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Tangent navigated robot path planning strategy using particle swarm optimized artificial potential field

Zhiyu Zhou [a,*], Junjie Wang [a], Zefei Zhu [b], Donghe Yang [a], Jiang Wu [a]

[a] School of Science Information and Technology, Zhejiang Sci-Tech University, Hangzhou, Zhejiang 310018, China
[b] School of Mechanical Engineering, Hangzhou Dianzi University, Hangzhou, Zhejiang 310018, China

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ABSTRACT

Artificial potential field has long been proposed in the field of robot path planning. But the well-known drawbacks like local minimal problem and low efficiency prevent its wide application. In this paper, we propose a particle swarm optimized tangent vector based artificial potential field path planning algorithm (PSO-TVAPF) to solve those problems. A tangent vector based on obstacles' information is added into artificial potential field (APF) model as an auxiliary force for obstacle avoiding process. This makes the original model, tangent vector based artificial potential field (TVAPF). To achieve more intelligent and efficient TVAPF, map and path information are taking into consideration dynamically while calculating tangent vector. In addition, particle swarm optimization has been used to refine TVAPF, which leads to the final model named PSO-TVAPF. Simulation experiments and physical validation results indicate that the proposed algorithm can overcome classic APF's drawbacks and improve path planning efficiency significantly.

1. Introduction

Robot path planning [1–3] is an important research field in robot automation and is also the foundation of quantities of robot tasks. It has been proved that they can help human beings in many works, such as handling cargos, cleaning, inspecting, autonomous underwater vehicle research [4,5], etc. The wide application and bright prospect makes path planning of wheel mobile robot an important research field.

In this paper, we propose a new approach called tangent vector based artificial potential field (TVAPF) and it is optimized model using particle swarm optimization (PSO-TVAPF) for path planning in mobile robots. The TVAPF proposal is based on artificial potential field (APF) enhanced with a tangent vector which figures out according to obstacles interactively. The path planning with TVAPF proposal consider the obstacle avoiding problem at its beginning different from most APF algorithm they start to go round obstacle at a very close distance. By this way, our algorithm eliminate local minimal problem and shorten total path length. To achieve more intelligent and efficient TVAPF, map and path information are taking into consideration dynamically while calculating tangent vector. In addition, particle swarm optimization has been used to refine parameters of TVAPF.

The rest parts of this paper are organized as follow. In Section 2, some basic theories and previous research results related to our works would be introduced. In Section 3, we give a detailed description about our proposed algorithms, TVAPF and

* Corresponding author.
E-mail address: zhouzhiyu1993@163.com (Z. Zhou).

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PSO-TVAPF, in robot path planning. Experiment results presents in Section 4, where we first compares four RPP approaches, APF, BPF, TVAPF and PSO-TVAPF on a MFC simulation program and then validate our algorithm on a wheel mobile robot produced by Ingenious Corporation. At last, a conclusion is given to summarize our algorithm in this paper.

2. Related works

Robot motion planning launched at mid-1960s, but it was not until Lozano-Prezs revolutionary contribution on spatial planning that MP drew most researchers' attention. In the past few decades, researchers in the field of mobile robot path planning have put forwarded many algorithms, which has been dominated by classical approaches such as the roadmap, cell decomposition and artificial potential field (APF). Representative proposals of roadmaps approaches are the visibility graph which is a collection of lines in the free space that connects the trait of an object to another; the Voronoi diagram of a collection of geometric objects is a partition of space into cells, each of which consists of the points closer to one particular object than any other. The idea of cell decomposition algorithm is to decompose the C-space into a set of simple cells, and then compute the adjacency among cells [6]. The given classification is as follows: probabilistic, heuristic and meta-heuristic approaches. In the former are the probabilistic roadmaps, rapidly-exploring random trees, level set and linguistic geometry. In the heuristic and metaheuristic approaches are the neural networks, genetic algorithm (GA) [7], simulated annealing [8], ant colony optimization [9], particle swarm optimization [10,11]. All the mentioned methods have their own strengths and drawbacks; they are deeply connected to one another, and in many applications, some of them were combined together to derive the desired robotic controller in the most effective and efficient manner.

The APF model was first put forward by Khatib [12] in 1986. Originally, APF was used on robot manipulators for obstacles avoidance, through the time, it has been well adopted for mobile robot path planning, an example is presented in [13]. The primary idea of APF is to construct a gravitational and repulsion field reflecting the obstacles and target in the working space which drive the mobile robot to find the goal. Local algorithms are usually based on APF due to its simple implementation and low processing needs, but it has a problem of local minima [14]. To eliminate local minimal problem, researchers have done efforts in two aspects. One kind of solution is to make change when local minimal problem appears, such as APF-B. It walks following the obstacle while local minimal happen. A BUG algorithm is introduced into the artificial potential field to escape from the local minima [15]. It can solve local minimal problems efficiently, but APF-B do not consider path length which usually get a longer path. Another kind solution is to improve APF with optimation approaches. One of them is evolutionary artificial potential field (EAPF) [16], here, the APF method is combined with GAs to derive optimal potential field functions [17]. The variation planning approach uses the potential as a cost function, and it attempts to find a path to reach the goal point that minimizes this cost [18]. [4] propose a novel artificial potential field (APF) method with a bacterial evolutionary algorithm (BEA) to obtain an enhanced flexible path planner method taking all the advantages of using the APF method, strongly reducing its disadvantages. Those two kinds improvement of APF can eliminate its drawbacks to a certain extent, but both of them has disadvantages. APF-B sacrifices path length to avoid local minimal. EAPF and BPF combine APF with optimal approaches can find a shorter path, but its convergence time is not sure especially for some difficult solve local minimal problems.

Inspired by pre-mentioned two kinds of enhance strategy and a visibility graph path planning algorithm [19], we make two aspects improvement of traditional APF to eliminate local minimal problems and shorten path length. To achieve those improvements, a novel path planning algorithm named TVAPF was proposed in which we added a tangent vector based on the obstacles in the map into the traditional APF model. The later experiment results indicated that our new approaches can perfectly solve those problems. In addition, we also give an enhanced edition of our path planning method TVAPF under the situation that global information was entirely available. Particle swarm is adopted to optimize the TVAPF model which leads to PSO-TVAPF. We also make enhance on traditional PSO. Numerous experiment data of parameters of optimized TVAPF is recorded as heuristic knowledge, while PSO initial particle and search for global best particle. We add the probability and search density particle appear in the optimal section when initial and the process of search for global best particle. The following experiment results verified that it makes a great promotion on TVAPF.

In order to make readers understand what have been done quickly and easily, this section will introduce some associated theories and path planning algorithms briefly. In Section 2.1, classical APF will be introduced. Section 2.2 is a concise description about PSO. Section 2.3 list the algorithm of EPA.

2.1. Artificial potential field

Artificial potential field (APF) [12] is commonly used in the field of robot path planning. The most prominent advantage of APF algorithm is briefness. APF model consists of two kind of potential field, the gravitational and repulsion field which based on the obstacles and the goal respectively corporately attract robot complete path planning. The trajectory generated by APF is smooth in mathematic which that mean the tangent and the velocity is always continuous. Those two characteristics improved robot stability during the motion process. Attraction field, $U_{Att}(q)$is construct as the following equation,

$$U_{Att}(q) = \frac{1}{2} k \rho^2(q, q_{goal}) \tag{1}$$