Final Exam

The big guns game.

Due date for electronic submission is Thursday December 13th of 2012 at 1pm.
This is the time by which the electronic report submission must be done.

We will meet at 2pm on Friday December 14th of 2012 for the final presentation and project defense.

During this time, your team will give a 10 min presentation about key aspects of your algorithm with other relevant information presented (equations, algorithms, plots, etc). Plan ahead and distribute presentation time among teammates so everyone has a chance to talk. Presentation value is 25 points and will be assigned to each speaker separately.

Members of other teams encouraged to ask questions related to the project and will be granted extra points depending on questions relevance.

Algorithm evaluation:

Your answers will be compared against those of the other teams. Each team's solution will be ranked based on the closest distance to a target which is achieved with aiming parameters provided by the team. If several teams land their shells at the same distance to the target then the speed of the algorithm will decide who gets the largest bonus. The best team will get 2.5 points, next best team, 2.0 points, and so on till 0.

The competition will have two rounds: one with optimal parameters calculated based on posted on the web problem file for this final and another where the aiming problem and the gun parameters file will be supplied during the final exam according to the specification outlined in the text below.

Your code should provide **parameters** for the gun aim (see requirements below). Even though to solve the problem you need your own simulation code, it will not be used in the competition. The simulation of the solution will be done with the instructor's computer and code using the input parameters supplied by your algorithm.

All test will be run during the competition on the desktop computer available in the class room. You are welcome to test your algorithm there before the competition.

- Discuss relevant equations, describe your solution, show results.
- All Matlab code/scripts must be present in the carbon copy as well.
- Report should be less than 10 pages long (listings length is not counted).
- Make all your calculations in the S.I. units (m, kg, s).

Your goal is to provide the best firing solution (aim parameters) for a super gun - the one which lands shells the closest to the target. 125 potential points total (95 for writeup + 5 maximum possible for competition + 25 for the presentation.

To succeed, you need to write the big gun simulator. Let's take for example the Paris Gun. It had the muzzle velocity (the final speed of a shell after escaping from the gun barrel) of $v_e = 1600$ m/s, the barrel diameter (caliber) of $D = 0.238$ m, and mass of the shell $m = 94$ kg. We have no knowledge of the drag coefficient (C_d) but let's assume it was 0.8.

With such parameters a shell could fly through the stratosphere with much smaller air density so we need to take this into account. The crude approximation of the air density (ρ) dependence on the altitude (h) above the Earth's surface is

$$\rho(h) = \rho_0 2^{-h/h_{1/2}}$$

where $\rho_0 = 1.2$ kg/m^3 is the density of air at the Earth's surface, and $h_{1/2} = 6800$ m is the altitude at which density of air drops by factor of 2.

Fortunately, we do not need to take curvature of the Earth or change of the acceleration due to gravity ($g = 9.8$ m/s^2) into account. We will assume that only gravity and air drag are acting on the flying shell

$$\begin{aligned} \vec{F} &= m\vec{a} = \vec{F}_g + \vec{F}_d \\ \vec{F}_g &= -mg\hat{y} \\ \vec{F}_d &= -\frac{1}{2}\rho(h)C_d A v\vec{v} \end{aligned}$$

where $\vec{F}_g$ is the gravitational pull force, $\vec{F}_d$ air drag force, $\hat{y}$ is the unit vector in the 'y' direction (we assume it points up), A is the area of the shell, and $\vec{v}$ is the velocity of the projectile.

We assume that our gun is situated in the plain, i.e. the landscape is flat.

Problem 1 (20 points)

Write a gun shell flight simulator. Which takes a given gun parameters and elevation angle (the angle with respect to horizon at which the shell is launched) and calculates the x and y position of the shell vs time. The time **must** span from zero till the time when shell hits the ground, i.e. no underground motion and a trajectory cut in mid-flight are permitted. The function must follow **precisely** the specification below

```
function [time, x, y] = shell_flight_simulator( m , D, Ve, Cd, ElAng)
```

`m` - shell mass, `D` - caliber, `Ve` - escape shell velocity, and `Cd` - drag coefficient), `ElAng` - elevation angle in **radians**.

Problem 2 (20 points)

Write the function which finds the maximum distance at which a gun (with parameters specified in the file) can deliver its shells. The solution function must comply to the following specification

```
function [MaxFiringDistance, ElAng, time, x, y] =
         gun_max_firing_distance(gun_parameters_file_name)
```

It should return the maximum firing distance, the elevation angle at which projectile should be fired, and trajectory itself: time, x, and y coordinates. Time should span from zero to hit the ground time.

The gun parameters file name will contain the following parameters: `m`, `D`, `Ve`, and `Cd`.

Find the maximum firing distance and required elevation angle of the Paris Gun (use this gun parameter file 'TheParisGun.mat' supplied at the web). Plot the trajectory of the shell.

Problem 3 (35 points)

During the final, you will be given a target positions file which will contain array named `TargetDistance` with distances from a gun to targets. You need to write a function which returns an array of elevation angles required to hit these targets, this array must contain zero if you unable to hit the given target.

To do so write a function **precisely** following the specification

```
function [ElevationAngle] = gun_firing_solution( gun_parameters_file_name ,
                                                 target_distance_file_name)
```

Find the firing solution for the Paris Gun (the gun parameter file 'TheParisGun.mat' posted at the web) for the targets contained in the file 'TargetsForParisGun.mat' posted at the web.

During the final you will be provided with different gun parameters files as well as target distances. You algorithm should be able to work with them.

Problem 4 (20 points)

This is a problem to solve at home.

To fire the gun you need the access codes for the launch mechanism. This code is delivered to you as a radio voice message. However the other teams know about it and try to jam the transmission. So the voice message recording will have a lot of noise. Each team will get its own voice recording of the code, available on the web site. What is your activation code (it should be a 6 digit number)?