YARP and iCub code tutorials

Software installation

- www.yarp.it → Installation
- http://wiki.icub.org/wiki/ICub_Software_Installation
- Installation from sources
- Linux virtual machine: http://www.icub.org/download/other/Ubuntu_1404_64-bit.zip

Code available on github

- https://github.com/lornat75/Teaching
- Type:

git clone git@github.com:lornat75/Teaching.git

Yarp from command line

A (very) simple example: read data to/from a port

[on terminal 1] yarpserver
[on terminal 2] yarp read /read
[on terminal 3] yarp write /write /read

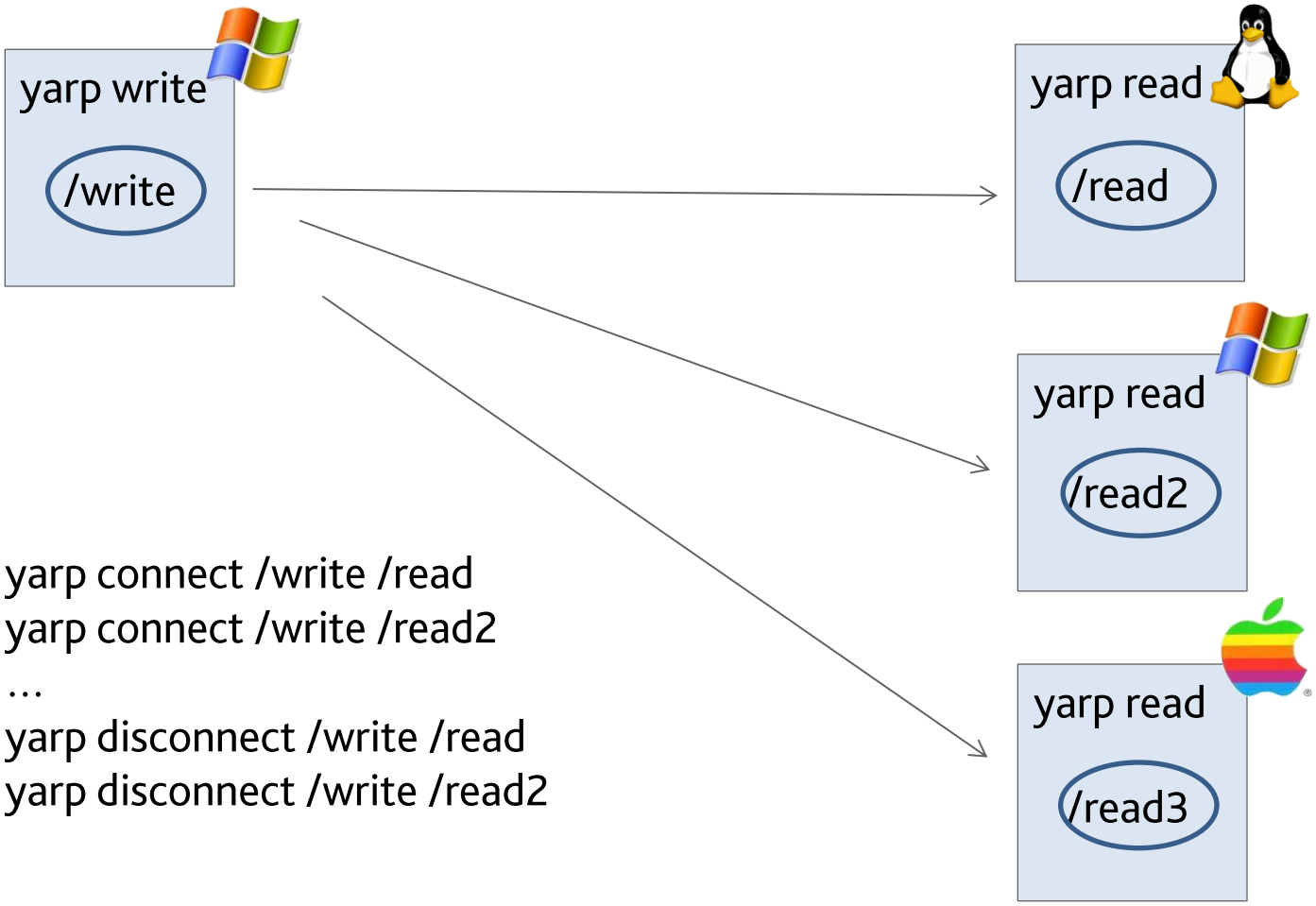

```
$ yarp write /write /read
Port /write listening at tcp://127.0.0.1:10012
yarp: Sending output from /write to /read using tcp
Added output connection from "/write" to "/read"
hello yarp
1 2 3
```

```
$ yarp read /read
Port /read listening at tcp://127.0.0.1:10002
yarp: Receiving input from /write to /read using tcp
hello yarp
1 2 3
```

yarp name list
yarp name query /read
yarp name register PORT CARRIER IP NUMBER
yarp name unregister PORT

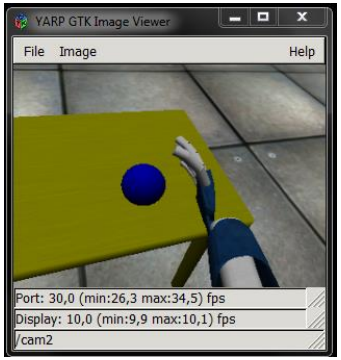
how the network grows

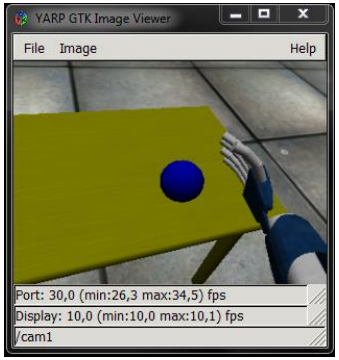
It is easy to add, for example, another reader…
Processes can run on different machines, with different OS




```
yarp connect /write /read
yarp connect /write /read2
…
yarp disconnect /write /read
yarp disconnect /write /read2
```

yarpview





yarpdev --device test_grabber --name /cam/right
yarpdev --device test_grabber --name /cam/left
yarpview --name /view1
yarpview --name /view2

yarp connect /cam/right /view1
yarp connect /cam/left /view2

YARP configuration file

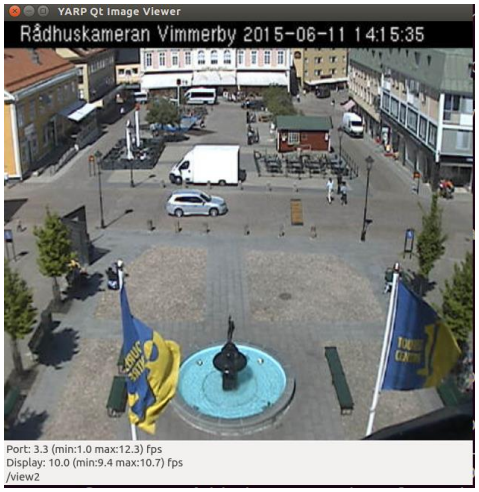
Where is the yarp nameserver?
icub@ubuntu-1404-64-vm:~$ yarp detect

icub@ubuntu-1404-64-vm:~$ yarp conf
/home/icub/.config/yarp/yarp.conf

icub@ubuntu-1404-64-vm:~$ cat /home/icub/.config/yarp/yarp.conf
192.168.59.128 10000 yarp

- **yarpserver** by default decides based on the available network card (i.e. eth0) on which adapter/ip to listen
- You can manually modify the yarp.conf file to change adapter/ip.
- **yarpserver** can accept that (--read) or overwrite it (--write).

Connecting to mjpeg



Make sure these CMake flags are enabled:
CREATE_OPTIONAL_CARRIERS=ON
ENABLE_yarpcar_mjpeg_carrier=ON

Run ccmake in YARP's build directory

yarp view –name /view
yarp connect /195.67.26.73:80 /view mjpeg+path./mjpg/video.mjpg

Alternatively you can register the remote address manually:
yarp name register /webcam mjpeg+path./mjpg/video.mjpg 195.67.26.73 80

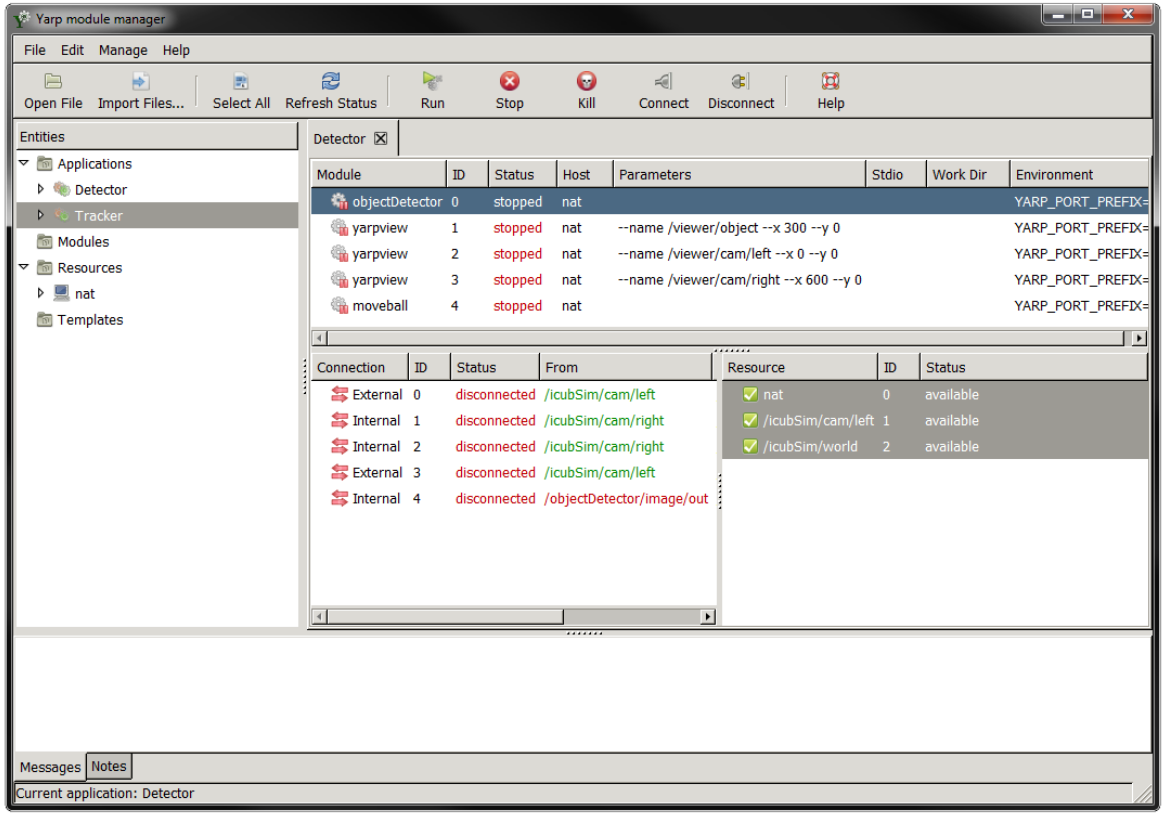
And use /webcam as an alias

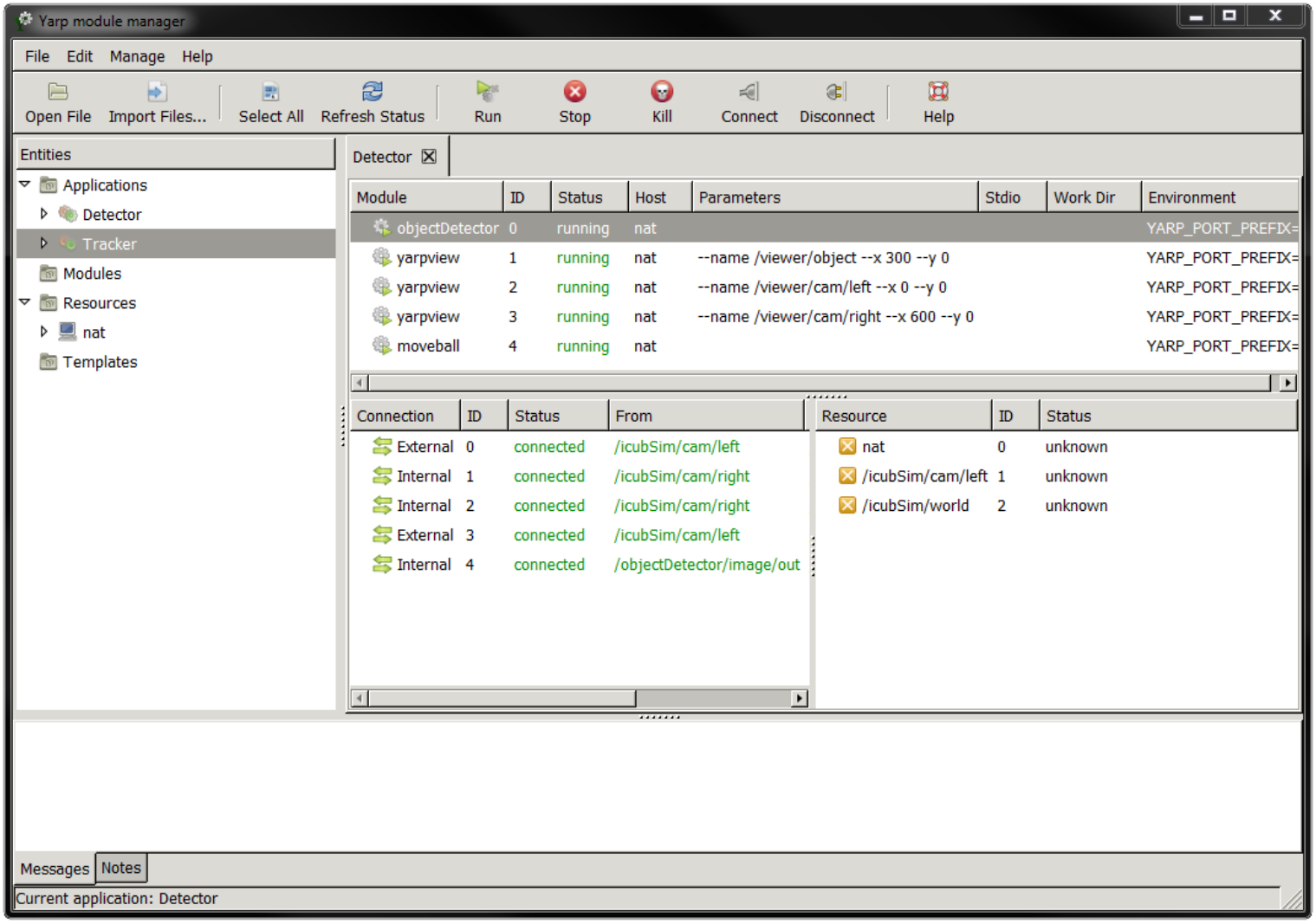
yarp connect /webcam /view

Automation

The YARP Manager

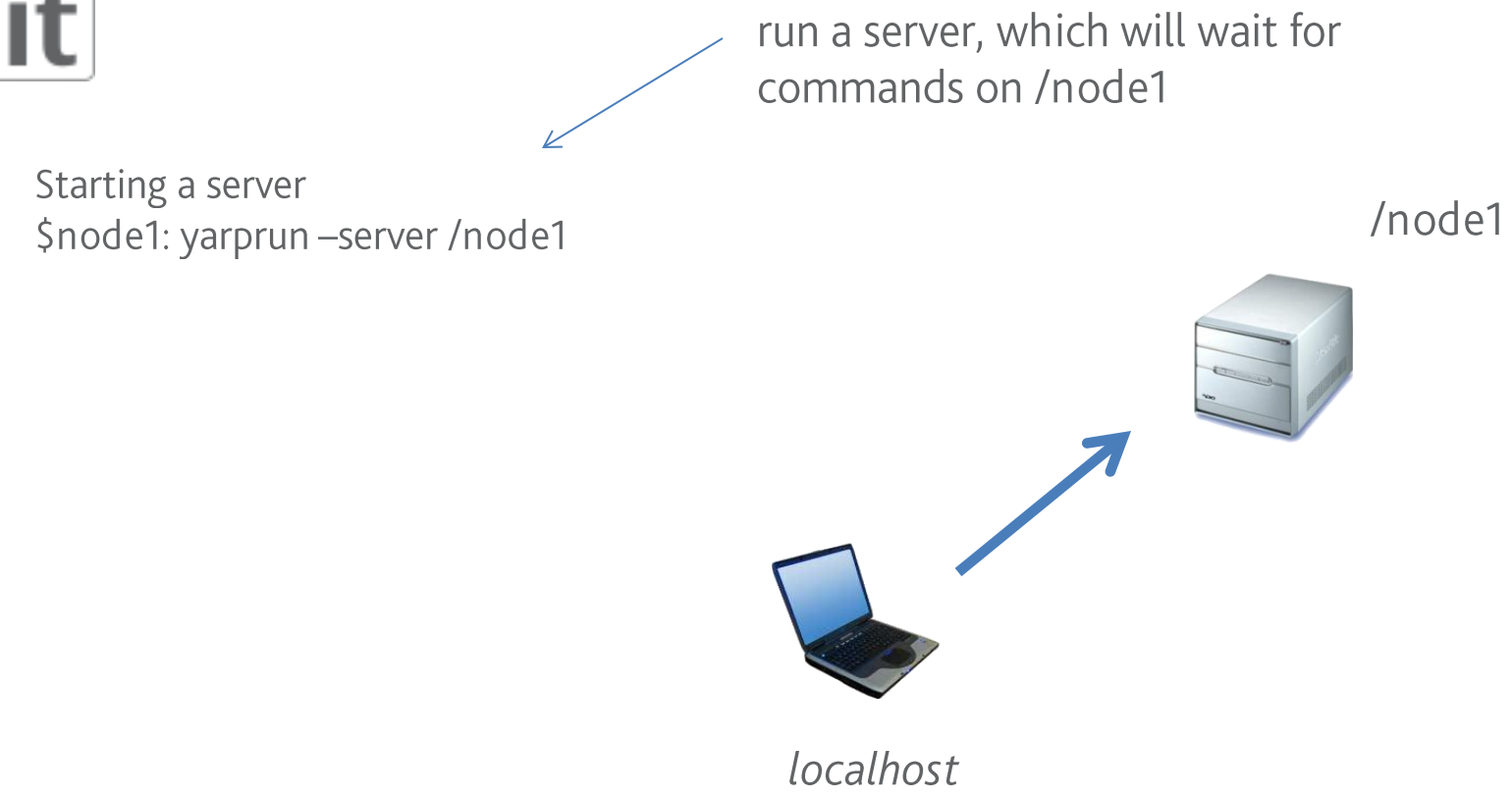
- The yarpmanager is a graphic interface to monitor processes
- It allows to start/stopping/monitor, redirect i/o
- In addition it automates establishing connections between modules




Yarp module manager
File Edit Manage Help
Open File
Import Files...
Select All
Refresh Status
Run
Stop
Kill
Connect
Disconnect
Help
Entities
Applications
Detector
Tracker
Modules
Resources
nat
Templates
Detector
Module ID Status Host Parameters Stdio Work Dir Environment
objectDetector 0 running nat YARP_PORT_PREFIX=
yarpview 1 running nat --name /viewer/object --x 300 --y 0 YARP_PORT_PREFIX=
yarpview 2 running nat --name /viewer/cam/left --x 0 --y 0 YARP_PORT_PREFIX=
yarpview 3 running nat --name /viewer/cam/right --x 600 --y 0 YARP_PORT_PREFIX=
moveball 4 running nat YARP_PORT_PREFIX=
Connection ID Status From
External 0 connected /icubSim/cam/left
Internal 1 connected /icubSim/cam/right
Internal 2 connected /icubSim/cam/right
External 3 connected /icubSim/cam/left
Internal 4 connected /objectDetector/image/out
Resource ID Status
nat 0 unknown
/icubSim/cam/left 1 unknown
/icubSim/world 2 unknown
Messages
Notes
Current application: Detector

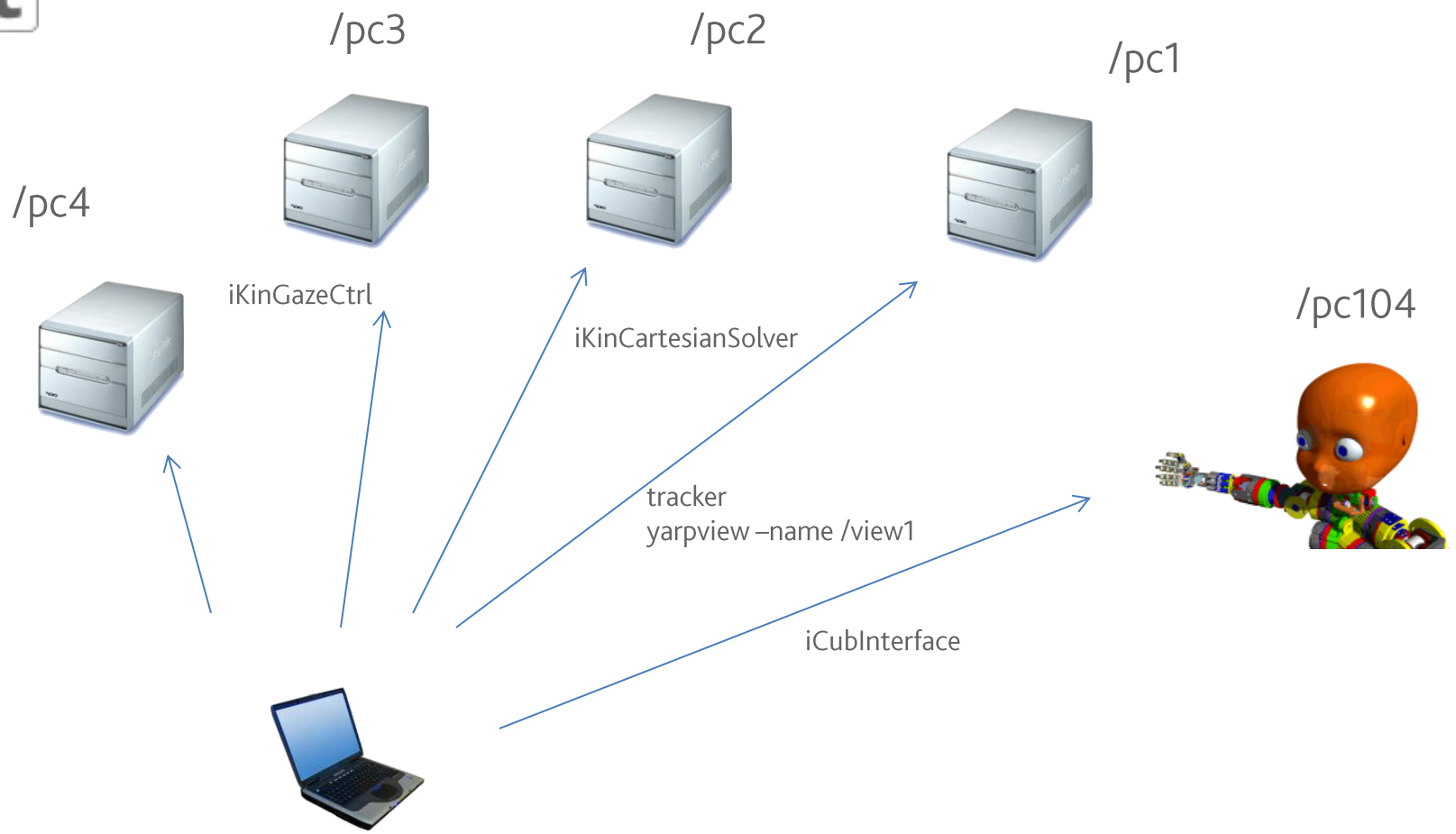
yarpmanager documentation

- http://wiki.icub.org/yarpdoc/yarpmanager.html



- The manager has two ways to execute processes: locally (localhost) or through yarprun
- yarprun is a server that waits for commands on a port
- start/termination/kill monitor lifecycle

  http://wiki.icub.org/yarpdoc/db/dd7/yarprun.html


/pc3
/pc2
/pc1
/pc4
/pc104
iKinGazeCtrl
iKinCartesianSolver
tracker
yarpview –name /view1
iCubInterface

Syntax

```
<application>
    <name>Name of the application</name> //this can be anything, just a symbolic name

    <dependencies>
      <port>/port1 </port>
      <port>/port2 </port>
    </dependencies>

    <module>
      <name>mymodule1 </name>
      <parameters>--threshold 1 --name /myName</parameters>
      <node>localhost</node>
    </module>

    <module>
      <name>mymodule2</name>
      ...
    </module>

    <connection>
      <from>/port1</from>
      <to>/otherport</to>
      <protocol>udp</protocol>
    </connection>

    <connection>
      …
    </connection>

</application>
```

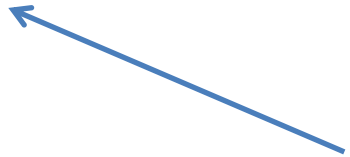
```
<application>
      <name>Name of the application</name> //this can be anything, just a symbolic name

      <module>
       <name>yarpdev</name>
       <parameters>--device test_grabber --name /cam/right</parameters>
       <node>localhost</node>
      </module>

      <module>
       <name>yarpview</name>
       <parameters>--name /view/right</parameters>
       <node>localhost</node>
      </module>

      <connection>
       <from>/cam/right</from>
       <to>/view/right</to>
       <protocol>udp</protocol>
      </connection>

</application>
```



or any other node in the network:
/node1, /node2 etc..
E.g. on the iCub: icub14, icub15, icub-b11…

Other tags

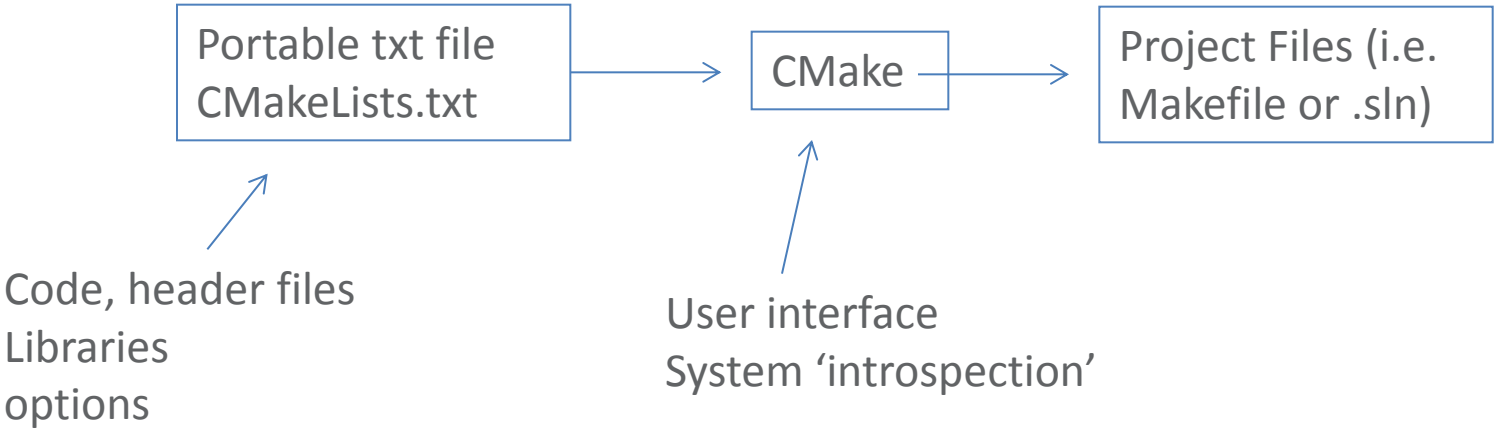
```
<dependencies>
    <port>/icub/cam/left</port>
    <port>/icub/cam/right</port>
</dependencies>

<module>
    …
    <workdir>C:/mydir</workdir>
    <stdio>node3</stdio>
</module>
```

CMake Basics

Introduction

- Open source build manager
- Specify build parameters in a simple portable text format



Problems solved by CMake

- Write and maintain project files for multiple platforms
- Optional components?
- Build on more than a single machine: different OS have different libraries, same OS can be installed differently → automatically search for programs libraries header files
- Build directory tree different from source tree
- Handle dependencies
- Static versus Dynamic libraries
- …

Basics

- Commands (case insensitive)
- Variables (case sensitive)

```
command(a b c)
set(FOO a b c)

command(${FOO})
command("${FOO}")
```

Consider:

```
set(PATH_TO_MY_FILE C:\program files\myfile)
command(${PATH_TO_MY_FILE})

command("${PATH_TO_MY_FILE}")
```

Hello World with CMake

```
cmake_minimum_required(VERSION 2.8)

project(hello)

include_directories(${CMAKE_CURRENT_SOURCE_DIR})

message(STATUS "--> Hello from CMake")

if (WIN32)
        message("--> Running on windows")
else()
                message("--> Assuming running on Linux")
endif()

if (NOT EXISTS "${CMAKE_CURRENT_SOURCE_DIR}/hello.cpp")
    message(FATAL_ERROR "File hello.cpp not found!")
endif()

add_executable(hello hello.cpp)
```

How to run CMake

- Source versus build directories
- From command line:
  - mkdir build
  - cd build
  - cmake ../ or ccmake ../
- From gui:
  - mkdir build
  - cmake-gui
  - Set source and build directories
- Hit “c” until you get “g”

When build = source dir: in source build
When build != source dir: out of source build

Cache

- Some variables are determined only once and cached on disk; CMake will not touch them, only the user can
- E.g. user options or result of system introspection, info that are expensive to determine (compiler to use, system libraries, etc..)
- To do a fresh restart, clean the cache
  - From the gui
  - Remove CMakeCache.txt

Commands on targets

- add_executable(name file1.cpp file2.cpp header1.h header2.h)
- target_link_libraries(name libname)
- add_library(name file1.cpp file2.cpp header1.h)
- include_directories(dir1 dir2)
- add_definitions(-DFOO -DBAR)

Example:

```
#if _ENABLE_DEBUG_
  printf(“Value of variable v is %d”, v);
#endif

option(ENABLE_DEBUG "Enable debugging messages"
       FALSE)

if (ENABLE_DEBUG)
    message(STATUS "Debugging messages are enabled")
    add_definitions(-D_ENABLE_DEBUG_)
endif()
```

Installation

- In some builds include an installation step
- You can add installation rules using CMake

install(TARGETS myExe RUNTIME DESTINATION <dir>)

install(FILES files DESTINATION <dir>)

<dir> can be:

- Absolute path
- Relative path, in this case it will be CMAKE_INSTALL_PREFIX\<dir>
- The user can customize CMAKE_INSTALL_PREFIX

Hello World with CMake (2)

```
...
add_executable(hello hello.cpp)
install(TARGETS hello
        RUNTIME DESTINATION
        ${CMAKE_CURRENT_SOURCE_DIR}/../bin)
```

Finding libraries

- The problem
- You want to compile an executable that links libraries from another package, e.g. YARP
- Naïve way:

```
cmake_minimum_required(VERSION 2.8)

project(hello)

include_directories("C:\Program files\yarp\include")

add_executable(hello hello.cpp)

target_link_libraries(hello "C:\Program files\yarp\lib\libYARP_OS.lib")
```

Finding libraries

- The problem
- You want to compile an executable that links libraries from another package, e.g. YARP
- Naïve way:

```
cmake_minimum_required(VERSION 2.8)

project(hello)

include_directories("C:\Program files\yarp\include")

add_executable(hello hello.cpp)

target_link_libraries(hello "C:\Program files\yarp\lib\libYARP_OS.lib")
```

Os dependent (.a in Linux)

Installation dependent

Finding libraries…

- CMake has a few commands that can be used to find directories, executables and libraries inside a computer

```
find_file(<var> name dir1 dir2)
find_library(<var> name dir1 dir2)
find_path(<var> name dir1 dir2)
```

- However there is a better interface…

find_package()

- A package should provide you:
  - Paths to libraries
  - Paths to header files
  - Linker flags (if any)

find_package(<PACKAGE> [VERSION])
This function attempts to locate the package called <PACKAGE> and will return a set of variables:

<PACKAGE>_FOUND
<PACKAGE>_INCLUDE_DIRS
<PACKAGE>_LIBRARIES
<PACKAGE>_VERSION
<PACKAGE>_VERSION_MAJOR
<PACKAGE>_VERSION_MINOR

Example:

find_package(YARP)

YARP_FOUND

YARP_INCLUDE_DIRS

YARP_LIBRARIES

- How does find_package() work?
  - Looks for system directories

    C:\Program files\<package>

    /usr/<package>

    /usr/local/<package>

    …
  - Look for environment variables, very popular <PACKAGE>_DIR
- CMake does not enforce a particular set of variables each package set different variables
- Other examples:

<PACKAGE>_INCLUDE_DIR

<PACKAGE>_LIBS

etc..

Hello YARP

```
cmake_minimum_required(VERSION 2.8)

project(myproject)

find_package(YARP)

include_directories(${YARP_INCLUDE_DIRS})

add_executable(hello hello.cpp)
target_link_libraries(hello ${YARP_LIBRARIES})

add_executable(hello2 hello.cpp)
target_link_libraries(hello2 ${YARP_LIBRARIES})
```

Hello yarp

```
#include <stdio.h>
#include <yarp/os/Time.h>

int main()
{
	printf("Starting the application\n");
	int times=10;

	while(times--)
	{
		printf("Hello iCub\n");
		yarp::os::Time::delay(0.5);		//wait 0.5 seconds
	}
	printf("Goodbye!\n");
}
```

Ports

A (very) simple example: read data to/from a port

[on terminal 1] yarpserver
[on terminal 2] yarp read /read
[on terminal 3] yarp write /write /read


```
$ yarp write /write /read
Port /write listening at tcp://127.0.0.1:10012
yarp: Sending output from /write to /read using tcp
Added output connection from "/write" to "/read"
hello yarp
1 2 3
```

```
$ yarp read /read
Port /read listening at tcp://127.0.0.1:10002
yarp: Receiving input from /write to /read using tcp
hello yarp
1 2 3
```

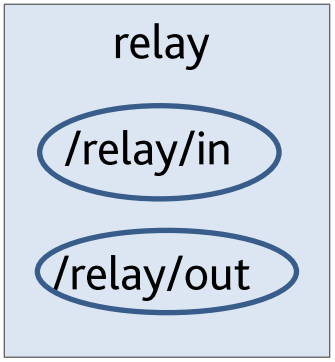
How do we get this?

Let's now to write a simple "relay" executable which takes whatever comes from a port and forwards it to another one.

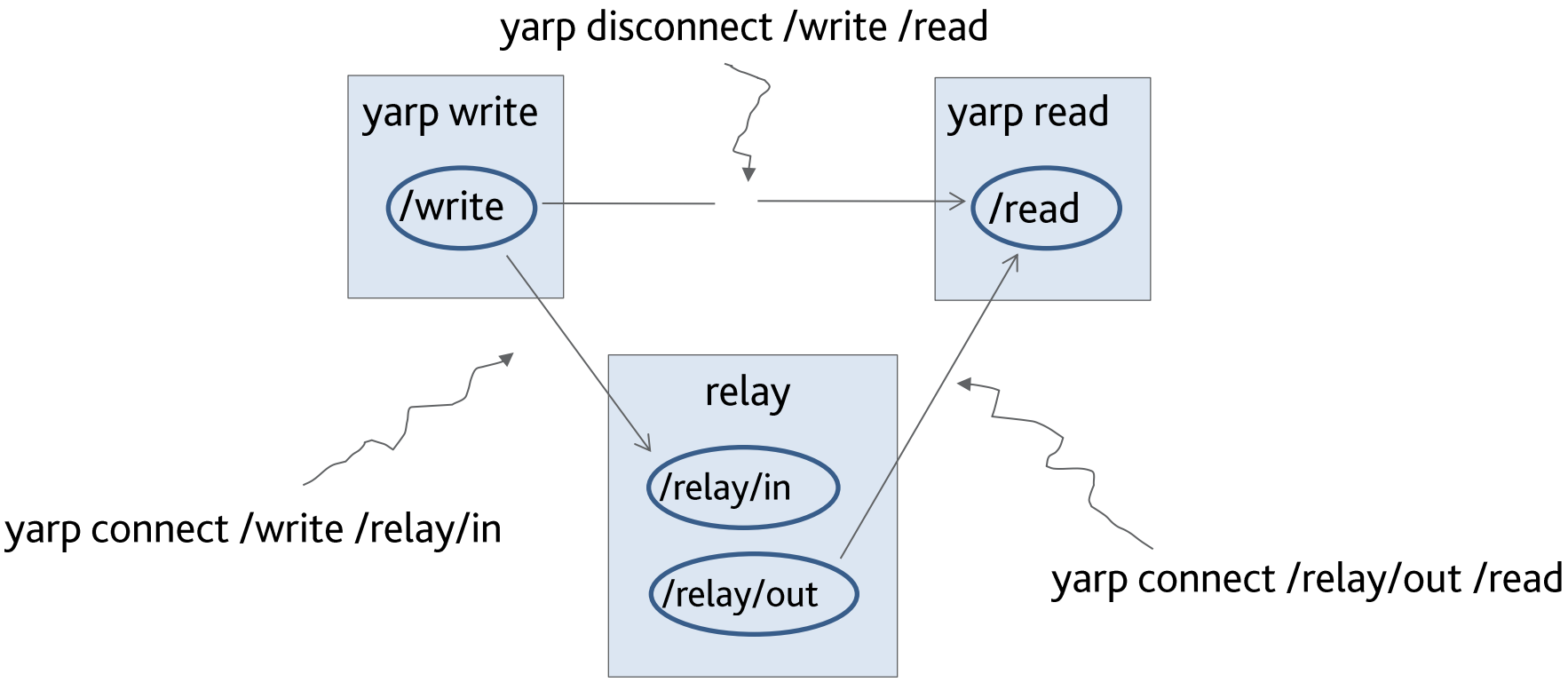
```
int main(int argc, char *argv) {
    Network yarp;
    Port inPort;
    inPort.open("/relay/in");

    Port outPort;
    outPort.open("/relay/out");


    while (true) {
        cout << "waiting for input" << endl;
        Bottle input,output;
        inPort.read(input);
        output=input;
        cout << "writing " << output.toString().c_str() << endl;
        outPort.write(output);
    }
    return 0;
}
```

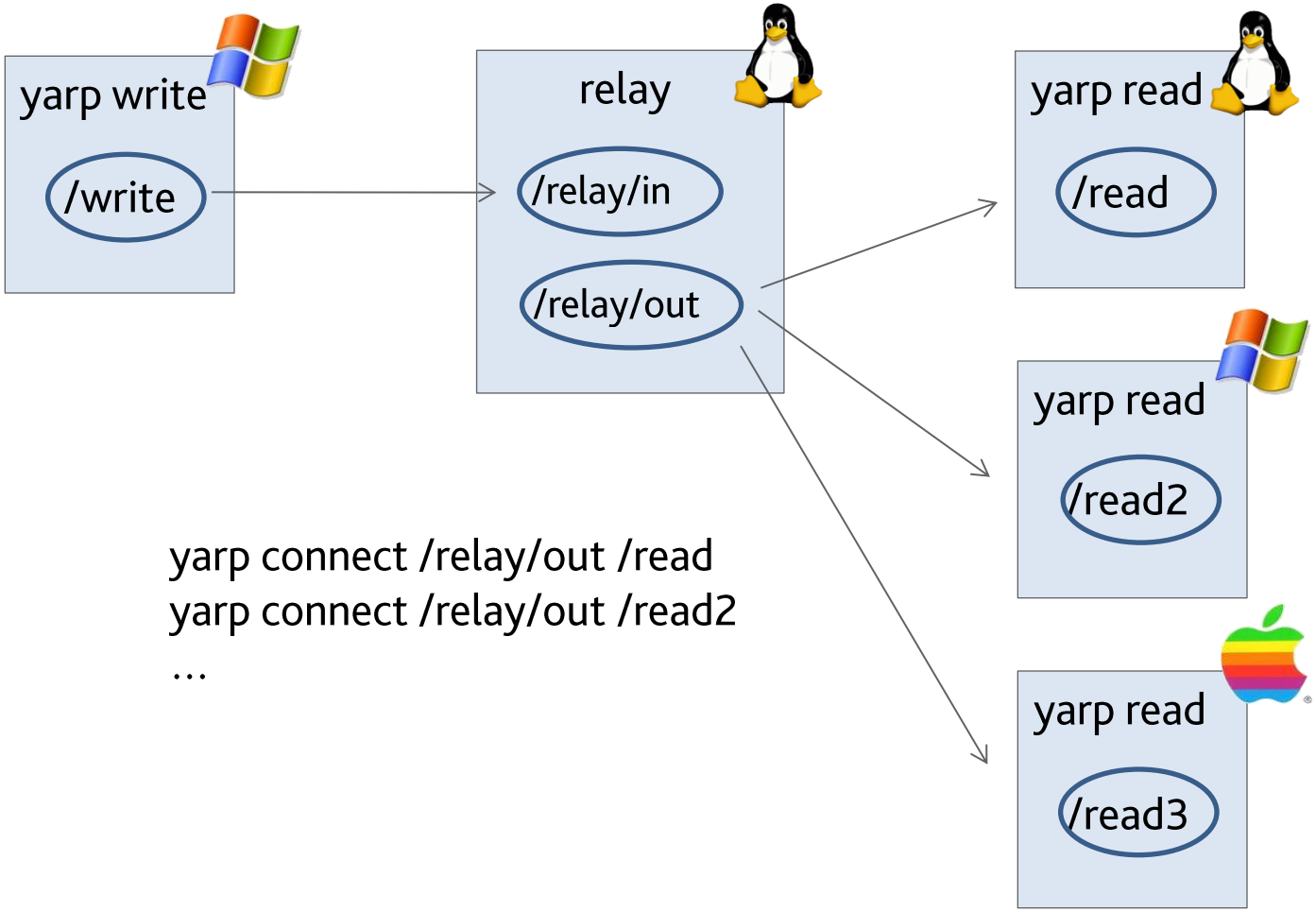


Connect the new module to our network



how the network grows

It is easy to add, for example, another reader…
Processes can run on different machines, with different OS



BufferedPort

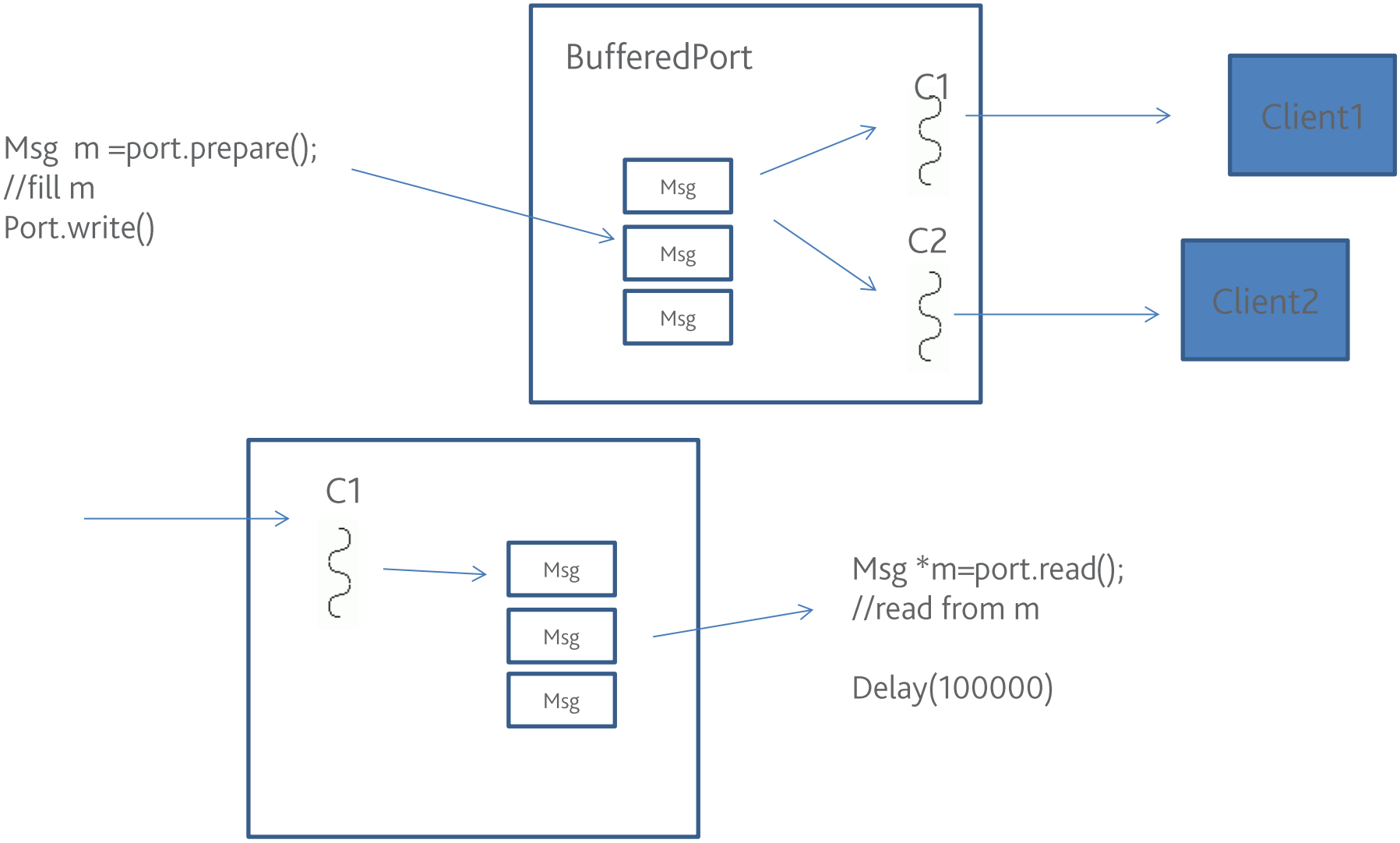
- In the previous example timing between ports is coupled:
  - The reader waits until data arrives to the port
  - The writer waits until data is transmitted
- Buffered ports allow decoupling time:
  - non blocking read
  - non blocking write
- May loose messages

- Read:

```
BufferedPort<Bottle> p;          // Create a port.
p.open("/in");                   // Give it a name on the network.
while (true) {
      Bottle *b = p.read();      // Read/wait for until data arrives. ...
      // Do something with data in *b
 }
```

- Write:

```
BufferedPort<Bottle> p;          // Create a port.
p.open("/out");                  // Give it a name on the network.
while (true) {
      Bottle& b = p.prepare();   // Get a place to store things. ...
      // Generate data.
      p.write();                 // Send the data.
}
```


BufferedPort
C1
C2
Msg
Msg
Msg
Client1
Client2
Msg m =port.prepare();
//fill m
Port.write()
C1
Msg
Msg
Msg
Msg *m=port.read();
//read from m
Delay(100000)

- Polling: when you do not want to wait for input data:

```
BufferedPort<Bottle> p;
...
Bottle *b = p.read(false);
if (b!=NULL) {
  // data received in *b
}
```

Getting callbacks

- Callbacks: useful if you want to be notified when data arrives
- Easy to do with BufferedPorts

```
class DataPort : public BufferedPort<Bottle> {
    virtual void onRead(Bottle& b) {
        // process data in b
    }
};
...
DataPort p;
p.useCallback();  // input should go to onRead() callback
p.open("/in");
```

Things are a bit more complicated with normal ports

```
class DataProcessor : public PortReader {
    virtual bool read(ConnectionReader& connection) {
        Bottle b;
        bool ok = b.read(connection);
        if (!ok) return false;
        // process data in b
        return true;
    }
};

Port p;
p.open(..)
DataProcessor processor;
...
p.setReader(processor);  // no need to call p.read() on port any more.
```

Replies in a callback

```
class DataProcessor : public PortReader {
    virtual bool read(ConnectionReader& connection) {
        Bottle in, out;
        bool ok = in.read(connection);
        if (!ok) return false;
        ...      // process data "in", prepare "out"
        ConnectionWriter *returnToSender = connection.getWriter();
        if (returnToSender!=NULL) {
          out.write(*returnToSender);
        }
        return true;
    }
};
DataProcessor processor;
...
p.setReader(processor);  // no need to call p.read() on port any more.
```

Bidirectional communication: Getting replies

Client side

```
RpcClient p;                // Create a port.
p.open("/out");      // Give it a name on the network.
while (true) {
  Bottle in,out;     // Make places to store things.
  ...                // prepare command "out".
  p.write(out,in);   // send command, wait for reply.
  ...                // process response "in".
}
```

Server side

```
RpcServer p;                    // Create a port.
p.open("/in");          // Give it a name on the network.
Bottle in, out;         // Make places to store things.
while (true) {
  p.read(in,true);      // Read and warn that we'll be replying.
  ...                   // Do something with data, prepare reply
  p.reply(out);         // send reply.

}
```

YARP modules: RFModule

The RFModule class

- You create a new module by deriving a new class from RFModule

```
class MyModule:public RFModule
{
public:
        bool configure(ResourceFinder &rf)
        { //module configuration }
        bool close()
        { //code executed at shutdown }
};

MyModule module;
ResourceFinder rf;
//configure resource finder

module.runModule(rf);      //if configure returns true block here until the module closes
```

get parameters form RF and configure the module, return true on success, false otherwise

perform cleanup, close ports, delete memory

We skip this

- What does a module do?
- Nothing, really…

- What does a module do?
- Nothing, really…
- Wait for termination signal (message or ctrl-c)
- Can be configured to receive messages from a port/keyboard
- Can perform periodic activities
- It is a container for active objects (threads)

Attach callbacks

```
class MyModule::RFModule
{
    Port handlerPort;
    …
    bool configure(ResourceFinder &rf)
    {
     // use rf to configure your module

     handlerPort.open("/myModule");
     attach(handlerPort);
     …
    }
…
}
```

- Now add a respond message to catch data from terminal or/and the handler port

```
// Message handler. Just echo all received messages.
bool respond(const Bottle& command, Bottle& reply)
{
    cout<<"Got something, echo is on"<<endl;
    if (command.get(0).asString()=="quit")
       return false;
    else
       reply=command;
    return true;
 }
```

Periodic Activities

- In MyModule overload:

define period in seconds

```
double getPeriod()
 { return 1; }

bool updateModule()
{
      // place here code that will be
      // executed every "getPeriod" seconds
      return true;
}
```

this function will be executed until termination

- You can interrupt blocking reads on ports in the interrupt method:

```
bool interruptModule()
 {
     port1.interrupt();
     port2.interrupt();
     …
     return true;
  }
```

Threads

```
#include <yarp/os/Thread.h>

Class yarp::os::Thread
{
public:
        virtual bool start();
        virtual bool stop();

        virtual bool threadInit();
        virtual bool threadRelease();
        virtual void run();

        bool isStopping();

};
```

yarp::os::Thread is the class that provides thread support in YARP

```
#include <yarp/os/Thread.h>

Class MyThread: public Thread
{
public
        void run()
        {
                while(!isStopping)
                //thread body
        }
};

MyThread thread;
thread.start();
…
thread.stop();
```

You can implement your own thread by deriving a class from Thread

```
Class MyThread: public Thread
{
public
        bool threadInit()
        {
                //perform init tasks, memory allocation…
                //return true if successful false otherwise
        }
        bool threadRelease()
        {
                //cleanup memory, release resources…
        }
        void run() {..}
}
```

Override threadInit() and threadRelease() to peform initialization and cleanup:

```
#include <yarp/os/RateThread.h>

Class yarp::os::RateThread
{
public:
        RateThread(int period); //periodicity, ms
        virtual bool start();
        virtual bool stop();

        virtual bool threadInit();
        virtual bool threadRelease();
        virtual void run();

};
```

Very often you want a thread to perform periodic activities (e.g. control loop)

RateThread supports periodic threads

```
#include <yarp/os/RateThread.h>

Class MyRateThread: public RateThread
{
public:
        MyRateThread(int p=50):
RateThread(p){}

        void run()
        {
                …
        }
};

MyRateThread rthread;
rthread.start();
…
rthread.stop();
```

Getting images

- YARP defines an image class
- ImageOf<…> is a template class that provides:
  - basic methods for image manipulation
  - support for remotization (i.e. images can travel across Ports/the network)
- data format is opencv compatible
- See: YARP image class online documentation

- Images from cameras are streamed from two ports:
  - /icub/cam/right
  - /icub/cam/left
- Easily read:

```
BufferedPort<ImageOf<PixelRgb> > imagePort;
imagePort.open("/imageProc/image/in");
ImageOf<PixelRgb> *image = imagePort.read(); //read an image:
```

```
BufferedPort<ImageOf<PixelRgb> > imagePort;

imagePort.open("/imageProc/image/in");

//read an image:
ImageOf<PixelRgb> *image = imagePort.read();

//do something with the image, for example cycle through all pixels
int ct=0
for (int x=0; x<image->width(); x++) {
            for (int y=0; y<image->height(); y++) {
               PixelRgb& pixel = image->pixel(x,y);
               // very simple test for blueishness
               // make sure blue level exceeds red and green by a certain factor
               if (pixel.b>pixel.r*1.2+10 && pixel.b>pixel.g*1.2+10) {
                           xMean += x;
                           yMean += y;
                           ct++;
                }
       }
 }

if (ct>0) {
      xMean /= ct;
      yMean /= ct;
 }

printf("Best guess at blue target: %g %g\n", xMean, yMean);
```

- Complete tutorial shows a program example that control the gaze of the robot to fixate a blue ball:
  - http://wiki.icub.org/iCub/dox/html/icub_basic_image_processing.html

Controlling the simulator

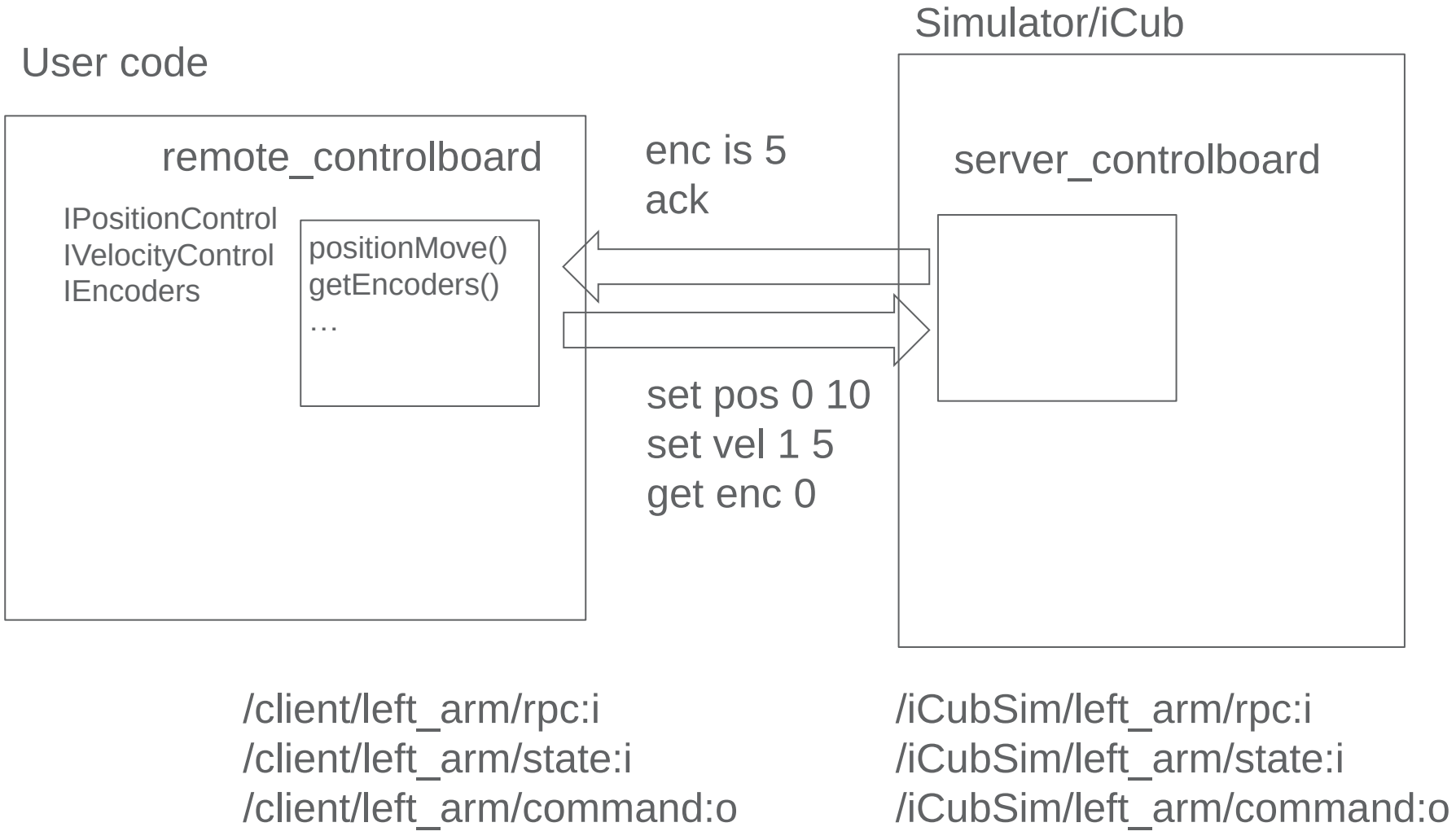
- Set of ports for parts {head} {left_arm} {torso} etc…
- Ports:

/icubSim/head/rpc:i

/icubSim/head/command:i

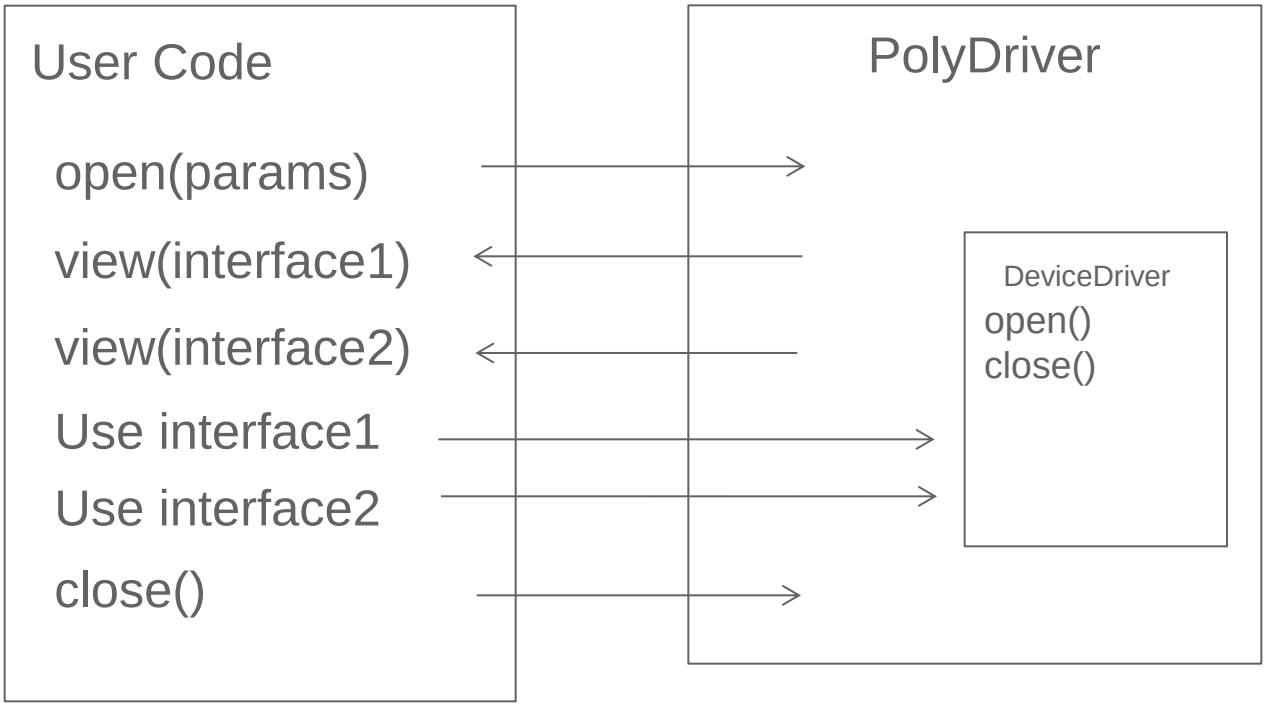
/iicubSim/head/state:o

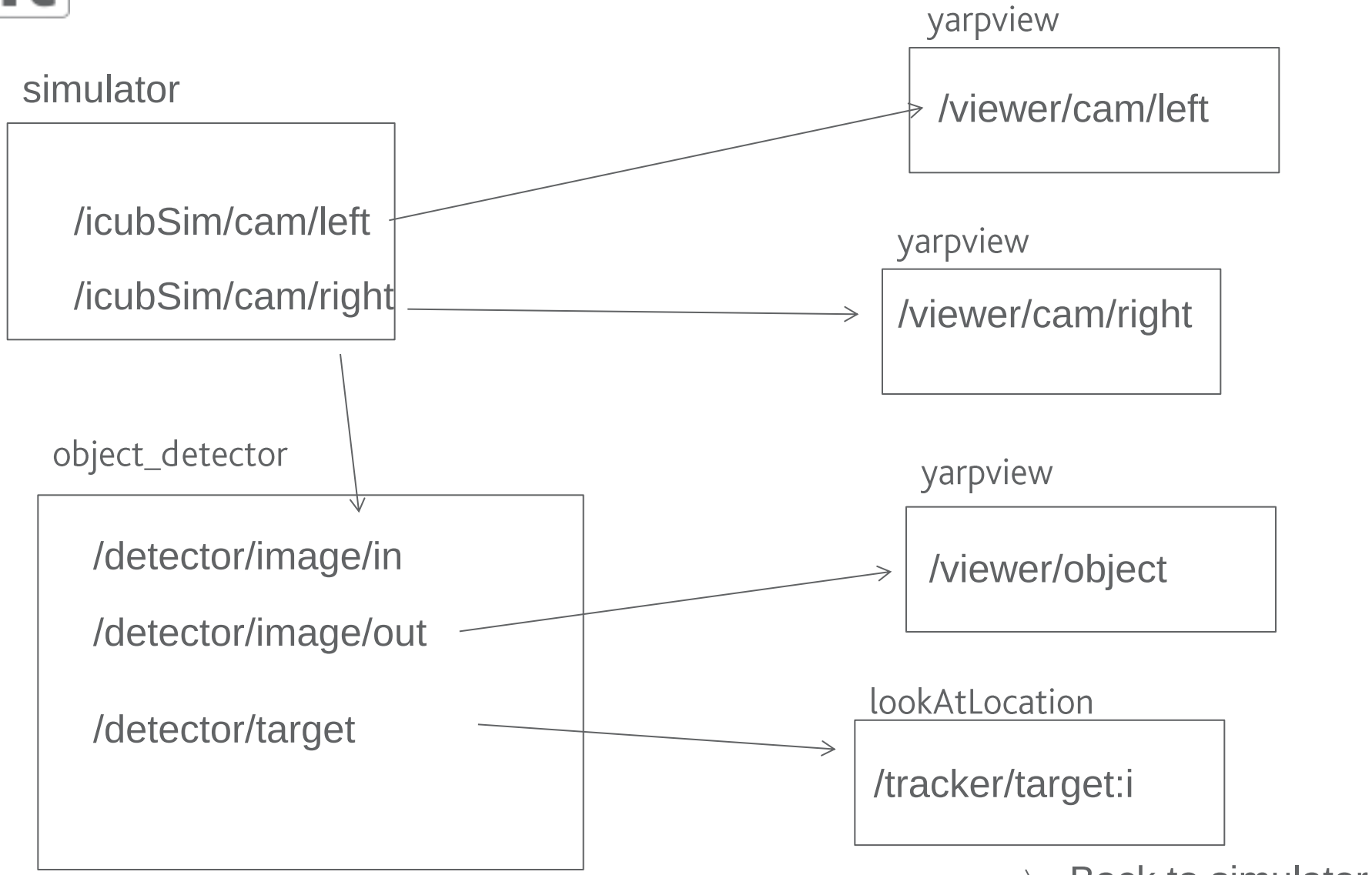
```
icub@ubuntu-1404-64-vm:~$ yarp rpc /icubSim/head/rpc:i
>>get encs
Response: [is] encs (-0.000015 0.000004 -0.000004 -0.0 0.0 -0.0) [tsta] 1 1434026836.655992 [ok]
>>set pos 0 -10
Response: [ok]
>>set pos 1 20
Response: [ok]
>>set poss (0 0 0 0 0 0)
Response: [ok]
>>get encs
Response: [is] encs (-0.0005 0.000971 -0.000004 -0.0 0.0 -0.0) [tsta] 2 1434026858.553787 [ok]
>>
```

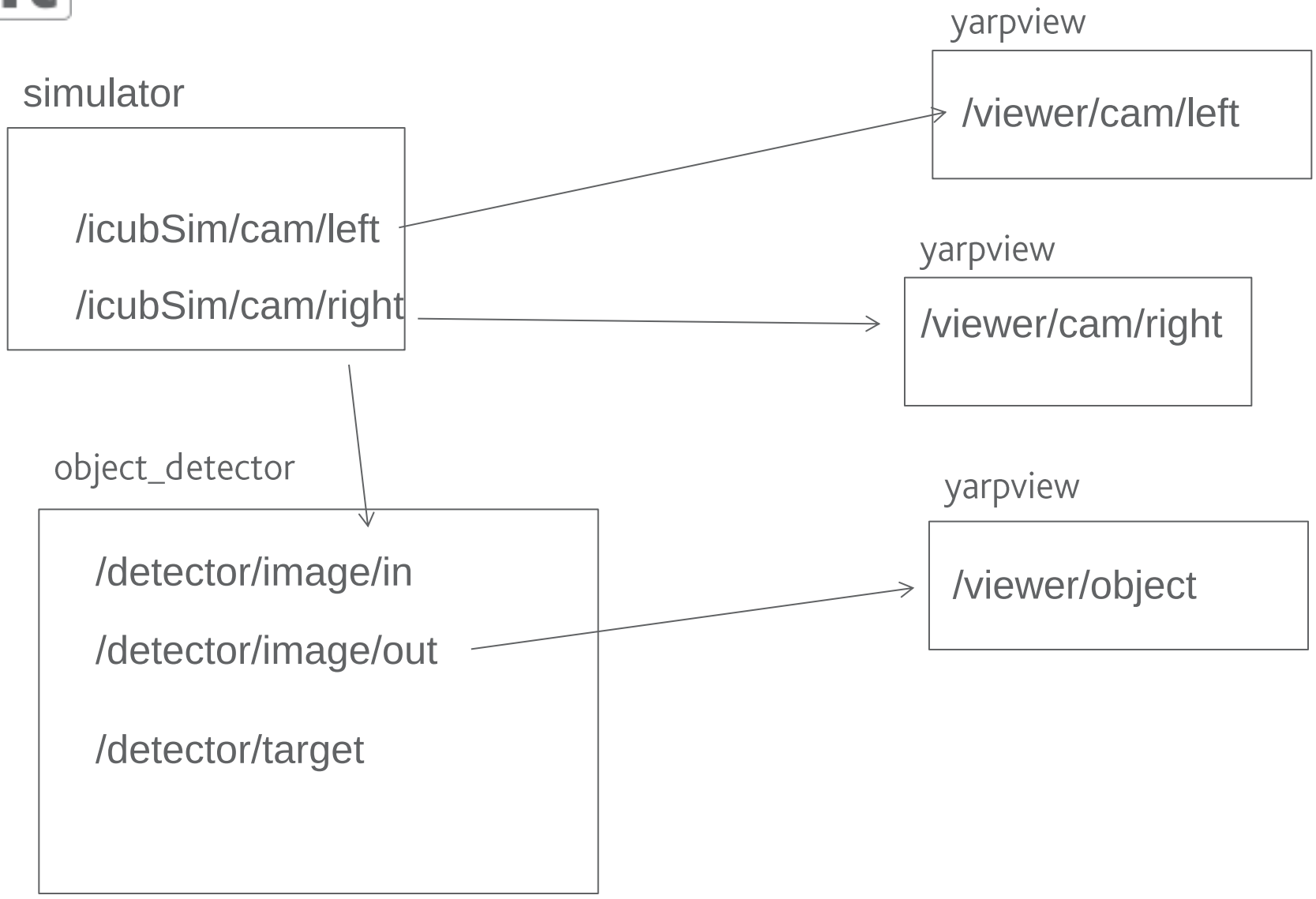

User code
remote_controlboard
IPositionControl
IVelocityControl
IEncoders
positionMove()
getEncoders()
…
enc is 5
ack
set pos 0 10
set vel 1 5
get enc 0
Simulator/iCub
server_controlboard
/client/left_arm/rpc:i
/client/left_arm/state:i
/client/left_arm/command:o
/iCubSim/left_arm/rpc:i
/iCubSim/left_arm/state:i
/iCubSim/left_arm/command:o

- http://wiki.icub.org/yarpdoc/classyarp_1_1dev_1_1IPositionControl.html
- http://wiki.icub.org/yarpdoc/classyarp_1_1dev_1_1IVelocityControl.html

PolyDriver


User Code
open(params)
view(interface1)
view(interface2)
Use interface1
Use interface2
close()
PolyDriver
DeviceDriver
open()
close()


yarpview
simulator
/viewer/cam/left
/icubSim/cam/left
/icubSim/cam/right
yarpview
/viewer/cam/right
object_detector
yarpview
/detector/image/in
/viewer/object
/detector/image/out
lookAtLocation
/detector/target
/tracker/target:i
Back to simulator
… head/rpc:I


yarpview
simulator
/viewer/cam/left
/icubSim/cam/left
yarpview
/icubSim/cam/right
/viewer/cam/right
object_detector
yarpview
/detector/image/in
/viewer/object
/detector/image/out
/detector/target