CS-417 Introduction to Robotics and Intelligent Systems

Software Architectures for Robot Control

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Low Level Control

- Robot H/W control Software (drivers):
  - RHeXLib
  - **Player**
  - Ndirect, seriald (Nomadics)
- Simulation
  - RHeX SimSect?
  - **Stage**
  - Nclient, server
  - RD11

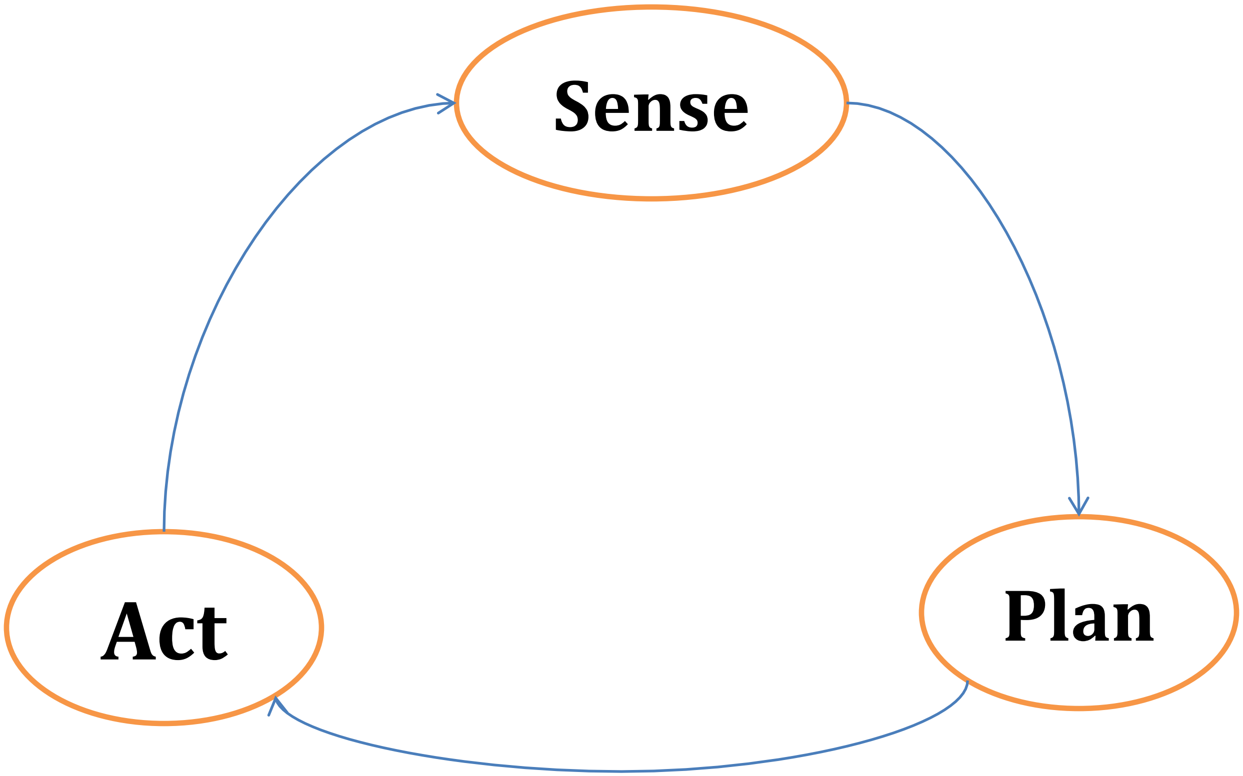
High Level Control

- Important when multi-tasking
- Especially in Multi-Robot settings
- Brief Historical note:
  - Subsumption Architecture (Rodney Brooks)
  - Behaviour based Architecture
  - Three Layer Architectures
    - Combining the above two plus some more ☺

Several Options

- Player/Stage (USC)
- Microsoft Robotics Developers Studio
- ROS (willow garage)
- ALLIANCE (L. Parker)
- RoboDevel/RHeXlib (U. Saranli)
- Robodaemon [RD11] (MRL product)
- CLARAty (JPL)
- CAMPOUT (JPL)
- SAPHIRA (Konolige)
- CARMEN (Thrun, Roy)
- EPICS (Junaed, J. Smith suggestion)
- Subsumption (Rodney Brooks)
- Three layer Architectures
- DCA (Christensen)
- Reid Simmons projects
- TeamBots (Balch),Mission Lab (Arkin), Ayllu (Werger), ARIA (ActivMedia)

Sense Plan Act



Subsumption

- The Subsumption architecture is built in layers.
- Each layer gives the system a set of pre-wired behaviors.
- The higher levels build upon the lower levels to create more complex behaviors.
- The behavior of the system as a whole is the result of many interacting simple behaviors.
- The layers operate asynchronously.

See: http://ai.eecs.umich.edu/cogarch0/subsump/index.html

Subsumption

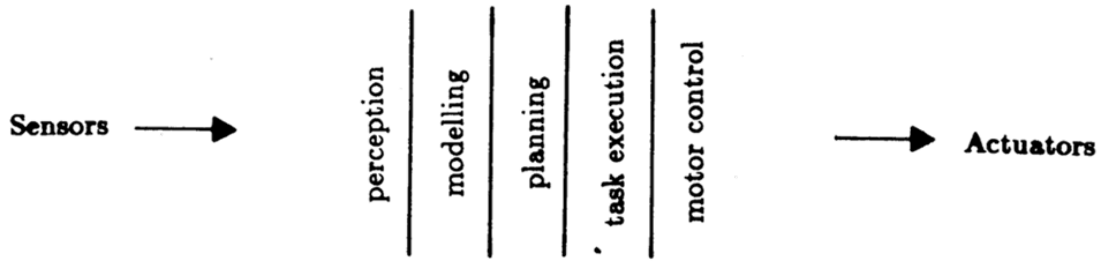


Figure 1. A traditional decomposition of a mobile robot control system into functional modules.

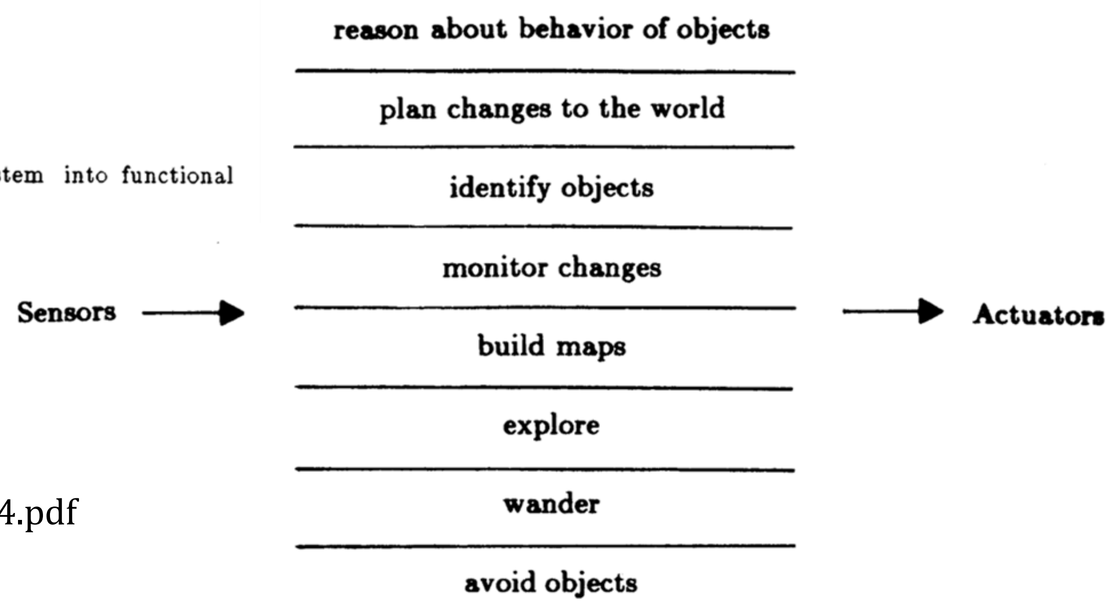


Figure 2. A decomposition of a mobile robot control system based on task achieving behaviors.

See: http://people.csail.mit.edu/brooks/papers/AIM-864.pdf

Three-Layer Architectures

- The Controller (low level, tight coupling)
- The Sequencer (selecting low level behaviours)
- The Deliberator (time-consuming computations)

See: http://www.flownet.com/gat/papers/tla.pdf

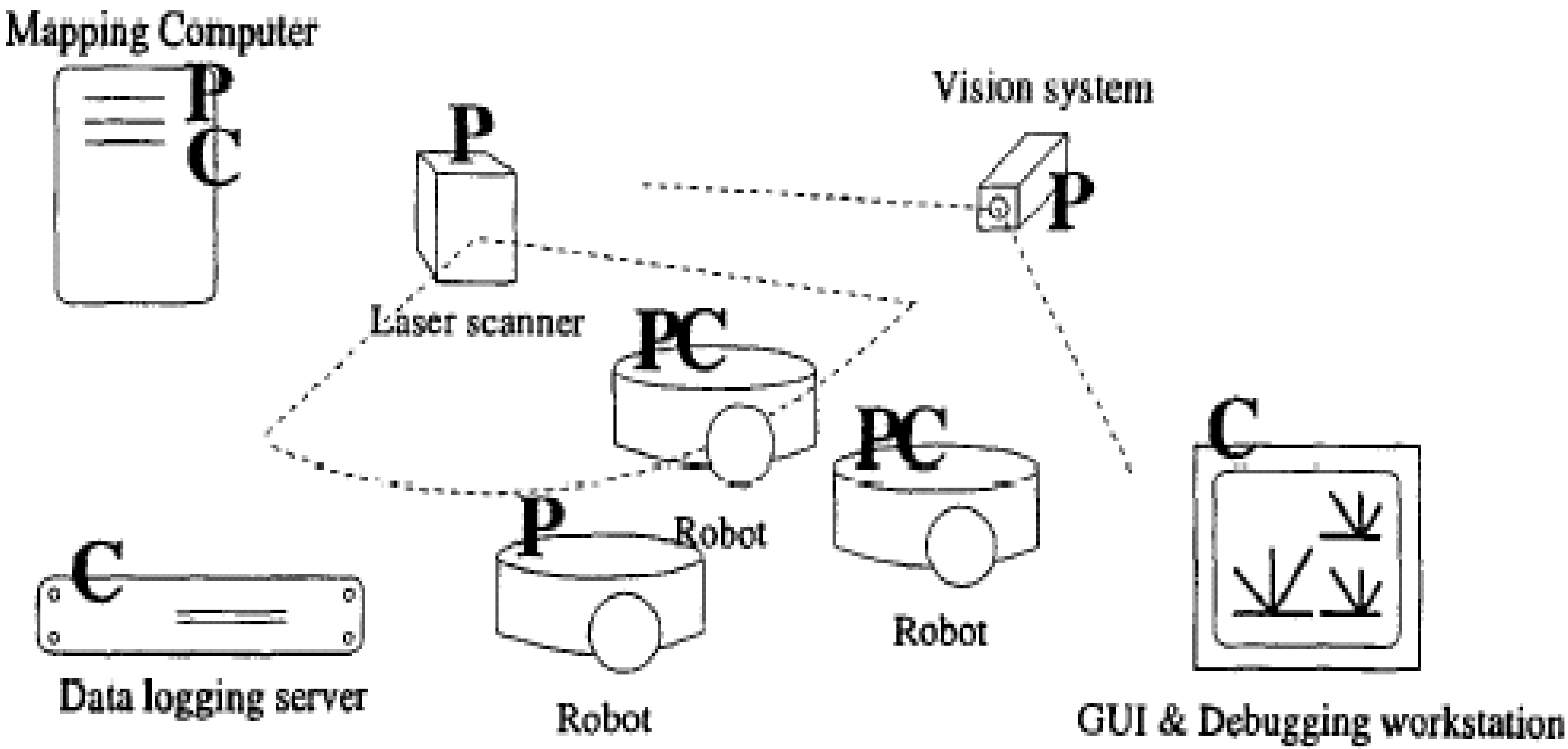
Player and Stage

- Following the bazaar/open_source model
- Player is the low level control interface
- Stage is a simulation engine (2D)
- Gazebo is a 3D simulation engine

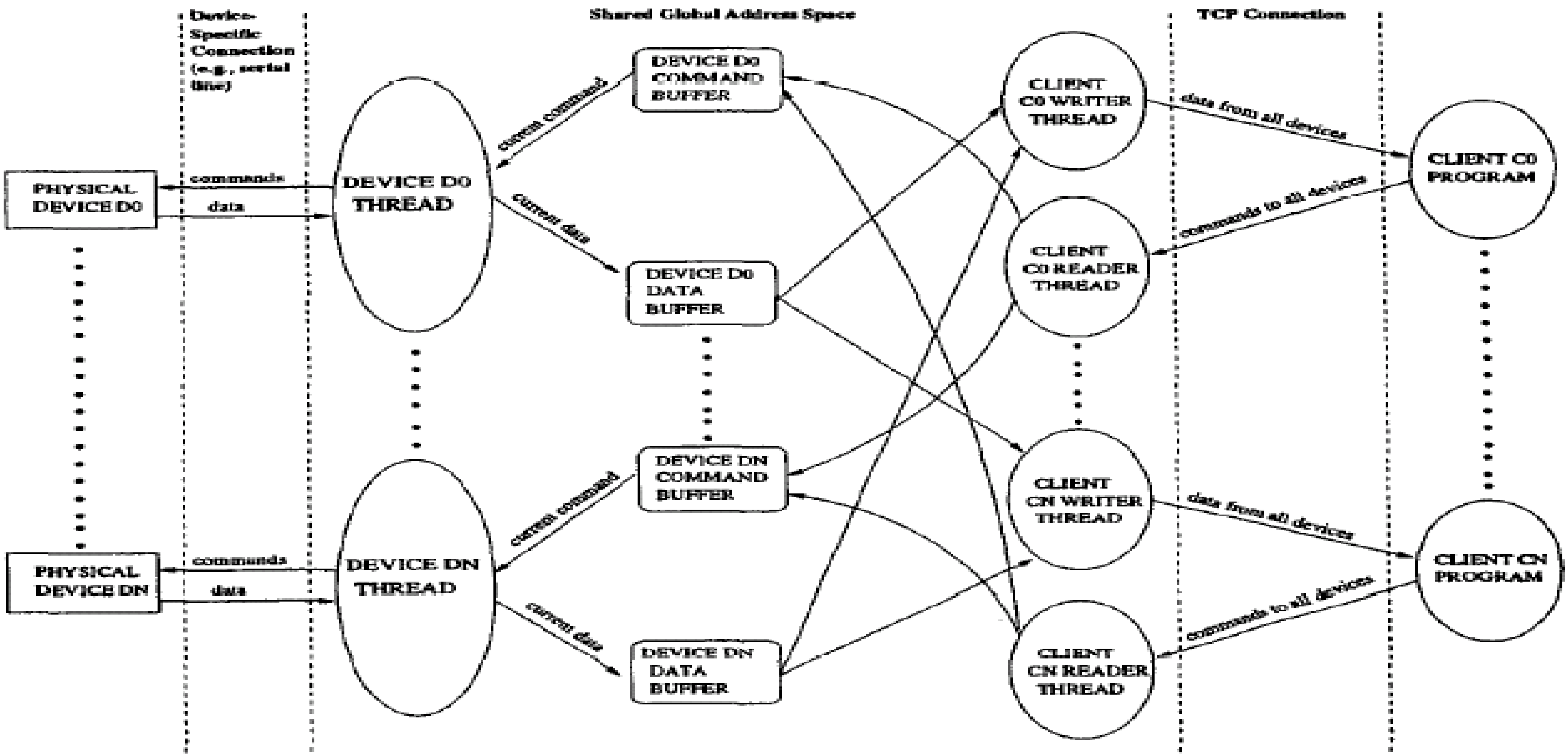
Player

- TCP socket server
- Clients connect to the server and send/receive commands/data
- Sensor and actuator abstraction

Player


Mapping Computer
P
C
P
Vision system
P
Laser scanner
PC
PC
C
P
Robot
C
Robot
Data logging server
Robot
GUI & Debugging workstation

Player Architecture



CARMEN

- Welcome to CARMEN, the Carnegie Mellon Robot Navigation Toolkit.
- CARMEN is an open-source collection of software for mobile robot control.
- CARMEN is modular software designed to provide basic navigation primitives including:
  - base and sensor control
  - logging
  - obstacle avoidance
  - localization
  - path planning
  - mapping

Carmen
Robot Navigation Toolkit

See: http://carmen.sourceforge.net/

Microsoft Robotics Developer Studio

- Concurrency and Coordination Runtime
- Decentralized Software Services
- Visual Programming Language (VPL)
- Physics based Simulation Engine
- Web-based Technology
- Not-Open Source

See: http://msdn.microsoft.com/en-us/robotics/default.aspx

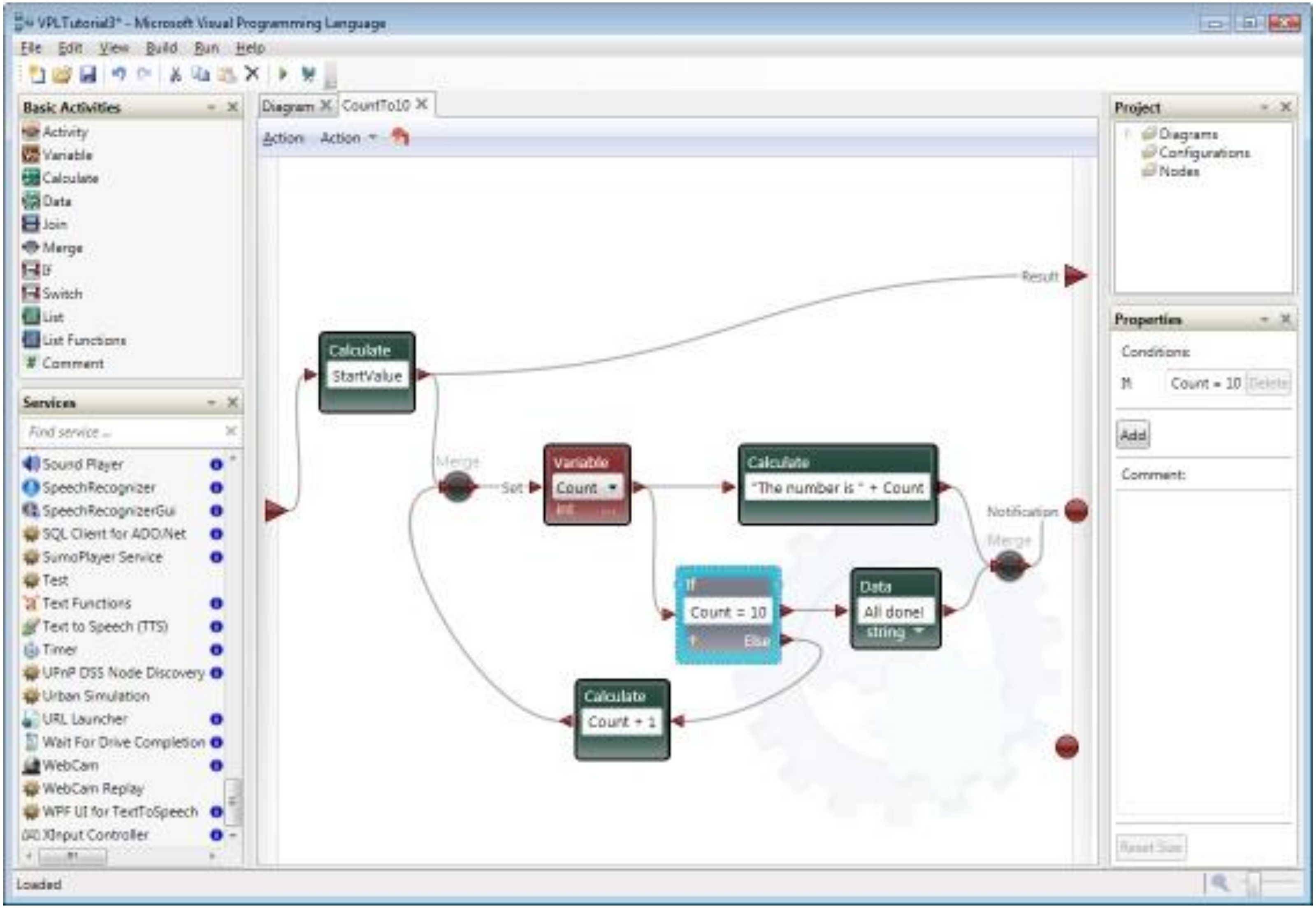
Concurrency and Coordination Runtime (CCR)

- Concurrency and Coordination Runtime (CCR) is a managed code library, a Dynamically Linked Library (DLL), accessible from any language targeting the .NET Common Language Runtime (CLR).
  - Service-oriented applications
  - manage asynchronous operations
  - deal with concurrency
  - exploit parallel hardware and deal with partial failure.
  - The software modules or components can be loosely coupled
  - They can be developed independently and make minimal assumptions about their runtime environment and other components.

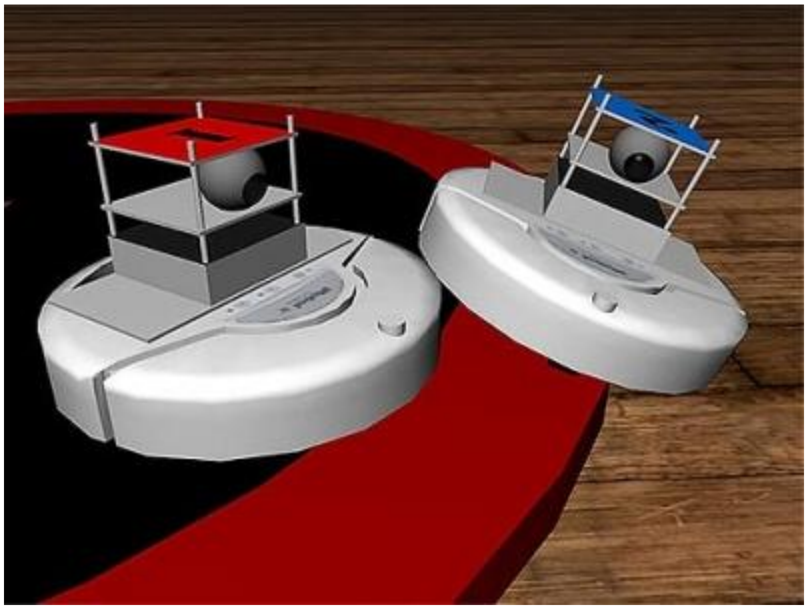
Decentralized Software Services (DSS)

- Decentralized Software Services (DSS) is a lightweight .NET-based runtime environment that sits on top of the Concurrency and Coordination Runtime (CCR):
  - Lightweight
  - state-oriented service model
    - Combines the notion of representational state transfer (REST) with a system-level approach for building high-performance, scalable applications.
  - DSS services are exposed as resources which are accessible both programmatically and for UI manipulation.
  - Integrating service isolation, structured state manipulation, event notification, and formal service composition
  - Robustness
  - Composability
  - Observability

Graphical Programming

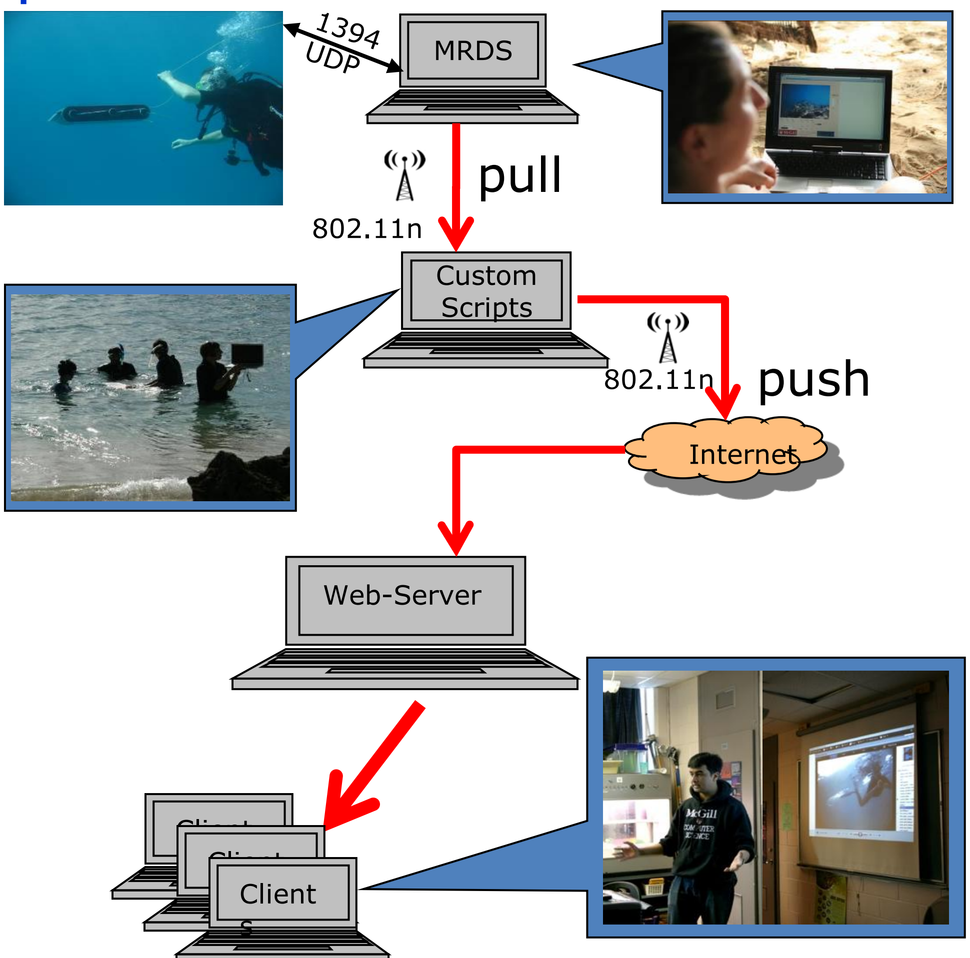


Physics based Simulation Engine



Web based Interface

Aqua in Barbados



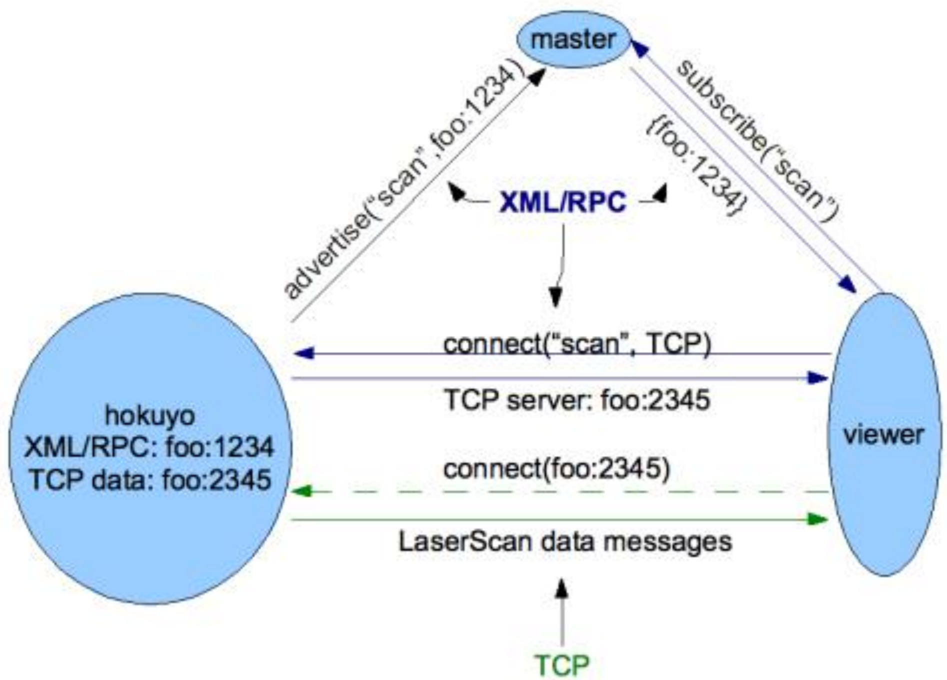
Presentation at St. Georges high school, Montreal

ROS

- ROS is an open-source, meta-operating system for robots.
- It provides the services expected from an operating system, including hardware abstraction, low-level device control, implementation of commonly-used functionality, message-passing between processes, and package management. It also provides tools and libraries for obtaining, building, writing, and running code across multiple computers.
- ROS is similar in some respects to 'robot frameworks,' such as Player, YARP, Orocos, CARMEN, Orca, MOOS, and Microsoft Robotics Studio.
- The ROS runtime "graph" is a peer-to-peer network of processes that are loosely coupled using the ROS communication infrastructure.
- ROS implements several different styles of communication, including synchronous RPC-style communication over Services, asynchronous streaming of data over Topics, and storage of data on a Parameter Server.

See: http://www.ros.org/wiki/ROS

ROS

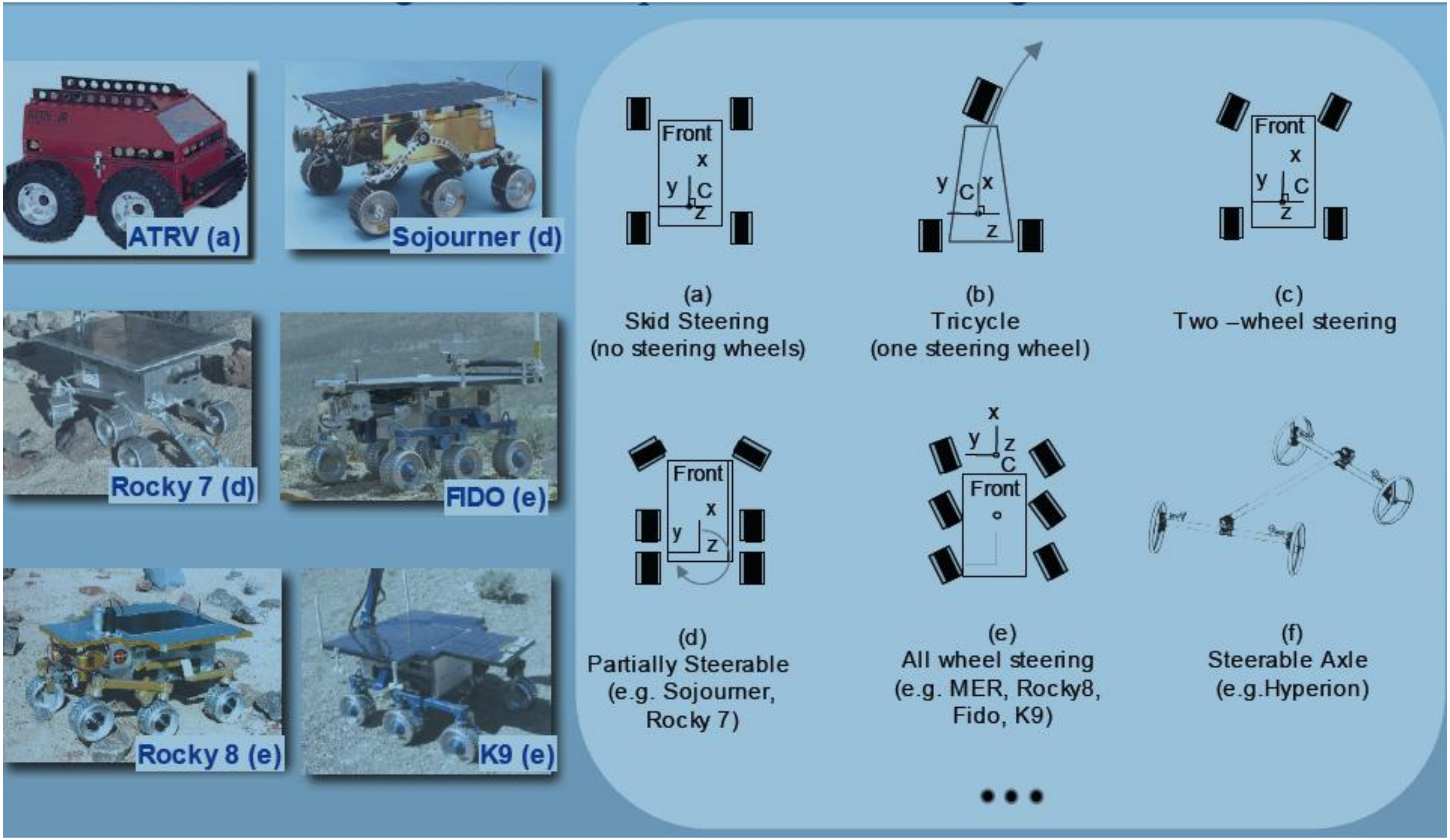

master
advertise("scan",foo:1234)
subscribe("scan")
{foo:1234}
XML/RPC
connect("scan", TCP)
TCP server: foo:2345
hokuyo
XML/RPC: foo:1234
TCP data: foo:2345
viewer
connect(foo:2345)
LaserScan data messages
TCP

CLARAty

- A two layer architecture
- Developed at NASA/JPL
- Supporting different h/w

See: http://claraty.jpl.nasa.gov/man/overview/index.php

Different Mobility platforms

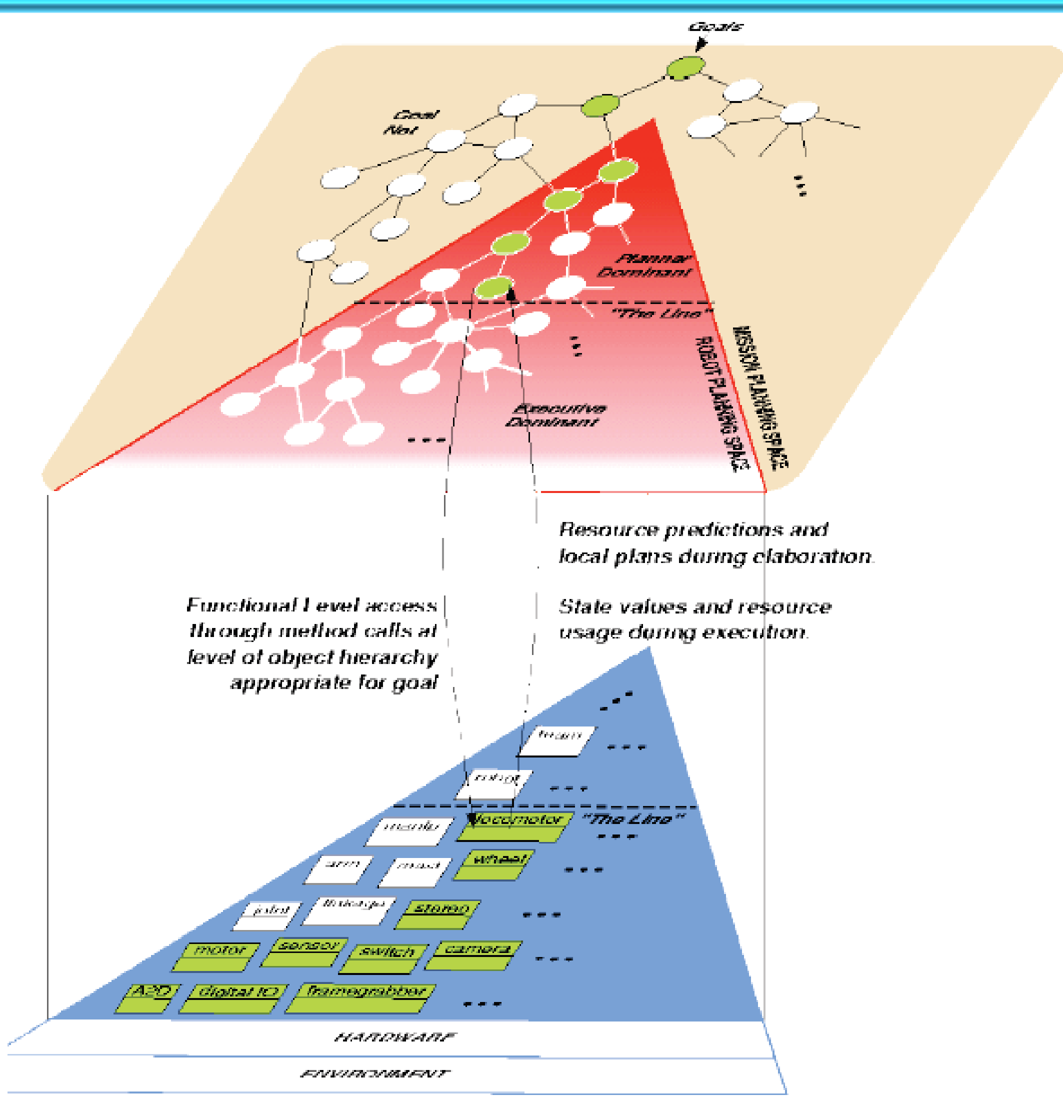


Approach

- Develop
  - Common data structures
  - Physical & Functional Abstractions
    - E.g. motor, camera, locomotor. Stereo processor, visual tracker
  - Unified models for the mechanism
- Putting it together
  - Start with top level goals
  - Elaborate to fine sub-goals
  - Choose the appropriate level to stop elaboration
  - Interface with abstractions
  - Abstractions translate goals to action
  - Specialize abstractions to talk to hardware
  - Hardware controls the systems and provide feedback

From: http://claraty.jpl.nasa.gov/main/overview/presentations/FY05/FY05_claraty_jtars.pdf

Two Layer Architecture

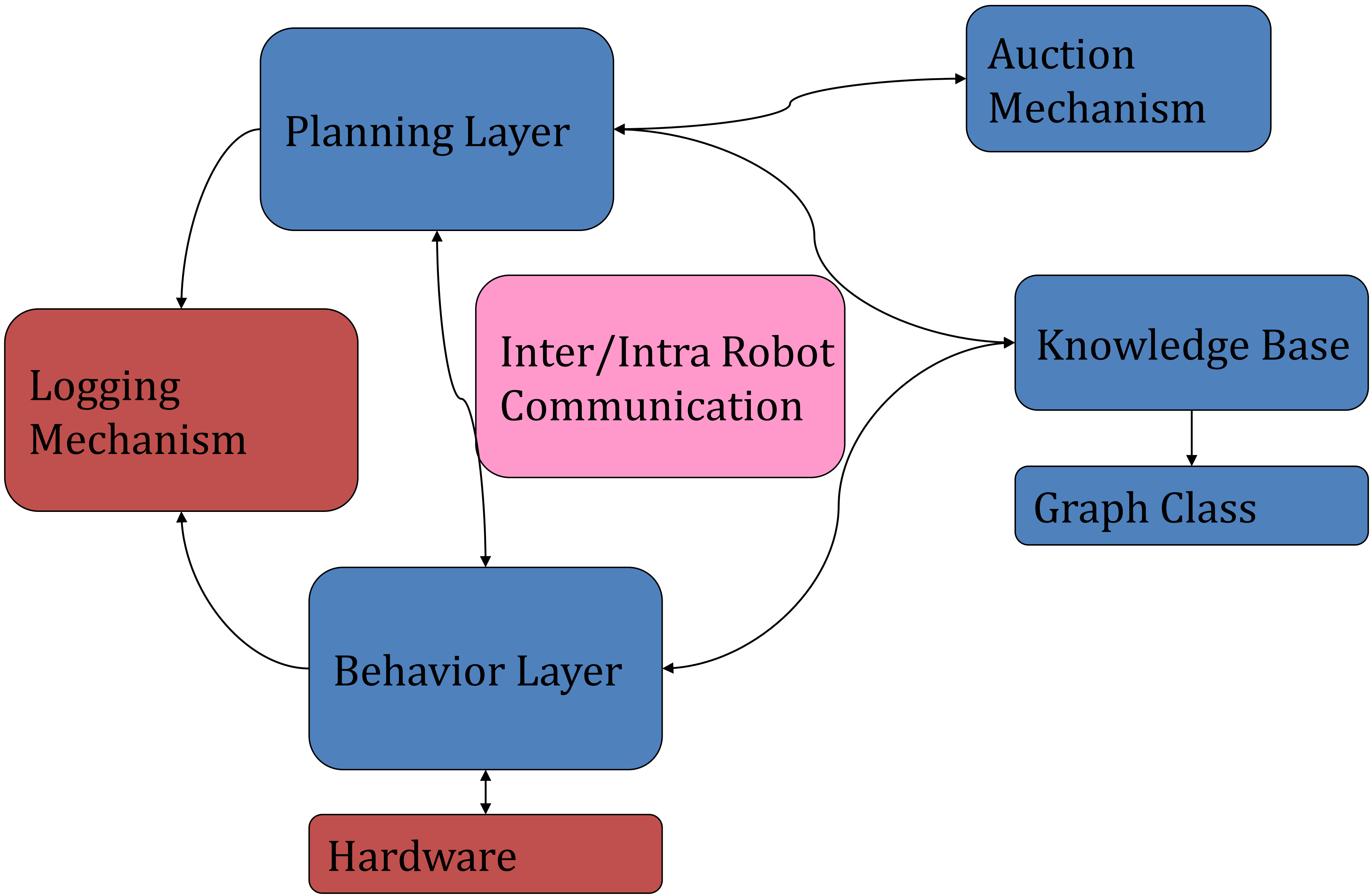


THE DECISION LAYER:
Declarative model-based
Global planning

INTERFACE:
Access to various levels
Commanding and updates

THE FUNCTIONAL LAYER:
Object-oriented abstractions
Autonomous behavior
Basic system functionality

Adaptation to a system


Planning Layer
Auction Mechanism
Logging Mechanism
Inter/Intra Robot Communication
Knowledge Base
Graph Class
Behavior Layer
Hardware

Behaviour Layer Base Loop