Matlab in Stokholm 2011
First session. Monday

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Shapes in nature: a shell (organic growth), a monument (architecture), and a trajectory (shape in space/time).
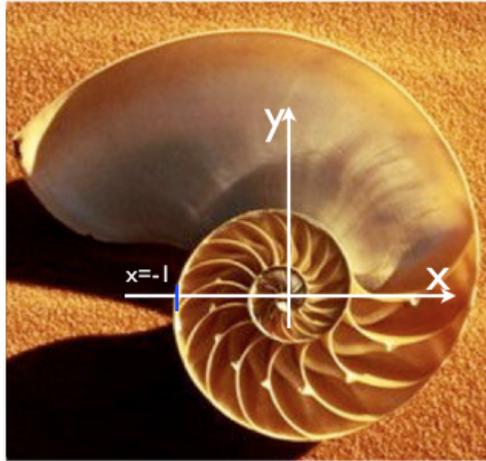
For image spirale.png: read the image from disc with «imread», display the image with «image» measure the pixels of the spiral shell using «ginput». Save the data in a file. Do the change of reference frame as shown on the image. Draw your data points. Show that the shell is a logarithmic spiral (equation below), by finding the two numerical parameters a and b. Plot the theoretical and experimental lines on top of each other.

$$r = ab^\theta, x = r\cos(\theta), y = r\sin(\theta)$$

1

Image chainette.png shows a view of the «gateway arch», Saint-Louis, Missouri, which is supposed to be a shape of a link hanging under gravity (but upside-down). This shape allows pure compression in the structure. The hanging link equation is given below, with «a» as its single parameter. Show by plotting the measured points against the theoretical line that the building is an inversed link. You should measure the points along the arch's centerline (the compression line). Draw as well a parabola wich goes through A B and C to see how a parabola differs from a link.

$$y = a\cosh(x/a)$$

2

Rebond d'une balle de ping-pong
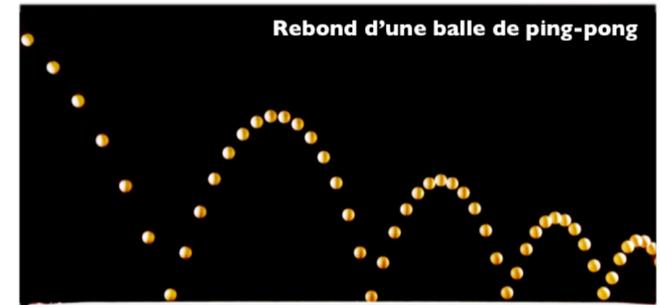
Image pingpong.png shows a bouncing table tennis ball. Draw the evolution in time of x (horizontal axis) and y (vertical axis), the velocity in x and y, and the acceleration in x and y. Do the analysis of this data: does it obey Newton's law? To check this you may plot on top of the measured data (in a well chosen reference frame) several different theoretical curves.

To compute the velocity: position at the time instant later minus the position at the time instant before, divided by twice the time interval (we will here ignore the first and last instants). Remember that the acceleration is the «speed of the speed».

Time interval: 0.04 seconds, ball's weight: 5 grams, pixel size: 1.7 millimeter, gravity acceleration: 9.8 m/s2.

Compute and draw the kinetic, potential and total energy. The energy is constant? Here is real life the air is giving a drag, and the ball is being deformed during the bounces. Can we say something about the way energy is lost during the bounces?

To go further: write a function which for a given initial position and speed computes the trajectory until next bounce (y=0). Use this function to draw several consecutive bounces which you will compare to your measured data. We suppose that at each bounce, the vertical velocity changes sign, and both components of the velocity are multiplied by a parameter alpha smaller than one (to be determined).

3

Matlab in Stokholm 2011
Second session. Tuesday

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Vectorization: making many operations with few commands, some graphs, some animations.

nappe

For this exercices, we are interested at the modelisation of inviscid fluid flows by the method of the velocity potential. We will consider the time evolution of a family of vortices. Each vortex is point-like (vorticity infinitely localized at x_0, y_0) and induces in its surrounding a velocity field with the formula given below. Delta is a small regularisation parameter with value 0.05. The velocity field induced by several vortices is the sum of the velocity fields induced by each vortex, and each vortex moves according to the velocity at its location induced by all the other vortices. The intensity (and sign) of each vortex is described by its circulation Gamma.

Particular cases: two counter-rotating vortices induce each other a translation trajectory, two corotating vortices induce each other a circular trajectory. Three vortices have a pseudo-periodic motion. Many vortices can together have a chaotic behaviour.

Today's operations can be easily coded with nested loops. For each step, code first with as many loops as you like, then use the techniques described in the lecture to skip loops, as many as you can. Each time, try to identify the category of vectorisation you are using to rationalize this process. Use «tic/toc» to compare the computation time of the different formulations.

$$u(x,y) = \Gamma \frac{-(y - y_0)}{2\pi[(x - x_0)^2 + (y - y_0)^2 + \delta]}, \quad v(x,y) = \Gamma \frac{(x - x_0)}{2\pi[(x - x_0)^2 + (y - y_0)^2 + \delta]},$$
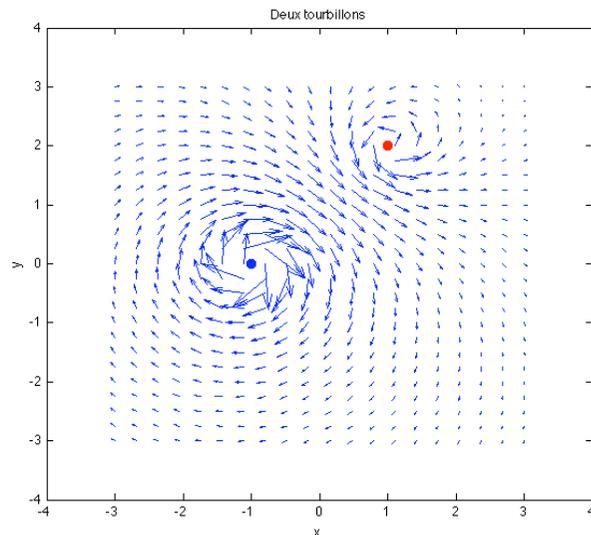
Deux tourbillons
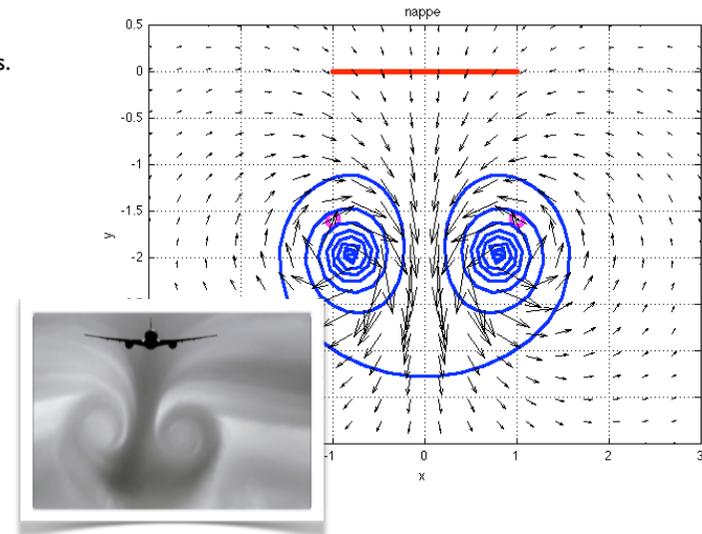
1)
Chose the position and intensity of two vortices, and draw the induced velocity field with the function «quiver» on a cartesian grid. Draw as well the position of the two vortices.

2)
Build a function «tourbi» which for each vortex of a family of n vortices, computes the velocity induced by the other vortices.

3)
Chose the position and intensity for three vortices and simulate their evolution in time, with a very simple marching algorithm: for each vortex and each time instant, the new position is equal to the old position plus the time step times the velocity vector you get from your function «tourbi».

4)
Draw the evolution in time of the velocity field with quiver on a fixed cartesian grid, and of the vortex positions. Make your time marching loop an animation by using the function «drawnow» at each iteration.

5)
Consider a line of many vortices as a model for the vortex sheet in the wake of an airplane, the distribution of the vortex intensity is given by the piece of code below. This corresponds to a continuous distribution of circulation 4x^3. Draw the evolution in time of this vorticity sheet and associated velocity field. Show that this is equivalent of the roll-up of the complete vorticity of two large wing-tip vortices (two counter rotating vortices inducing each other a downward translating trajectory.)

```
n=20;
xloc=linspace(-1,1,n);
yloc=0*xloc;
gamma=8*xloc.^3/n;
```

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Graphs and animations. The flow of sand.

Sand on an inclined plane will flow like a fluid. Sand flow has instabilities: flowing by himself (avalanches) or under the action of wind, water, can become dunes. We have the data from a direct numerical simulation of particles down a 21 degree plane, in the file sandflow.mat (courtesy of Lydie Staron). There are three arrays: x, y, and d: the x position, the y position and the grain diameters. The lines correspond to the different grains, and the columns correspond to the different time instants, following each grain from its initial position at rest. The simulation has periodic boundary conditions in the direction along the plate, so grains come back up periodicaly.

1) Draw the initial condition with circles.
2) Draw a dot at the center of each grain, with a different color depend on wether the grain is going up or is going down.
3) Display an animation of this granular flow.
4) We now will change the zoom during the animation: for the initial condition, focus on a small number of grains close to the bottom, and progressivelly enlarge the view such as to see the full flow at the end of the animation.
5) Use the buttondown property to display the evolution in time of the y position of one grain of the initial condition on which you click.
6) Use the same functionality to draw a the same time the y evolution of one grain and its 6 closest neigbours. This is to check wether grains stay close or depart from each other during their evolution, and check wether this depend on the depth of each grain.
7) Now draw the evolution in x of the selected grains: find the times for which the grain goes through the boundary condition using a logical array operation, and rectify its trajectory.
8) Compute for each time instant the average velocity profile in x. Draw an animation of the evolution in time of this profile.

Underwater

Avalanche study
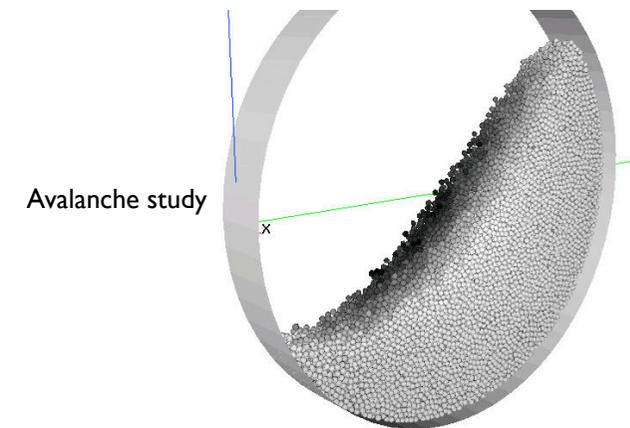
Long and short wavelengthes
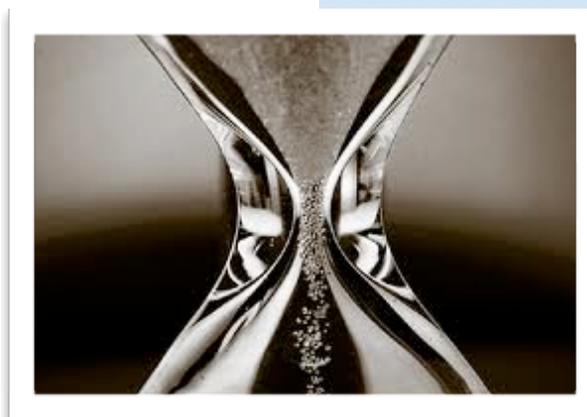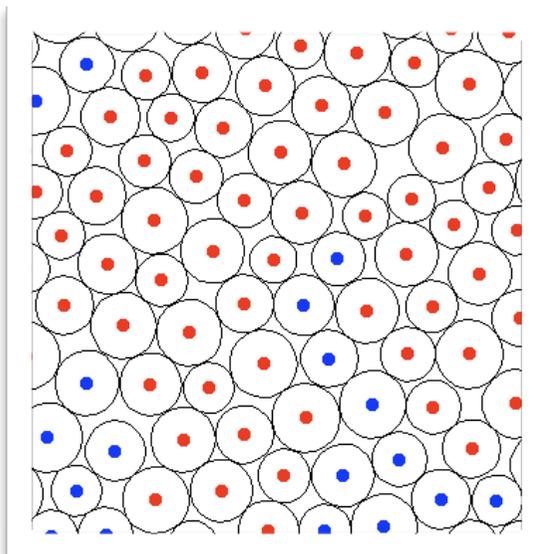
Matlab in Stokholm 2011
Fourth session. Thursday

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Interpolation; manipulating strings

Exercices:

We continue with the granular flow of yesterday.
If you have a compiled code, use our string manipulations to wrap its scheduling with matlab: loops for varying parameters and for reading the code's output. Then Graphical representation.

Project:

The goal is to make for me a session's exercice sheet following the example of the three previous days: pick one topic for which you have data, knowledge, ideas... Write one page with:
1) Images/photos
2) One paragraph of description of the context.
3) A list of questions that encourage the future student to use the capabilities we have studied during this course: vectorization, graphics, string manipulations, interpolation...

Then you make a report which solves all these questions, like you did for the three first sessions.

If the codes are easy to install and not too heavy for the computations, you can send me these codes but it is probably better if you can just give me the data that the student will use (max 100mega).

If your project is nice I will use it next time I give this course.