Welcome to:

System Modeling

Unit objectives

After completing this unit, you should be able to:

- Understand the concept of system modeling
- Gain knowledge on the process of system design
- Understand the goals and principles of intelligent systems
- Gain an insight into various types of robots as systems

Introduction (1 of 2)

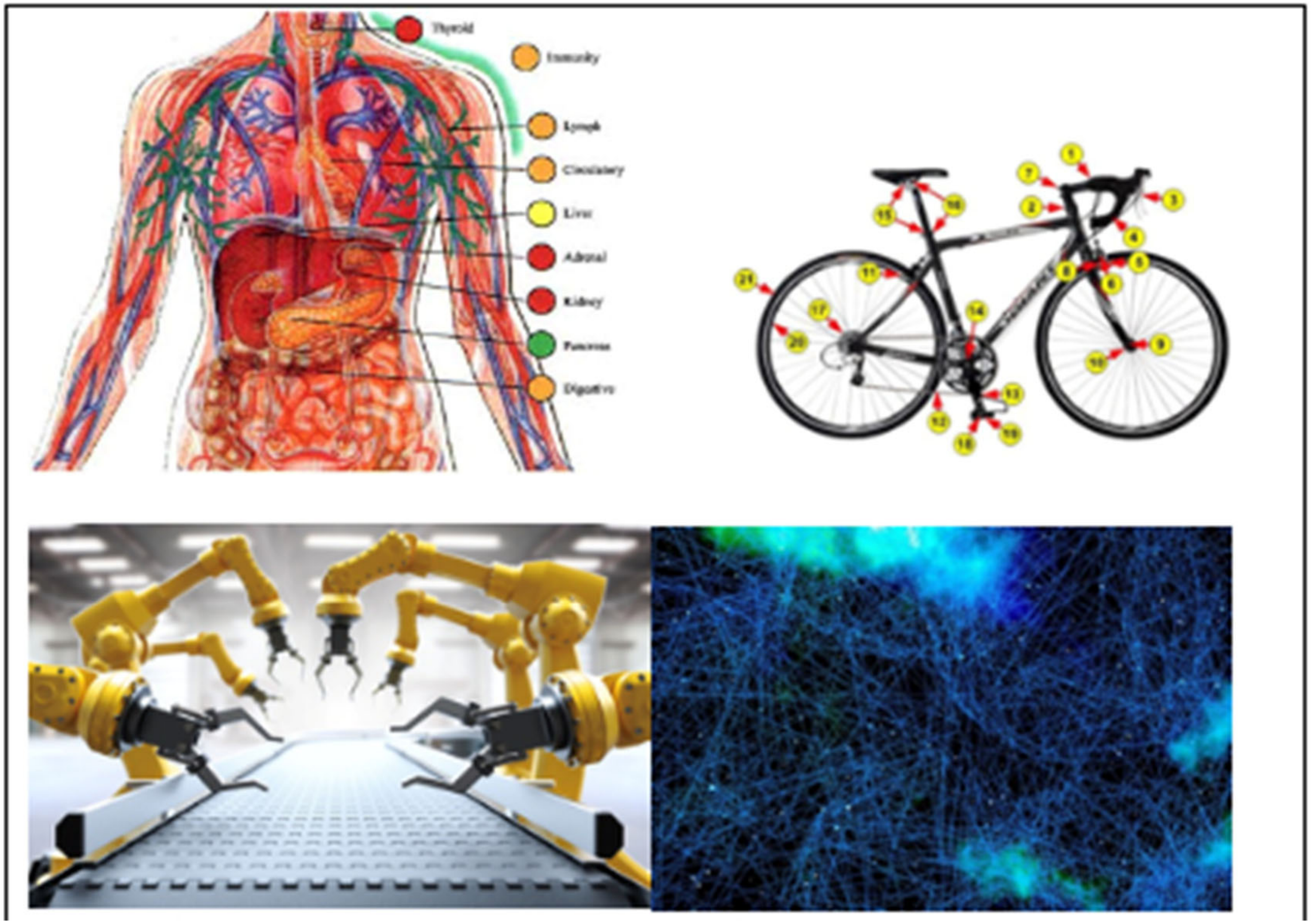


Figure: Systems found in the real world

Source: http://totalhumanbodysystems.blogspot.com/2012/12/summary-of-effects-therapeutic-effect.html
http://www.notesandsketches.co.uk/Mechanical_systems.html
https://www.robotics.org/blog-article.cfm/Pick-and-Place-Robots-What-Are-They-Used-For-and-How-Do-They-Benefit-Manufacturers/88
https://siliconangle.com/2018/11/01/graph-databases-get-boost-market-leader-neo4j-raises-80m/

Introduction (2 of 2)

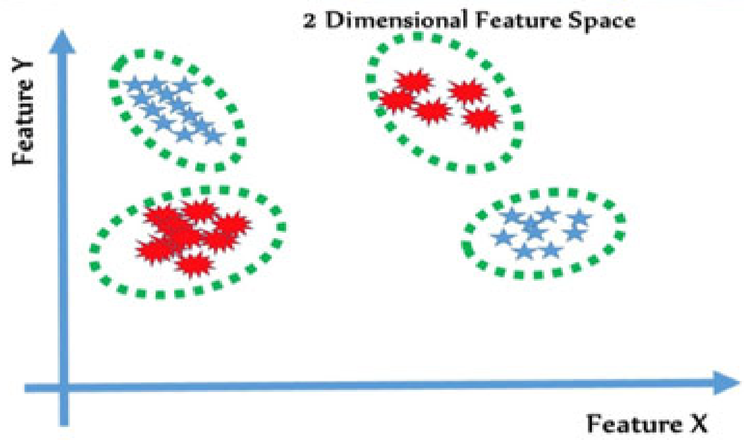


Figure: Intelligent Systems

Source: https://robohub.org/why-ethical-robots-might-not-be-such-a-good-idea-after-all/

 http://www.princeton.edu/~stengel/MAE345.html

https://www.petersincak.com/news/why-i-do-not-believe-in-error-backpropagation/

Biological and cognitive paradigms for robot design (1 of 8)

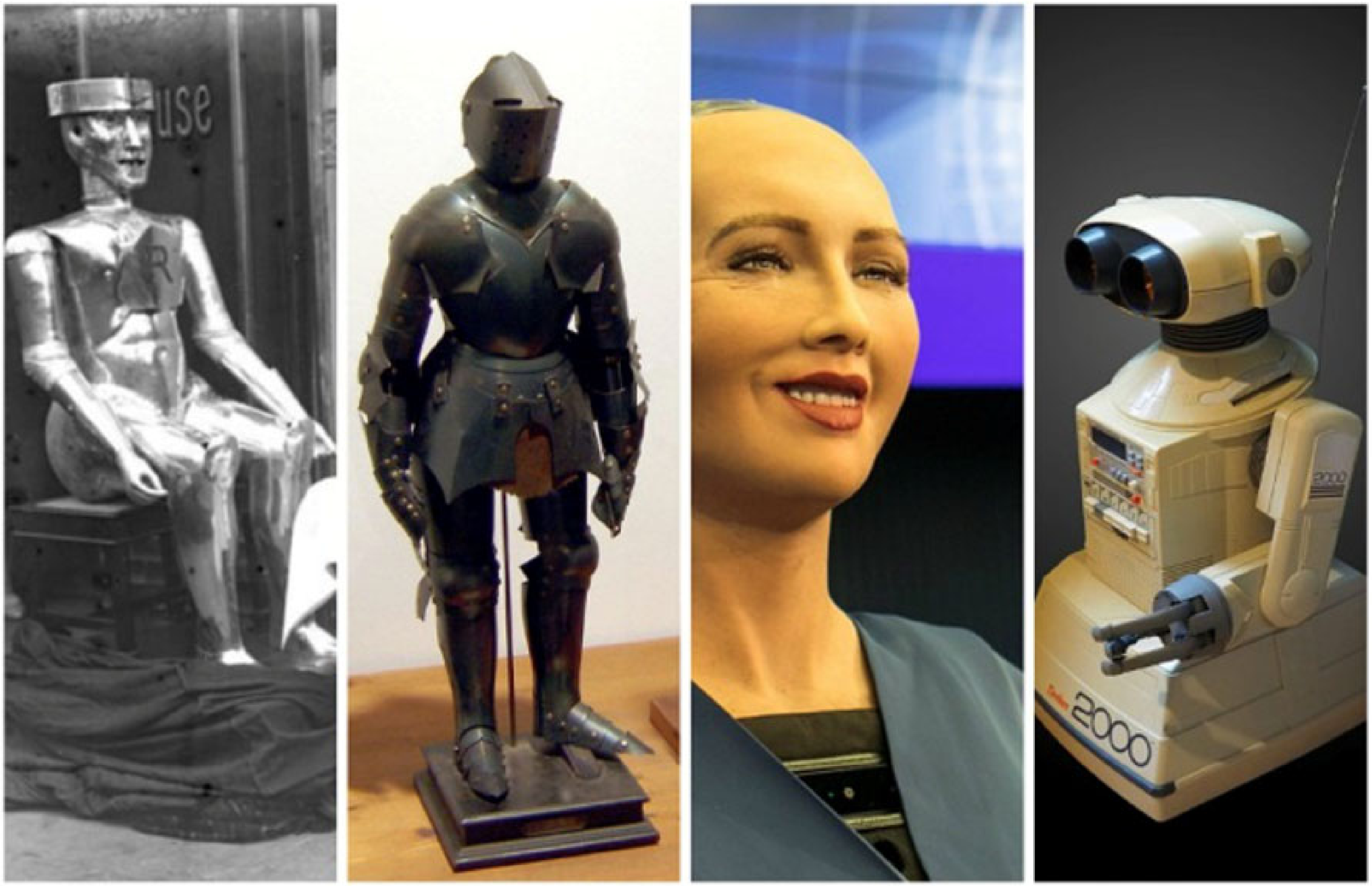
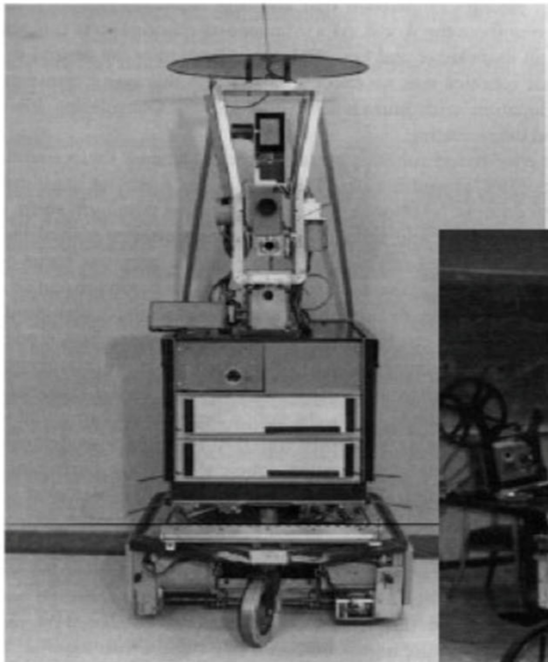


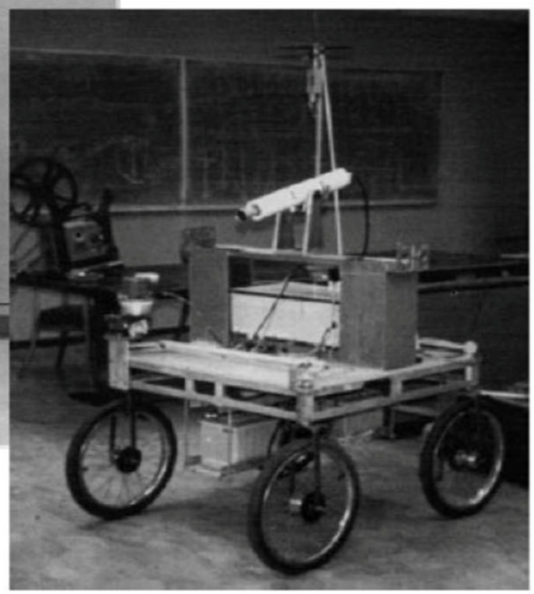
Figure: Robots in real world

Source: https://interestingengineering.com/the-history-of-robots-from-the-400-bc-archytas-to-the-boston-dynamics-robot-dog

Biological and cognitive paradigms for robot design (2 of 8)



Shakey



Stanford Cart

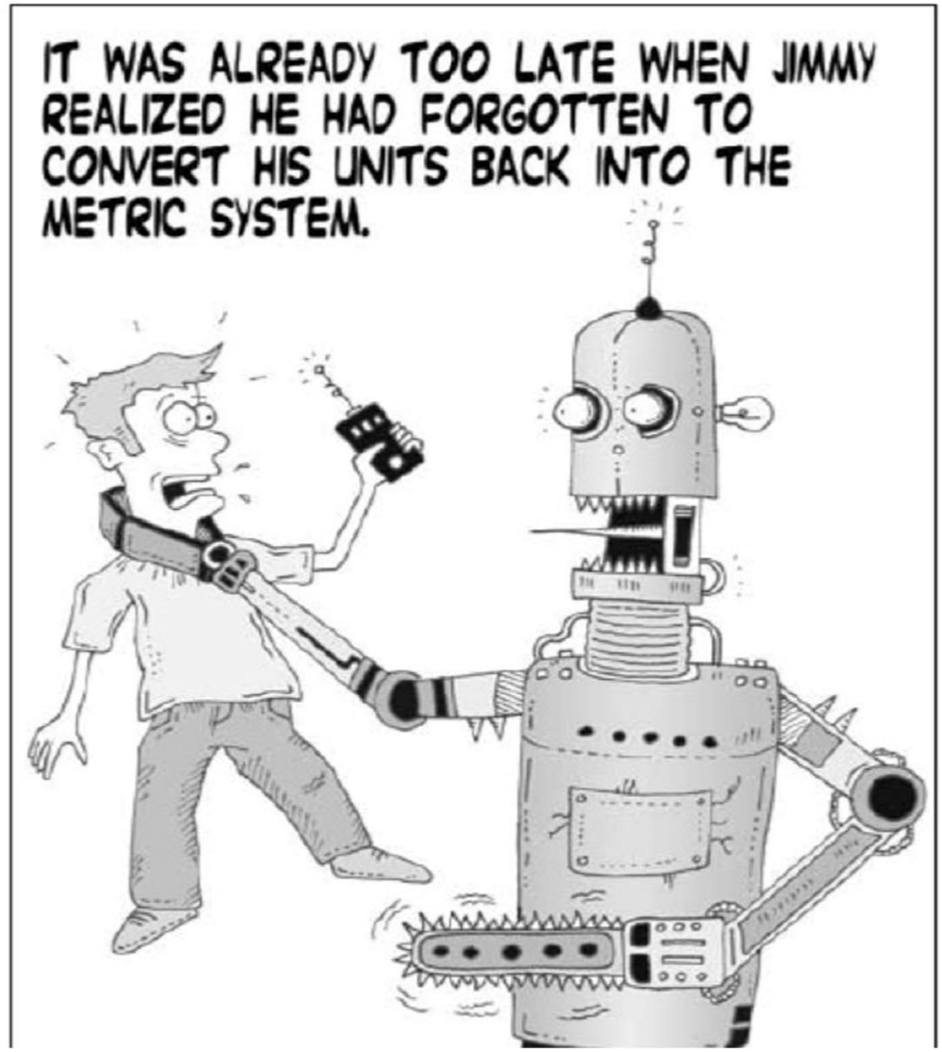


Figure: Various paradigms

Source: https://www.cpp.edu/~ftang/courses/CS521/notes/hierarchical%20control.pdf

Biological and cognitive paradigms for robot design (3 of 8)

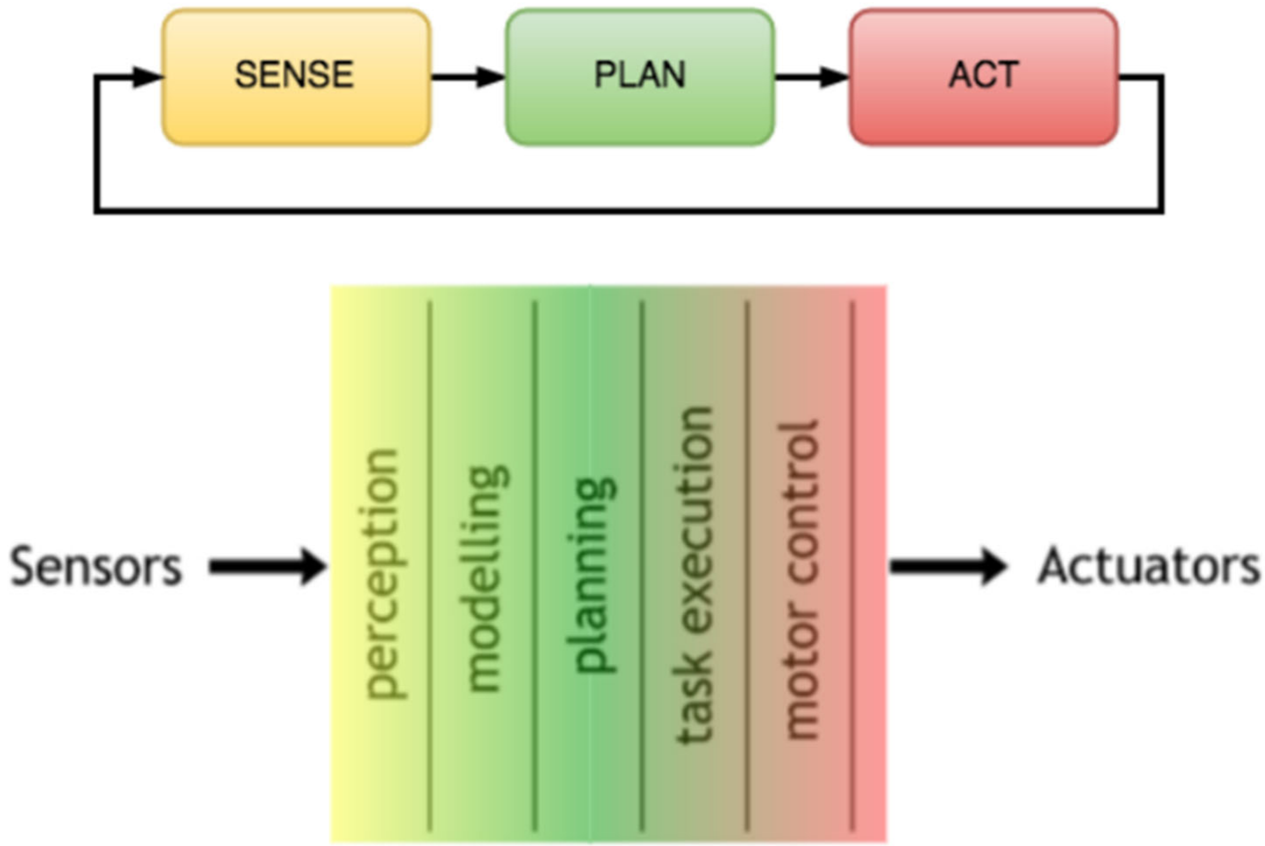


Figure: Hierarchical Paradigm

Source: Article: Designing the mind of a social robot by Nicole Lazzeri, Daniele Mazzei, Lorenzo Cominelli, Antonio Cisternino and Danilo Emilio De Rossi, Appl. Sci. 2018, 8, 302; doi:10.3390/app8020302

Biological and cognitive paradigms for robot design (4 of 8)

- Nested hierarchical controller

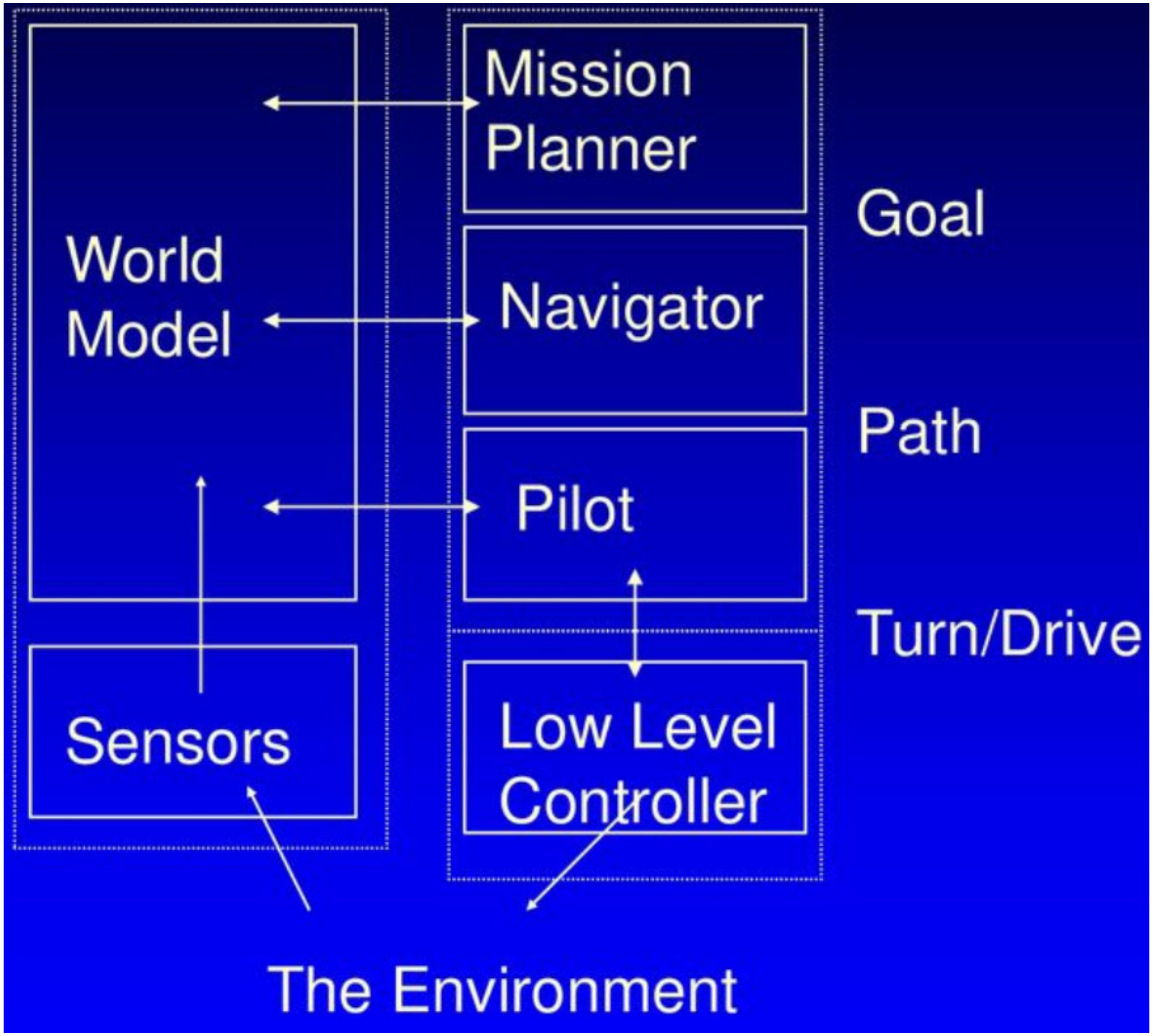
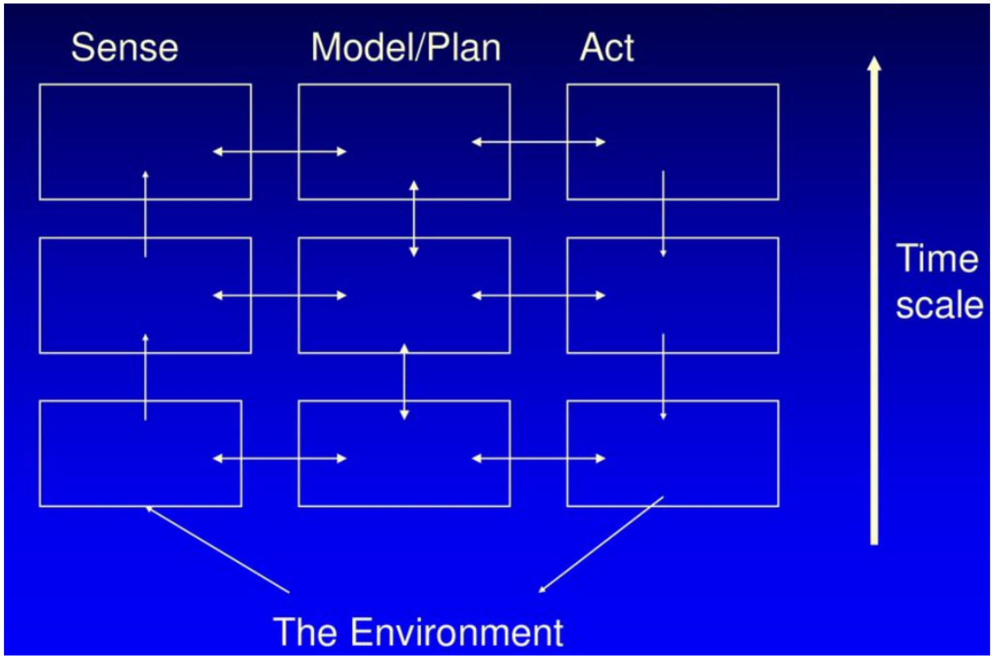


Figure: Nested hierarchical Controller

Source: CS4630: Intelligent Robotics and Perception; Planning (Chapter 2) slides by Ticker Balch

Biological and cognitive paradigms for robot design (5 of 8)

NIST Real time control system



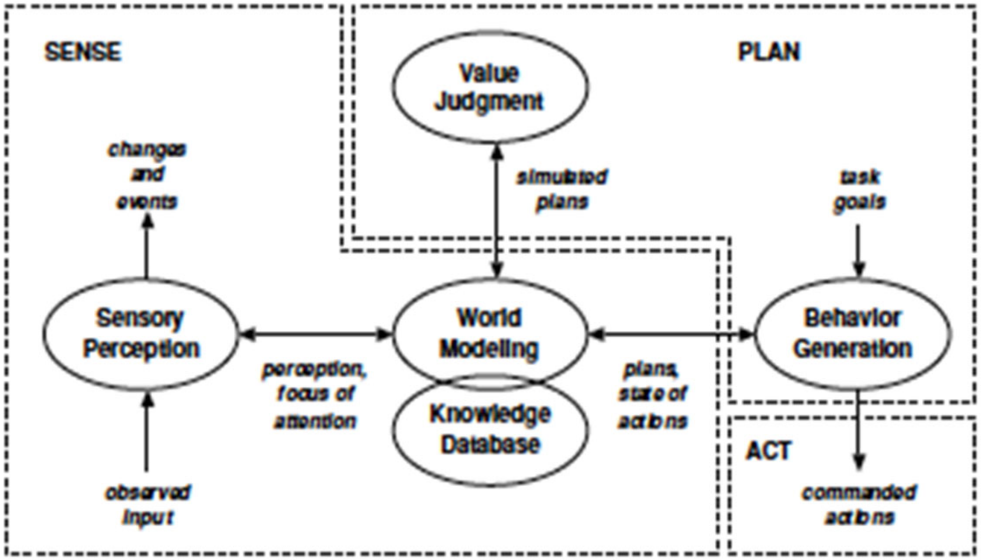


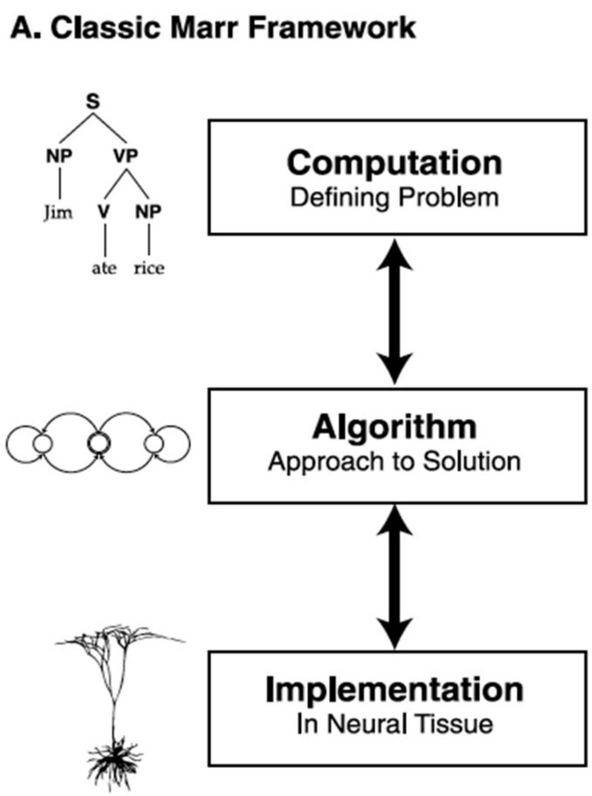
Figure: Real-time Control systems(RCS)

Source: CS4630: Intelligent Robotics and Perception; Planning (Chapter 2) slides by Ticker Balch

Introduction to AI Robotics by Robin R Murphy, A Bradford Book, The MIT Press Cambridge, Massachusetts, London, England

Biological and cognitive paradigms for robot design (6 of 8)

- Computational theory



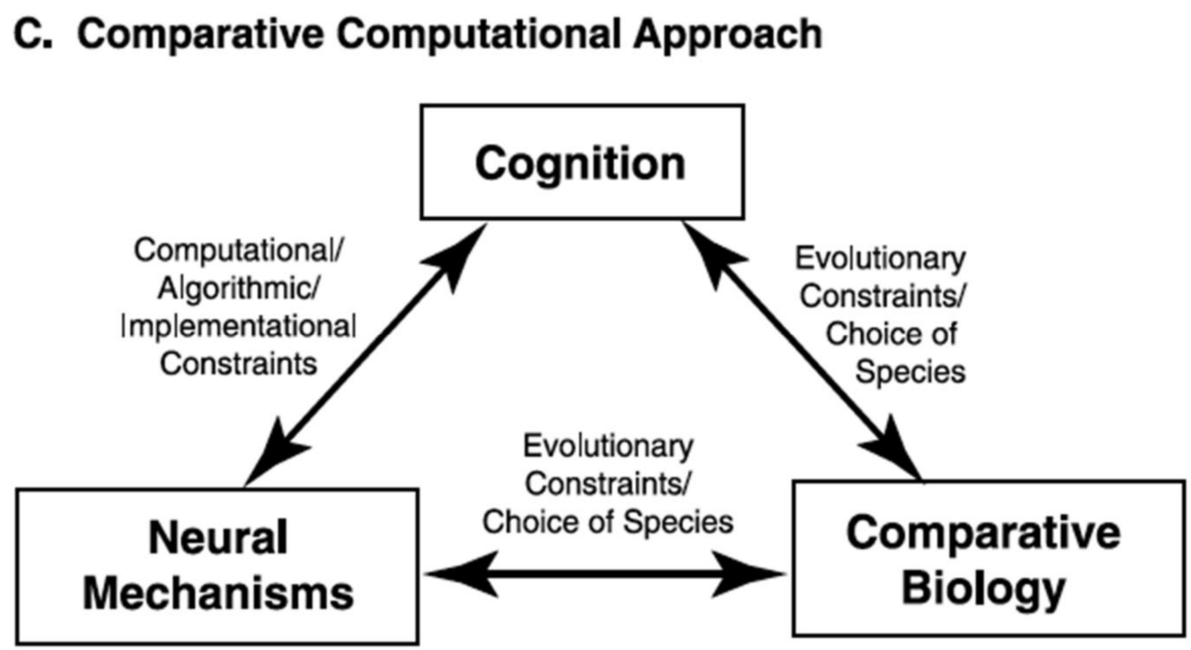


Figure: Computational Theory

Source: http://dx.doi.org/10.1016/j.plrev.2014.04.005, 1571-0645/© 2014 Published by Elsevier B.V., Open access under CC BY-NC-ND license.
https://www.socsci.uci.edu/~lpearl/courses/psych156A_2012spring/lectures/MidtermReviewbw.pdf)

Biological and cognitive paradigms for robot design (7 of 8)

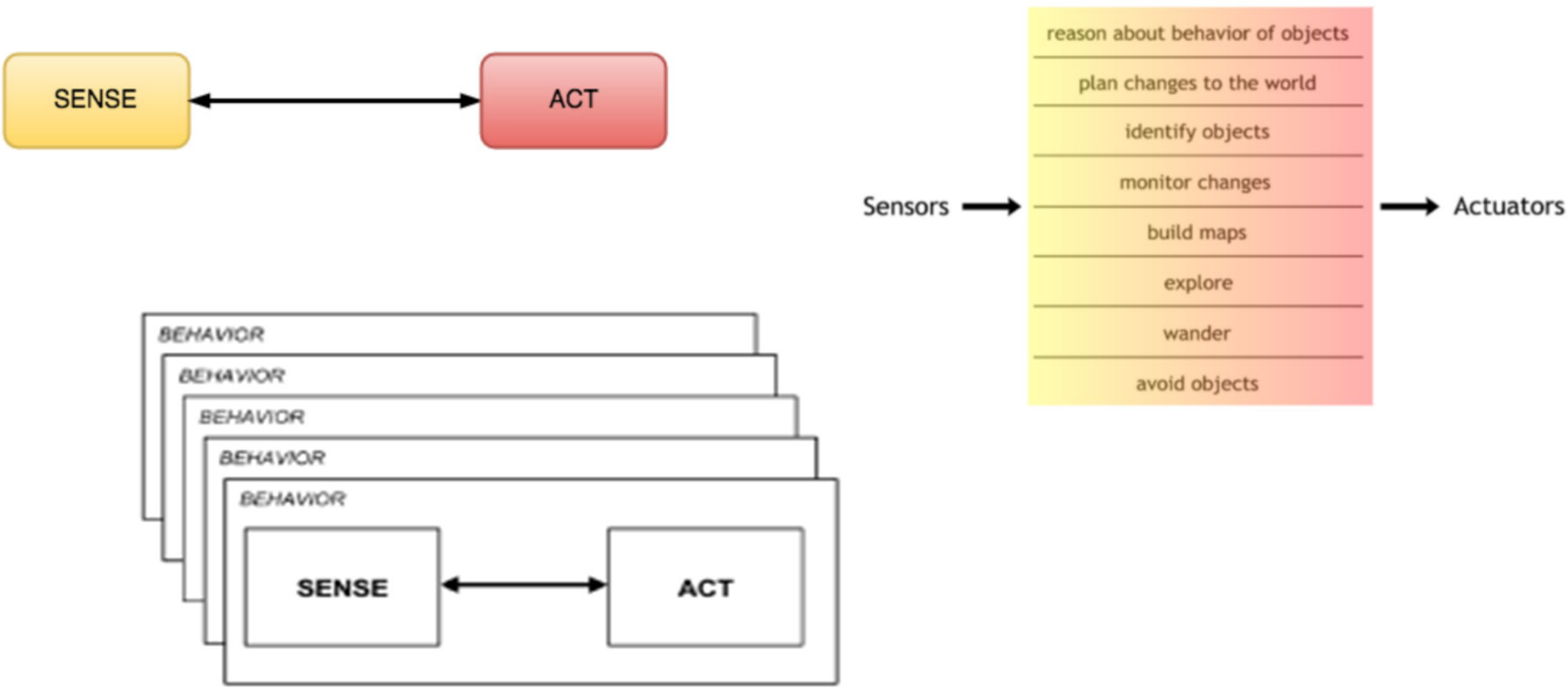


Figure: Reactive paradigm

Source: Article: Designing the mind of a social robot by Nicole Lazzeri, Daniele Mazzei, Lorenzo Cominelli, Antonio Cisternino and Danilo Emilio De Rossi, Appl. Sci. 2018, 8, 302; doi:10.3390/app8020302
Introduction to AI Robotics by Robin R Murphy, A Bradford Book, The MIT Press Cambridge, Massachusetts,London, England

Biological and cognitive paradigms for robot design (8 of 8)

- The FACE cognitive architecture based on the hybrid deliberative/reactive paradigm.

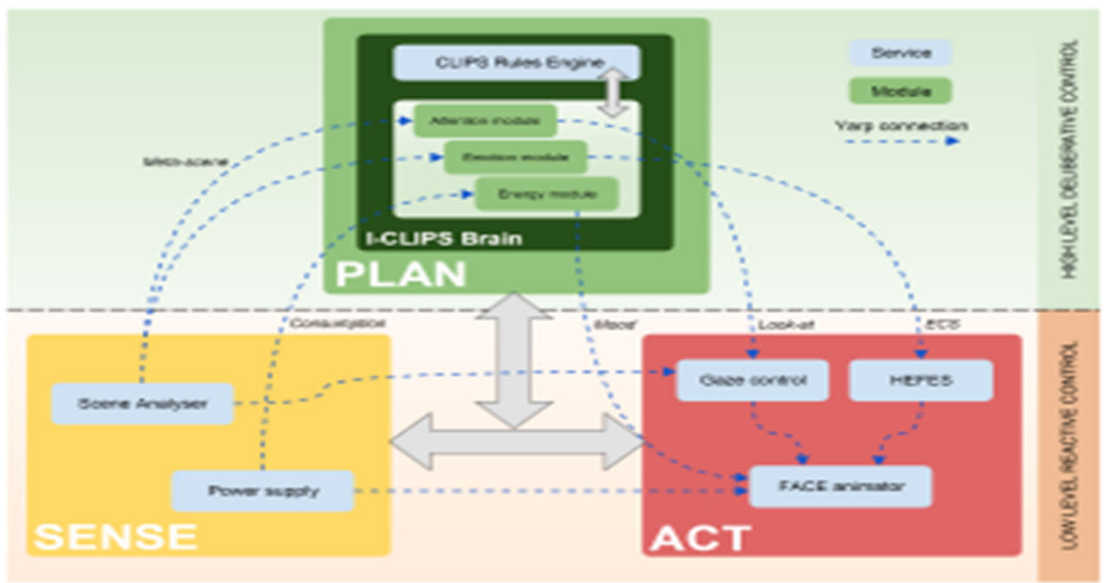
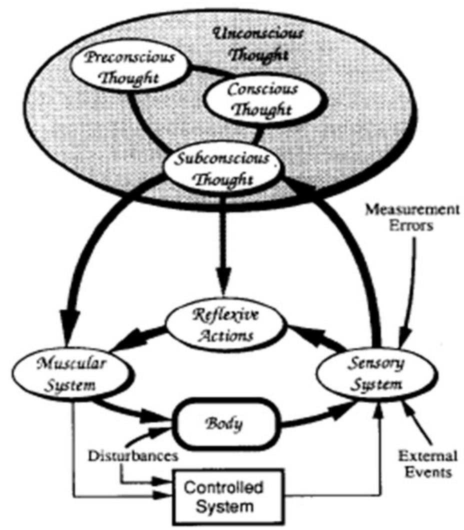


Figure: Hybrid deliberative/Reactive paradigm

Source: Article: Designing the mind of a social robot by Nicole Lazzeri, Daniele Mazzei, Lorenzo Cominelli, Antonio Cisternino and Danilo Emilio De Rossi, Appl. Sci. 2018, 8, 302; doi:10.3390/app8020302)

Declarative-Procedural-Reflexive hierarchy for decision making and control



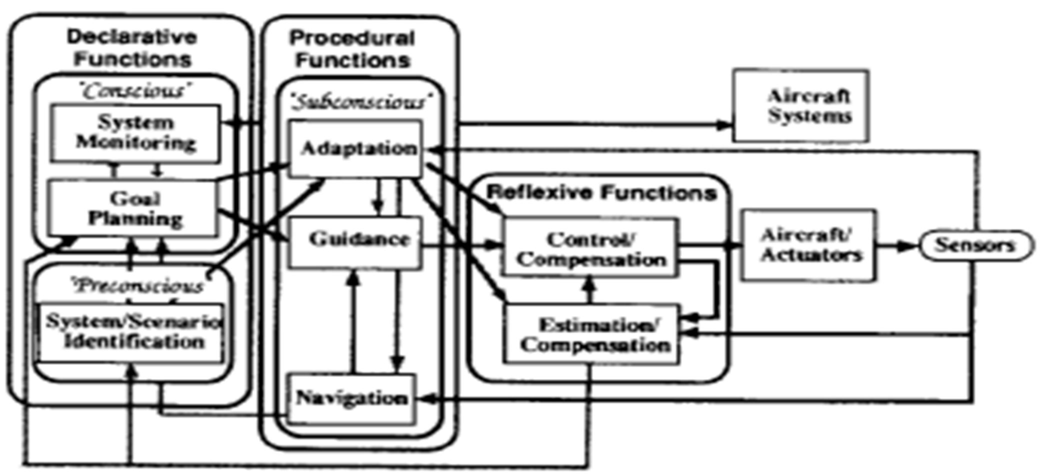
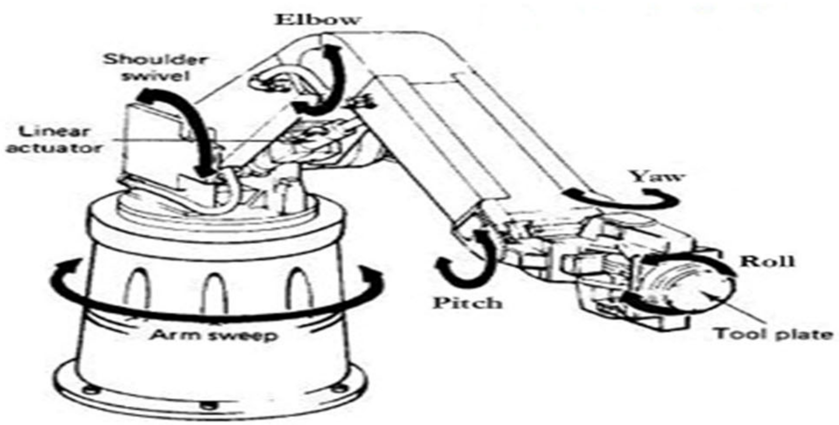
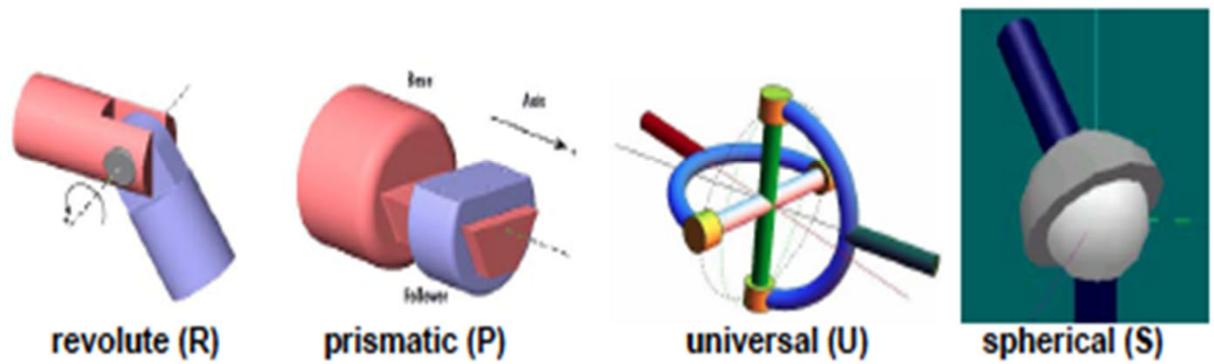


Figure: Cognitive/Biological Control Behavior

Source: Toward Intelligent Flight Control by Robert F. Stengel, Fellow, IEEE Transactions on Systems, Man and Cybernetics Vol 23, No 6, Nov/Dec 1993

Articulated robots (1 of 2)





Common Robot Joint Examples (1, 1, 2, and 3-dof, respectively)

Figure: Articulated robot and the common joints

Source: https://www.engineering.com/AdvancedManufacturing/ArticleID/12192/Articulated-Robot-Market-Worth-USD7958-Billion-by-2022.aspx

An Introduction to Robotics, Dr. Bob Williams, williar4@ohio.edu, Mechanical Engineering, Ohio University, EE/ME 4290/5290 Mechanics and Control of Robotic Manipulators, © 2019 Dr. Bob Productions

Articulated robots (1 of 2)

IBM ICE (Innovation Centre for Education)

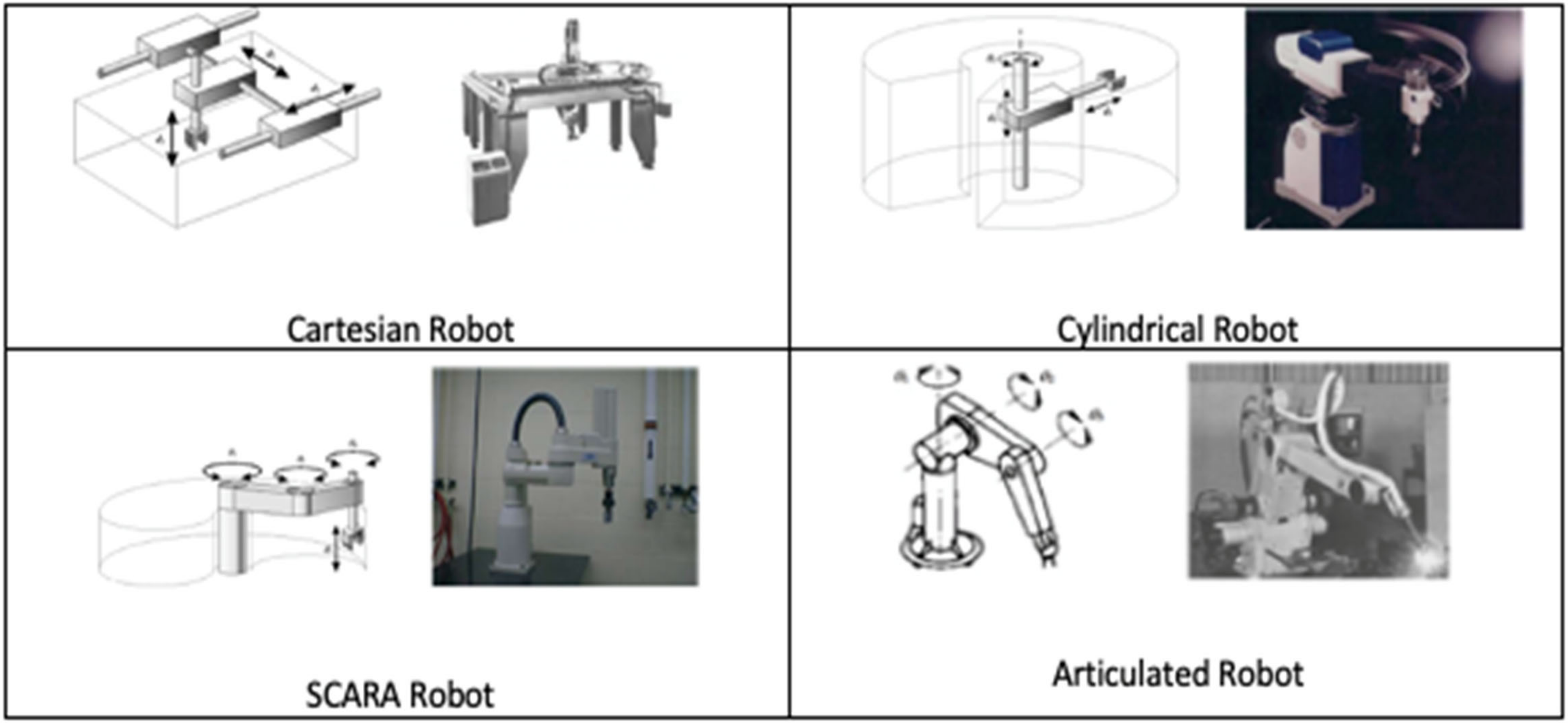
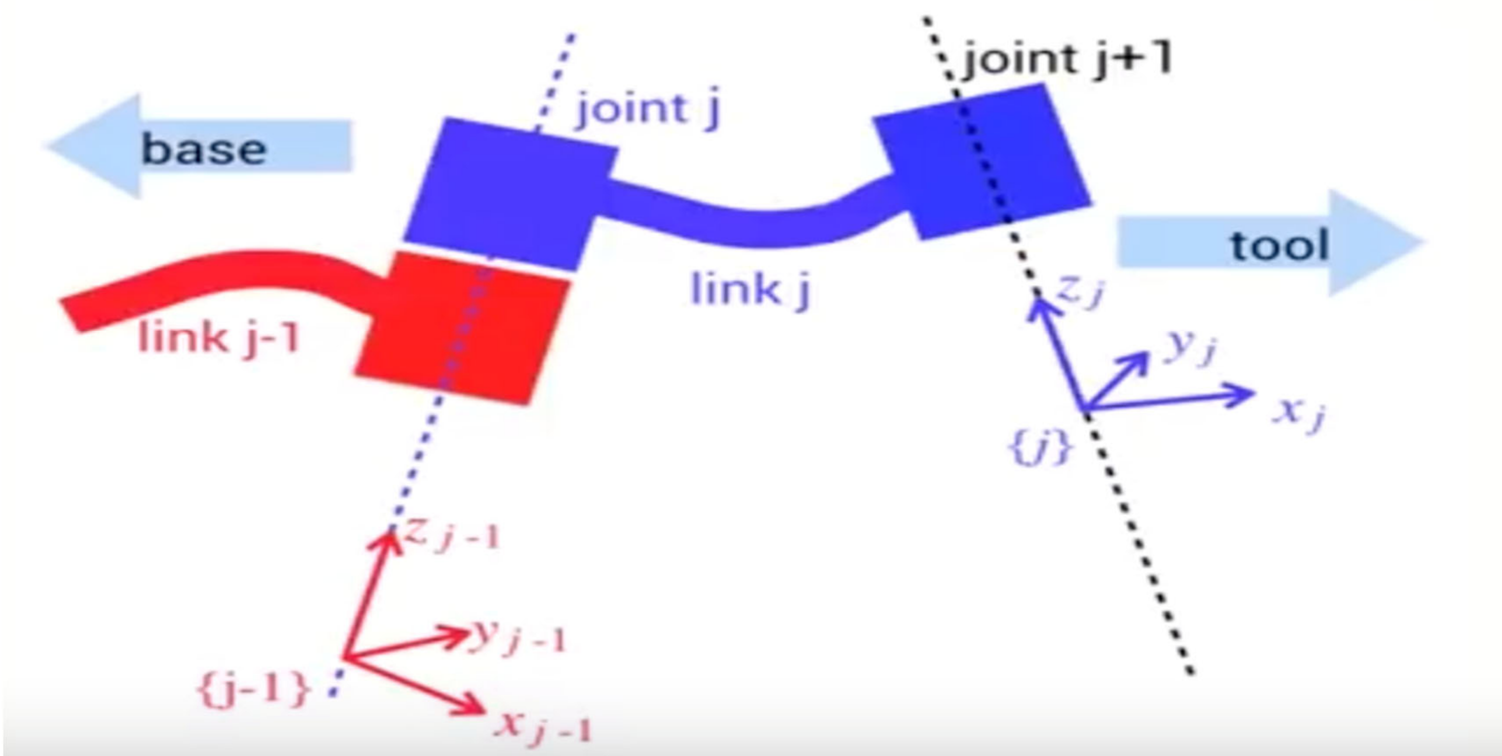


Figure: Common Robot Designs

Source: An Introduction to Robotics, Dr. Bob Williams, williar4@ohio.edu, Mechanical Engineering, Ohio University, EE/ME 4290/5290 Mechanics and Control of Robotic Manipulators, © 2019 Dr. Bob Productions

Joint-Link (Denavit-Hartenberg) transformations (1 of 4)



$$^{j-1}\xi_j \sim \mathbf{A} = \mathbf{R}_z(\theta_j)\mathbf{T}_z(d_j)\mathbf{T}_x(a_j)\mathbf{R}_x(\alpha_j) \qquad \text{----1.1}$$

Figure: Denavit-Hartenberg notation

Source: Denavit-Hartenberg notation | Robot Academy

Joint-Link (Denavit-Hartenberg) transformations (2 of 4)

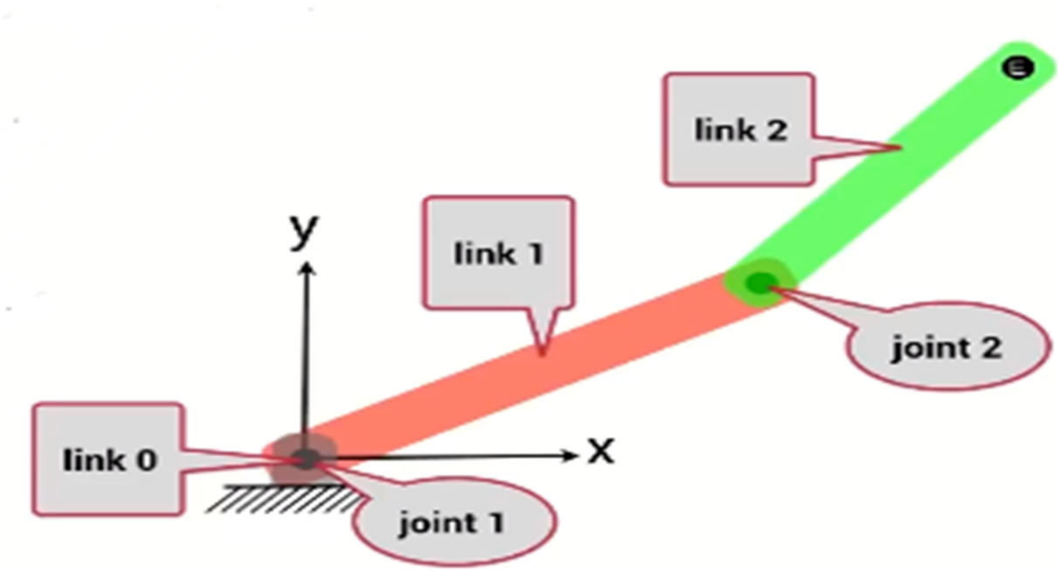
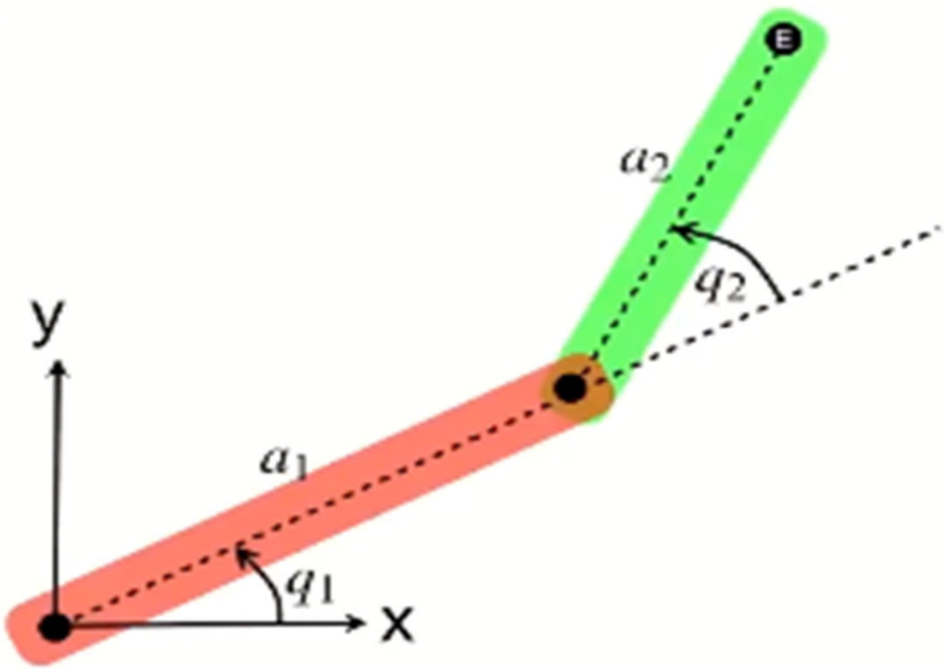


Figure: Serial link manipulator

Source: Denavit-Hartenberg notation | Robot Academy

Joint-Link (Denavit-Hartenberg) transformations (3 of 4)

Denavit-Hartenberg parameters for a 2 link robot



θ_j	d_j	a_j	α_j
q_1	0	a_1	0
q_2	0	a_2	0

Figure: Two-Link Robot and Kinematics of the Robot

Source: Denavit-Hartenberg notation | Robot Academy

Joint-Link (Denavit-Hartenberg) transformations (4 of 4)

Denavit-Hartenberg parameters for a 2 link robot

- All revolute joints (RRRRRR)

$$\mathbf{T}_E = \underbrace{\mathbf{R}_z(\overset{q_1}{\theta_1})\mathbf{T}_z(d_1)\mathbf{T}_x(a_1)\mathbf{R}_x(\alpha_1)}_{\textbf{revolute joint}}\ \underbrace{\mathbf{R}_z(\overset{q_2}{\theta_2})\mathbf{T}_z(d_2)\mathbf{T}_x(a_2)\mathbf{R}_x(\alpha_2)}_{\textbf{revolute joint}}\cdots\underbrace{\mathbf{R}_z(\overset{q_n}{\theta_N})\mathbf{T}_z(d_N)\mathbf{T}_x(a_N)\mathbf{R}_x(\alpha_N)}_{\textbf{revolute joint}}$$

- Revolute and prismatic joints (RPRRRR)

$$\mathbf{T}_E = \underbrace{\mathbf{R}_z(\overset{q_1}{\theta_1})\mathbf{T}_z(d_1)\mathbf{T}_x(a_1)\mathbf{R}_x(\alpha_1)}_{\textbf{revolute joint}}\ \underbrace{\mathbf{R}_z(\theta_2)\mathbf{T}_z(\overset{q_2}{d_2})\mathbf{T}_x(a_2)\mathbf{R}_x(\alpha_2)}_{\textbf{prismatic joint}}\cdots\underbrace{\mathbf{R}_z(\overset{q_n}{\theta_N})\mathbf{T}_z(d_N)\mathbf{T}_x(a_N)\mathbf{R}_x(\alpha_N)}_{\textbf{revolute joint}}$$

Figure: Two cases (i) with revolute joints only (ii) Revolute and prismatic joints

Source: Denavit-Hartenberg notation | Robot Academy

Mobile ground robots

IBM ICE (Innovation Centre for Education)

Lawn Mower Robot

Vacuum Cleaner Robot

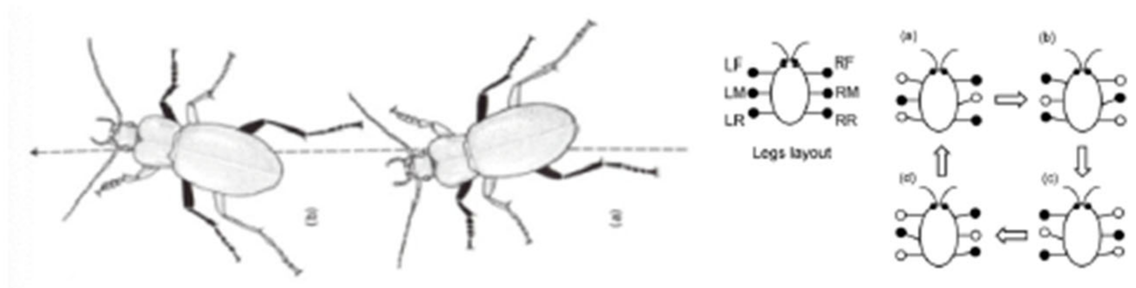


Figure: Legged Robots (gaits) (Ref: Gullan et al., The Insects: An outline of entomology, 2005 Iida et al., Science Direct, 63, 2008

Helper Robot

Figure: Mobile Ground Robots

Figure: Hexapod Walking robot (Ref: Introduction to Robotics-Lecture 1, Jan Faigl, Department of Computer Science, Faculty of Electrical Engineering, Czech Technical University in Prague

Source: An Introduction to Robotics, Dr. Bob Williams, williar4@ohio.edu, Mechanical Engineering, Ohio University, EE/ME 4290/5290 Mechanics and Control of Robotic Manipulators, © 2019 Dr. Bob Productions

Uninhabited ground robots (1 of 2)

Figure: Uninhabited Ground Robots

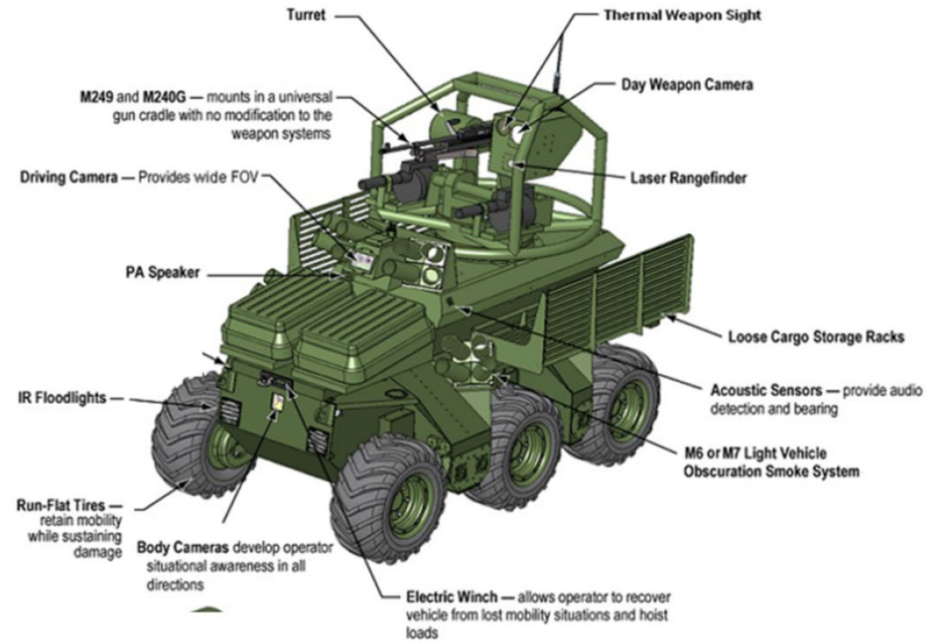


Figure: DOD robotic vehicle: Gladiator

Source: Military Robotics: Malignant machines or the path to Peace? Presented By: Dr. Robert Finkelstein President, Robotic Technology Inc., revised January 2010

Uninhabited ground robots (2 of 2)

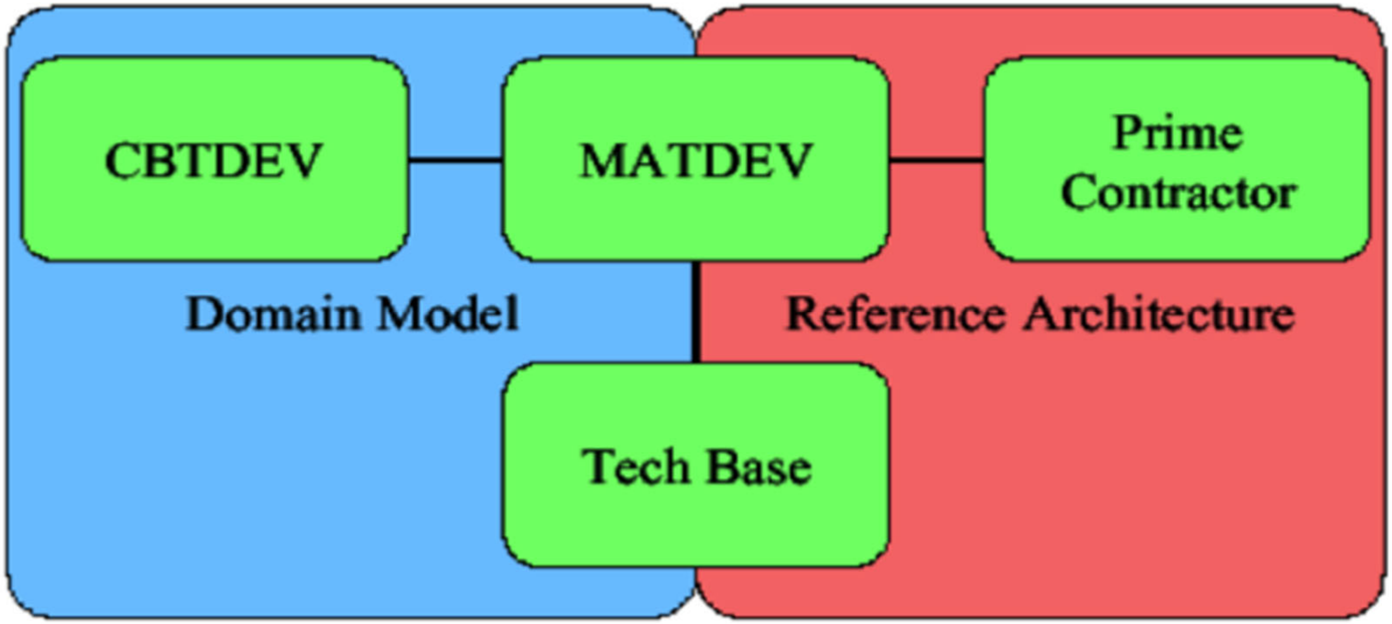


Figure: JAUGS Reference Architecture

Source: Military Robotics: Malignant machines or the path to Peace? Presented By: Dr. Robert Finkelstein President, Robotic Technology Inc., revised January 2010

Intelligent agents (1 of 4)

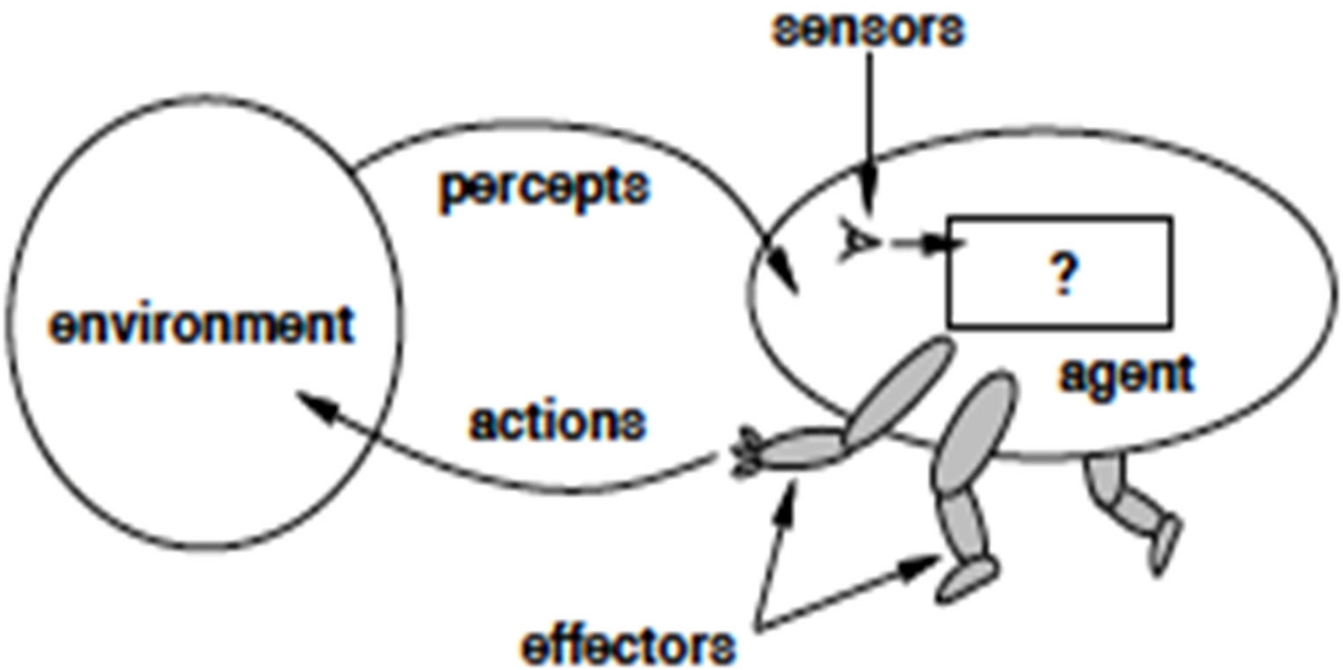


Figure: Agents(Ref: Artificial Intelligence: A Modern Approach by Stuart Russell and Peter Norvig, c 1995 Prentice-Hall, Inc.)

Source: Military Robotics: Malignant machines or the path to Peace? Presented By: Dr. Robert Finkelstein President, Robotic Technology Inc., revised January 2010

Intelligent agents (2 of 4)

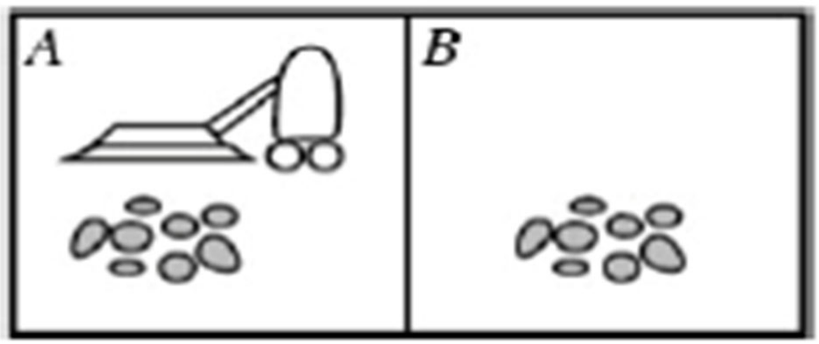


Figure: Vacuum-cleaner World
Source: CS 420:Artificial Intelligence Chapter 2 :Intelligent Agents

Percept sequence	Action
[A, Clean]	?
[A, Dirty]	
[B, Clean]	
[B, Dirty]	
[A, Clean], [A, Clean]	
[A, Clean], [A, Dirty]	
...	
[A, Clean], [A, Clean], [A, Clean]	
[A, Clean], [A, Clean], [A, Dirty]	
...	

Figure: Simple Agent Function
Source: CS 420:Artificial Intelligence Chapter 2 :Intelligent Agents

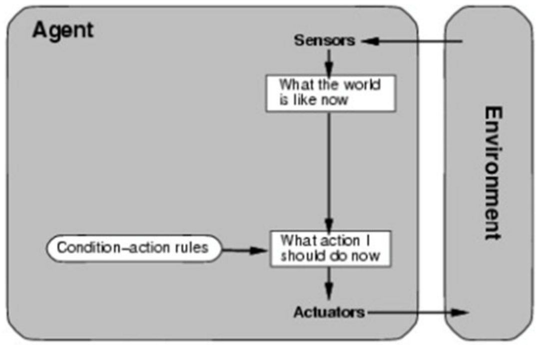
Intelligent agents (3 of 4)

Performance Measure	Environment	Actuators	Sensors
safe, fast, legal, comfortable trip, maximize profits	roads, other traffic, pedestrians, customers	steering, accelerator, brake, signal, horn, display	camera, sonar, speedometer, GPS, odometer, engine sensors, keyboard, accelerator

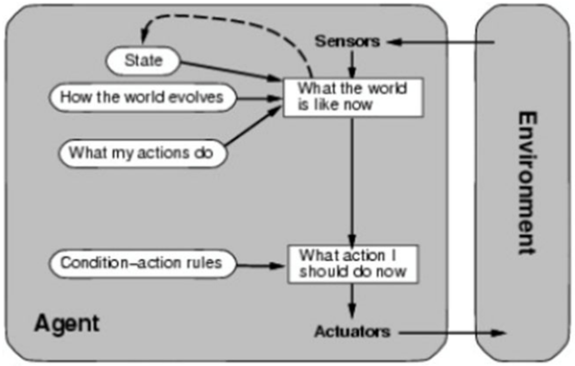
Figure: PEAS for Taxi Driver Example
Source: CS 420:Artificial Intelligence Chapter 2 :Intelligent Agents

Intelligent agents (4 of 4)

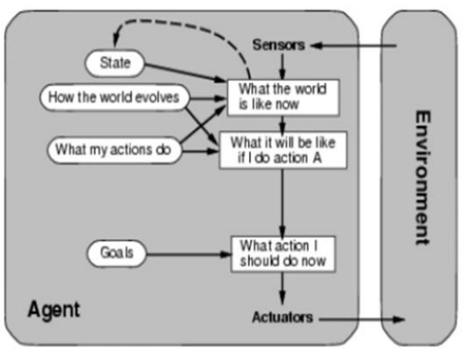
(i) Simple Reflex Agents



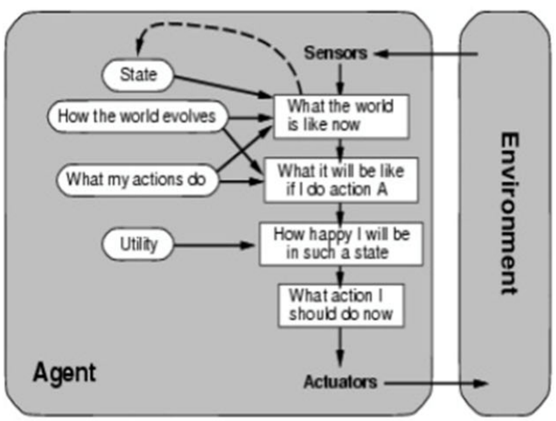
(ii) Model-based reflex agents



(iii) Goal-Based Agents



(iv) Utility-based agents



(v) Learning agents

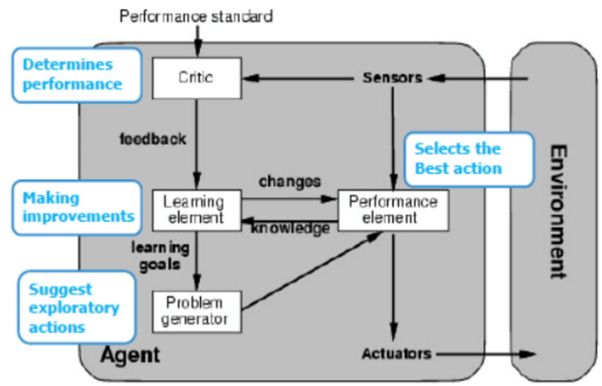


Figure: Basic Agent Types

Source: Artificial Intelligence: A Modern Approach by Stuart Russell and Peter Norvig, c 1995 Prentice-Hall, Inc.)

Open-loop and closed-loop systems (1 of 4)

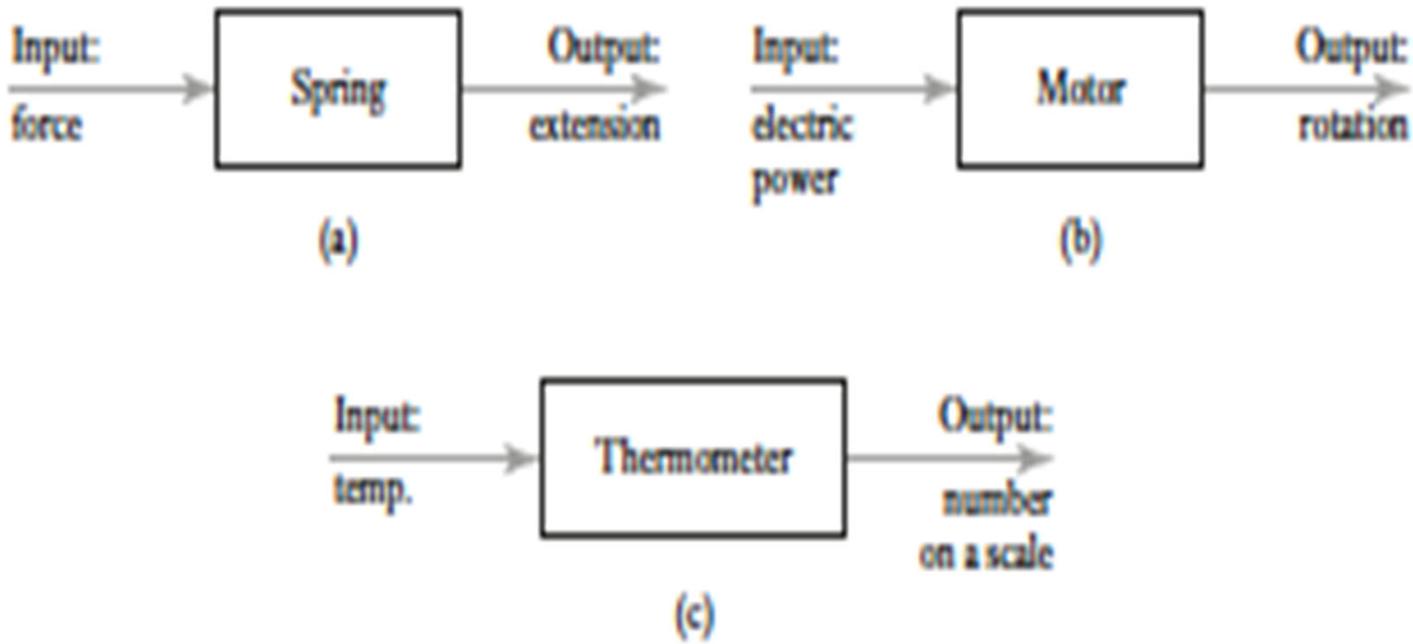


Figure: Systems found in the real world

Source: Mechatronics – Seventh Edition by William Bolton: https://books.google.co.in/books?id=BIV1DwAAQBAJ&pg=SA1-PA5&lpg=SA1-PA5&dq=spring+motor+and+thermometer+william+bolton&source=bl&ots=JHVk-Pto9C&sig=ACfU3U3hEsc2-_sgriCeu28ZUZwrqaMEEA&hl=en&sa=X&ved=2ahUKEwjl19Hgy9TkAhVEvY8KHbvSBuwQ6AEwCnoECAkQAQ#v=onepage&q=spring%20motor%20and%20thermometer%20william%20bolton&f=false .

Open-loop and closed-loop systems (2 of 4)

- System modeling

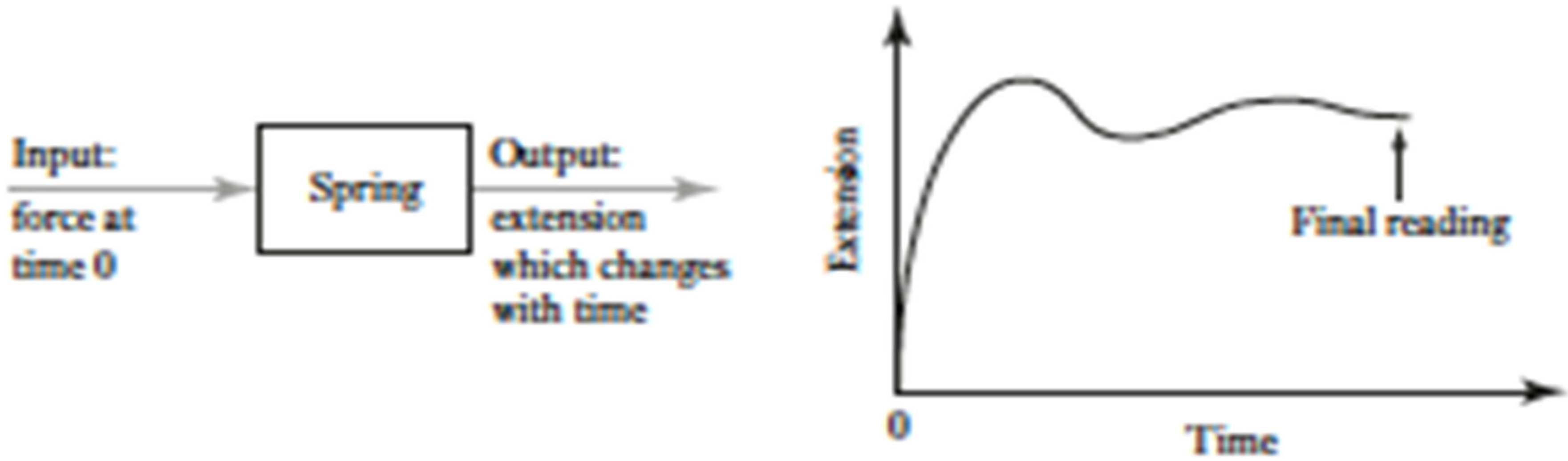


Figure: Response to an input for a spring

Source: Ref: Mechatronics – Seventh Edition by William Bolton: https://books.google.co.in/books?id=BlV1DwAAQBAJ&pg=SA1-PA5&lpg=SA1-PA5&dq=spring+motor+and+thermometer+william+bolton&source=bl&ots=JHVk-Pto9C&sig=ACfU3U3hEsc2-_sgriCeu28ZUZwrqaMEEA&hl=en&sa=X&ved=2ahUKEwjl19Hgy9TkAhVEvY8KHbvSBuwQ6AEwCnoECAkQAQ#v=onepage&q=spring%20motor%20and%20thermometer%20william%20bolton&f=false.

Open-loop and closed-loop systems (3 of 4)

- Digital camera

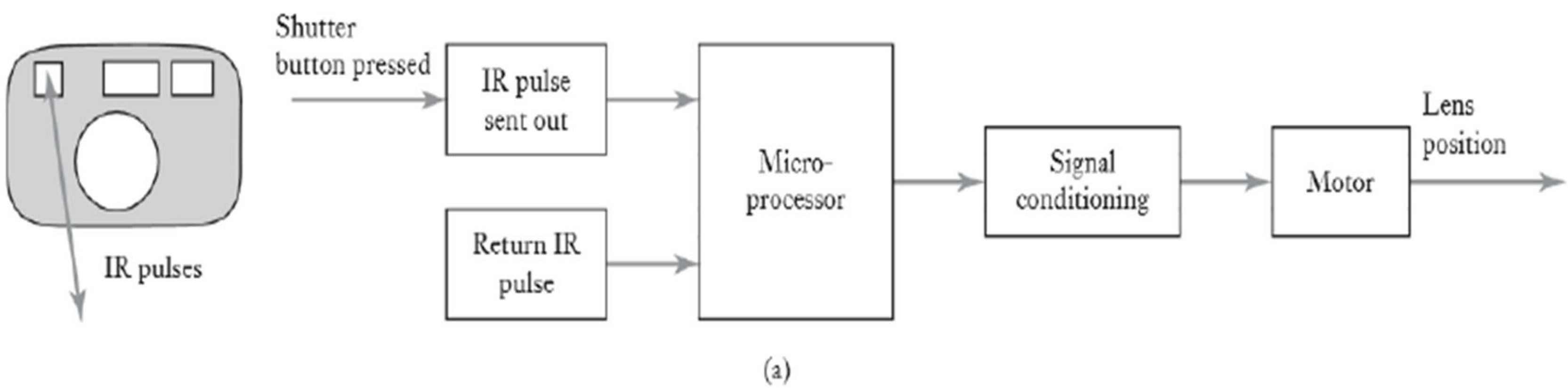


Figure: Digital Camera

Source: lecture slides of Dr. Atul Thakur, Module I.pdf

Open-loop and closed-loop systems (4 of 4)

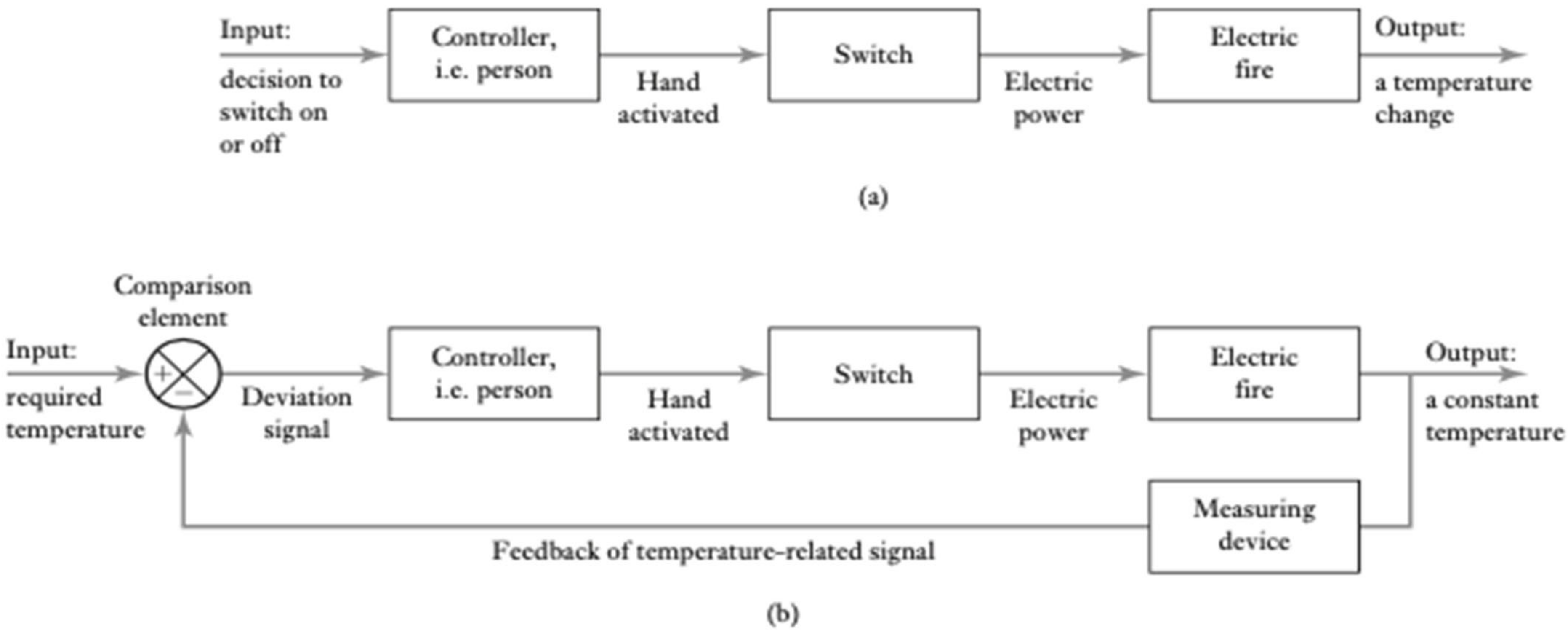


Figure: Open and closed loop system

Source: Ref: Mechatronics – Seventh Edition by William Bolton: https://books.google.co.in/books?id=BIV1DwAAQBAJ&pg=SA1-PA5&lpg=SA1-PA5&dq=spring+motor+and+thermometer+william+bolton&source=bl&ots=JHVk-Pto9C&sig=ACfU3U3hEsc2-_sgriCeu28ZUZwrqaMEEA&hl=en&sa=X&ved=2ahUKEwjl19Hgy9TkAhVEvY8KHbvSBuwQ6AEwCnoECAkQAQ#v=onepage&q=spring%20motor%20and%20thermometer%20william%20bolton&f=false

Checkpoint (1 of 2)

Multiple choice questions:

1. Which of these can be called a system .
   a) Human body
   b) Pick and place robot
   c) Graph database
   d) All of these

2. Who coined the term robot .
   a) Karel Capek
   b) Romi K
   c) Isac Asimo
   d) None of the above

3. NHS means
   a) Nested Home Controller
   b) Nested Hierarchical Controller
   c) New Home controller
   d) None of the above

Checkpoint solutions (1 of 2)

Multiple choice questions:

1. Which of these can be called a system .
   a) Human body
   b) Pick and place robot
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2. Who coined the term robot .
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   d) None of the above

3. NHS means
   a) Nested Home Controller
   b) Nested Hierarchical Controller
   c) New Home controller
   d) None of the above

Checkpoint (2 of 2)

Fill in the blanks:

1. ___________ architecture are best suited for semi-autonomous controlled robots
2. Device attached to the robot's wrist to perform a specific task are called ___________
3. A robot, which has two parallel rotary joints to provide compliance in a plane is called _________
4. ________ is the ability of a robot to repeatedly position itself when asked to perform a task multiple times.

True or False:

1. Reactive paradigm did not have planning or any reasoning functions. True/False
2. The Subconscious Thought module receives the information from the Sensory System and conveys commands to the Muscular System. True/False
3. Kinematics means the study of motion without regards to the forces or torques. True/False

Checkpoint solutions (2 of 2)

Fill in the blanks:

1. **NHC and RCS** architecture are best suited for semi-autonomous controlled robots
2. Device attached to the robot's wrist to perform a specific task are called **grippers.**
3. A robot, which has two parallel rotary joints to provide compliance in a plane is called **SCARA Robot.**
4. **Repatibility** is the ability of a robot to repeatedly position itself when asked to perform a task multiple times.

True or False:

1. Reactive paradigm did not have planning or any reasoning functions. **True**
2. The Subconscious Thought module receives the information from the Sensory System and conveys commands to the Muscular System. **True**
3. Kinematics means the study of motion without regards to the forces or torques. **True**

Question bank

Two mark questions:

1. Name the main components of industrial robots.
2. What parts does the DOD’s robotic vehicle have ?
3. What is an agent?
4. What is a system?

Four mark questions:

1. Discuss digital camera's system representation.
2. Describe open and closed loop systems.
3. Explain JAUGS reference architecture.
4. Write short note on mobile ground robots?

Eight mark questions:

1. Explain the concept of joint link transformations.
2. Explain the five basic agents in brief.

Unit summary

Having completed this unit, you should be able to:

- Understand the concept of system modeling
- Gain knowledge on the process of system design
- Understand the goals and principles of intelligent systems
- Gain an insight into various types of robots as systems