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Evaluation of the Mobile Robot Position according to the Profile of Known Environment

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Introduction

Mobile robots, which maintains industrial processes, must communicate and exchange information with supervisory system [1]. Supervisory system calculates traces of each mobile robot according to the tasks and sends it to each robot separately [2, 3]. Each robot must follow its path, because supervisory system has calculated its path according to clearance of the robot and its cargo and paths of other robots. Supervisory system solved possible conflict situations, such as path overlap and so on [4]. Supervisory system, which solves all mentioned problems and maintains feedback in real time with mobile robots, is realized using color Petri nets, in software CentaurusCPN.

Each mobile robot solves its tasks, while following the given path: scans environment in order to avoid suddenly emerged conflicts; follow given path and send feedback information to supervisory system. Robot, which reaches its target point, corrects its position. The correction must be done in order to avoid some deviations from real coordinates. Emerged deviations may have various reasons. One of the most important parameter, which influences successful work of the robot, is its exact position of the mobile robot. Information about these coordinates is sent to supervisory system, which performs functions of mobile robot control, and corrects the path. Reason of robot deviation from given path may be concerned with environment (oil on the ground, extraneous objects or rubbish). There are systems, which follows coordinates of the robots, but these systems are expensive (autonomic GPS systems, radio or laser beacon). This work describes evaluation of the mobile robot coordinates, using and analyzing information, which is visible for scanning system of mobile robot, about the profile of known environment. The problem is therein, that additional program means an additional time is needed for that purpose. Therefore, the solution of the problem may be such: robot solves tasks of motion [6] and visibility [7] and sends results to the supervisory system, which admits proper solutions.

Establishment of the profile of known environment

System, of mobile robots navigation, uses methodology, that supervisory system solves conflicts inside model, using trees of vector marks, and determines paths for mobile robots [1, 4]. Robots prosecute sended parameters of the path, using its scanning equipment. Robots must send feedback information, in order to get correct path coordinates from supervisory system if robot deviated from the given path. Deviations may emerge because of dynamic obstacles or swerve from the path or other. In order to avoid it, there is possibility to use expensive systems, which follows coordinates of moving robot, but it has own functionality problems.

Moving mobile robots prosecutes only two tasks: follows coordinates and maintains feedback with supervisory system. So there is possibility to solve some other tasks in free time intervals.

Mobile robots have various additional devices, which can be used for environment scanning. So, robot can gather information about environment, which is scanning and at the same time the environment profile can be compared to the profile, which is provided from the supervisory system. If the profiles match, the robot lays in the point where it should be according to the supervisory system. Problem emerges, when you need to compare information about profile. If the profiles match after this comparison, so it could be said, that robot lays in the coordinates where it should be, according to the supervisory system and aadditional equipment for robot coordinates tracking becomes redundant. In order to compare the profiles simply, the start angles of the mobile robot and the supervisory system should be the same. Therefore, mobile robot should have its own direction and orientation system. Such system is

gyroscope or system with compass included in i. New solutions of electronic equipment enable to use cheap elements, such as 1056 – Phidget Spatial element, which has mentioned equipment of orientation.

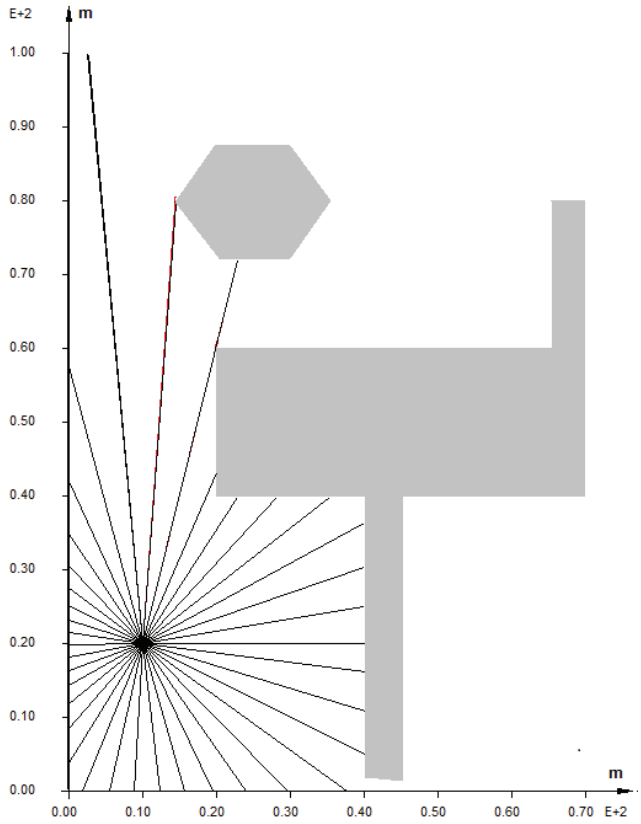

Fig. 1. Example of supervisor system scanning known environment, from the position where robot must be located

The profile of the environment can be determined using hardware, mentioned above. The essence of the suggested method, how to determine present robot coordinates without additional equipment, would be such. If robot present coordinates are the same, as supervisory system assigns and the scanning angles coincides, the comparison of the profiles does not awakes many problems of movement [5, 6] and visibility [7]. In these cases, the search could be affected by the accuracy of the mobile robot scanning system.

The different task is when the coordinates of robot and the supervisory system disagree. Fig, 1 shows example of supervisor scanning process, characterized profile of the known environment. If robot, for casual phenomenon, deviated from the given path and its coordinates changed, the correction of the present robot trajectory must be done in order to prosecute task of manufacturing. But robot coordinates are unknown, because it will be determinate only after the comparison of both profiles and corresponding calculations. As mentioned before, mobile robot does not use all its computer time, so it is possible to assign that task of present coordinates determination for it.

Mobile robot scans environment and determines profile from its own present point (Fig. 2.). There is significant deviation of present mobile robot coordinates from given in viewed examples in Fig.1 and Fig. 2. The result of the task will priory determine, how often procedure of robot coordinates designation should be used in order to get result, which always converges. Fig. 3 shows values of both profiles, which are got during scanning of the same environment, but from the different points.

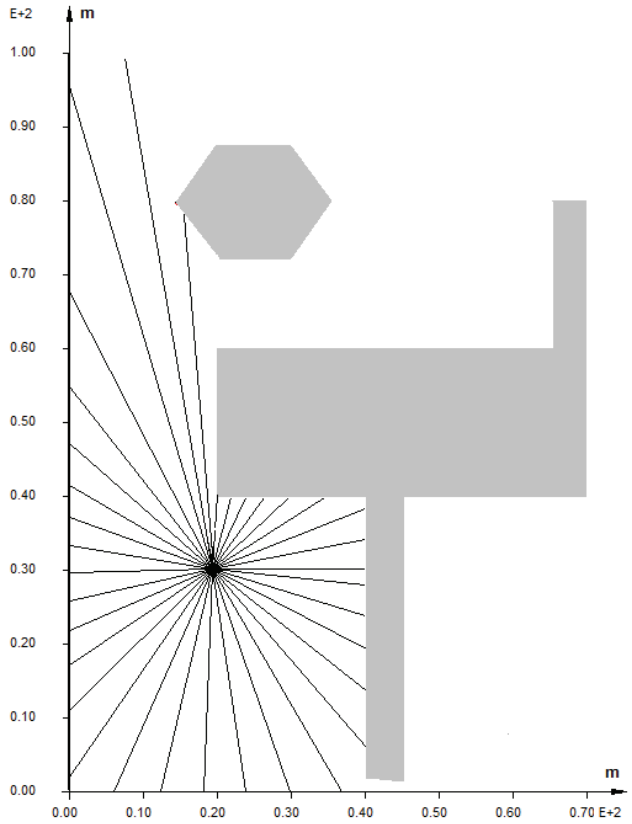

Fig. 2. Example of robot scanning known environment, from the position where robot is located

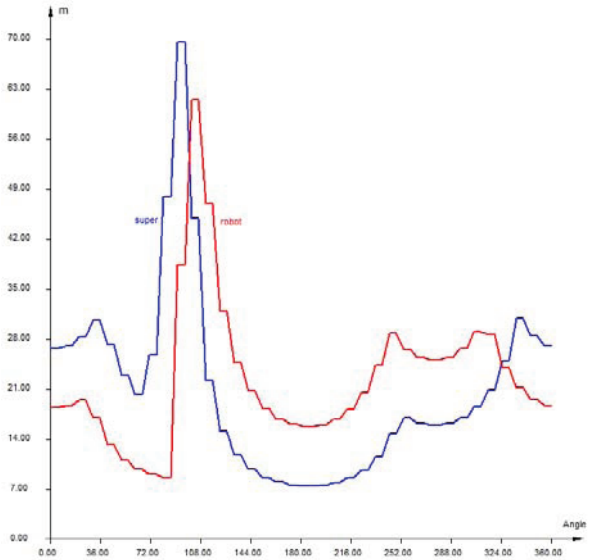

Fig. 3. Environment profiles: supervisor, which knows where robot must be located and robot, which for unknown reasons deviated from given path, but orientated in respect of environment

Classical linear programical tasks, solving problems of optimization, can be using for solving this task. The essence of the solution: mobile robot coordinates will be founded, while changing known supervisory system coor-

dinates, when the absolute integral minimum of the profile criterion $f(x)$ is founded. In this case, the search of optimization criterion is performed by changing x and y coordinates of the supervisory system scanner, according (1) expression

$$f(x,y) = \sum_{i=1}^{n} | b_{si} - b_{ri} | \Rightarrow \min, \qquad (1)$$

where b_{si} and b_{ri} - beam length values of the same direction central scanner and robot scanner.

The condition of (1) expression will be satisfied, when coordinates of scanner and robot will be coincide or close

$$x_s \cong x_r \text{ and } y_s \cong y_r. \qquad (2)$$

Coordinates, which was determined during process of optimization, of mobile robot, will be transmitted to the supervisory system in order to correct robot path.

A problem in detection of robots coordinates

If robot deviates from the given path, but does not lose its orientation, the minimum of integral profile difference could be found. So, it can be said, that integral profile difference will be zero or close to it, if supervisory system coordinates are changed, when the coordinates of the mobile robot and supervisory system will be equal.

Rosenbrock method could be used for such search. This method has its characteristic, which manages to find paths of the search, even if the configuration of the multidimensional space is complicated. In this case, the search is executed in plane i.e. two-dimensional environment. Method of automatic search, implemented in the software "CentaurusCPN", used for the search of the coordinates.

Fig. 3 shows the differences of the profiles (accuracy up to 1 mm for x and y coordinates separately). The search of the coordinates was automatic. The proper result was obtained after 60 steps of the search. Initial difference in both axes was 10m. The same task, but the accuracy up to 1 cm, was accomplished using 46 steps of the search (Fig. 4.).

If the profiles are identical, the search converges, irrespective of distances between supervisory system and mobile robot coordinates. Additional conditions and restrictions are needed in order to do convergation, if the profiles are not equal. The profiles, for the same known environment, becomes not equal, if moving, according the trace, mobile robot is late or hasten and the supervisor and the robot is distinguished by the corner of the obstacle. The procedure of coordinate determination, in places, where direction of the robot path changes, should be performed in order to avoid it. The next condition: time intervals of the procedure of coordinate determination should be performed, depending on the speed of the movement.

The determined optimal value of radar turn angle is 1^0, because if the object, which size is 1m, is located after 25m and it commits as an obstacle, there is no difference from what turn angle the scanning starts. The influence of difference of errors between ideal scanner and scanner, which works with 10% error of measurement, is only 2% of final result.

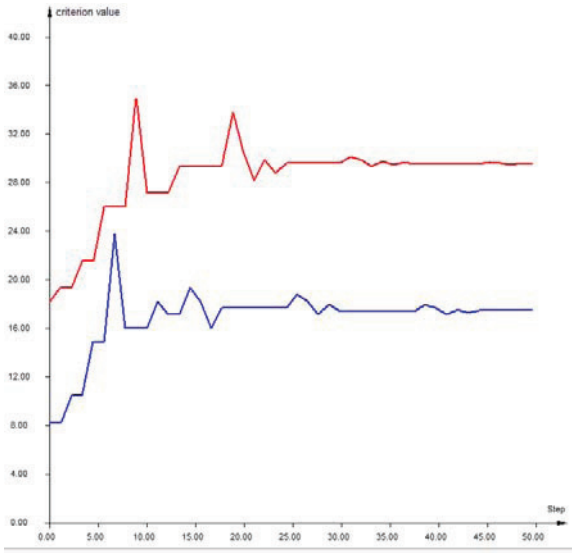

Fig. 4. Variation of x and y coordinates during evaluation of exact robot location using Rosenbrock optimisation method

The accuracy of the mobile robot scanner does not affect the results critically, because the results equilibrate during the integration of the scanner measurement. The results of the search, when the results of measurement are influenced by white noise. Desirable result is obtained during 54 steps of the search.

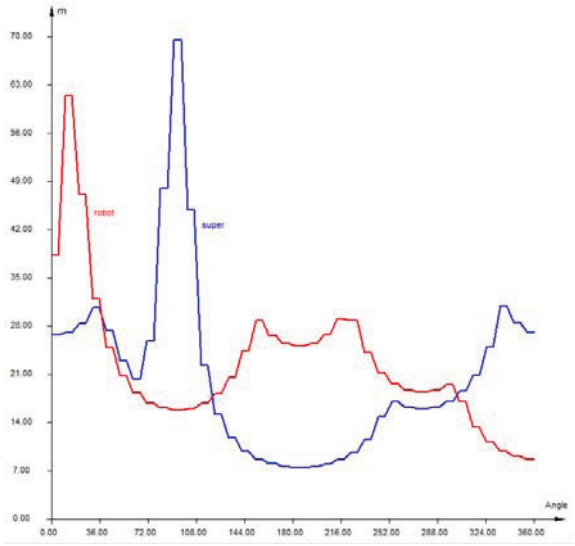

Fig. 5. Environment profiles: supervisor, which knows where robot must be located and robot, which for unknown reasons deviated from given path and lost orientation in respect of environment

Another problem is that if mobile robot do not has system of direction establishment, it is uncertain from where profile scanning starts. In this case, even if the scanning is started from the same point in the environment, profiles are not equal and the results of optimisation do not reach desirable values. Such situation is possible always, when due to the robot deviation from the path, robot turns and loses its orientation, which was received from the supervisor. Fig. 5 shows profiles that are not equal. To solve

that problem, another mathematical methods should be used or to use some special marks or other criterion for profile shifting, in order to get desirable result. This problem can be solved very easy: it is necessary that compass or other gyroscopic system should be included into robot. Then, it does not matter how much robot deviate, the beginning of the profile remains the same.

Robot coordinates system is tested in analysed environment (Fig.1.), when there are additional moving objects, i.e. other mobile robots. There are additional six robots, in the analysed environment (100x100m) and in smaller environment (40x100m), which are in such coordinates: (30, 30), (10, 50), (20, 10), (5, 10), (5, 30), (5, 70). Supervisory system fixed, that robot must be in coordinates (10, 20), but robot deviated to coordinates (19.3, 30.2). The search (Fig.6.) was successful after 58 search steps (the clearance of the robot is 1x1m.).

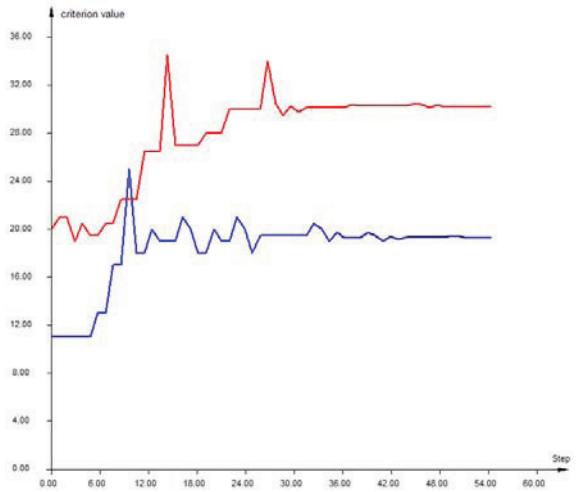

Fig. 6. Variation of x and y coordinates during evaluation of exact robot location, when environment scanning is influenced by 6 other robots

Conclusions

1. Method of evaluation of the mobile robot position according to the profile of known environment is suggested and verified. Algorithm of coordinates evaluation according to the profile of known environment operates reliably if deviation from real coordinates is considerable, scanner mensuration are affected using white noise and if there are several robots in the scanning environment.

2. It is necessary that equipment of orientation in environment (compass or gyroscope system) should be included in mobile robot.

3. Verification of the coordinates should be performed in places, where the direction of the robot movement changes and it should be performed frequently. This procedure should be performed by control system of the robot; obtained result should be transmitted to supervisory system, which will make corrections of the mobile robot path.

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Method of evaluation of the mobile robot position according to the profile of known environment is suggested and verified. Algorithm of coordinates evaluation according to the profile of known environment operates reliably if deviation from real coordinates is considerable, scanner mensuration are affected using white noise and if there are several robots in the scanning environment. However it is necessary that equipment of orientation in environment should be included in mobile robot. Verification of the coordinates should be performed frequently. This procedure should be performed by control system of the robot. Ill. 6, bibl. 7 (in English; abstracts in English and Lithuanian).

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Pasiūlytas ir patikrintas metodas mobiliojo roboto koordinatėms nustatyti pagal žinomos aplinkos profilį. Koordinačių nustatymo pagal profilį pasirinktu metodu algoritmas patikimai funkcionuoja esant didelei nuokrypai nuo tikrų koordinačių, veikiant skanerių matavimus baltuoju triukšmu ir esant skenuojamoje aplinkoje kitiems mobiliesiems robotams. Tačiau mobilusis robotas turi turėti orientavimosi aplinkoje aparatūrą. Koordinates reikia tikrinti kaip galima dažniau. Tai turi atlikti roboto valdymo sistema. Il. 6, bibl. 7 (anglų kalba; santraukos anglų ir lietuvių k.).