Magnetic mapping using a trailed magnetometer

Quentin Brateau[1,✉]

[1]ENSTA Bretagne, Brest

The realization of a magnetic map of a terrain is a powerful tool especially used in mine warfare. This cartography can be done with a magnetometer, but the task is quite difficult. This is why it is useful to use robots to make this cartography. The problem induced by this solution is the addition of magnetic disturbances related to the structure of the robot and its actuators. It is then possible to drag the magnetometer on a sled behind the robot.

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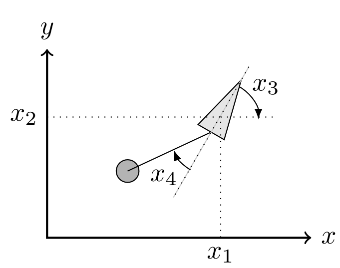
Correspondence: ***quentin.brateau@ensta-gretagne.org***

Modelisation of the system

The system is composed of a vehicle that will drag a sledge that transports a magnetometer. The towing vehicle is a tank type vehicle, and the sled is attached to it with a rope. Assuming that the rope is constantly under tension, we are able to find the equations describing the dynamics of the system. By noting x the state of the system and u its inputs, the dynamics of the system is described by :

$$\dot{x} = f(x,u) = \begin{cases} \dot{x_1} = \dfrac{u_1+u_2}{2}.cos(x_3) & \textbf{(1)} \\ \dot{x_2} = \dfrac{u_1+u_2}{2}.sin(x_3) & \textbf{(2)} \\ \dot{x_3} = u_2 - u_1 & \textbf{(3)} \\ \dot{x_4} = -\dfrac{u_1+u_2}{2}.sin(x_4) - \dot{x_3} & \textbf{(4)} \end{cases}$$

Here x_1, x_2 and x_3 are respectively the abscissa, the ordinate and the heading of the trailing robot, x_4 is the angle of the sled to the tractor vehicle.



Simulator

A python simulation was realized using VIBES in order to test the behavior of the system. A class *Tank* has been created to instantiate a vehicle with its sled. Then the script integrates the evolution equation using Euler's method in order to obtain the state of the system x according to the u inputs. We could see that the behavior of the system seems correct and the model is faithful to reality. Moreover, the GNSS sensor and an accelerometer are simulated in order to enclose the real position in a box.

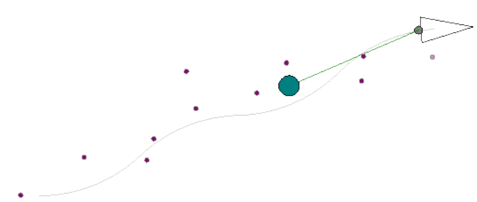


Fig. 1. Simulation of the system

Reliable set of sled's angle

Considering that the rope remains continuously under tension while the robot is moving, then the evolution of the angle x_4 of the sled relative to the towing vehicle is described by the *Differential Equation* 4.
We are able to find the trajectory of the sled by computing the interval containing the angle x_4, considering that initially x_4 belongs to $[-\pi/2;\pi/2]$. Then by applying the *Differential Equation* 4 on this interval, knowing the control vector u, we end up obtaining a fine interval framing the real angle x_4, independently of the initial angle as we can see on the FIGURE 2.

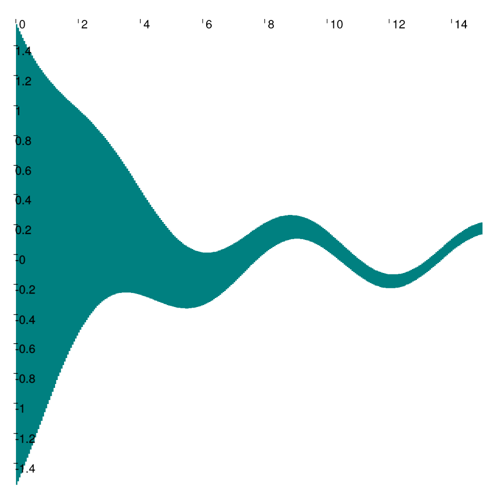


Fig. 2. Integration example using intervals

Sled localization

By having a box enclosing the trailing robot, and an interval framing the angle x_4, we are able to obtain a box containing the sled, knowing the length of the rope.
This box has the shape of a pie sector. *Equation* 5 presents the position of the magnetometer as a function of the state of the system x_1, x_2 and x_4. Here all these variables are intervals. By applying a polar contractor to these intervals, we are able to obtain the intervals containing x_m and y_m.

$$\begin{cases} x_m = x_1 - L.cos(x_4) \\ y_m = x_2 - L.sin(x_4) \end{cases} \quad (5)$$