Introduction to Module A – High Level Robot programming for industrial applications

Robot Programming and Control
Accademic Year 2021-2022

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Department of Computer Science – University of Verona
Altair Robotics Lab

Robotic programming and Control -- Course organization (2)

The course is divided in 2 modules:

- Low Level Robot Programming and Control – Module A
- High Level Robot Programming – Module B

Teachers

- Module A: Andrea Calanca – andrea.calanca@univr.it
- Module B: Diego Dall'Alba – diego.dallalba@univr.it

Teaching hours

- Tuesday 14:30 –16:30 – Lab. Ciberfisico
- Thursday 13:30 –16:30 – Lab. Ciberfisico

Office Hours:

- Appointment by e-mail

Assessment Methods And Criteria

- The exam will consist of a project addressing some topics discussed during the course.

Splitting between lab and theory is not strict!

Robotic programming and Control -- Course organization (2)

Assessment Methods And Criteria

- Each module will assign homework during the lecture period which will be independently verified. **Please refer to the detailed information provided by each teacher.**
- Each student must complete the homework of each module +
- Each student should complete a project related to only one of the two module.

Course Material

- Slides and Notes provided by the teacher.
- Lessons hand notes
- Shared Folder (Datasheet) + Suggested Links
- GitLab Repository

Overview

- Course Organization
- Personal introduction
- Module B program overview
- Why learning robotic programming
- Brief history and introduction to industrial manipulator
- From a robotic manipulator to a robotic cell

Personal Introduction: Diego Dall’Alba

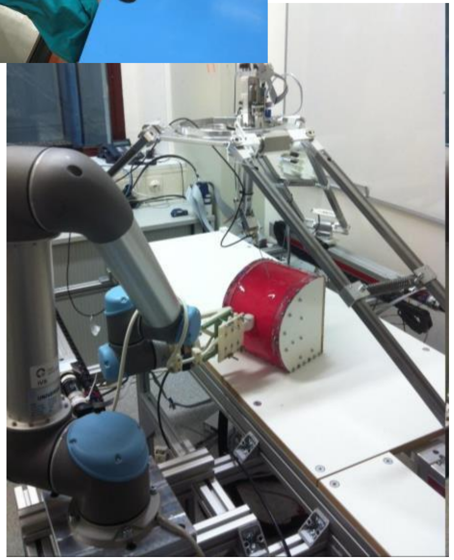
I am currently an Assistant Professor in Altair robotics lab – Department of Computer Science @ University of Verona (Italy)

I have worked in several European project: AccuRobAs, Safros, I-Sur, MURAB

Actually, I am actively involved in ARS and ATLAS

Office hours: appointment by email

diego.dallalba@univr.it



ALTAIR robotics lab

Module B – Program Overview

Everything you saw in robotics
….plus more!

- High level robot programming, focusing on industrial manipulator task
  - Modern approach to robotics: conventions and data representation
  - Motion planning: from general concepts to real robot motions
  - Robotic system integration: EE tooling, simple work-cell design, external com, and much more
- Software engineering for robotic applications:
  - Robotic middleware:
    - ROS case study: crash course + motion plan
    - ROS evolution: ROS Industrial and ROS2
  - Best practice in complex robotic projects

ROS.org

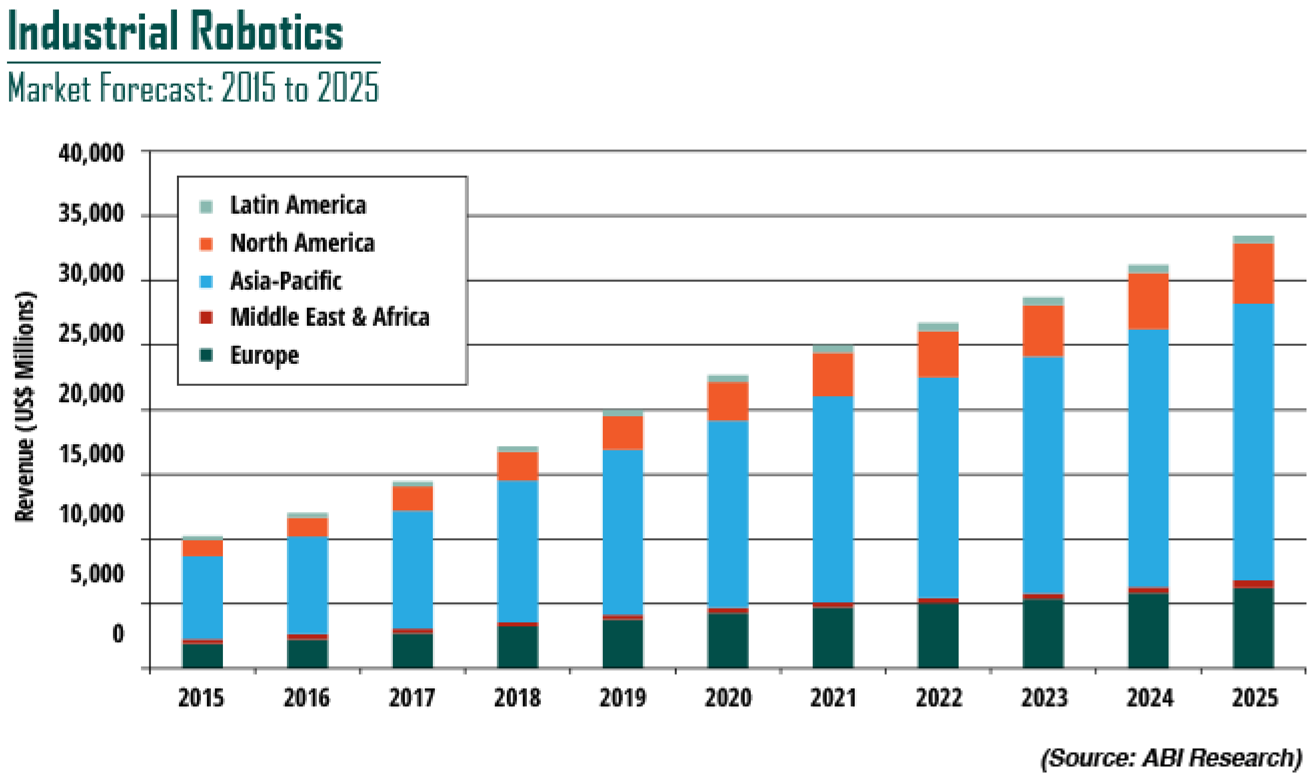
Why learning robotic programming?

↗ Increasing demand

1	Data Analysts and Scientists
2	AI and Machine Learning Specialists
3	Big Data Specialists
4	Digital Marketing and Strategy Specialists
5	Process Automation Specialists
6	Business Development Professionals
7	Digital Transformation Specialists
8	Information Security Analysts
9	Software and Applications Developers
10	Internet of Things Specialists
11	Project Managers
12	Business Services and Administration Managers
13	Database and Network Professionals
14	Robotics Engineers
15	Strategic Advisors
16	Management and Organization Analysts
17	FinTech Engineers
18	Mechanics and Machinery Repairers
19	Organizational Development Specialists
20	Risk Management Specialists

According to World Economic Forum 2020, Robotics Engineers are in the top 20 most requested jobs

Industrial robotics market is constantly increasing



http://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf

Why learning robotic programming?

1. Ingegnere robotico
2. Ingegnere del machine learning
3. Cloud architect
4. Ingegnere dei dati
6. Consulente di data management
9. Software account executive
10. Cyber security specialist
12. Data scientist
13. Sviluppatore back-end
20. Ingegnere full stack
21. Infrastructure architect

https://www.linkedin.com/pulse/linkedin-lavori-crescita-2022-le-25-professioni-ascesa-/

Technologies likely to be adopted by companies surveyed

Technology/Sector	AGRI (%)	AUTO (%)	CON (%)	DIGICIT (%)	EDU (%)	ENG (%)	FS (%)	GOV (%)	HE (%)	MANF (%)	MIM (%)	OILG (%)	PS (%)	TRANS (%)
3D and 4D printing and modelling	54	67	39	39	69	69	27	45	65	69	48	79	40	60
Artificial intelligence (e.g. machine learning, neural	62	76	73	95	76	81	90	65	89	71	76	71	76	88
New materials (e.g. nanotubes, graphene)	15	46	22	36	67	65	36	33	47	51	37	36	27	27
Power storage and generation	75	64	59	38	27	88	55	33	31	62	57	69	45	46
Quantum computing	18	21	17	51	25	41	44	36	38	21	29	25	19	38
Robots, humanoid	42	50	38	44	47	24	47	31	47	41	15	17	25	21
Robots, non-humanoid (industrial automation, drones, etc.)	54	60	52	61	59	65	53	50	56	79	90	79	35	69
Text, image and voice processing	50	59	82	90	89	88	88	89	88	64	76	87	79	65

Source

Future of Jobs Survey 2020, World Economic Forum.

Note

AGRI = Agriculture, Food and Beverage; AUTO = Automotive; CON = Consumer; DIGICIT = Digital Communications and Information Technology; EDU = Education; ENG = Energy Utilities & Technologies; FS = Financial Services; GOV = Government and Public Sector; HE = Health and Healthcare; MANF = Manufacturing; MIM = Mining and Metals; OILG = Oil and Gas; PS = Professional Services; TRANS = Transportation and Storage.

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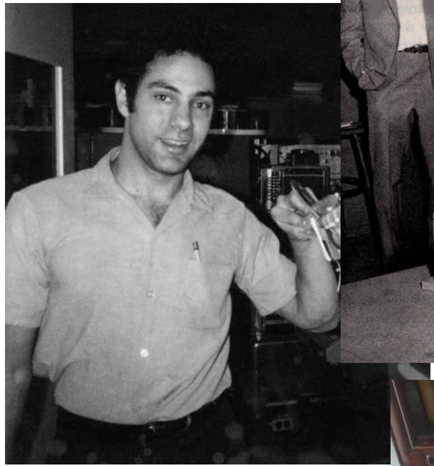
Robots will steel our jobs… but that ok!

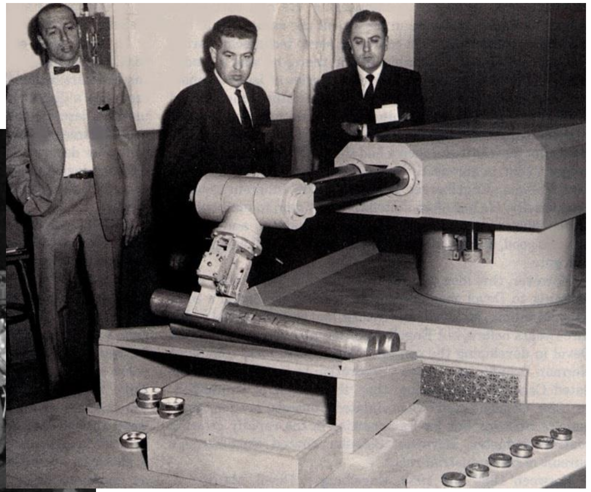
Brief history of industrial robotics (1)

George Devol applied for the first robotics patents in 1954 (granted in 1961). The first company to produce a robot was Unimation, founded by Devol and Joseph F. Engelberger in **1956**. Unimation robots were also called **programmable transfer machines**. They used hydraulic actuators and were programmed in joint coordinates, i.e. the angles of the various joints were stored during a teaching phase and replayed in operation.

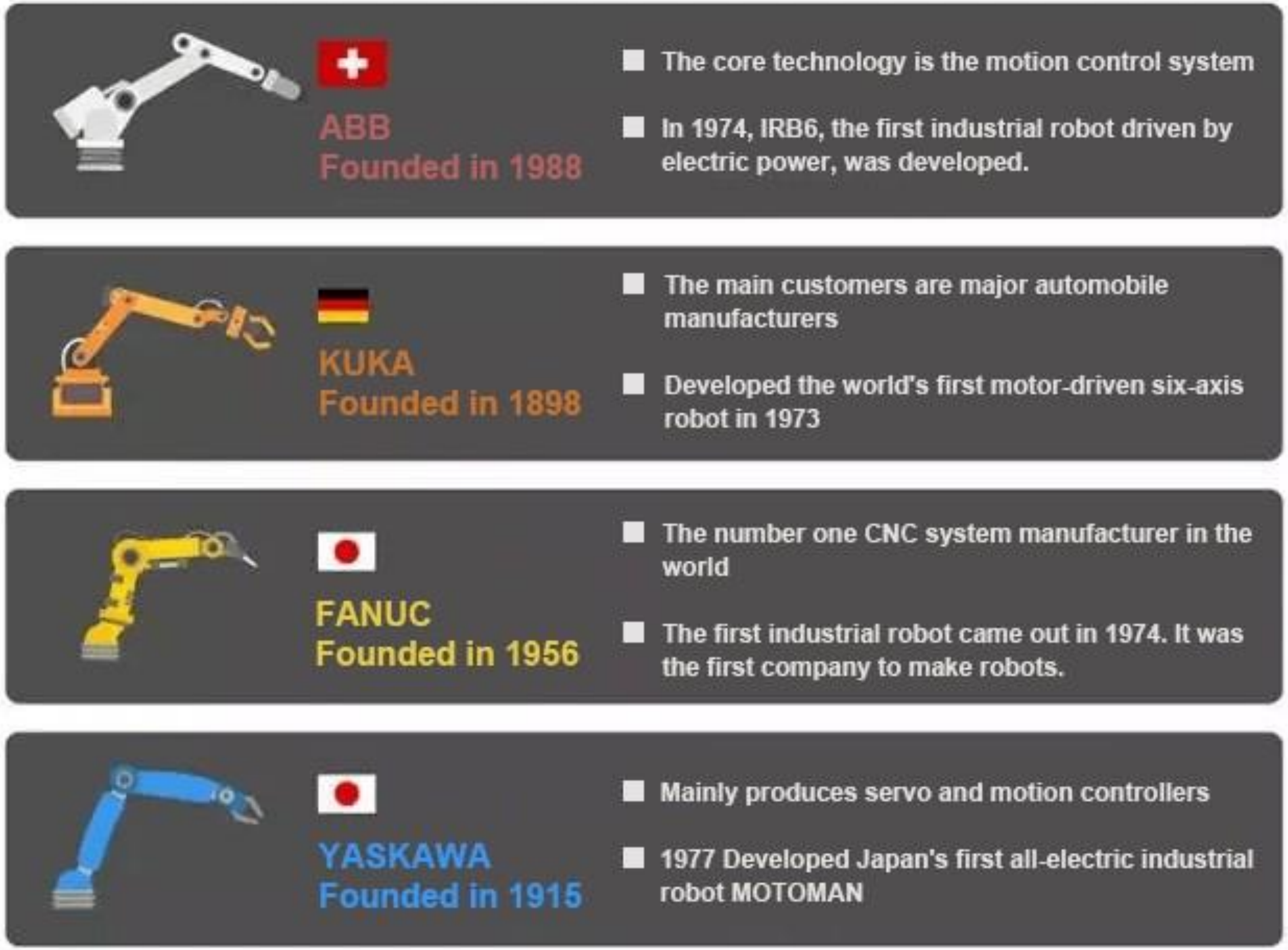
In **1969 Victor Scheinman** at Stanford University invented the **Stanford arm**, an all-electric, 6-axis articulated robot designed to permit an arm solution. This allowed it accurately to follow arbitrary paths in space and widened the potential use of the robot to more sophisticated applications such as assembly and welding. Scheinman sold those designs to Unimation who further developed them with support from General Motors and later marketed it as the **Programmable Universal Machine for Assembly (PUMA)**.

Starting from 1970 Industrial robotics took off quite quickly worldwide





Brief history of industrial robotics (2)



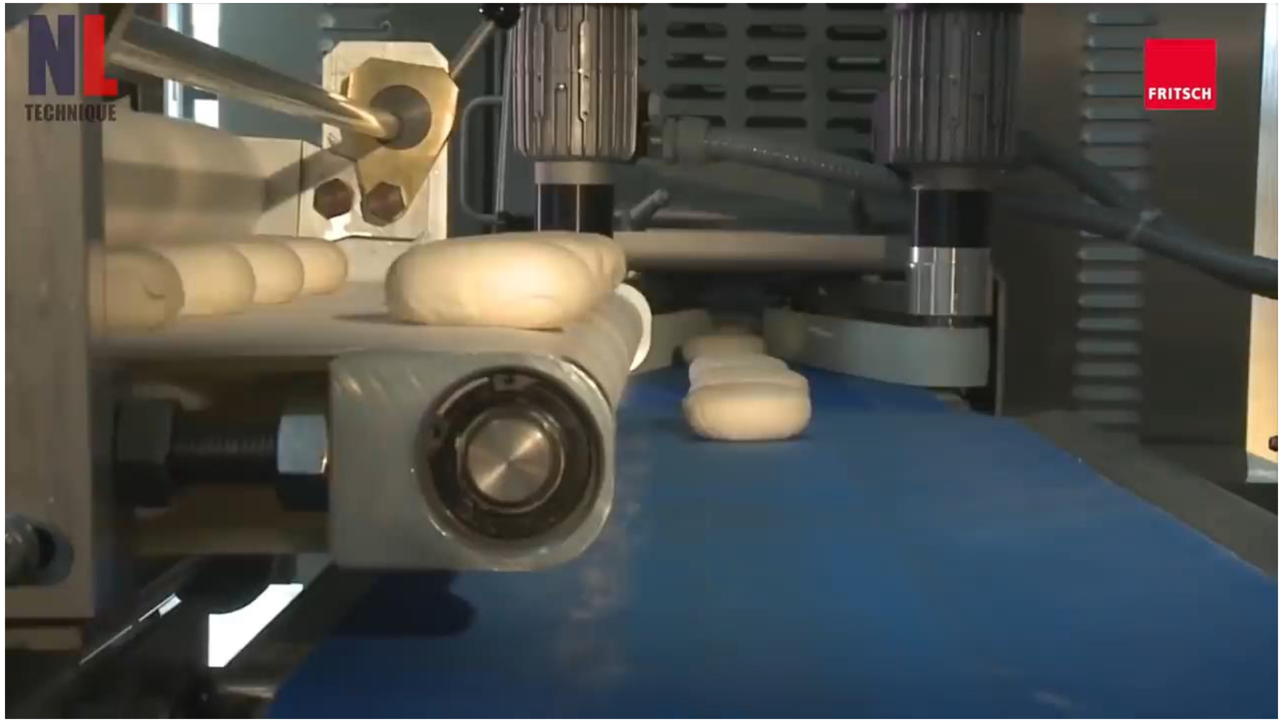
Company	Head Quarter
ABB	Zurich, Switzerland
YASKAWA	Kitakyushu, Japan
KUKA	Bavaria, Germany
FANUC	Yamanashi Prefecture, Japan
Kawasaki	Tokyo, Japan
EPSON	Tokyo, Japan
STÄUBLI	Pfäffikon, Switzerland
NACHI NACHI-FUJIKOSHI CORP.	Toyama, Japan
COMAU	Turin, Italy
omron adept	California, U.S.

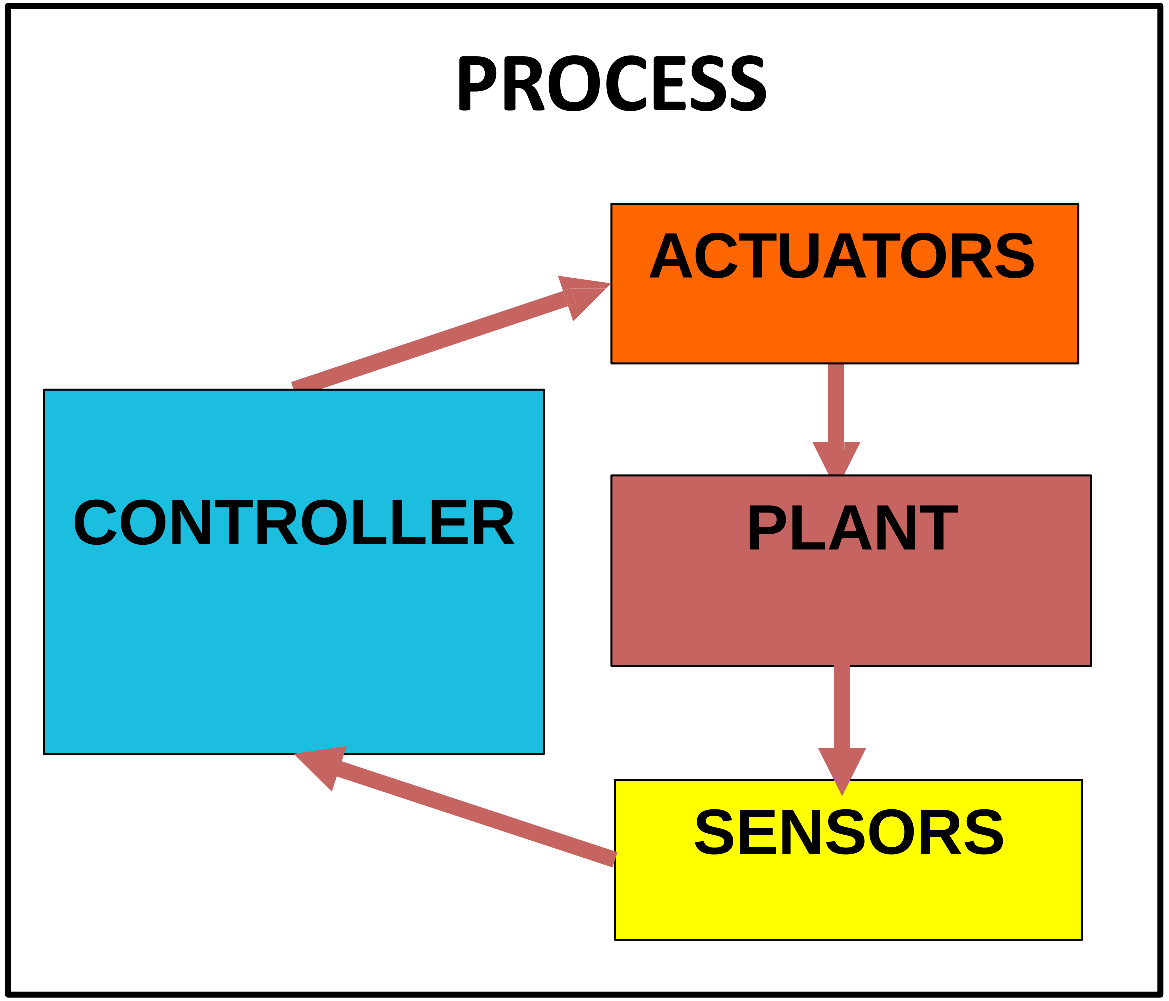
Automation VS Autonomy

- There is some ambiguity:
  - **What is “Autonomy” for some people is “Automation” for other**
- **Automation:**
  - **The technique of making an apparatus, a process, or a system operate with a self-acting or self-regulating mechanism (Merriam Webster)**
  - **It is the ability to carry out actions without Human interventions.**
  - These actions are well defined, can be described with precise rule, and they are done in a known and well-structured environment. Automation has a small and defined degree of adaptation.
- **Autonomy:**
  - **The quality or state of being “self-governing”, (Merriam Webster)**
  - **It is the ability to carry out complex tasks and take cognitive decisions.**
  - These actions are defined in general terms, executed adapting previous knowledge, in an unknown and uncertain environment with adaptation learned by the system.

The robot makes the new plan

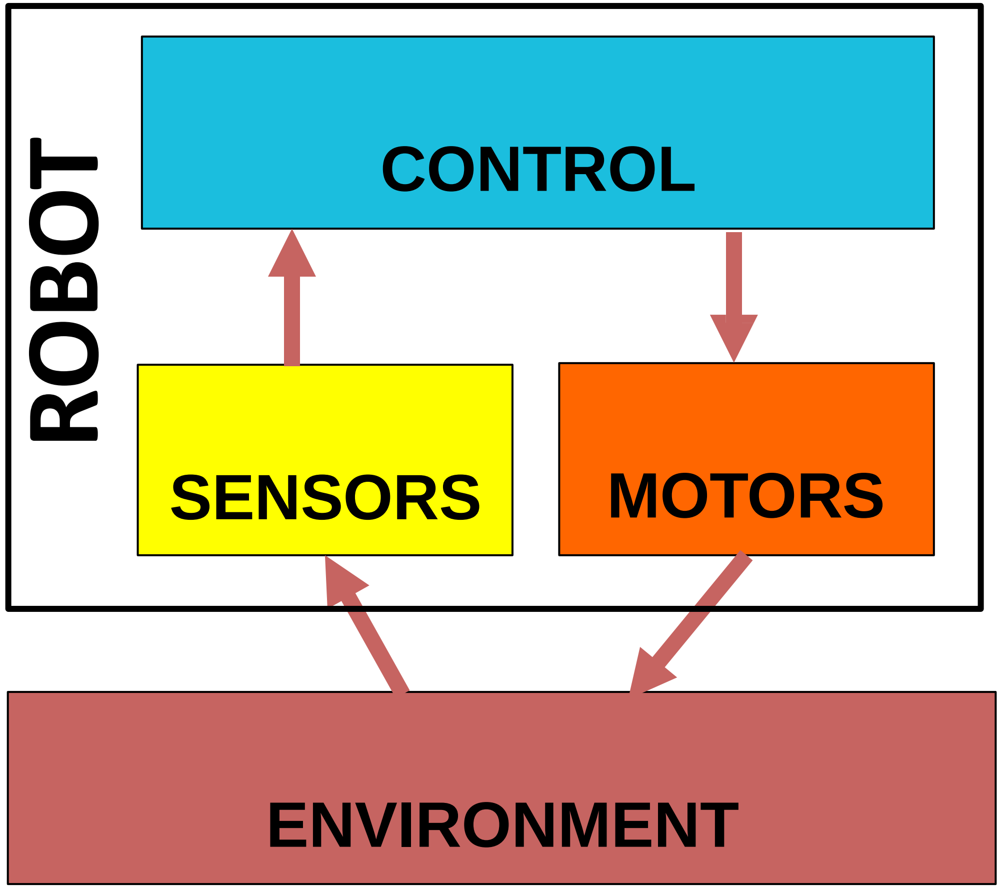
Automatic Control



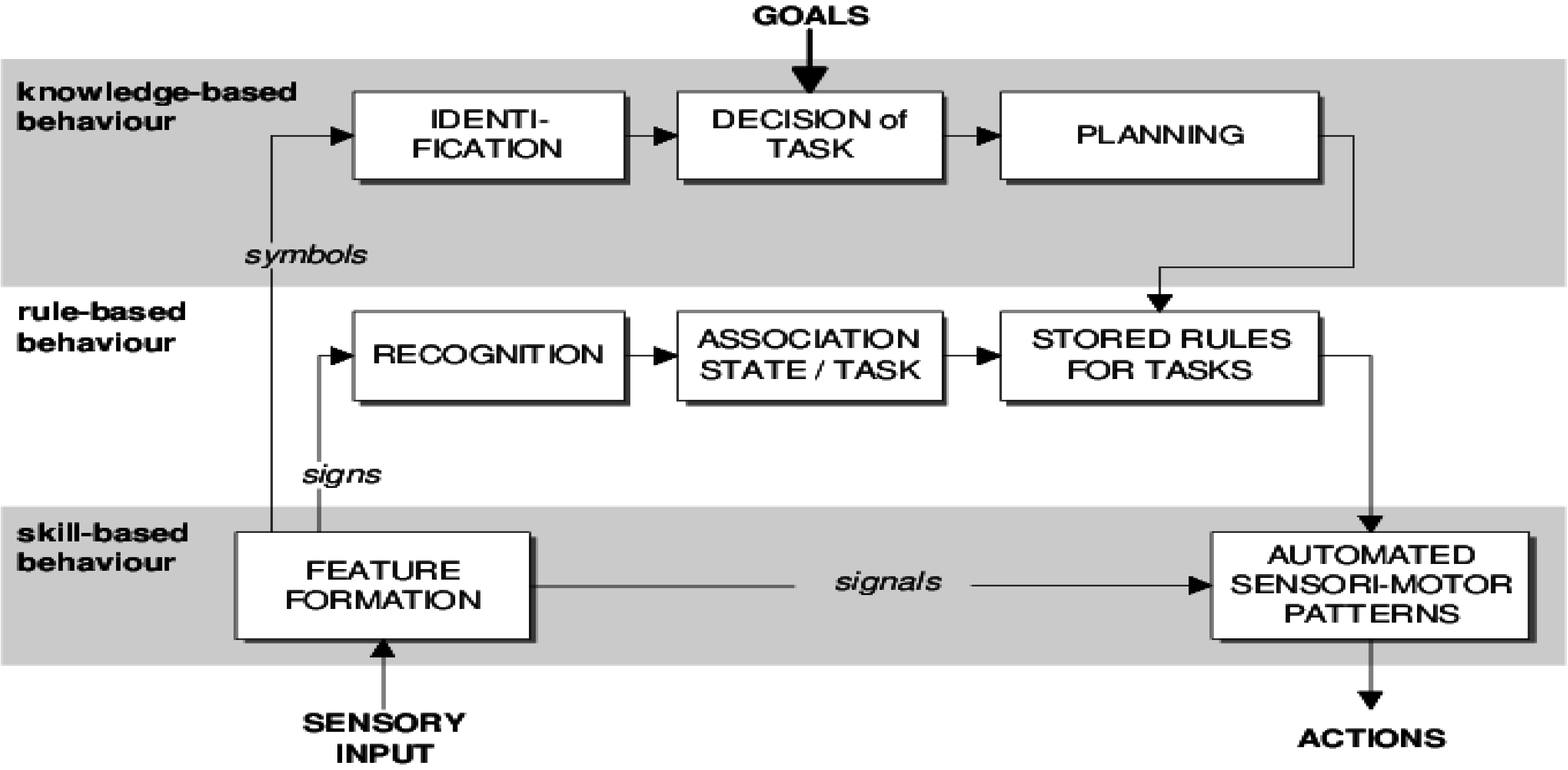


Robotics

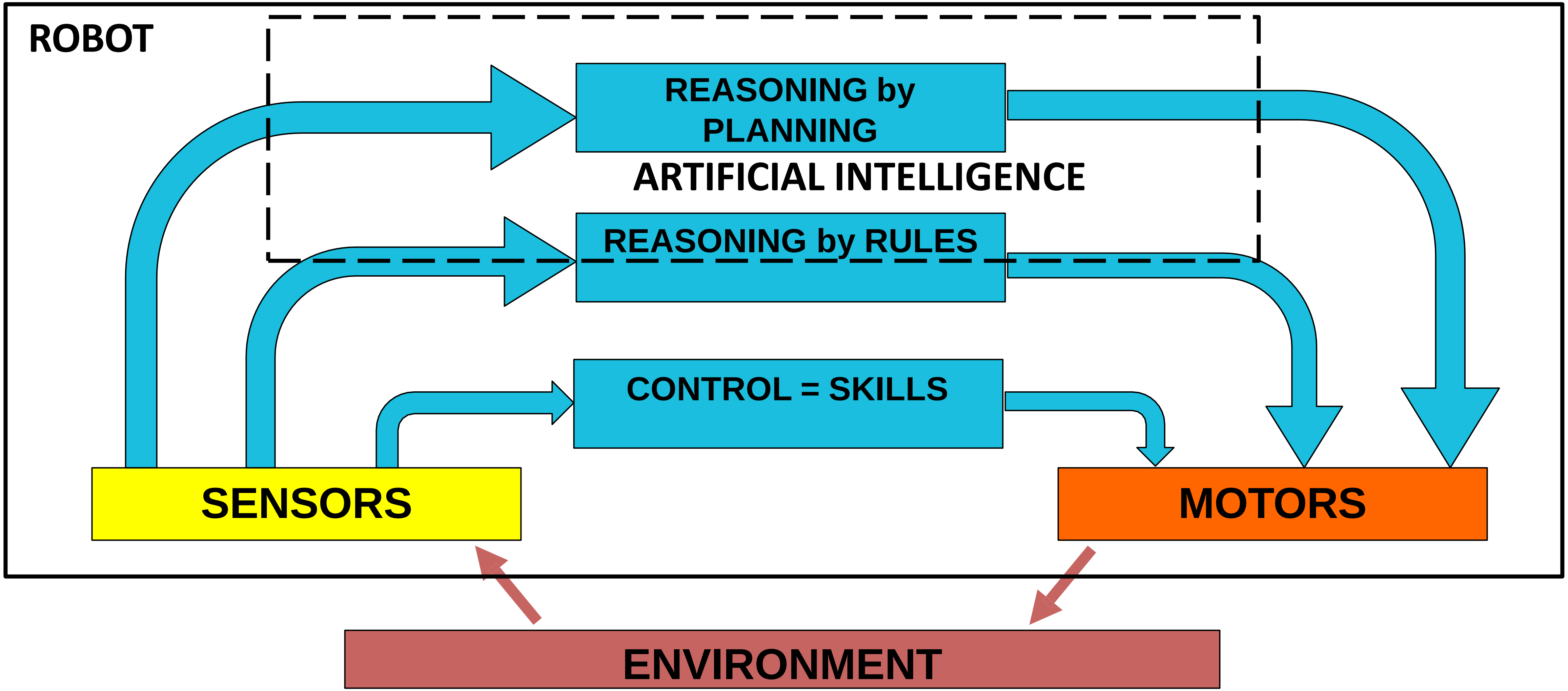
Robotics is the **Intelligent Connection between Perception and Action** to achieve a desired **Result**



Model of Human Reasoning (Rasmussen 1985)



Autonomous Robotics



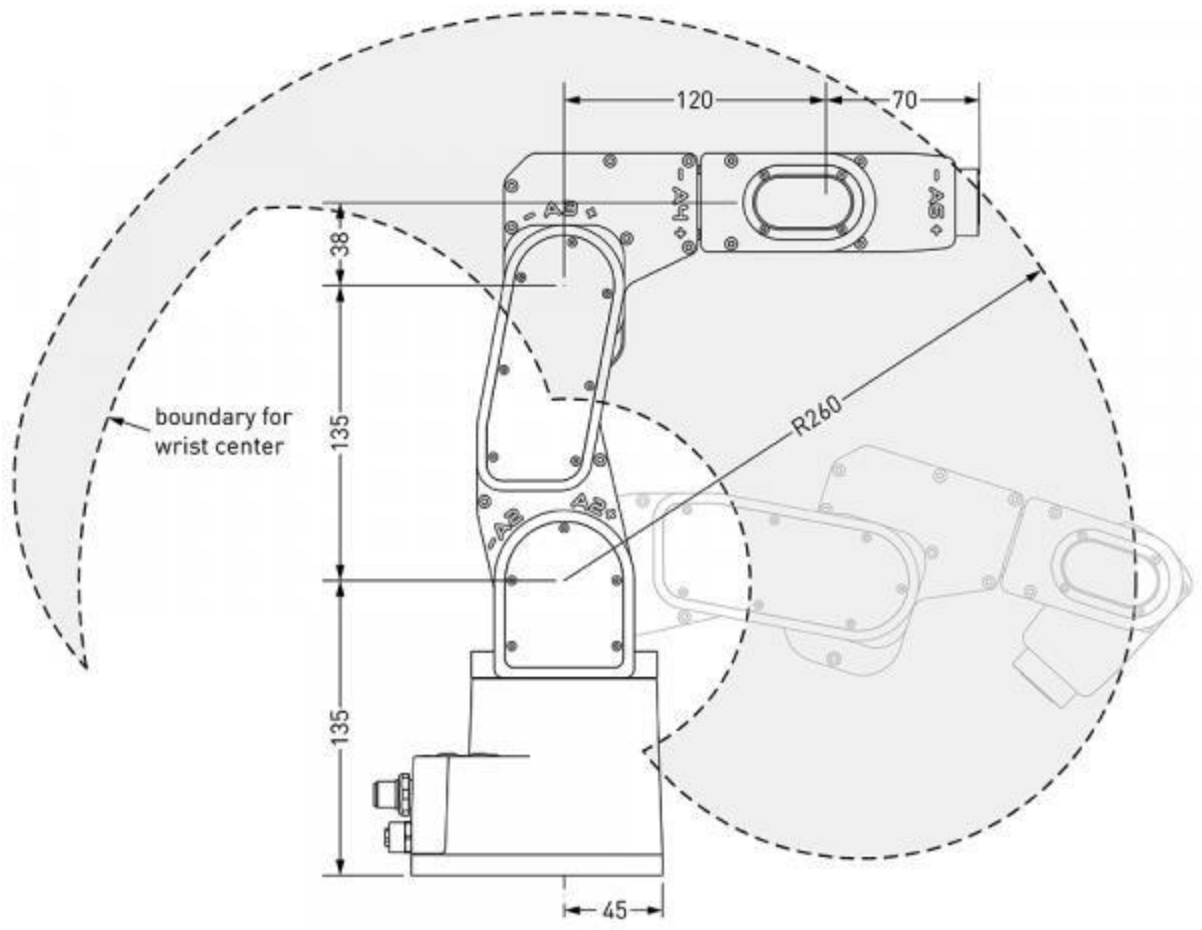
What is a industrial robot?

“An industrial robot is defined to be an ‘automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications.’ ”

Source: “International robot standardization within ISO,” IFR, https://ifr.org/standardisation

Which are the main characteristics/parameters?

- Number of axes or Degrees of freedom
- Kinematics arrangement
- Working envelope
- Carrying capacity or payload
- Speed and Acceleration
- Accuracy
- Repeatability

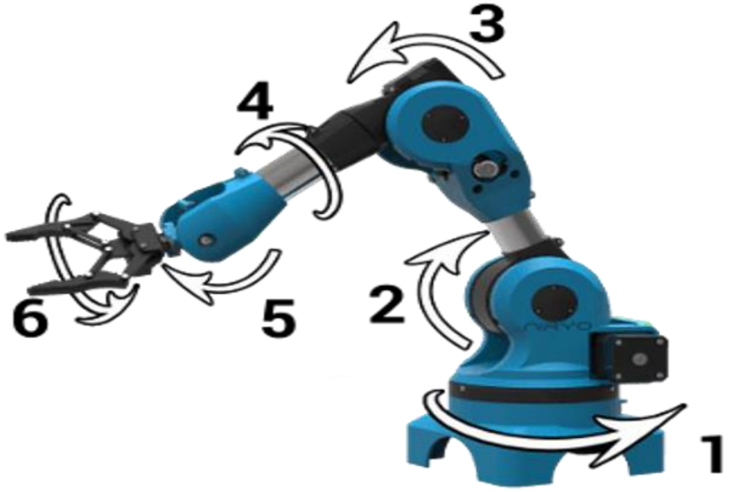


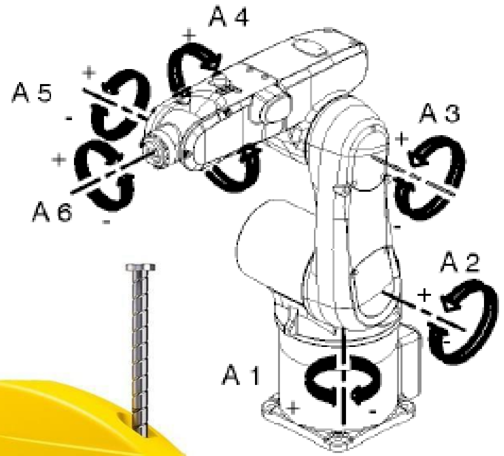
Number of axes or Degrees of freedom

The degrees of freedom (DoF) of a mechanical system is the number of independent parameters that define its configuration or state.

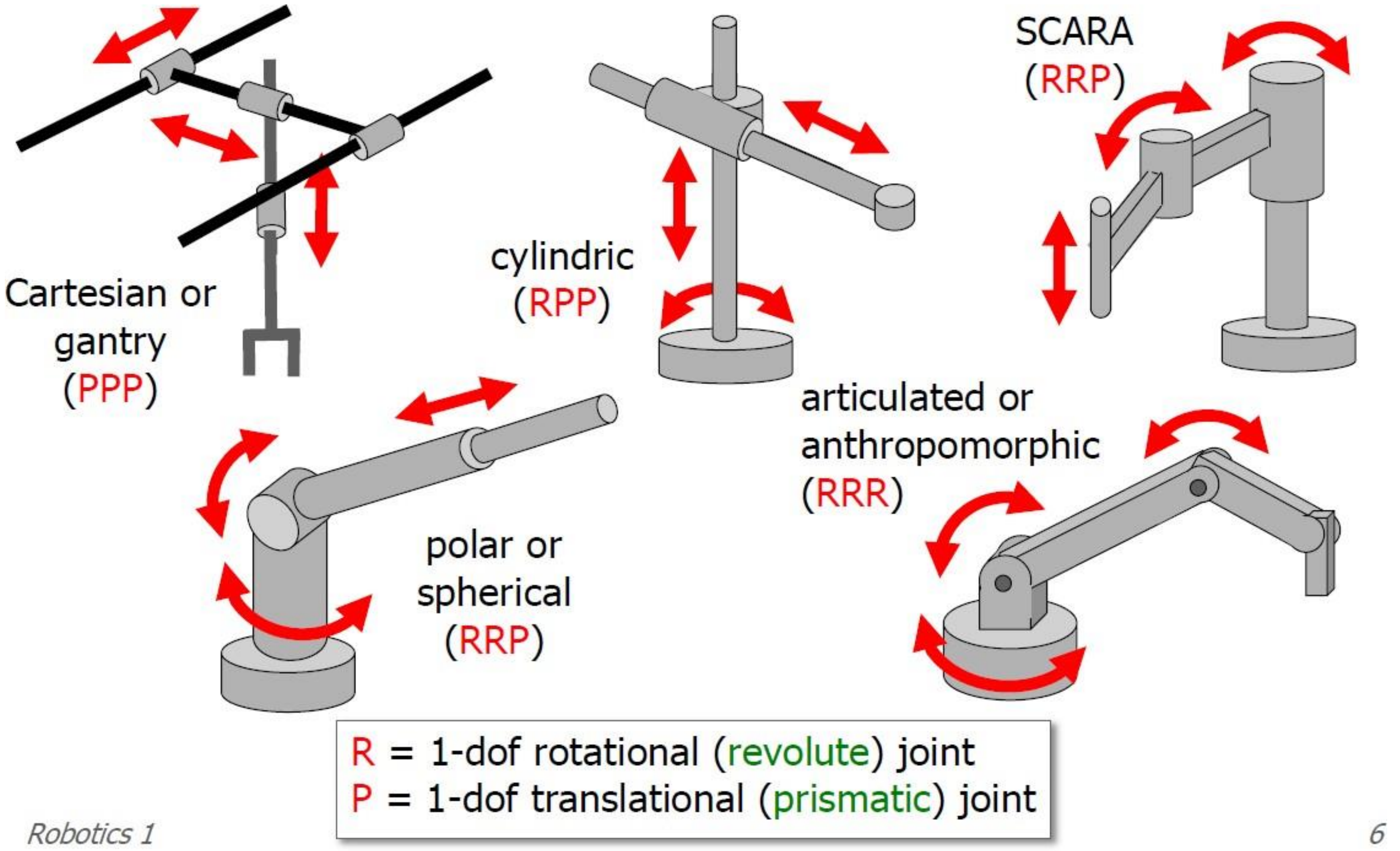
Two axes are required to reach any point in a plane;
Three axes are required to reach any point in space.
To fully control the orientation of the end of the arm(i.e. the *wrist*) three more axes (yaw, pitch and roll) are required.

Some designs (e.g. the SCARA robot) trade limitations in motion possibilities for cost, speed, and accuracy.





Kinematics arrangement

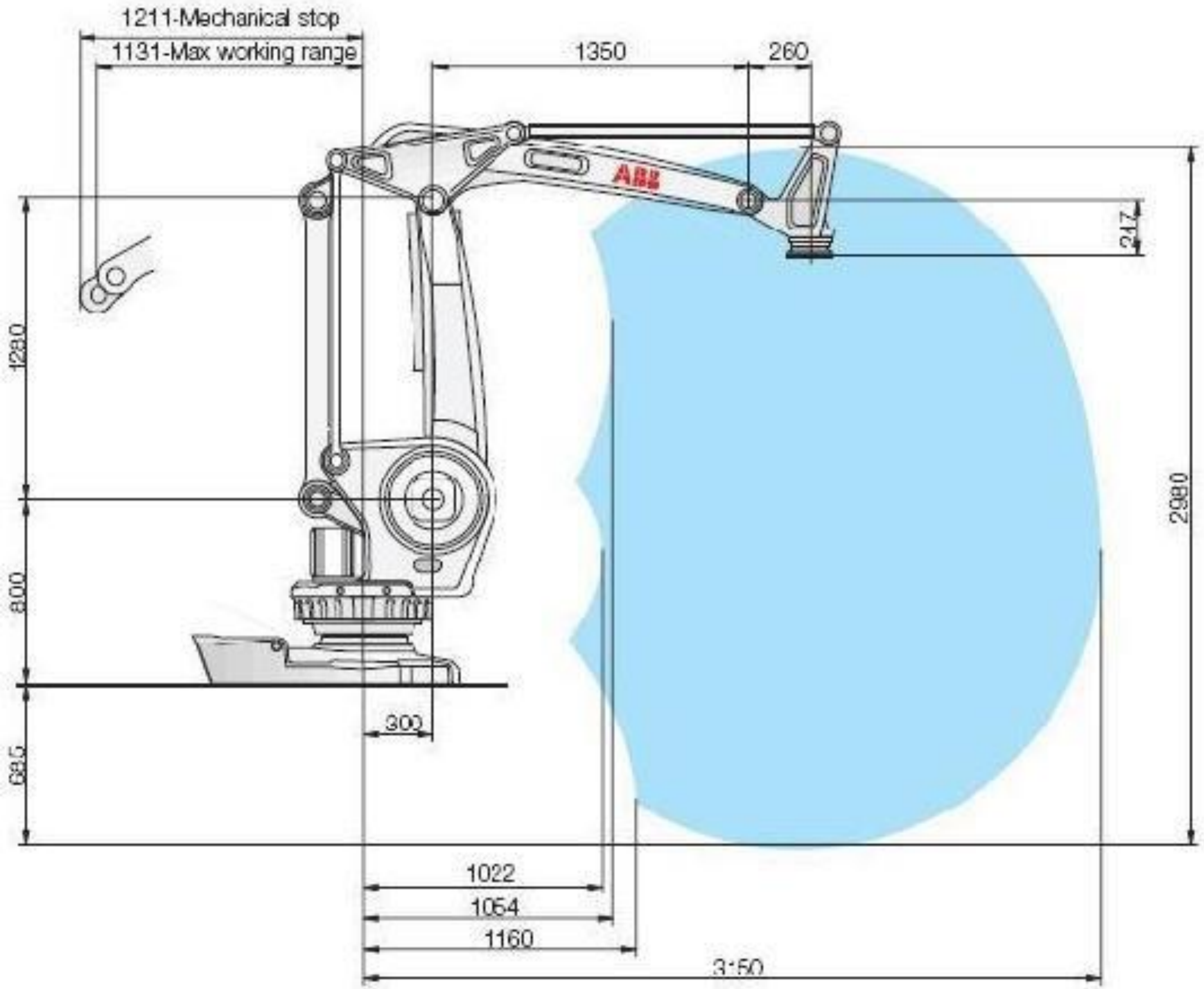


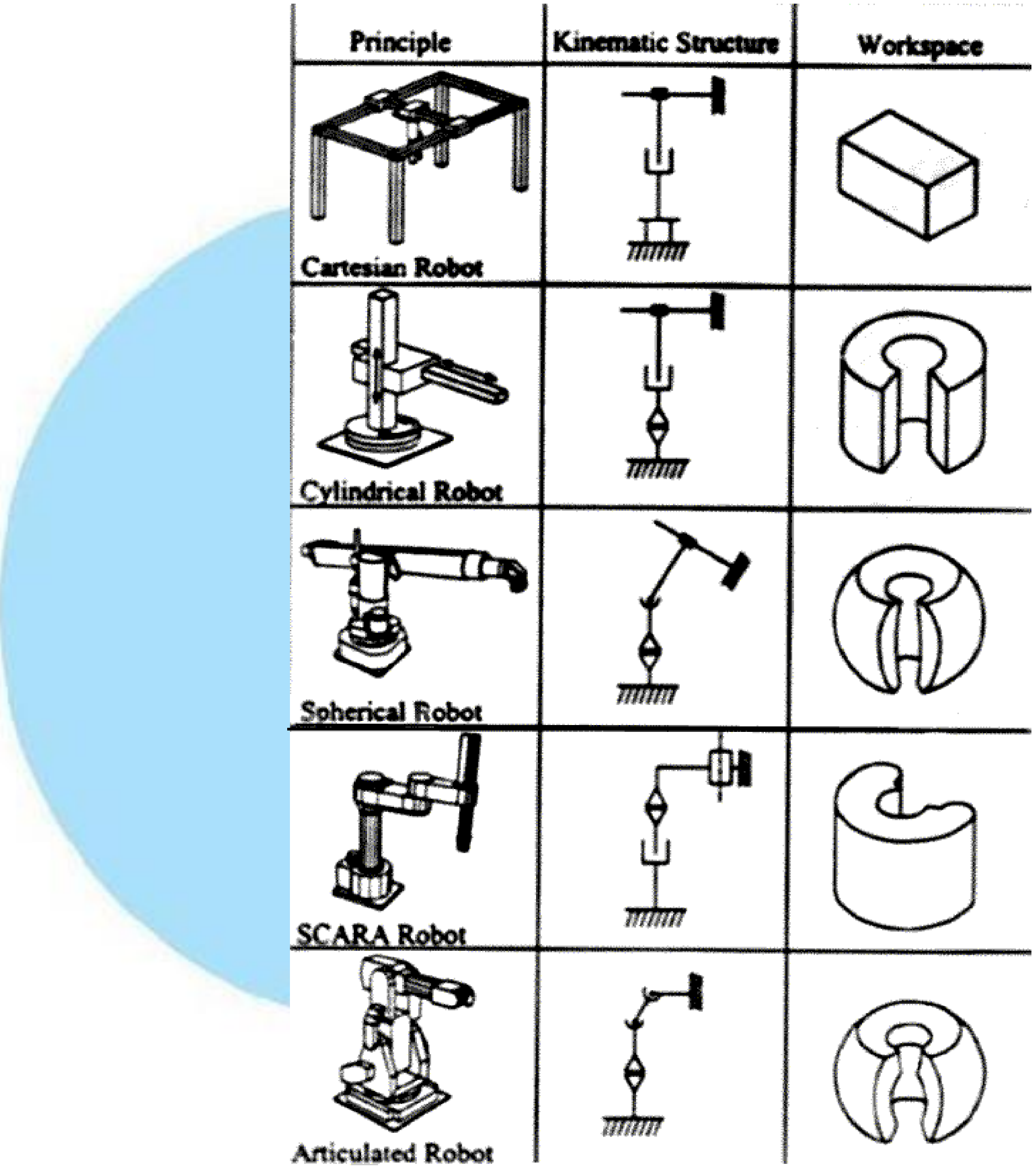
The actual arrangement of rigid members and joints in the robot, which determines the robot's possible motions.

Classes of robot kinematics include:

- cartesian,
- cylindric
- SCARA,
- polar,
- articulated,
- Parallel,
- and many more…

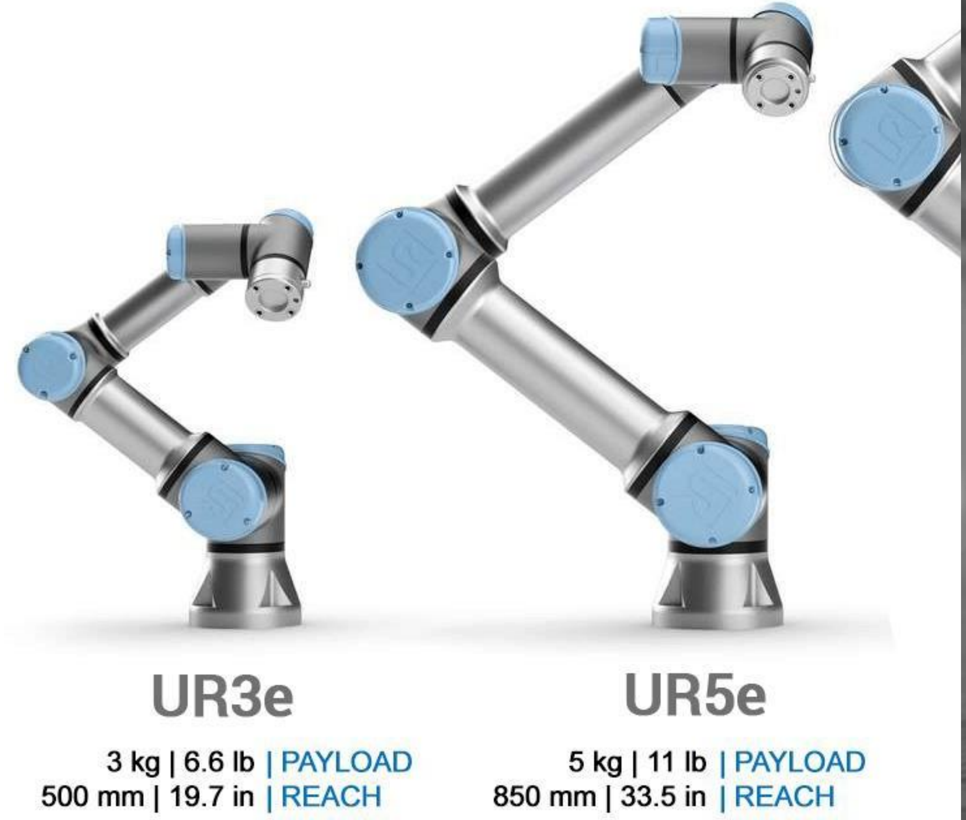
Working envelope





The region of space a robot can reach.

Carrying capacity or payload



Speed and Acceleration

Speed – how fast the robot can position the end of its arm. This may be defined in terms of the angular or linear speed of each axis or as a compound speed i.e. the speed of the end of the arm when all axes are moving.

Acceleration – how quickly an axis can accelerate. Since this is a limiting factor a robot may not be able to reach its specified maximum speed for movements over a short distance or a complex path requiring frequent changes of direction.

Accuracy and Repeatability (Precision)

Accuracy – how closely a robot can reach a commanded position. When the absolute position of the robot is measured and compared to the commanded position the error is a measure of accuracy. Accuracy can be improved with external sensing, for example a vision system

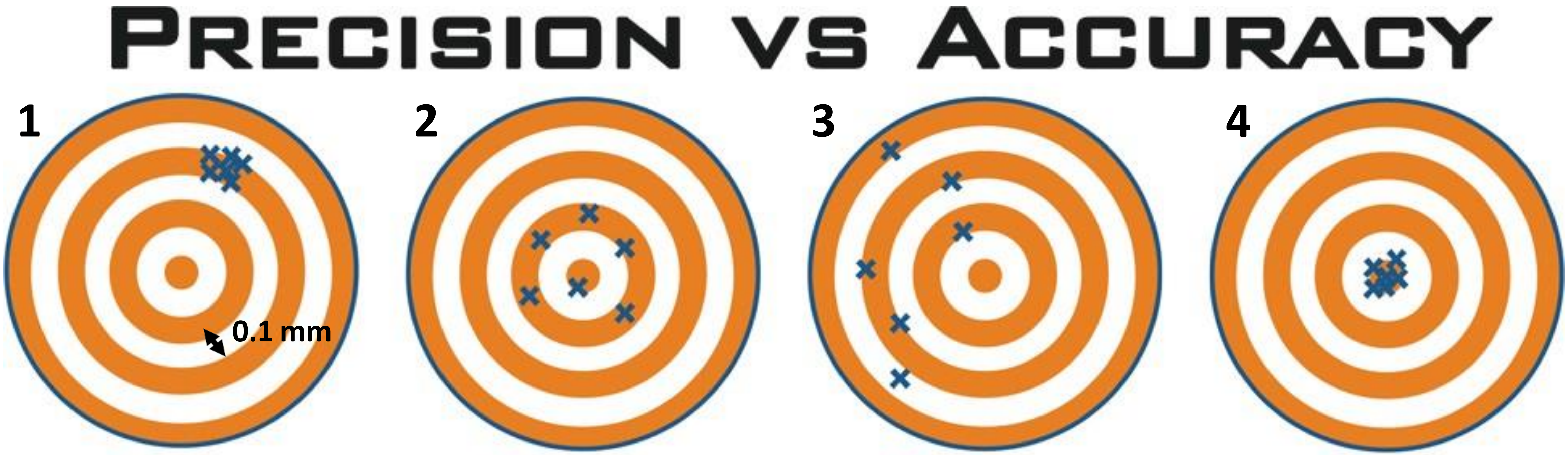
See Robotic Vision and Control

Accuracy can vary with speed and position within the working envelope and with payload.

Repeatability – how well the robot will return to a programmed position. <u>This is not the same as accuracy</u>.

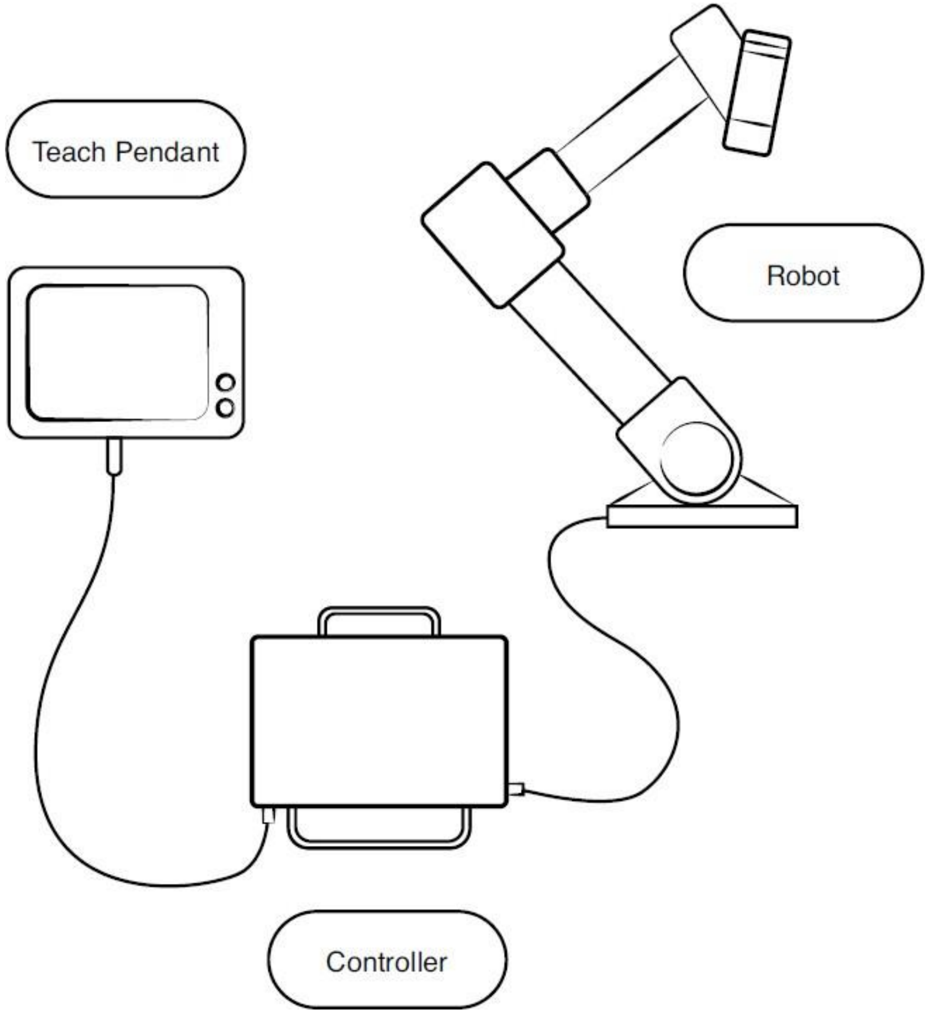
It may be that when told to go to a certain X-Y-Z position that it gets only to within 1 mm of that position. This would be its accuracy which may be improved by calibration. But if that position is taught into controller memory and each time it is sent there it returns to within 0.1mm of the taught position then the repeatability will be within 0.1mm.

Accuracy VS Precision



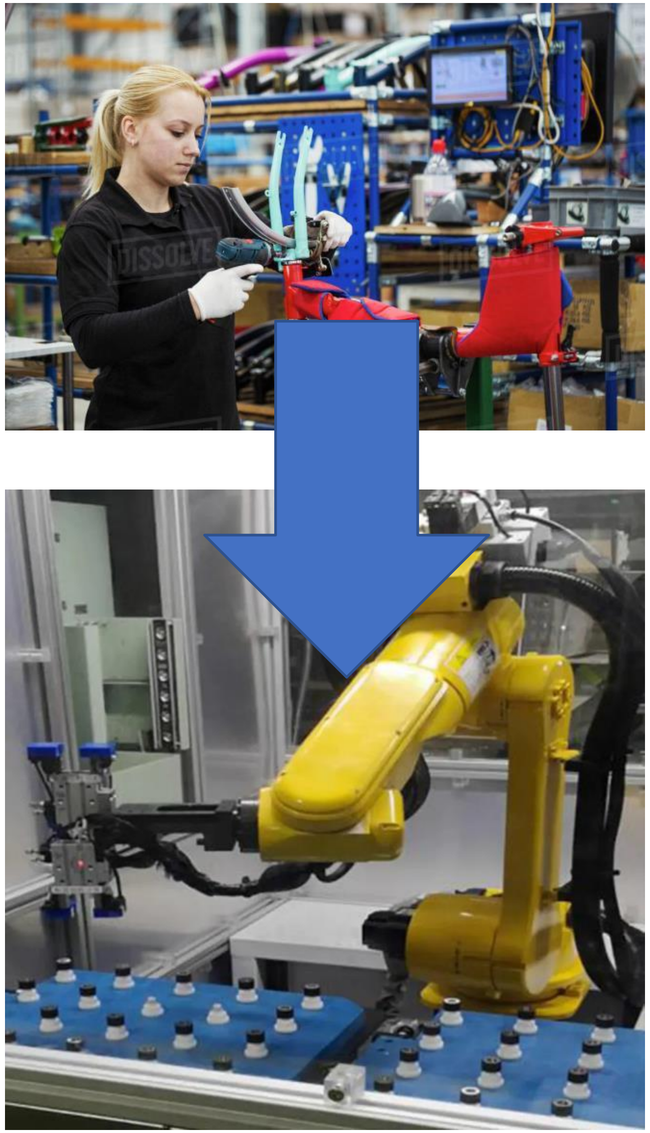
Which is the most accurate plot? And the most precise?

Main components of an industrial manipulator

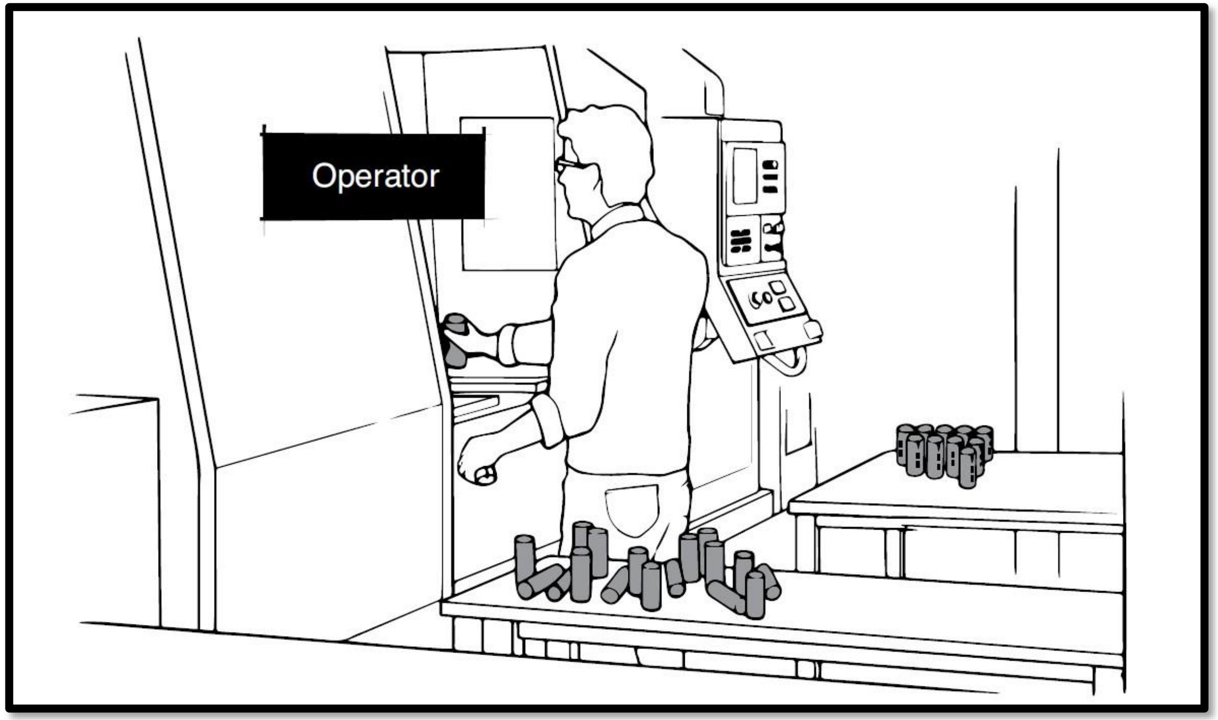


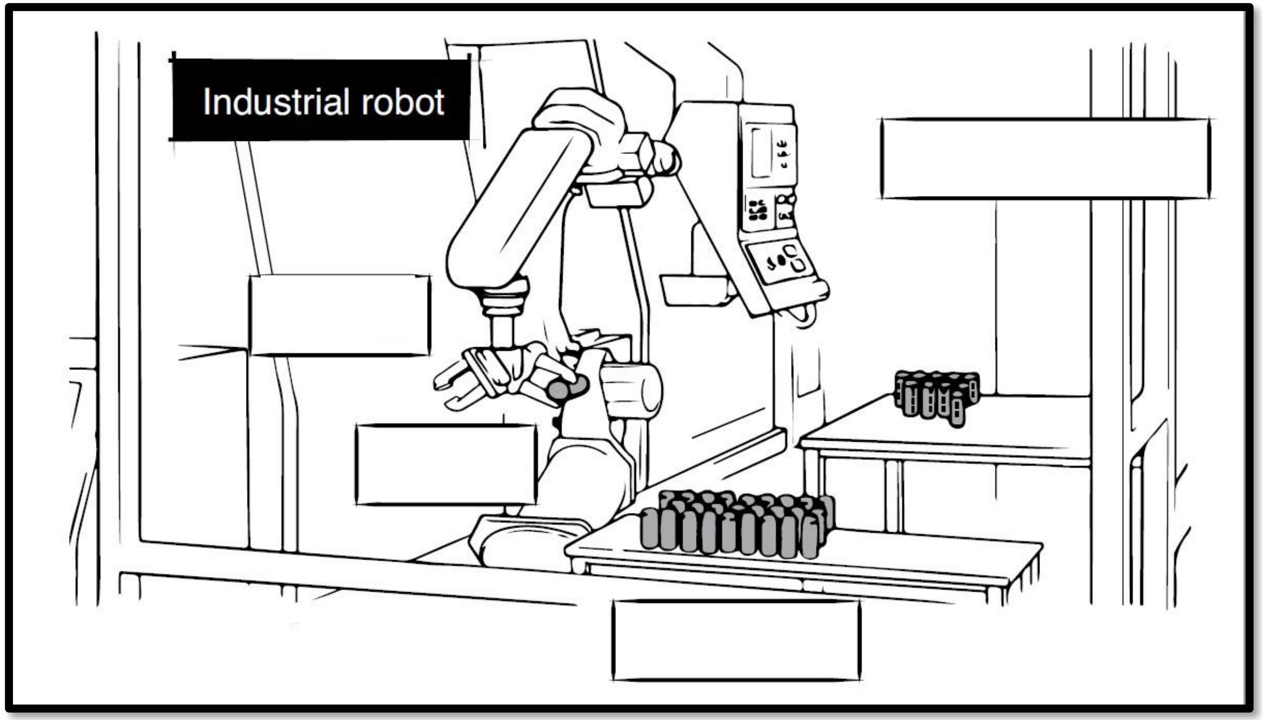
From a robotic manipulator to a robotic cell

There is not much you can do with just a robotic arm.
You need other components too to enable the robot to perform useful manufacturing tasks.
That's why it makes more sense to talk about **a robotic cell** rather than just a robot.
In general, a cell is any station in the manufacturing process, such as on a production line, where a specific operation is being done.
If the operation is done by a human, the station is known as a manual cell.
When factories install a robotic cell, their purpose is to automate a process.
That process could be one that's currently done at a manual cell, or it could be an entirely new function.
As you may have guessed by now, a robotic cell is simply a station that includes at least one robot



Human station VS robotic cell





Find the differences!

Example of a typical robotic cell

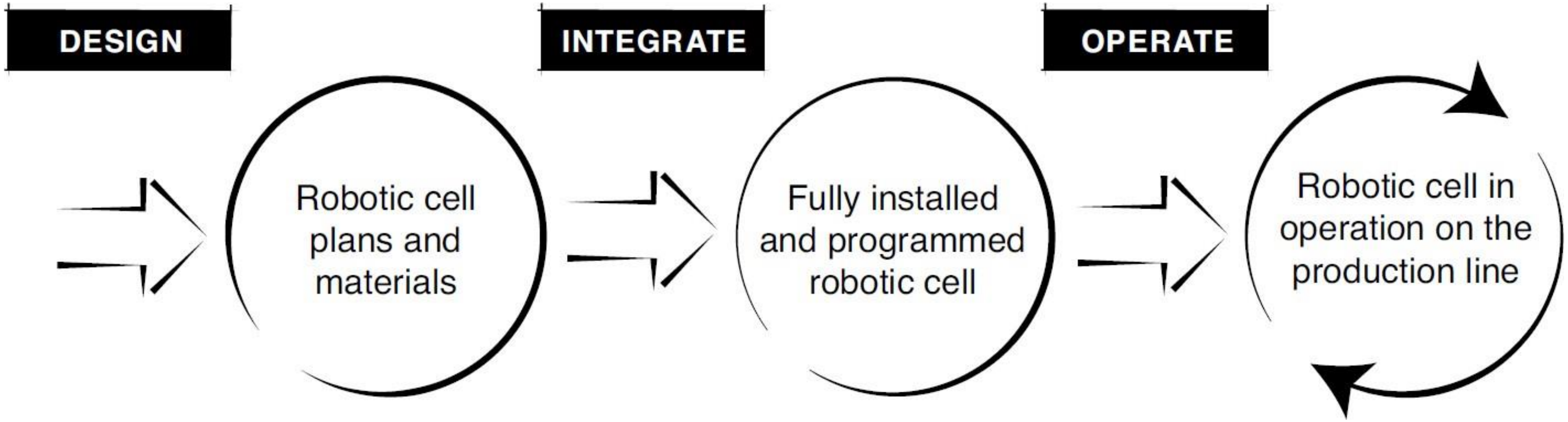
Collaborative robotic cell

Human-robot collaboration

Requires dedicated collaborative robot (cobot) able to share the same workspace respecting strict safety constraints

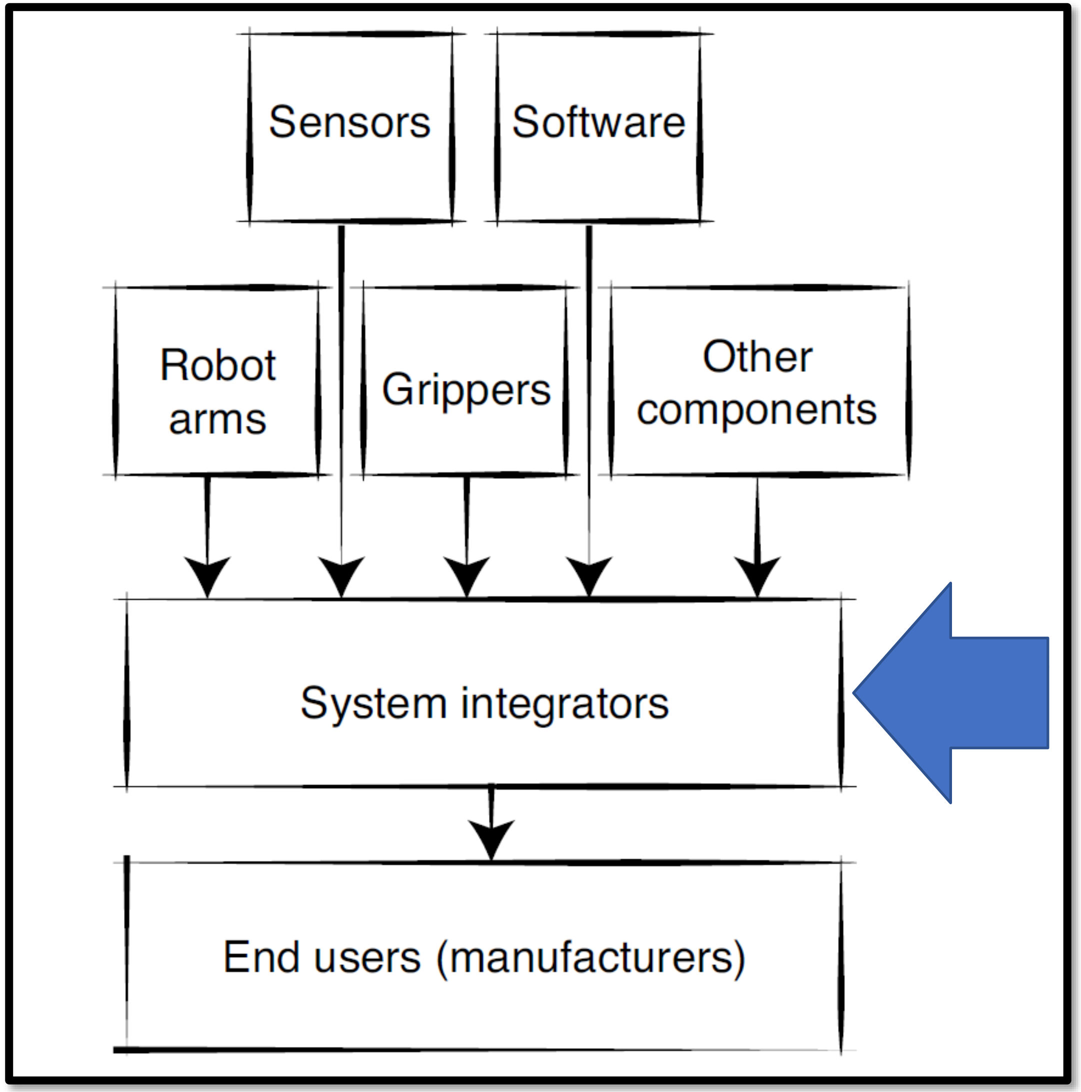
Which are the limits of this solutions?

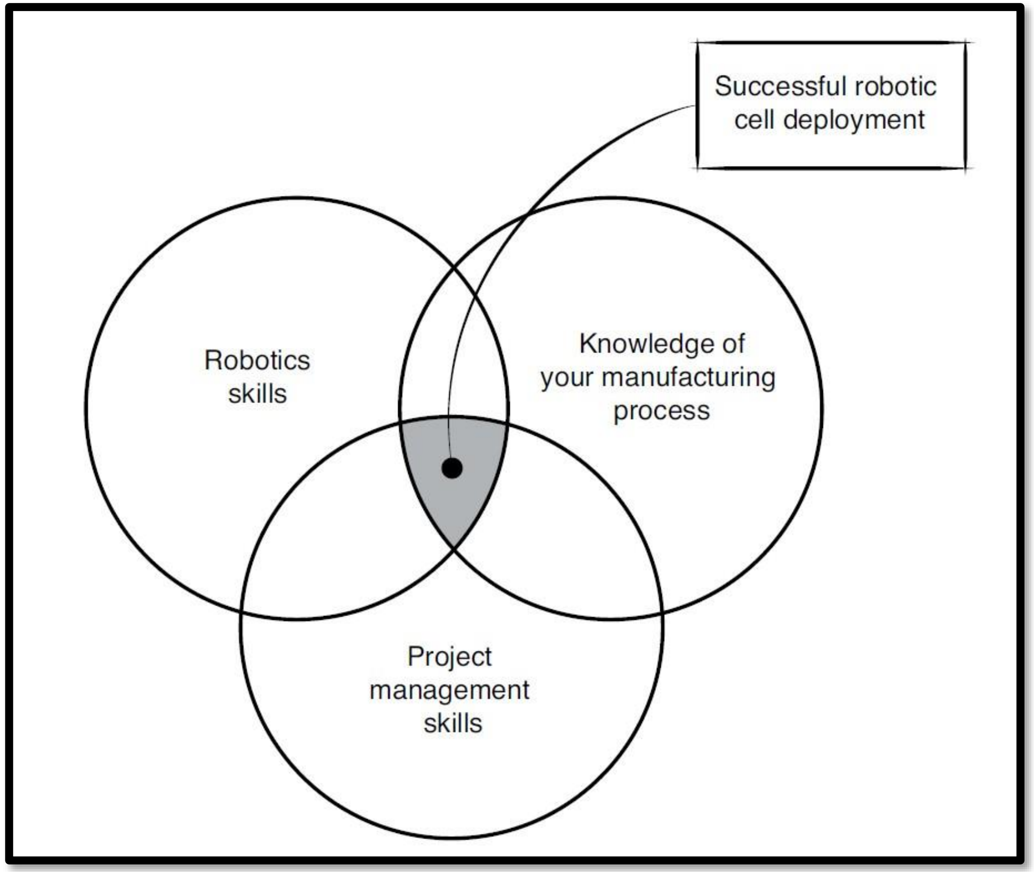
Robotic cell deployment cycle



- The **design phase** includes all the tasks needed to go from the manual (or original) process to having the plan and materials for the robotic cell.
- the **integrate phase** consists of putting the pieces of the robotic cell together, programming it, and installing the cell on the production line.
- The **operate phase** represents the end goal of deployment: having a productive robotic cell that does its job properly on an ongoing basis.

The role of system integrators in this process…





Most of the time you need a team with different skills to successfully deploy a robotic cell.

Questions?

The contents of these slides are partially based on: