# FMS – Dead-reackoning navigation

## Lab work nº1 (cont.)

## 1 Objectives

- To understand the principle of dead-reackoning navigation and to practice it.
- To design a simplified autopilot.

## 2 Introduction

This document describes additional tasks that are part of the first lab work (FMS).

Consider that an aircraft must flight a route defined by the coordinates of the following sequence of cities,

1-Lisboa, 2-Paris, 3-Moscow, 4-Oslo, 5-Rome, 6-Madrid, 7-Funchal-Madeira, 8-Ponta Delgada-Açores, 9- New York, 10-Halifax-Canada, 11-London, 12-Lisboa.

The trajectory between to consecutive waypoints is defined by the great-circle that contain the two consecutive waypoints. Each trajectory segment (leg) is flown at a constant speed (400km/h, 700km/h, ...). This information should be included in the text file that contains the waypoints.

## 3 The problem

The motion model of the aircraft in the air (no wind) is given by the following equations,

$$V_{north}(t)=V_{TAS}(t)\cos(\theta_{path}(t))\cos(\psi_T(t)) \quad ,$$

$$V_{east}(t)=V_{TAS}(t)\cos(\theta_{path}(t))\sin(\psi_T(t)) \quad ,$$

where $\mathbf{V_{TAS}}$ **(t)** represents the true air speed, $\boldsymbol{\theta_{path}}$**(t)** is the angle between the velocity vector and the local tangent plane, $\boldsymbol{\psi_T}$ **(t)** is the true heading, that can be measured (approximately) using the compass.

The change of the aircraft's altitude is modelled using

$$dh(t)/dt=-\alpha h(t)+\alpha h_r(t) \quad ,$$

where **h(t)** represents the altitude of the aircraft, $\mathbf{h_r}$**(t)** represents the target altitude for a trajectory segment, and $\alpha > 0$ is a constant parameter to be chosen to smooth altitude changes.

1. Use the trajectory waypoints to compute the true heading as a function of time. Knowing the initial position, the time, and the exact functions of time $\boldsymbol{\theta_{path(}}$(t) $\mathbf{V_{TAS}}$ (t), and $\boldsymbol{\psi_T}$ (t), the aircraft will cross all waypoints. These function are reference signals.

2. The sensor that measures **$V_{TAS}$** (t) causes an error in the measurements,

$$V_m(t)=V_{TAS}(1.0+0.01*\sin(2\pi\, t/T)) \quad ,$$

   where T=20min. Compute the trajectory using **$V_m$** (t) instead of **$V_{TAS}$** (t). For each time t the error between the two trajectories should be computed, in particular the position error at the waypoints must be evaluated.

3. Design an autopilot to adjust the position of the aircraft using the information that is provided by the true air speed sensor (described in the above point). Compute the new trajectory with the autopilot on, and comment the results.

4. Assume that near each waypoint, the pilot can correct the position estimate by updating the dead-reackoning system with the true position. Compute the trajectory for this case, and comment the results.

# 4 Evaluation

The following points will be considered in the evaluation of this lab work:
1. Description of the scientific principle used.
2. Software design, clean code.
3. Program output.
4. Tests used to evaluate the solution.
5. Comments and results obtained.

Delivery date: Defined in the first theoretical class.