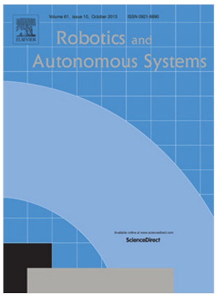

Reactive versus cognitive vehicle navigation based on optimal local and global PELC*

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Reactive versus Cognitive Vehicle Navigation based on Optimal Local and Global PELC*

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Abstract

This paper addresses the challenging issue of determining the most suitable control strategy (planning-decision-action and their interactions), for autonomous navigation of vehicles which must deal with different environments contexts (e.g., cluttered or not, dynamic or not, etc.). The paper's main proposals are decomposed into two main parts: Firstly, the proposition of reliable and flexible components to perform short and long-term planning: at beginning, a generic and safe path planning-based on Parallel Elliptic Limit-Cycle (PELC) and its multi-criteria optimization (PELC*) have been proposed to perform either reactive or cognitive navigation. Afterwards, it is proposed to suitably sequence several PELC/PELC* in order to obtain an optimal global path-based on PELC (gPELC*). Secondly, this paper proposes an overall Hybrid (reactive/cognitive) multi-controller architecture for autonomous navigation using PELC* and gPELC*. This architecture has been designed in order to use a uniform set-points convention and a common control law to perform several sub-tasks (e.g., obstacle avoidance, target reaching/tracking, path following, etc.). A multitude of simulations and a real experiment have been performed in order to confirm the potentialities of the overall proposed methodology.

Keywords: Autonomous vehicle navigation, Hybrid (reactive/cognitive) control architecture, Obstacle avoidance, Limit-cycle approach, Local and global path planning, Multi-criteria optimization, Optimal planning.

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1. Introduction

To perform fully autonomous robot navigation, while having accurate perception and localization capacities [1] [2] [3], the robot must also have the ability to be controlled online in different kinds of environments (e.g., cluttered or not, dynamic or not, uncertain or not, etc.) and to react safely to unpredictable events. Thus, the used control architecture must permit us to answer this important question "*How do we reach safely and efficiently a predetermined location in an environment while taking into account available environmental knowledge (the road limits for instance) and reacting online to unpredictable events (e.g., other robots, obstacles, etc.)?*".

Furthermore, it is not sufficient to guarantee only the reliability and the safety of the navigation; the robot must also ensure, in transportation applications for instance [4] [5], smooth navigation for the comfort of the passengers. In [6], the author characterizes this smooth navigation while using a cost function which reflects the trade-off between the travel time and the integral of acceleration (which characterizes the jerking amount of angular and linear robot velocities). Fully autonomous navigation needs therefore to satisfy simultaneously a multitude of criterion. For this aim it is important to have a reliable, safe and flexible control architecture [7]. Several navigation strategies (using dedicated control architectures) have been proposed in the literature. They permit autonomous navigation even in dynamic and cluttered environments. This means that "obstacle avoidance" function is always an important primitive and is tightly inherent to the performed autonomous navigation strategy. Thus, special attention should be taken for its development [7]. The generic proposed obstacle avoidance primitive will be detailed in section 3.1.1.

1.1. Reactive versus cognitive control architecture

Control architectures can be split into two categories: Cognitive and Reactive. The cognitive (or deliberative) architectures make their main focus on the path/trajectory[1] planning and replanning [8], while generally taking into account the overall environment knowledge. The obtained trajectory takes into account all obstacle configurations (and maybe their dynamic) in the planning step. In fully cognitive navigation, once a trajectory is obtained, the robot follows it as accurately as possible using the dedicated or generic control laws, for instance using the well-known laws proposed in [9] or [10]. A multitude of methods exist in the literature to deal with path/trajectory planning, among them: Artificial Potential Field (APF) [11]; Voronoï diagrams [12]; visibility graphs [13]; navigation functions [14] or planning based on grid map [2]; Rapidly-exploring Random Tree (RRT) [15], Sparse A* Search (SAS) [16]. It is commonly used in cognitive control architectures a pre-planned reference trajectories, which means that they are properly selected before robot movement [17]. The majority of the cited techniques could be used even for short or long-term path/trajectory planning. In the first case, these techniques could be used for reactive navigation. The focus will be made in what follows on the case of global path/trajectory planning

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[1] It is to be noted that the term trajectory or path are used according, respectively, if the time is taken or not into account during the planning phase.