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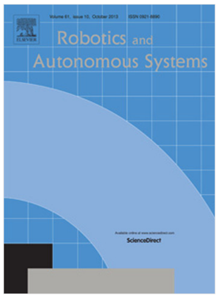

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A Self-Navigating Robot using Fuzzy Petri nets

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Abstract

Petri nets (PNs) are capable of modeling nearly any conceivable system and can provide a better understanding of the idealized action sequence in which to most effectively describe or execute said system through their powerful analytical capabilities. However, because real world instances are rarely as consistent and ideal as simulated models, basic PN modeling and simulation properties may be insufficient in practical application. We remedy this through specialization in Fuzzy Petri nets (FPNs). Fuzzy logic is incorporated to better model a self-navigating robot algorithm, thanks to its versatile multi-valued logic reasoning. By using FPNs, it is possible to simulate, assess, and communicate the process and reasoning of the navigational algorithm and apply it to real world programming. In this paper, we propose a series of specific fuzzy algorithms intended to be implemented in concert on a mobile robot platform in order to optimize the sequence of actions needed for a given task, primarily the navigation of an unknown maze. A set of varied maze configurations were developed and simulated as PN and FPN models, providing a testing environment to examine the efficiency of several methodologies. Five methods, including an original proposal in this paper, were compared across 30,000 simulations, evaluating in particular performance in processing cost in time. Our experiments concluded with results suggesting a very competitive task completion time at a considerable fraction in processing cost compared to the closest performing alternatives.

Keywords: Petri nets, Fuzzy Petri nets, Fuzzy Logic, Modeling and Simulation, Autonomous Robot Navigation

1 Introduction

Safe and effective path planning for mobile robots has been one of the most pervasive challenges in automated robotics and navigation. For many proposed solutions, research has been dedicated to optimizing the array of finite resources and knowledge a robot platform possesses when faced with unknown and even known environments. These resources typically consist of sensory input (the ability of the robot to perceive the surrounding environment), motor control (the ability of the robot to mobilize itself), and processing expenses (the amount of computational exertion required by the robot to organize and retain the information needed to function). As mobile robots gain greater autonomy in more varied tasks, these resources quickly become constraints.

Consequently, the responsibilities delegated to automatons are dependent on response time and contextual reasoning; the capability to adapt and overcome unforeseen variables or complications in a reasonable timeframe. The 2005 World's Fair, for instance, featured robot receptionists and tour guides, occupations with a heavy emphasis on socialization and maneuverability [8]. The ability to navigate independently and spontaneously in a crowded environment as well as respond to simple questions with people is an integral part of their duties. The successful demonstration of these robots is a wonderful proof of concept that with a high level of reasoning, a robot's potential is limited only by its physical capabilities. As such, engineers and scientists must overcome the challenge of modeling, simulating, and implementing flexible reasoning programming for these robots in an intuitive manner.

Using a Petri net (PN) model, it is possible to design an extensive model of autonomous navigation behavior. PNs provide a graphical and mathematical representation of a chain or series of events, making it a valuable tool for conveying processes visually and simulating algorithm runs. When used in tandem with fuzzy logic reasoning, a fuzzy PN (FPN) model enables an algorithm to receive and evaluate many levels of data precision and independently draw conclusions from them, mimicking or likening it to the thought process of a person [10]. This FPN model can provide the fundamental basis for a wide variety of algorithms, including autonomous robot navigation.

The remainder of this paper is organized as follows: Section 2 summarizes the state of recent literature in autonomous robot navigation. Section 3 provides an overview of the fundamental concepts of Fuzzy Petri nets while Section 4 discusses its application in development of navigational algorithms, particularly in an environment for a firefighting robot. Section 5 introduces past and newly proposed navigational algorithms with the developmental process and logic behind them. Section 6 demonstrates

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