ANALYSIS OF EXISTING ROBOTS CLASSIFICATIONS

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INDEX

INTRODUCTION

This document introduces potential classifications of robots by the point of view of the technician. It is important to understand which are the key issues that a technician points out in its work to better move towards a common ground of reciprocal understanding.

The first part of the document illustrated technical classifications, aimed at describing working features of the machine or its application area.

The main classifications in this direction build on features of the robots which are not linked to interaction with humans but that are technological features facilitating the assigned task.

This makes clear the current initial point of view of the designer, whose focus is on the goal to be accomplished by the machine and its feasibility in terms of needed components.

The second part of the document reports about an existing classification focusing on the human robot interaction, so closer to REELER approach.

Next step in our analysis will be a reviewing of the current classification to design a comprehensive one that may gather the two perspectives in view of the definition of Human Proximity Levels (HPL) that may be accepted and used by the robot developers community.

Just to be noticed that the same concept of proximity may be differently interpreted in the human sciences and technological sciences communities.

ROBOTS' TAXONOMY

Robotics, intended as "the branch of technology that deals with the design, construction, operation, and application of robots" [1] is a wide, complex and multidisciplinary matter, therefore the classification of robots is not trivial nor unique. According to the highlighted characteristic, e.g. mechanical structure, task, morphology, they can be classified in different ways.

First of all, it is fundamental to state what is intended for robot. The definition is given in the ISO standard 8373:2012 [2] created to specify vocabulary used in relation with robots and robotic devices operating in both industrial and non-industrial environments. Thus **a robot is an actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks**. To do that four main subsystems can be identified (Figure 1):

- sensors used to perceive the surrounding environment;
- actuators, e.g. servomotors, to interact with the environment;
- a control structure i.e. the brain of the robot;
- the mechanical structure of the robot itself.

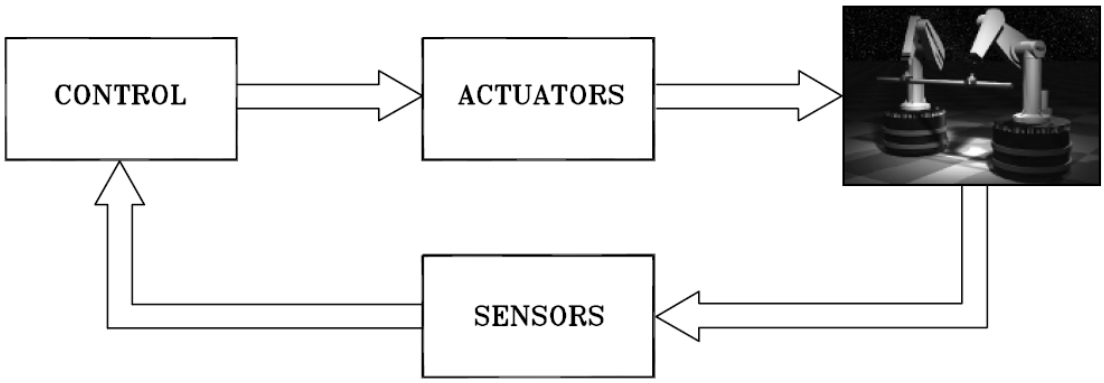

Figure 1 Components of a robotic system [2]

A first distinction can be done based on the mechanical structure of robots. They can be divided into fixed robots, i.e. manipulators (Figure 2), and mobile robots. Furthermore, mobile robots can be divided into wheeled, tracked, legged and undulating [3].

A second and more meaningful classification is done according to the working environment. Robotics can be divided into industrial and advanced. Industrial robotics is located in a structured environment whose geometrical or physical characteristics are mostly known a priori. Three main working areas can be identified: material handling, manipulation and measurements. On the other hand, advanced robotics operates in unstructured environments, whose geometrical or physical characteristics would not be known a priori. It can be further divided into field robotics, i.e. the working environment is not safe, and service robotics, i.e. its scope is to improve quality of life (Figure 3) [3].

Figure 2 ABB manipulator

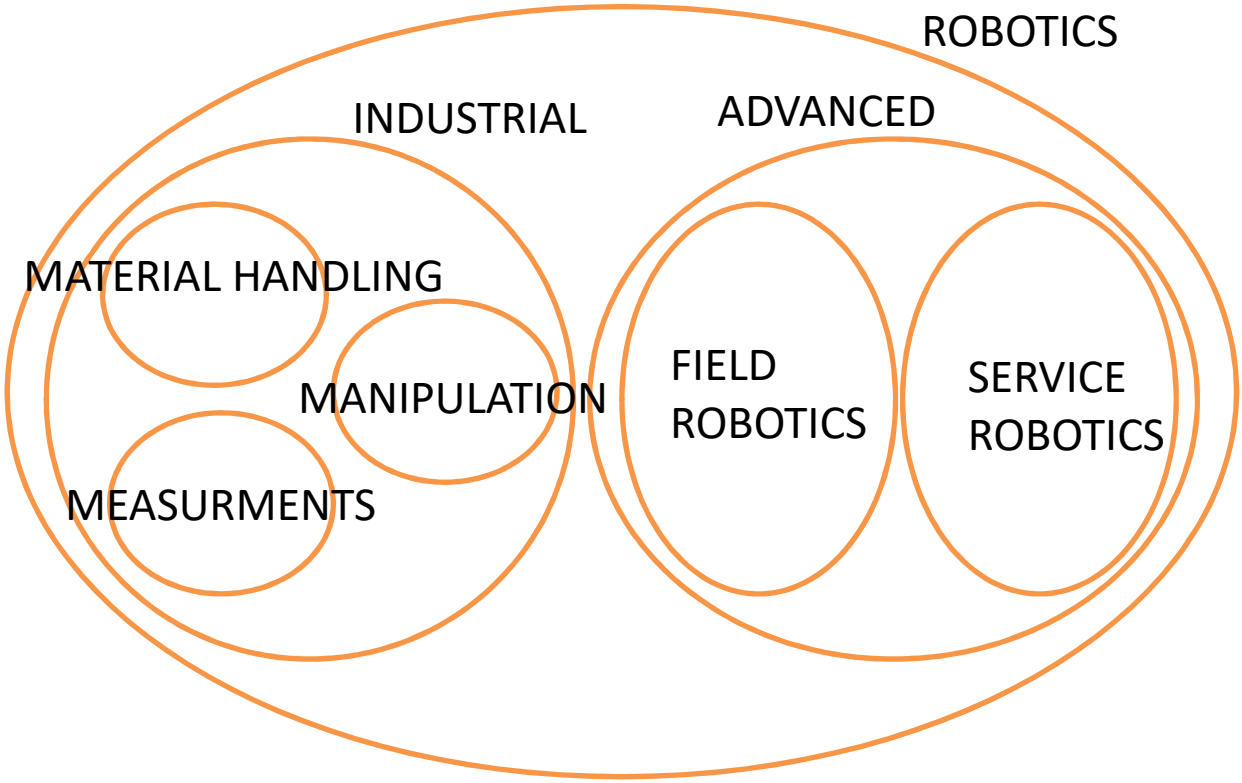

Figure 1 Robots' classification according to work environment

A third and more formal classification, similar to the previous one, is given in [4]. Following the ISO nomenclature [2] robots are mapped in industrial robots and service robots that are also separated in personal service robots and professional service robots. The definition of industrial robot is: "an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications" [2]. In the same way service robot is: "a robot that performs useful tasks for humans or equipment excluding industrial automation application" [2]. The additional distinction is done whether the robots is used for commercial or non-commercial tasks.

A list of a wide range of service robots is given below [4].

Personal / Domestic Robots

Robots for domestic tasks

- Robot butler/companion/assistants/humanoids
- Vacuuming, floor cleaning
- Lawn mowing
- Pool cleaning
- Window cleaning

Entertainment robots

- Toy/hobby robots
- Robot rides
- Pool cleaning
- Education and training

Handicap assistance

- Robotized wheelchairs
- Personal rehabilitation
- Other assistance functions

Personal transportation (AGV for persons)

Home security & surveillance

Professional Service Robots

Field robotics

- Agriculture
- Milking robots
- Forestry
- Mining systems
- Space robots

Professional cleaning

- Floor cleaning
- Window and wall cleaning (including wall climbing robots)
- Tank, tube and pipe cleaning
- Hull cleaning (aircraft, vehicles, etc.)

Inspection and maintenance systems

- Facilities, Plants
- Tank, tubes and pipes and sewer
- Other inspection and maintenance systems

Construction and demolition

- Nuclear demolition & dismantling
- Other demolition systems
- Construction support and maintenance
- Construction

Logistic systems

- Courier/Mail systems
- Factory logistics (incl. Automated Guided Vehicles for factories)
- Cargo handling, outdoor logistics
- Other logistics

Medical robotics

- Diagnostic systems
- Robot assisted surgery or therapy
- Rehabilitation systems
- Other medical robots

Defence, rescue & security applications

- Demining robots
- Fire and bomb fighting robots
- Surveillance/security robots
- Unmanned aerial vehicles
- Unmanned ground based vehicles

Underwater systems

Mobile Platforms in general use

Robot arms in general use

Public relation robots

- Hotel and restaurant robots
- Mobile guidance, information robots
- Robots in marketing
- Others (i.e. library robots)

Special Purpose

- Refuelling robots
- Others

Customized robots

An interesting aspect is the quantification of robots in the world. Figure 4 shows the number of industrial robots supplied since 2003, in 2015 253,748 industrial robots have been sold. Figure 5 shows the quantity of service robots for professional use sold in 2014-2015 in four main areas. The total of service robots sold in 2015 have been 41,060. Thus, can be observed that the majority of robots belongs to the industrial environment, meanwhile service robots are a minor part. However, is important to notice a huge growth in service robots' sales estimated for the next years (Figure 6).

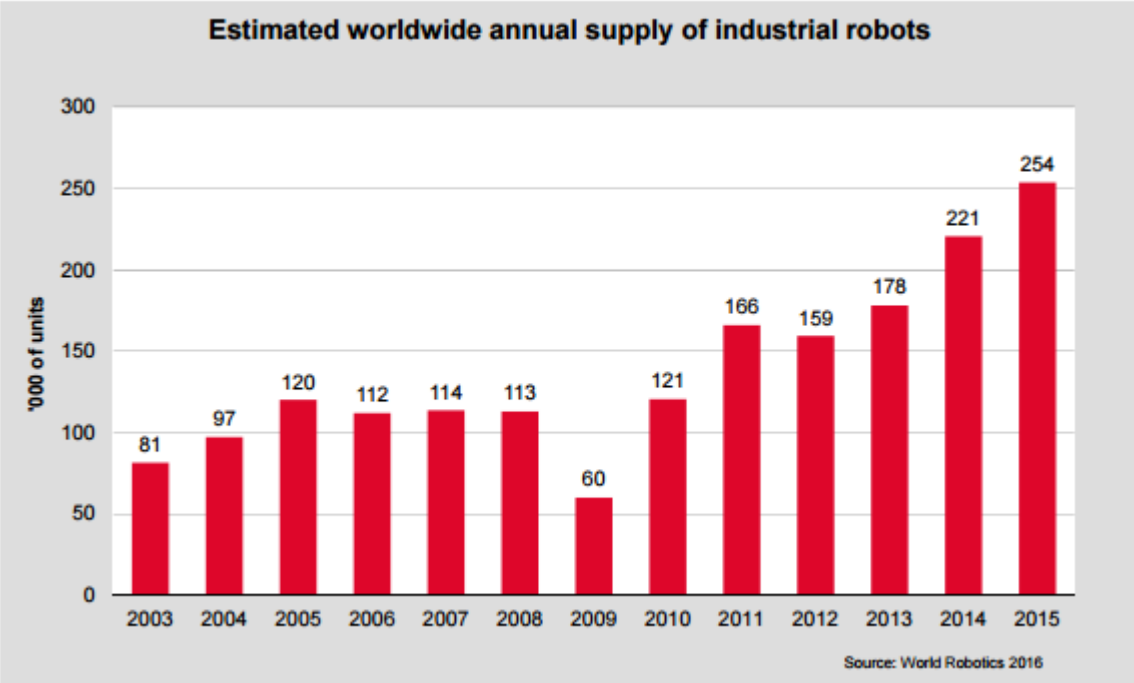

Figure 4 Estimated worldwide annual supply of industrial robots [5]

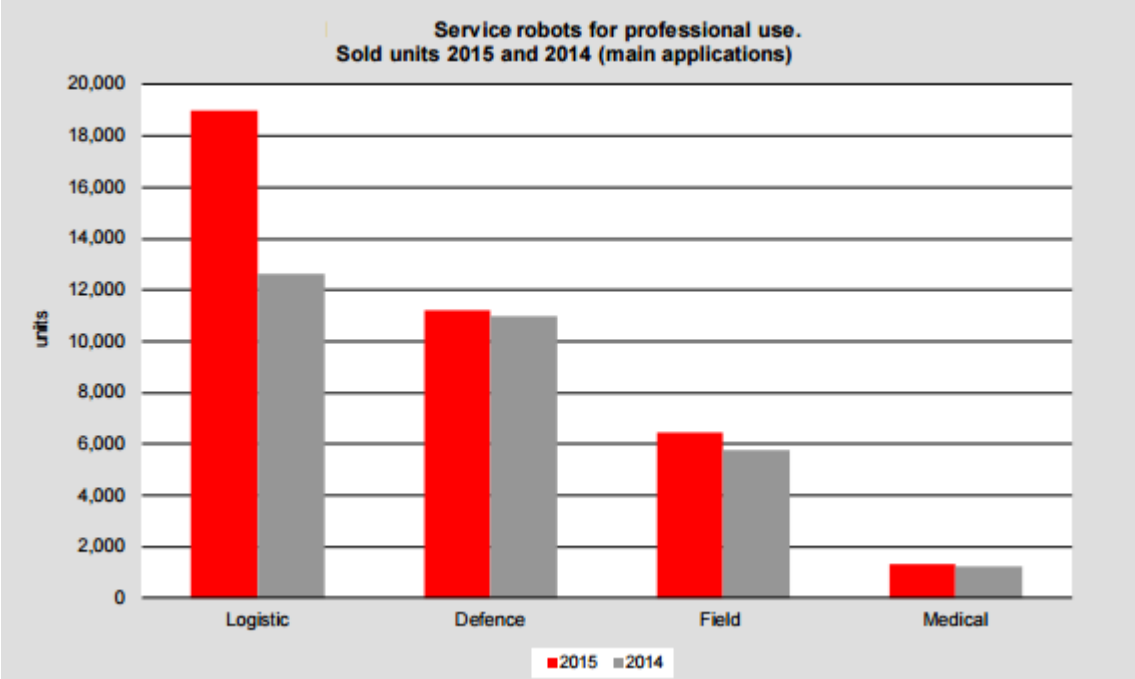

Figure 5 Service robots for professional use [6]

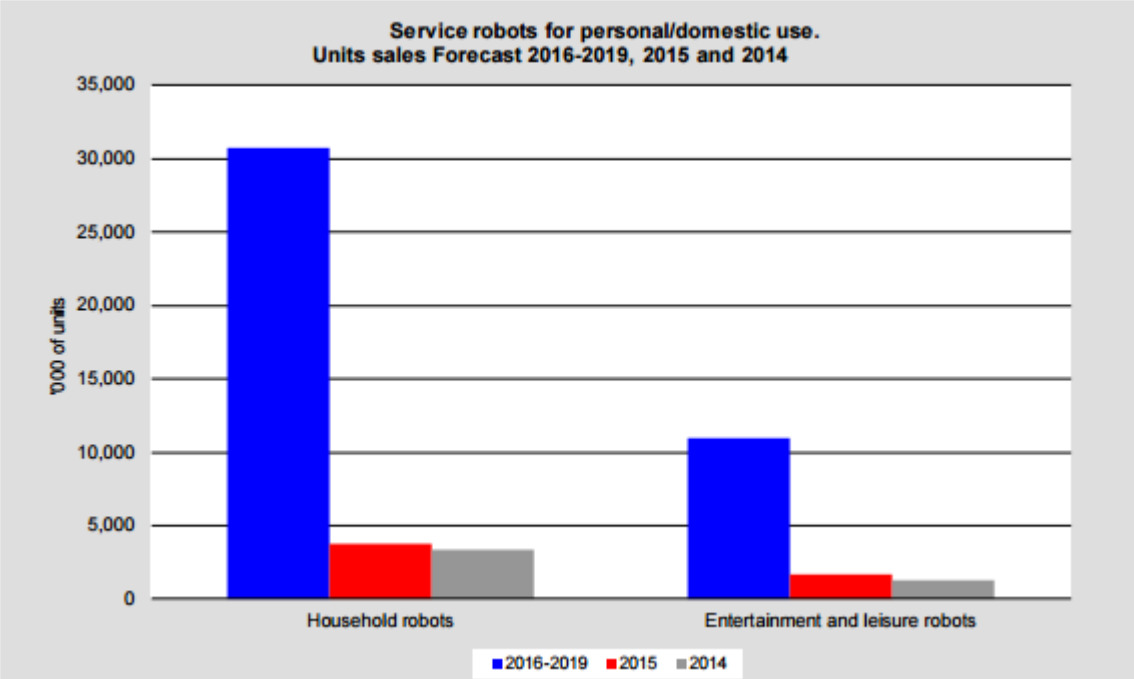

Figure 6 Service robots for personal/domestic use [6]

HUMAN-ROBOT INTERACTION TAXONOMY

If the human-robot relation is stressed, a different taxonomy ca be introduced. In [7] and [8] a possible classification of human-robot interaction, and therefore a classification of robots based on their interactions, is explained.

Yanco et al. introduce 11 fields to map human-robot interaction. They are enumerated and briefly explained below:

1. Task type
   A brief description of the robot's mission.
2. Task criticality (low-medium-high)
   Criticality is related to the damage that the non-accomplishment of the task cause to men's life e.g. a food delivery robot has a low criticality, a robot that delivers medicine has a medium criticality while a robotic wheelchair as a high criticality.
3. Robot Morphology (anthropomorphic, zoomorphic, functional)
   The physical shape of the robot. Functional means that structure is related only to the robot function.
4. Human-Robot Ratio
   Simply the number of humans and robots involved in the task.
5. Robot-Team-Composition (Heterogeneous, Homogeneous)
   Whether the robots are all of the same type or not.
6. Interaction (one human, one robot; one human, robot team; one human, multiple robots; human team, one robot; multiple humans, one robot; human team, robot team; human team, multiple robots; and multiple humans, robot team)

This field tries to classify the time of communication between humans and robot (Figure 7)

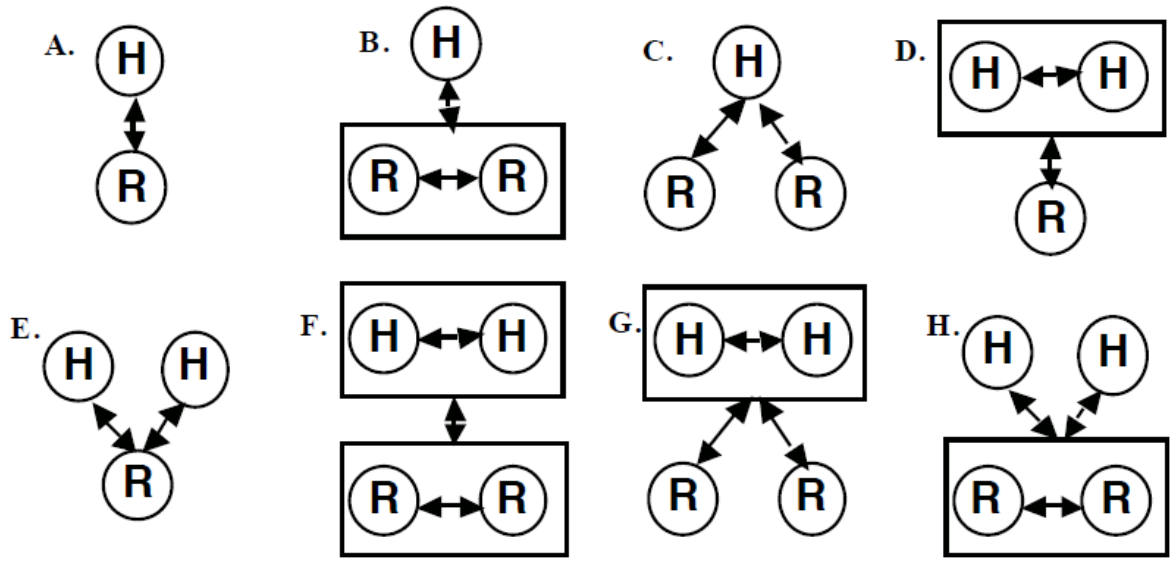

Figure 7 Types of human-robot interactions [8]

7. Interaction-Role (supervisor, operator, teammate, mechanic/programmer, and bystander)
   Roles that humans may have when interacting with robots.
8. Physical-Proximity (none, avoiding, passing, following, approaching, and touching)
   Describes the physical relation that robots and humans may have.
9. Decision support for operator
   Is divided into: available sensors, provided sensor, sensor fusion, pre-processing. The aim of this element is to describe the information available for the robots, which data have been chosen, how they are combined and whether they have been elaborated.
10. Time-space taxonomy (collocated, non-collocated/synchronous, asynchronous)
    Describes the mutual relation between humans and robots i.e. if they are in the same place and if the communication is synchronous or not.
11. Autonomy (0-100)
    Amount of human intervention required to control robots.

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