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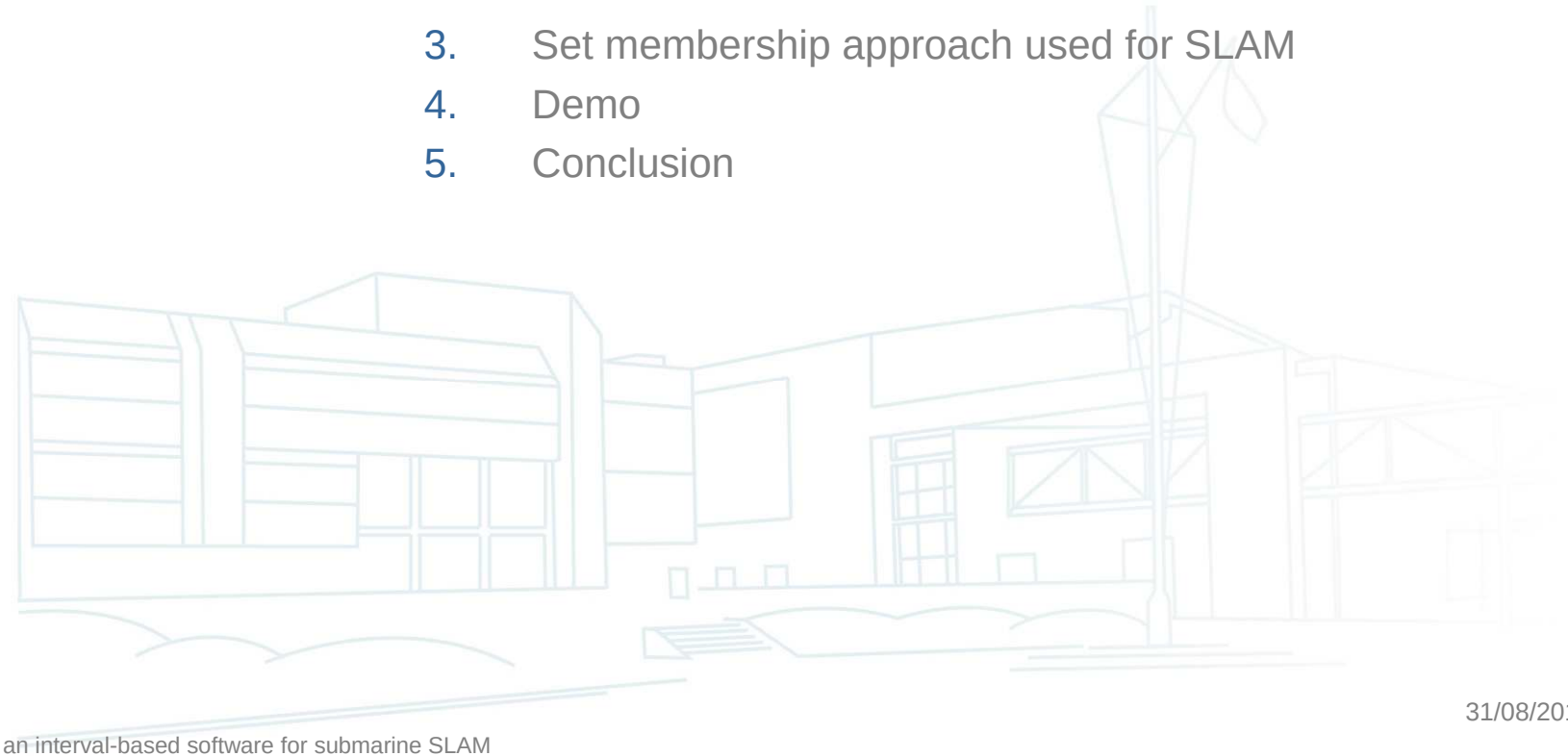
GESMI, an interval-based software for submarine SLAM

Fabrice LE BARS

> Plan

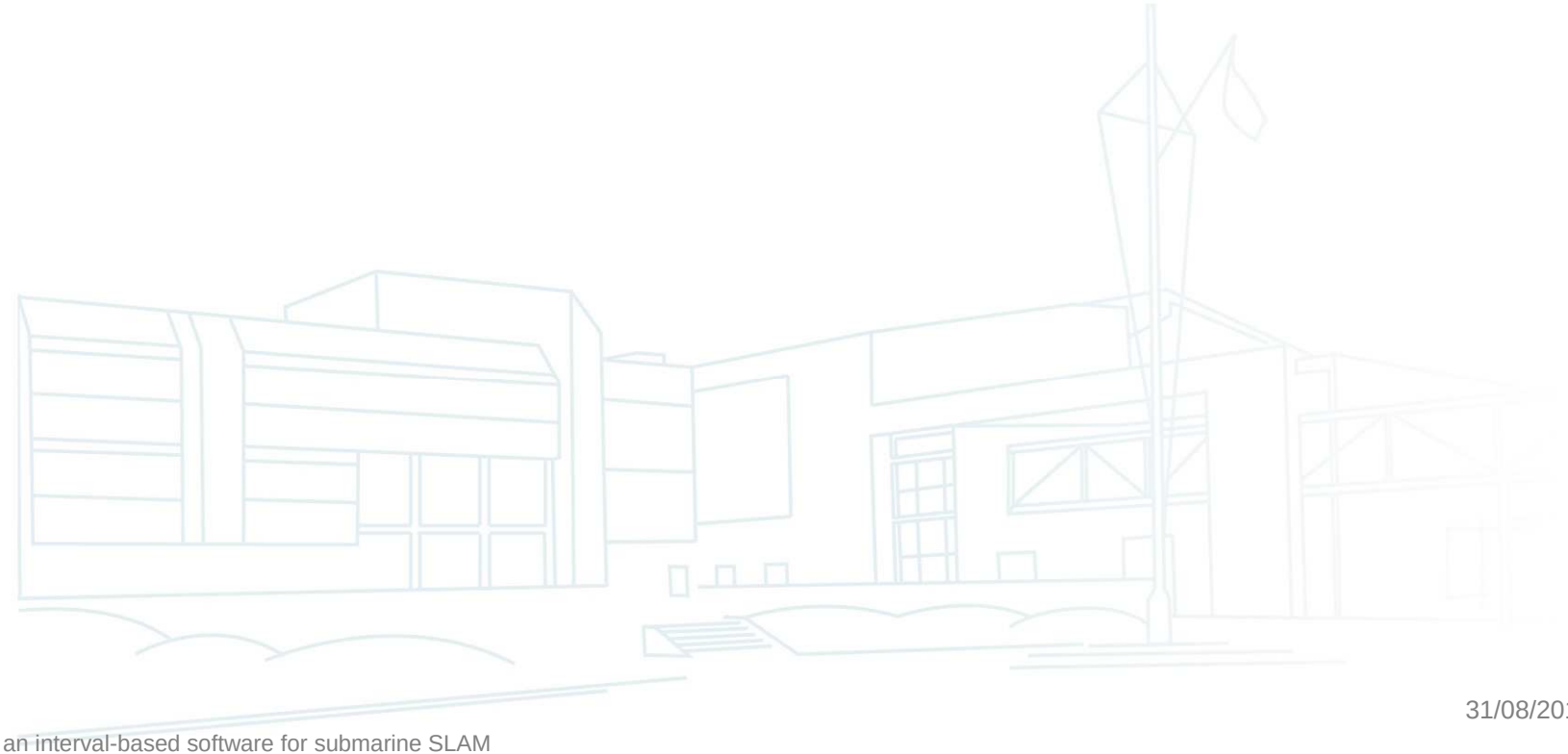
1. Introduction
2. GESMI
3. Set membership approach used for SLAM
4. Demo
5. Conclusion



Introduction

Introduction

- Context: offline SLAM for a submarine robot using interval arithmetic and constraint propagation (without outliers)

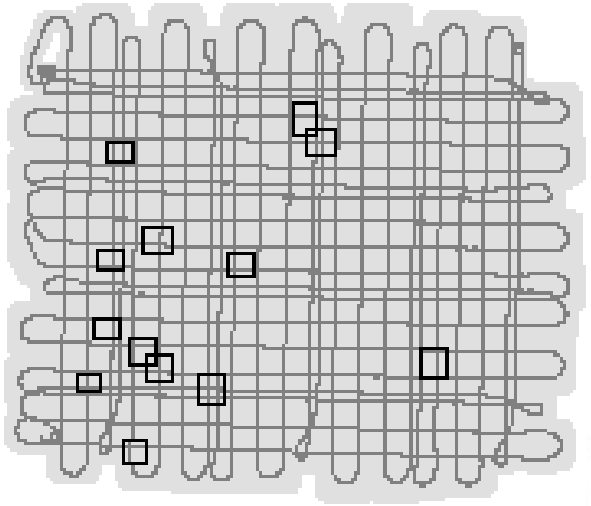


Introduction

- Daurade, a submarine robot of the GESMA

Introduction

- Experiment in the Douarnenez bay (Brittany)



GESMI

GESMI

- Goals of GESMI:
  - Compute and show an envelope for the trajectory of the robot
  - Compute sets which contain some detected marks
  - Check the consistency of input data
  - Help the human operator for the detection/identification of the marks
  - Everything is represented as intervals or boxes

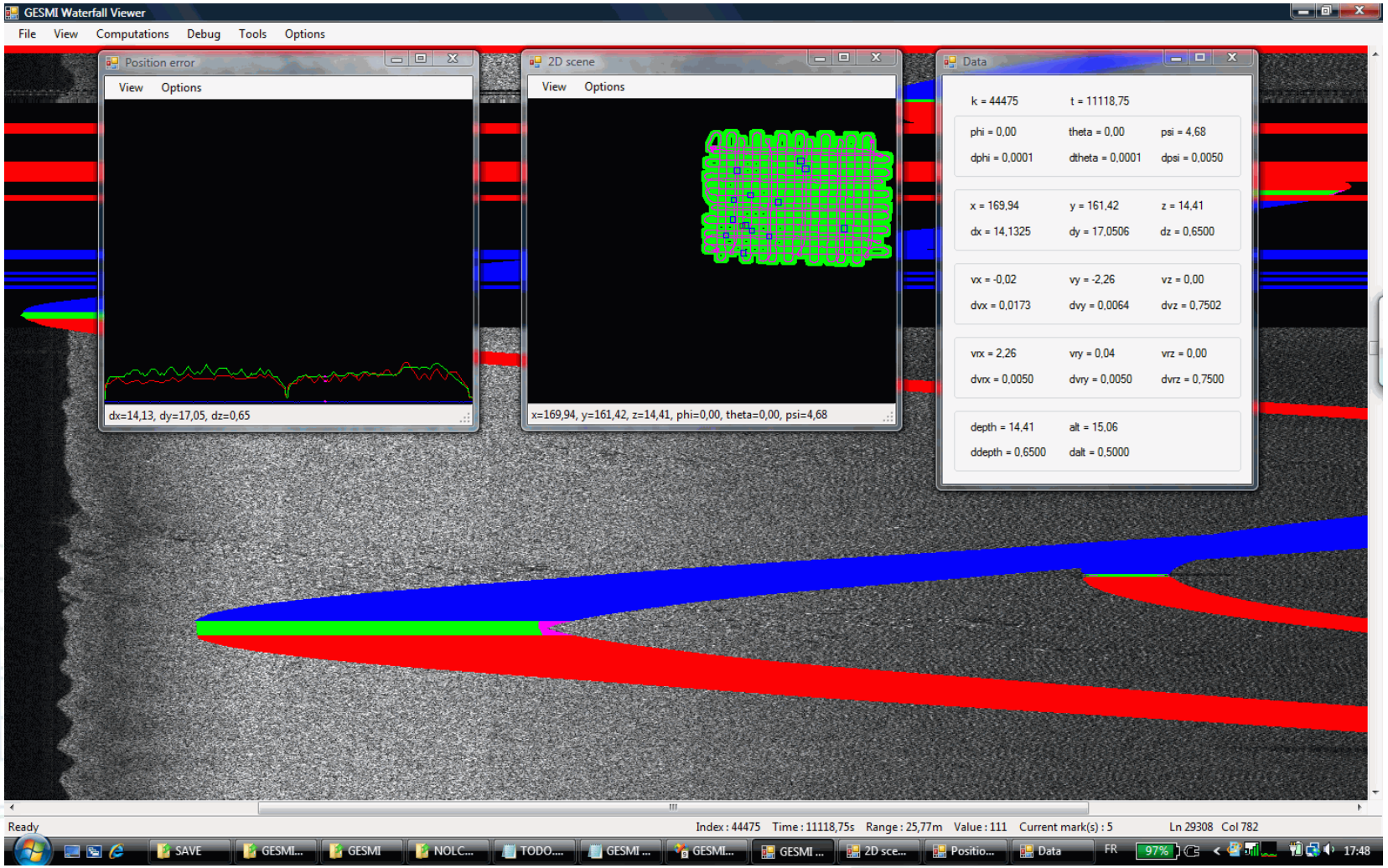
GESMI

- Input:
  - Navigation data of the submarine (Euler angles, depth, altitude, speed, some GPS positions)
  - Marks detections on the sonar image (distance)
  - Time and max error for each data

GESMI

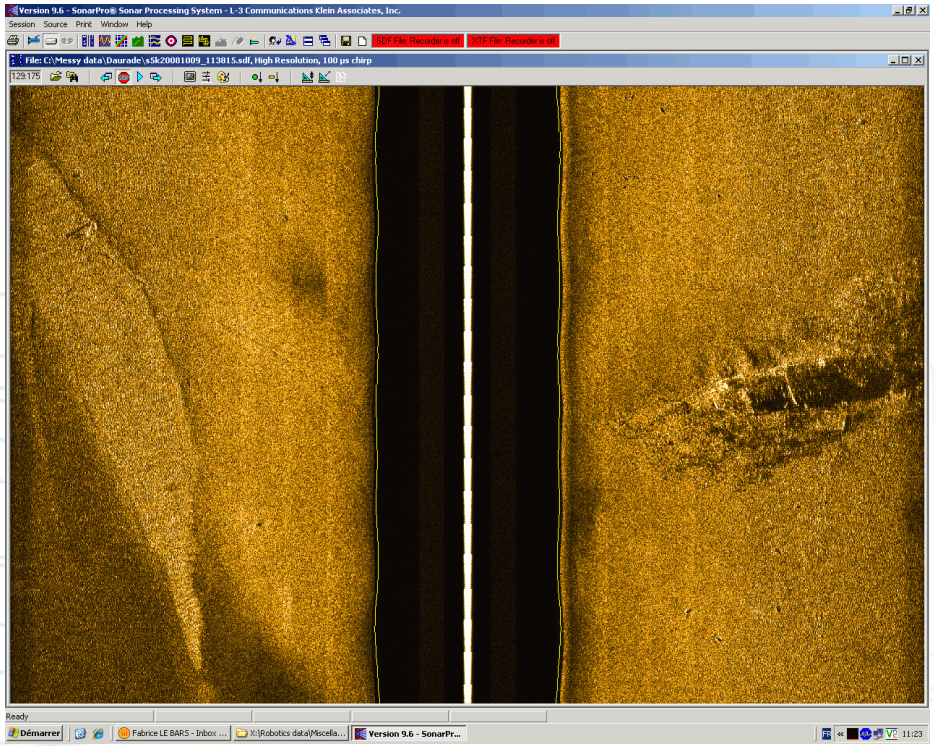
- Output:
  - Trajectory (envelope and center)
  - Position of marks in the sea (envelope and center)
  - Error evolution with respect to time
  - Warterfall (sonar image) reconstitution showing when and where the submarine should have been next to the marks

GESMI


GESMI Waterfall Viewer
File View Computations Debug Tools Options
Position error
View Options
dx=14,13, dy=17,05, dz=0,65
2D scene
View Options
x=169,94, y=161,42, z=14,41, phi=0,00, theta=0,00, psi=4,68
Data
k = 44475 t = 11118,75
phi = 0,00 theta = 0,00 psi = 4,68
dphi = 0,0001 dtheta = 0,0001 dpsi = 0,0050
x = 169,94 y = 161,42 z = 14,41
dx = 14,1325 dy = 17,0506 dz = 0,6500
vx = -0,02 vy = -2,26 vz = 0,00
dvx = 0,0173 dvy = 0,0064 dvz = 0,7502
vrx = 2,26 vry = 0,04 vrz = 0,00
dvrx = 0,0050 dvry = 0,0050 dvrz = 0,7500
depth = 14,41 alt = 15,06
ddepth = 0,6500 dalt = 0,5000
Ready
Index : 44475 Time : 11118,75s Range : 25,77m Value : 111 Current mark(s) : 5 Ln 29308 Col 782
SAVE GESMI... GESMI NOLC... TODO.... GESMI ... GESMI... GESMI ... 2D sce... Positio... Data FR 97% 17:48

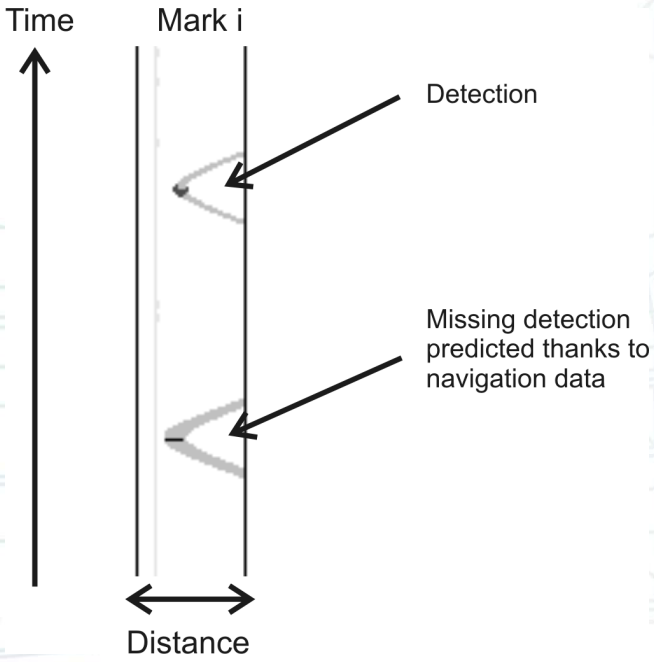
GESMI

- For our experiment, most of the detections of the marks were performed by a human operator after the mission of the robot with a dedicated software.



GESMI

- However, GESMI needs only 1 detection for each mark : with the navigation data, it can predict when the submarine could have been next to the mark another time

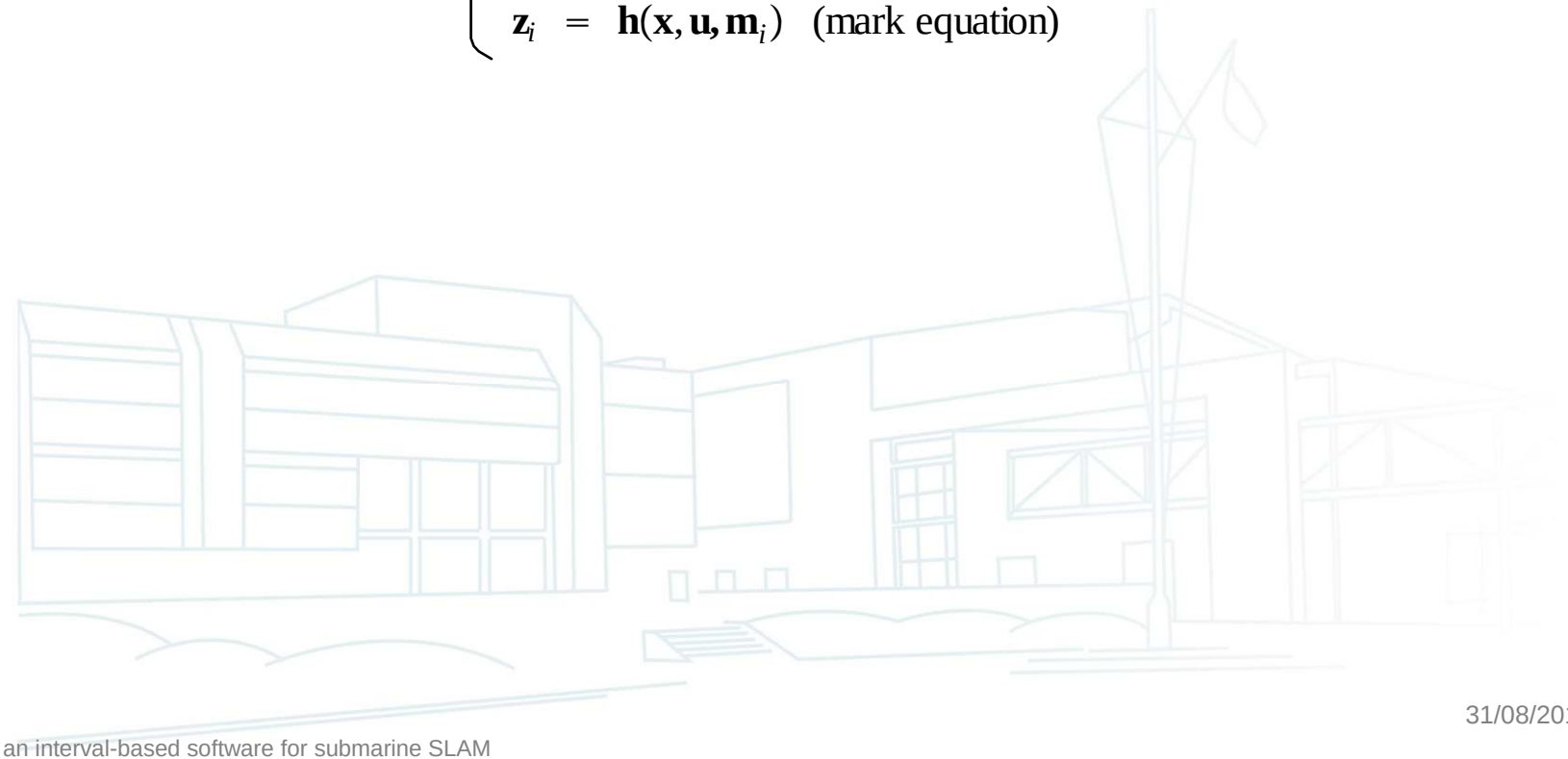


Set membership approach used for SLAM

Set membership approach used for SLAM

- Equations:

$$\begin{cases} \dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}, \mathbf{u}) & \text{(evolution equation)} \\ \mathbf{y} = \mathbf{g}(\mathbf{x}) & \text{(observation equation)} \\ \mathbf{z}_i = \mathbf{h}(\mathbf{x}, \mathbf{u}, \mathbf{m}_i) & \text{(mark equation)} \end{cases}$$



Set membership approach used for SLAM

- 3 main steps for the position estimation:
  - Forward contraction
  - Backward contraction
  - Contraction with mark detections
- These steps have to be run several times until the estimation does not change any more
- Generation of the reconstructed waterfall showing potential missing detections

Demo

Conclusion

Conclusion

- GESMI is a program that estimates the trajectory of a submarine robot and the position of marks using set membership methods
- In the same time, it checks the consistency of input data and helps the user to detect marks on the sonar image to improve the position estimation

Conclusion

- Prospects :
  - Using the sonar image to eliminate zones where we are sure there is no object (no bright points) could help the user to see which parts of the sonar data might contain objects and also improve the precision of the positions estimation (sonar image contraction)
  - The trajectories and functions could be represented as tubes (box-valued functions which are constant for all t inside intervals)

References

- L. Jaulin. *A Nonlinear Set-membership Approach for the Localization and Map Building of an Underwater Robot using Interval Constraint Propagation.* IEEE Transaction on Robotics 25(1), 88-98 (2009).
- L. Jaulin, M. Legris, F. Dabe. *GESMI, un logiciel pour l'aide à localisation de mines sous-marines*. In "JIME 2006 (Journées Identification et Modélisation Expérimentale)", Poitiers (France) (2006).
- L. Jaulin, M. Kieffer, O. Didrit, E. Walter. *Applied Interval Analysis, with Examples in Parameter and State Estimation, Robust Control and Robotics*. Springer-Verlag, London (2001).