ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2010. No. 5(101)
ELEKTRONIKA IR ELEKTROTECHNIKA

AUTOMATION, ROBOTICS
T 125
AUTOMATIZAVIMAS, ROBOTECHNIKA

Rationalization of the Path Search Algorithm

V. Baranauskas, A. Dervinienė, K. Šarkauskas
Department of Control Engineering, Kaunas University of Technology,
Studentų str. 48-318, LT-51367, Kaunas, Lithuania, phone: +370 37 300292, e-mail: virgisbar@yahoo.com,
Studentų str. 48-324, LT-51367, Kaunas, Lithuania, phone: +370 37 300294. e-mail: alma.derviniene@ktu.lt
Studentų str. 48-107, LT-51367, Kaunas, Lithuania; phone: +370 610 25585, e-mail: kastytis.sarkauskas@ktu.lt
S. Bartkevičius
Department of Electric Engineering, Kaunas University of Technology,
Studentų str. 48-230, LT-51367, Kaunas, Lithuania, phone: +370 37 300253, e-mail: stanislovas.bartkevicius@ktu.lt

Introduction

The simplest method to find shortest path is to strain elastic thread from start point *A* to target point *B*, bypassing obstacles *C* and *D*, as showed in Fig. 1. Path touches obstacles and repeats obstacle profile in touch intervals, while stretch sections compose it in free space. So, the path could be defined if some typical points (touch points *E, F* and break points *G, H*) are known.

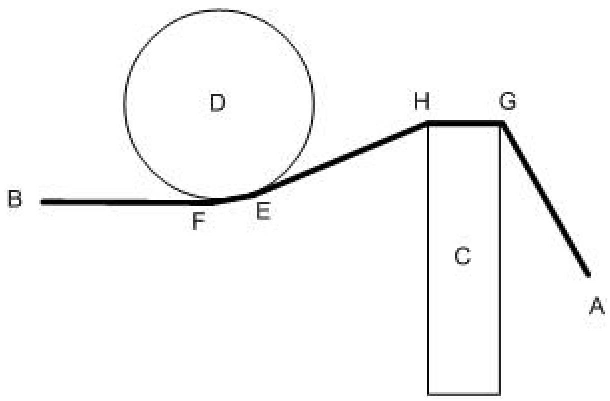

Fig. 1. Shortest path from *A* to *B*

Work [1] suggest to use vectors (vector marks), which vertexes are in typical points, and its orientation is concurrent to the direction of possible way, instead of using these points. Amount of necessary vector marks is such that, from any point, which is free from obstacles, in surrounding at least one vector mark could be visible. The task of vector marks determination is related with the task of "museum guards" [2], i.e. if surrounding could be divided into *n* prominent polygons [3] (Fig.s), then, the amount of vector marks is no more than *n/3*. The usage of vectors allows robot to forecast further turns, i.e. to perform necessary corrections of motion speed, evaluating dynamic features. The usage of sections (vectors) instead of points, allows using simple (fast) way for obstacle avoidance [1] – section is visible even from places in surrounding, from which point could not be visible. Fig. 1. shows the path, which is described only with 3 vectors, although there are 4 typical points.

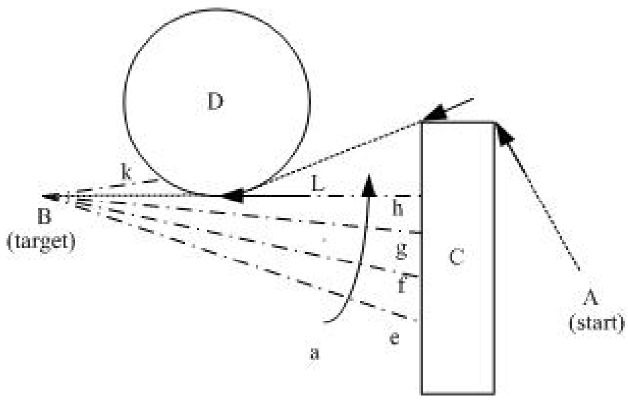

Fig. 2. Jump of the distance and vector marks

Detection of vector marks is executed while scanning known environment and finding radar jumps to the obstacles.

Work analyses known environment, so global search algorithm [4, 5, 6] should be used for path trajectories calculations. The purpose is to find shortest path to the target point.

Vector marks, which are used for determination of the shortest path from initial robot point to the target point, are created for robot navigation [1]. The logic of formation of vector marks is based on scanning known virtual environment, when the real scanner work is imitated.

Problems in detection of break points

It is rational to comminute the step of scanner scanning angle in points, where the possible distance jump is founded while scanning using virtual scanner. However such treatment can significantly reduce speed of the search. In order to avoid it, fast convergent search method is used, for example, binary search. Despite it, this method should be modified, in order to don‘t omit real points, where are distance jumps. Such risk emerges, because spurious break points might be detected, for example, near the wall.

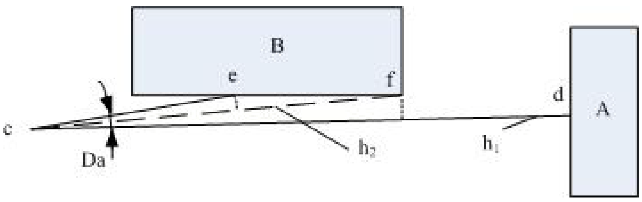

Fig. 3. Two distance jumps h_1, h_2 and only one opening

Fig. 3 shows two positions of the scanner beam, sections *cd* and *ce*, the angle between them is equal to the scanner step angle $\Delta\alpha$. The length of beams are significantly different, i.e. exceeds fixed aesthesia *g*, so there could be distance jump point, describing opening, between them. If traditional binary search is used, the scanner step should be reduced doubly and new interval, where the typical point is, of angle should be defined. In this case distance jumps $h_1=|cd|-|cf|$ and $h_2=|cf|-|ce|$ are large-sized: $h_1>g$ and $h_2>g$. In this case, it is not clear among which beams there is real beam distance jump (opening). Traditional binary search will be used only if such indeterminacy will be eliminated. Obvious way to eliminate indeterminacy is to pulverize step of the search, in interval $\Delta\alpha$, until the changes of the distance will be less than aesthesia *g*, when scanning the wall of obstacle *B*. Authors suggest other method, which is procedure of recursive binary search. This procedure is applicable in every interval, where is possible distance jump. This method is faster, because it is not necessary to calculate distances using minor step in places, where binary search gives fast and positive effect.

Problems appear with long narrow corridors and narrow holes in them. In such cases, a lot depends upon the scanning angle of the scanner. A hole in a corridor might not be detected in cases with a particular scanning angle of the scanner. It will not be found because the scanner will ‘miss’ it.

If the point from which scanning is performed is near the wall (Fig.4, point *A*) and the angle α between the wall and the radar beam is small enough a slight alteration of the scanner angle $\Delta\alpha$ can influence significant changes in the length of the scanner beam. The distance between the points *A*-*C* and *A*-*B* is considerably different by value Δl even though the radar beam is rotated at a small angle $\Delta\alpha$.

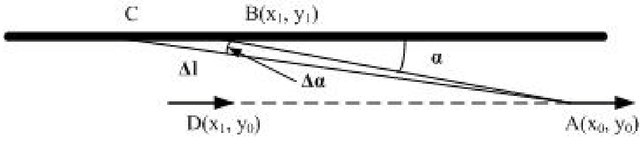

Fig. 4. Pseudo break near the wall

The vector marks generation method demonstrated in Fig. 4 points ‘*B*’ and ‘*C*’ will be considered as break points. When scanning further on break points are detected as well. Therefore, using the created fixation rule of the detection of break points in case of a small angle between the wall and the radar beam break points are obtained. If the wall is long a break point will be detected in every step as value Δl every time will be bigger than previously. If break points are detected in three consecutive steps and they are in one straight line it is determined that a parallel wall is found. The following features are used in order to detect a parallel wall:

1. Break points are detected in three consecutive steps.
2. All three break points are in one straight line.

If a parallel wall is detected the mark point lying on the straight line, which is parallel to the pseudo-wall near the first break point of the triad, is generated. At this point the vertex of an additional vector is formed. Fig. 4 demonstrates the case where scanning is started from point ‘*A*’. Starting with point ‘*B*’ more significant changes than previously are detected; therefore, point ‘*B*’ is considered as a break point. Break points are detected in the next two steps as well. It is determined that a wall is detected since all the three break points are in one straight line. In the case demonstrated in Fig. 4 point ‘*D*’ is the vertex point of an additional vector mark. It is formed near the first point of a determined triad. The length of the formed additional vector mark is measured in the window of a software tool. When the generation of an additional vector mark is done all the other previously detected points forming a straight line are ignored.

When younger generation vector marks are being searched for scanning is continued from the end point of the formed additional vector mark.

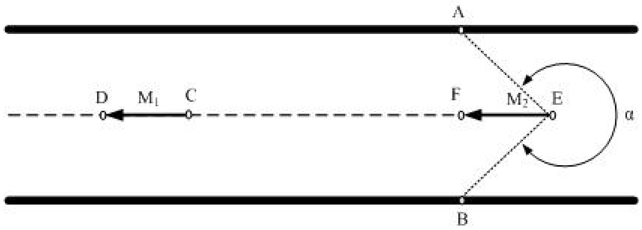

Fig. 5. Too large radar view angle conditions the appearance of additional vector marks

When scanning the environment between two parallel walls the radar view angle influences the formation of additional vector marks. In Fig. 5 vector marks M_1 and M_2 are additional and the direction of further scanning is opposite to the direction of these vector marks.

When scanning from the end *C* of the vector mark M_1 break points are detected in three consecutive steps and those break points are in one direct line. A parallel wall is determined. The first point of the detected triad in Fig. 4 is *B*. In point *F* parallel to point *B* a new additional vector mark M_2 is formed. The end of this mark is in point *E* as demonstrated in Fig. 5. When scanning from the end point *E* of the vector mark M_2 it is possible to detect pseudo break points in the previously scanned territory if the radar view angle α is unrestricted. Such break points could be detected in the range between point B and the end *C* of the vector mark M_1. In order to avoid detection of pseudo break points it is advisable to limit the radar view angle. The angle α should be such that the last visible points are points *A* and *B* which are parallel to the vertex point *F* of the vector mark M_2. In the case demonstrated in Fig. 5 the angle α is limited to 270^0.

If the wall is detected the additional vector mark is set at the point on the radar beam parallel to the wall at distance corresponding to the first (nearest) break point. All pseudo break points lying on the previously find direct line are ignored after the additional mark is put. When the next generation of vector marks is under searching near the wall, the scanning begins from the point D and the angle between radar beam and the wall is not so small. It is important that such additional vector mark cannot be cancel as redundant.

Narrow corridor might be treated as two parallel walls. Such corridor is showed in Fig. 6. Usage of points (from B to I) with additional vector marks makes possible to avoid pseudo break points and found the hole J. Some of additional marks are redundant, B and C for example, and may be deposed.

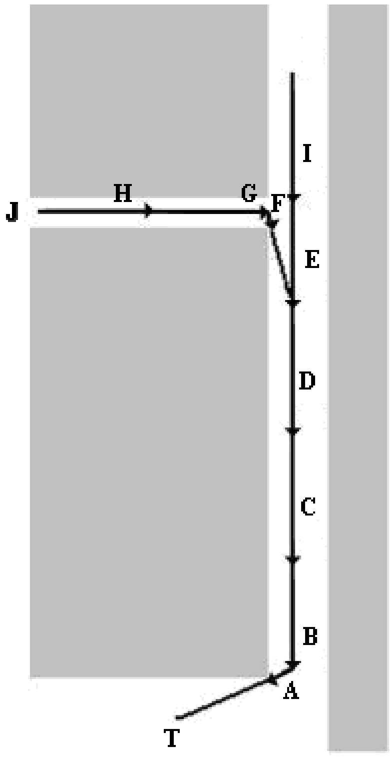

Fig. 6. Example of narrow corridor with points of additional vector marks

Rationalization of the search algorithm

Method of vector marks generation, showed in Fig. 5, accomplishes process of generation of vector marks. In this case it is necessary to use additional assumptions for elimination of path search problems. This emerges from assumption of evaluation of accuracy of existing real scanners. Tree of vector marks exits only in virtual world in other words – it is inside supervisory system, which controls robots. In this case, the problem of vector marks generation can be solved using virtual scanner, which has own resolution and this resolution is warranted of used software, where supervisory system is organised. Main parameters, which describes perfect scanner are: perfect resolution and minimal scanner turn angle. Fig 7 shows unrationalised method of vector marks generation, when scanning of the environment is executed in long corridors with or without openings at the end of it. This example shows problem of unnecessary vectors (vectors from *D* to *G*), generated in long corridors without exits. This situation occurs because real scanner has its resolution and can‘t identify is the opening at the end of corridors or not. Data base is burdened with unnecessary information, which does not affect final result. This process elongates time of calculations or selection of the path, because all possible paths must be reviewed and only one, the shortest path must be selected.

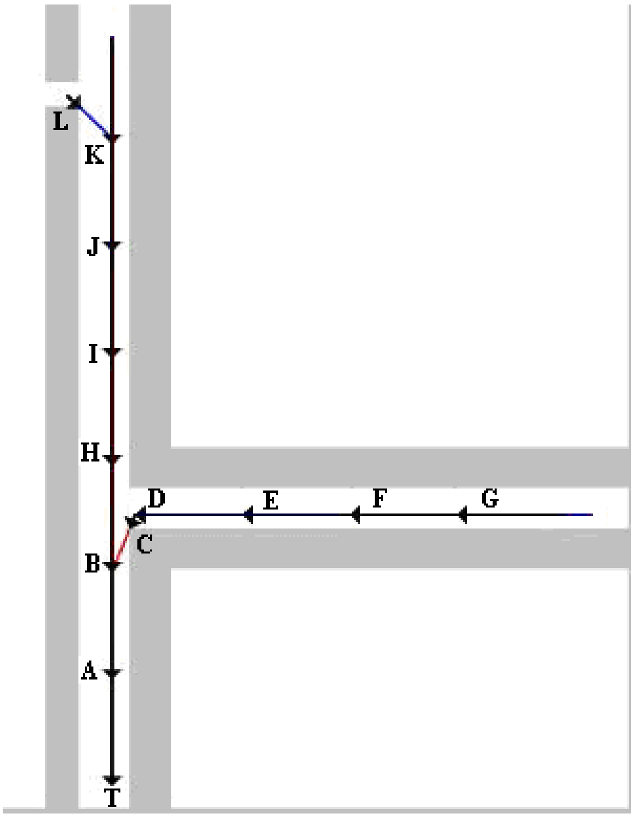

Fig. 7. Vector marks tree in corridors with dead ends, composed using unrationalised algorithm

If perfect scanner is used (the beam of the scanner does not has scatter, but it is perfect; the system, which ensures turn angle of scanner, could have any alteration of the turn angle), absolutely different result, showed in Fig. 8, is received. Fig. 8 obviously shows, that virtual scanner is able to determine openings even if the scanning angle is very small. If there is no opening in the end of long corridor, according to rationalized algorithm, vector marks are not generated. Target point, in viewed example, is very close to the wall, so the aim of the experiment is to show what possible scanner turn angle will be vouched for determination of the opening in the corridor. Experimental results are: scanner is 3 centimetres from the wall; the distance from the scanner to the opening is 80 metres. So

$$arctg\frac{3}{8000} = arctg(0.000375) = 1.29' \qquad (1)$$

scanning angle resolution is 1.29 minute, which could not be realised using real scanner.

Data base with generated vector marks is significantly smaller, intellectual path calculation system uses less time for path calculations and transmition of special path points to real robot.

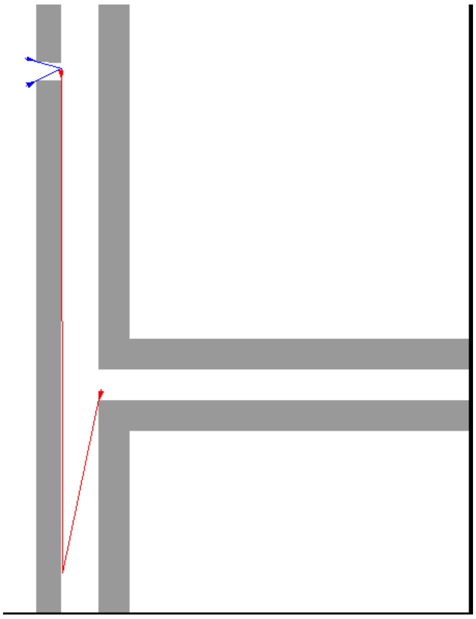

Fig. 8. Vector marks tree in corridors with dead ends, composed using rationalised algorithm

Conclusions

1. New algorithm, which allows organizing virtual scanner turn angle with resolution, not less than 1.29 minute, is proposed and implemented in virtual supervisory system.
2. The time of vector marks tree formation is short enough; the tree is not complicated with unnecessary information, which uses resources of computer memory in further calculations.
3. Implementation of new vector marks formation algorithm into supervisory system allows effectively reduce database, which is used for faster calculations of movement trajectory for any robot in any place in the environment.

References

1. **Baranauskas V., Bartkevičius S., Šarkauskas K.** Creation of vector marks for robot navigation // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – No. 4(84). – P. 27–30.
2. **O'Rourke J.** Art gallery theorems and algorithms. – Oxford University press, 1987. – 282 p.
3. **Pimenta L.** Robot navigation based on electrostatic field computation // IEEE Transactions on magnetics, 2006. – Vol. 42, no. 4. – P. 1459–1462.
4. **Siegwart R., Illah R.** Introduction to autonomous mobile robots. – Cambridge, Massachusetts, London, England, 2004. – 321 p.
5. **Garrido, S., Moreno, L.** Path planning for mobile robot navigation using Voronoi diagram and fast marching // International conference on Intelligent robots and systems, 2006. – P. 2376–2381.
6. **Pradhan S., Parhi D., Panda A**. Fuzzy logic techniques of several mobile robots // Applied soft computing, 2009. – Vol. 9, iss. 1. – P. 290–304.

Received 2010 01 25

V. Baranauskas, A. Dervinienė, K. Šarkauskas, S. Bartkevičius. Rationalisation of the Path Search Algorithm // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 5(101). – P. 79–82.

New algorithm, which allows organizing virtual scanner turn angle with resolution, not less than 1.29 minute, is proposed and implemented in virtual supervisory system. Implementation of new vector marks formation algorithm into supervisory system allows effectively reduce database, which is used for faster calculations of movement trajectory for any robot in any place in the environment. Usage. Ill. 8, bibl. 6 (in English; abstracts in English, Russian and Lithuanian).

В. Баранаускас, А. Дервинене, К. Шаркаускас, С. Барткевичюс. Рационализация алгоритма поиска пути // Электроника и электротехника. – Каунас: Технология, 2010. – № 5(101). – С. 79–82.

Предложен и внедрен в виртуальную супервизорную систему новый алгоритм позволяющий осуществить поворот виртуального сканера с разрешающей способностью не меньше чем 1,29 минуты угла поворота. При внедрении данного алгоритма в супервизорную систему при генерации векторного древа удалось эффективно уменьшить объем базы данных, которую использует интеллектуальная система супервизора при определении и расчете нужной трасы движения робота с любой точки на любую точку. Ил. 8, библ. 6 (на английском языке; рефераты на английском, русском и литовском яз.).

V. Baranauskas, A. Dervinienė, K. Šarkauskas, S. Bartkevičius. Kelio paieškos algoritmo racionalizavimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 5(101). – P. 79–82.

Pasiūlytas ir įdiegtas virtualioje supervizinėje sistemoje naujas funkcionavimo algoritmas, leidžiantis organizuoti virtualaus skenerio posūkio kampo skiriamąją gebą ne mažiau kaip 1,29 minutės. Naujo vektorinio medžio generavimo sistemos algoritmo įdiegimas supervizinėje sistemoje leido efektyviai sumažinti duomenų bazę, kuria naudodamasi intelektuali sistema kur kas greičiau parenka ir apskaičiuoja reikiamą bet kurio roboto judėjimo trasą iš bet kurios jo buvimo vietos. Il. 8, bibl. 6 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).