

TD 4 : Physical Simulation

Module : Haptic Interaction and Physical Models

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1 Integration and bottafumeiro

In this exercise, we will see how to numerically compute solutions of a differential equations' set.

Lets talk a bit about the physical situation we will consider. In the Santiago de Compostela cathedral, there is a huge thurible, named the botafumeiro. You can search for its history on Wikipedia.

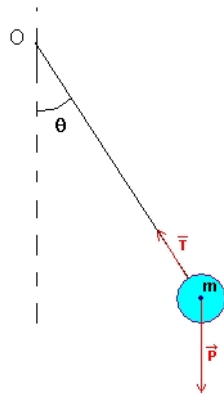


It is pretty easy to derive its movement equations.
You just have to start from the second Newton's law.

$$m\vec{a} = \sum \vec{forces}$$

The forces are :

- The gravity
- The damping
- The wire tension



In fine, you will obtain the following equations :

$$\frac{dp}{dt} = q$$

and

$$\frac{dq}{dt} = - \left(\frac{\nu}{m} + 2 \times \frac{dl}{dt} \frac{1}{l} \right) q + \frac{g}{l} \sin(p)$$

where p is the angle of the pendulum from the normal,
 q is the angular velocity,
 g is the gravity,
 ν is the damping factor, and m the pendulum mass,
 l and $\frac{dl}{dt}$ are the length and the time derivative of the pendulum's length. It is obvious

that you will only need the angular position and the length of the pendulum to draw it, at a given time. Nevertheless, for being able to integrate the system ie to guess where the pendulum will be just after, you will have to solve the previous equations. We present you two ways to integrate a differential equations' set : the Euler method

and the Ruge-Kutta 4 one. You can find these methods on wikipedia, and on the white board !

2 Work to achieve

You will have to implement these methods in a Visual Express solution.

2.1 Euler and haptic

Implement in the solution the Euler's method, then the haptic feedback function.

2.2 Runge-Kutta and haptic

Implement in the solution the Runge-Kutta's method, then the haptic feedback function.

2.3 User's Choice

Implement in the solution a function able to use both of the methods, at the user's choice.

2.4 Error and difference

Implement in the solution a function which will print out the magnitude of the difference (in the L2 sense) between the two methods.