

## Target Retrieval in Known Environment

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### Introduction

The problem of robot navigation in known environment with obstacles is the purpose of the article. If robot does not see the target point, the problem of target search arises. The problem can be solved using methods of optimization, if a virtual surface, representing the environment, is formed and an appropriate criterion of search is determined. The gradient methodology seems to be the best in this case. The subject of this article is to discuss assumptions and requirements necessary to make the pseudo-surface.

### Assumptions of method formation

Main assumption – target point lays on a surface, which is weighted and value of the weight is maximum at the point. In other words, it is possible to create an artificial surface shaped so that the gradient of it would be directed to target. Local extremes are not desired too. The easiest way to form such surface is to form it from flowing viscous fluids or gas.

Navier-Stokes equations, which are used to describe flow of incompressible viscous fluid, are one of the most important research objectives in mathematical physics. Solution characteristics of Navier-Stokes systems and its asymptotic has important practical values, because this system describes real processes of fluid flow. In the 2000 year Clay Mathematics Institute (CMI), USA published seven most important mathematical problems for next millennium (Millennium Prize Problems). One of them is global solvability of ambulatory Navier-Stokes system and solidarity of the solution. This proves importance and topicality of the Navier-Stokes equations and solutions for them [1].

There are known solutions for laminar flow of gas in the fixed cross-section pipe, following such assumptions:

1) fixed size of gas amount is not changing during process of flowing,

2) flow is being observed, when the distributions of the purposeful gas speed is the same in whole cross-section pipe length,

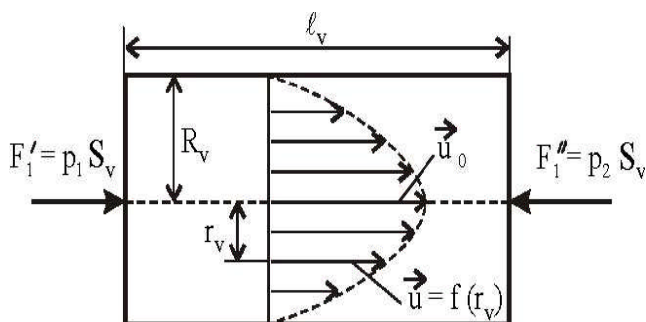
3) flow is laminar – gas is flowing at the direction, parallel to the axis of the pipe, turbulent vortexes does not appears,

4) purposeful speed of the moving flow is equal to zero beside the wall.

All these assumptions are correct if the gas flows in long pipes and at the low speed. This means, that the quadrate of the Mach number is lesser than one [2].

When flow access the gap of the pipe, the speed of the flow is approximately uniform in the whole area of the gap. Forces of viscosity generate tension after particular initial part of the pipe forms the fixed purposeful distributed profile, when the gas is moving in the pipeline. In the round cross-section pipe this profile is parable. In this case, maximum speed of flowing gas is at the axis of the pipe. Due to the greater values of the interaction forces and kinetic energy of accelerating flow, in the initial part of the pipe, the pressure is varying sharply than in the formed flow.

Laminar viscous flow in the round cross-section pipe is called the Puazeil flow. It is partial case of viscous flow. This case is suitable in pipelines, with length much more major than the cross-section of the pipe [2].



**Fig. 1.** Poiseuille flow model

Puazeil equation is not complicated. Let us analyze flow distribution in element of round cross-section pipe, which internal radius is  $R_v$  and it is shown in Fig. 1[2].

Given flow element of gas is coaxial to pipeline. It's ray is  $r_v$ , length is  $l_v$ . This element, due to external pressure from left side, is under affect of force  $p_1\pi r_v^2$ , from the right side  $-p_2\pi r_v^2$ ; where  $p_1$  and  $p_2$  – pressure at the end of given pipe element. Resultant pressure force is equal to:

$$F_1 = (p_1 - p_2)\pi r_v^2. \quad (1)$$

These examples are only partial solution of the Navier–Stokes equation.

The Euler and Navier–Stokes equations describe the motion of a fluid in  $R^n$  ( $n = 2$  or  $3$ ). These equations are to be solved for an unknown velocity vector

$$u(x, t) = (u_i(x, t))_{|i| \leq n} \in R^n \quad (2)$$

and pressure  $p(x, t) \in R$ , defined for position  $x \in R^n$  and time  $t \geq 0$ . We restrict attention here to incompressible fluids filling all of  $R^n$ .

The Navier–Stokes equations are then given by

$$\begin{cases} \frac{\partial}{\partial t} u_i + \sum_{j=1}^n u_j \frac{\partial u_i}{\partial x_j} = \nu \Delta u_i - \frac{\partial p}{\partial x_i} + f_i(x, t); \\ \operatorname{div} u = \sum_{i=1}^n \frac{\partial u_i}{\partial x_i} = 0. \end{cases} \quad (3)$$

Waves follow our boat as we meander across the lake, and turbulent air currents follow our flight in a modern jet. Mathematicians and physicists believe that an explanation for and the prediction of both the breeze and the turbulence can be found through an understanding of solutions to the Navier-Stokes equations. Although these equations were written down in the 19th Century, our understanding of them remains minimal. The challenge is to make substantial progress toward a mathematical theory which will unlock the secrets hidden in the Navier-Stokes equations [1].

Elliptical and parabolical equations for partial derivatives, describing many physical processes and having practical worths, are investigating in many science centres in the world. There are many investigated tasks, related to critical tasks of elliptical and parabolical equations, and systems in complicated (singular, endless) ranges.

So, we can predicate, that without complicated calculations, using methodology of finite elements, it is difficult to establish exact formation of the surface. At the same time let's analyze if it is necessary. Gradient methods calculate gradient at the one point and further search is continued at the selected direction until the extremum point of the criterion is reached. We are interested in critical features of the criterion, where new direction of the gradient must be established. There are calculations, how to distribute flows in various openings and pipelines in literature [3].

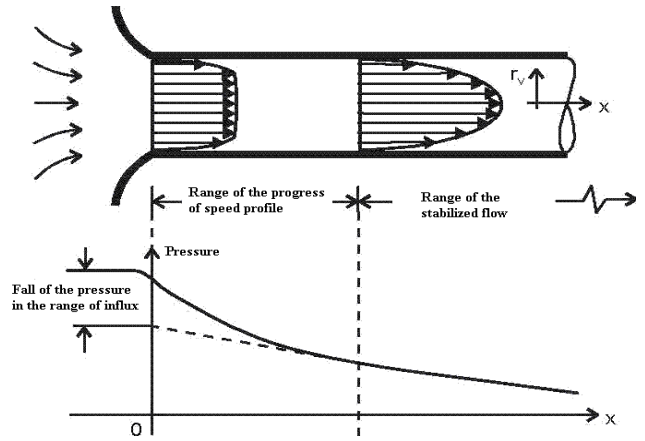


Fig. 2. Variations of the pressure and profile of the gas speed in initial part of the pipe

Distribution of waves and flows are calculated for pipelines and analogous elements. Our problem is analyzed in plane or with one or two lateral walls if there are obstacles. Viscous element could be smell of the gas (gradient according the power of the smell) or more picturesque - viscous flow from the target point. This viscous flow forms surface with incline from the target point.

### Idea of proposed method

Let us analyse the situation, how to find track among the obstacles, when there are straight visibility between initial point and target point, when viscous fluid outflows from the target point, like analysed before. Distribution of the equidistance when the surface is forming is viewed in Fig. 3.

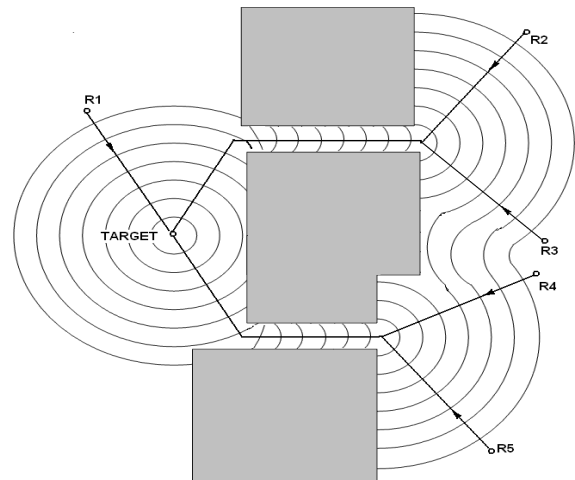
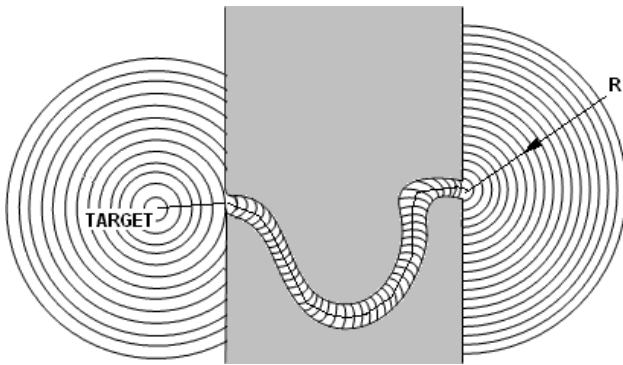


Fig. 3. Distribution of the equidistance, out flowing viscous agent from TARGET and the directions of the gradients from points R1 – R5 to target

There are five beginning points (R1 – R5) in given example. If movement will be executed from any of them, and the movement will be executed in the increasing direction of the gradient, the target point will be reached in the shortest path, because the surfaces are fashioned in that aim. Fig. 4 shows analogical situation, but the channel is modelled to have free form. According to Puazeil and Na-

vier-Stokes equations, the gradient of the surface in the channel spreads in such manner, as it is shown in picture.



**Fig. 4.** Distribution of the equidistance, out flowing viscous agent from TARGET and the directions of the gradients from point R to target

In the task of the optimisation, the maximum or minimum of the goal function  $f(x)$ , using algorithm of iteration process is the following

$$x^{k+1} = x^k + \alpha_k p^k; \quad k = 1, 2, \dots; \quad (4)$$

where  $p^k$  – vector of the step direction;  $\alpha_k$  – length of the step.

If the function is differentiating, so using partial meanings of the function, it is possible to forecast the direction to minimum or maximum.

Gradient  $\nabla f(x^0)$  of the function  $f(x)$  describes direction of the greatest rate of increase at the point  $x^0$ . Analogically, direction – conversely to the direction of the gradient – antigradient -  $-\nabla f(x^0)$ , is the direction of the fastest decrease (incline) in point  $x^0$  of the function  $f(x)$ .

So optimisation methods of the function, where the vector of the direction is characterized as gradient, are called gradient (or fastest incline, or fastest descent) methods. This methodology and the mathematics of it will be used in further work, due to possibility to use conclusions of the gradient methods in our problem solution.

For our problem, we suggest such methodology. It is not necessary to move according to the gradient. It is enough to choose the direction of the movement to zone, where direction of the gradient changes. As we see from Fig. 3 and Fig. 4, the alteration of the surface gradient is possible, where are the alterations of the obstacles (openings, sharp corners and so on). So it is possible to use results of the surrounding scanning. Scanner defines break points, where it finds alterations of the obstacles. We characterize break points in vector marks. The formation of vector marks is described [4, 5, 6]. These works [4, 5, 6] shows solutions for some complicated situations and various solutions for raised problems.

### Modelling results

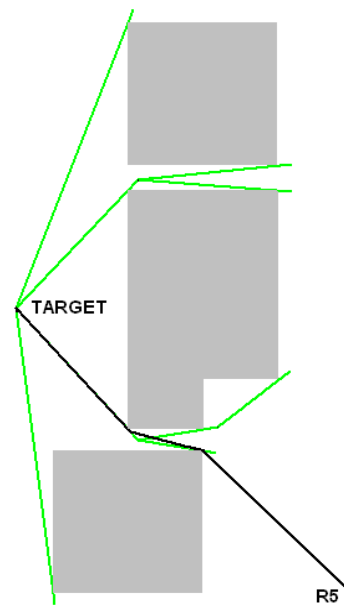
Solution of the task is effective using vector marks. As the aim of the search is to find shortest path from the

initial point to the target, vector marks has its weight coefficients. Weight coefficient comprises of distances to the target point. If there are several visible vector marks from the initial position, it is picked only one, with the minimal weight coefficient, evaluating corrections of the distance from initial position to the selected vector mark:

$$f = \min_{i=1}^n (S_i + \sqrt{(x_i - x_R)^2 + (y_i - y_R)^2}); \quad (5)$$

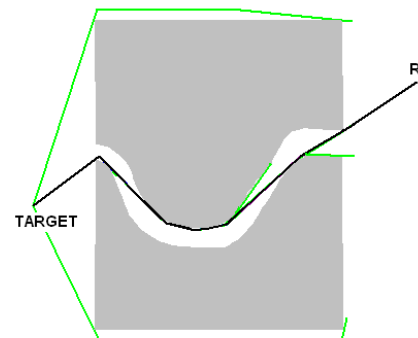
where  $S_i$  – the weight coefficient of visible vector mark;  $x_i, y_i$  – the coordinates of the visible vector mark;  $x_R, y_R$  – robot coordinates.

Described search algorithm is realised using colored Petri nets in software CENTAURUS. Analysed examples (Fig 3 and Fig 4) are realised programmally and results are shown in Fig. 5 and Fig. 6.



**Fig. 5.** Modelling results, using vector marks, for situation, showed in Fig. 3.

In the first example (Fig. 5) robot R5 sees 5 vector marks, from them one vector mark with the minimal weight coefficient is selected.



**Fig. 6.** Modelling results, using vector marks, for situation, showed in Fig. 4.

In the second example (Fig. 6) robot R sees 4 vector marks, from them one vector mark with the minimal weight coefficient is selected.

In both cases, usage of vector marks for purposes of the path search correlates to described search methodology, according fictitious gradient of the formative surface.

## Conclusions

1. According to the method of gradient search, vector marks are formed, due to the search of the shortest path, when moving object and the target aren't in visible zone, considering that the search is proceeded in viscous liquid, out flowed from the target point, forming surface.

2. Program package allowing simulation, based on colour Petri nets, of movement of mobile objects and detect the shortest path to the target, using weight coefficients of visible vector marks.

3. The realized default procedures and interface with graphic subsystem probably makes presumptions for learning of mobile robots to choose optimal route to the target.

## References

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Target retrieval in known environment, when there is no straight visibility between robot and target point, is executing using various search systems, but each of them has their own lacks. If the target point forms surface, which gradually sinks from it, independently from form and amount of the obstacles, the gradient methods seems to be the best for the search. It is enough to know the direction of the gradient, if we want that the robot move directly to the target point in the shortest path. Gradient direction variations are established in order to form vector marks. Weight coefficients are assigned to vector marks. This coefficient is directly proportional to distance to target point. Using formed assumptions of this method, software tool, based on colored Petri nets, is created, which clearly demonstrated efficiency of the method. Independently from forms of obstacles, the shortest path to the target point is calculated. Il. 6, bibl. 6 (in English, summaries in English, Russian and Lithuanian).

**V. Баранаускас, К. Шаркаускас, С. Барткевичюс. Поиск цели в известной обстановке // Электроника и электротехника. – Каунас: Технология, 2008. – № 8(88). – С. 91–94.**

Поиск цели в известной обстановке, когда робот и цель не находятся в прямой видимости относительно друг друга, производится разными поисковыми системами, имеющими одни или другие недостатки. Если считать, что цель формирует поверхность понижающую от нее, очень хорошо для поиска подходят градиентные методы, какие и каким образом не были бы расположены преграды. Чтобы робот двигался целенаправленно, наикратчайшей дорогой к цели, достаточно знать направление градиента. С этой целью определяются точки изменения направления градиента, формируя так называемые векторные метки с весовыми коэффициентами пропорциональными расстоянию до цели. На основе предпосылок, сформированных предлагаемым методом, цветными Петри сетями создано программное обеспечение очень наглядно показывающая эффективность метода: при любой конфигурации и расположении преград выбирается наикратчайший путь к цели. Ил. 6, библи. 6 (на английском языке; рефераты на английском, русском и литовском яз.).

**V. Baranauskas, K. Šarkauskas, S. Bartkevičius. Tikslų paieška žinomoje aplinkoje // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – Nr. 8(88). – P. 91–94.**

Tikslų paieška žinomoje aplinkoje, kai tarp roboto ir tikslo nėra tiesioginio matomumo, atliekama įvairiomis sistemomis, kurių kiekviena turi vienokių ar kitokių trūkumų. Jei tarsim, kad tikslas formuoja paviršių, tolygiai žemėjantį nuo jo, labai gerai paieškai tinka gradientiniai metodai, kad ir kokios ir kaip būtų išdėstytos kliūtys. Kad robotas judėtų kryptingai, trumpiausiu keliu link tikslo, pakanka žinoti gradiento kitimo kryptį. Tuo tikslu nustatomi gradiento krypties pakitimo taškai, formuojant vadinamuosius vektorinius žymeklius priskiriant jiems svorinius koeficientus, proporcingus atstumui iki tikslo. Šio metodu suformuotų prielaidų pagrindu spalvotais Petri tinklais sukurta programinė priemonė aiškiai pademonstravo metodo efektyvumą esant bet kokios konfigūracijos kliūtims, parinkdama trumpiausią judėjimo kelią link tikslo. Il. 6, bibl. 6 (anglų kalba, santraukos anglų, rusų ir lietuvių k.).