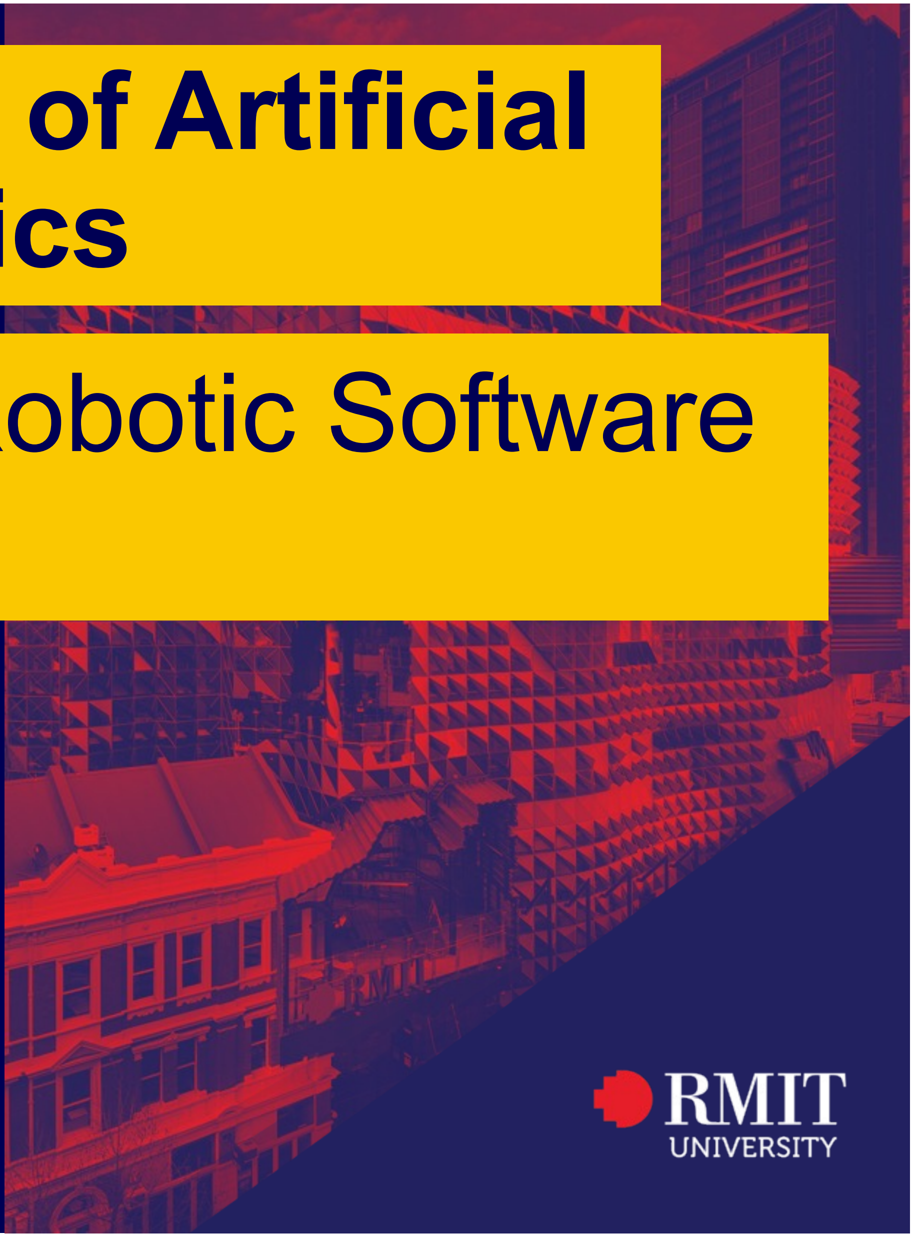
Practical Applications of Artificial Intelligence for Robotics

Day 1: Introduction to Robotic Software and Architectures

Dr. Timothy Wiley
School of Computing Technologies
RMIT University

ESSAI July 2023



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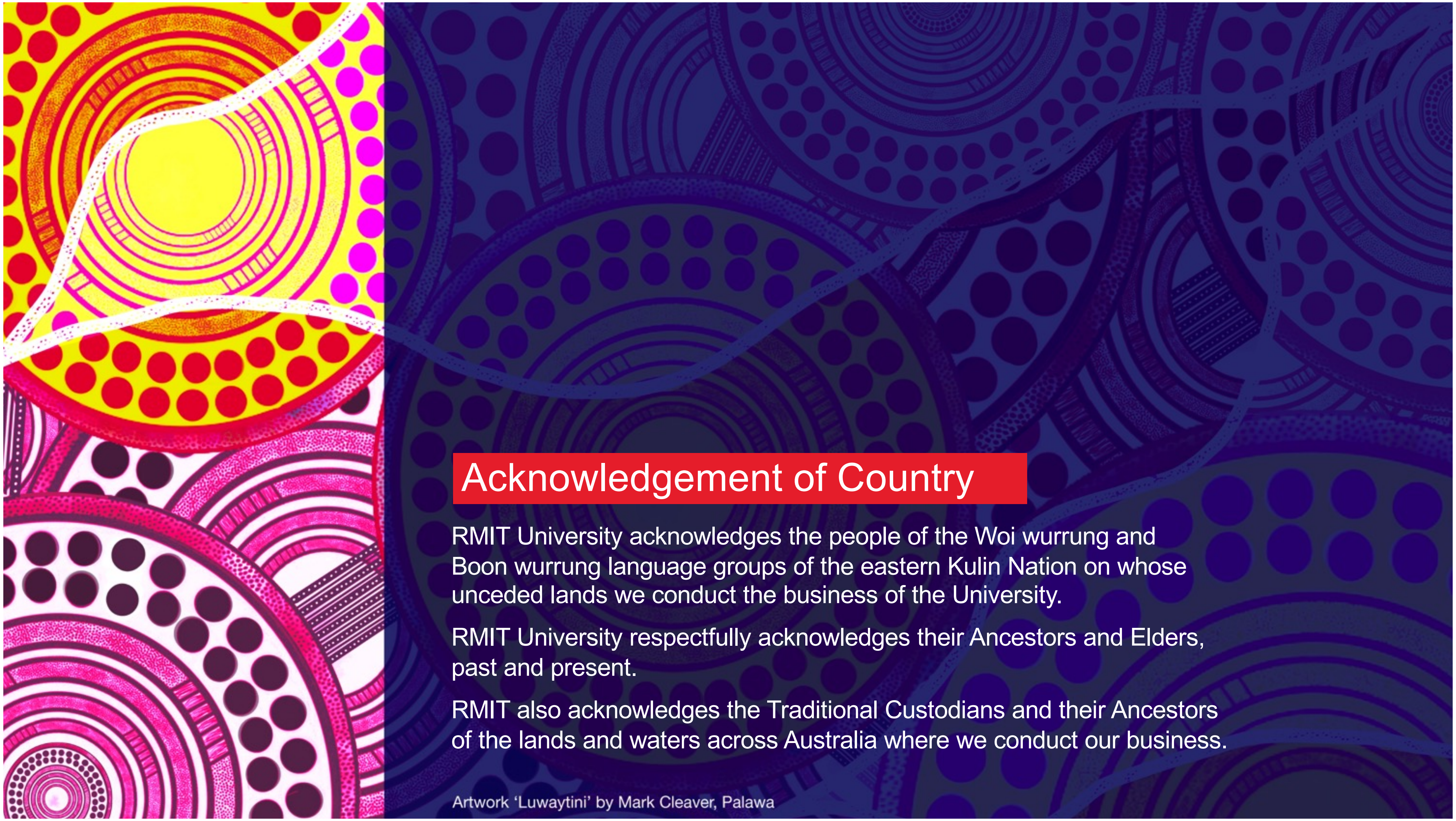


Acknowledgement of Country

RMIT University acknowledges the people of the Woi wurrung and Boon wurrung language groups of the eastern Kulin Nation on whose unceded lands we conduct the business of the University.

RMIT University respectfully acknowledges their Ancestors and Elders, past and present.

RMIT also acknowledges the Traditional Custodians and their Ancestors of the lands and waters across Australia where we conduct our business.

Artwork 'Luwaytini' by Mark Cleaver, Palawa

About me: Dr. Timothy Wiley

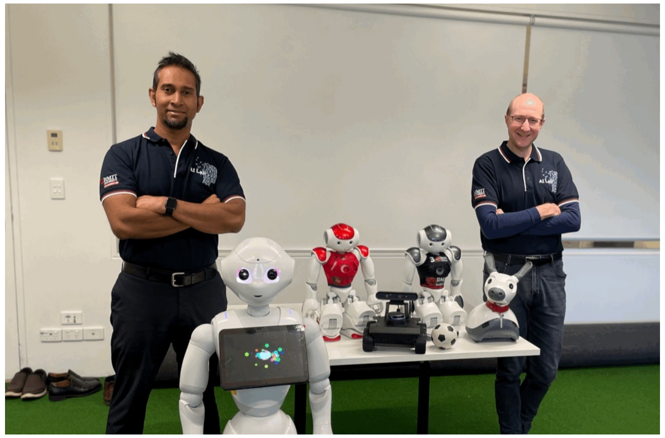
PhD, Online Learning of Robotic Behaviours, UNSW Australia

Lecturer, Artificial Intelligence, STEM College, RMIT University

Manager, RMIT Artificial Intelligence Innovation Lab

Research Interests:

- Autonomous Robotics
- Reinforcement Learning
- Qualitative Reasoning
- Sim2Real



Motivation

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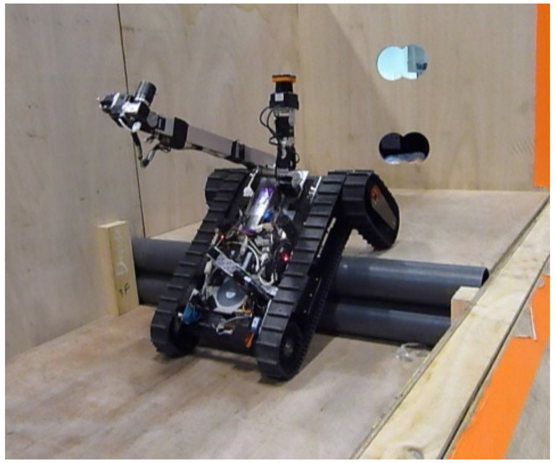
What defines an Autonomous Robot?

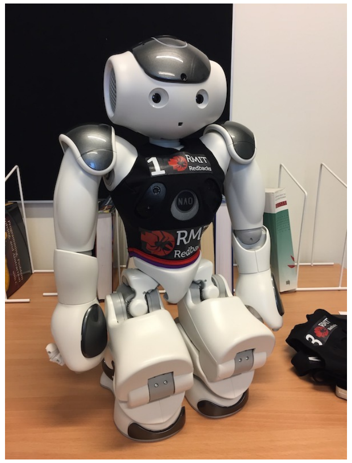
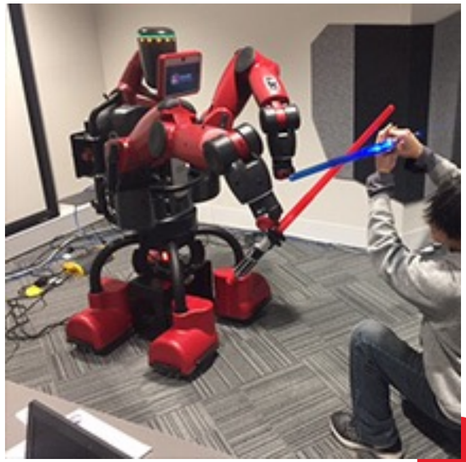
What defines an autonomous robot to you?

What defines an Autonomous Robot?

Aside from the obvious “act autonomously” that is, “think-and-act for themselves”:

- Perceive the environment
- Interact with the environment
- Internal reasoning



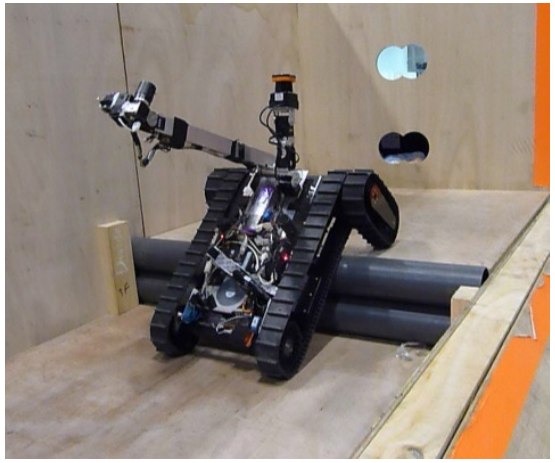



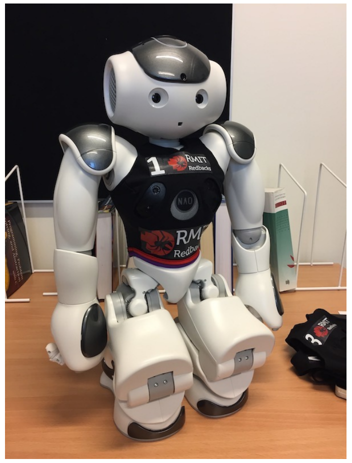
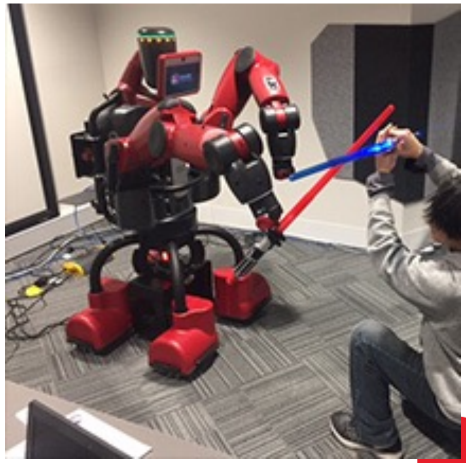
What defines an Autonomous Robot?

Aside from the obvious "act autonomously" that is, "think-and-act for themselves":

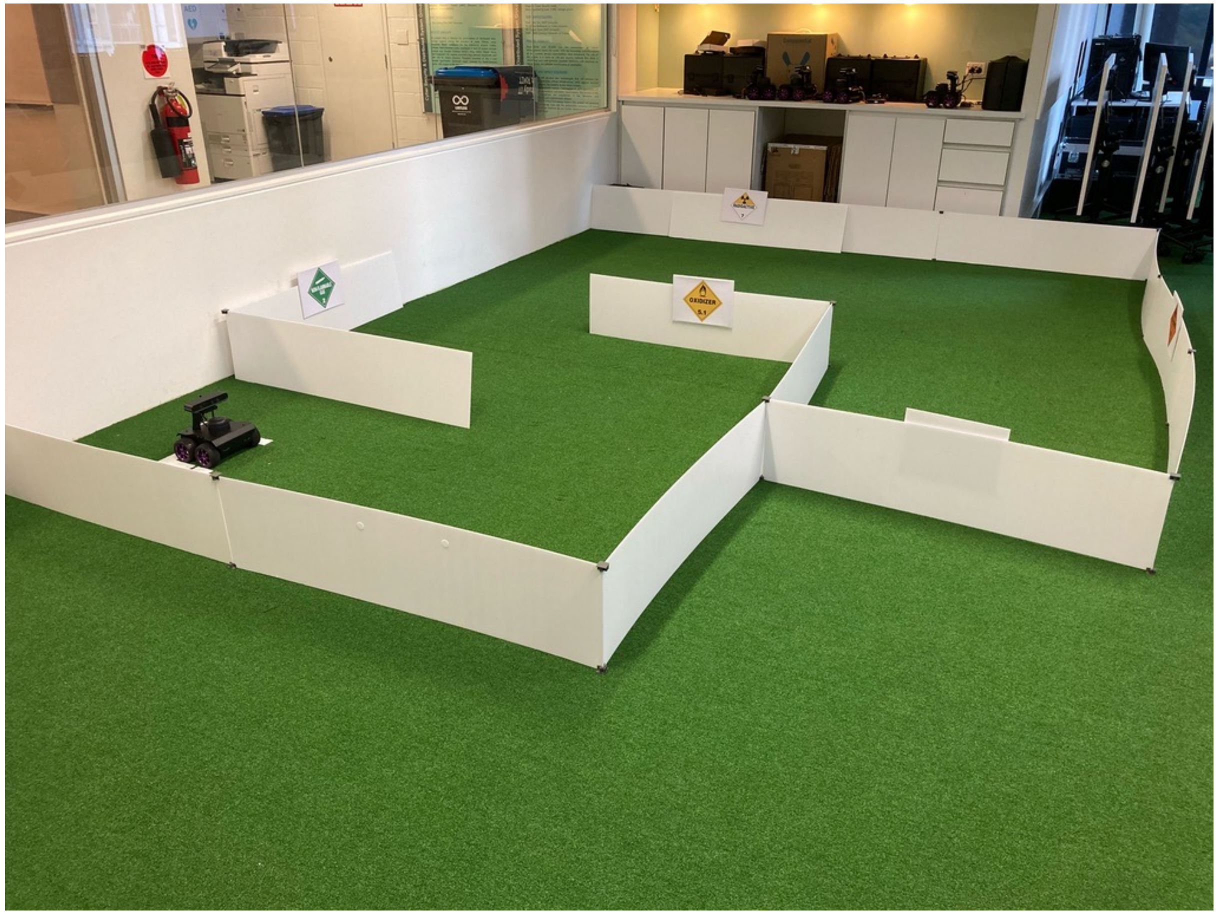
- Perceive the environment
- Interact with the environment
- Internal reasoning ← This is where AI sits, but…

What separates robotics from other fields of AI is the physical input/output



Problem: Maze



Problem: Maze

Problem: RoboCup Soccer

About the Course

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This Course is about…

- Overview of Autonomous Robotics
- Give a breadth of knowledge rather than a depth
- Provide operational knowledge on autonomous robotic system for later in-depth study
- Applied AI/ML
- Hopefully convince you to work in robotics 😛
- Practical activities on TheConstruct

Topics

Day 1: Introduction to Robotic Software and Architectures

Day 2: Kinematics and Manipulation

Day 3: Localisation, Mapping and Navigation

Day 4: Robotic Vision

Day 5: Task Planning & Miscellaneous topics

This Course is presumes…

- Some familiarity with common AI techniques such as:
  - Graph algorithms
  - Heuristic Search (A*)
  - Random Sampling
  - Machine Learning fundamentals
  - Neural Network structures

Elements of Robots

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Elements of an Autonomous Robot

Generally, the elements of an Autonomous Robotic System are

1. Sensor Processing / Perception
2. World Modelling
3. Behaviour Generation
4. Actuation

Elements of an Autonomous Robot

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All of these can be performed at different levels of abstraction:

- Raw sensor signals and raw actuator operations
- Quantised numerical processing
- Sub-symbolic representations & reasoning
- Symbolic representations & reasoning

Software Architectures

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AI Agent Models

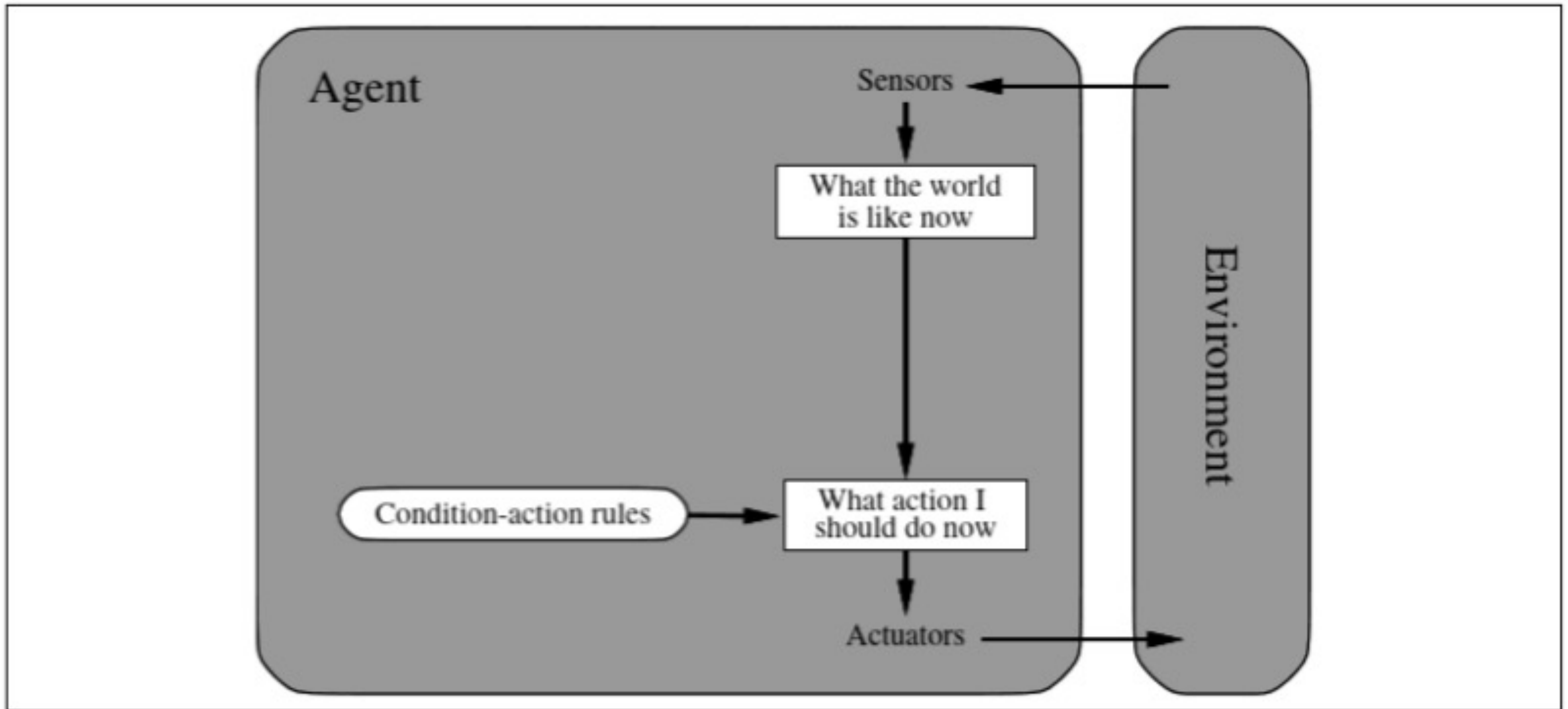


Figure 2.9 Schematic diagram of a simple reflex agent.

Russel & Norvik. Artificial Intelligence: A Modern Approach (2017),

AI Agent Models

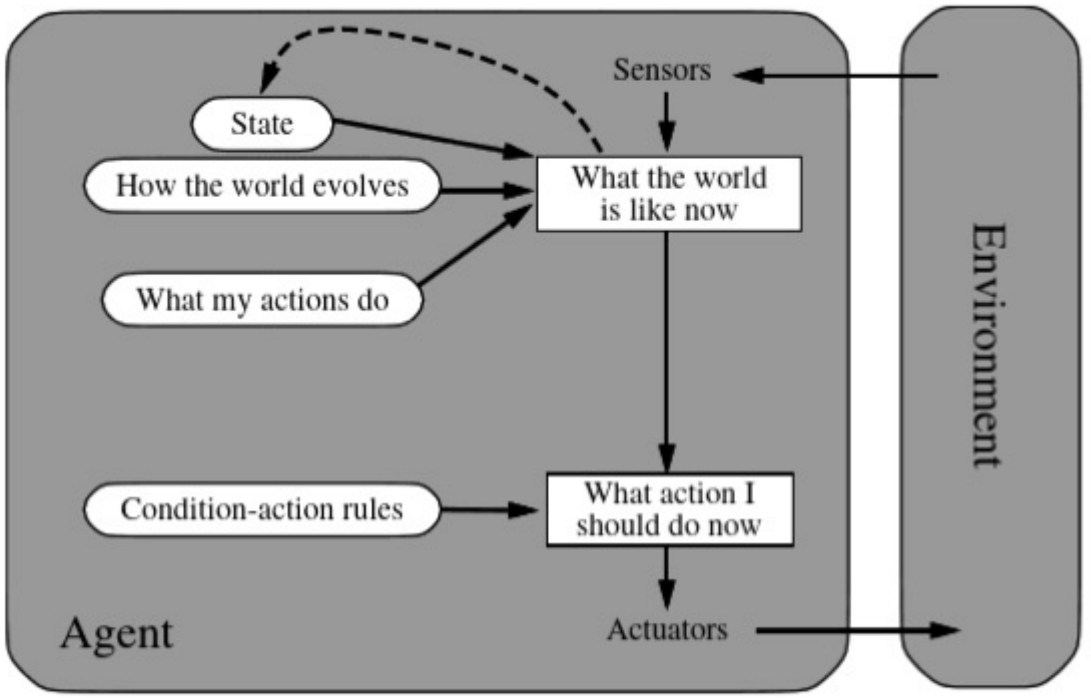


Figure 2.11 A model-based reflex agent.

Russel & Norvik. Artificial Intelligence: A Modern Approach (2017),

AI Agent Models

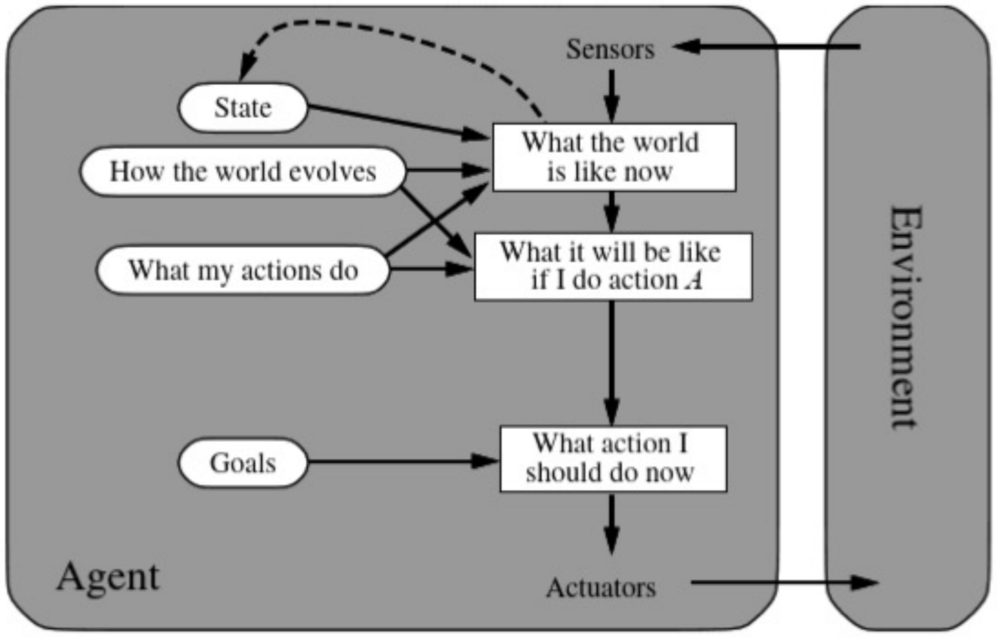
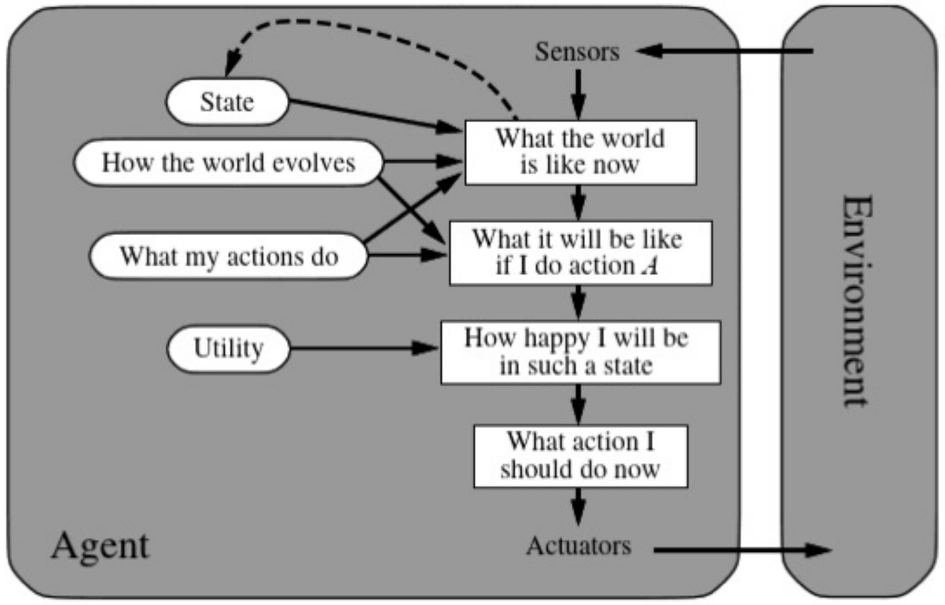

Sensors
State
How the world evolves
What my actions do
What the world is like now
What it will be like if I do action A
Goals
What action I should do now
Actuators
Agent
Environment

Figure 2.13 A model-based, goal-based agent. It keeps track of the world state as well as a set of goals it is trying to achieve, and chooses an action that will (eventually) lead to the achievement of its goals.

Russel & Norvik. Artificial Intelligence: A Modern Approach (2017),

AI Agent Models

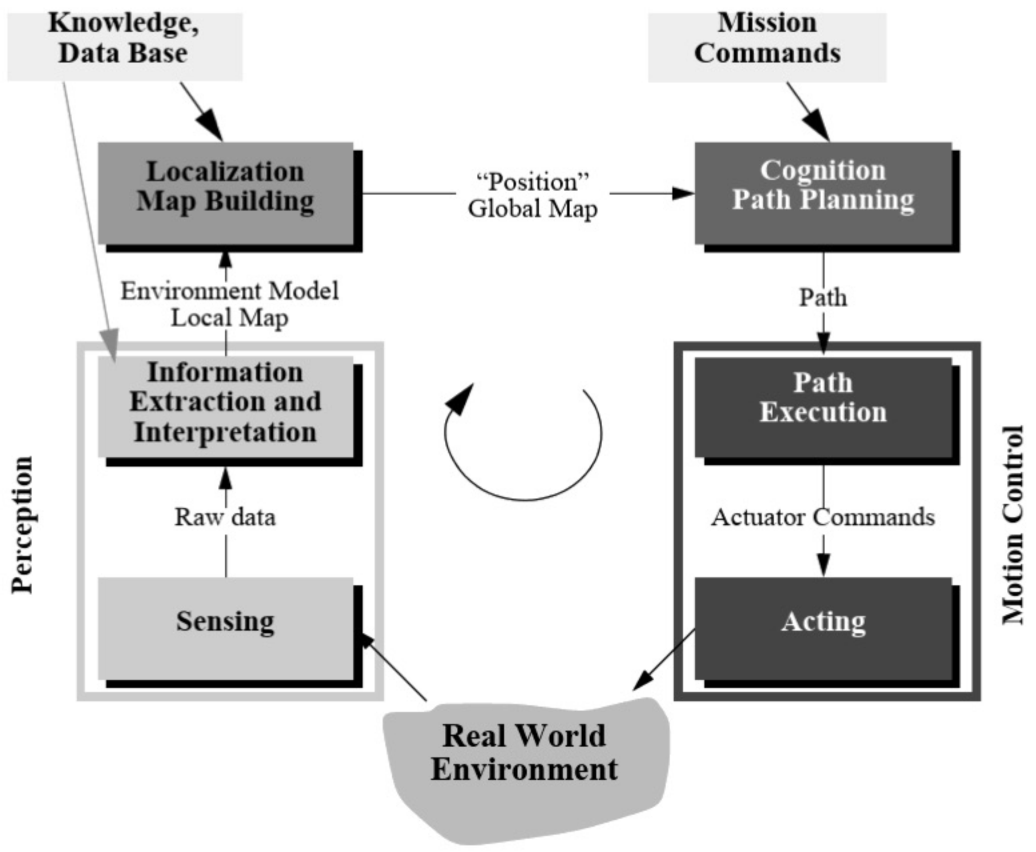


Sensors
State
What the world is like now
How the world evolves
What my actions do
What it will be like if I do action A
Utility
How happy I will be in such a state
What action I should do now
Agent
Actuators
Environment

Figure 2.14 A model-based, utility-based agent. It uses a model of the world, along with a utility function that measures its preferences among states of the world. Then it chooses the action that leads to the best expected utility, where expected utility is computed by averaging over all possible outcome states, weighted by the probability of the outcome.

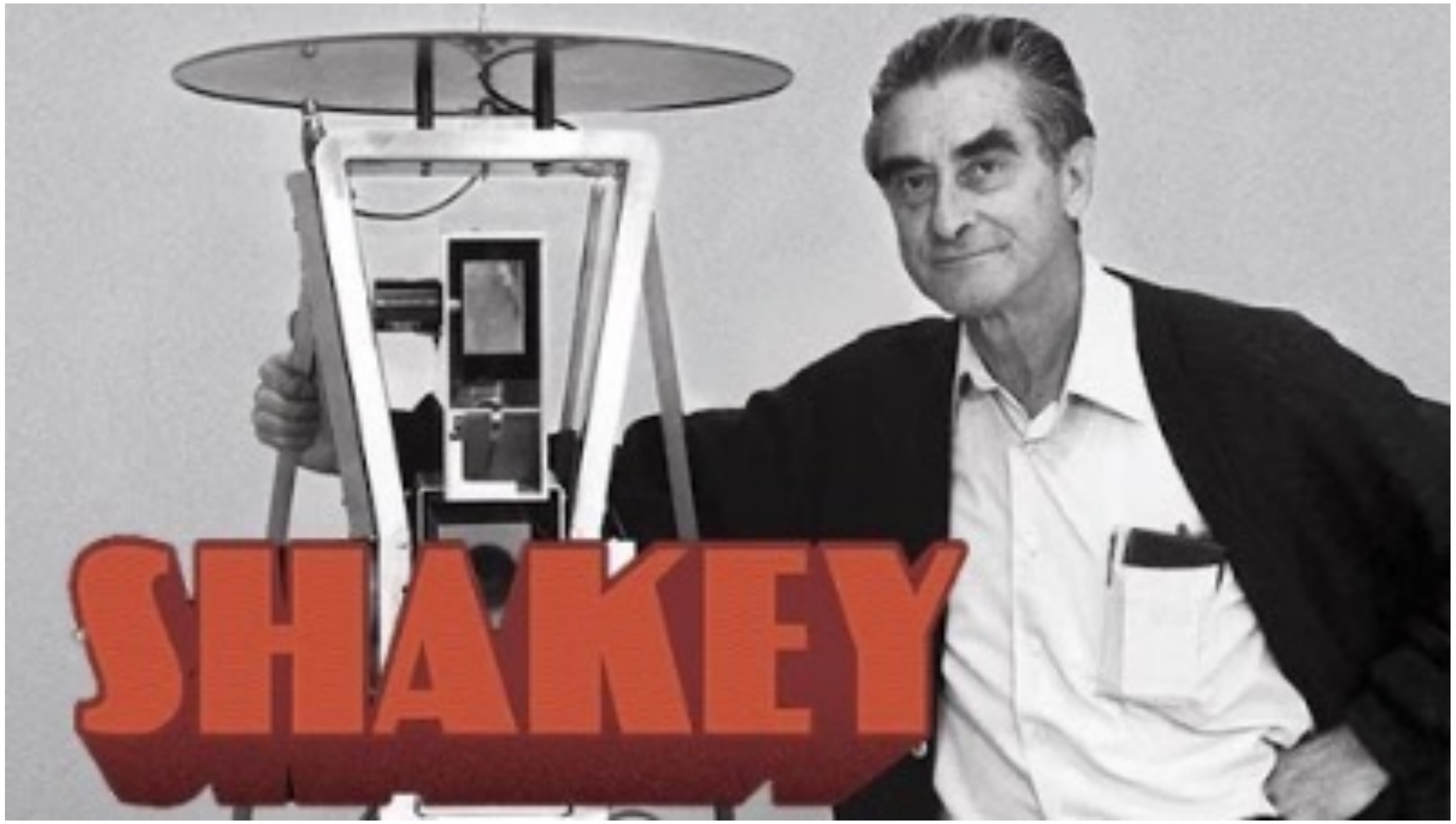
Russel & Norvik. Artificial Intelligence: A Modern Approach (2017),

Classic Robot System



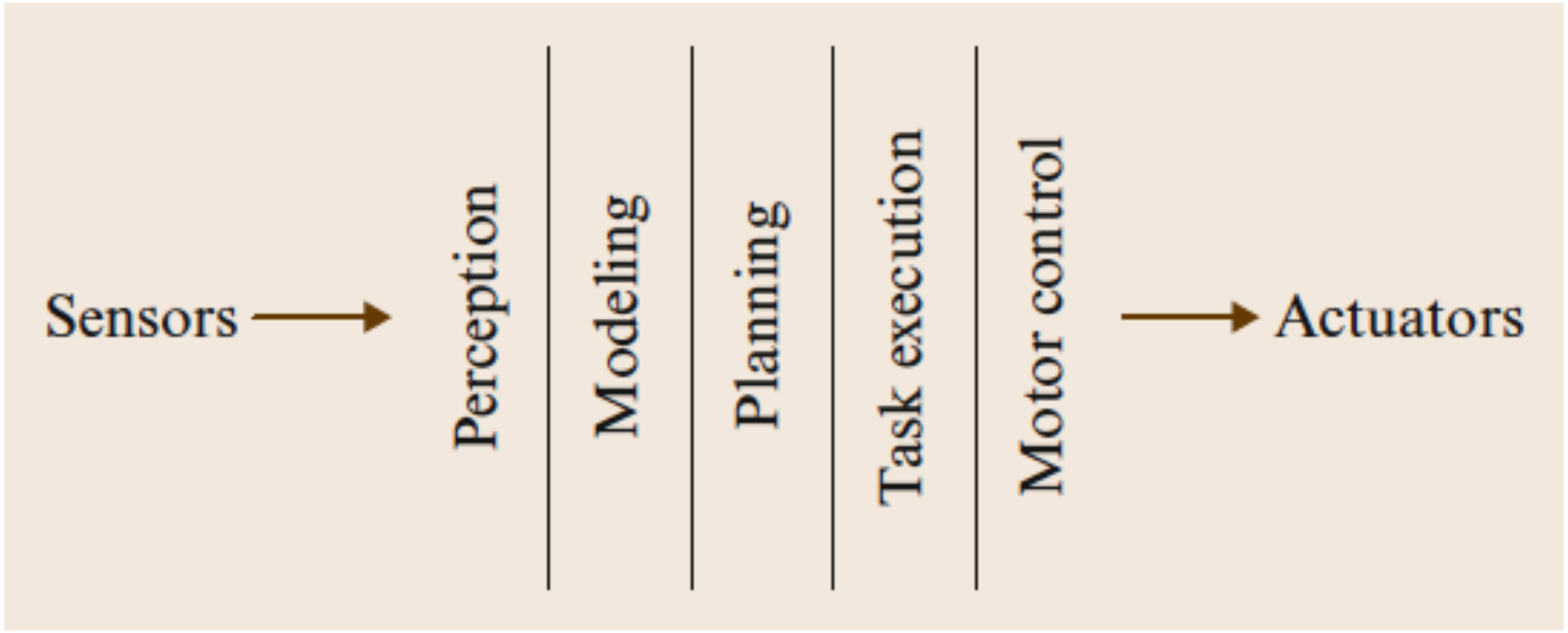
Siegwart, Nourbakhsh & Scaramuzza. (2011) *Introduction to Autonomous Mobile Robots*

Shakey the Robot



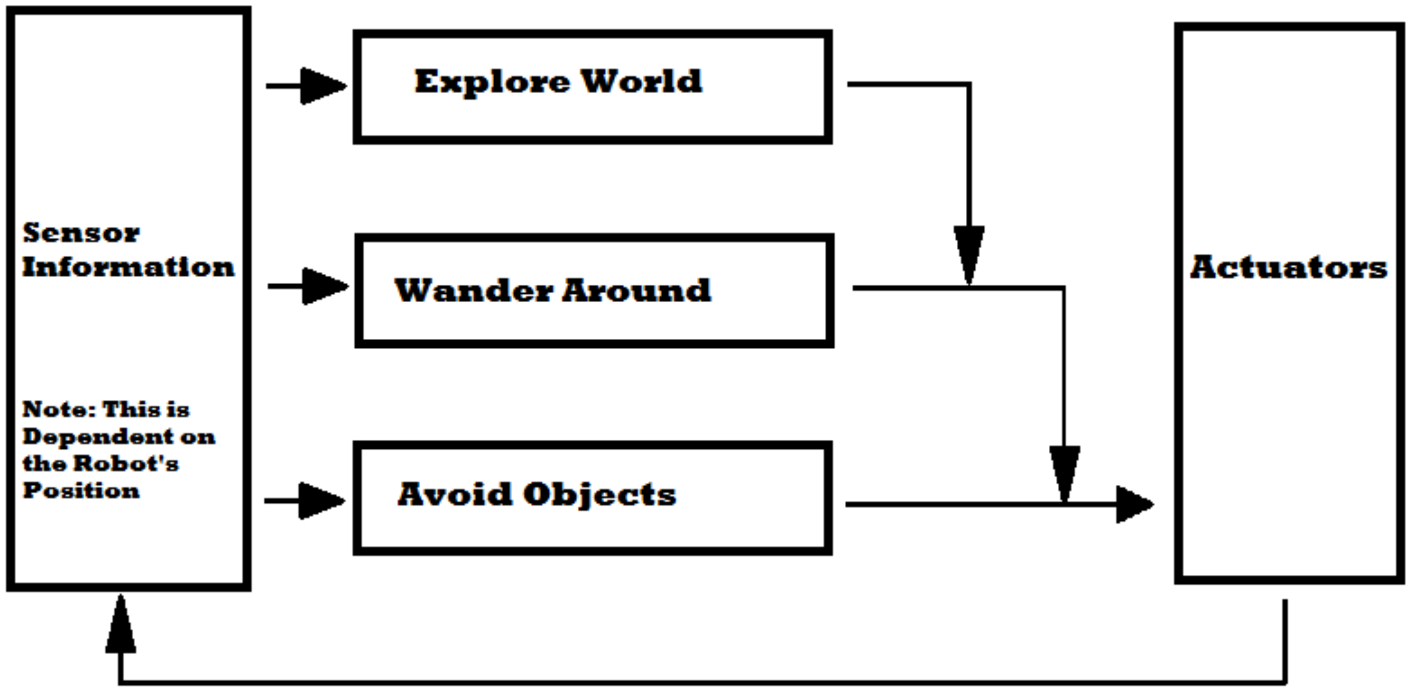
Nilsson, N. J. (1982). Principles of Artificial Intelligence. Berlin Heidelberg: Springer-Verlag

Software Architectures: Sense-Plan-Act



Nilsson, N. J. (1982). Principles of Artificial Intelligence. Berlin Heidelberg: Springer-Verlag

Software Architectures: Subsumption



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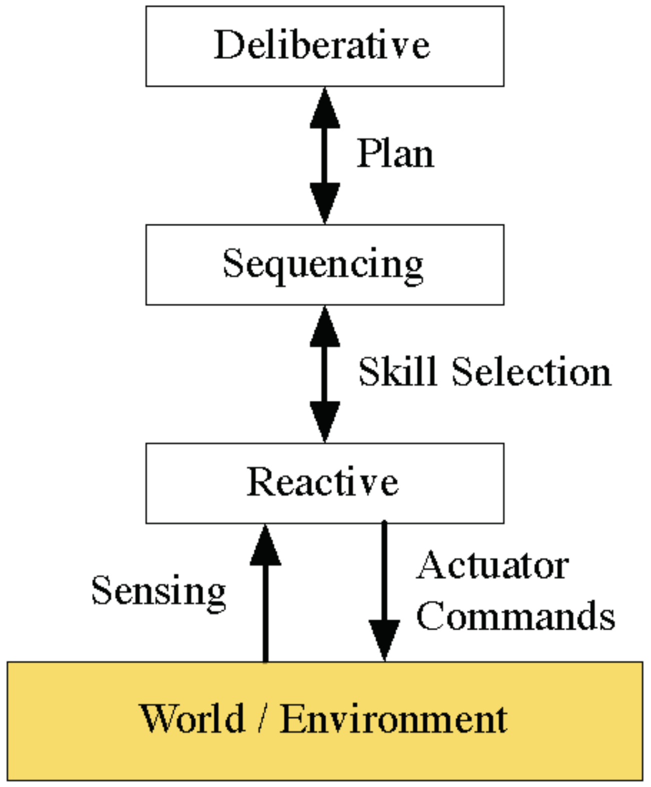
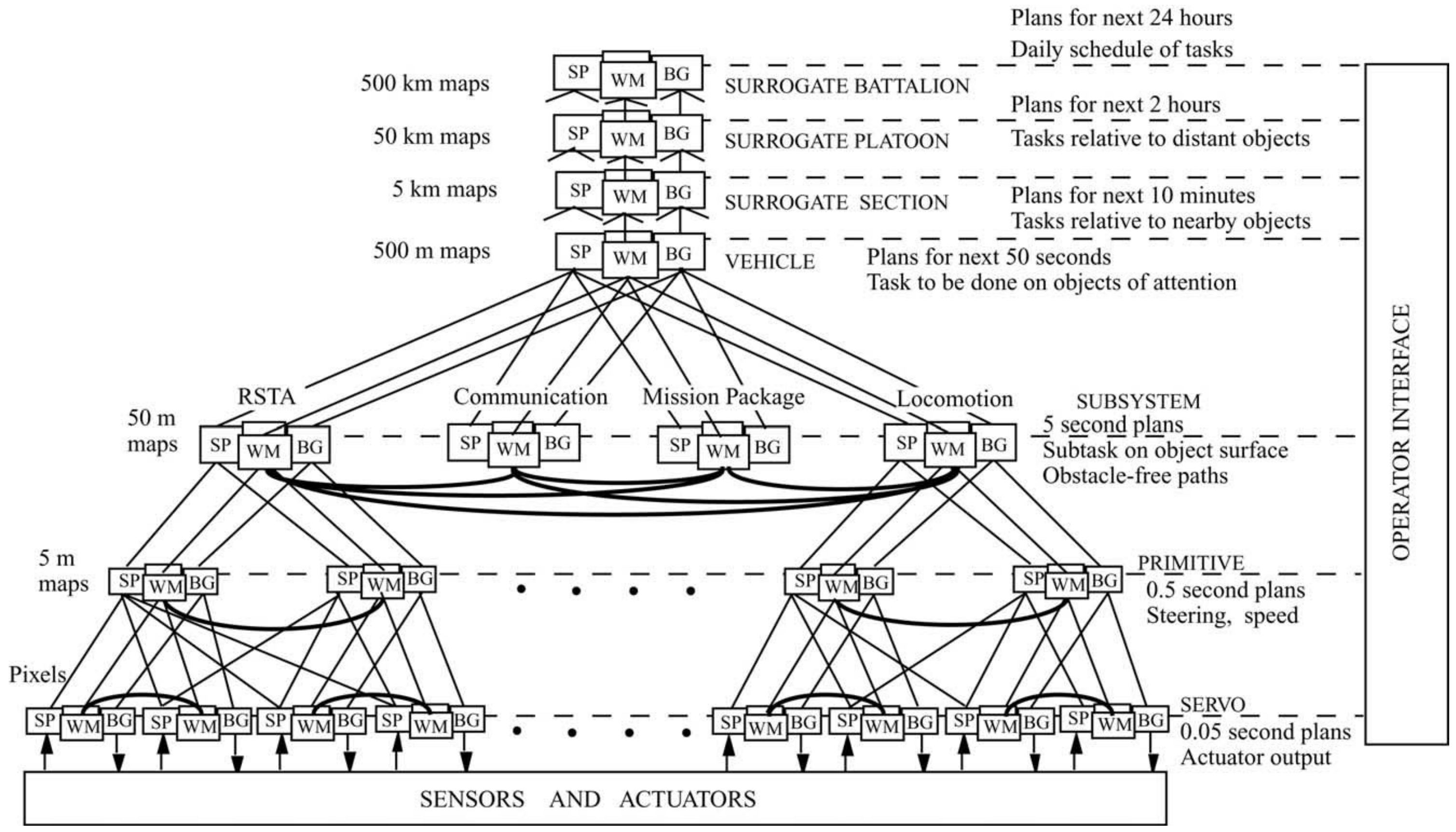
Software Architectures: Three-Layer



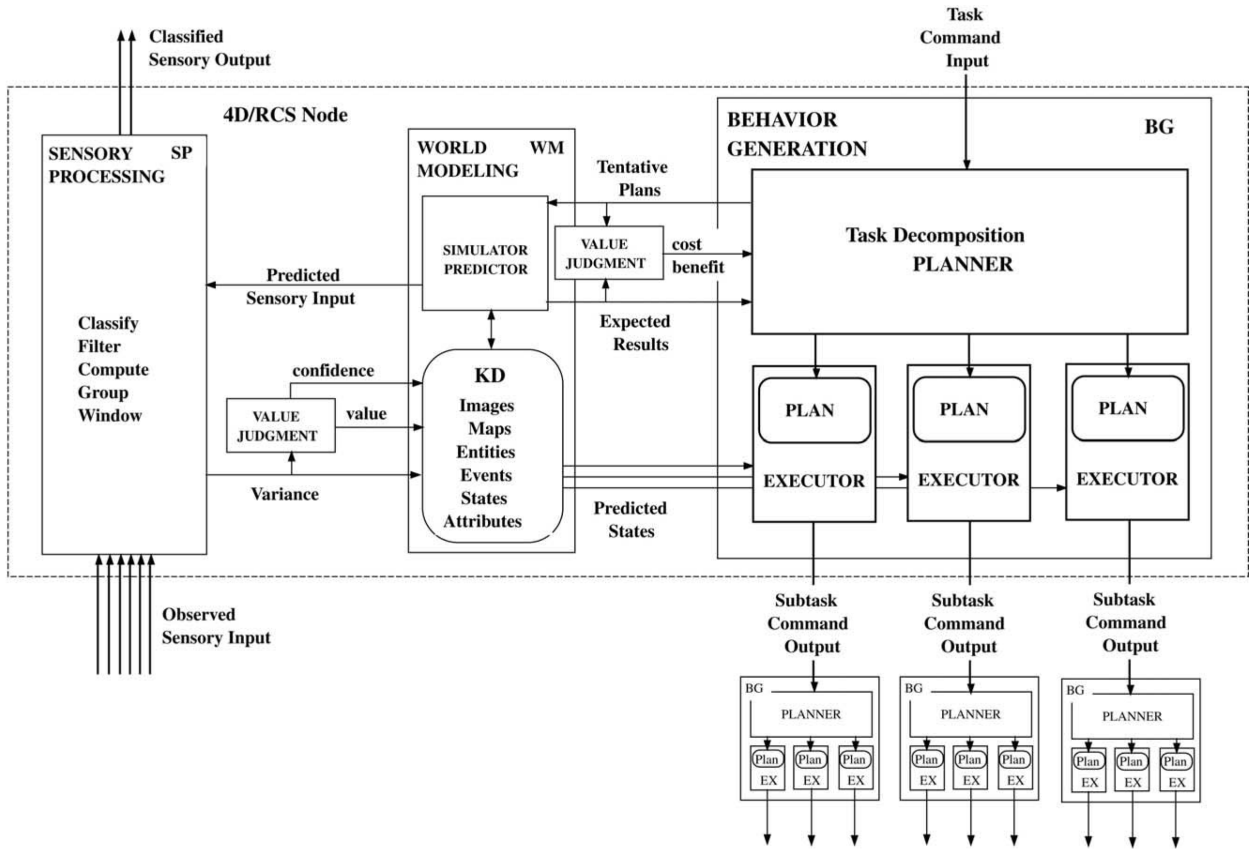
Bonasso, P. et. al. (1997). Experiences with an architecture for intelligent, reactive agents. Journal of Experimental & Theoretical Artificial Intelligence 9(2-3):237– 256

Software Architectures: RCS



Albus, J. S. & Barbera, A. J. (2005) RCS: A cognitive architecture for intelligent multi-agent systems. Annual Rev Control 29, 87–99.

Software Architectures: RCS



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ROS

Robot Operating System

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ROS: Robot Operating System

ROS is a standard platform for developing robotic software.

ROS provides:

1. Consistent Communication Framework
2. Transparent Network handling
3. Common software packages
4. Open Source Package library

ROS: Robot Operating System

ROS was first created by Willow Garage in 2010.

Now supports:

- Annual version tied to the xx.04 Ubuntu annual release
- ROS (v1)
  - Original ROS framework
  - Large package library
  - Centralised structure with “roscore”
- ROS2 (v2)
  - Revised & improved networking stack
  - Decentralised structure
  - Package library less well supported

ROS Concepts: Nodes

Standalone container of single software executable:

- Asynchronous execution & communication
- By default, each node is run is a separate thread
- Can be given configuration parameters
- Named by:
  - /<namespace>/<node_name>
- Executed by either:
  - rosrun
  - roslaunch

ROS Concepts: rosrun

Command line utility to launch a single node

Typical call

```
rosrun <package_name> <node_name>
```

ROS Concepts: roslaunch

Command line that reads a launch configuration file.

The configuration file may:

- Launch multiple nodes
- Take arguments to define how the file is processed
- Configure parameters of nodes

Typical call

```
roslaunch <package_name> <launch_filename>
```

ROS Concepts: Topics

Define a communication stream. The communication is defined by:

- Topic name: /<namespace>/<topic>
- Messages are sent via the topic between nodes
- Topic type: The ROS message type of the communication, such as string, image, geometry, transform, map, etc.
    - Types can be simple, to as complex as needed
- Stateless communication

Any node can:

- Publish a message to a topic
- Subscribe to a topic, to receive all messages published to the topic

ROS Concepts: Topics

The ROS infrastructure:

- Manages all networking regardless of where nodes are running.
- Established direct node-to-node links between all pairs of codes that publish/subscribe to a topic
- Uses TCP connections for nodes on different machines
  - 🚨 ROS networking is particular about having correct configuration, especially in ROS1.
  - ROS chooses random TCP ports to establish connections, and these must be open for bi-directional communication

ROS Concepts: Services

Topics are a publisher/subscriber model, so have no state.

ROS Services allow for callable methods:

- Use a client-server model
- A service call includes:
  - Request from the client to the server
  - Reply from the server to the client
  - Status updates from the server to the client

ROS Concepts: roscore

In ROS 1, the management of nodes, topics, messages, and services is handled by the centralised “roscore”:

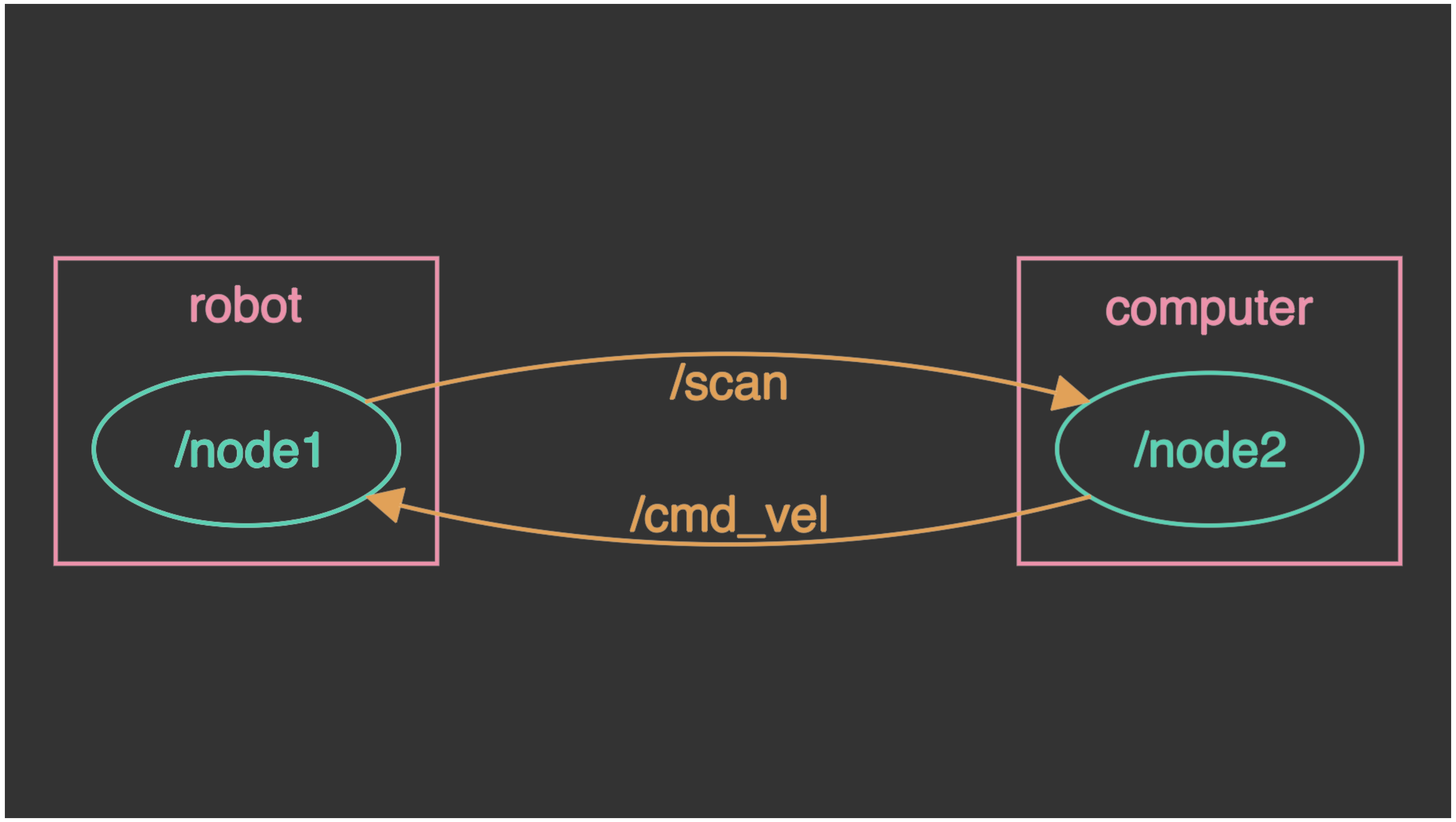
- A separate standalone process
- All nodes “register” with the roscore
- Roscore established links
- Environment variable configuration is required to define machines (terminals) that are within the same roscore region, by defining:
  - ROS_IP / ROS_HOSTNAME
  - ROS_MASTER_URI

ROS Concepts: Package

A ROS Package encapsulates:

- Nodes (source code and compilation instructions)
- Launch files
- Custom ROS message types

ROS Overview



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Thank you

Day 2: Kinematics, Motion, and Manipulation

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