TÉCNICO LISBOA

Robotics

Spring 2020

Departamento de Engenharia Electrotécnica e de Computadores

2nd lab assignment

Autonomous Cars

(Due by May 22, 2020)

1 Introduction

This lab assignment aims at developing a simulation of an autonomous car operating inside IST campus. The car must be able to move between any two arbitrary configurations along trajectories entirely contained inside the road areas normally reserved for vehicles.

While moving the vehicle must comply with events defined prior to the starting of the mission. These events will be selected from a list below.

The lab groups must have no more than 3 elements.

One element must be designated as responsible for the low level control of the motion of the car. Another element must be designated as responsible for the handling of events and high level control (supervision) of the car. The third element, if it exists, will act as a link between the other two. Proper teamwork is a must for the successful completion of this assignment.

2 Syllabus

Consider a mobile robot, with car-like kinematics,

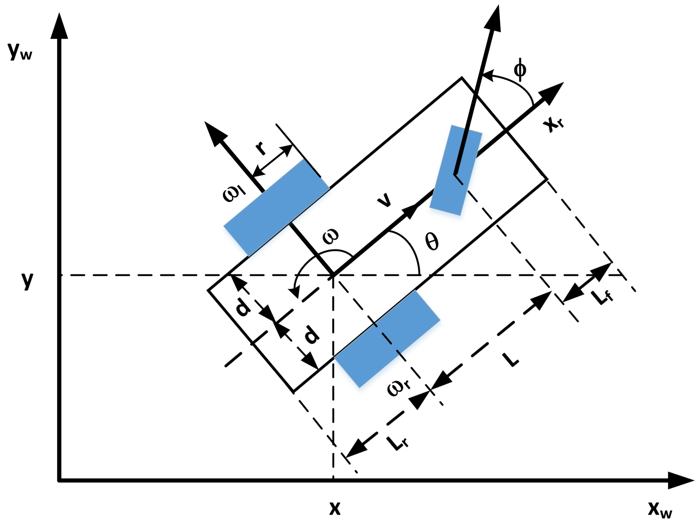

Figure 1: Kinematics of a car-like robot

that will be used in the role of an Autonomous Car (AC), to navigate around IST-Alameda campus (see figure 2 – this file is also available at the course webpage). Table 1 shows the specs of the car.

The world frame to be considered is marked with tick black lines (real dimensions are indicated for scaling purposes).

This map was obtained from Google Maps. For the purpose of the lab students can use zoomed versions of the map, obtained also from Google Maps.

Figure 3 below shows a diagram with a (very) simple architecture of the system to be developed.

The lab assignment requires the development of the following components.

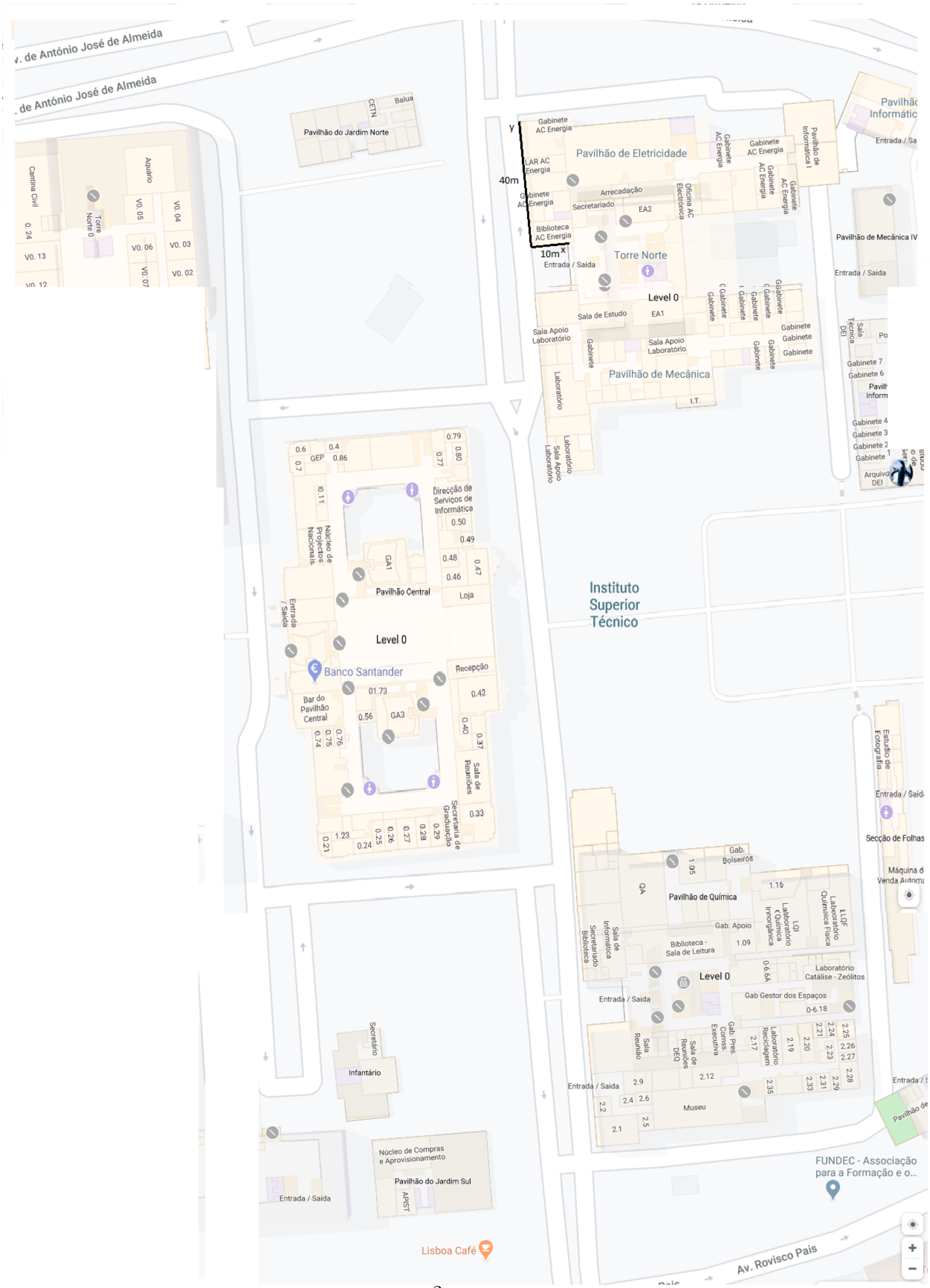

Figure 2: IST Alameda campus

L	2.2 m
L_r	0.566 m
L_f	0.566 m
d	0.64 m
r	0.256 m
Length	3.332 m
Width	1.508 m
Mass	810 Kg

Table 1: Vehicle specs

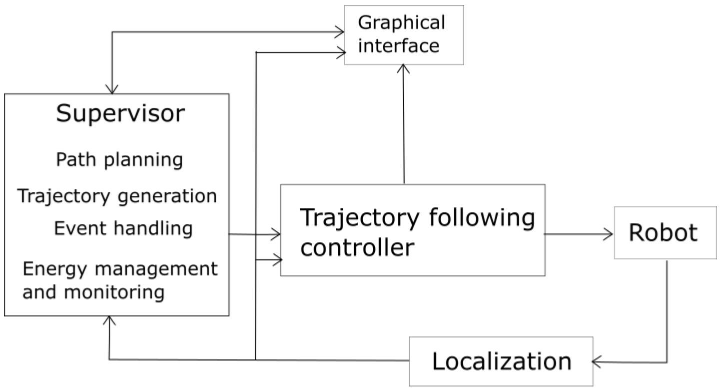

Figure 3: Simplified architecture for the Robotics-Lab autonomous car

1. A simulator for the robot; this will be a function,

   - Accepting as inputs x_t, y_t, θ_t, the current position and orientation in the world frame, v_t, ϕ_{s_t}, with v_t the linear velocity of the car (of the origin of the car reference frame in figure 1) applied at instant t, and ϕ_{s_t} the angular position of the steering wheel at t, and $\delta t > 0$ a time interval;
   - An alternative is to consider as input to the car the steering velocity ω_s (as expressed by the kinematic model); in fact this is more realistic than simply assuming that the steering wheel can move to an arbitrary position instantaneously.
   - Returning the position and orientation of the car in the world frame at time $t + \delta t$, that is $x_{t+\delta t}, y_{t+\delta t}, \theta_{t+\delta t}$.

2. A high level controller (supervision) than can handle mission control, i.e., manage all aspects not included in the low level control.

   - Guidance and navigation aspects must be considered at this level.
   - The car is assumed to know its configuration within a pre-specified error.
   - A path planning and trajectory generation module that accepts
     - The initial and final configurations, $(x, y, \theta)_{initial}$ and $(x, y, \theta)_{final}$,
     - A set of intermediate via configurations, that will be used to “guide” the path through specific regions,
     - A set of locations where specific events (selected from a list below) will happen; these events will have an impact in the execution of the task by the car.

   This module returns a trajectory that will be fed to the low level control.

3. A low level controller that can make the car to move between any two arbitrary configurations $(x, y, \theta)_{initial}$ and $(x, y, \theta)_{final}$ inside IST campus. Only points lying in traffic roads are admissible.

4. An interface over the IST campus map provided to input (i) the initial and final configurations, (ii) the via configurations, and (iii) the location of traffic regulation signs.

5. The AC must move according to an energy budget, i.e., the vehicle will have a limited (and fixed) amount of available energy to go between any two arbitrary configurations; this budget will be set before the simulation starts.

   At each instant, the amount of energy available must be displayed.

   For a car robot of mass M, moving with velocity $v(t)$, the amount of energy used during an interval Δt is given by

$$\Delta E = (|F(t)| + P_0)\ |v(t)|\, \Delta t = (M\, |\dot{v}(t)| + P_0)\ |v(t)|\ \Delta t$$

   where P_0 is a constant value.

The list of events to be considered by the car while executing the task is presented below.

- E1 Stop traffic sign, at a fixed location.
- E2 Speed limit traffic sign, at a fixed location.
- E3 Pedestrian crossing traffic sign, at a fixed location.
- E4 Pedestrian crossing at a pre-specified location and time; the duration of the crossing is also pre-specified.

Event E4 is not a traffic sign. Instead, when defining this event the user specifies (i) its location, (ii) a simulation time when the event starts, and (iii) the duration of the event. For example, it can be a pedestrian (or a group of pedestrians) that decide to cross the road at an arbitrary location.

3 Expected outcomes

Students must deliver a zip/rar file containing all the software developed, tests ran, and adequate pdf documentation explaining, clearly, the project and how to use the software.

The project must demonstrate that

- The trajectory of the car lies entirely in the admissible regions,
- The behavior of the car upon detection of an event is adequate.

4 Bonus points

Bonus points may be awarded in the following situations.

- Considering additional events (to those in the above list) that are, unquestionably, relevant to the autonomous car problem.
- Considering the environment divided into areas where vehicle localization is available and areas in which it is not (shadow areas).
- Dependability demonstration for the overall system.