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Detecting the Mobile Robot Position Using the Profile of Known Environment

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***Abstract*—The present wayward robot on the task tracks the coordinate search, using only scanners, located inside robot. In order to determine robot coordinates, the virtual scanner and scanner obtained profiles are used. The profile mismatch formed optimization criteria, the surface of which has a lot of local minimum, a number of which depends on the scanning step. Selected scanning angle step size, and determined what should be the optimization strategy, that the searched result converged. The obtained results allow carrying out further research, given the setup process dynamics, the robot moves and coordinate accuracy is a critical problem solution in determining the coordinates, time.**

***Index Terms*—Intelligent robots, mobile robots, optimization methods, Petri nets.**

I. INTRODUCTION

There are not only productions mechanisms in the computer aided manufacturing (CAM) system but also there are serving the auxiliary machinery: cranes, hoists, and robots. Mobile robots serve for automated process for the problems of handling process in the last period. However, a number of unresolved issues, variety of researches of robotic navigation in known and unknown space is prosecute. Mobile robots compared to the other robots, has a very powerful sensory system with different types of sensors, which collected information is used by the test data [1]. Depending on the type of robot sensory system, which may be with various types of systems, scanners and video cameras with image analysis and GPS systems [2]. However, the apparatus includes a wider range of information, the more time needed to achieve the desired result. Meanwhile, mobile robots delays for solving production task must be potentially minimized. As the number of mobile robots CAM system depends on the volume of production, and there are large, up to several tens of robots, their movement trajectories setting are problematic. Any production task can execute any mobile robot, this is one of their trajectories retrieval need to organize a very large database, and evaluating other ancillary operations (robot battery loading and so on.), the amount of data becomes even greater. The solution has been optimized using supervisory system that generates each track the movement of mobile robot according to the robot assigned task execution [1], choosing a free robot, and it would be closest to the start of the task, because it is the only moment at which to optimize i.e. spend the least time to get productive assignment. However, it automatically raises another problem, how to ensure the safe operation of the robot movement, because there are a number of other moving mobile robots, in order to avoid collisions. This research is being conducted predicting potential conflict situations and finding solutions to some as the realization [3]. Colored Petri nets, in software CentaurusCPN, are used in order to solve these two tasks.

Upon disposal of these two tasks the robot while moving its trace, solve other tasks in order to ensure the success of the movement toward a goal, i.e., scans the environment determining the additional obstacles that are not covered in serving supervisory system and therefore was forced to change the way the movement. A robot moving according the given trajectory may inform about corrections supervisory system, through the devices of reversionary links. Robot adjusts its position parameters when reaches target points, because, some parameters may have particular deviations, due to various reasons. Various systems follows moving robot, fixes and corrects its coordinates. Data about the coordinates is transmitting to the supervisory system, which performs control functions, or corrects traces of the mobile robot movement, using methods of optimization [4]. Solution of this task may be given to robot, which has time to solve these tasks [5]–[9] and obtained result may be transmitted to the supervisory system, which solves problem of robot navigation.

II. DETERMINITION OF THE PROFILE OF KNOWN ENVIRONMENT

In order to determine environment profile, mobile robot is equipped with some form of scanning equipment, allowing sufficient precision to measure the distance to the wall or other fixed obstructions. In previous work which the results are reflected in [10], the main goal was to determine whether the method is functional, so the tests were carried out for

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simple profiles, regardless of the chosen algorithm performance. The main goal was to create a virtual scanner, capable of sufficient accuracy from any point of the environment, to find a profile with which we could try to determine the robot's coordinates. It was found that the method is efficient with a 100% guarantee, if the environmental profile is homogeneous (no high wall or other structural protrusions could hide behind the robot). But it has not been paid attention to smaller design elements destroying the homogeneity.

Heterogeneous production environment situation is used in research, but the study was thought that mobile robot will never hide themselves for possible capes. Indoors existing production facilities influence on the identification of profiles.

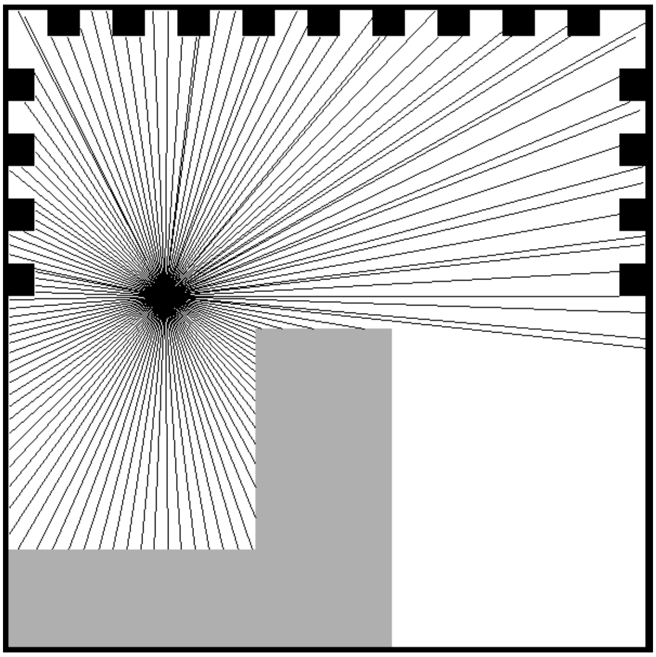

Fig. 1. Supervisor virtual scanning beam star, according to its length the profile of known environment is composed. The point from which the scan is running is the point where robot must be. Small squares are manufacturing devices.

As shown in Fig. 1 manufacturing equipment violates some profile homogeneity, but a decisive influence for profiles comparison, as will be shown below, do not have.

Fig. 2 shows how looks the robot scanner rays star, which is different in the sense that each step got from a scanner profile differs from the supervisor visible profile. During the research is taken that the mobile robot is far removed from the required trajectory, or task point location, in purpose to show that the method is functioning properly. One of the objectives of the study was to determine what steps to set the maximum scan profiles will successfully resolve the values required goal, i.e. without other means of identifying the coordinates to find the real robot coordinates. In reality, the coordinate set must be made even if deviations, from the given path of mobile robot, are smaller.

About the need to perform coordinate inspection informs the robot itself, if it has the exigencies of the uncertain situation had to change coordinates.

Other coordinate inspection must be performed at certain intervals, evaluating employment of supervisory system, but that does not play a decisive role, since the calculation procedure will be forwarded to a mobile robot control system.

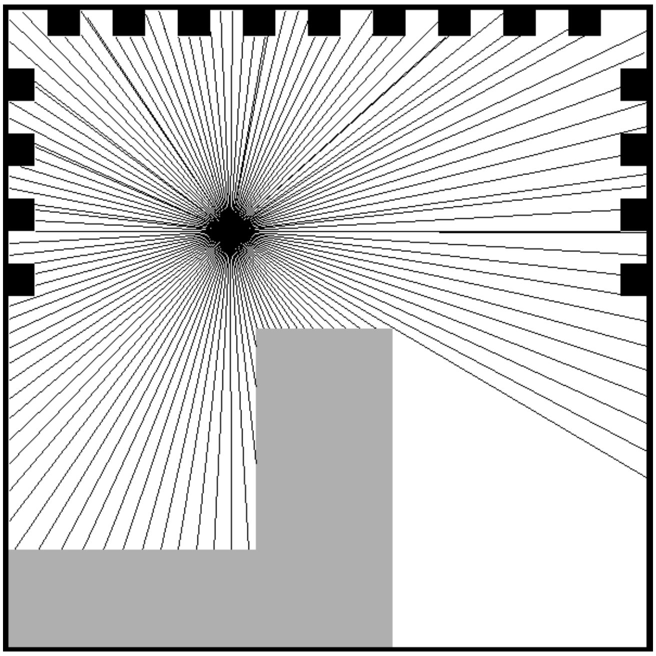

Fig. 2. One of the situations where the robot deviated from the actual coordinates, the robot scanner beam star, and profile of visible known environment of deviated robot is composed from the length of the beam.

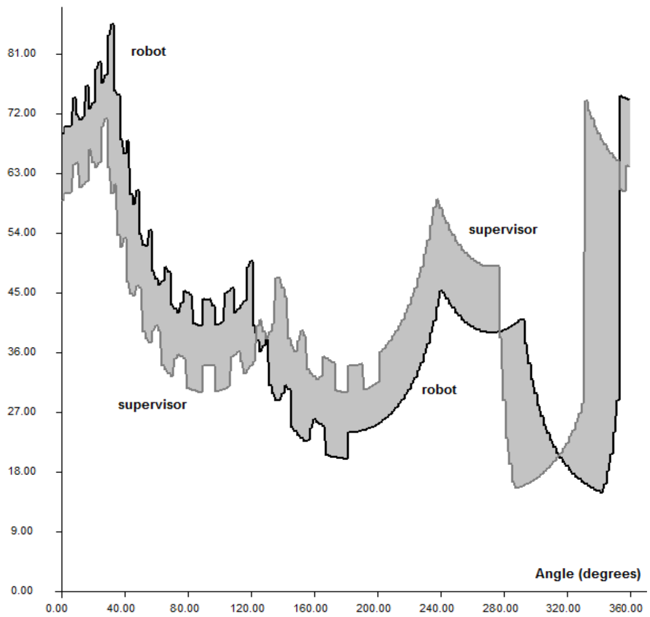

Fig. 3. The supervisor and the mobile robot profiles, according to it the difference can be identified mobile robot coordinates. Area between supervisor and robot profiles criteria value for optimization.

The essence of mobile robot coordinate determination is that if the area, showed in Fig. 3 will be equal to zero, then the profiles are identical and a mobile robot is located at the point where the virtual robot is in the supervisory system. If space is nonzero, the supervisor and the robot coordinates do not match, so if one of the optimization methods is chosen, we can change the supervisor coordinates that minimize the searching functional (in our case the width) minimum.

Integration step is equal to the step of the scanner scanning step, as shown further, determines time, used for calculations

$$E = \int_0^{360} \left| F_{S\alpha} - F_{R\alpha} \right| d\alpha \Rightarrow \min , \quad (1)$$

where $F_{S\alpha}$ and $F_{R\alpha}$ - supervisor and the robot scanner stellar radius corresponding to the same scan angle direction, and α is the step of scanner angle.

Reverse value for the functional E is showed in Fig. 4. In this figure, the surface representation of functional evolution of the empty room is showed. Optimization task of such functional does not awakes, because the surface has only one pronounced extreme.

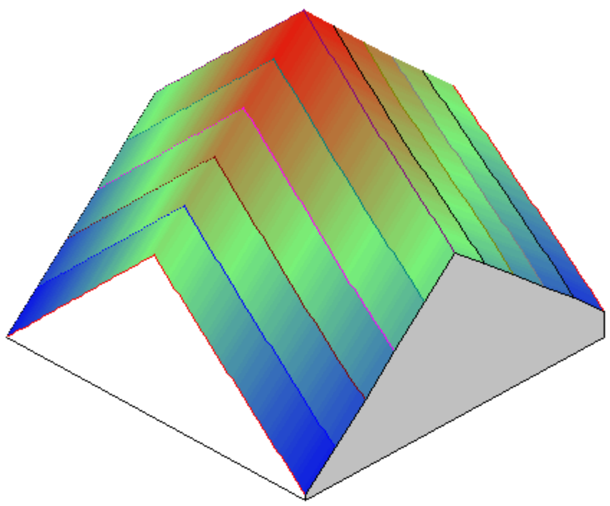

Fig. 4. Empty space reverse functionally surface with one expressed extreme.

Since the initial virtual supervisors mobile robot coordinates are known, during the procedure of supervisor's coordinate conversion, the chosen optimization method, it is easy to find and the actual coordinates of the robot, but it is unclear how much time will have to spend for this solution.

III. DETECTION OF ROBOT COORDINATES IN VARIED SITUATIONS

One of parametric optimization methods is used for such detection, for example, method of Rosenbrock, which has a feature to find ways of detection even from multidimensional space with complicated configuration. In our case, detection takes place in two dimensional space. Successfully approved method of automatic detection installed in CentaurusCPN software is used.

It is proved that if there are no prominent walls or other constructions, detection always converge despite the distance between supervisor and coordinates of mobile robot. In other words, if profiles are identical, minimum of global criteria will always be found, i.e. detection will converge. Profiles for the same environment become not identical when robot, while moving along the trace, is late or early and barrier angle separates supervisor and mobile robot. To avoid that, it is necessary to implement procedure of adjustment of coordinates when direction of movement of robot has to change. Next condition is to adjust time intervals when procedure of adjustment of coordinates, according to speed of movement, has to be performed.

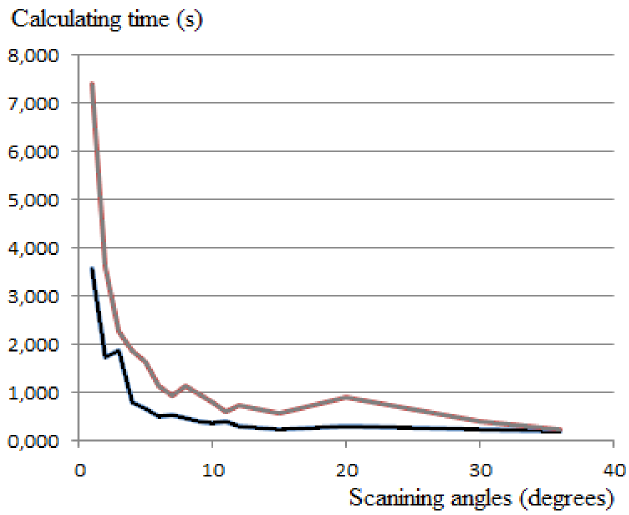

Fig. 5. Time for coordinate adjustment depending on size of step (angle) of scanning. Upper curve is for profile presented in Fig. 1, lower one is for simpler profile.

For difference of profiles presented in Fig. 3, automatic detection of coordinates of robot with accuracy to 1 mm separately for coordinates x and y, when initial difference between one and the other axis was 5.3 m and 5.2 m. Time for solving this task depending on angle of scanning is shown in Fig. 5. System, used to perform adjustment of robot coordinates, is Pentium Dual-Core CPU 2.60 GHz and RAM 4.00 GB.

As it is shown in Fig. 5, it is recommended to take angle of scanning in range of 10-20 degrees, because time for adjustment of coordinates does not exceed one second even if accuracy of coordinate adjustment is 1 mm.

If the room is not empty, and in this case it looks like the plan shown in Fig. 1, factorial surface looks complicated, with lots of local extreme. Fig. 6 represents the functionally representing its surface opposite meaning, as if to represent fair value, all surface features disappear.

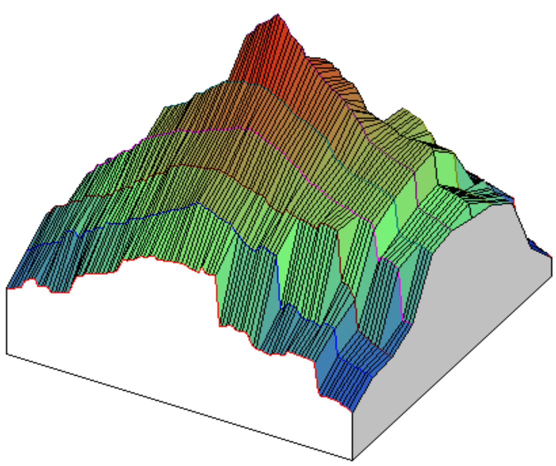

Fig. 6. Environment, analyzed in Fig. 1, reverse functionally relevant surface with a single global extreme and the number of local extrema. Their existence can clearly be seen the incision of the surface.

Studies have shown that, unlike this analysed situation, surfaces of the functionally has a lot of local minima, which causes the production facilities distorting profile homogeneity. In such surface, the strategy of optimization is used for a detection of global extreme global and it allowed solving the tasks.

Logics of functioning algorithm of Rosenbrock optimization can be described as: in case of successful step, next step on that coordinate is doubled. If step is unsuccessful, algorithm returns to the beginning of the step and begun from initial step. If it does not help, step is reduced in half. The same procedure is performed along the other coordinate. Required meaning of criteria is achieved in 42 steps. From the calculations it can be said, that coordinates of robot can be adjusted in less accuracy and earlier at 24 step of optimization. If system of robot scanning works with some error, influence of the error for accuracy of measurement is less than measurement error of the scanner itself.

In case of scattering of error to one side or another, integration reduces size of error so that it becomes not critical for calculations. Experiments showed how procedure of detection varies and required detection result is achieved after the same number of steps of optimization. Another possible situation where the robot deviation from the track and loses orientation of direction which was received from supervisor. This requires other mathematical methods, for example to move profiles according to special features or any other criteria in order to reach required result. This task is solved providing the robot with compass or gyroscopic system when it is not important how much the robot deviates but the beginning of profile reading is always the same.

Another problem which was solved improving calculation algorithms is that detection of robot coordinates using profile and performing one or another method of optimization is of iterative nature. Therefore it is purposeful to look for different method of adjustment robot coordinates avoiding iteration procedure.

Variation of optimization methods emerged because of different functional origin of optimization criteria. All gradient methods have disadvantage that they tend to perform search towards the closest criteria minimum. Tests were performed for different profiles. Conclusions of the tests are:

1. If profile is homogeneous, functional of criteria has only one minimum;

2. If profile is homogeneous, with little variation of profile range, there are a lot of local minimums but with initial big detection step, it is possible to find local minimum very close to global minimum by its meaning;

3. If profile is not homogeneous, i.e. it has prominent walls, niches, etc., it is impossible to state that detected minimum is global and it is impossible to perform that method.

Because of reasons mentioned above it is recommended to use optimization method not connected with gradient detection, most effective of all is method of simplex.

Another particularly important method is that scanning and calculation goes on in dynamic environment when robot moves, therefore initial accuracy is too big as in case of delay in one second, if robot's speed is 1 m/s, coordinates of robot by results of calculation can vary up to 1 m. Therefore main attention was maid how to improve calculation algorithms and how to choose optimal scanning step to achieve positive result with the smallest deviation from initial calculation value. But if robot deviates much more than calculated because of its movement, it is recommended to choose smaller accuracy of coordinates adjustment, calculation takes even less time not losing required accuracy of result.

IV. CONCLUSIONS

Determination of robot coordinates, using the known systems (supervisor) resulting profile and the unknown system (the robot) the resulting profile, and search through one of the optimization methods can be successfully resolved coordinates search procedure, even evaluate robot system working with some scanning errors.

Identification of the coordinates may be carried more frequently, until the coordinate deviations are not large, since it depends on the number of local minima of functional. The search should be carried out starting from large initial steps, since it manages to get close to the value of global minimum, i.e. determine robot coordinates at the highest possible accuracy.

Experimental results showed, that it is enough 1 second in order to calculate environment profile using scanner step from interval from 10 to 30 degrees, irrespective of the shape of the profile, with accuracy to 1x1mm and with 5x5m deflection, and measurements were reflected with white noise.

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