

Automatic Running Planning for Omni-Directional Mobile Robot By Genetic Programming

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Abstract : This paper presents a omni-directional mobile robot which can run on off-road and run over a obstacle. The robot equipped with crawler-roller running system. The motion analysis is also discussed to realize the autonomic off-road running. In order to automatically control the robot to run in optional direction and an orbit. We have to decide the inputting volts of the motors according to given direction or orbit. Even though we can do this by analysis theory, it is difficult to control the robot in real time. So we propose an intelligent control method using Genetic Programming (GP) to search an optimum route leading the robot to given destination and avoiding obstacles. We have carried out many practical running tests and simulations to verify the efficiency of the mechanism and the intelligent control method. In this paper we show an example of the tests.

Key-Words : off-road running, omni-directional mobile robot, crawler-roller running system, genetic programming, obstacle, running planning.

1. Introduction

The Omni-directional Mobile Robot (OMR) has ability to be able to move freely in the optional direction without steering. Up to now, many types of OMR is proposed, but they can only move on a flat floor because these OMRs have the running mechanism of wheels installed with free rollers or balls[1]-[3]. They cannot be used for outdoor works, due to the poor ability of running over an uneven road. The report on the orbit-tracking and obstacle avoidance by high precision to make the most of the characteristics of the OMR is very few.

The purpose of this study is to realize generation of the optimum route for the OMR with the obstacle avoidance by Genetic Programming (GP). In this paper, we report the detail of the method for the OMR and show results of verification experiments.

2. Omni-Directional running system

Fig.1(a) shows the omni-directional running system called crawler-roller running mechanism proposed in this study. Free rollers are installed on the outsides of

the crawler and two free rollers constitute one group. Their rolling direction is perpendicular to the crawler. The free rollers not only enable the crawler to move sideways, but also enable the robot to run up some obstacles. The robot is steady because the area that a robot touches the ground can be made wide and the unevenness of the road surface can be absorbed by this mechanism.

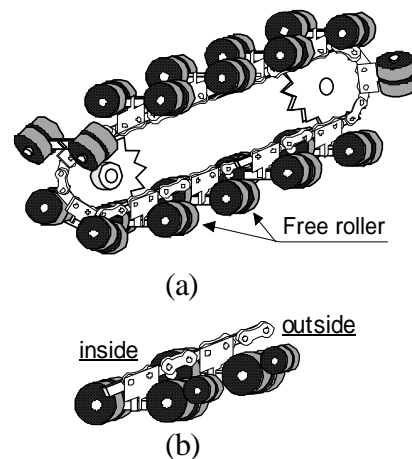


Fig.1 Crawler with free roller

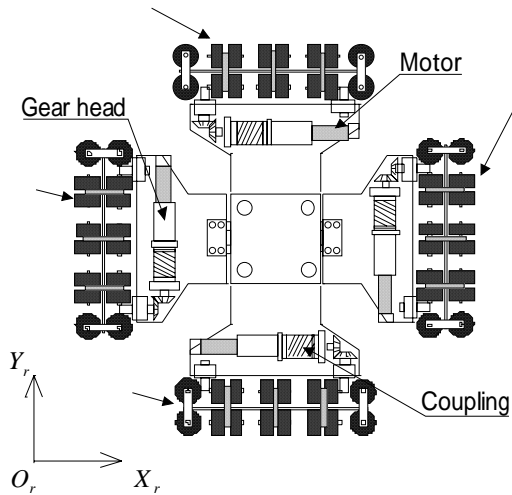


Fig.2 Top view of the robot

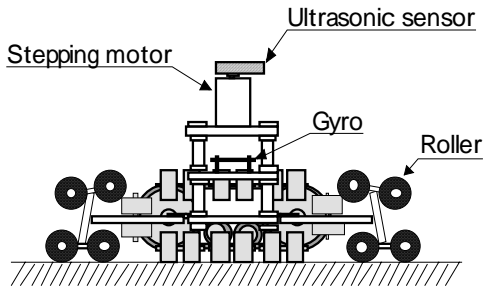


Fig.3 Side view of the robot

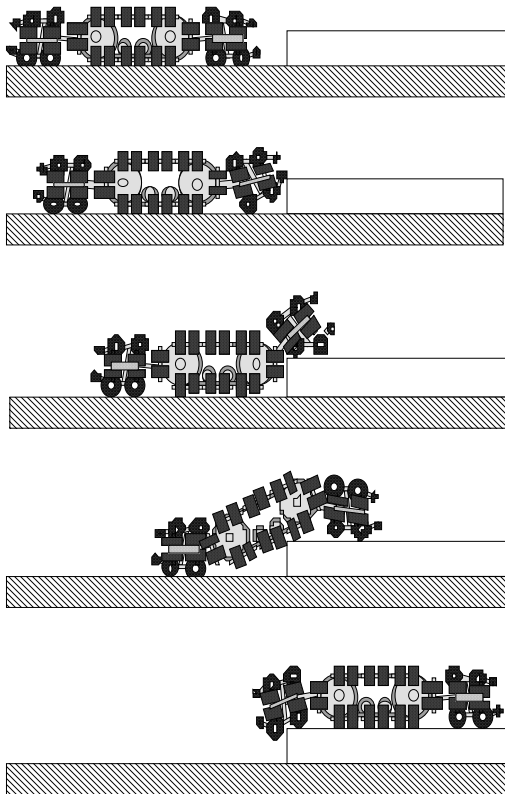


Fig.4 Running up the obstacle

Fig.1(b) shows the side view of the free rollers. The small rollers mounted on the large rollers play a role of running over some high obstacles and the principle will be explained in the later part of this paper. These small rollers don't have an influence on the omni-directional running, because they don't usually touch the ground.

As shown in Fig.2, four crawlers are installed in parallel to each axis (X_r, Y_r) in the robot coordinate fixed on the body. Then, two crawler roller motor units are connected by cross-linking to make it have a freedom. The crawler-roller-motor-unit is equipped with crawler-roller running mechanism and motor. And, the installation place of the sensor is secured by installing two sheets of plate in parallel in the center-body as shown in Fig.3. This time, a gyrocompass to measure the direction angle is installed in the middle plate, and an ultrasonic sensor to measure the distance to the standard point is installed in the top plate.

Next, we think that the robot run over some higher obstacles. When meeting a obstacle, the robot can run over it as shown in Fig. 4. The procedure of running over the obstacle is as follows.

- (1) When the robot encountered a obstacle, small free roller contact with the obstacle firstly .
- (2) Crawler-roller-motor-unit is getting up the obstacle by the thrust of the robot and by the small free roller.
- (3) Continuing to running, the center-body and crawler-roller-motor-unit get on the obstacle.
- (4) Finally, all of the robot get on the obstacle .

3. Motion Analysis

At first, the absolute coordinate system and the robot coordinate system are defined as shown in Fig.5. The symbol $\Sigma_w (O_w - X_w Y_w)$ represent the absolute coordinate and in the first state, the robot coordinate correspond the absolute coordinate. ϕ is degree between X_w axis and X_r axis. Coordinate transformation from the robot coordinate to the absolute coordinate are shown as eq.(1).

$${}^w R_r = \begin{pmatrix} \cos \phi & -\sin \phi \\ \sin \phi & \cos \phi \end{pmatrix} \quad (1)$$

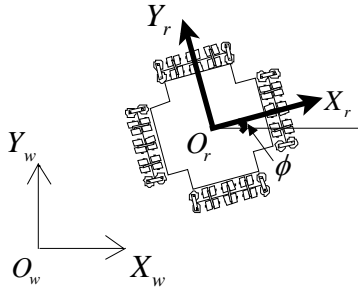


Fig.5 Absolute coordinate and robot coordinate

Fig.6 shows the side view of the crawler. In the figure, t_i is crawler moving speed, r is crawler radius, ω is angular speed of crawler. Moving speed of crawler t_i is given by eq.(2).

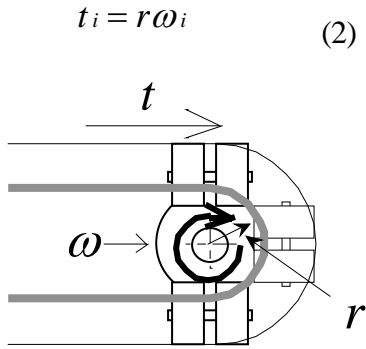


Fig.6 Side view of the crawler

The speed direction of each crawler is decided as shown in Fig.7. In the figure, L is distance from center of the robot to each crawler, \dot{x}_r and \dot{y}_r express the speed of X_r and Y_r direction. Eq.(3) shows the relation between moving speed of robot ($\dot{x}_r, \dot{y}_r, \dot{\phi}$) and crawler speed (t_i).

$$\begin{pmatrix} \dot{x}_r \\ \dot{y}_r \\ \dot{\phi} \end{pmatrix} = \begin{pmatrix} -1/2 & 0 & 1/2 & 0 \\ 0 & 1/2 & 0 & -1/2 \\ 1/(4L) & 1/(4L) & 1/(4L) & 1/(4L) \end{pmatrix} \begin{pmatrix} t_1 \\ t_2 \\ t_3 \\ t_4 \end{pmatrix} \quad (3)$$

For example, if crawler speed is $t_1 = -t_3$ and $t_2 = t_4 = 0$, the robot will move in the X_r direction. In the same way, crawler speed is $t_2 = -t_4$ and $t_1 = t_3 = 0$, movement direction of robot is Y_r direction. When all crawlers are driven at same speed in same rotation direction, the robot only rotates on the center of the robot. By eq.(3), this robot has three motion freedom (X_r, Y_r, ϕ) that it can move freely in any posture.

Eq.(4) shows that moving speed of crawlers can be calculated from the moving speed (\dot{x}_r, \dot{y}_r) and angular speed ($\dot{\phi}$) of the robot.

$$\begin{aligned} r\omega_1 &= -\dot{x}_r + L\dot{\phi} \\ r\omega_2 &= \dot{y}_r + L\dot{\phi} \\ r\omega_3 &= \dot{x}_r + L\dot{\phi} \\ r\omega_4 &= -\dot{y}_r + L\dot{\phi} \end{aligned} \quad (4)$$



Photo 1 Off-road running of the robot.

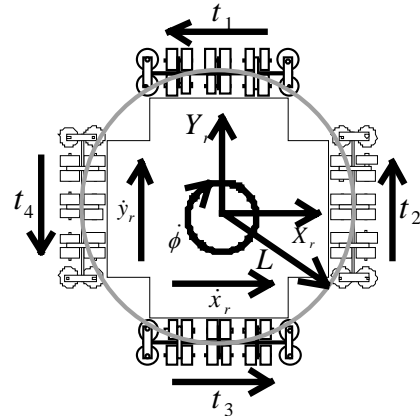


Fig.7 Top view of the robot motion

4 . GP and Path Planning

Tree structure is been applied to GP for gene arrangement. GP may solve problems which have not been solved by GA and problems with enormous calculations in the conventional GA. Here we apply GP to the problem of path planning problem.

4.1 Expression of a gene

Fig 8 shows an example of a gene expressed by tree structure. For example, Eq.(5) can be expressed with Fig.8.

$$\{(P_1 - P_2) + P_2 / P_4\} \times P_1 + P_3 \quad (5)$$

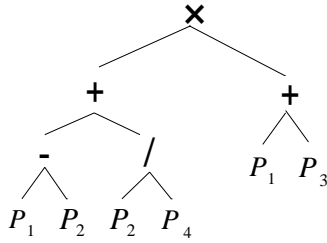


Fig.8 An example of tree structure

In this study, there 8 terminal marks of GP. They show directions (up, right_up, right, right_down, down, left_down, left, and left_up) in which the robot should move. As shown in Fig.9, “up” expresses the direction of “go up”. “right_up” expresses the direction of the upper right, and “right” expresses the direction of the right, and the like.

Non-terminal marks are functions of prog2 (terminal 1 and terminal 2) and prog3 (terminal 1, terminal 2, terminal 3). The robot will move at 10cm/s following the function in the direction of a terminal specified by the function. For example, if the function is prog2 (up and right), the robot will move at 10cm /s in the direction of “up” and at 10cm /s in the direction of “down”.

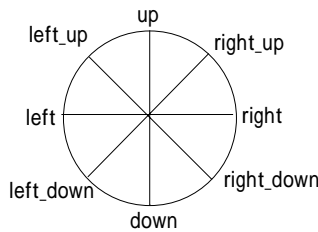


Fig.9 Terminal factors of GP

4.2 Fitness Value

Eq.(6) shows fitness of GP for the purpose.

$$fitness = \frac{1}{w1 * dis\ tan\ ce1 + w2 * dis\ tan\ ce2 + Penalty} \quad (6)$$

Here, “distance1” is the distance between the robot and the goal after the robot stopping. “distance2” is total distance of the robot from start position to the stopping position. When a robot is coming out outside the running field or it goes into the dangerous area in which the robot may collide an obstacle, the factor “Penalty” is given large number. “w1” and “w2” are weights of “distance1” and “distance2”.

In this case, the larger the value of “fitness” is, the better the gene of GP. With the revolution of generation, the robot’s trajectory becomes the shortest course from the start position to the goal position. The flow chart of GP for the movement planning is shown in Fig.10.

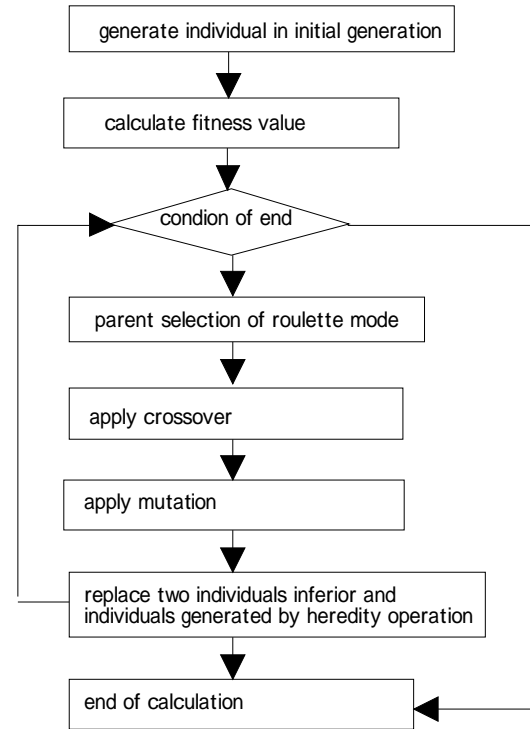


Fig.10 Flow Chart of planning by GP

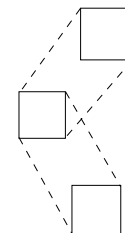


Fig.11 Tangent lines between obstacles

5. Course Optimization

A robot’s course generated by GP cannot be said as the shortest course yet after the processing of GP, because of the local zigzagged route as shown in Fig. 13. Then, the course will be optimized using the tangent lines between obstacles. The tangent lines are drawn as shown in Fig11. The first intersection of a tangent line and the orbit is nearest to the goal position. Next, the intersection obtained last time and the intersection newly made between the tangent

line and the orbit are connected. It is finished until it arrives at a start position. And the straight lines obtained by the method serve as the optimal orbit of the orbit acquired by GP.

6. Simulaion

Simulation experiments have been performed to verify the efficiency of the method proposed in this paper. Fig.12 shows simulation circumstance of an example. Fig.13 shows result of the simulation using GP parameter shown Table.1. Fig.14 shows optimum route using the tangent lines between obstacles.

Table1 Parameter for GP

Individual	40
Generation	50
crossover probability	1.0
Mutation probability	1.0
w1	1.0
w2	0.15

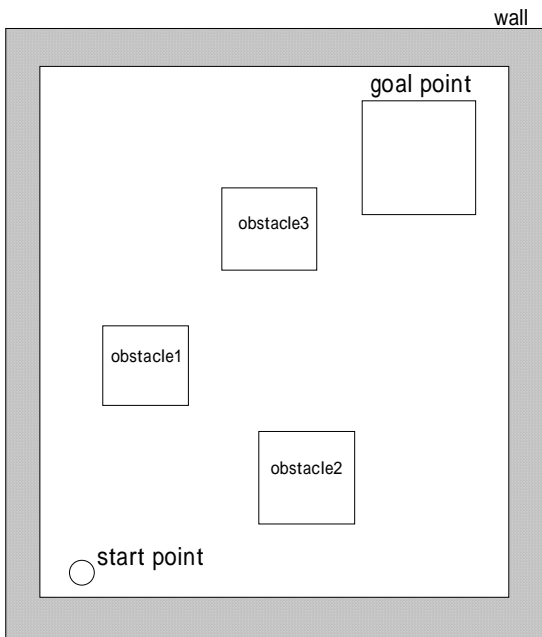


Fig.12 Simulation circumstance

7. Conclusion

In this paper, we showed a new type of Omni-directional Mobile Robot which can run on an off-road, and applied GP to solve the problems of movement planning and obstacle avoidance for the Omni-directional Mobile Robot. The optimum route for the robot is finally obtained by GP and tangent

line method. The simulation experiments are performed to verify the efficiency of the methods proposed in this paper. As the future project, we will improve the mechanism, control system and precise control on an off-road.

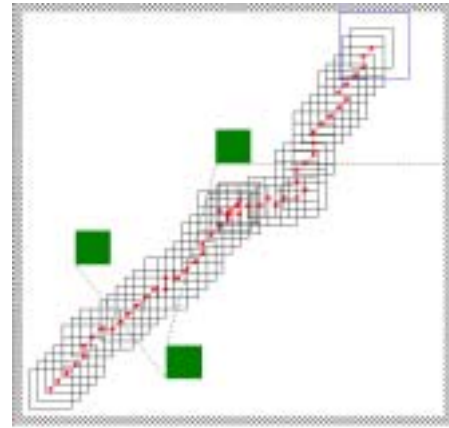


Fig.13 Planning result by GP

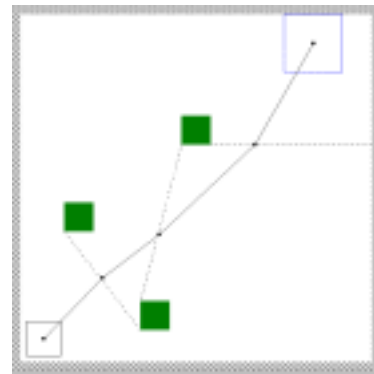


Fig.14 Optimization of running route

REFERENCES

- [1]A.Nishikawa, M.West, H.Asada : Development of a Holonomic Omnidirectional Vehicle and an Accurate Guidance Method of the Vehicles, JRSJ Vol.13, No.2, pp.249-256 (1995)
- [2]S.M.Killough, F.G.Pin : Design of an Omnidirectional and Holonomic Wheeled Platform Prototype, IEEE int. Conference on Robotics and Automation, pp84-90(1992)
- B.Carlisle, et al : An Omni-Directional Mobile Robot, IFS, pp.79-87(1983)
- [3]S.Hirose : Robotics -Vector Analysis of Mechanical System-, pp.126-128
- [4] H.Hirose :Genetic Programming and Genetic Algorithm (2000)
- [5] M.Iba : Genetic Programming(1996)