RobotCub

YARP

An Introduction

or …

how to live in harmony with your (robotic) world

Cogsys
Cognitive Systems

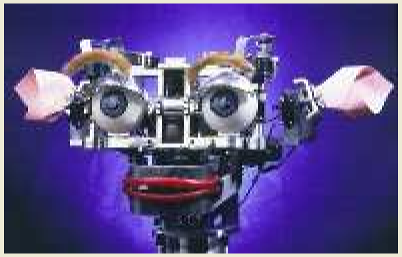
Overview of seminar

1. What is YARP?
2. How does it work?
3. Some examples
4. A (simple) demonstration
5. What can YARP do for me?
6. How to get started

Please feel free to ask questions as we go …

Yet Another Robot Platform

- YARP is an open-source software library for humanoid robotics
- History
  - An MIT / Lira-Lab collaboration
    - Paul Fitzpatrick, Giorgio Metta, Lorenzo Natale
  - Born on Kismet, grew on COG
  - With a major overhaul, now used by RobotCub consortium,
  - Used by the broader open-source community
  - And of course, KASPAR, here at UH



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What is YARP?

- YARP is an **open-source** software library for humanoid robotics
  - Network communication, device abstraction
- Designed to support and encourage:
  - **Collaboration** (code-sharing across space)
  - **Longevity** (code-sharing across time)
- YARP encourages **modular** development of robotics software
- Provides OS and build tool **independence**
  - Also some *language* independence

Modularity

- The opposite of a **modular** system is a **coupled** one.
- In a “coupled” system, changes in one part trigger changes in another.
  - Coupling leads to **complexity**
  - Complexity leads to **confusion**
  - Confusion leads to **suffering**
- This is the path to the Dark Side

Why Modularity for Robots?

- Robot code is notoriously ***hardware-specific*** and ***task-specific***
- But hardware and target tasks **change quickly**, even within the lifetime of one project
- Our humanoid robots are far more complex than one person can build and maintain, both in terms of hardware and software
- They need to be **modular**

Modularity

- Modular approaches to robotics:
  - **Player/Stage** (mobile robotics)
    - Robot control (Khepera, Pioneer), simulator
  - **Orocos** (industrial robotics)
    - Real-time control, kinematics library, other libs
  - **YARP** (humanoid robotics)

SOURCE: Chad Jenkins, June 11, 2005, Workshop Introduction

Robotics 2005 Workshop on Modular Foundations for Control and Perception

Escaping the Operating System

- We shield code from the details of the **operating system** it runs on
  - Then individual projects can use whichever OS we prefer or need (e.g. specific devices or libraries may only be supported on one OS)
- We shield software from the details of the **"build tools"** used
  - Visual Studio (Microsoft) people and emacs/g++ (Linux etc.) people can finally be friends

OS independence

- Start from ACE – the “Adaptive Communication Environment”
  - Free and Open Source
  - Widely used, widely tested
- YARP uses ACE in its implementation, but doesn't require YARP users to to so
  - ACE is big, complex, daunting, changing
  - You can understand and use YARP without understanding ACE

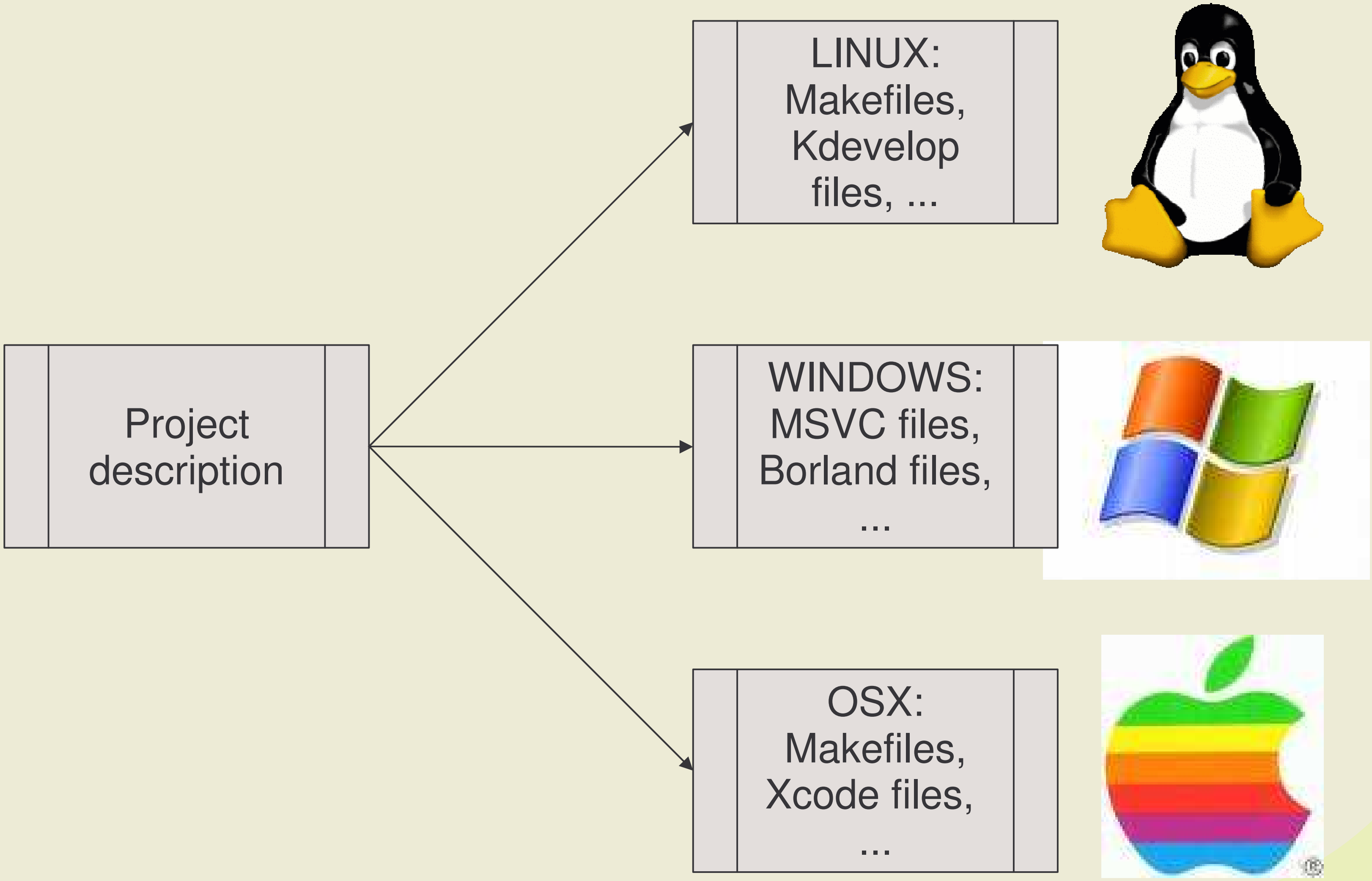
Build tool independence

CMake

Cross-platform Make

- Start from CMake
- Free, Open Source
- CMake lets us describe our programs and libraries in a cross-platform way
- CMake takes care of creating the makefiles or workspaces needed by your preferred development environment

Build tool independence



Project description

LINUX: Makefiles, Kdevelop files, ...

WINDOWS: MSVC files, Borland files, ...

OSX: Makefiles, Xcode files, ...

Integrating other libraries

- With CMake, we can easily include other libraries in a cross-platform way
  - "OpenCV" computer vision library
  - "Boost" peer-reviewed libraries
  - "OpenGL" graphics library
  - "GTK" windowing library ...
- For YARP, we expect users will exploit such libraries, but minimize our own use of them (so as not to force their choice)

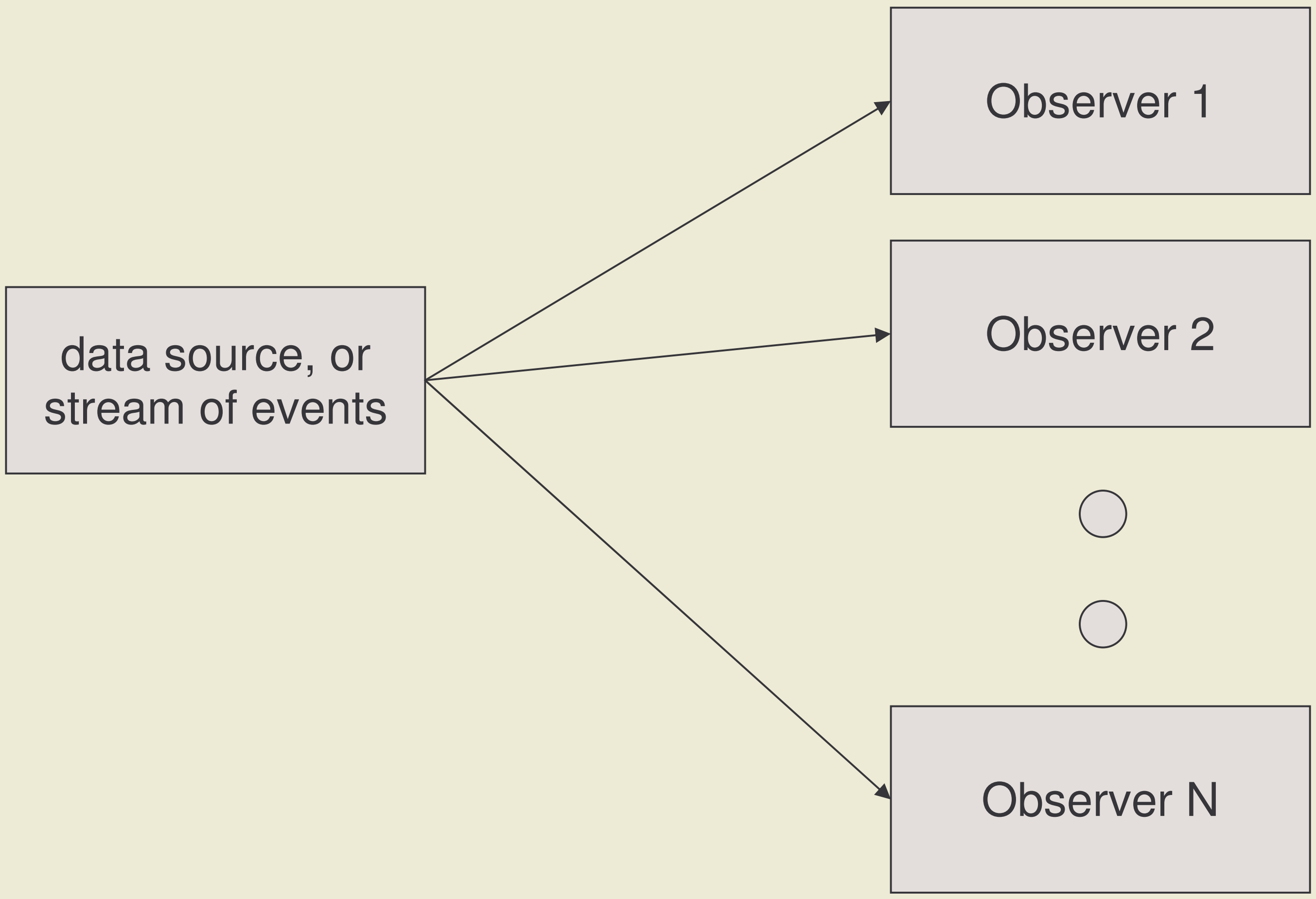
Beyond the Operating System

- ACE decouples source code from OS
- CMake decouples compilation from OS
- But, for humanoid robotics, our effective "OS" also includes:
  - Many **special hardware devices**
  - A (typically ever-changing) **network of computers**
- YARP tries to decouple our code from this "OS"

Beyond the Operating System

- YARP shields programs from the details of **how they communicate**
  - We can then reroute this "plumbing" as we wish, e.g. to send output to new programs
- YARP shields users from the details of the **devices they control**
  - The devices can then be replaced over time by comparable alternatives; user code may be useful to others

Communication independence: the Observer pattern



data source, or stream of events

Observer 1

Observer 2

Observer N

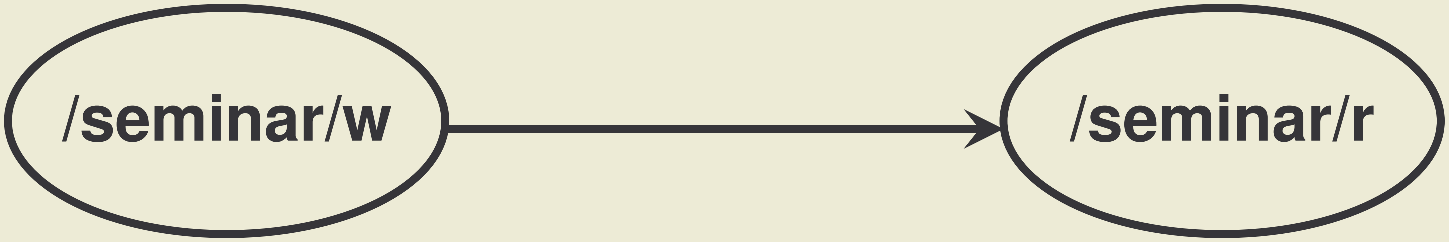
YARP Ports

- We follow the **Observer** design pattern.
- Special "Port" objects deliver data to:
  - Any number of observers (other "Port"s) ...
  - ... in any number of processes ...
  - ... distributed across any number of computers ...
  - using any of several underlying communication protocols with different technical advantages
- This is called the YARP Network

A simple example

- In this simple example the “yarp” command line utility is used to create yarp ports …

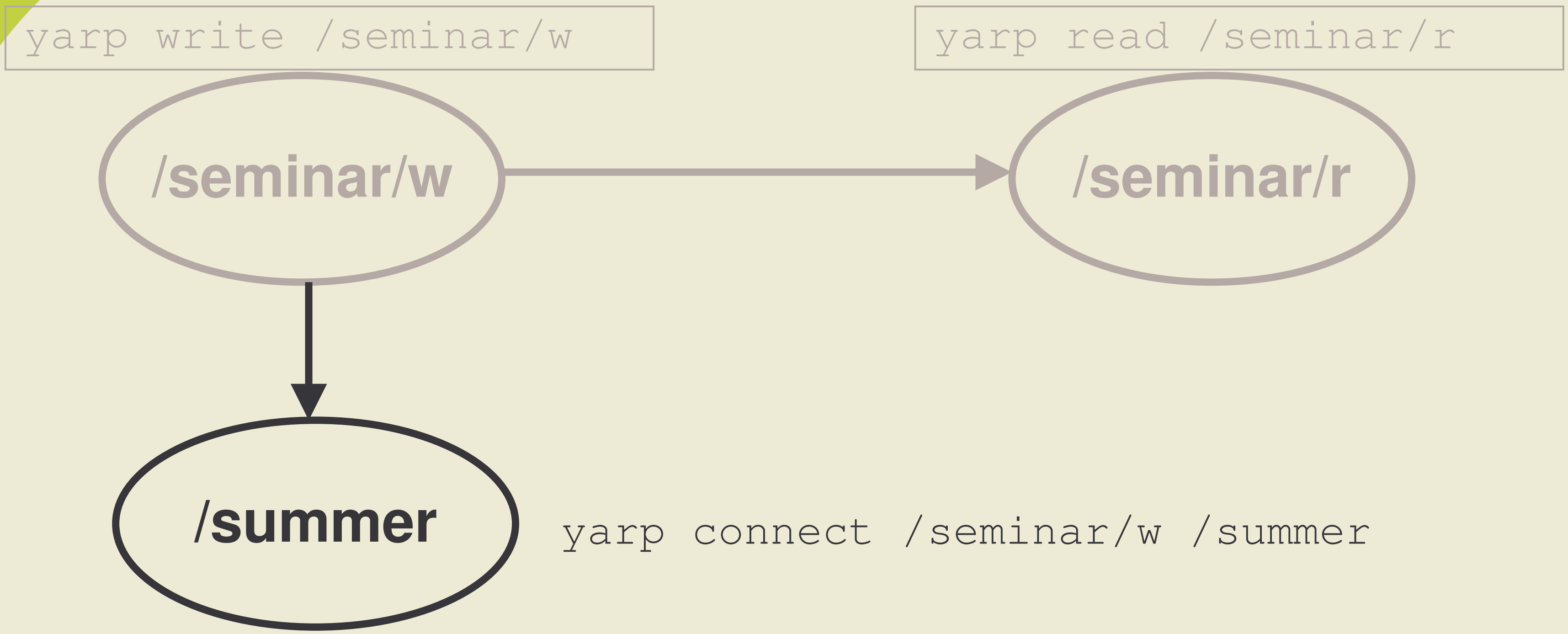
```
yarp write /seminar/w                    yarp read /seminar/r
```



```
yarp connect /seminar/w /seminar/r
```

- … and connect them together
- All output from the write port is sent to the read port

A simple example



```
yarp write /seminar/w
```

```
yarp read /seminar/r
```

/seminar/w

/seminar/r

/summer

```
yarp connect /seminar/w /summer
```

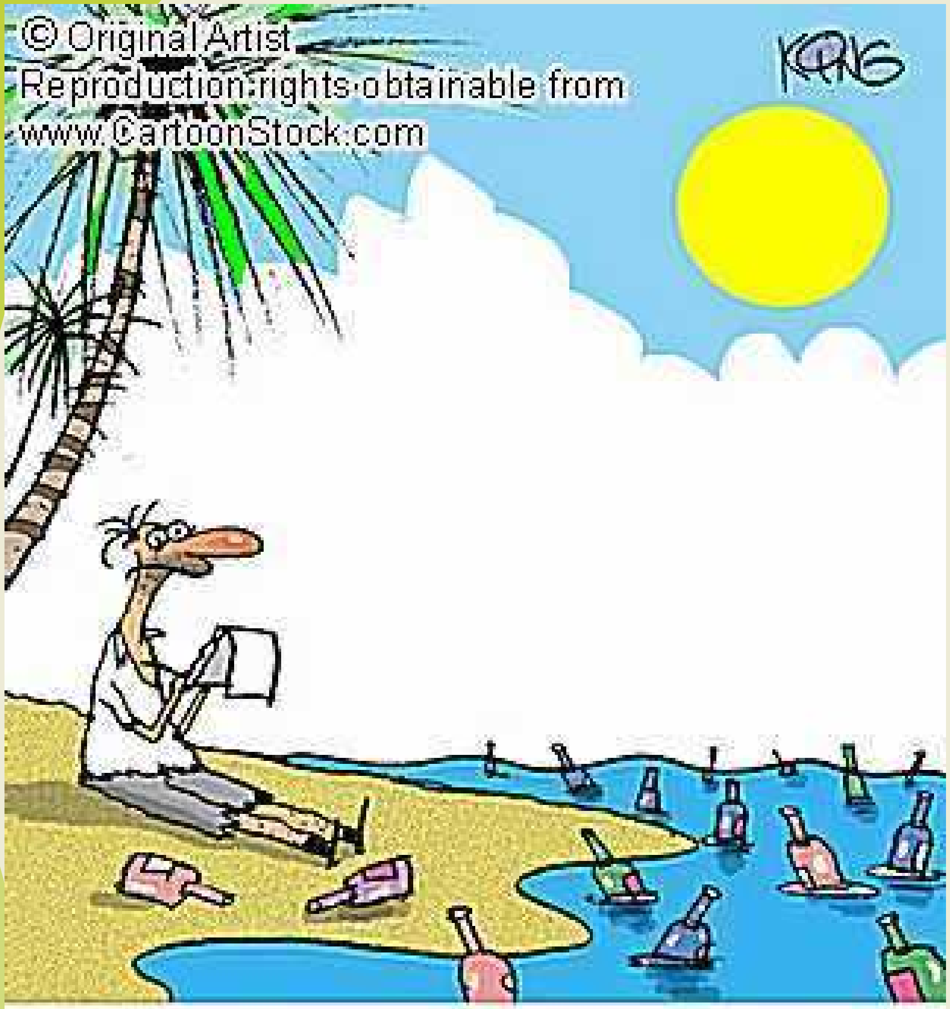
- The output from /seminar/w could at the same time be sent to another process through another port

In code (C++)

- Here is some code that opens a port and writes to it

```
#include <yarp/os/all.h>
#include <stdio.h>
using namespace yarp::os;

int main() {
        Network::init();

        BufferedPort<Bottle> in;
    BufferedPort<Bottle> out;
        in.open("/in");
    out.open("/out");

    // Connect the ports so that anything written from /out arrives to /in
    Network::connect("/out","/in");

    // Send one "Bottle" object.
    Bottle& outBot1 = out.prepare();   // Get the object
    outBot1.fromString("hello world"); // Set it up the way we want
        out.write();                          // Now send it on its way

        // Read the object
    Bottle *inBot1 = in.read();
    printf("Bottle 1 is: %s\n", inBot1->toString().c_str());

        Network::fini();
    return 0;
}
```

Message in a bottle: *an aside*

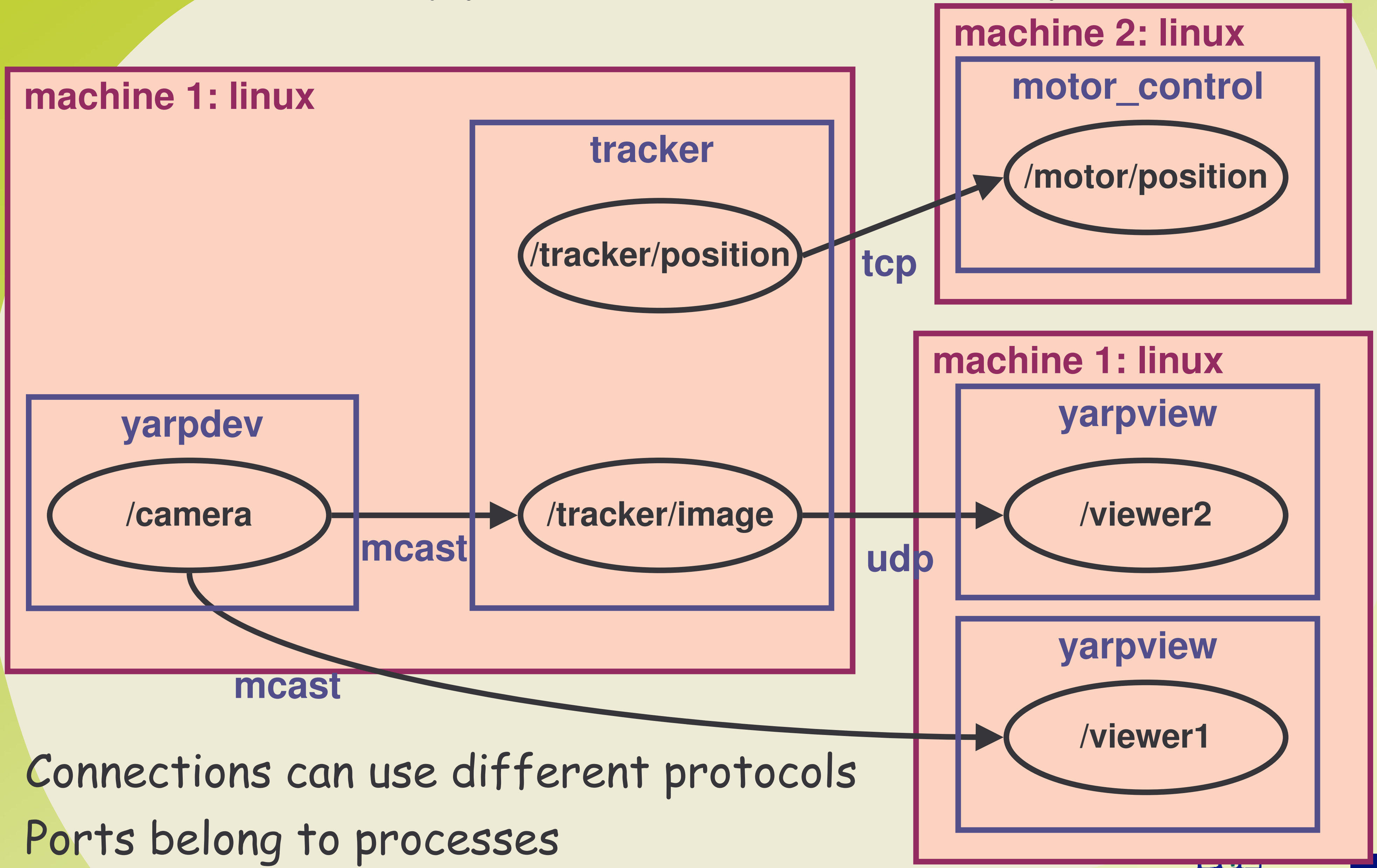


Day 267: After sending out that message in a bottle stating my location, I've been bombarded with junk mail.

- Messages in YARP are wrapped in objects called "bottles"
- *From the YARP documentation:*

"The name of this class comes from the idea of throwing a "message in a bottle" into the network and hoping it will eventually wash ashore somewhere else. In the very early days of YARP, that is what communication felt like. "

Typical network of ports



- Connections can use different protocols
- Ports belong to processes
- Processes can be on different machines/os

Beyond the Operating System

- YARP shields programs from the details of **how they communicate**
  - We can then reroute this "plumbing" as we wish, e.g. to send output to new programs
- YARP shields users from the details of the **devices they control**
  - The devices can then be replaced over time by comparable alternatives; user code may be useful to others

Another example ☺

- Create a (fake) frame grabber using **yarpdev** e.g.
  - `yarpdev -device test_grabber -framerate 20`
  - creates a device using a generic factory method
  - wraps the device in a generic network interface
- Open a viewer which accept images on its input port and displays them
  - `yarpview -name /viewer1`
- Connect the grabber and viewer
  - `yarp connect /grabber /viewer1 mcast`
  - the optional parameter selects the communication method

YARP Devices

- There are three separate concerns related to devices in YARP:
  - Implementing **specific drivers** for particular devices
  - Defining interfaces for **device families**
  - Implementing **network wrappers** for interfaces

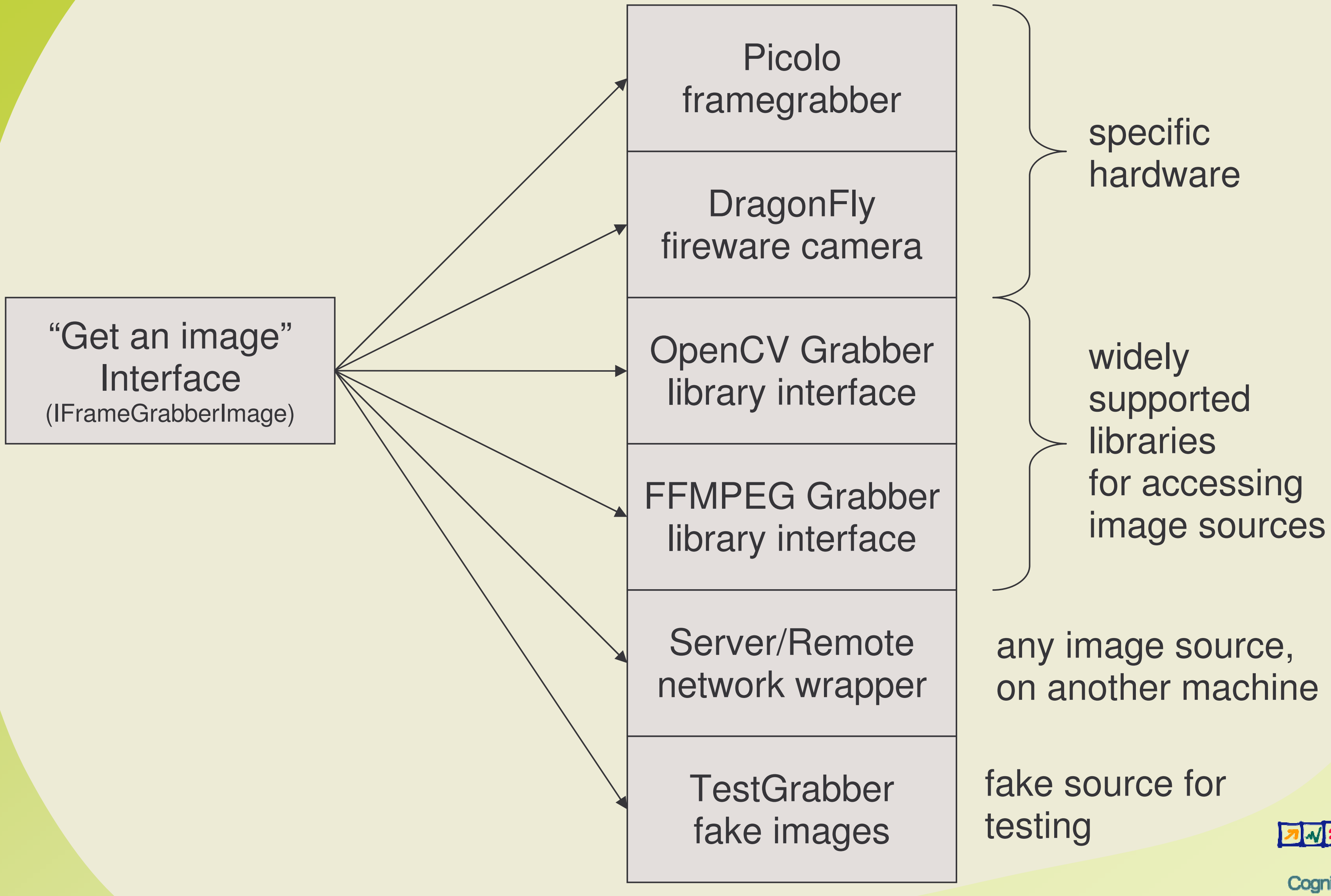
1: implementing drivers

- The first step, creating drivers for particular devices, is obvious; every robotics project needs to interface with hardware somehow.
  - Cameras, microphones
  - Motors, encoders
  - …

2: families of devices

- The second step, defining interfaces for families of devices, is important in the longer term.
- If you change your camera or your motor control board, how much of your code needs to change too?
- If you view your devices through well thought out interfaces, the impact of device change can be minimized.

Example: image sources



“Get an image” Interface (IFrameGrabberImage)

Picolo framegrabber

DragonFly fireware camera

OpenCV Grabber library interface

FFMPEG Grabber library interface

Server/Remote network wrapper

TestGrabber fake images

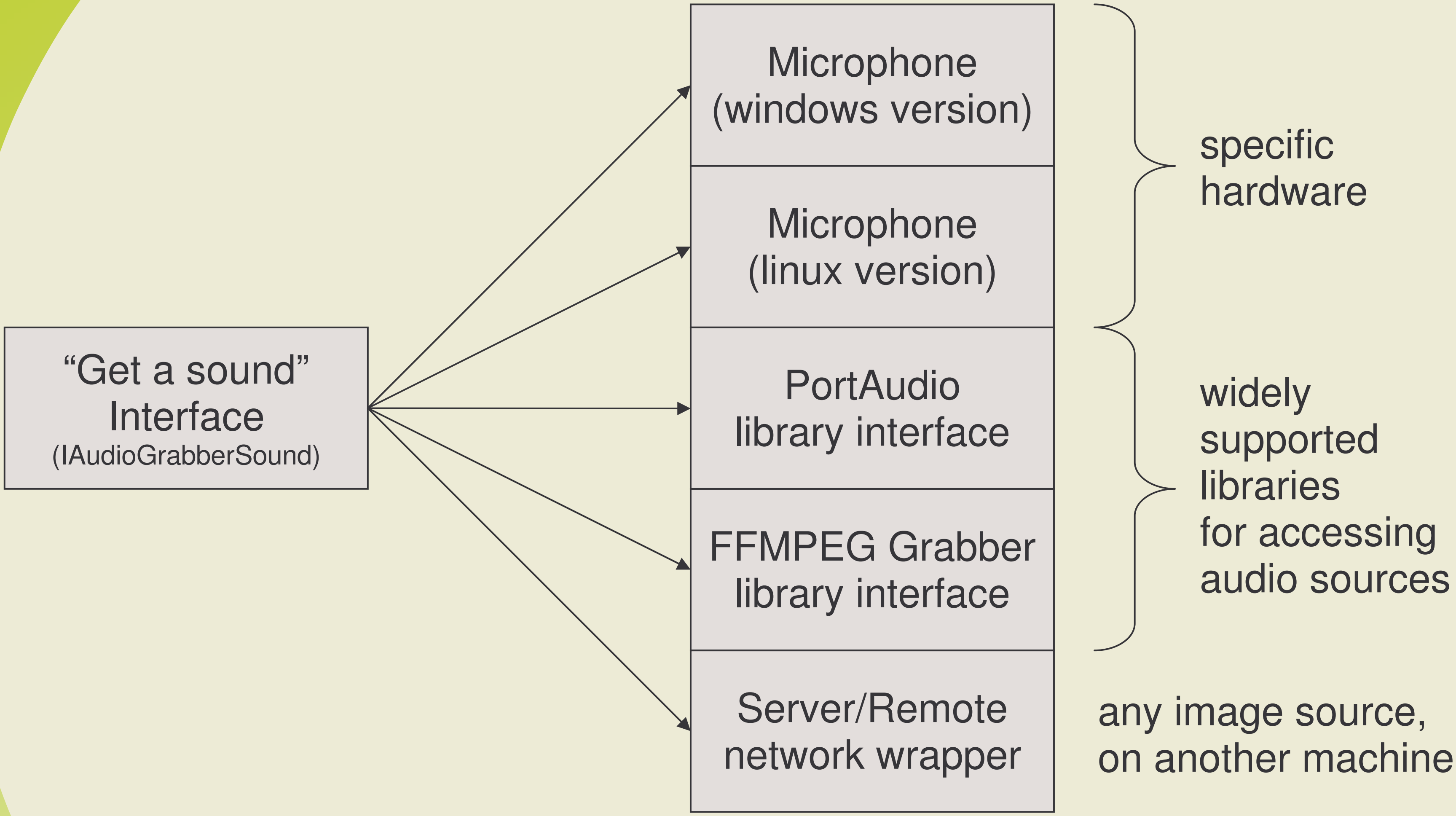
specific hardware

widely supported libraries for accessing image sources

any image source, on another machine

fake source for testing

Example: audio sources



“Get a sound” Interface (IAudioGrabberSound)

Microphone (windows version)

Microphone (linux version)

PortAudio library interface

FFMPEG Grabber library interface

Server/Remote network wrapper

specific hardware

widely supported libraries for accessing audio sources

any image source, on another machine

3: network wrappers

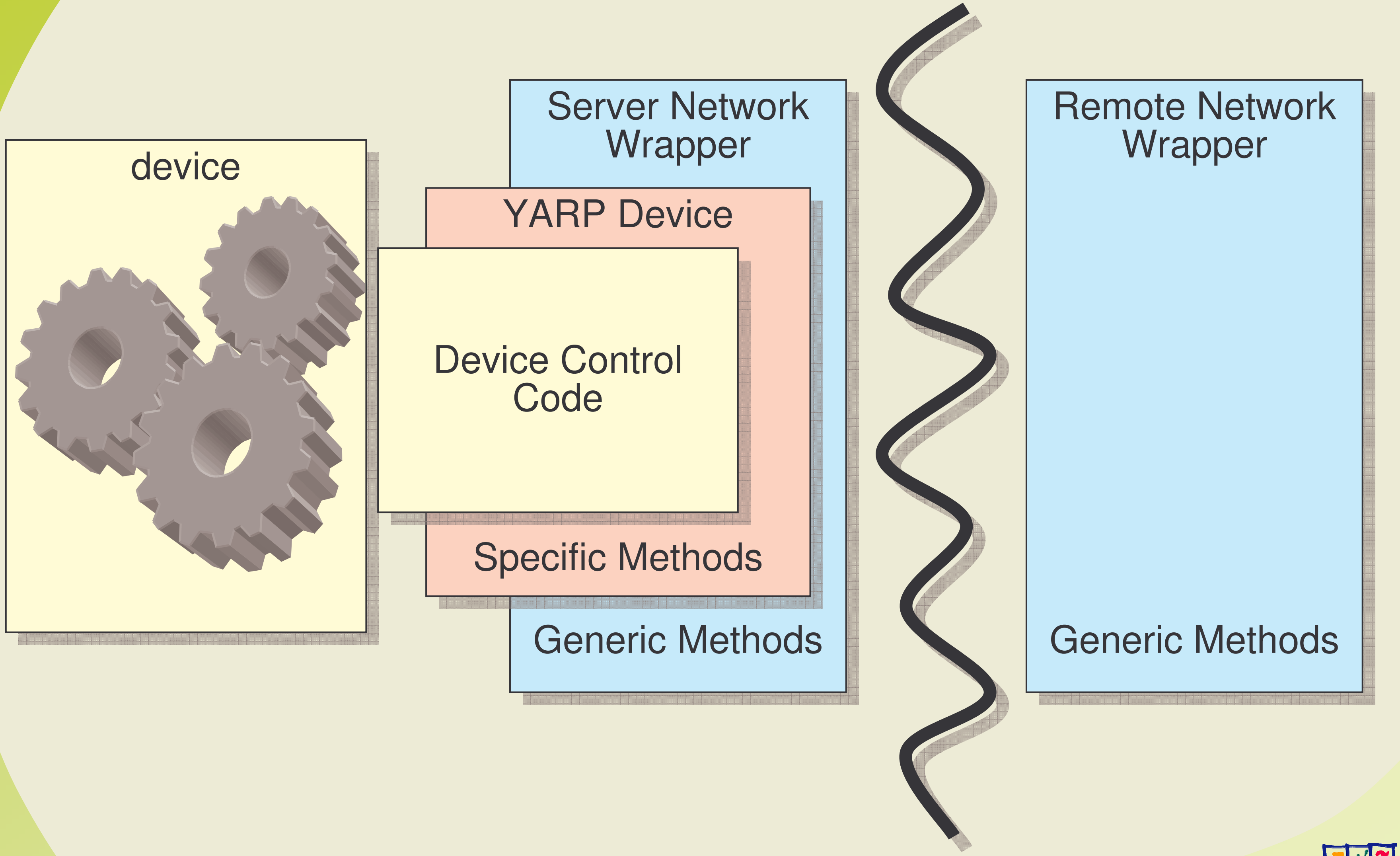
- The third step, network wrappers, is important to give flexibility.
- You can scale up your computing cluster, or isolate hardware devices that don't play well together, or have specific OS dependencies etc.

Two Views

- YARP offers two views of a robot
  - A set of devices which you can control or query according to a choice of interfaces (***device* view**)
    - If you are responsible for *configuring* and *starting* devices, this is the ***local device* view**
    - If configuration and starting-up/shutting-down is *packaged* with the robot, so you don't have to take care of it, this is the ***remote device* view**
  - A set of ports to which you can connect and get data or send commands (***port* view**)

Devices

- Local and Remote devices



Modularity revisted

- A device driver implements the DeviceDriver interface at a minimum and also any other interfaces it is going to provide

```
…
class FakeFrameGrabber : public yarp::dev::IFrameGrabberImage,
                         public yarp::dev::DeviceDriver {
```

- In code, you open a device like this:

```
…
Property config.fromString("(device fake_grabber) (w 640) (h 480)");

PolyDriver dd(config);

IFrameGrabberImage *grabberInterface;
dd.view(grabberInterface);
```

- This starts and configures the device using a generic device factory method using the options you select
- Then views the generic device as one that implements the generic IFrameGrabber interface

Modularity revisted

- A device driver implements the DeviceDriver interface at a minimum and also any other interfaces it is going to provide

```
…
class FakeFrameGrabber : public yarp::dev::IFrameGrabberImage,
                         public yarp::dev::DeviceDriver {


 …code to implement open(), close() methods for DeviceDriver and
  getImage(), width() and height() methods for IFrameGrabberImage
```

- You can open this device and just use it without any bureaucracy:

```
FakeFrameGrabber fakey;
fakey.open(640,480);
ImageOf<PixelRgb> img;
fakey.getImage(img);
...
```

Modularity revisted

- But, If we're smart, we'd make as much of our code as possible depend just on the interface IFrameGrabberImage, so that we can reuse it or substitute in a different framegrabber later:

- This is a standard software engineering technique for minimizing unnecessary coupling between modules.

```
// creation and configuration -- depends on specific device type
FakeFrameGrabber fakey;
fakey.open(640,480);
IFrameGrabberImage& genericGrabber = fakey;
// now we only care that our device implements IFrameGrabberImage
ImageOf<PixelRgb> img;
genericGrabber.getImage(img);
```

Modularity revisted

- But, we can go further:
- In order to open the device using the generic factory, we simply register it with YARP …

```
DriverCreator *fakey_factory =
new DriverCreatorOf<FakeFrameGrabber>("fakey","grabber","FakeFrameGrabber");
Drivers::factory().add(fakey_factory); // hand factory over to YARP
```

- We can open the device directly with default parameters:

```
PolyDriver dd("fakey");
```

- With some configuration parameters

```
Property config("(device fakey) (w 640) (h 480)");
PolyDriver dd(config);
```

- Or even with a network grabber so that is is available on the network

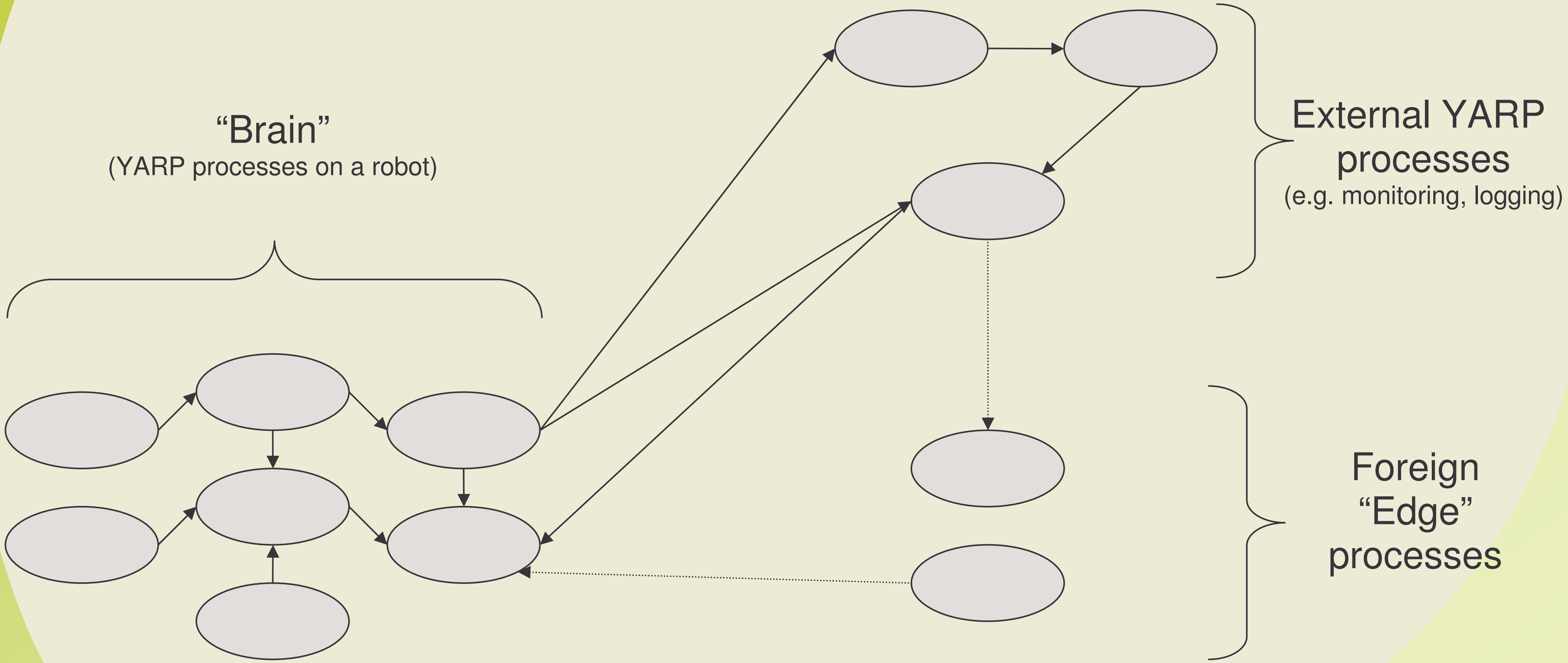
```
Property config("(device grabber) (subdevice fakey) (w 640) (h 480)");
PolyDriver dd(config);
```

Port view

- Of course a process could start the device, grab frames from the device and make them available on a port.

```
//code as above opens a port viewed through “grabber_interface”
…
BufferedPort< ImageOf<PixelRgb> > outPort;
outPort.open(“/grabber/img”);

if (grabberInterface != NULL) {
      ImageOf<PixelRgb> imgIn;

      while (grabber->getImage(imgIn)) {

            // Buffered ports require that you get the next
      // outgoing object to put your data in
            ImageOf<PixelRgb>& imgOut = outPort.prepare();

      imgOut.copy(imgIn);

            / Actually send out the image on the port
      outPort.write();
      }
}
```

YARP Network



“Brain”
(YARP processes on a robot)

External YARP processes
(e.g. monitoring, logging)

Foreign “Edge” processes

The “Edge” of a YARP Network

- To participate in a YARP Network, it is not necessary to use C++
  - The YARP library can be “wrapped” for Java, Matlab (via Java), Python, Perl, C#, Chicken...
- It is also simple to communicate with Ports without using any YARP code

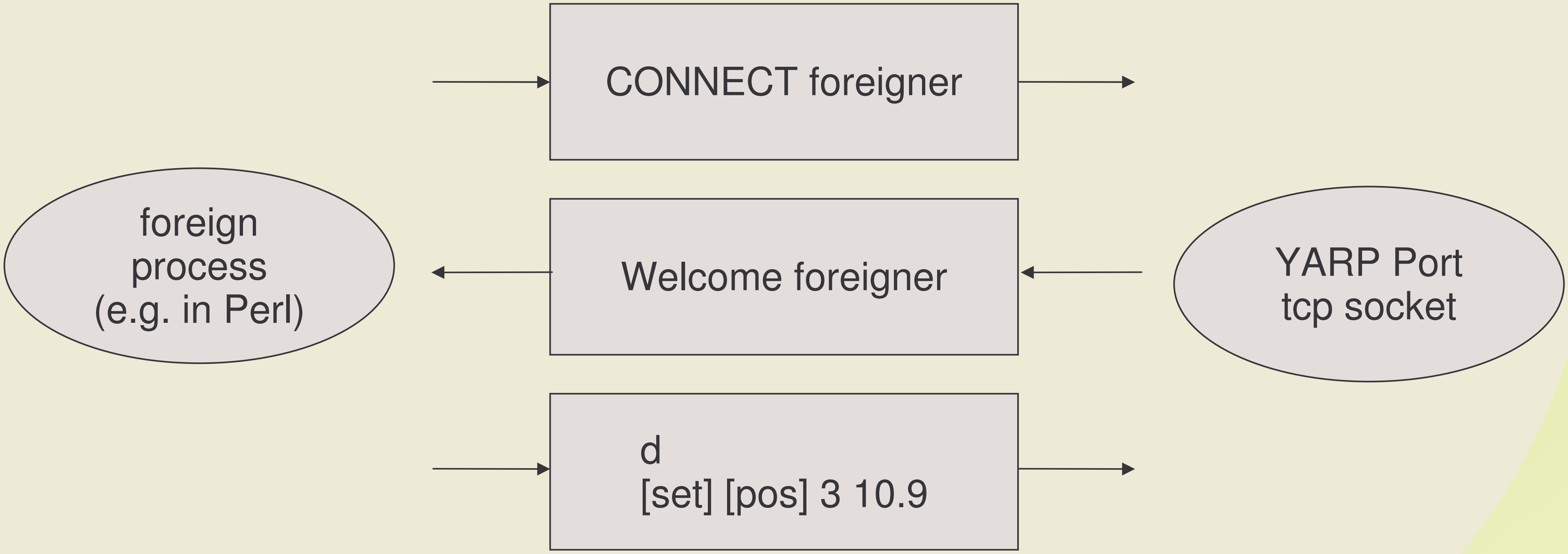
ACE+CMake+Libraries

- With ACE, CMake, and appropriate libraries, we are as portable as Java
- Why program in C/C++?
  - Flexible: as high-level or low-level as we need
  - And for robotics we often need to go quite low-level, e.g. to interface with devices
- YARP makes effort to support other languages via bindings and protocol documentation

The “Edge” of a YARP Network

- User can implement just enough to make a connection to a single Port
  - Easy! Ports support several protocols, so just use the simplest one – a trivial text-mode protocol
  - Don't get efficiencies of more complex protocols but that's often okay
- Called “Edge” of the Network since it is not a true Port, just a connection going “off the map”

"Edge" Example



foreign process (e.g. in Perl)

CONNECT foreigner

Welcome foreigner

d
[set] [pos] 3 10.9

YARP Port tcp socket

What can YARP do for me?

- Help you write robot control code that will last and can be shared
- Let you easily spread processes over many machines
  - Audio processing on one, object detection on another, tight-loop control on a dedicated machine, etc.
- Even if you don't want to control robots, the networking code could be useful in itself
- Free yourself from the tyranny of the operating system for which your control drivers were written
- Make the world a better, friendlier place …   ;-)

How to get YARP

- Download:

  http://yarp0.sourceforge.net

- Or via CVS

  See the documentation …

- Documentation:

  http://yarp0.sourceforge.net/specs/dox/user/html/

- More notes at the summer school site:

  http://eris.liralab.it/wiki/VVV06

Thank you all for your attention …

Please come and ask me if you need any help with installing or using YARP