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Improving the stability of algorithms for path planning based on boundary value problems

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Abstract

Robots have been used for industrial production processes automation. Such robots did not need to deal with dynamics environments and unforeseen situations, just performing well defined repetitive tasks. So it was possible to program all the possible actions of the robotic agent for it to perform satisfactorily. However, with technological development, robots began to be used for other purposes in dynamics environments, as with entertainment (games), medicine (surgery), and performing tasks in dangerous or inaccessible environments to human (e.g., space and underwater). In this context, our purpose is to develop autonomous mobile robots to do a great number of complex tasks, that theirs predecessors (industrial robots) could not realize.

The main limitation working with these robots is on how to control them, i.e., how to develop algorithms able to operate these complex machines. Complexity grows even more when we take into account, not just one robot, but a team of robots. Techniques are then required to enable them to interact effectively with their environment. An essential part of this interaction is the path planning module, that allows each robot to find its own way in the environment.

Oriented Potential Fields (OPF) proposed by [3], Equation 1, and Locally Oriented Potential Fields (LOPF)[1] proposed by [2], Equation 2, are path planning techniques based on numerical solutions of Boundary Value Problems which generate a given trajectory of a particular Elliptic Partial Differential Equation. The first is applicable to only one robot, however, for each robot to be controlled, a process (a thread with it's own map, consequently, with it's own grid to be relaxed) could be created. And using the second method, many robots can be controlled in a same process, in a same grid.

As shown in [1], these techniques have a limitation in a crucial aspect of the PDE that directs the behavior of the robots [2] (see Figure 1(a)). This limitation arise from the linear system solver (LSS) utilized. In this work, Jacobi-Richardson and Gauss-Seidel are utilized. To guarantee the convergence of these LSS using central differences, must be imposed $|\epsilon(x,y)| \leq 2$ (see Figure 1(b)).

$$\nabla^2 P + \epsilon \langle \nabla P, v \rangle = 0 \tag{1}$$

with $\epsilon \in \mathbb{R}$, $v \in \mathbb{R}^2$ and $||v|| = 1$.

$$\nabla^2 P(x,y) + \epsilon(x,y) \langle \nabla P(x,y), v(x,y) \rangle = 0 \tag{2}$$

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[1]Can be viewed that with $\epsilon(x,y)$ and $v(x,y)$ constants, the LOPF method has the same behavior of OPF.

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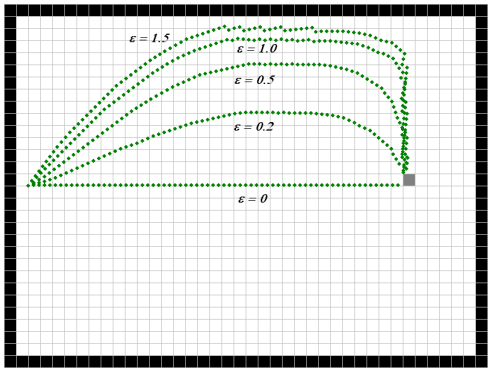
where

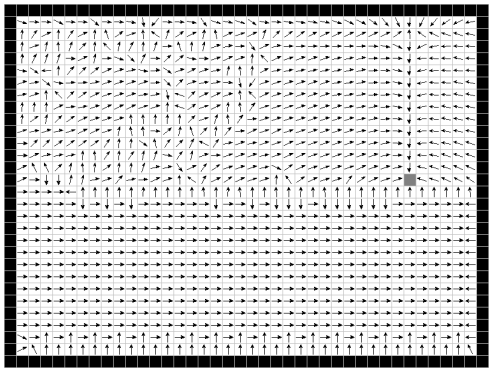
$$\epsilon(x,y) = \begin{cases} \epsilon_k & \text{with } \epsilon_k \in \mathbb{R}, \text{ if } (x,y) \text{ is inside the} \\ & \quad \text{area of influence of robot } k \\ 0 & \text{otherwise} \end{cases}$$

and,

$$v(x,y) = \begin{cases} v_k & \text{with } v_k \in \mathbb{R}^2, \text{ and } ||v_k|| = 1, \text{ if } (x,y) \text{ is inside the} \\ & \quad \text{area of influence of robot } k \\ \overrightarrow{0} & \text{otherwise} \end{cases}$$



(a) Comparison among some trajectories followed by the agent. (The gray square is the goal and, a square in left is the start point of robot)



(b) With $\epsilon = 4$. There are points that doesn't have a path until the goal.

Figure 1: OPF: Several influence rates ϵ with $\mathbf{v} = (0, 1)$ [2]

In this work, a different numerical procedure is shown, utilizing the upwind scheme for Equations 1 – 2, which is proved to avoid the limitation described in [1]. The limitation is therefore not from the OPF or LOPF methods but from numerical methods used.

In this way, it has became possible to create new behaviors (only by using $\epsilon \geq 2$) of the robots. These behaviors are evaluated and tested.

Keywords: *Path Planning, Path Planning BVP based, Numerical Methods, Robotics*

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