# Chapter 5
# Motion Planning of Non-Holonomic Wheeled Robots Using Modified Bat Algorithm

**Abhishek Ghosh Roy**
*IIT Kharagpur, India*

**Pratyusha Rakshit**
*Jadavpur University, India*

## ABSTRACT

*The chapter proposes a novel optimization framework to solve the motion planning problem of non-holonomic wheeled mobile robots using swarm algorithms. The specific robotic system considered is a vehicle with approximate kinematics of a car. The configuration of this robot is represented by position and orientation of its main body in the plane and by angles of the steering wheels. Two control inputs are available for motion control including the velocity and the steering angle command. Moreover, the car-like robot is one of the simplest non-holonomic vehicles that displays the general characteristics and constrained maneuverability of systems with non-holonomicity. The control methods proposed in this chapter do not require precise mathematical modeling of every aspect a car-like system. The swarm algorithm-based motion planner determines the optimal trajectory of multiple car-like non-holonomic robots in a given arena avoiding collision with obstacles and teammates. The motion planning task has been taken care of by an adaptive bio-inspired strategy commonly known as Bat Algorithm.*

## INTRODUCTION

Population increase in large cities results an increase in the number of vehicles used by the community which causes an increased demand for autonomous motion planning for commuter vehicles. Complications like closed parking bays, dense traffic, and driving fatigue are very common in city life. Parking of a car in a parking lot may be agreed to be one of the most complex parts of the driving action. By the help of the improvements in computer technology, automatic control of local vehicle maneuvers to obtain a self-parking action is no more a fantasy. Most of the research about this subject is done to develop a

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self-parking strategy and some to develop driver aid systems. The studies about self-navigating cars and mobile robots are also important because of the similar control techniques that are used.

The motion planning problem considered here aims at determining a continuous collision-free path for transportation of *n* car-like robots from their given starting positions to fixed goal positions in an arbitrary rigid polyhedral environment by application of appropriate steering angles (Daxwanger & Schmidt, 1996; Miyata et al., 1996; Motoji & Akira, 1995; Moran & Nagai, 1995; Kong & Kosko; Laugier et al., 1999; Roy et al., 2013). The paths of the car-like robots can be determined globally or locally. The local planning is more flexible to its global counterpart because of its capability to take care of dynamic obstacles. Moreover, small time is required in local planning to identify the next position of the car-like robots only, rather than deriving the entire trajectory of their motion. Consequently, in this chapter, the local planning is addressed to solve the motion planning problem.

The kinematics of non-holonomic car-like systems are represented by constraint equations concerned with the time derivatives of the system configuration variables. Unfortunately, such systems suffer from the difficulty of non-integrability of the constraint equations when the number of control inputs is less than the configuration variables (De Luca et al., 1998). It thus restricts the application of the classical geometric techniques for motion planning for non-holonomic car-like systems. Moreover, till today, there is no general motion-planning algorithm for any non-holonomic system to ensure their successful arrival at given goal configurations. The existing approximate methods (Dubins, 1957; Laumond et al., 1998) guarantee only the system reaches a neighborhood of the goal. It thus paves the way for applying evolutionary and swarm optimization techniques together with geometric methods to address the motion planning of the non-holonomic car-like.

This chapter considers a swarm optimization framework for motion planning of non-holonomic car like systems of definite size. The starting and the goal positions of each car-like robot on the grid map are given, and a swarm algorithm is used to locally plan their trajectory of motion with an aim to minimize the total path traversed without collision with obstacles and teammates. Constraints due to obstacles are expressed directly in the manifold of configurations. The non-holonomic constraints in the tangent space linking the parameter derivatives (Laumond et al., 1998) are also considered during development of the optimization framework of the present motion planning problem.

Any traditional swarm algorithm can be selected to solve the problem. We have here selected *bat algorithm* (BA) (Yang, 2010; Yang & Gandomi, 2012; Yang & He, 2013; Chowdhury et al., 2014) in the present context for its proven merits in global optimization. Some of the attractive features of BA, justifying its selection in the design of motion planning algorithm for car-like robots, include its structural simplicity with ease of coding and faster convergence with respect to other swarm/evolutionary algorithms. Recently, BA (Yang, 2010; Yang & Gandomi, 2012; Yang & He, 2013; Chowdhury et al., 2014) has gained immense popularity in the domain of population-based metaheuristic search algorithms by effectively employing the swarm behavior of bats to solve complex multi-modal real-world optimization problems. However, there exists literature indicating that BA may often get trapped at the local optima primarily due to its fixed step-size control parameter (Chowdhury et al., 2014). On the other hand, accurate tuning of the step-size over its possible span [0, 1] by trial and error process may improve the performance of the BA, however, at the computational cost. Therefore, it is desirable to adapt the values of these parameters over generations. In this chapter, we propose a modified BA (MBA) to gradually self-adapt the values of step-size over generations by learning from their previous experiences in generating quality solutions (locations of bats). Consequently, a more suitable value of step-size can be determined adaptively to match different search phases.

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