

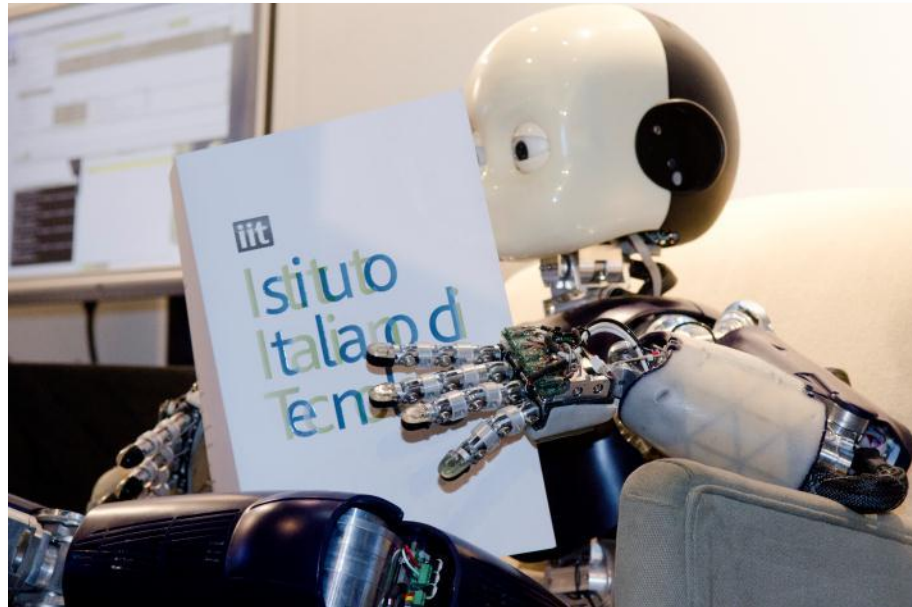
Lorenzo Natale

iCub Facility

Istituto Italiano di Tecnologia, Genova

Course on iCub programming

Lorenzo Natale, V. Tikhanoff, U. Pattacini, D. Domenichelli





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Program

- class 1 Overview of YARP. Introduction to CMake. Say hello world with YARP.
- class 2 Overview of YARP and the main classes. YARP Threads and Ports.
- class 3 YARP modules
- class 4 Image processing, Head tracker
- class 5 and class 6 Gaze and Arm controller
- class 7 GIT



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Schedule

June 24, 2014 10.00-12:00

June 27, 2014 10.00-12:00

July 7, 2014 10.00-12:00

July 8, 2014 16.30-18:30

July 9, 2014 10.00-12:00

July 10, 2014 10.00-12:00



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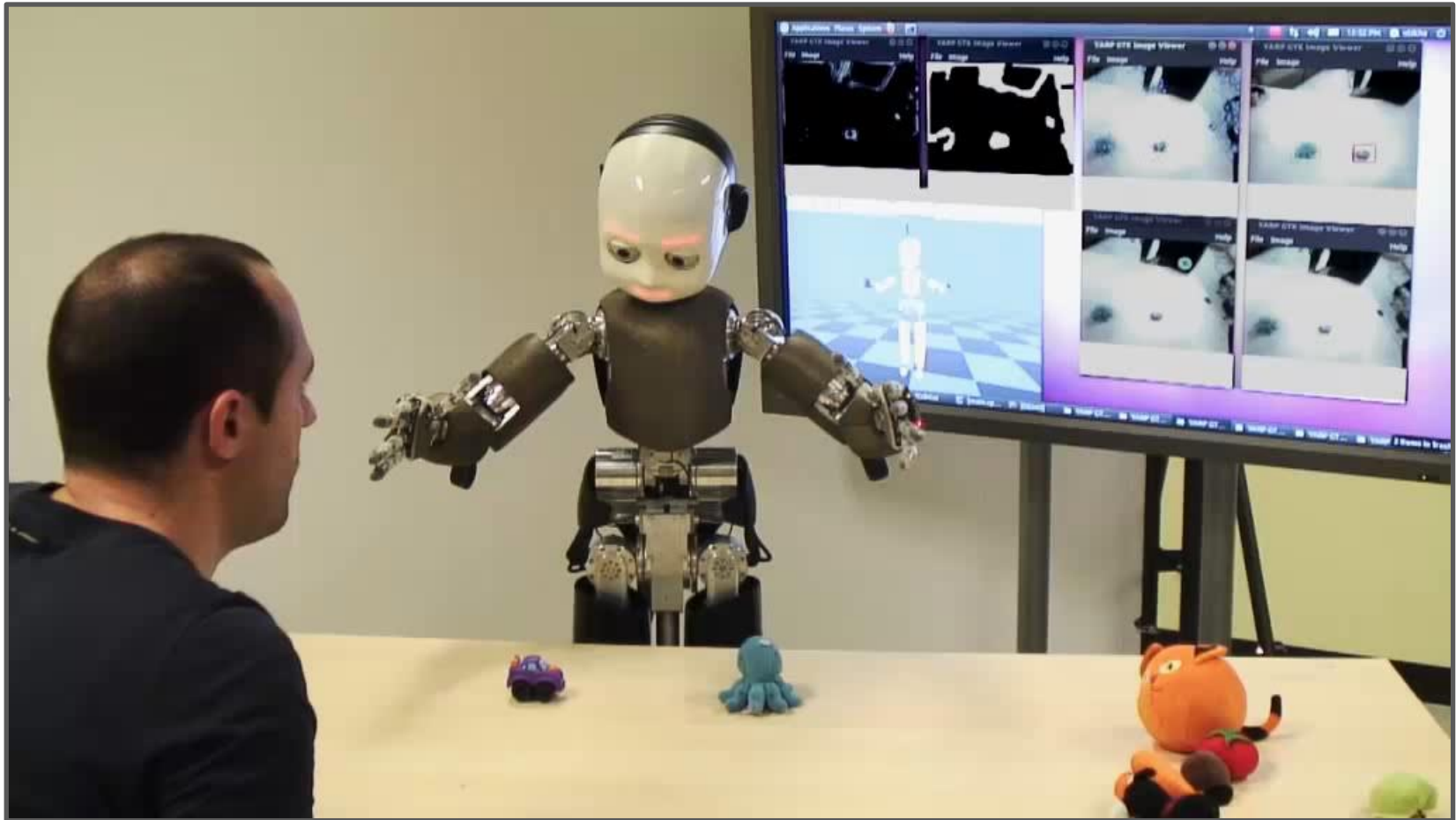
References

- YARP: www.yarp.it
 - Documentation
 - Paper: Towards long-lived robot genes
- iCub: <http://wiki.icub.org/wiki/Manual>
- CMake:
 - www.cmake.org → documentation & wiki
 - Mastering CMake, by Kitware Inc.
- C++:
 - Thinking in C++, Bruce Eckel
 - The C++ programming language, Bjarne Stroustrup
 - Anything else

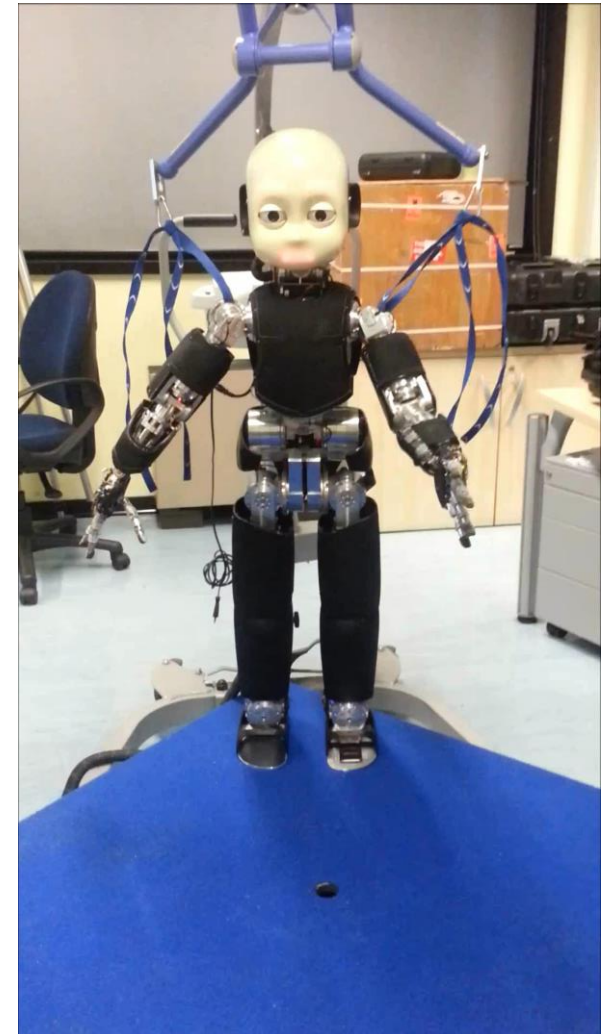
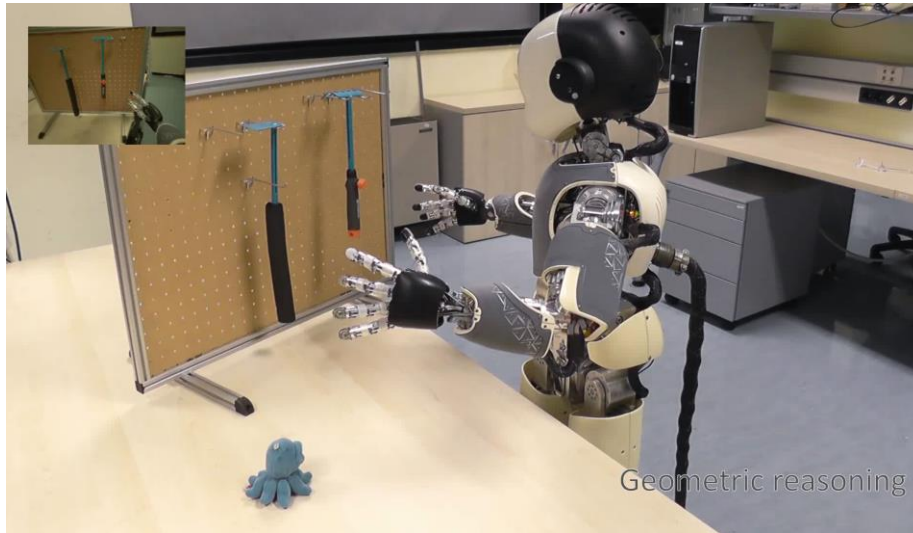
Motivations



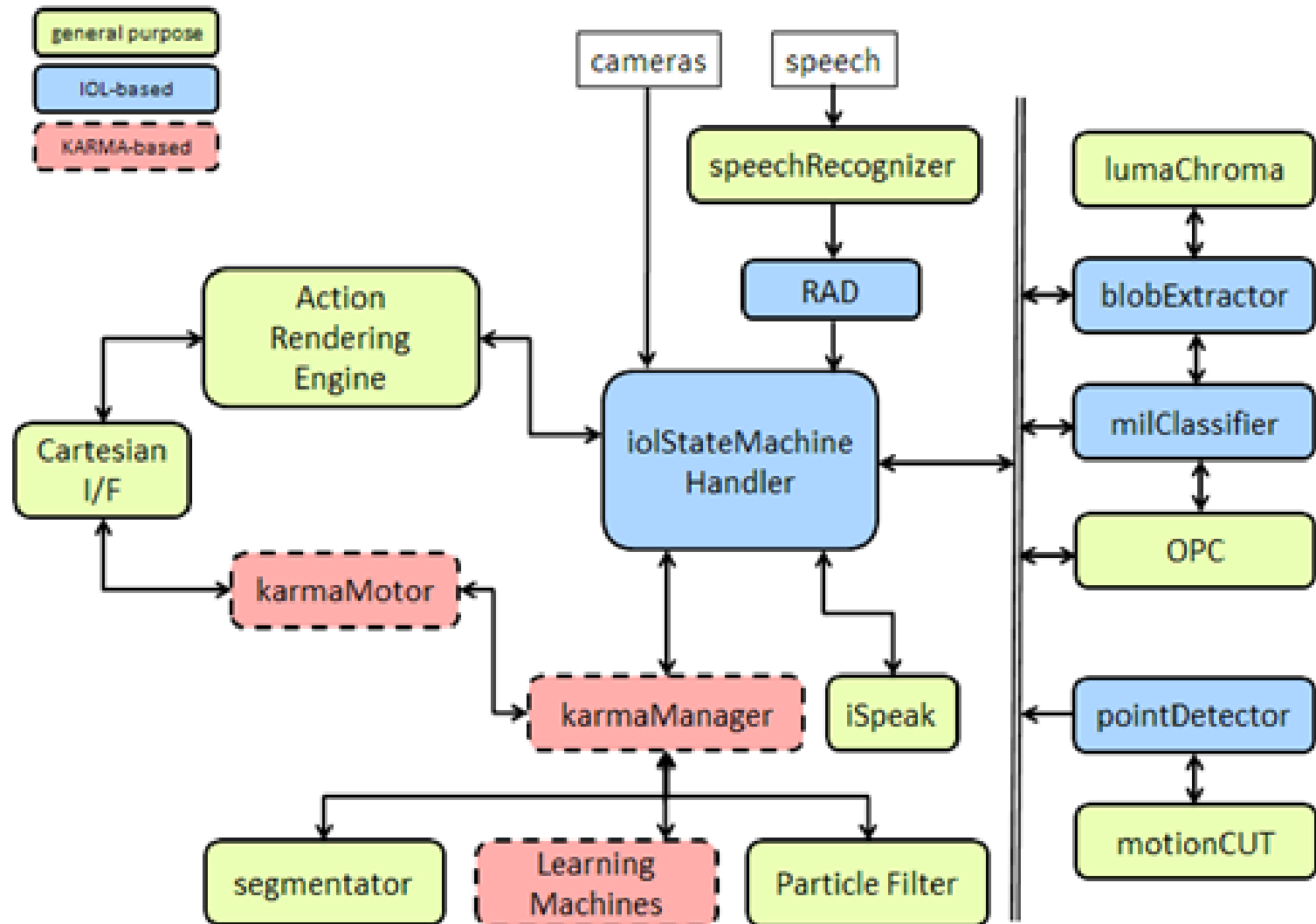
Complex behaviors



Integration of software components

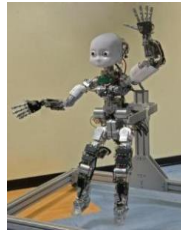
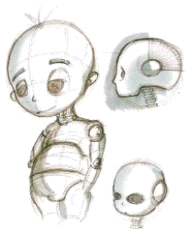


Complex behaviors



Key issues

- Asynchronous development
- Various scenarios and platforms
- Lack of standards
- Inherent complexity, distributed processing, lots of sensors, real-time
- Fluctuation in hardware and algorithms, lots of open questions



Software architecture

- Major cost in software development is debugging, recycling code is key
- Divide and conquer
- Modularity
- Factor out platform specificities
 - Hardware Abstraction Layer
 - Communication Abstraction
 - Operating system
 - Parameters
 - Computing infrastructure

Separation of concerns (5C)

Goal: separate software components

- Computation
- Communication
- Connection
- Configuration
- Coordination

Separation of concerns (5C)

Goal: separate software components

- Computation ← What we are interested in
- Communication
- Connection
- Configuration
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Separation of concerns (5C)

Goal: separate software components

- Computation ← What we are interested in
- Communication ← Dependent on the hardware, network topology
- Connection
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- } Application dependent



Separation of concerns (5C)

Goal: separate software components

- Computation ← What we are interested in
 - Communication ← Dependent on the hardware, network topology
 - Connection
 - Configuration
 - Coordination
- } Application dependent

```
output myAlgorithm(input)  
{  
  ...  
  out = call alg1(in)  
  ...  
  out = call alg2(in)  
  getImage() // from usb camera  
  ...  
}
```

```
output alg1(input)  
{code}
```

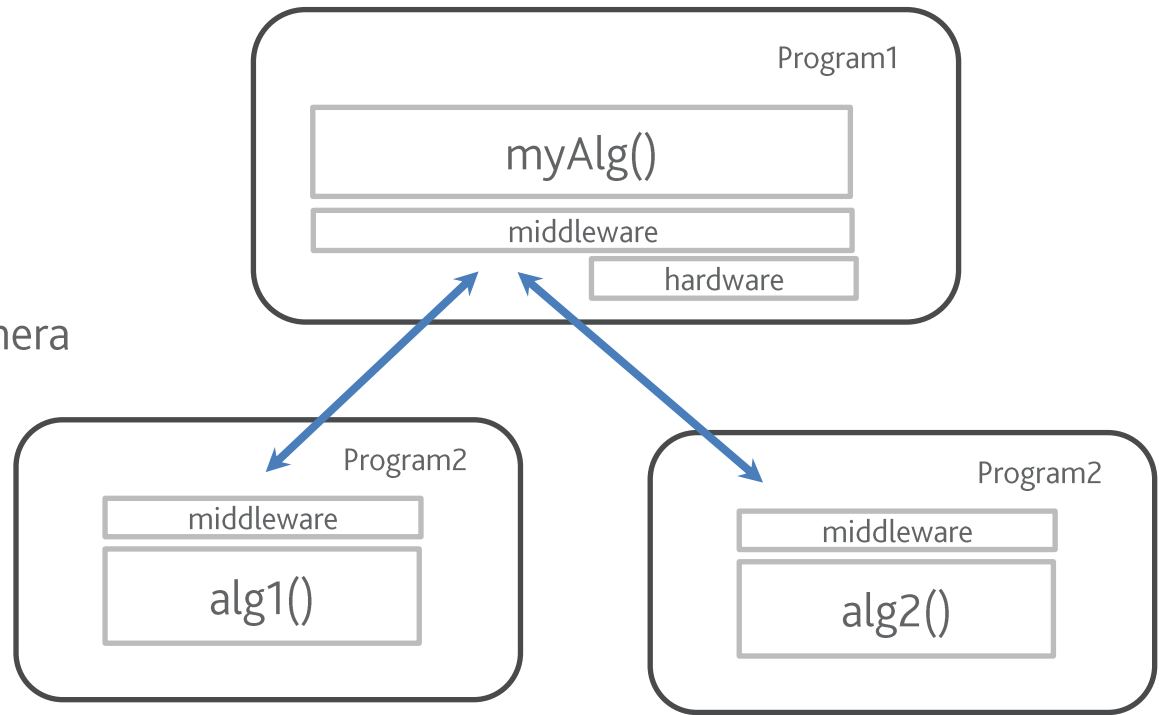
```
output alg2(input)  
{code}
```

Middleware: General concepts

```
output myAlgorithm(input)
{
  ...
  out = call alg1(in)
  ...
  out = call alg2(in)
  getImage() // from usb camera
  ...
}
```

```
output alg1(input)
{code}
```

```
output alg2(input)
{code}
```

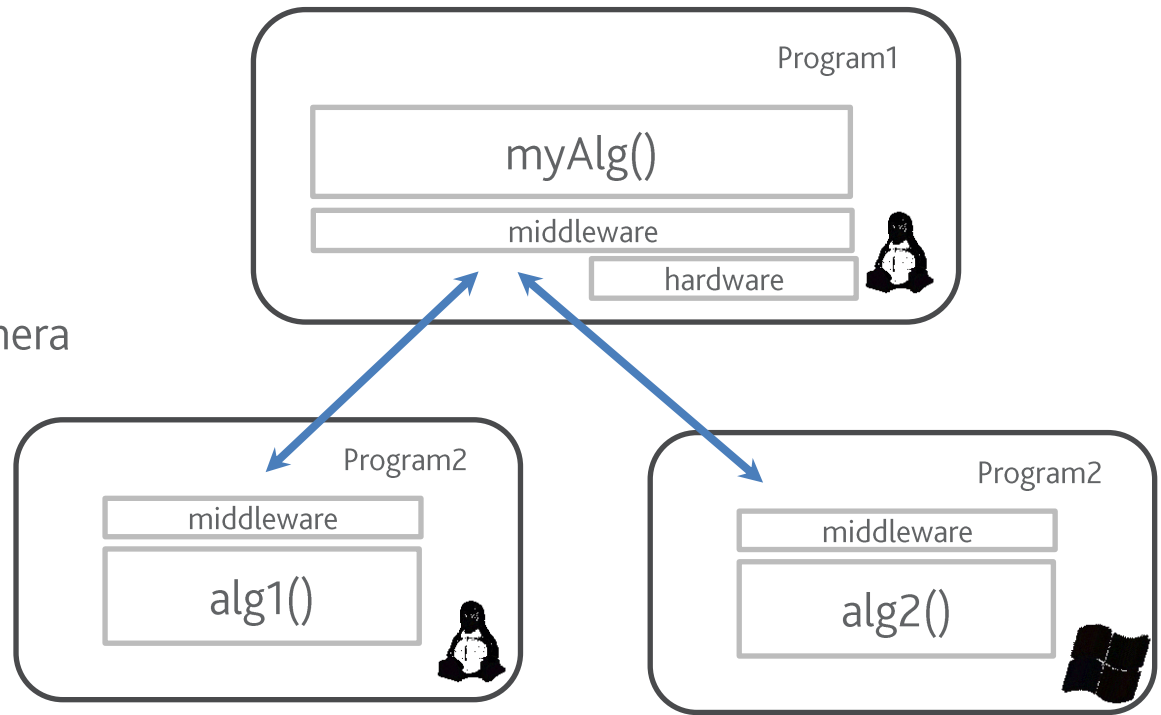


Middleware: General concepts

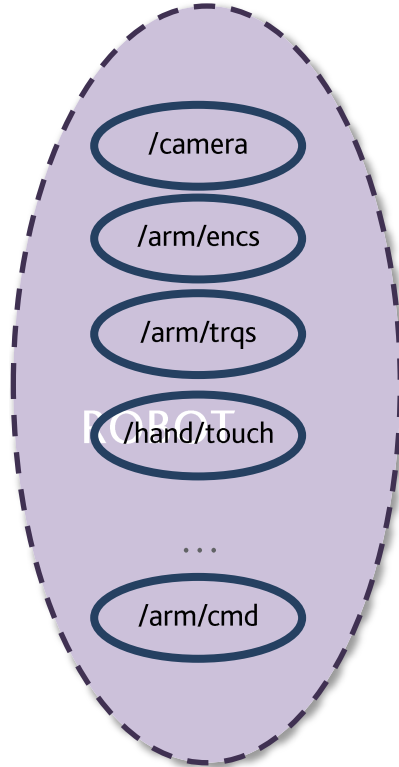
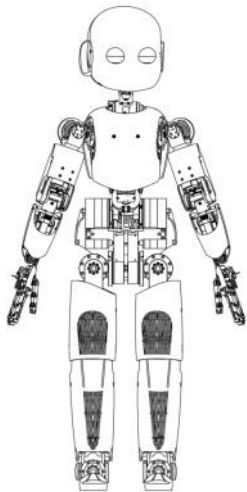
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{code}
```

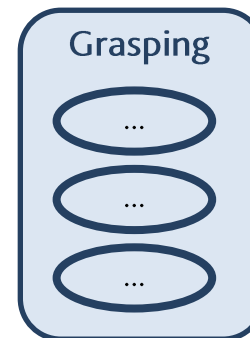
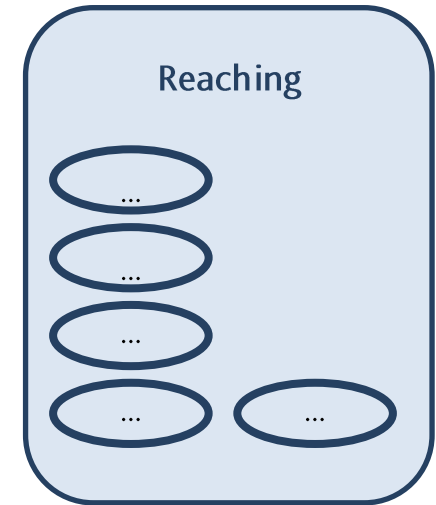
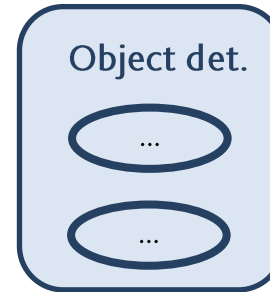
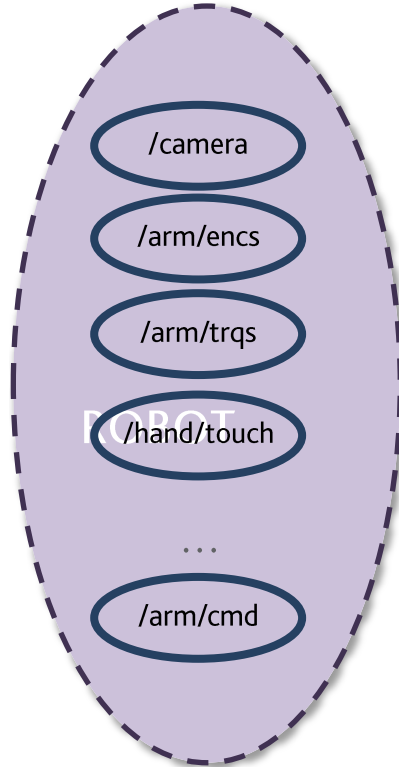
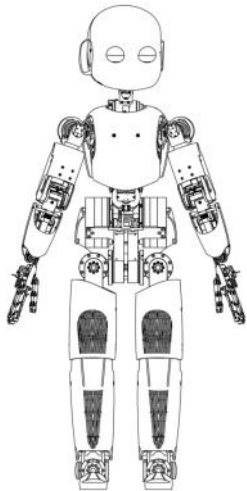
```
output alg2(input)
{code}
```



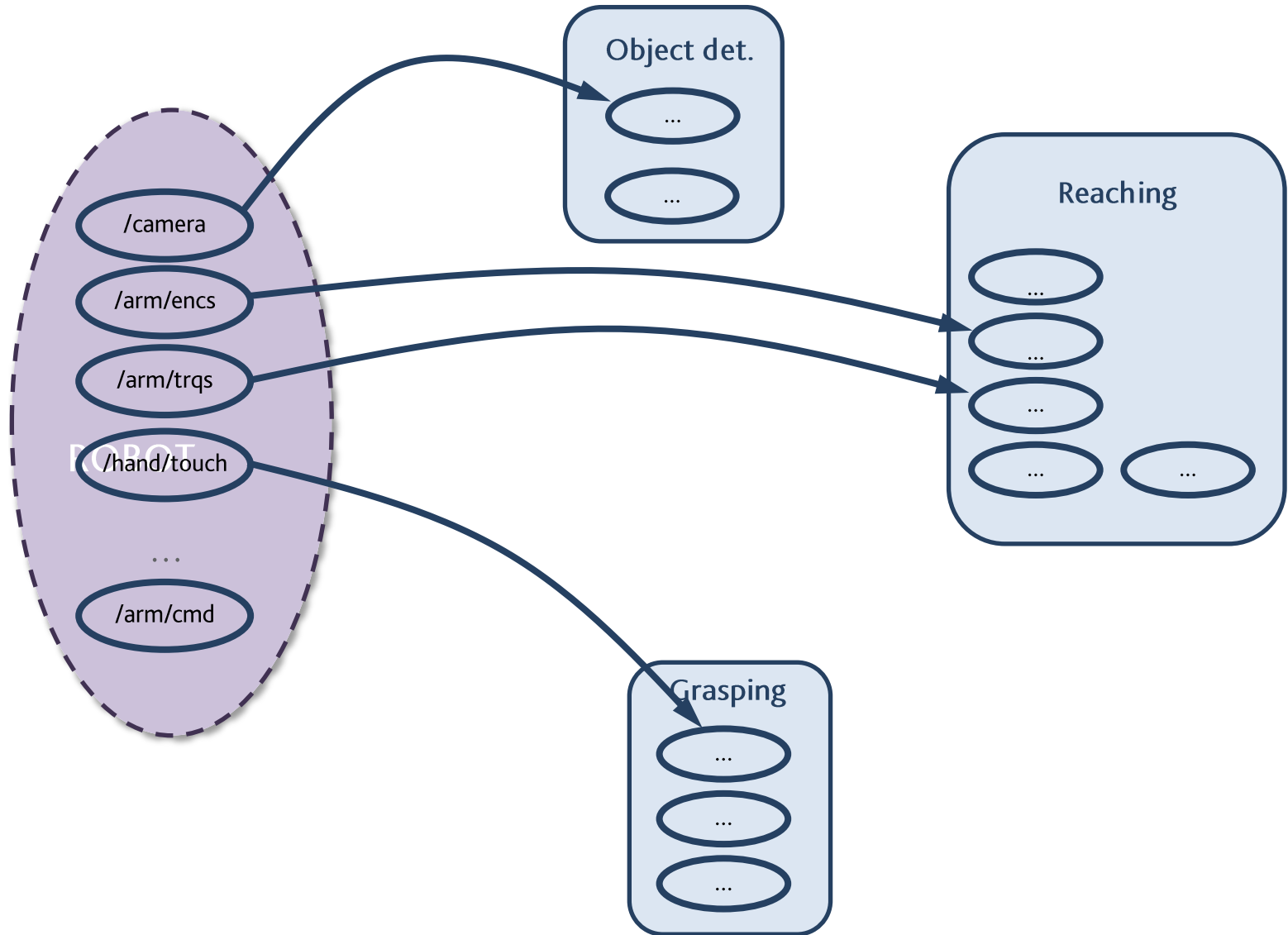
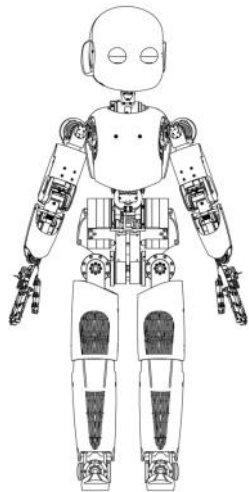
iCub software architecture



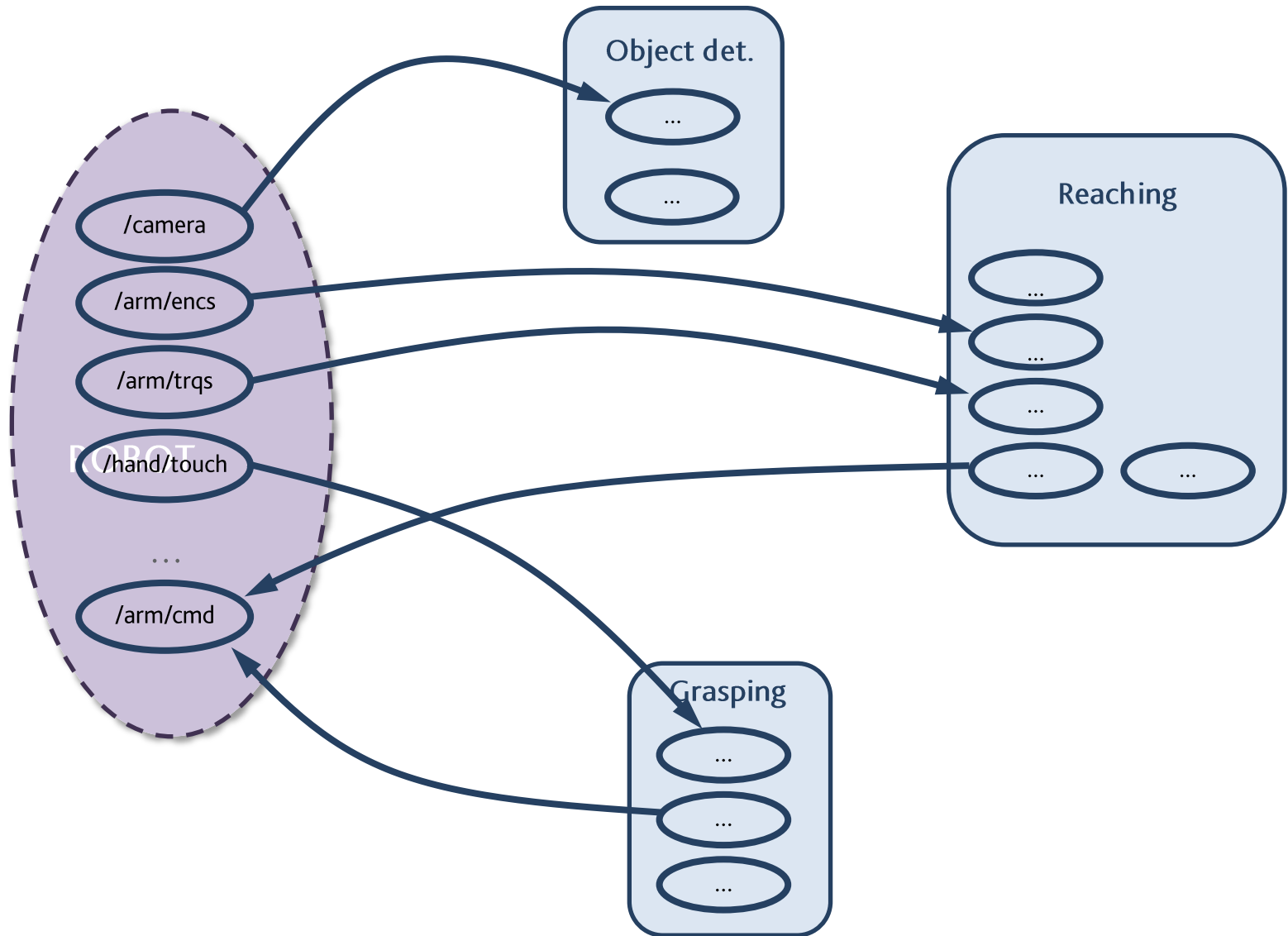
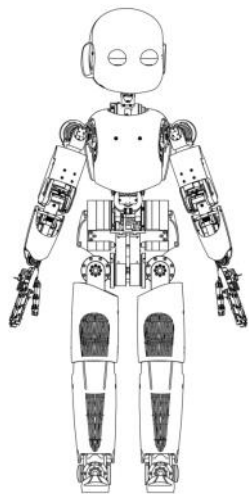
iCub software architecture



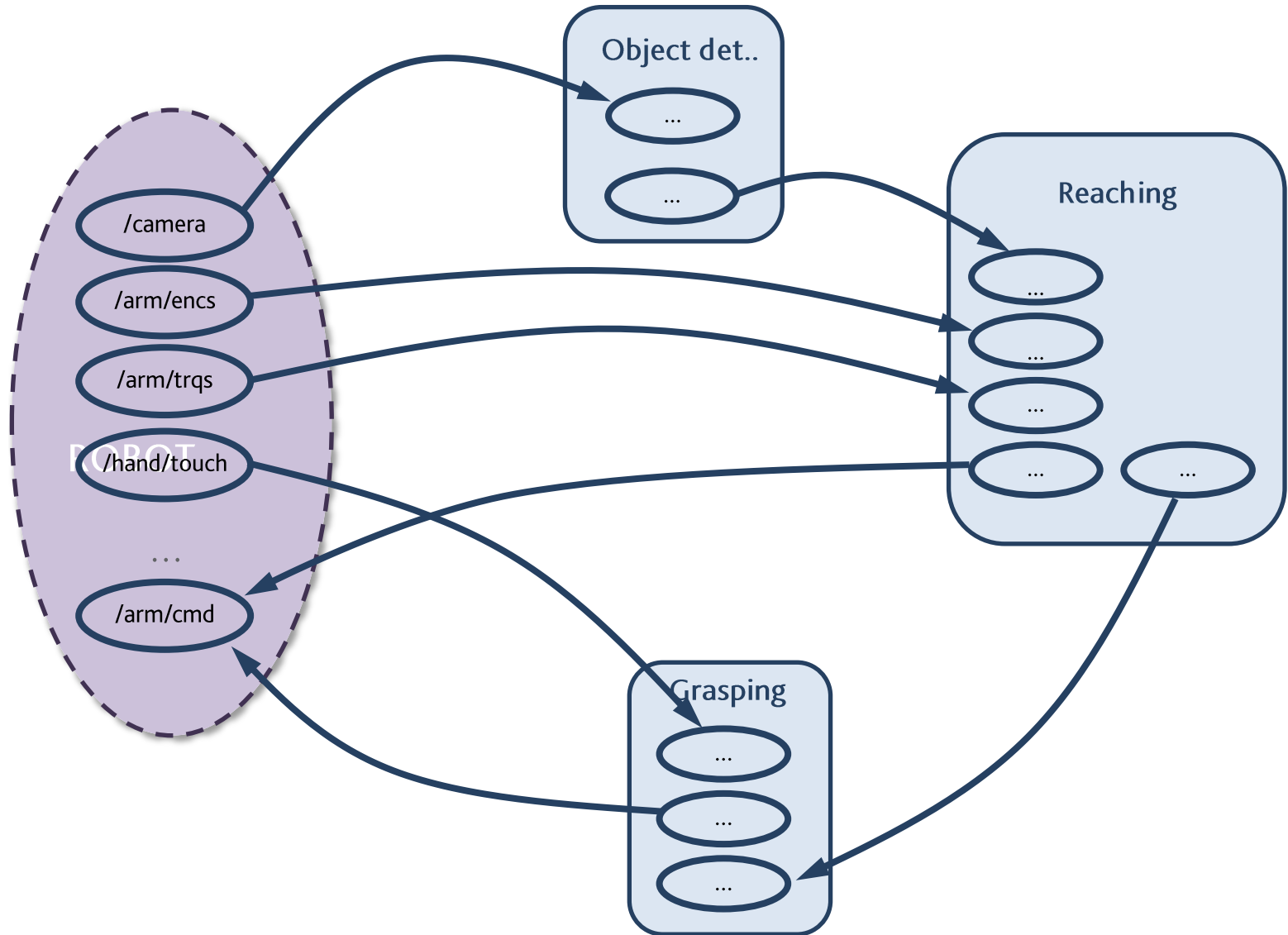
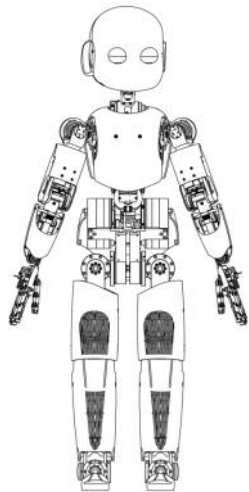
iCub software architecture



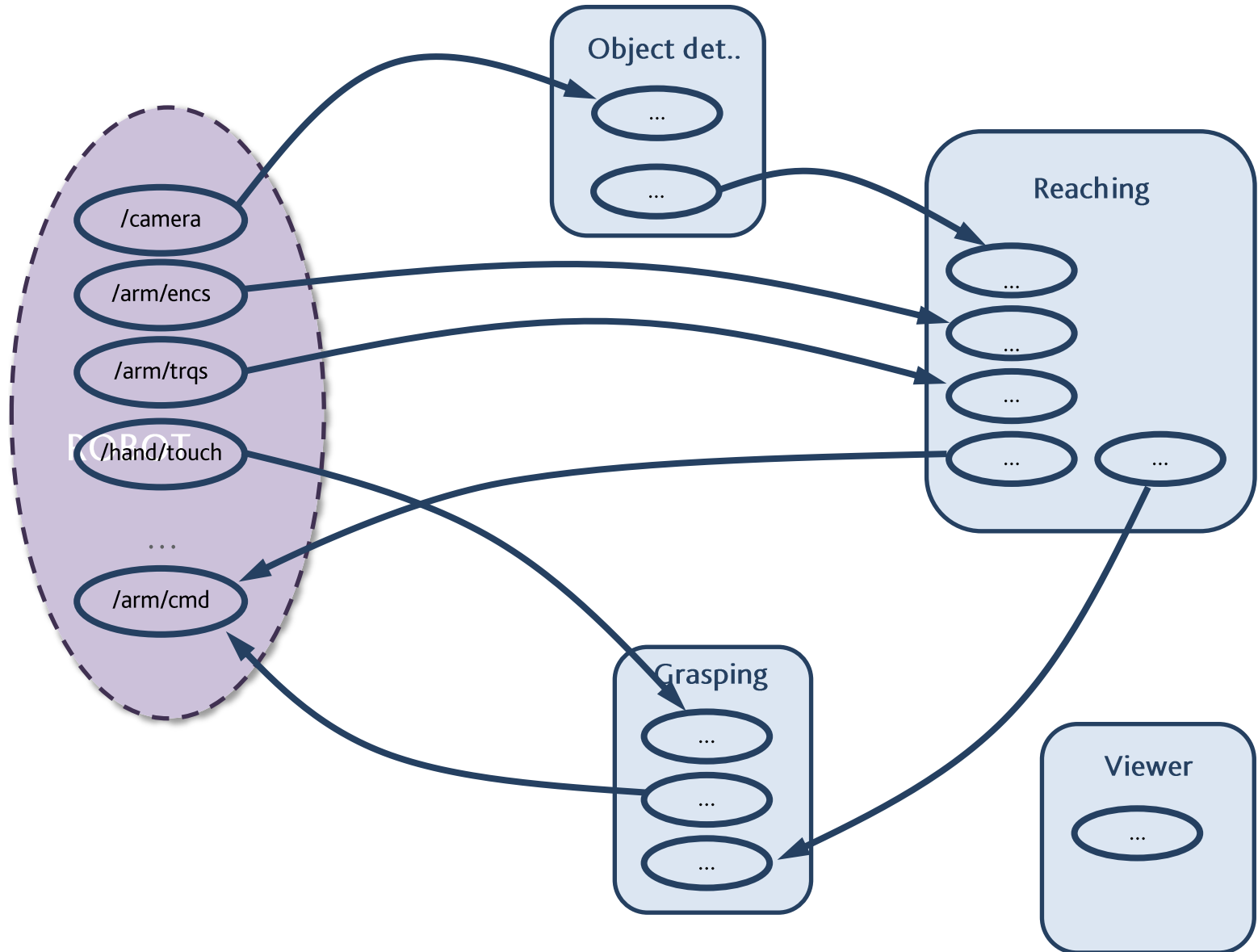
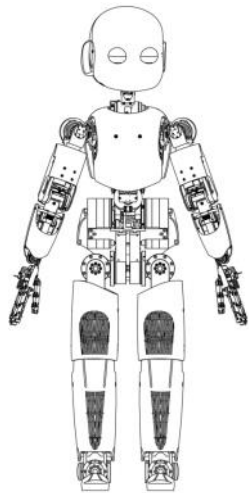
iCub software architecture



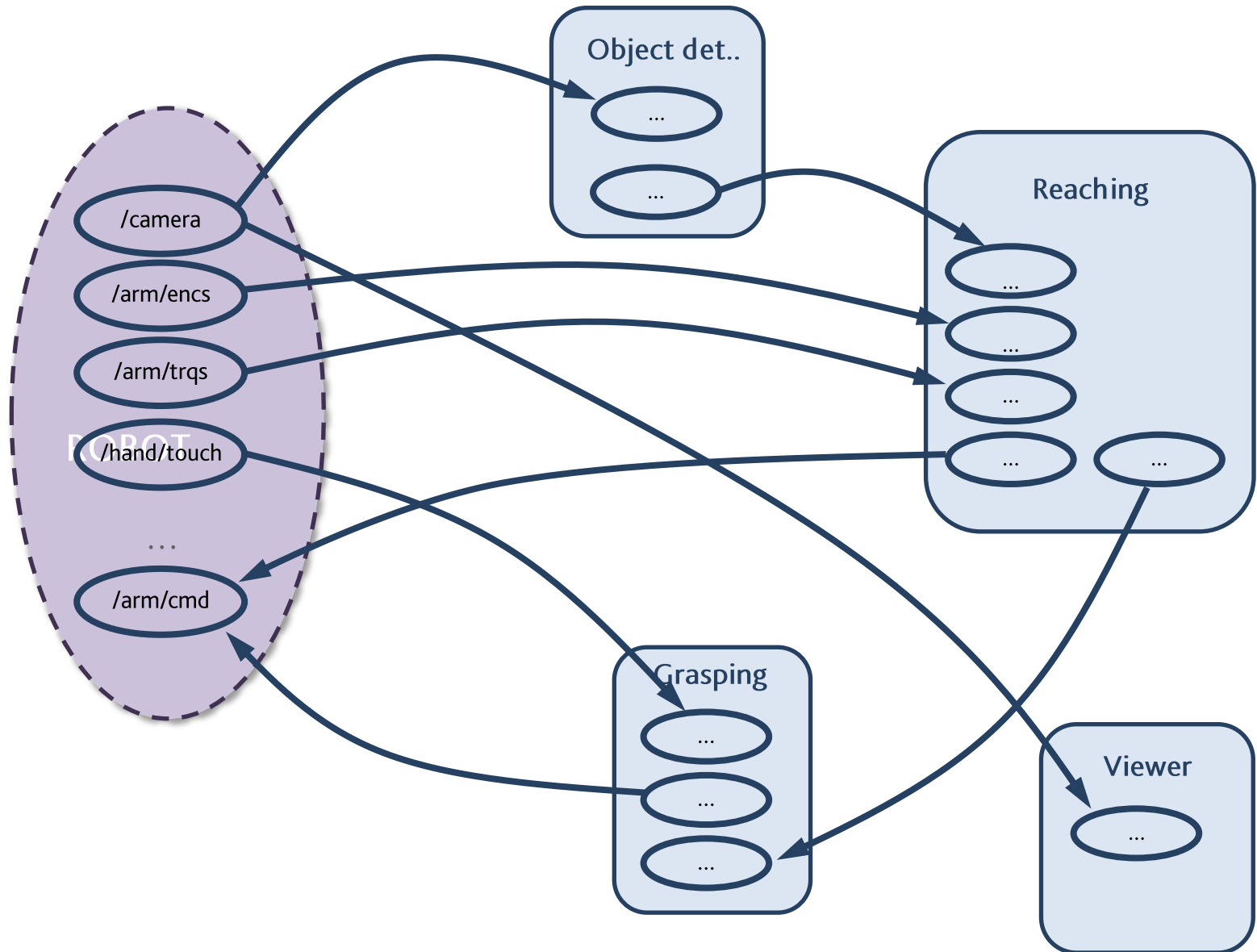
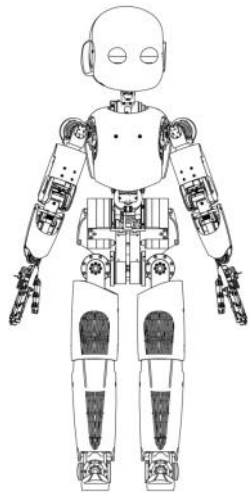
iCub software architecture



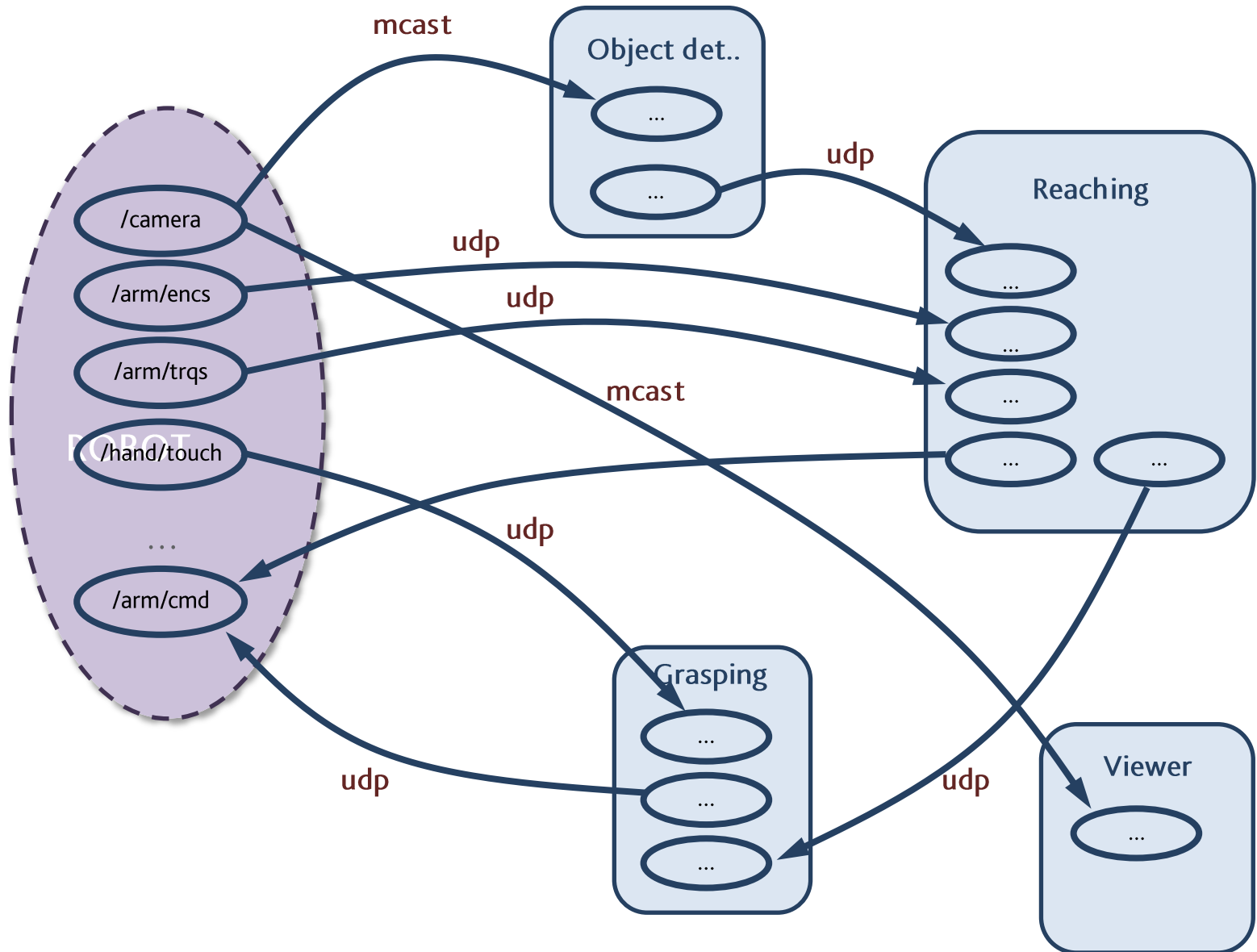
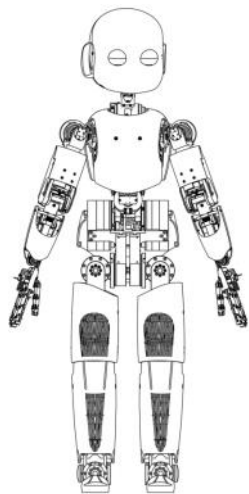
iCub software architecture



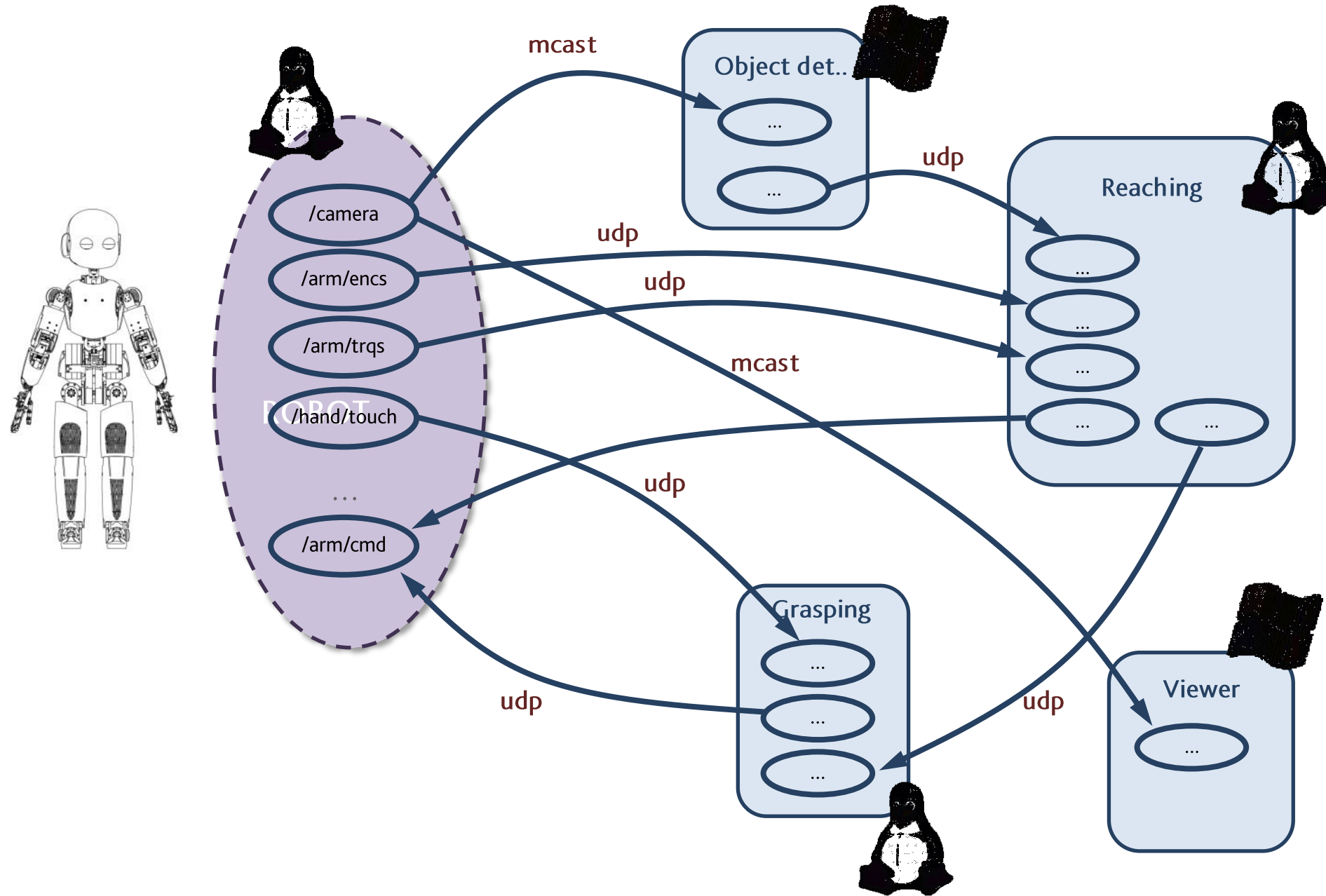
iCub software architecture



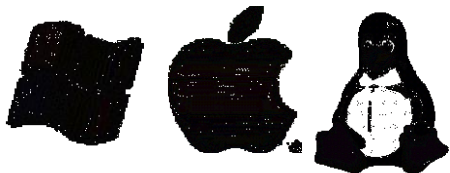
iCub software architecture



iCub software architecture



- Peer-to-peer, **loosely coupled**, communication
- Very stable code base >10 years old
- **Flexibility** and minimal **dependencies**, fits well with other systems
- Easy install with **binaries** on many OSes/distributions (Ubuntu, Debian, Windows, MacOS)
- Many **protocols**:
 - Built-in: tcp/udp/mcast
 - Plug-ins: ROS tcp, xml rpc, mjpg etc..



CMake
Cross-platform Make



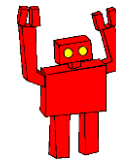
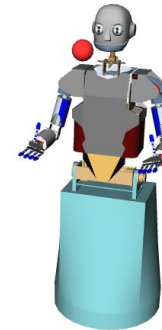
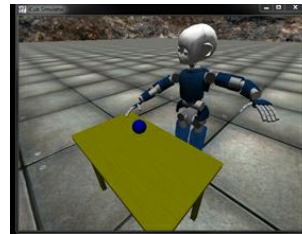
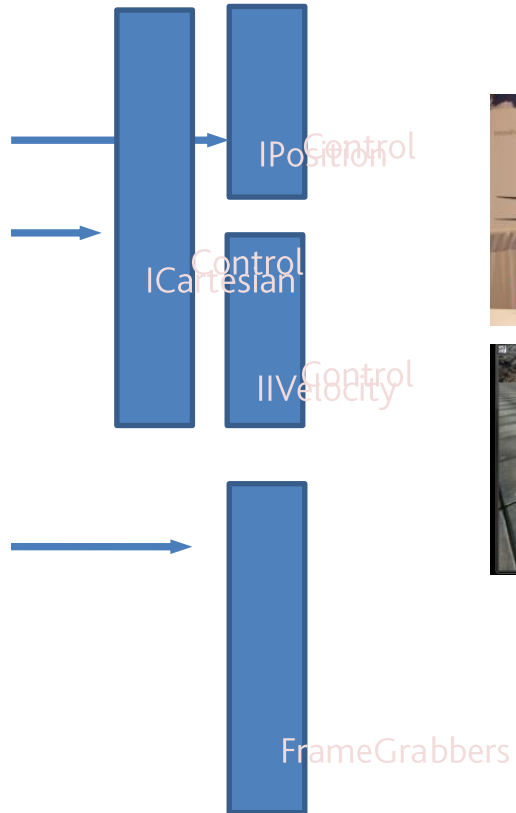
Interfaces

- Define interfaces to **motors** and **sensors** so to minimize the impact of changes in the hardware
- Also: network stubs allow **remotization**

Interfaces

User Code:

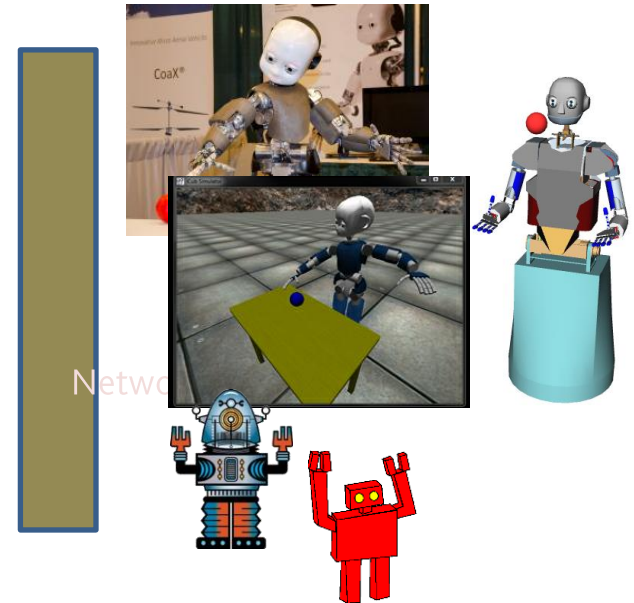
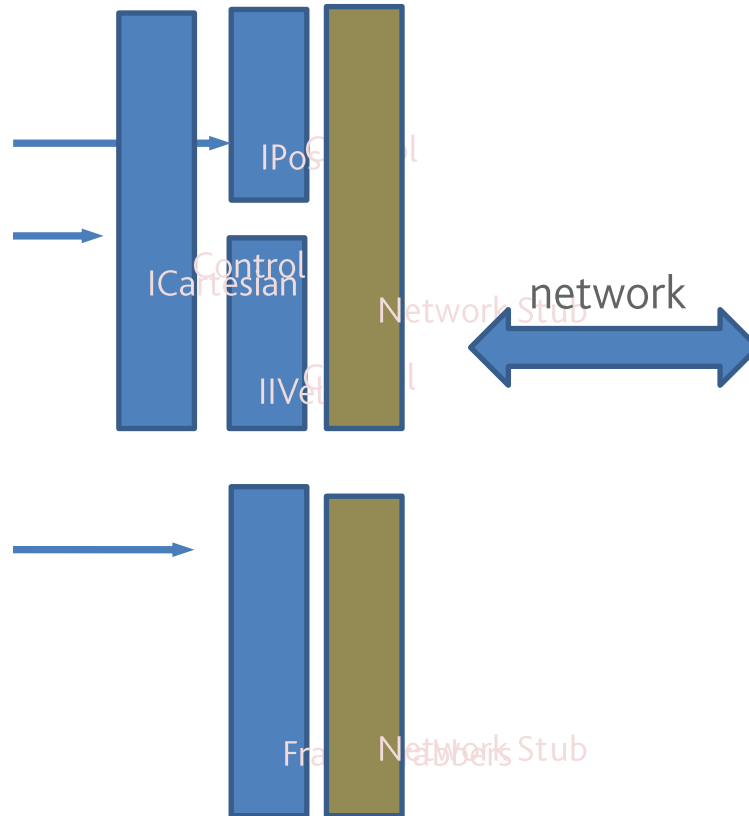
```
...
getImage();
...
lookAt();
reach();
grasp();
...
.
```



Interfaces

User Code:

```
...
getImage();
...
lookAt();
reach();
grasp();
...
.
```



YARP plugins

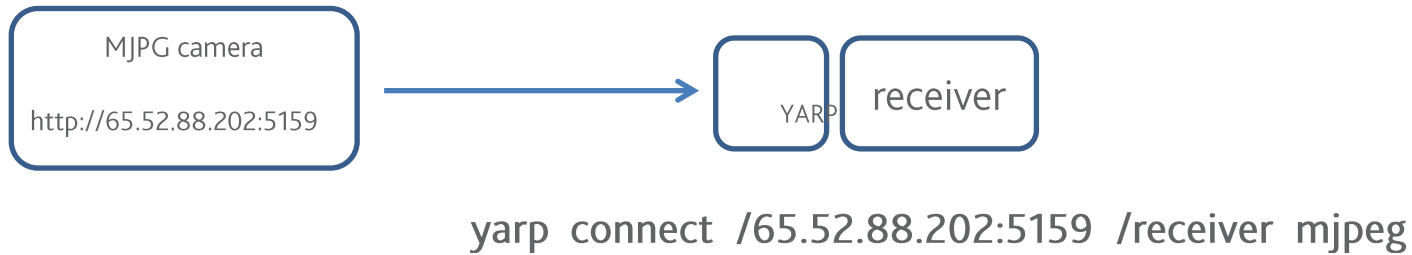
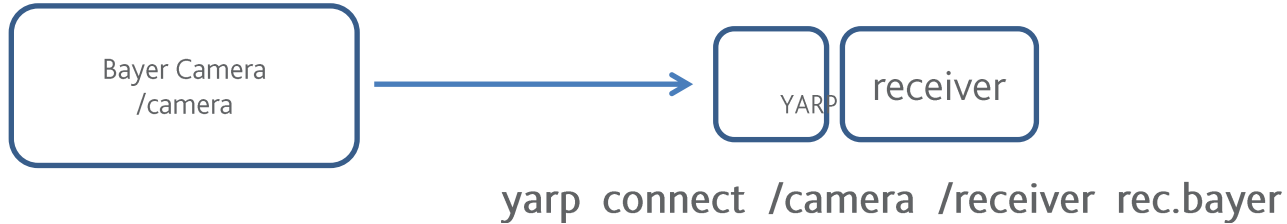
- YARP includes a plugin system for drivers and protocols (carriers)
- Interchangeable carriers allow:
 - interfacing existing software with ports (without bridges)
 - change significantly port behavior
- Examples:
 - ROS, mjpeg, xml rpc, etc...
 - bayer carrier, priority based communication

Examples

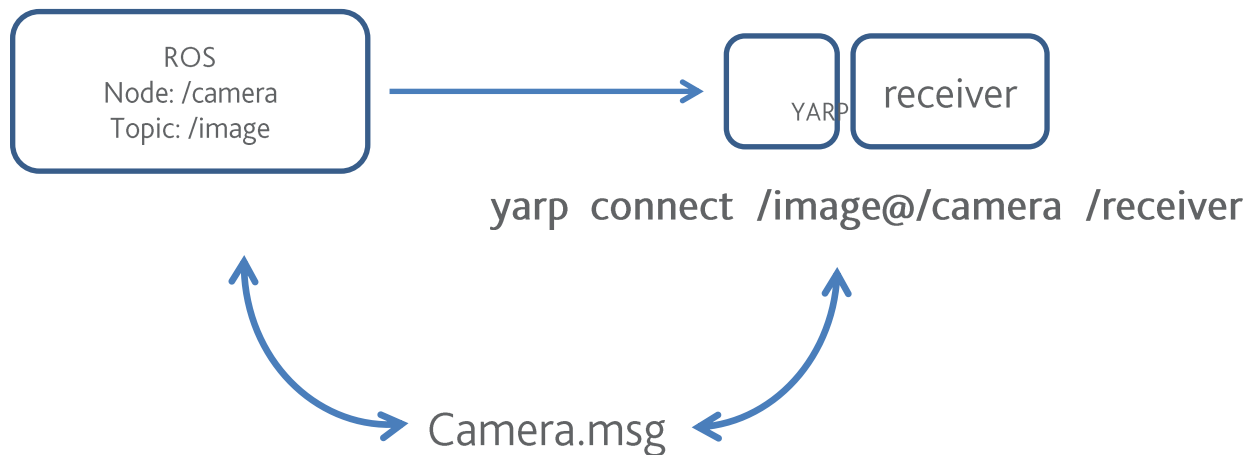
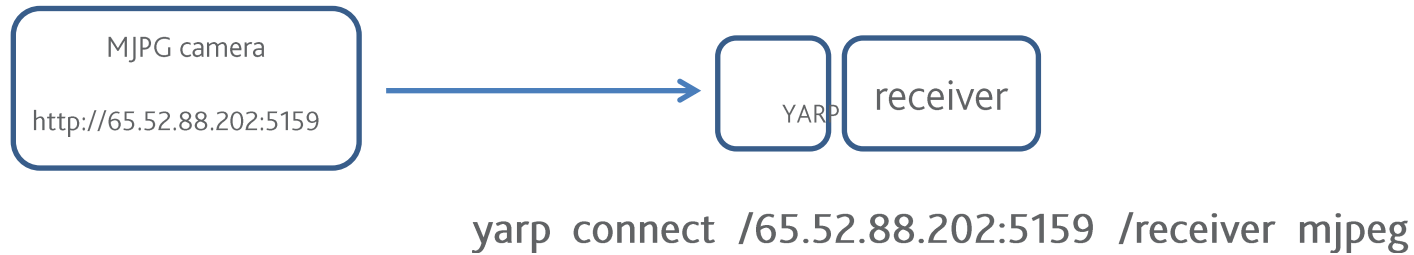
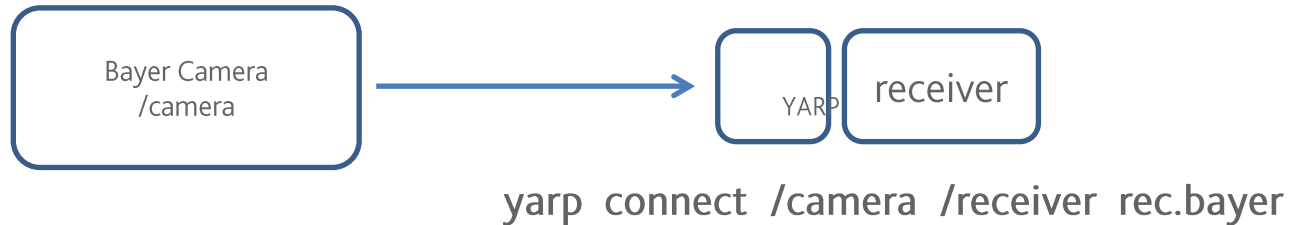


```
yarp connect /camera /receiver rec.bayer
```

Examples



Examples



Tools: working offline

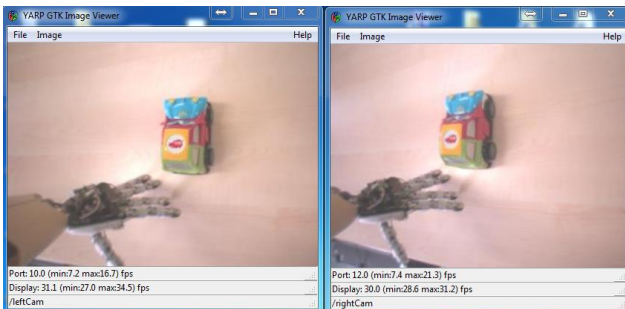
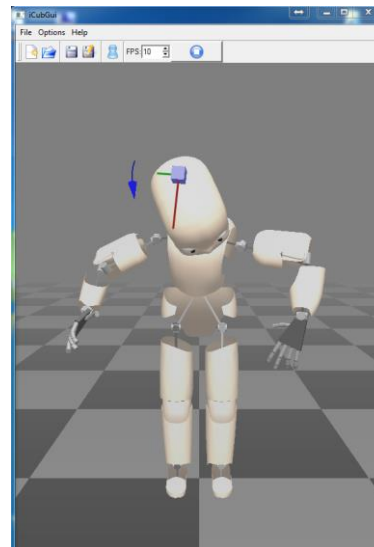
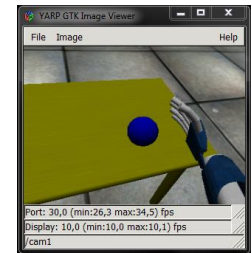
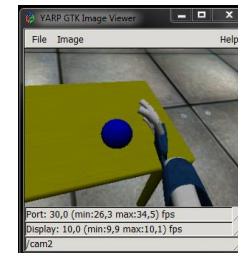
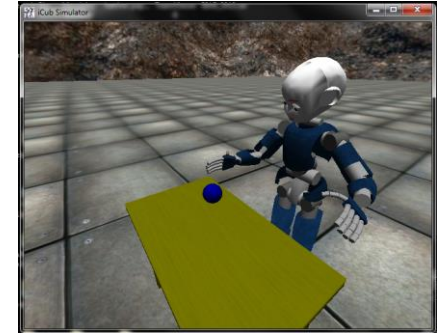
- Data collector/player
- Simulator
- GUIs

dataSetPlayer

Active	Part	Type	Frames	Sample Rate	Port Name	Status
<input checked="" type="checkbox"/>	calibMatrix_left	Bottle	1333	106 ms	/calibMatrix/left:o	33 %
<input checked="" type="checkbox"/>	calibMatrix_right	Bottle	1720	103 ms	/calibMatrix/right:o	33 %
<input checked="" type="checkbox"/>	head	Bottle	6327	6 ms	/icub/head/state:o	29 %
<input checked="" type="checkbox"/>	images_left	Image:ppm	1444	63 ms	/icub/camcalib/left/out	30 %
<input checked="" type="checkbox"/>	images_right	Image:ppm	1832	69 ms	/icub/camcalib/right/out	30 %
<input checked="" type="checkbox"/>	inertial	Bottle	12614	1 ms	/icub/inertial	29 %
<input checked="" type="checkbox"/>	leftArm	Bottle	6052	24 ms	/icub/left_arm/state:o	30 %
<input checked="" type="checkbox"/>	leftLeg	Bottle	6384	24 ms	/icub/left_leg/state:o	29 %
<input checked="" type="checkbox"/>	plots	Image:ppm	225	682 ms	/karmaLearn/plot:o	35 %
<input checked="" type="checkbox"/>	rightArm	Bottle	6377	25 ms	/icub/right_arm/state:o	29 %
<input checked="" type="checkbox"/>	rightLeg	Bottle	6078	24 ms	/icub/right_leg/state:o	30 %
<input checked="" type="checkbox"/>	torso	Bottle	6042	25 ms	/icub/torso/state:o	31 %

Speed: 2.0x

C:\Users\Carlo\Desktop\dataTEST



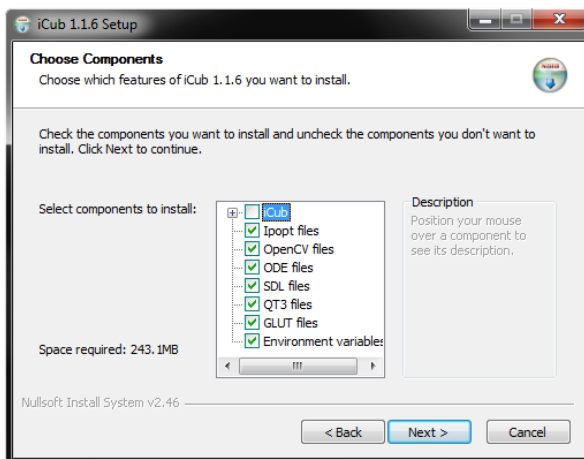
Repositories and online resources

- YARP online documentation: www.yarp.it
- iCub: <http://wiki.icub.org>
- GitLab: <https://gitlab.icub.org/>
- Github: <https://github.com/robotology>
 - yarp
 - codyco
- Sourceforge:
 - Robotcub (iCub: main and contrib, poeticon++, emorph, darwin)
 - efaa
 - xperience

Binaries

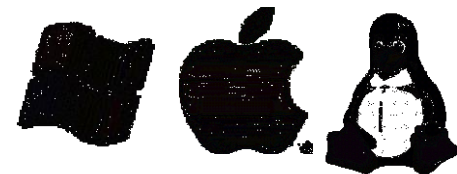


Libraries and modules for
motor control, machine
learning, vision...



wiki.icub.org/iCub

→ Software Installation
→ Tutorials



Automatic documentation and compilation tests

- <http://dashboard.icub.org>
- <http://www.yarp.it>

CDash - iCub

Facility Servers List - iCub F...

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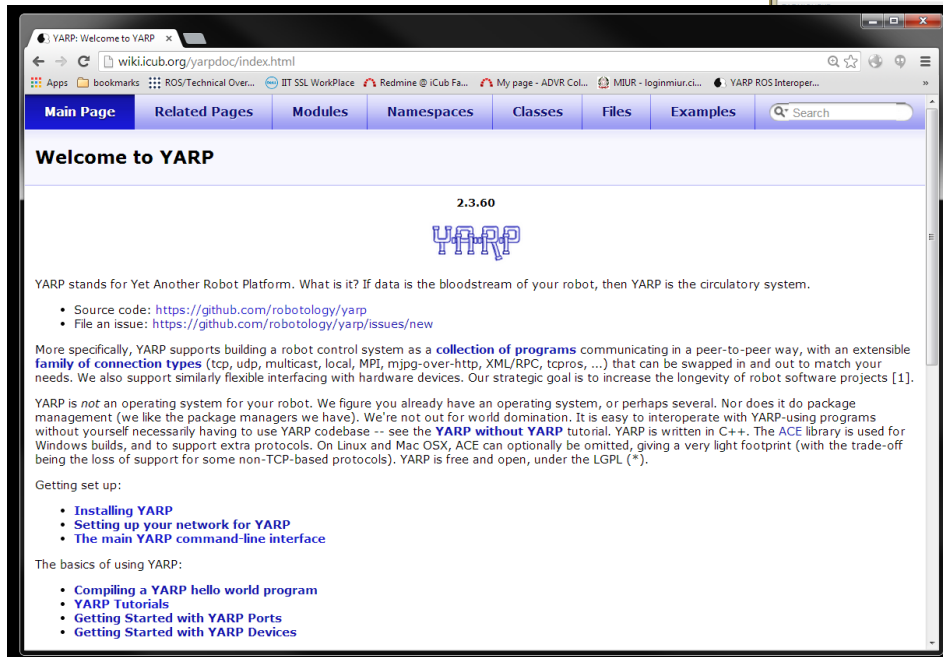
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YARP: Welcome to YARP

2.3.60

Welcome to YARP

YARP stands for Yet Another Robot Platform. What is it? If data is the bloodstream of your robot, then YARP is the circulatory system.

- Source code: <https://github.com/robotology/yarp>
- File an issue: <https://github.com/robotology/yarp/issues/new>

More specifically, YARP supports building a robot control system as a **collection of programs** communicating in a peer-to-peer way, with an extensible **family of connection types** (tcp, udp, multicast, local, MPI, mjpg-over-http, XML/RPC, tcp/roscpp, ...) that can be swapped in and out to match your needs. We also support similarly flexible interfacing with hardware devices. Our strategic goal is to increase the longevity of robot software projects [1].

YARP is not an operating system for your robot. We figure you already have an operating system, or perhaps several. Nor does it do package management (we like the package managers we have). We're not out for world domination. It is easy to interoperate with YARP-using programs without yourself necessarily having to use YARP codebase -- see the **YARP without YARP** tutorial. YARP is written in C++. The ACE library is used for Windows builds, and to support extra protocols. On Linux and Mac OSX, ACE can optionally be omitted, giving a very light footprint (with the trade-off being the loss of support for some non-TCP-based protocols). YARP is free and open, under the LGPL (*).

Getting set up:

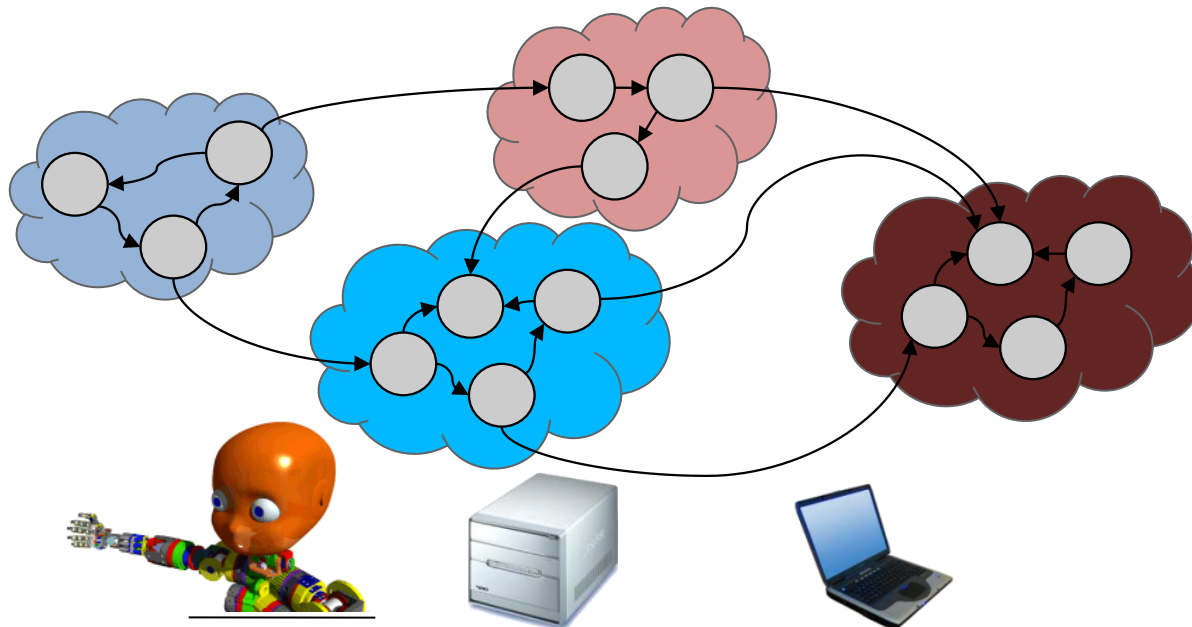
- **Installing YARP**
- **Setting up your network for YARP**
- **The main YARP command-line interface**

The basics of using YARP:

- **Compiling a YARP hello world program**
- **YARP Tutorials**
- **Getting Started with YARP Ports**
- **Getting Started with YARP Devices**

Modularity: where to draw the line?

- Libraries
- Components (processes)
- Functionalities (group of components)



Managing complexity

In a modular system integration becomes an issue:

- Execution and monitoring
- Development
- Coordination



Execution and monitoring: YARP manager

Required
modules
connections
nodes
resources

Available
resources

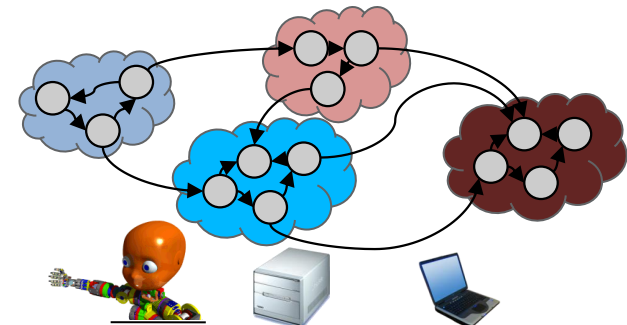
The screenshot shows the YARP module manager interface. The left pane lists various modules under 'Entities'. The right pane shows a table of running modules with their IDs, status, host, and parameters. Below this is a table of connections showing their status and the resources they are connected to.

Module	ID	Status	Host	Parameters
icubmoddev	0	running	pc104	--device grabber --subdevice dragonfly2 --width 320 --height 2
icubmoddev	1	running	pc104	--device grabber --subdevice dragonfly2 --width 320 --height 2
camCalib	2	running	icub-b14	--context cameraCalibration/conf --from icubEyes.ini --group C
camCalib	3	running	icub-b15	--context cameraCalibration/conf --from icubEyes.ini --group C
yarpview	4	stopped	icub14	--name /icub/view/left --x 0 --y 0 --synch
yarpview	5	stopped	icub14	--name /icub/view/right --x 320 --y 0 --synch
frameGrabberGui2	6	running	icub14	--local /icub/fggui/left --remote /icub/cam/left --x 0 --y 350 --wi
frameGrabberGui2	7	running	icub14	--local /icub/fggui/right --remote /icub/cam/right --x 320 --y 350

Connection	ID	Status	From	To	Carrier	Resource	ID	Status
Internal 0	0	disconnected	/icub/cam/left	/icub/camcalib/left/in	udp	pc104	0	available
Internal 1	1	disconnected	/icub/cam/right	/icub/camcalib/right/in	udp	icub-b14	1	available
Internal 2	2	disconnected	/icub/camcalib/left/out	/icub/view/left	udp	icub-b15	2	available
Internal 3	3	disconnected	/icub/camcalib/right/out	/icub/view/right	udp	icub14	3	available
						icub01	4	available

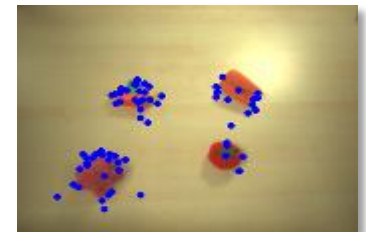
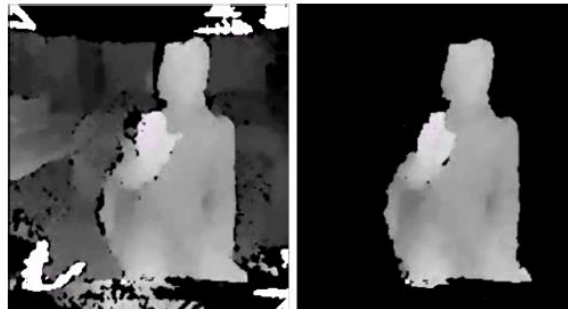
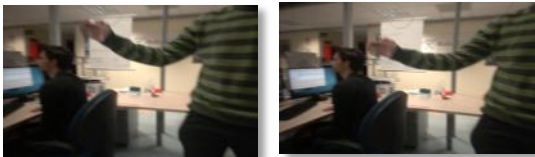
[ERR]: (Face) cannot stop yarpdev on pc104 : Timeout! Cannot stop yarpdev on /pc104

Current application: Calibrated_Cameras



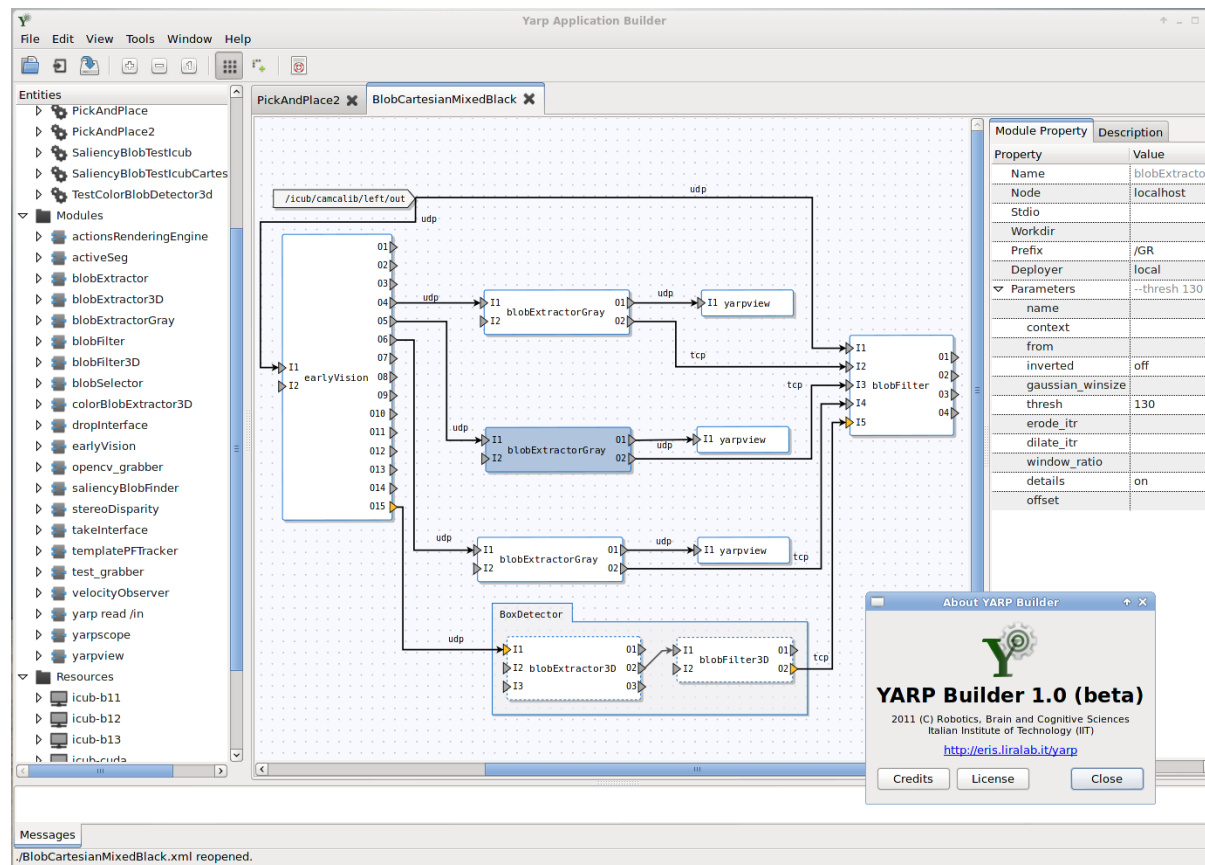
Components: some examples from the iCub repository

- Algorithms for motion computation and egomotion compensation
- Machine learning for vision
- Disparity map
- Action recognition
- Segmentation

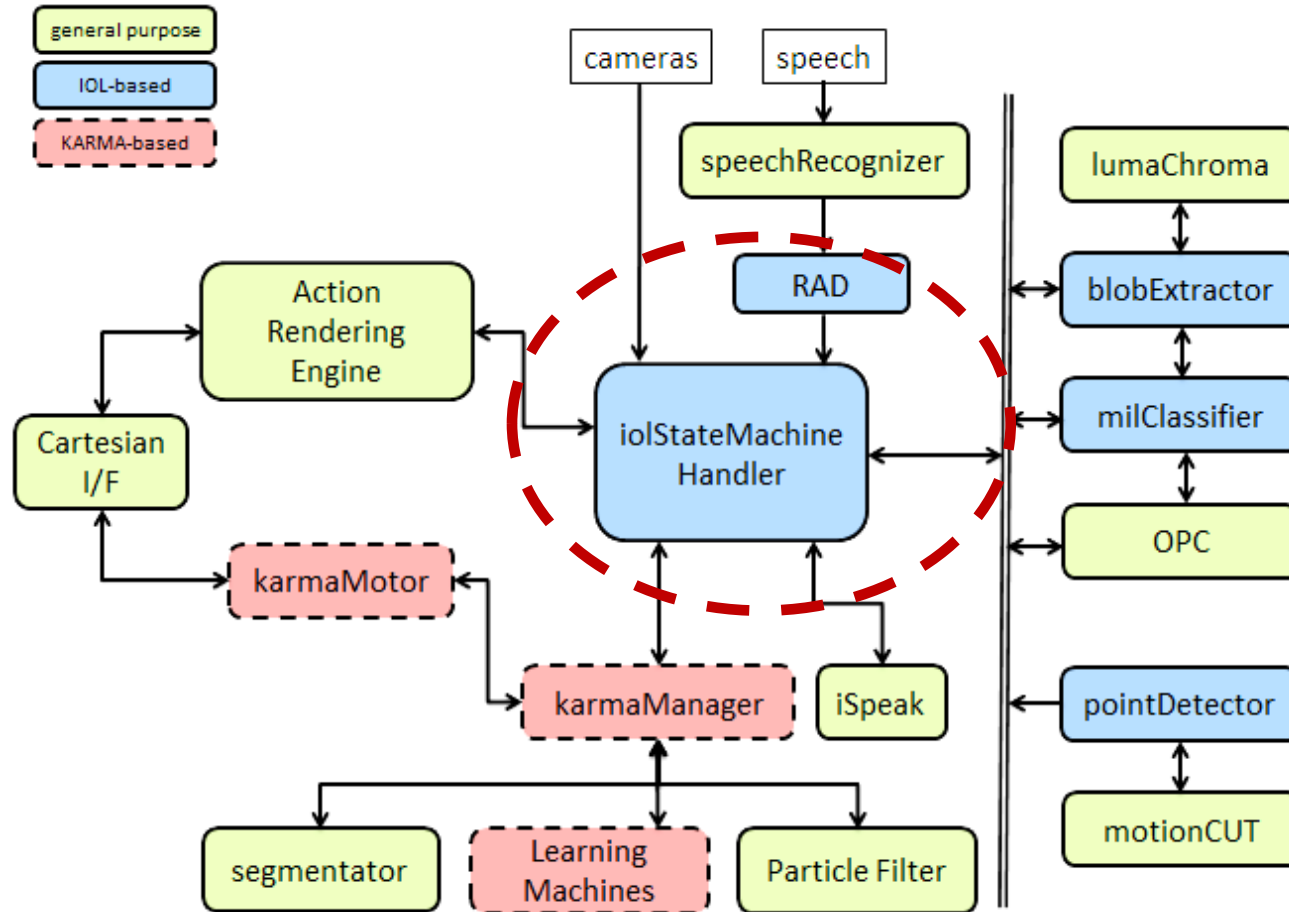


Tools for rapid development

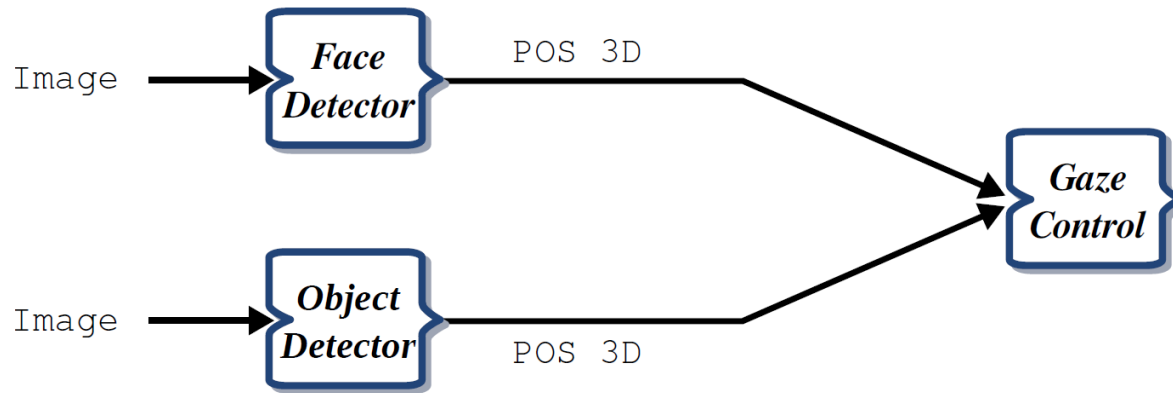
- YARP builder: graphical tool to design application
- Interface Definition Language (IDL):
 - formalization of types and interfaces between modules
 - automatic generation of message handlers



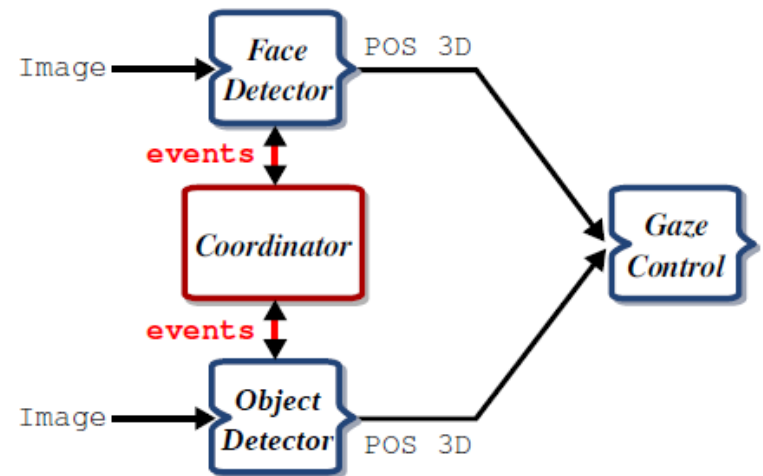
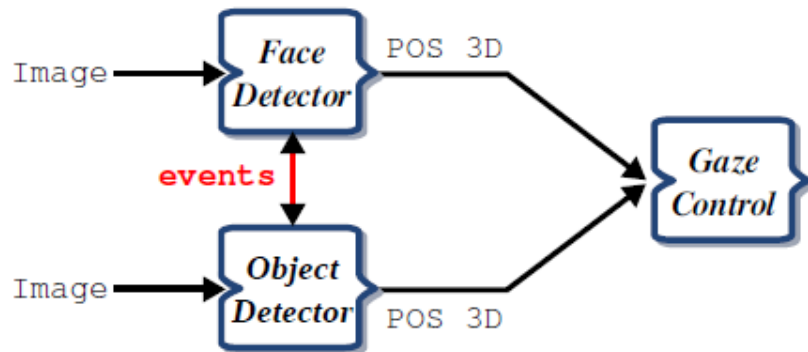
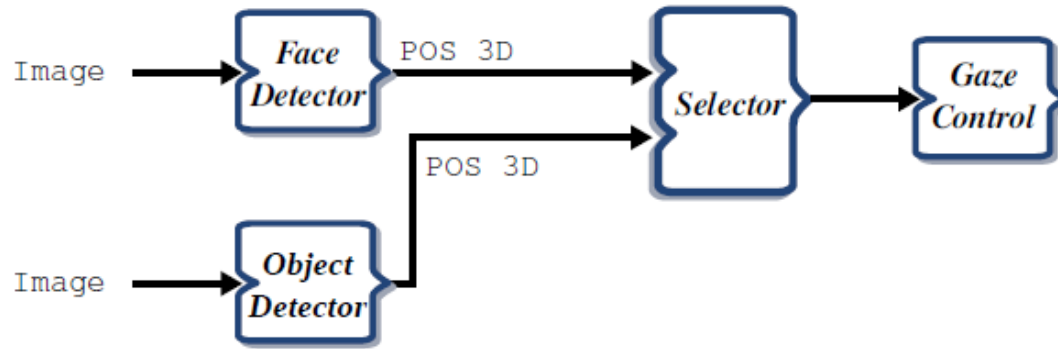
Coordinating modules



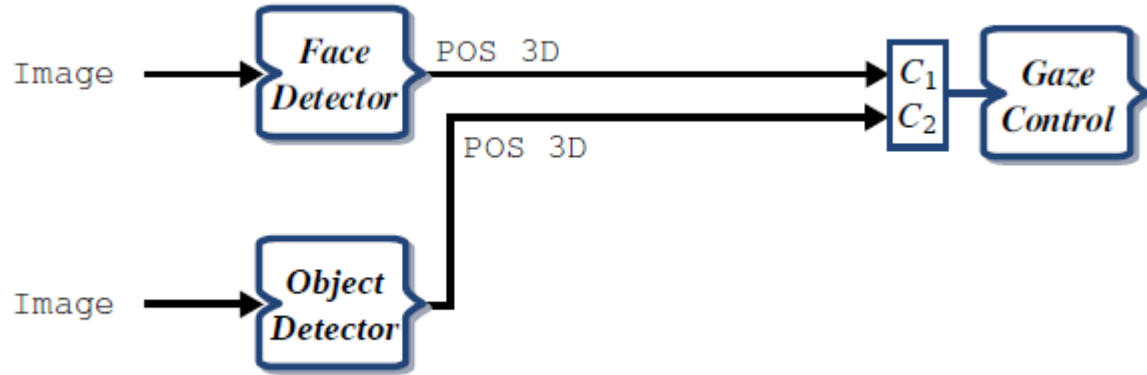
Arbitration and coordination



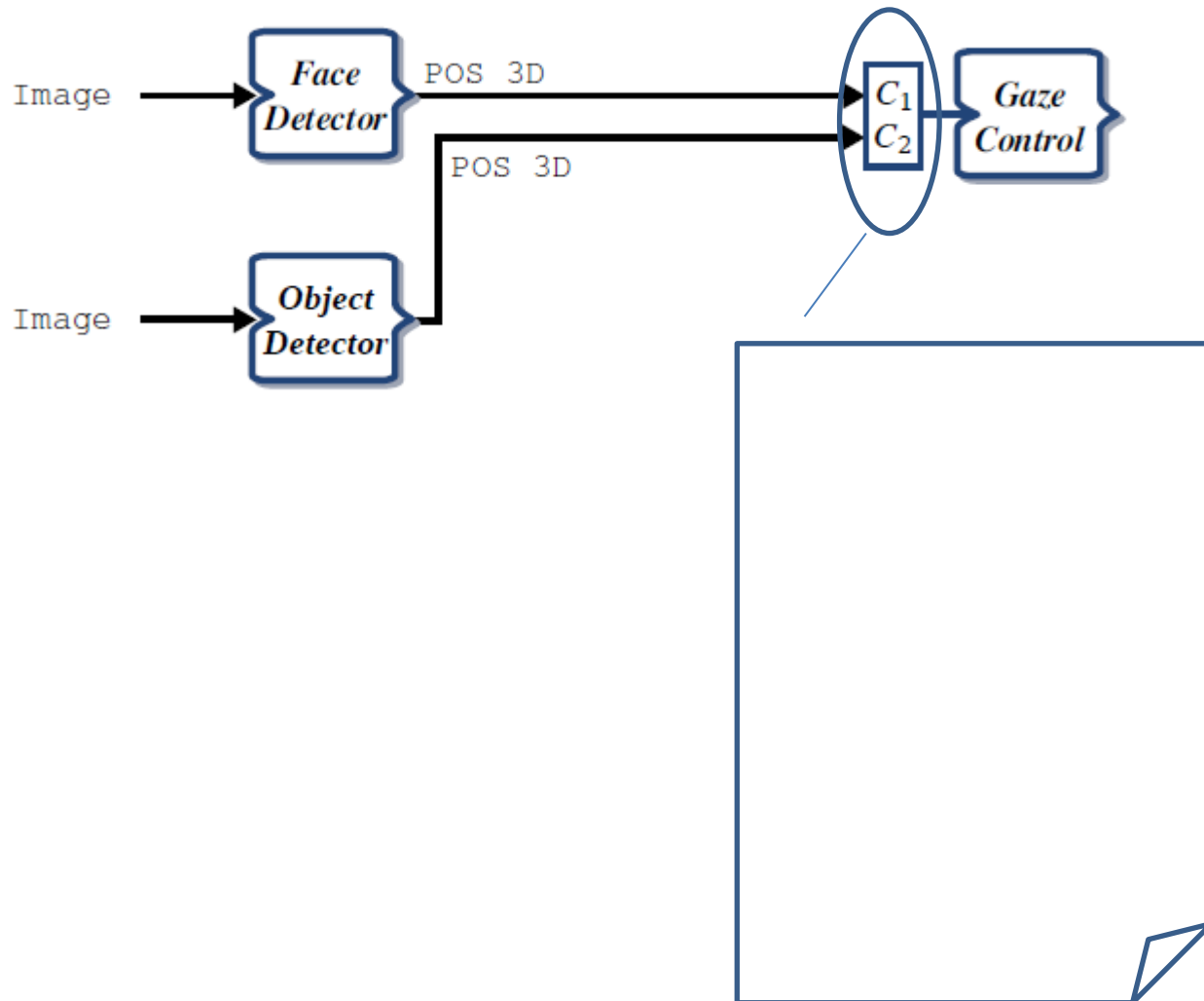
Arbitration and coordination



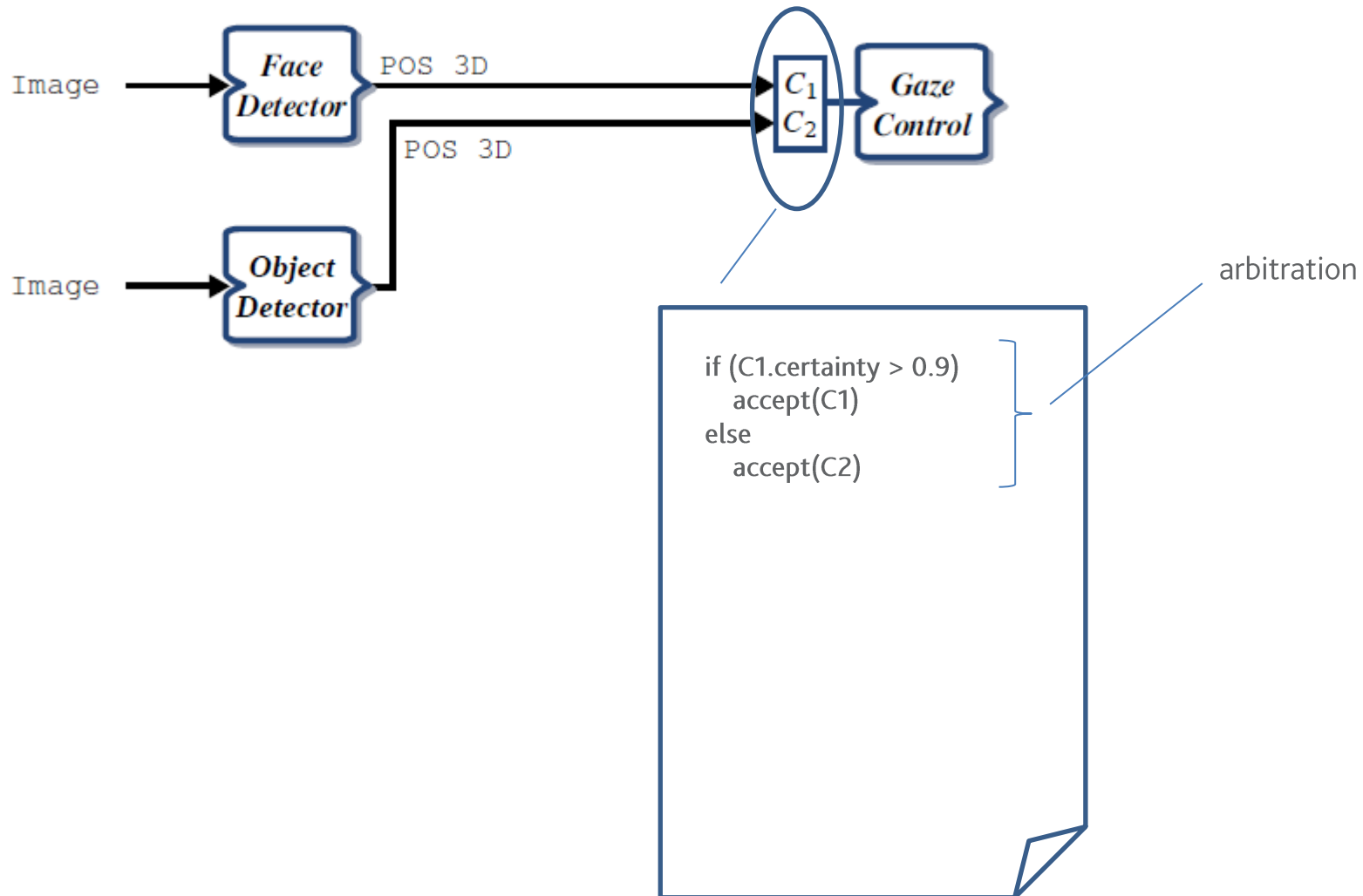
Our solution: Port Monitor



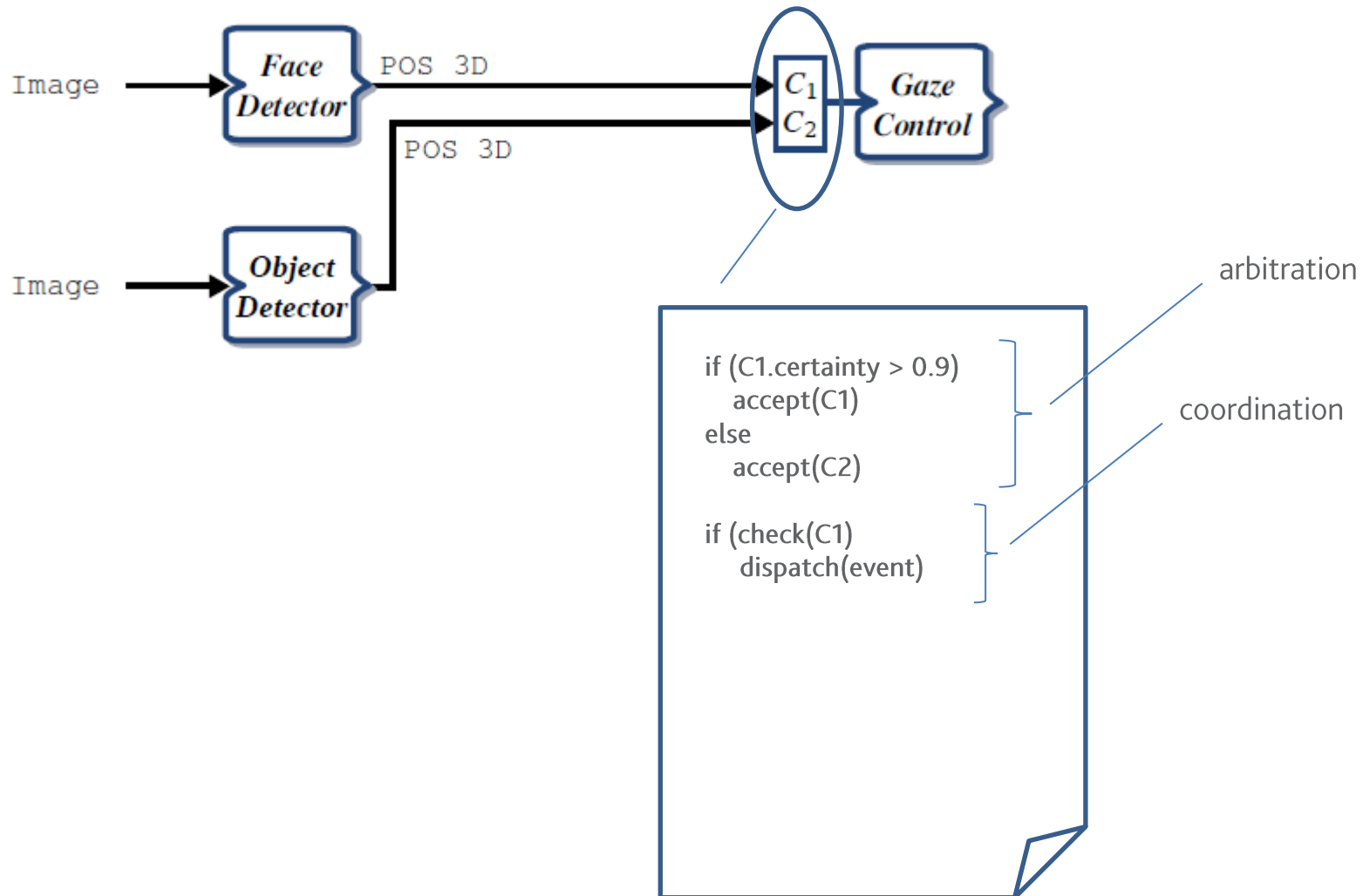
Our solution: Port Monitor



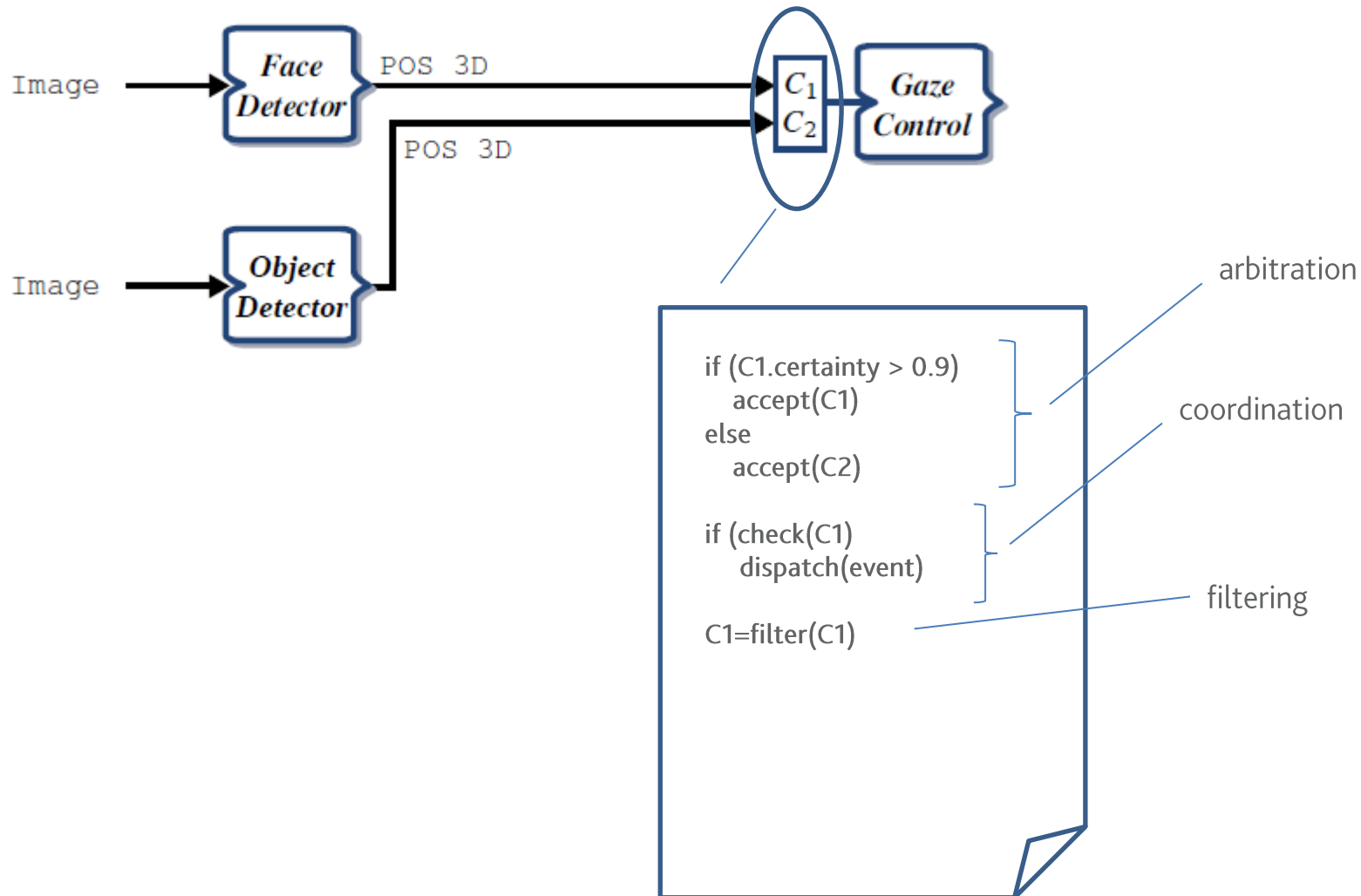
Our solution: Port Monitor



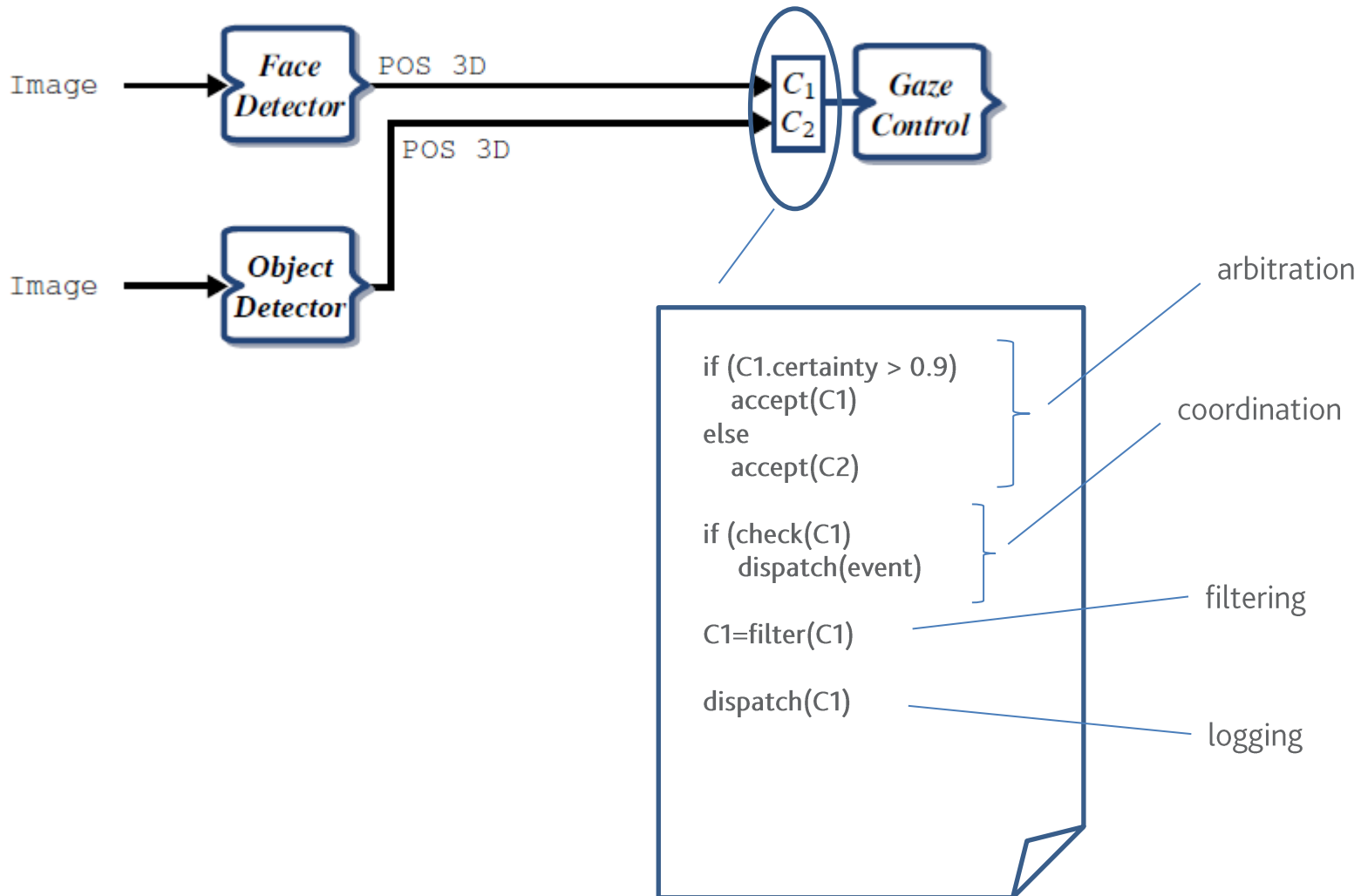
Our solution: Port Monitor



Our solution: Port Monitor



Our solution: Port Monitor



Our solution: Port Monitor

