Targeting the Scicos Codegenerator for embedded applications

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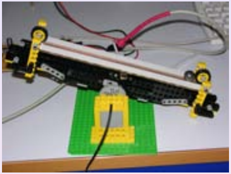
Objectives

(Prices in Euro)	Commercial Control design environment	Proposed solution
Core SW	1950.-	0.-
Control SW	1000.-	0.-
Graphical GUI	3000.-	0.-
Code generator	7500.-	0.-
RT target	3000.-	0.-

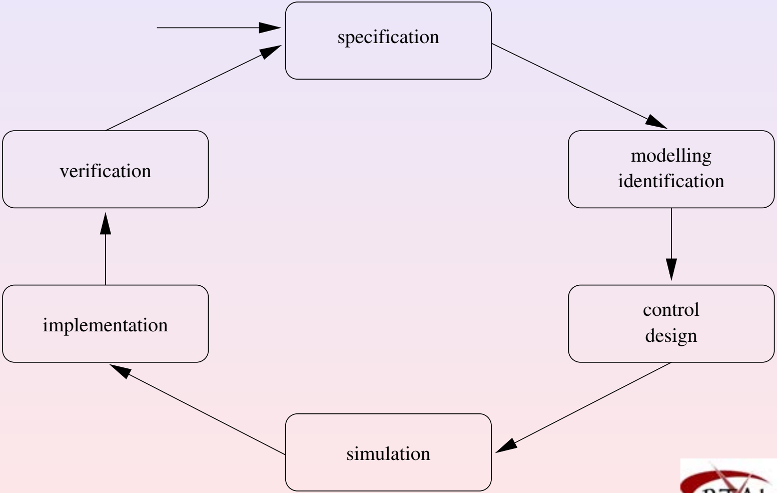
Objectives



Outline

1. Rapid Controller Prototyping
2. Linux RTAI
3. Scilab/Scicos and Linux RTAI
4. Implementation
5. Examples
6. Conclusions

Control Design Loop



Rapid Controller Prototyping - Requirements

- 2 main components
  1. An OS with hard real-time features
  2. A Computer Aided Control System Design environment including a code generator

→ Linux RTAI + RTAI-Lab + Scilab/Scicos

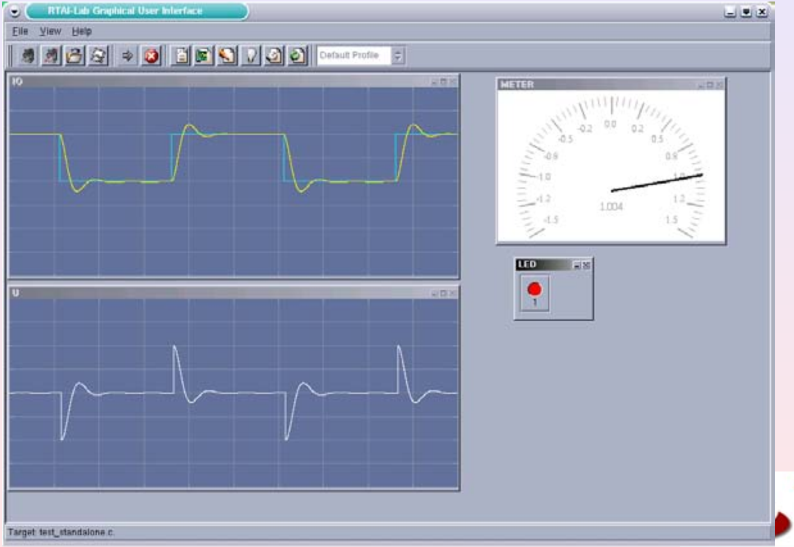
The Linux RTAI project

- Hard real-time extension to the Linux OS
- Based on the ADEOS pipeline (with some improvements!)
- Free Open Source Software (FOSS)
- Implementation of hard real-time controllers using general purpose hardware
- Same PC for the controller design, the hard real-time controller task and the soft real-time monitor task
- Hard real-time in kernel and user space
- Distributed control through the net_rpc module

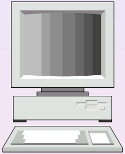
Linux RTAI - Features

- Latency: $< 10\mu s$ depending on the HW
- Typical sampling frequencies: $1 \ldots 10kHz$

The GUI application - xrtailab

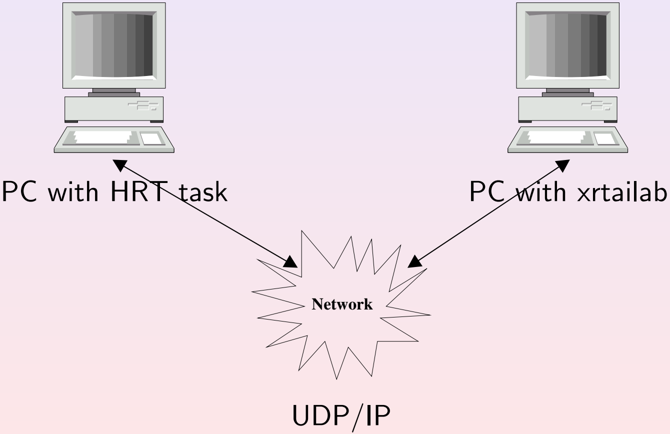


The GUI application - xrtailab



PC with HRT task and xrtailab

The GUI application - xrtailab



PC with HRT task

PC with xrtailab

UDP/IP

Systems controlled with Linux RTAI

Cycab (INRIA)

Biped Robot (INRIA)

http://www.inrialpes.fr/sed

RTAI example 2

National Radio Astronomy Observatory controlled with Linux RTAI - West Virginia

http://www.gb.nrao.edu/43m/

Add-ons for Scilab/Scicos

The link between Scilab/Scicos and Linux RTAI is implemented through:

- A code generator → RTAICodeGen_.sci.
- A *rtmain.c* (main file for the real-time task) specific for the Scilab/Scicos environment.
- An external "template Makefile"
- A new scicos palette *RTAI-Lib.cosf*.
- Macros for the new blocks (Scicos interface functions).
- A RTAI library specific for the new Scicos blocks (Scicos implementation functions).

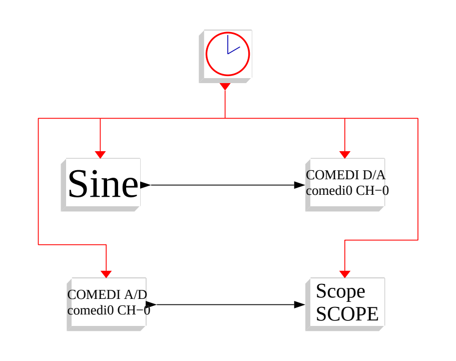
RTAICodeGen_.sci

The code generator used in RTAI is a modification of the standard Scicos code generator

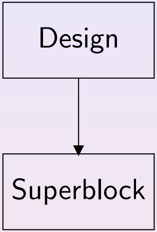
- Only stand-alone generation with specific main procedure (rtmain.c)
- Sensors and actuators are integrated in the Scicos block diagram as specific custom peripheral blocks
- Each block can be identified by a name which is then referred in RTAI-Lab

Code generation

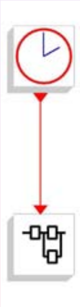
Design



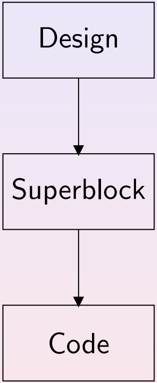
Code generation


Design

Superblock



Code generation



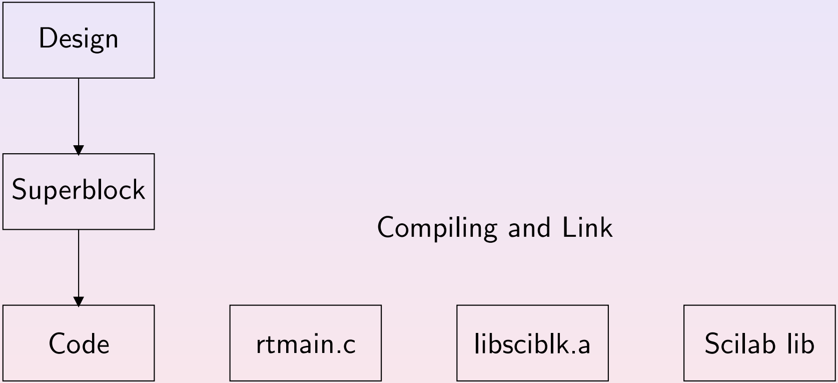
Design

Superblock

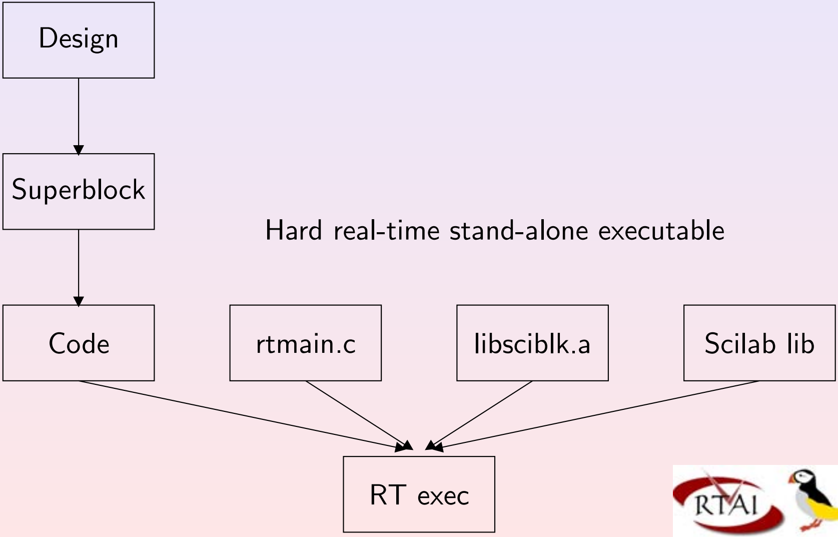
Code

RTAICodegen_.sci

Code generation

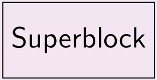


Code generation



Hard real-time stand-alone executable

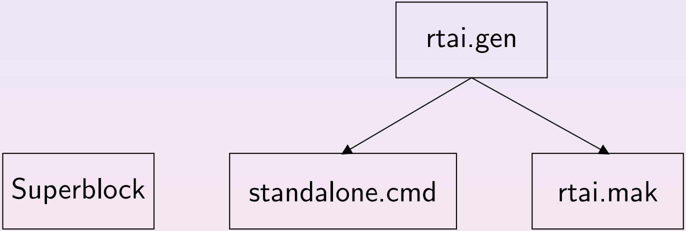
Code generation -Details



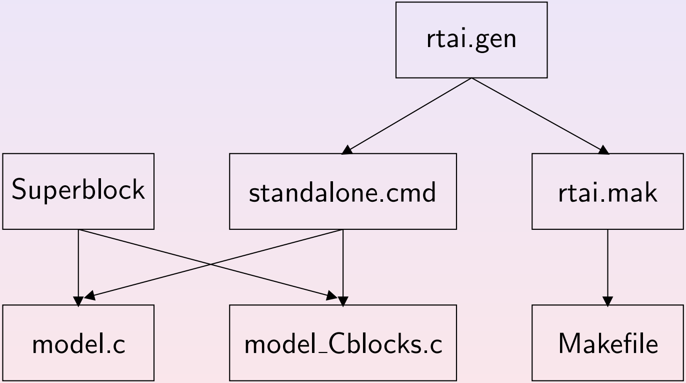
Superblock

Code generation -Details

Code generation -Details



Code generation -Details



Target specific files - The “gen” file

```
rtai.mak
standalone.cmd
```

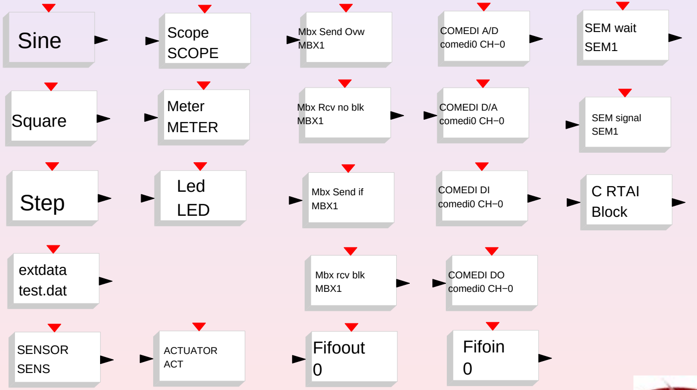
Target specific files - The “cmd” file

```
[CCode,FCode]=gen_blocks()
[Code,Code_common]=make_standalone42();
files=write_code(Code,CCode,FCode,Code_common);
Makename=rt_gen_make(rdnom,files,archname);
ok=compile_standalone();
```

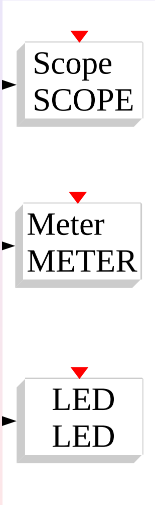
Target specific files - The “mak” file

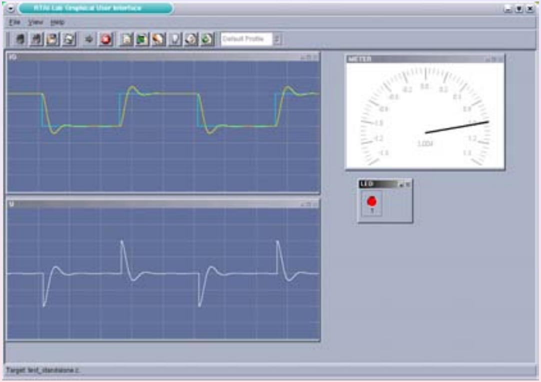
```
all: ../$$MODEL$$
...
CC = gcc
CC_OPTIONS = -O -DNDEBUG -Dlinux -DNARROWPROTO -D_GNU_SOURCE

MODEL = $$MODEL$$
OBJSSTAN = rtmain.o common.o $$MODEL$$.o $$OBJ$$

SCILIBS = $(SCIDIR)/libs/scicos.a $(SCIDIR)/libs/poly.a $(SCIDIR)/libs/calelm.a
OTHERLIBS =
ULIBRARY = $(RTAIDIR)/lib/libsciblk.a $(RTAIDIR)/lib/liblxrt.a

CFLAGS = $(CC_OPTIONS) -O2 -I$(SCIDIR)/routines -I$(SCIDIR)/routines/scicos $(C

rtmain.c: $(RTAIDIR)/share/rtai/scicos/rtmain.c $(MODEL).c
        cp $< .

../$$MODEL$$: $(OBJSSTAN) $(ULIBRARY)
        gcc -static -o $@  $(OBJSSTAN) $(SCILIBS) $(ULIBRARY) -lpthread $(COMED
        @echo "### Created executable: $(MODEL) ###"
```

The new Scicos palette

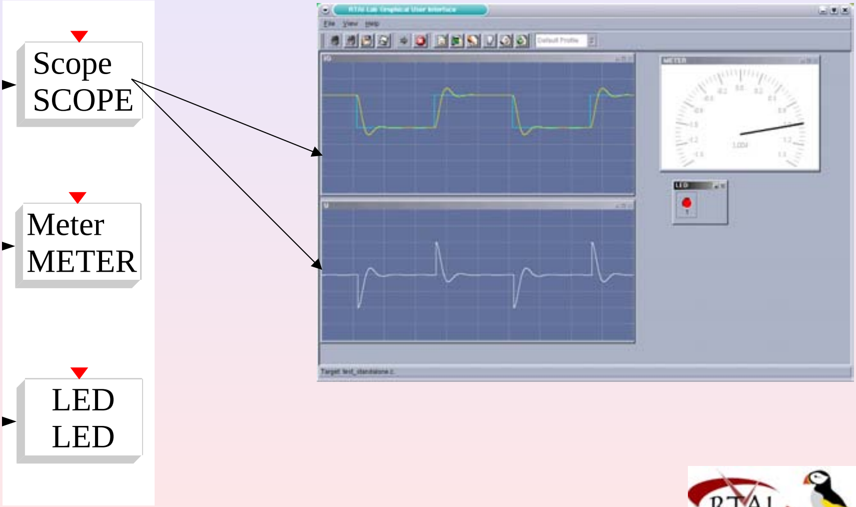


Specific blocks for RTAI-Lab

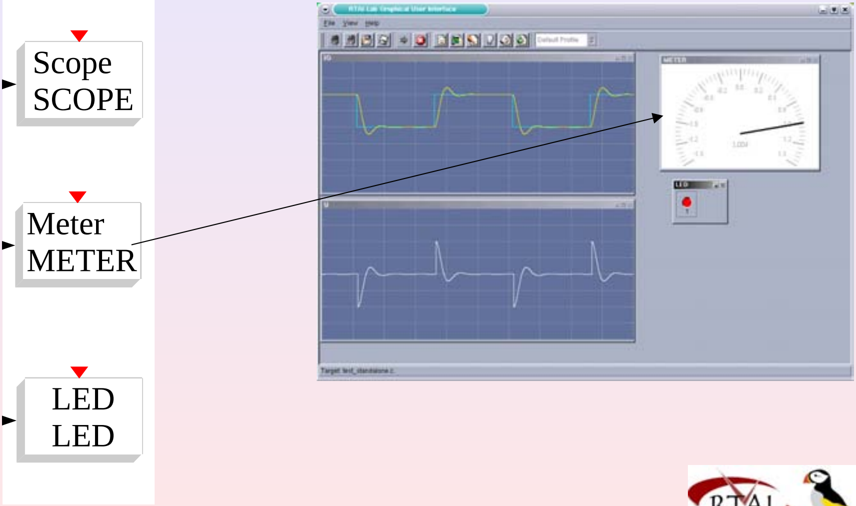




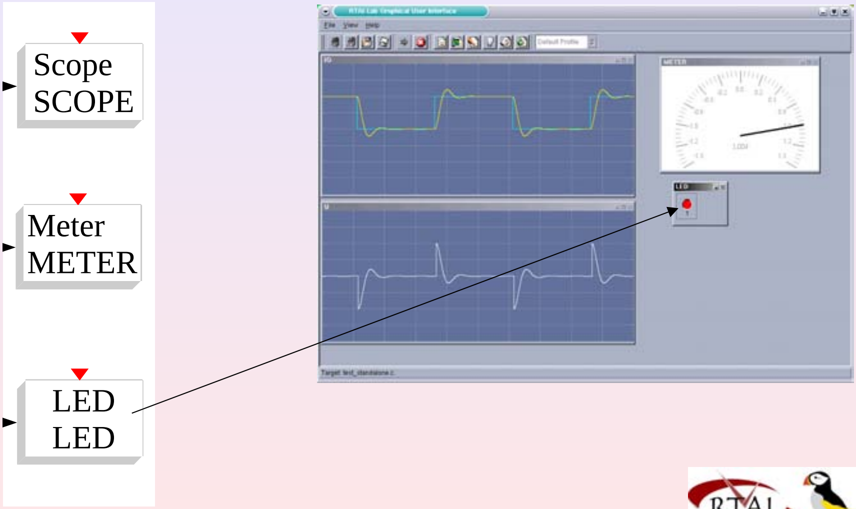
Specific blocks for RTAI-Lab



Specific blocks for RTAI-Lab



Specific blocks for RTAI-Lab

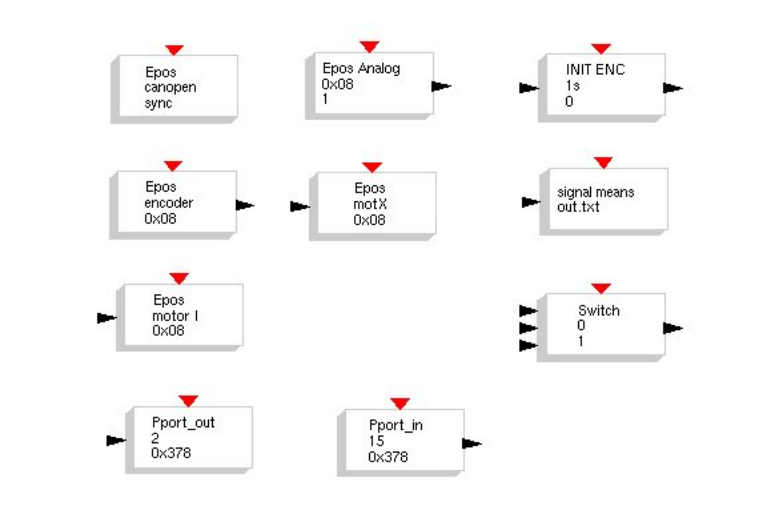


Scope
SCOPE

Meter
METER

LED
LED

Additional palettes

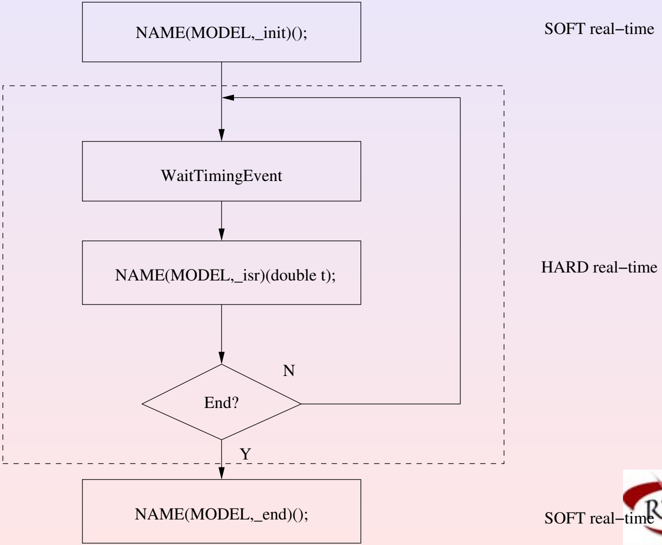


The main file *rtmain.c*

3 threads:

- Main thread *rtMain*
- Hard RT thread *rt_BaseRate*
- Communication thread with the GUI client application *rt_HostInterface*

The *rt_BaseRate* thread



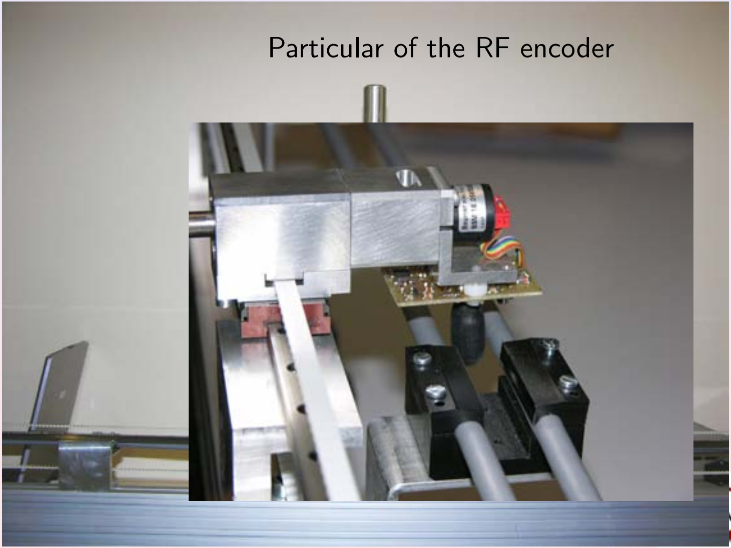
Adding a new block

Each new block needs

- An interface function (".sci")
- An implementation function (".c")

The Inverted Pendulum

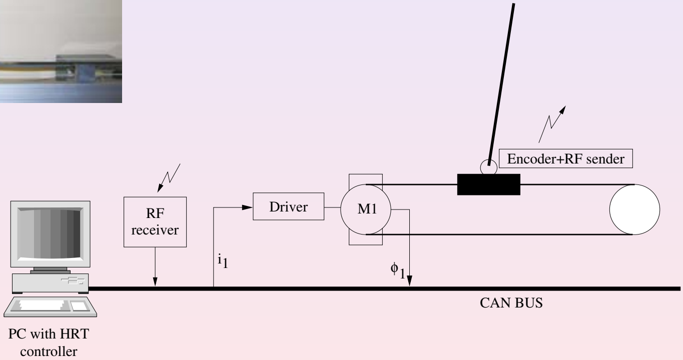
The Inverted Pendulum



Particular of the RF encoder

The Inverted Pendulum

The Inverted Pendulum



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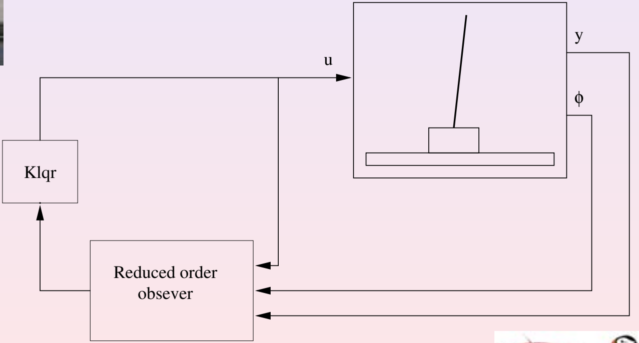
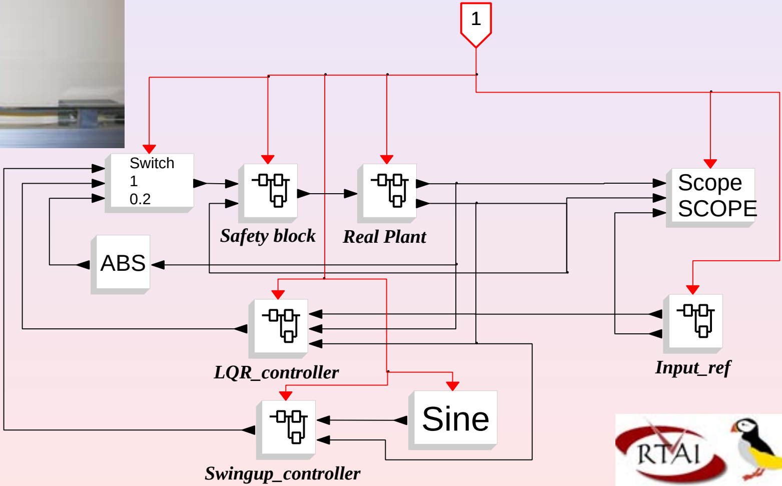
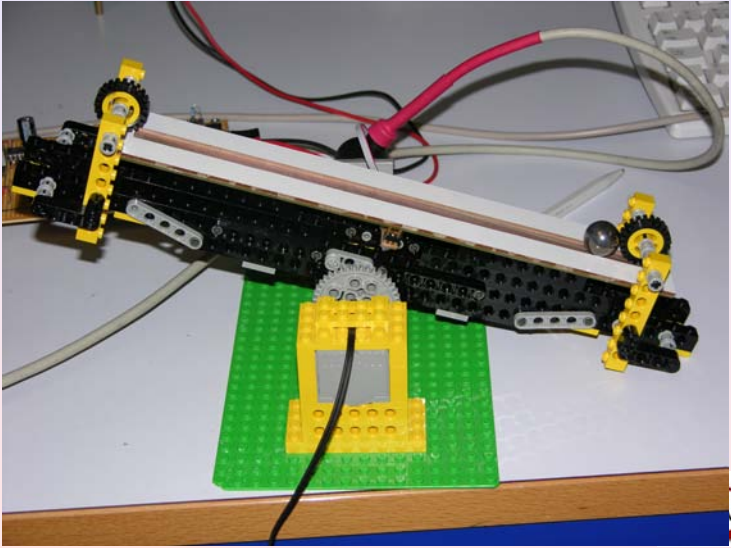


The Inverted Pendulum

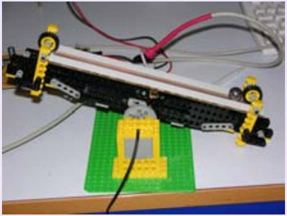
The Scicos scheme



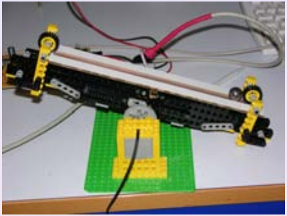
Ball on Beam



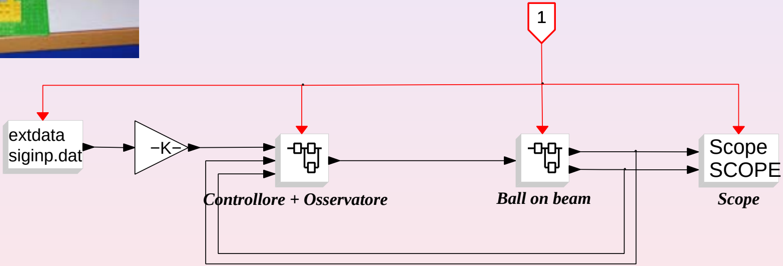
Ball on Beam



Ball on Beam



The Scicos scheme



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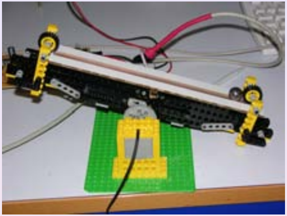
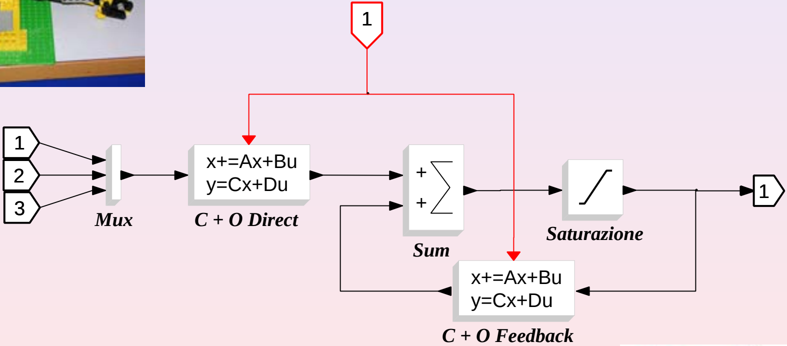
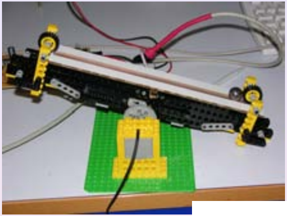


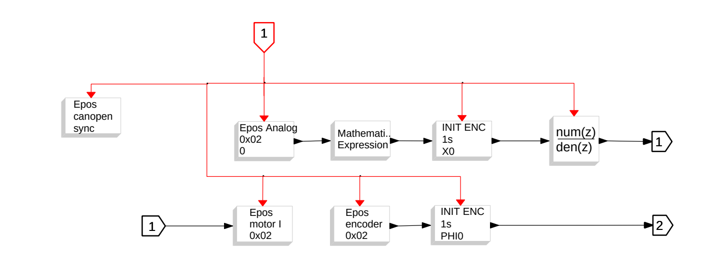
The anti-windup controller



Ball on Beam



The CANopen blocks



Videos

Sample Videos

Conclusions

- Open source!!!
- Complete and stable.
- Able to solve complex control problems in a simple way.
- It runs parallel to a MATLAB/Simulink/RTW environment in my student laboratory

Questions?

Thank You

- www.rtai.org
- www.dti.supsi.ch/∼bucher/scilab.html
- www.dti.supsi.ch/∼smt/labo04.html