# Autonomy Field Exam

## Question 1

Your task is to develop a 3D path planner for an autonomous flying blimp that must travel through a network of canyons to surveil a target deep in a mountain range.
These canyons form a maze-like environment that can be discretized and represented as an $m$ x $n$ grid. At each time step the blimp can take one of six actions: yaw left 90 degrees, move forward, move diagonal left, move diagonal right, yaw right, change altitude. Blimp altitude is a binary variable: high or low. A grid square is traversable only at low altitude in canyons and only at high altitude over mountains. If the blimp tries to move into a canyon wall then proximity sensors detect the hazard, the move does not succeed and the blimp stays where it is. The map of the area is known in advance.
The blimp's task is to navigate from a start position to a designated goal position. In addition to moving within the canyons the blimp can ascend over mountains, but any change in altitude doubles the blimp's travel time to the next grid location.

- Draw an example map for this problem. Formally describe the general search problem, provide a minimal state space representation, and the size of the state space. Name two methods you could use to solve this search problem to provide a minimum time path to the goal. What considerations would compel you to choose one solution technique over the other. Solve the search problem for your example map.

Now assume there are two blimps and their only task is to rendezvous in the same grid square. Your task is to solve a search problem for a sequence of actions that will reunite the blimps regardless of where they start (if such a sequence exists). Assume the blimps are not allowed to ascend over mountains, the map of the area is known, but the initial locations of the two blimps are not known. The blimps are not able to exchange information on each other's location, but are able to detect when the two blimps occupy the same grid square at the same time (this is the goal test).

- Formulate the search problem to find the sequence of actions that reunites the blimps, regardless of their initial positions. Give the minimal state space representation, the size of the state space, and a solution method.

Now assume the motion of the blimps can be seriously affected by wind flow disturbances. The topology of the mountain range results in a convenient property: the wind gusts are stochastic but their distribution is stationary and is dependent only on the blimp's current grid position. Assume you know the stationary wind-gust patterns at the start, and that the blimp's altitude is not impacted by wind flow disturbance.

- Describe in detail how you would formulate and solve the rendezvous planning problem with wind flow disturbance.

Consider an alternate scenario where there is no wind flow disturbance and the two blimps no longer need to rendezvous. Instead there is one blimp that must surveil a set of targets following a minimum-time path, starting and ending at the home base.

- Describe your problem formulation and solution technique for this path planning problem.

## Question 2

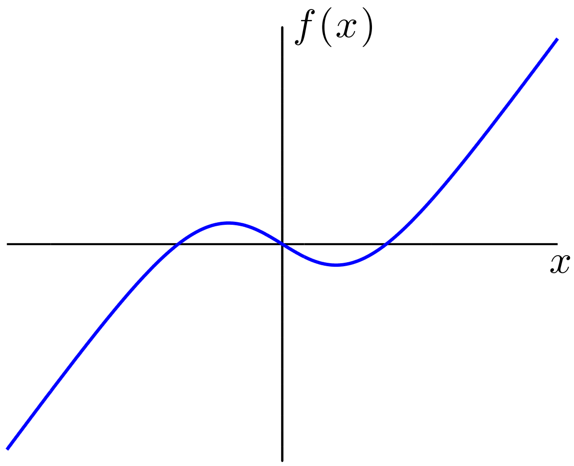
Consider a stochastic first-order system with linear dynamics and nonlinear measurement given by

$$\dot{x} = -x + w$$
$$y = f(x) + v$$

where

$$f(x) = \frac{12}{7}x - 5\,\frac{e^x - 1}{e^x + 1}$$

The process noise $w$ and measurement noise $v$ are independent, zero mean, Gaussian white noise processes with intensities $W$ and $R$, respectively. The initial state of the system is known to be $x(0) = 0$. A plot of $f(x)$ is below. For reference, the slope of $f$ at $x = 0$ is approximately $-0.252$, and $f(x)$ crosses the $x$ axis at approximately $x = \pm 2.48$.




Describe how you would develop a state estimator for this problem, and the problems you might encounter. You might consider some limiting cases:

1. $W \ll 1$, $R \ll W$
2. $W \ll 1$, $R \gg W$
3. $W \gg 1$, $R \ll W$
4. $W \gg 1$, $R \gg W$