Synchronous programming exercises

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MOSIG - PDES - Embedded Systems

Programming Environment

Within Ensimag

The tools are available on the *EnsiPc* machines running Linux (e.g. room E100).

To setup your environment, copy these lines in your .bashrc file:

```
export LUSTRE_INSTALL=/user/5/raymond/lustre
source $LUSTRE_INSTALL/setenv.sh
```

Personal install

- Search for ”lustre v4 distrib” on the web,
- Download and untar a distribution adapted to your machine
  (if possible, prefer the linux64 distribution)

First steps with Lustre

Rising edge node

Write a node detecting the rising edges of its Boolean input. The profile should be:

```
node edge(x:bool) returns (e:bool);
```

Simulation

Use the graphical simulator for testing the program:

`luciole tp.lus edge`

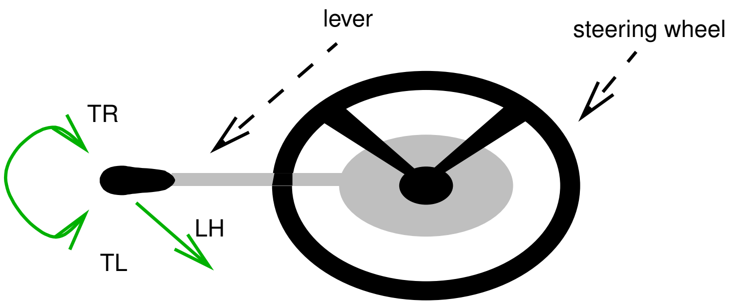
Or simply **`luciole`** then browse.

- try the ”clock” options (auto-step vs compose, real-time clock)
- try the associated ”tools” (sim2chro)

Write and simulate other nodes

For instance the ones presented in the course (**`switch`**, **`counter`**, **`stopwatch`** etc).

Car lights controller



behaviour

- from ”all lights off”, turn left (TL) sets side lights,
- from ”side lights”, turn left switches off the side lights and sets low lights,
- from low or high lights, pulling the lever (LH) switches between low and high,
- turning right in low/high state returns to side lights,
- turning right in side state returns to ”all lights off”.

Controller

Write, test, simulate the controller:

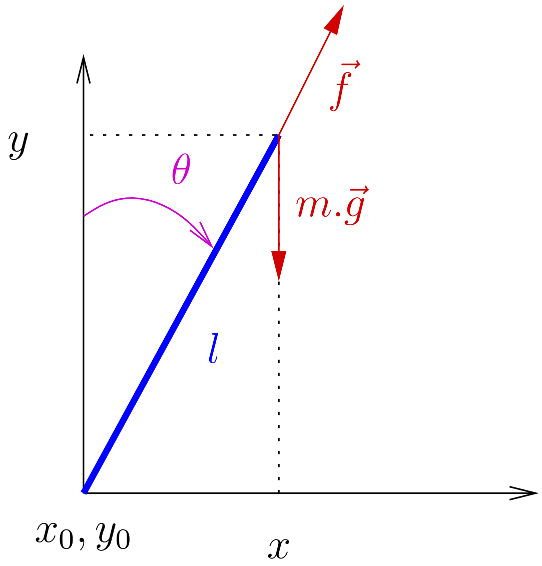
To go further:

- add a ”fog lamp” functionality, controlled by a check button, and effective only in low lights mode
- add a ”long range lamp” functionality, controlled by a check button, and effective only in high lights mode

The reverse pendulum

A typical example involving numerical computing and ”signal processing method”.

Principle



- Forces:
  $m.\vec{g}$ (weight), $\vec{f}$ (reaction)
- Geometry:
  $x = x_0 + l\ \sin(\theta)$,
  $y = y_0 + l\ \cos(\theta)$

Newton’s equations: $m\vec{g} + \vec{f} = m.\vec{\gamma}$

Mathematical model

- Tangential and radial acceleration $\vec{\gamma} = \vec{\gamma_r} + \vec{\gamma_t}$
  with: $\gamma_t = x''.\cos(\theta) - y''.\sin(\theta)$
- Projection on tangent: $\gamma_t = g.\sin(\theta)$
- And (basic geometry):

$$\begin{aligned} x' &= x'_0 + l.\sin(\theta).\theta' \\ x'' &= x''_o - l.\sin(\theta).\theta'^2 + l.\cos(\theta).\theta'' \end{aligned}$$

$$\begin{aligned} y' &= y'_0 - l.\sin(\theta).\theta' \\ y'' &= y''_0 - l.\cos(\theta).\theta'^2 - l.\sin(\theta).\theta'' \end{aligned}$$

Mathematical model (contd)

- Substitution ... $g.\sin(\theta) = x''_o.\cos(\theta) - y''_0.\sin(\theta) + l.\theta''$
- And finally:

$$\theta'' = ((y''_0 + g)/l).\sin(\theta) - (x''_0/l).\cos(\theta)$$

Programming a numerical library

For a given (constant) sampling period of T seconds, write:

- a discrete derivative node: **`node D(x:real) returns (dx:real)`**
  hints: the discrete derivative if the slope
- a discrete integrator node: **`node I(dx:real) returns (x:real)`**
  hints: the integral is the surface area between the curve and the axis, it can be approximated by accumulation small rectangles (or trapezes) areas.
- a delayed discrete integrator node: **`node ID(dx:real) returns (x:real)`**
  such that **`x`** does not depend instantaneously on **`dx`** ?

Programming the pendulum equation

Program *directly* the equation with a node that:

- takes as input the acceleration of the basis point **`d2x0,d2y0`**
- computes the current angle **`theta`**

```
node pend( d2x0,d2y0:real) returns (teta:real);
```

Programming a game based on the pendulum

The player tries to stand in balance a stick on the palm of is hand:

- the inputs are the coordinates of the basis of the stick (x_0, y_0),
- the outputs are the coordinates of the top of the stick(x, y)

```
node game(x0,y0:real) returns (x,y:  real)
```

Running the program ...

- Using luciole is not convenient for this example.
- We provide an ad-hoc main graphical program written in tcl/tk.
- Download the necessary files here:

`http://www-verimag.imag.fr/~raymond/edu/mosig/pendulum.tgz`

Warning !

- The program file must be called **`game.ec`**,
- Use **`lus2ec my_program.lus game`** to create it (or see the given Makefile),
- the sampling period in the lustre program (e.g. 0.02 s) must be coherent with the one of the tcl/tk program (given in ms, e.g. 20)
- The length of the pendulum should be 4.0.

Remarks

- the shorter is the period, the smoother is the simulation,
- ... but the execution method used here (interpreter + unix pipes) is rather inefficient, and don't support high rates (50 Hz, i.e. 20 ms is reasonable).

Adding a frictional damping force

The simulation is quite unrealistic, cause the pendulum cannot loose kinetic energy.

- Think about a way for introducing some frictional damping force in the equation.
- hints: a simple approximation consist in introducing a damping force proportionnal to the angular velocity, the Newton's Equation becomes:
  $g.\sin(\theta) - x_0''.\cos(\theta) + y_0''.\sin(\theta) - l.\theta'' - a.\theta' = 0$
- Try with different values of a.

Programming with Esterel

Mouse click detector

- two "clicks" separated with less than 5 basic-clock ticks are considered has a "double click", otherwise it is a simple click.
- copy the code in a file **mouse.strl**

```
module mouse:
input click;
output single, double;
loop
  await click;
  abort
    await 5 tick; emit single
  when click
  do emit double end
end.
```

Running the Esterel program

An Esterel program can be simulated using luciole:

- call the script **`esterel2dro mouse.strl mouse`**
  builds a dynamic library **`mouse.dro`**, in a format recognizable by luciole
- run **`luciole`** and load **`mouse.dro`** to start the simulation.

Visualizing the Esterel program semantics

The automaton of an Esterel program can be explored using atg:

- call the script **`esterel2 mouse.strl mouse`**
  compiles the program into an automaton **`mouse.atg`**,
- run **`atg mouse.atg`**, then press 'x' to start the exploration.

To go further

- Write and simulate the examples seen in the course.
- Write an Esterel version of the car lights controller
- hints:
  - ↪ the **`sustain X`** statement is a (convenient) shortcut for **`loop emit X; pause end`**
  - ↪ more generally, see the slides on Esterel to find a list of Esterel statements.