Chapter 18

Trajectory Planning and Control Algorithms of Mobile Robots for Static Environments

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ABSTRACT

In this chapter, different types of trajectory control and planning algorithms for mobile robots in static environments are analyzed and assessed. To this end, a mobile robot is made to plan and follow a route between two arbitrary points in an autonomous way. This work goes in depth into the discrete space techniques and those based on search trees. First, kinematics, trajectory planning and contour maps, robot control, etc. are reviewed. Second, computer simulations that validate these theoretical results are also designed and implemented. Finally, the strengths and weaknesses of each trajectory planning methodology are assessed.

INTRODUCTION

Currently, the development of mobile robotics has undergone substantial progress in terms of construction, programming, and adaptation to different environments. Therefore, autonomous mobile robots operated remotely or programmed only for a specific operation are now easily found in the market.

These mobile robots are aimed to improve the workers quality of life, because they can substitute workers in carrying out tedious and dangerous jobs, as well as performing operations where human access is limited. Some of these tasks are cleaning and inspecting air ducts, supervision of mining exploration, cleaning windows of buildings and households, transporting heavy objects, military applications such as mine deactivation and espionage, and space research, among others.

However, there are some problems in the programming and implementation of algorithms needed to ensure a good functioning of these mobile robots, such as location, mapping, trajectory planning, and control (Pant, Kumar, Kishor, Anand, & Singh, 2015; Kumar, Pant, & Singh, 2016; Kumar, Pant, & Singh, 2017).

DOI: 10.4018/978-1-5225-5709-8.ch018
When developing kinematic models of mobile robots, the anatomy of the robot, as well as the holo-
nomic arrangement and characteristics of each of its wheels need to be taken into account. In this respect,
the literature points to different robot models, such as four fixed wheels, differential traction (Ayari &
Chatti, 2007; Kumar, Pant, & Ram, 2017), and omnidirectional robots (castor, spherical, Swedish wheels).

A variety of control techniques exist for making robots follow a reference trajectory or move from
one point to another. In this field, some mathematical methods are found to correct the existing error
between the reference and the real route (pure prosecution, geometric methods, and linear and nonlinear
control laws). In addition, there are more advanced control mechanisms such as adaptive PID controllers,
fuzzy control, neural networks, and neuro-fuzzy controllers, among others.

At the time of localizing the mobile robot, it is possible to use techniques based on odometry (encod-
ers, ultrasonic and infrared sensors, GPS, etc.) and visual marks (Bhatnagar, Rastogi, & Kumar, 2013;
Kumar, Pant, Ram, & Singh, 2017). In this context, to achieve a correct localization and be able to trace
the trajectories of a mobile robot, we must know the surroundings in which the robot is moving. To better
know these surroundings, map drawing is fundamental (Pant, Kumar, & Ram 2017; Pant, Kumar, Singh,
& Ram, 2017). Finally, another important factor that must be tackled is trajectory planning, which consists
of determining a precise trajectory within the workspace of the mobile robot using a set of actions and
states. To this end, an initial and a final position are considered in such a way that the mobile robot does
not collide with the obstacles that have been placed in the map of the surroundings. The determination
of this trajectory must also fulfill the kinematic restrictions of each robot.

KINEMATICS OF THE MOBILE ROBOT IN THIS STUDY

The position of the mobile robot considered in this study can be established by means of a relation
between the global reference system (Figure 1a) and a local reference system (Figure 1b) of the robot.

Point P of Figure 1b denotes the local reference system, while the global position of the robot is
described by means of a three-element vector $\xi_G = \begin{bmatrix} x \\ y \\ \theta \end{bmatrix}^T$, where coordinates $x$ and $y$ correspond
to the position of P in the global reference system, and $\theta$ is the angular difference between the global
and the local reference systems.

To obtain the robot’s movements and express them in the global reference system, motion is mapped
based on the local reference axes. Mapping is achieved through the robot’s orthogonal rotation matrix,
so from Figure 1b we obtain Equation (1) and Equation (2).

$$
\begin{bmatrix}
{x}_L \\
{y}_L \\
\theta
\end{bmatrix} =
\begin{bmatrix}
\cos(\theta) & \sin(\theta) & 0 \\
-\sin(\theta) & \cos(\theta) & 0 \\
0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
{x}_g \\
y_g \\
\theta
\end{bmatrix}
$$

(1)