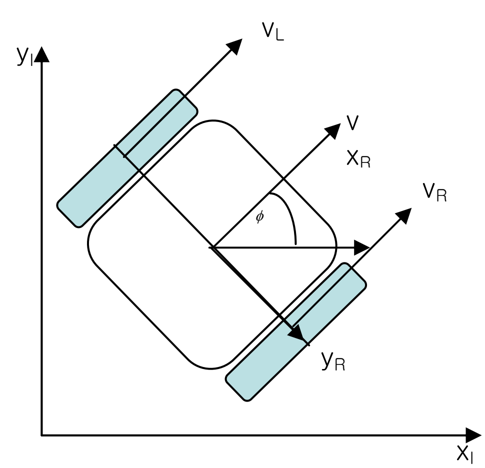


Fig. 4. The structure of DDWMR.

By using classification type, the robot can pass through the narrow passage

Fig.8. shows sensed location of 1st exploration and exploration strategies. The blue line is a goal finding path for robot 1 (it is shown blue box left up corner in Fig. 5) and red line is a goal finding path for robot 2 (it is shown red box left bottom corner in Fig. 5). If a robot meets the moving obstacle at the location A then the robot must follows red dotted line.

Fig. 9 is 3rd and 5th exploration results. By comparing (a), (b) and Fig. 7, the goal finding procedure become very fast and the path of goal finding becomes very simple. These result shows us the robot become more smarter and it have simple type of intelligence.

V. CONCLUSION

In this paper, a intelligent approach of chaotic exploration and goal finding algorithm is presented. An reactive type of robot control structure is considered. To give learning ability, the robot consisted of multi sub-agents such as sensor sub agent, behavior computation sub-agent, action selection sub-agent, etc.,. Each of these agents have its own functions. To make the robot action clearly, we made the robot selects an action one of (2~4) by using performance. Also, in this sub-agent, a new velocity of left and right wheel is computed as the weighted sum of current velocity and previous one.

It is shown by simulation that the suggested algorithm works well and shows good results.

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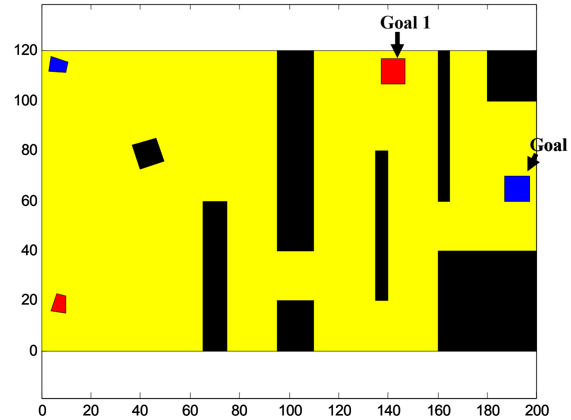


Fig. 5. The simulation environment

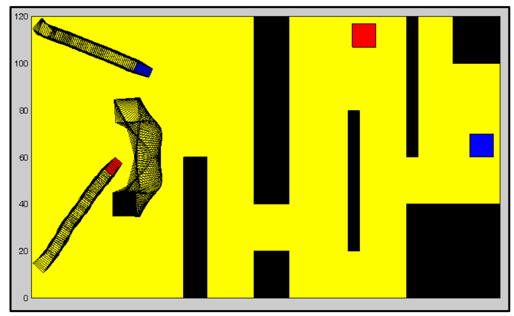


Fig. 6. Initial movement of robot and moving obstacle

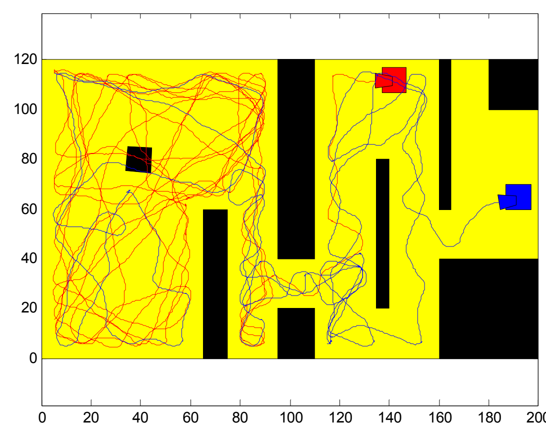


Fig. 7. The 1st exploration

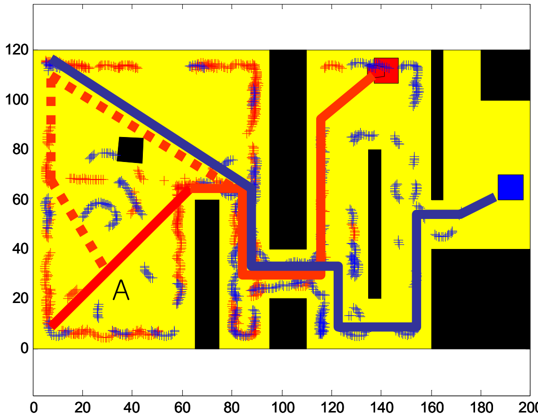
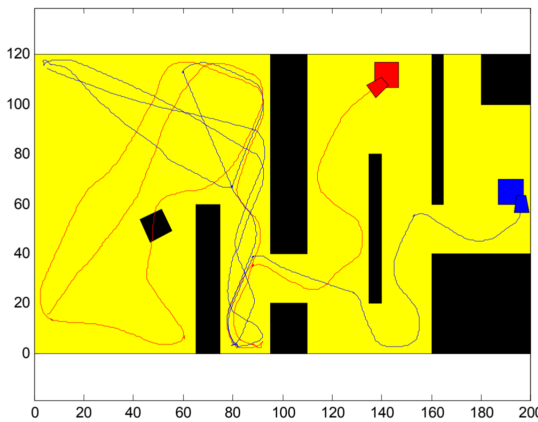
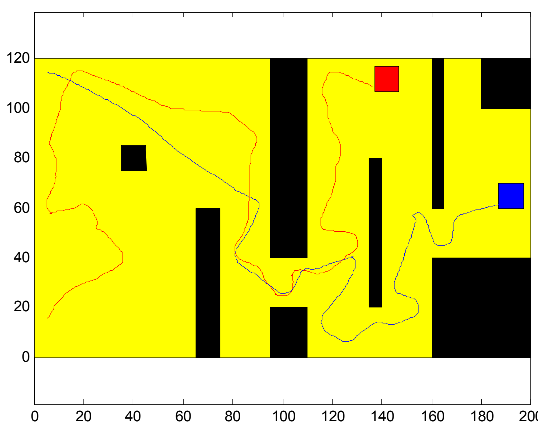


Fig. 8. Goal finding strategy.



(a) 3rd exploration result.

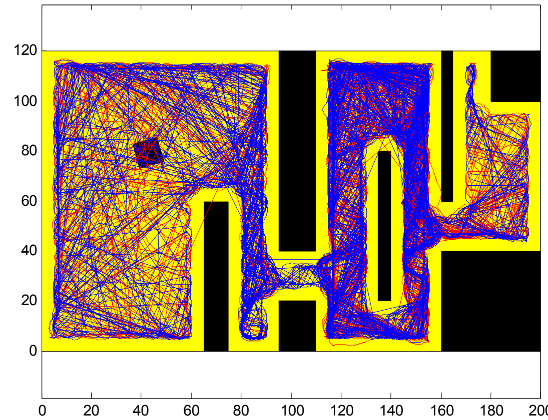


(b) 5th exploration results

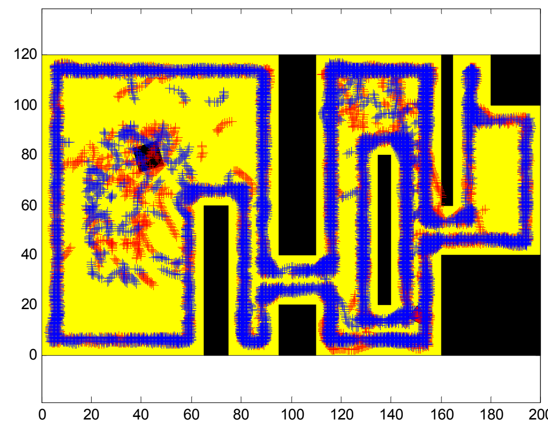
Fig. 9. 3rd and 5th exploration results

APPENDIX

Fig. 10. (a) and (b) is a simulation results of chaotic exploration only.



(a) Trajectories



(b) Sensed positions

Fig. 10. Simulation results of chaotic exploration only.