

Chapter 23

Optimal Robot Path Planning With Cellular Neural Network

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ABSTRACT

This paper presents a new methodology based on neural dynamics for optimal robot path planning by drawing an analogy between cellular neural network (CNN) and path planning of mobile robots. The target activity is treated as an energy source injected into the neural system and is propagated through the local connectivity of cells in the state space by neural dynamics. By formulating the local connectivity of cells as the local interaction of harmonic functions, an improved CNN model is established to propagate the target activity within the state space in the manner of physical heat conduction, which guarantees that the target and obstacles remain at the peak and the bottom of the activity landscape of the neural network. The proposed methodology cannot only generate real-time, smooth, optimal, and collision-free paths without any prior knowledge of the dynamic environment, but it can also easily respond to the real-time changes in dynamic environments. Further, the proposed methodology is parameter-independent and has an appropriate physical meaning.

INTRODUCTION

Real-time collision-free motion planning in a non-stationary environment is an important and challenging issue in many autonomous systems including robotics and intelligent systems. It provides intelligent robotic systems with an ability to plan motions and to navigate autonomously. This ability becomes critical particularly for robots which operate in dynamic environments, where unpredictable and sudden changes may occur. Whenever the robot's sensory system detects a dynamic change, its planning system

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has to adapt and modify its paths accordingly. Prominent examples include real world environments that involve interaction with people, such as museums, shops, and households.

Based on the analogy between cellular neural network (CNN) and robot path planning, this paper presents a new neural dynamics based methodology for optimal collision-free robot path generation in an arbitrarily varying environment. The real-time collision-free robot trajectory is formulated as the dynamic CNN activity. The target activity is treated as an energy source injected into the neural system, and is propagated in the state space by neural dynamics. By formulating the local connectivity of cells as the local interaction of harmonic functions, an improved CNN model is established to propagate the target activity within the state space in the manner of heat conduction, which guarantees the target and obstacles remain at the peak and bottom of the activity landscape, respectively. The proposed neural network model cannot only generate real-time, smooth and optimal robot paths without learning procedures, prior knowledge of target or barrier movements, optimizations of any cost functions, and explicitly searching over the free work space or collision paths, but it can also easily respond to real-time changes in dynamic environments. Further, the proposed neural network model is parameter-independent and has an appropriate physical meaning.

RELATED WORK

The earliest work on robot path planning was by Lozano-Perez and Wesley (1979), who presented a path planning algorithm to avoid polyhedral obstacles based on a visibility graph. Since then, various approaches have been studied, especially during the past twenty years. Plenty of global approaches such as decomposition, road-map, distance transform and retraction methods, randomized approaches and genetic algorithms were reported to search the possible paths in the work space (Latombe, 1991; Hwang & Ahuja, 1992; Zelinsky, 1994; Henrich, 1997). A number of local methods such as potential field methods were also reported (Khatib, 1986; Barraquand & Latombe, 1991; Glasius, Komada, & Gielen, 1994; Li & Bui, 1998). Oriolo et al. (1998) proposed a method by combining global and local approaches for robot path planning, in which a global path planning plus a local graph search algorithm and several cost functions are used. Seshadri and Ghosh (1993) presented a path-planning model by using an iterative approach. This method is computationally complicated, especially in a complex work space. Ong and Gilbert (1998) presented a method for robot path planning with penetration growth distance. This method searches over collision paths instead of the free space, and it can generate optimal and continuous robot paths only in a static environment. In general, although most of the above methods can generate the accessible path with free collision in the work space, they can only deal with the static environment. A moving object or introduction of new objects requires that the whole work environment be constructed dynamically. In addition, with the increase of obstacles, the complexity of the algorithms increases exponentially.

Neural network based methods have received considerable attention for generating real-time robot paths. There is a number of learning based neural networks reported for mobile robot path planning (Svestka & Overmars, 1997; Zalama et al., 1995, 2002; Quoy, Moga, & Gaussier, 2003; Lebedev, Steil, & Ritter, 2005). These learning based approaches are time-consuming in operation, and the generated paths are not optimal, particularly during the initial learning phase (Willms & Yang, 2006). To avoid the

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