



# **Tutorial: Constraint Programming for Robotics**

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## Constraint Programming

- Goal: state estimation in mobile robotics
- Given:
  - a set of constraints/rules (coming from state equations)
  - a (possibly infinitely large) initial estimation of the solution
- Idea:
  - Iet a solver perform the estimation by adhering to all constraints
  - inconsistent parts of the initial estimation are removed from the solution set







### Organization

- The tutorial stands on the Tubex library (https://github.com/SimonRohou/tubex-lib)
- Requirements: basic knowledge of Python or C++ (the exercises are available in both languages)
- Four weeks of exercises starting from October 26th
  - Week 0 (installation) must be completed previously
- By completing all exercises, it is possible to obtain a Diploma (equivalent to 40 hours of lessons)
- Interactive meeting sessions every Tuesday afternoon at 2PM (UTC) starting from October 27th
- Slack channel for easy communication (will be announced on the website)





## Organization

- All information and exercises are available on the tutorial website
- http://simon-rohou.fr/research/tubex-lib/doc/tutorial

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UTORIAL FOR MOBILE ROBOTICS	This tutorial is about Constraint Programming (CP), Interval Analysis (IA) and their applications to mobile
Main page	robotics.
ntroduction	Interval analysis yields methods to compute intervals in
. Intervals and contractors	place of real numbers, enclosing uncertainties in the
. Static range-only localization	mean time.
. Static range-bearing localization	Constraint Programming aims at solving a complex problem by defining it in terms of constraints coming
. Building our own contractor	from the equations or the measurements. This totaxial is expected in the IBOS
An and subes	Both concepts match perfectly for a large number of 2020 Conference International
Asynchronous measurements	applications including Robotics, which is the subject of Conference on Intelligent Robots
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	Requirements

Rohou, Voges, Jaulin, Desrochers Tutorial: Constraint Programming for Robotics





- Introduction to the concepts of Constraint Programming and Interval Analysis
- Installation of the Tubex library
- Run some Hello World! program to ensure that everything works





- Lesson A: Getting started with intervals and contractors
- Serves as an introduction to intervals, constraints and networks of contractors
- Lesson B: Static range-only localization
- State estimation of a static robot between some landmarks
- Initial assumption: the robot does not move
- Measurements (constraints): range-only data from the landmarks







- Lesson C: Static range-and-bearing localization
- Measurements (constraints): both range and bearing data
- A decomposition of the problem becomes necessary
- Lesson D: Building our own contractor
- Indistinguishable landmarks: association problem
- Develop our own contractor to solve this problem







- Lesson E: Hello tubes
- Dealing with uncertainties on trajectories
- Lesson F: Localization with asynchronous measurements
- Range-only localization (cf. Lesson B) in a dynamical context with asynchronous measurements







- Lesson G: Dynamic localization with data association
- Set-membership state estimation by solving data association
- Extension of the problem from Lesson D to a dynamical context
- Lesson H: Range-only SLAM
- Simultaneous Localization and Mapping (SLAM)
- Application of all previous concepts of constraints and interval analysis
- (optional) Online SLAM

