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Automatic Path Planning of Industrial Robots Comparing Sampling-Based and Computational Intelligence Methods

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Abstract

In times of industry 4.0 a production facility should be "smart". One result of that property could be that it is easier to reconfigure plants for different products which is, in times of a high rate of variant diversity, a very important point. Nowadays in typical robot based plants, a huge part of time from the commissioning process is needed for the programming of collision free paths. This mainly includes the teach-in or offline programming (OLP) and the optimization of the paths. To speed up this process significantly, an automatic and intelligent planning system is necessary. In this work we present a system which can plan paths for industrial robots. We compare widely used sampling-based methods like PRM or RRT with Computational Intelligence (CI) based methods like genetic algorithms.

Keywords: Path Planning, Industrial Robots, Intelligent and Flexible Manufacturing, Genetic Algorithm

1. Introduction

Industry 4.0 robotic facilities should be flexible and easy to reconfigure. The term describes the change of production facilities to smart factories [1]. State of the art robotic cells are programmed for a special task which

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clearly defines all necessary steps and can only react to small deviations in the process. Reconfiguration means downtime of the production and programing of the robots which can either be done on the real hardware or in an offline programming tool like DELMIA or RobCAD. In both cases this means the facility cannot be used. According to the complexity of the new process the programming can need quite a long time.

2. Related Work

In general there are not very many publications in the area of 3D path planning for industrial robots. Suh et al. [2] and Chen et al. [3] present a system for the automatic path planning of spray robots for a consistent application. However the method is very specialized and only applicable for the proposed scenario. Ting et al. [4] and Klanke et al. [5] show an approach using wave expansion method. Oh et al. [6] combine a support vector machine with a Rapidly Exploring Random Trees (RRT) algorithm for a 6-DOF industrial robot. Qin et al. [7] use a randomized parallel search algorithm for a PUMA 200 robot.

Compared to the small number of publications for realistic path planning problems with actual industrial robots there is a huge amount of publications for robots with a high degree of freedom (DOF). The primary goal was to find complete planners which means that the planner will find a path if one exists. Due to the high computation amount these kinds of planners only work for robots with a small DOF [8]. Today sampling-based planners are often used, whose advantage is that not the complete collision free room is constructed in advance. Instead the space is just examined at specific positions called samples for collisions. Sampling-based algorithms have been treated in a great number of publications like [9] [10] [11]. The most famous are Probabilistic Roadmaps (PRM) and RRT.

In general there are a manageable number of publications using Genetic Algorithms (GAs) for path planning. A popular use case of GA is in the area of mobile robots [12] [13]. In this field the planning is reduced to a 2D problem because the robots are not able to move in z-direction. Another application of GAs can be found in the area of 2D manipulators [14] [15]. In [16] [17] [18] GAs are used for path planning of industrial robots. Mostly the mapping of the robot in the simulation is done with a very reduced model which just represents the kinematic of the robots and not the real 3D structure because the collision detection can be very CPU-intensive.

3. Automatic Path Planning of Industrial Robots

3.1. Implementation

In [19], [20]and [21] the CoCo (**Co**llision-free **Co**operation) simulation environment has been introduced and stepwise improved. It has been developed using the C# programming language. For the visualization of 3D objects the Helix Toolkit [22] is used which has been combined with BEPUphysics [23] library for collision detection. To speed up the calculation internally the objects are represented as convex hull (see Fig. 2c). For sampling-based path planning the Open Motion Planning Library (OMPL) [24] has been integrated into CoCo. OMPL itself does not have a visualization or collision detection mechanisms which allows integrating the library into systems that provide these functionalities. In our case the CoCo collision detection callback method is registered in OMPL. OMPL consists of many state-of-the art sampling-based motion planning algorithms like Probabilistic Roadmaps (PRM), Rapidly Exploring Random Trees (RRT), RRTconnect, RRT*, SPArse Roadmap Spanner (SPARS) and many more. For the implementation of GA planners we used the AForge [25] library as basis which is also written in C# and provides a lot of functions for Computer Vision and Artificial Intelligence e.g. neural networks, genetic algorithms, machine learning, etc..

3.2. Path Planning

In general collision-free path planning means: (a) avoid collisions between obstacles and the robots, and (b) optimize the path according to predefined constraints like path length or smoothness. Given that the GAs work in Cartesian space also called SE(3) space we also used that space for the sampling-based planners to have a good comparability.