Synchronous programming exercises (programming)

Pascal Raymond

Verimag-CNRS

MOSIG - Embedded Systems

Environment

Copy these lines on your .bashrc file:

```
for idir in /usr/local /user/5/raymond ; do
    if [[ -f $idir/lustre/setenv.sh ]]; then
        export LUSTRE_INSTALL=$idir/lustre
        source $idir/lustre/setenv.sh
        break
    fi
done
```

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
```

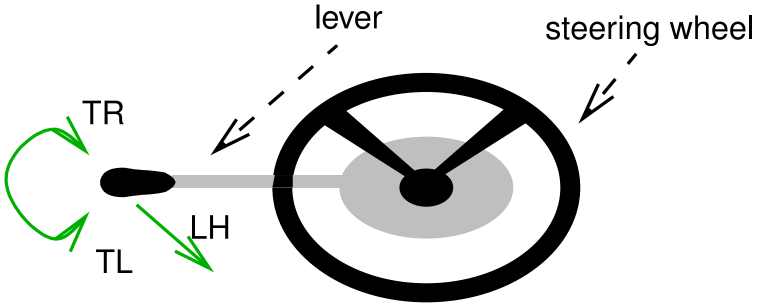
Or simply `luciole` then browse.

- 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:

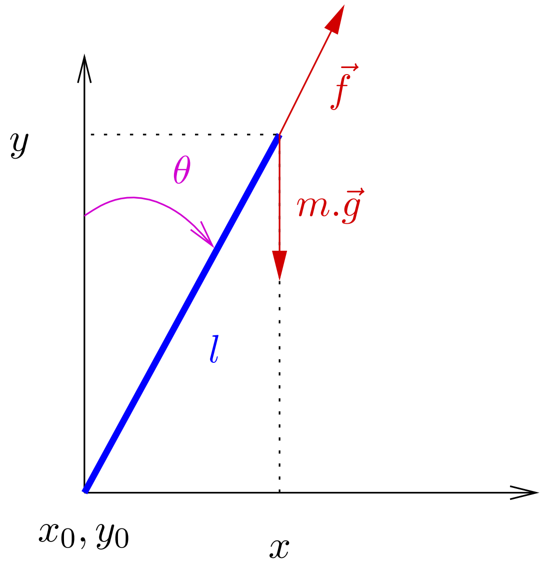
To go further:

- 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/r̃aymond/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.