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Subject Evaluation of Mr. Erik Derner's PhD thesis

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To whom it may concern,

In this letter, I give my assessment of the Ph.D. thesis by Ing. Erik Derner, titled "Data-Efficient Methods for Model Learning and Control in Robotics."

The thesis presents original research results in model learning for control, with a focus on robotic applications. More specifically, it investigates an attractive alternative to nowadays popular data-hungry solutions, which also allows for the straightforward introduction of a priori knowledge into the learning process. Erik Derner authored and co-authored several articles that have been presented to quite good venues, which have already impacted the literature. Their research is of high quality, and below I give a few suggestions of what might have been improved or would, in my opinion, deserve more attention in their thesis.

The main shortcoming of this work is the limited validation, which is a pity considering that the proposed methods clearly show the wherewithal to work in less ideal conditions than the one tested. Many evident constraints may have prevented experimental validations, especially considering that the candidate has carried out a large part of the work in CoVid times. Nonetheless, the candidate could have obviated this issue by testing their work with more realistic simulations. One option would have been to rely more on advanced simulation engines (e.g., Gazebo). Another would have been introducing usual unideal components, like actuator dynamics and noise in sensor measurements.

Another aspect that I would have liked to see more is a discussion of the control application and, for example, how mismatches in the learned model can affect the assessment of structural properties and the design of feedback controllers. For example, the unicycle is identified as being an open-loop unstable system due to a small constant excitation acting on phi. Also, to what extent is the model's interpretability useful in RL? Some other model-based techniques could have benefitted more from this nice property of symbolic regression.

The thesis is well written but could be improved on a few points.
For example, I find the structure of Chapter 2 confusing and its title misaligned with the content, as my impression is that the chapter is not exclusively about preliminaries. The chapter starts (2.1) with a high-level discussion that we had already seen in the introduction. Similar discussions are also carried out at the beginning of all remaining chapters. Then, less than one page (2.2) introduces the actual preliminaries. After that,

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the Author starts introducing some (basic) concepts whose motivation is unclear until reading the following chapters. These are – in my opinion – not preliminaries, as they are not state-of-the-art concepts that need to be known to understand the contributions. Then Sec. 2.5 goes back to actual preliminaries, which are not essential to understanding the contribution. I would have preferred having the preliminaries introduced to a more considerable extent and the initial concepts in 2.3 and 2.4 not introduced. For example, it would have been nice to see an example of how to translate the tree structure into vector form (i.e., some improved upon Fig. 2.2).
Another example is that the actual extent of the contribution is not apparent until Pag. 24, where it becomes clear that the thesis reports the first examples in the literature of using symbolic regression in model-based control. This is an impressive contribution and, if I am not mistaken, it is not clearly stated before.

Finally, the thesis states that Robotics is its main application domain – to the extent that it is present in the title - but I do not see in which sense the proposed methods are specific to this field. Is there any specificity of the methods that make them particularly suited to learning the dynamics of robots instead of – for example – chemical plants? Since most of the validation is in any way in simulation, it would have been interesting to see how these techniques perform in different domains.

In summary, my conclusion is that the Ph.D. thesis deals with timely challenges, and it presents original research results of significant importance for robotics and control communities. Therefore, I firmly and without hesitation recommend that the candidate be awarded the doctoral degree.

Sincerely,

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