Doctoral thesis – opponent's evaluation report

Title: Demonstration-based Optimal Control of Nonlinear Systems

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Evaluator: doc. RNDr. Tomáš Bárta, Ph.D.

The thesis deals with algorithms for finding an optimal control in nonlinear systems of ordinary differential equations. The aim is to find a control function that steers the system from a given set of initial states to a given set of goal states and avoid the set of obstacles on the way. The starting point of author's research is the LQR-tree algorithm introduced by R. Tedrake which enables practical applications of the theoretical results of the control theory, e.g. in robotics. In the thesis, this algorithm is improved in several ways, theoretical and practical.

The thesis consists of eight chapters. Short chapters 1, 2 and 8 contain respectively introduction, summary of author's contribution, and conclusion. Chapter 3 introduces the reader to theoretical basis of the control theory and LQR-trees. The remaining four chapters are based on author's research papers. Chapter 4 studies the original algorithm more deeply than preceding works and presents a proof of reachability and optimaility of the algorithm. Chapter 5 introduces switching of demonstrations and reachability certificate, two improvements of the algorithm that make the computation substantially faster. Chapter 6 improves the way the new demonstrations are added and Chapter 7 brings the idea to construct funnels by numerical optimization instead of the sum of squares method, this enables e.g. solving higher dimensional systems.

The thesis is well structured and clearly written. Chapters 4 and 5 contain theoretical results. The mathematical text is rigorous, all proofs are correct and well explained. Results of Chapters 5, 6 and 7 are applied to particular real-life problems and it is shown in which situations has the improvement high impact. The text contains an acceptable amount of misprints. One more reading of the text might remove some of the inconsistencies, e.g.

- p.41, l.19 should be Proposition 1, not Proposition 2

- p.44, l.1-2 speaks about a Proposition proved in the appendix and there is no proposition (only a lemma) and no appendix (proof immediatly below the lemma).
- p.79, l.11 'in this paper' instead of 'in this chapter'

Since all the three research papers of the candidate are joint works with his supervisor, I am not able to assess the contribution of the candidate. However, the topic of the thesis is highly topical and the presented results benefit both theory and applications. Moreover, the candidate demonstrated his ability to write scientific papers and also a longer text. Therefore, I recommend the manuscript to be accepted as a doctoral thesis.

Prague, April 17, 2024

doc. RNDr. Tomáš Bárta, Ph.D.