HIL and MC lab handbook

TMR4243

November 4, 2014

Contents

Nomenclature

cRIO National Instruments compact reconfigurable input/output real-time embedded industrial controller

RPi Raspberry Pi single-board computer

VI virtual instrument, a LabVIEW program

1 Introduction

Hva skal denne labben handle om?

1.1 Structure

Part I describes the laboratory facilities and equipment. A general overview of hardware and software.

Part II is a user guide intended for students of the course. Step-by-step instructions for development and deployment of programs to the real-time controller are given. Lower level details, intended for laboratory assistants are given in Part V.

Part I
Laboratory equipment

2 MC-Lab

The Marine Cybernetics Laboratory is the newest test basin at the Marine Technology Centre. It is located in what was originally a storage tank for ship models made of paraffin wax.

As the name indicates, the facility is especially suited for tests of marine control systems, due to the relatively small size and advanced instrumentation package. It is also suitable for more specialised hydrodynamic tests, mainly due to the advanced towing carriage , which has capability for precise movement of models in 6 degrees of freedom.

The MCLab is operated by the Department of Marine Technology, and has been a Marie Curie EU Training Site (2002-2008). It is mainly used by Master and PhD-students, but it is also available for MARINTEK and external users.

The software in use was developed using rapid prototyping techniques and automatic code generation under Matlab/Simulink and Opal. The target PC onboard the vessel runs the QNX real-time operating system while experimental results are presented in real-time on a host PC using Labview.

Sakset rett fra nettsiden http://www.ntnu.edu/imt cybernetics-lab

2.1 Towing carriage

Carriage : towing speed 2 m/s, 5 (6) DOFs forced motions Current generation: 0-0.15m/s

2.2 Wave generator

The wave genertor is located at the end of the tank and is operated from its own copmuter. It has the capability to create first order Stoke waves or irregular recreate different wave spectras such as JONSWAP or PM spectras.
Significant wave height $H_s = 0.3$ [m] with period T between 0.6 [s] and 1.5 [s]

2.2.1 First order Stoke waves

First order stoke waves are regular linear waves. Very nice to do calculations with, but not so representative for real life conditions. Described by potential theory

2.2.2 Irregular waves

2.3 Qualisys positioning system

The positioning system works by tracking reflectors placed on the ship with the use of high speed cameras.
Qualisys consists of three systems

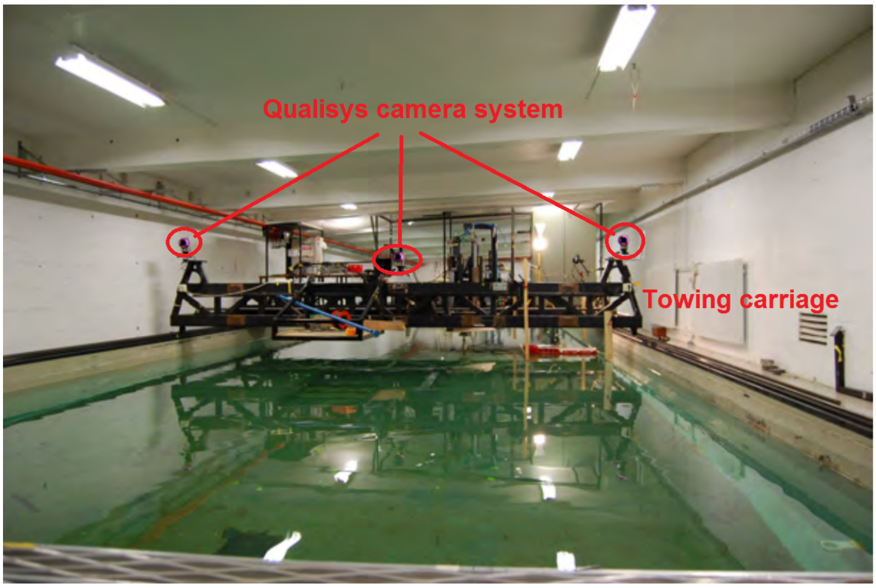

Figure 1: Towing carriage

- Qualisys Oqus: The cameras used to register/see the IR markers
- Qualisys Motion Capture Systems: is the system that process the data from Oqus
- Qualisys Track Manager: The userinterface to interact with Motion Capture System

2.4 Ethernet communication network

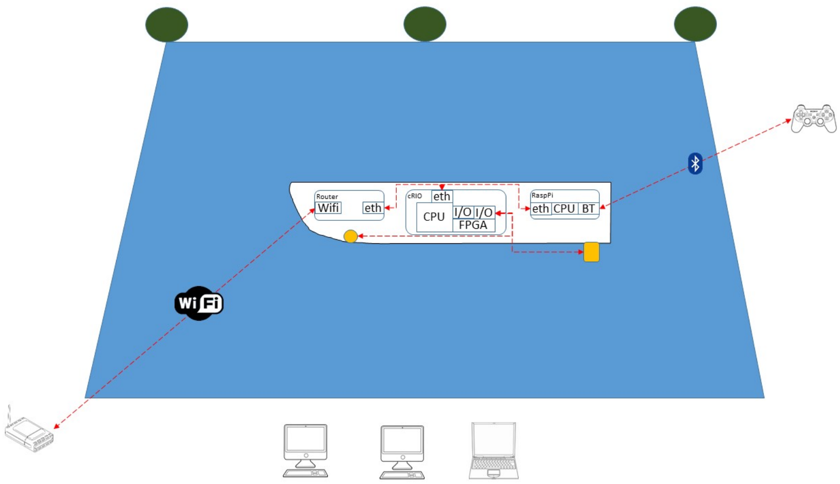

Figure 2: Towing carriage

For communication with the ship, the wireless network HILlab is used

3 CSE1 - C/S Enterprise I

Figure 3: C/S Enterprise I

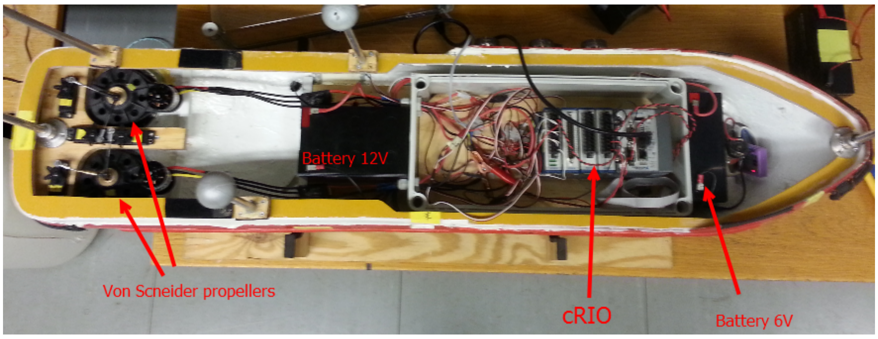

Figure 4: CSE1 - Hardware

3.1 Control system

3.1.1 Real time hardware

CompactRIO
CompactRIO is a reconfigurable embedded control and acquisition system. The CompactRIO system's rugged hardware architecture includes I/O modules, a reconfigurable FPGA chassis, and an embedded controller. Additionally, CompactRIO is programmed with NI LabVIEW graphical programming tools and can be used in a variety of embedded control and monitoring applications.
For more info vistit the producer website

Sakset fra ni.com/compactrio

3.1.2 Real time software

LabVIEW - Real time module
National Instruments real-time technology offers reliable, deterministic performance for your time-critical applications. Use the LabVIEW Real-Time Module to develop and deploy complex real-time systems quickly and efficiently to the

CompactRIO microprocessor.
Veristand

3.1.3 Input/Output signals

PWM

Digital output

3.1.4 NI Labview user interface

3.1.5 Startup procedure

Connecting to Cybership Enterprise 1 (RT CompactRIO - NI-cRIO9024-CSE1 (192.168.0.77))

Nam sin prosedyre fra readme.txt

1. Place "Main battery" (large fat one) beneath wireless anntenna, adjacent to waterproof box, between the wires, with battery terminals furthest away from it.

2. Place "Servo battery" (small slim one) at bow between tunnel thruster and waterproof box, with battery terminals closes to the waterproof box.

3. Postive battery terminal ("RED-port") at portside and negative battery terminal ("BLACK-port") at starboard side
   Connect wire with red isolation ("RED-wire") to "RED-port" and wire with black isolation ("BLACK-wire") to "BLACK-port"

4. Connect first the "RED-wire" before the "BLACK-wire" to the batteries.

5. The "Main battery" (large fat one) should be connected first then wait a few sec (5s) before connecting the "Servo battery" (small slim one).

6. Note: it should not matter in which order it is done, but from experience connectiong "RED-wire" before "BLACK-wire" gives a much higher probability for communication with the CompactRIO on Cybership Enterprise 1 (99-100%'ish) than connecting the "BLACK-wire" before the "RED-wire" (25%ish), and it is a habit to connect main before the servo, since main powers "CompactRIO" while servo powers "D-Link wireless bridge"

7. There should be 3 red lights lighting up, one at bow in a purple box for indicatiing power to tunnel thuster two close to "Main battery", one on each side for each Voith Schneider propeller

8. The indicators on "ACT/LiNK" port 1 should light up (green) to indicate communication with "HILlab"

9. Test communication:

   - Open "Command Promt"
   - write: ping 192.168.0.77

   A successfull ping should return somthing like

```
C:\Documents and Settings\mcl>ping 102.168.0.77

Pinging 192.168.0.77: bytes=32 time = 5ms TTL=64
Pinging 192.168.0.77: bytes=32 time = 5ms TTL=64
Pinging 192.168.0.77: bytes=32 time = 5ms TTL=64
Pinging 192.168.0.77: bytes=32 time = 2ms TTL=64

Ping statistics for 192.168.0.77:
Packets: Sent = 4, Received = 4, Lost = 0 <0% loss>,
Approximate round trip times in milli-seconds:
Minimum =2ms, Maximum = 5ms, Average = 4ms
```

10. The most imprtant thing is that you receive packets in return, the time might vary but the important thing is that it responds to the ping.
11. If Lost = 100% meaning no repons means either "Laptop" or "CompactRIO" is unable to communicate with "HILlab".
12. Check Laptop is connected to wireless network "HILlab", if not connect to it "HILlab"
13. Check ACT/LiNK" port 1 are showing activity e.g. are lit, blinking, if not check ethernet cable is connected to "ACT/LiNK" port 1 and to the "D-Link Wireless Bridge" if not connect to those Battery gives power to "CompactRIO" and "D-Link", lights/indicators are lit/blinking if not check wiring
14. Check battery voltages, "Main battery" should be 10 Volt or more, maximum around 13 Volt, regular 11 to 12 Volt, low 10 Volt "Servo battery" should be in 5 Volt or more, max around 6.4 Volt, regular around 6 Volt
15. Note: Black wire should always be the last to be connected, and "Main Battery" first

3.1.6 Template: DP control system

3.2 HIL Simulation Setup

3.2.1 Hardware topology

3.2.2 Software C/S E1

PWM tick = FPGA clock pulse

$tickinseconds = 1/frequency = 1/40MHz = 1/(40 * 10^6) = 25 * 10^-9 = 25ns$

output at 50 Hz demands output every $40MHz/50Hz = (40 * 10^6)/50 = 800000tick$

3.2.3 Startup procedure

3.3 Development procedure

3.3.1 Development for new algorithms in modules in Simulink

3.3.2 Development with structural changes in I/O or Labview UI

4 Software

MATLAB	Mathworks	
LabVIEW	National Instruments	
VeriStand	National Instruments	Interfacing
NI MAX	National Instruments	Measurement & Automation Explorer: configurering av cRIO
Qualisys?		

Table 1: Software

Hva brukes det enkelte programmet til?

Part II
Laboratory user guide

5 Model compilation

model, controller, Simulink-¿dll

6 Model deployment

Veristand osv

7 System interfacing

work space

8 Deploying basic VI

1. Open LabVIEW
2. Create project
3. Blank project
4. In the left pane tree, right-click Project: XXX, New -¿ Targets and devices
5. Keep setting Existing target or device, Discover an existing target(s) or device(s)
6. In the tree, expand Real-Time CompactRIO, wait for search and select the cRIO
7. In the Project Explorer, drag and drop the VI to the device
8. Right-click the VI, Run

Part III
Theory

Part IV
Lab exercises and expected results

Forslag fra Roger

- Estimere pivot point
- Estimere bølgefrekvens og bølgehøyde??
- Tuning PID parametere
- Analysere agressivitet ved ulik tuning
- Analysere og teste notch effekt i bølgefilter
- Thrust allocation
- Lyapunov function. UGES $\rightarrow$ estimate convergence rate $\rightarrow$ simulate convergence rate $\rightarrow$ test convergence rate
- Bandwidth!

From TMR 4243 and 4515

- Robust nonlinear control methods (different backstepping methods, ISS designs, sliding-mode designs, passivity-based control, nonlinear PID and integral control).
- Adaptive control designs for nonlinear systems (adaptive backstepping, gradient methods, L1 adaptive control, etc.)
- Maneuvering control theory and path-following control designs for marine vessels (path parameterization, path generation, guidance theories, and feedback control laws).
- Fault-diagnosis and fault tolerant control (failure-mode detection, fault isolation, and control redesign to detect and handle failures in equipment and processes).

Part V

Equipment setup and configuration

A cRIO

A.1 Input and output

A.1.1 PWM output

VeriStand FPGA programming LabView -¿ Create project -¿ All -¿ NI VeriStand FPGA project -¿ Compact RIO -¿ Discover existing system -¿ Velge eget utstyr -¿ Vente på discovering -¿ I Project explorer *.vi (er bitfilen) *.fpgaconfig (egentlig XML) Endre på *.vi Fjerne overføldige pakker Oppdatere antall pakker i XML-filen og fjerne pakker som ikke er aktuelle, oppdatere tall på beholdte pakker. Kompiler

Kopier bit-file ut i samme mappe som *.fpgaconfig I System exlporer, FPGA -¿ Add FPGA target -¿ Finne *.fpgaconfig

A.1.2 Analog input

Eirik: FPGA-greier osv

A.2 Secondary ethernet port

A.2.1 Enabling the port

1. Start *NI MAX*
2. In the left pane tree, select the cRIO under *Remote Systems*
3. Open the *Network Settings* tab (located at the bottom of the window)
4. Set *Adapter Mode* to *TCP/IP Network*
5. Set *Configure IPv4 Address* to *Static*

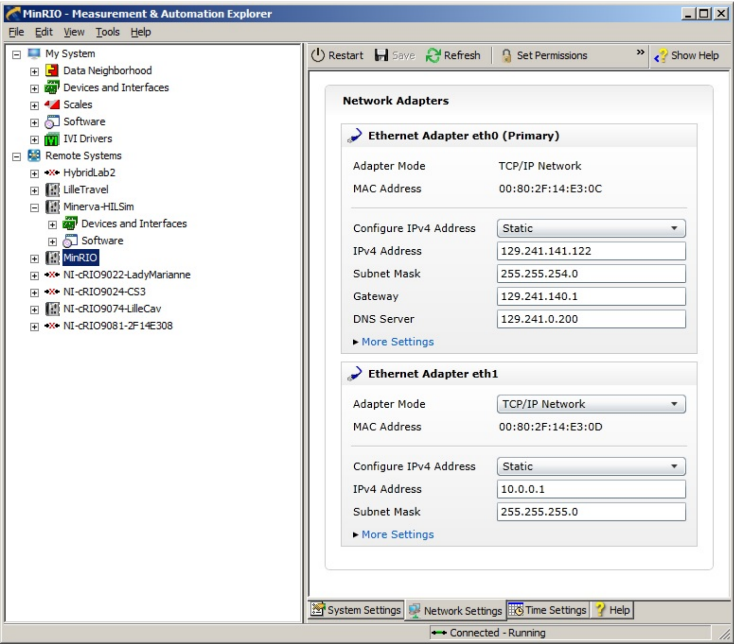

Figure 5: NI MAX - Network Settings

B Raspberry Pi

B.1 OS installation

http://hertaville.com/2012/09/27/raspbian-raspberry-pi/

B.2 Terminal access

The RPi may be accessed through the network, i.e. without having to directly connect a monitor and keyboard.

B.2.1 Step 1 - determining RPi IP address

This step can be skipped if the IP is known.

Advanced IP scanner http://www.advanced-ip-scanner.com/. By default the RPi has name *raspberrypi*. The IP is given in the next column, as in Figure 6.

B.2.2 Step 2 - connect via SSH

Putty http://www.chiark.greenend.org.uk/~sgtatham/putty/download.html

Default RPi are

```
Username: pi
Password: raspberry
```

However, the password is changed to the MC-lab standard.

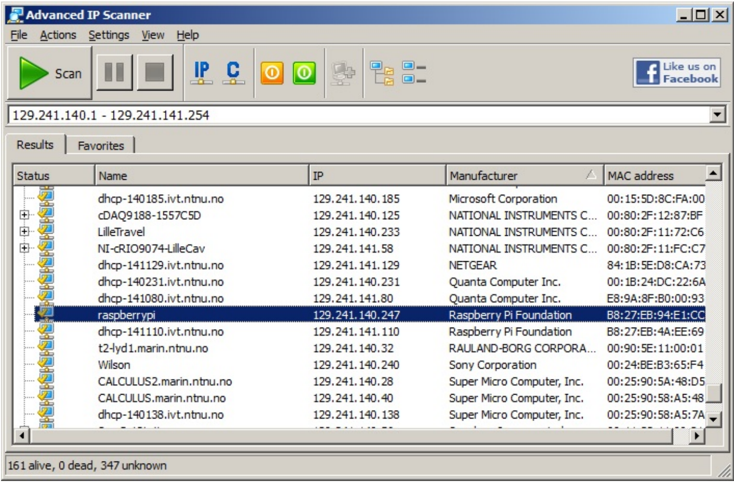

Figure 6: Advanced IP Scanner

B.3 PS3 Controller

Eirik: driver, python-Joystick osv

C Qualisys

calibration

Part VI
Misc

D Contributers and points of contact

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Table 2: POCs

See Table D

E Suppliers

Laptops	Dell
cRIO	National Instruments
VSP	Thrusters were ordere at `www.cornwallmodelboats.co.uk/acatalog/voith_schottel.html`. Per 2014, availability is variable.

Table 3: Suppliers

F YouTube demonstration

`http://www.youtube.com/watch?v=MiESJsIZO04`

G To do list

- Etablere fargekoder for simulinkblokker (spesielt “ikke røre”-farge)
- Konsekvent notasjon: C/S Enterprise 1 eventuelt CSE1
- Forklaring av hva realtime betyr i HW og SW

- Troubleshooting-prosedyrer for de vanligste feilene
- Implementere “fail to zero” for når kommunikasjonen avbrytes.
- legge til IMU/gyro på båten

H Software needed

- Matlab
- Labview
- LabVIEW development system
- LabVIEW Real-Time Module
- LabVIEW FPGA Module (recommended)
- NI-RIO driver
- VeriStand