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Report on the Ph.D. thesis of **Rafal Mateusz SOBAŃSKI** :

"Cooperative distributed navigation for wheeled mobile robots using the Vector Field Orientation approach under time constraints"

The Ph.D. thesis of Rafal Mateusz SOBAŃSKI presents the design of algorithms for the cooperative control of mobile nonholonomic robots. The main contributions of the manuscript are : 1) the development of a Vector Field Orientation control law for nonholonomic robots that guarantees fixed time performances; 2) the adaptation of the control law to the multi-agent systems formalism; 3) the formal stability analysis and the corresponding numerical and experimental validation. The manuscript of 96 pages is written in English and is structured in four chapters containing the state of the art, preliminaries, theoretical contributions faor a single robot and for multiple robots, and the numerical and experimental validations. The document starts with some mathematical preliminaries on fixed-time stability, control of nonholonomic robots and the control of multi-robot systems.. The second chapter focuses on the control design for a single robot described by an unicycle dynamics. We find here both the theoretical developments and the numerical validation of the main results The theoretical contributions related to multi-vehicle setup composed of nonholonomic systems are presented in the third chapter. The chapter contains the problem formulation, an observer based formation algorithm, a consensus based formation algorithm and the numerical validation of the main results. Some general conclusions and perspectives are drown in Chapter 4 at the end of the manuscript.

The first chapter of the manuscript introduces some preliminary concepts on fixed-time stability, control of nonholonomic systems and control of multi-agent systems which are essential for the understanding of the subsequent developments of the candidate.
Chapter 2 presents the main results related to the control of a single unicycle dynamics. Precisely the chapter presents two designs for the controller of unicycle systems allowing to achieve a set-point in fixed-time and track a prescribed trajectory in fixed-time, respectively. Both controllers are based on Vector Field Orientation methodology. In a first stage a nominal control law is designed without taking into account the control input constraints. In a second step the candidate proposes a post-processing that uses a scaling procedure in order to meet the imposed control constraints. Numerical simulations with Matlab-Simulink are validating the theoretical results.
Chapter 3 focuses on the control design for a multi-agent system composed of unicycle vehicles. The candidate proposes two approaches for the formation control. First an observer based approach is presented. In this approach the set-point fixed-time VFO control law is successfully applied. Next, a consensus based approach is designed and discussed. Numerical validations ends this chapter.
General conclusions and brief research perspectives are presented in Chapter 4 at the end of the manuscript.

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In his Ph.D. thesis, Rafal Mateusz SOBAŃSKI presents a collection of impactful research works on the cooperative distributed navigation for nonholonomic multi-vehicle systems. The presented results have a strong theoretical background but they also have a clear practical application. The proposed research perspectives are timely, relevant and promising.

In conclusion, from my reading of his Ph.D. thesis and from my evaluation of his track record, I can say that Rafal Mateusz SOBAŃSKI got good results and I recommend/authorise the defense of his manuscript.

Yours sincerely,
Constantin Morărescu