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El Paso, September 29, 2021

Report on the Ph.D. Dissertation of Joris Tillet, Ph.D. student at École Nationale Supérieure de Techniques Avancées Bretagne, France

In his Ph.D. work, Joris Tillet tackles the problem of the safe control and localization of a towed sensor. This work is motivated by the underwater exploration of seabed in search of buried shipwrecks.

General impression of the document. This Ph.D. thesis reads really well. A lot of care has been put in the exposition of topics central to the research work. The document is pedagogical: Joris Tillet demonstrates the breadth of his knowledge and his ability to explain it very clearly. It is commendable. Although it touches on an array of topics, the document's style indeed ensures that everyone can follow.

Structure and content. The dissertation is structured in 6 chapters. The work is well referenced, with over 160 cited references, once again, from an array of research domains.
The introduction manages to give both a nice survey and a crash course in history and the challenges of underwater exploration. Joris Tillet does a very good job at presenting the issues and research questions his research focuses on. In particular, he tackles the problems of control and localization of an underwater robot. This is notable as his work ranges from applied to very theoretical, which is quite challenging but well delivered. In Chapter 2, relevant background information is provided, which makes it clear that Joris Tillet has a good grasp of all of the varied aspects of his work.
The main contributions of this work are presented in Chapters 3, 4, and 5.
The conclusion is succinct but clear and the directions for future work very insightful.

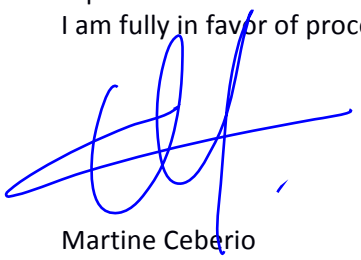
Contributions.
Chapter 3 focuses on the design of a safe controller for the trajectory of the sensor, in particular a sensor that is towed. To this end, the model that is used is that of a towed system (e.g., car/trailer): this allows to focus in a 2D version of the problem, assuming that it would either be the case in the underwater situation, or the 3rd D would be addressed later. The notion of follow

set is proposed and implemented using interval analysis (using SIVIA). It is a very interesting concept and allows expanding the work on the controller to handling safety concerns. The use of interval analysis to derive the follow set, which allows to observe the inner and outer approximations, is a good way to discuss and assess safety vs. risk.
This chapter includes a couple of examples that show how follow sets can be used to either guarantee that stats constraints, e.g., collision, will occur or not. More examples as well as more discussion about the runtime of such computations would have nicely completed the chapter, but nevertheless, the presented work is very rigorous and insightful. I am also wondering if this was used underwater to test the safety of the approach as an approximation to the 3D case.
A very neat aspect of this contribution is that the model chosen to represent the system with a towed sensor applies to above ground situations as well, making the contribution very usable beyond the underwater motivating goal.
As the rest of the document, this chapter is very pedagogical.

Chapters 4 and 5 focus on localizing a robot.
Chapter 4 provides an introduction to tackling the localization of a robot using acoustic sonar. It includes a nice description of the problem, including its challenges, and a survey of existing techniques for localization. Using constraints is proposed to model relevant information or characteristics (the notion of silence constraint is introduced) and interval analysis is used to solve the constraint problem. One major advantage of interval analysis is that it provides guaranteed results. Specifically, a new contractor is proposed and experiments conducted and reported. The chapter is very focused and well written. The notion of silence constraints is simple yet elegant and well illustrated. The examples and experiments are very descriptive and support very well the presented work, including one in an actual pool. Only minor comments: similarly to my earlier comment on Chapter 3, I would have like to see more examples/experiments and mentions of the execution time. In particular, how can execution time be a problem? If so, what would be ways to alleviate this potential bottleneck?

Chapter 5 goes further into the localization of underwater robots. The focus of this chapter is in the extension of the previous purely interval approach to the expressiveness of Fuzzy sets. The granularity and expressiveness Fuzzy Logic brings allows to extend the problem of solving constraints using intervals, as shown in Chapter 4, to solving soft constraints, still using intervals, but with a different model (fuzzy sets). In particular, this allows prioritizing the constraints that need to be solved, as opposed to monolithically handling all as equal and required. This chapter is the culminating part of the dissertation work. It is treated with the same rigor as the rest of the document.
α-cuts are presented and formulated w.r.t. score functions as constraints, for which contractors are presented and interval analysis can be used, all the more in light of the defined interval-based and furthermore box-based α-cuts. This is a very insightful way to combine intervals and fuzzy sets to enhance expressiveness and conserve guarantees in the solving process. The work in defining the new concepts constitutes the main achievement of this work in my opinion and it is very elegant. This is all brought back together in examples for the localization of robots where one more layer of complexity / expressiveness if needed: the notion of granules, originally presented as crisp, needs to be relaxed to being fuzzy because these granules come from otherwise uncertain data (e.g., distance to a beacon).
Overall, the work presented in this chapter is very promising and insightful. The reflections on this work are also outstanding.

Overall assessment. Joris Tillet conducted very rigorous and thorough research work. He put together a Ph.D. dissertation of great quality. His work on the identification/design of controllers to guarantee a given trajectory along with interval analysis to derive a follow set lays the foundation for studies on further safety properties of the trajectory. His work on localization is nicely tied with the use of fuzzy logic to handle uncertainty and express a wider range of information than intervals alone. The expressiveness ability opens the door to looking at many future problems, including how to automate expert decision on score functions. I enjoyed reading this dissertation and gleaning new knowledge as I did so. I particularly appreciate the care that is put in seeing the problems through: from the application to the very low level formal representations that will then allow to ensure safety for instance, and guaranteed results.
I am fully in favor of proceeding with the defense of this Ph.D. work.



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