Tutorial proposal:
Constraint programming for mobile robotics

Simon Rohou, Luc Jaulin, Benoît Desrochers, Raphael Voges

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1 Type and Duration

Full-day tutorial.

2 Title

Constraint programming for mobile robotics.

3 Organizers

– **Simon Rohou** (primary contact person)
ENSTA Bretagne (Lab-STICC)
2, rue Franois Verny
29806 Brest Cdex 9 (France)
+33(0)2 98 34 87 66
simon.rohou@ensta-bretagne.fr
`http://simon-rohou.fr/research/`

– **Luc Jaulin**
ENSTA Bretagne (Lab-STICC)
2, rue Franois Verny
29806 Brest Cdex 9 (France)
+33(0)2 98 34 89 10
lucjaulin@gmail.com
`https://www.ensta-bretagne.fr/jaulin/`

– **Benoît Desrochers** (support)
benoit.desrochers@ensta-bretagne.org
`http://benensta.github.io/pyIbex/`

4 URL

Website for the proposed tutorial:
`http://simon-rohou.fr/research/icra2020-tutorial`

The exercises will stand on the Tubex library, see the official website:
`http://simon-rohou.fr/research/tubex-lib/`

5 Abstract

There are several ways to deal with state estimation for mobile robotics. The constraint programming approach [Sam-Haroud and Faltings, 1996, Cruz and Barahona, 2003] consists of defining a problem as a set of rules and letting a solver perform the estimation. For mobile robotics, rules are constraints coming from state equations or uncertainties from the measurements [Jaulin et al., 2001].

Efforts have been done to propose operators and solvers to apply these constraints [Chabert and Jaulin, 2009, Desrochers and Jaulin, 2016]. The goal of this tutorial is to learn how to use them and understand the efficiency of the approach on realistic robotic applications. We will see that some problems that are difficult to solve with conventional methods (Kalman filters, particle approaches) can be easily dealt with by constraint programming [Rohou, 2017]. This is for instance the case of poor observation measurements, time uncertainties [Rohou et al., 2018], delays [Bethencourt and Jaulin, 2014], or when the initial conditions of the system are not known.

The tutorial will stand on the Tubex library, that provides tools for computations over sets of trajectories. It has been designed to deal with dynamical systems defined by non-linear differential equations and involving constraints such as trajectory evaluations, time uncertainties or delays. These computations stand on interval analysis, a well suited tool that reliably propagates uncertainties.

6 Content

The event will start with scientific presentations, providing the audience with elementary knowledge on constraint programming, interval analysis and tubes. Next presentations will concentrate on the python library so that the audience may be able to use the tools. A list of exercises will then be proposed, with realistic robotic applications involving both simulations and actual datasets.

Confirmed speakers will be Simon Rohou and Luc Jaulin.

We state that we have read the RAS guidelines for workshops and tutorials and are willing to follow them.

7 Plan to solicit participation

Invitations will also be extended to the communities of interval analysis and constraint programming by advertising the event on mailing lists.

Note that similar events have already been organized in the past by Luc Jaulin (one of the authors):

- **Control summer school of Grenoble**
  Grenoble. 12-16 septembre 2005
- **Lessons of interval robotics** (10h)
  Porto Alegre, UFRGS7
- **Lessons of interval robotics**
  Manchester, Control Systems Research Group School of Electrical and Electronic Engineering. March 4,5,6 2013
- **Summer school on Interval Analysis (IAMACS)**
  IFAC, Toulouse, 2017
- **Summer school on cyber physical systems**
  CPS2017, july 17-21, Halmstad, Sweden

8 Dissemination

All the content that will be provided during the tutorial will be uploaded on the website. This includes beamer presentations, list of exercises, corrections, and videos resulting from the exercises.

9 Equipment

The participants are required to come with their own computer (preferably an Ubuntu OS, Windows also accepted). The installation step will be included in the tutorial day.

References

[Bethencourt and Jaulin, 2014] Bethencourt, A. and Jaulin, L. (2014). Solving Non-Linear Constraint Satisfaction Problems Involving Time-Dependant Functions. *Mathematics in Computer Science*, 8(3):503–523.

[Chabert and Jaulin, 2009] Chabert, G. and Jaulin, L. (2009). Contractor programming. *Artificial Intelligence*, 173(11):1079–1100.

[Cruz and Barahona, 2003] Cruz, J. and Barahona, P. (2003). Constraint Satisfaction Differential Problems. In Rossi, F., editor, *Principles and Practice of Constraint Programming - CP 2003: 9th International Conference, CP 2003, Kinsale, Ireland, September 29 - October 3, 2003. Proceedings*, pages 259–273. Springer Berlin Heidelberg, Berlin, Heidelberg.

[Desrochers and Jaulin, 2016] Desrochers, B. and Jaulin, L. (2016). A minimal contractor for the polar equation: Application to robot localization. *Engineering Applications of Artificial Intelligence*, 55(Supplement C):83–92.

[Jaulin et al., 2001] Jaulin, L., Kieffer, M., Didrit, O., and Walter, É. (2001). *Applied Interval Analysis*. Springer London, London.

[Rohou, 2017] Rohou, S. (2017). *Reliable robot localization: a constraint-programming approach over dynamical systems*. PhD dissertation, Université de Bretagne Occidentale, Brest, France.

[Rohou et al., 2018] Rohou, S., Jaulin, L., Mihaylova, L., Le Bars, F., and Veres, S. M. (2018). Reliable non-linear state estimation involving time uncertainties. *Automatica*, 93:379–388.

[Sam-Haroud and Faltings, 1996] Sam-Haroud, D. and Faltings, B. (1996). Consistency techniques for continuous constraints. *Constraints*, 1(1-2):85–118.