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Designing a Service/Care robot

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<p>Abstract</p> <p>Designing a service/care robot differs a lot from designing an industrial robot. The main reason for this is that service/care robot interacts with a human, industrial robots not. Service/care robots work for a human.</p> <p>Security in service/care robot design is the most important design aspect. A robot needs to be both actively and passively safe. Actively safety means that the robot's own movements cannot create dangerous situations. This can be achieved with an active or passive sensor. Active sensors, like sonar, scan the environment and stop the robot if something crosses a trigger zone. Passive sensors, like micro switch at robot feet, are triggered when some external force is used against them. Passive safety means that, for example, if a robot falls, it does not hurt people. This can be achieved with careful mechanical design. Failsafe mode is also needed in all service/care robots. Failsafe mode means that if a robot faces a situation where it does not know what to do, it should stop all movement and switch off.</p> <p>Usability is another key area for service/robot design. Usability means that a robot is easy to use, its controls are intuitive and interaction with human is errorless. Without good usability, a robot will end up in robot graveyard. The key to achieving good usability is to involve both the end user and domain experts in all design phases.</p> <p>Designing a service/care robot requires a multitasking team. This is also where it differs most from designing an industrial robot. Industrial robot design team consists mainly of engineers, but in service/care robot design, a psychologist, linguist and designers are also involved.</p> <p>The service and care robot market is growing fastest of all robot domains. Still no one has created a multipurpose, affordable robot. Finnish companies can still enter the market and create a robot which could be used worldwide.</p>	

Abstrakti

Palvelu/hoito robotin suunnittelu eroaa paljon teollisuusrobotin suunnittelusta. Suurin ero tulee siitä, että palvelu/hoito robotti on vuorovaikutuksessa ihmiseen, teollisuusrobotti taas ei. Palvelu / hoito robotti toimii ihmisen *kanssa*.

Turvallisuus on palvelu / hoito robotin suunnittelun tärkein näkökohta. Robotti on oltava sekä aktiivisesti että passiivisesti turvallinen. Aktiivinen turvallisuus tarkoittaa, että robotin omat liikkeet ei voi luoda vaarallista tilannetta. Tämä voidaan saavuttaa joko aktiivisella tai passiivisella anturilla. Aktiivinen anturi, kuten kaiku, skannaa ympäristön ja pysäyttää robotin jos jotain ylittää rajavyöhykkeen. Passiiviset anturit, kuten mikrokytkin robotti jalassa, toimivat, kun jokin ulkoinen voima kohdistuu siihen. Passiivinen turvallisuus tarkoittaa esimerkiksi sitä, että jos robotti kaatuu, niin se ei satuta ihmisiä. Tämä voidaan saavuttaa huolellisella mekaanisen rakenteen suunnittelulla. Vikaturvallinen tila tarvitaan myös kaikkiin palvelun / hoito robotteihin. Vikaturvallinen tila tarkoittaa, että jos robotti joutuu tilanteeseen, jossa se ei tiedä, mitä tehdä, se lopettaa liikkeen ja katkaisee virran.

Käytettävyys on toinen palvelu /hoiva robotin suunnittelun keskeisiä alueita. Käytettävyys tarkoittaa, että robotti on helppo käyttää, se säätimet ovat intuitiivisia ja vuorovaikutus ihmisen kanssa on virheetön. Ilman hyvää käytettävyttä, robotti voi päätyä robottien hautausmaalle. Miten saavuttaa hyvä käytettävyys? Tärkeintä on olla sekä loppukäyttäjia että asiantuntijoita kaikissa suunnitteluvaiheissa.

Kahdesta edellisestä kappaleesta voimme nähdä, että palvelu / hoito robotti suunnitteluun tarvitaan moniosaajien ryhmä. Tämä on myös se missä palvelu/hoiva robotin suunnittelu eroaa eniten teollisuusrobottien suunnittelusta. Teollisuusrobotiikan suunnittelutiimi koostuu lähinnä insinööreistä, kun taas palvelu / hoito robotti suunnittelu tiimissä on myös psykologeja, kielitieteilijöitä sekä muotoilijoita

Palvelu ja hoiva robottien markkinat kasvavat nopeimmin kaikista robotiikan alueista. Silti kukaan ei ole vielä luonut monikäyttöistä, edullista robottia. Suomalaiset yritykset voivat vielä tulla markkinoille ja tehdä robotin jota myydään miljoonia

Keywords

service robot, care robot, designing, robot

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List of Abbreviations

SLAM simultaneous localization and mapping

1 Introduction

Service robotics is evolving fast and there are lot of new players on market. Also old industrial robot manufacturer are coming to service robot market. Everybody is trying to be first to invent a robot which will blow the market.

Service robots is a large group of different kind of robots, their main character is that they work for human or they work alongside human. Working with human creates a specific needs for designing robot, especially safety and usability.

Care robots is one of the most hot service robot area and ultimate target is to create human like companion, but this target is also most difficult reach. Care robots will evolve from one task specific like shopping assistants and vacuum cleaner robots to multitask capability.

Designing a service robot is not only a technical and cost challenge but also about human feelings. Some human fear robots, some don't want to use them, some even hate them. Mainly this challenge should be handled by Government and robot manufacture associations. If this will not be addressed it can create an obstacle for service robot adaption.

Designing a home care robots is very challenging task, what are most useful features, but still a very reasonable price? They also have to adapt to changing environments and to be small enough to navigate in people's homes. Price pressure can be eased with government subsidies, a money saved from hospital care can be used as subsidy.

Design parameters for facility care robots is almost opposite to home care robots, they can be much more expensive, because they are shared. They can be bigger, because more space. Their navigation is easier, facilities are all the same, but it still needs to remember that also in facilities there can be obstacles which were not there before. In the near future facilities will be designed for robots, i.e. a robot architecture..

Table 1. Different design constrains between facility and home care robots.

Item	Facility	Home
Price	Easy	Difficult
Navigation	Easy	Difficult

Features	One task	Several
Size	Big	Small

This work consist of two different topics. First one is about service and care robots design. The other one is practical part of programming a Nao Humanoid robot and evaluate it's usability for elderly care.

Study methodology

- Internet
- Google scholar
- Interviews
- Field study
- Nao at home

2 Definitions

There are multiple competing definitions for robot. Personally I like this definition most, **sense – think – act**, this separates robot from automatic machines, which just repeat same procedure.

Sense A robot perceives it's environment

Think A robot analyses sensed information and decides what to do. Decision making can be simple "what if – then else" logic or more elaborate artificial intelligence.

Act A robot acts according it's decision. Act can be physical move, but also speech is act.

The list below is longer definition list and it is from Care robot standard ISO 13482:2014 (1)

Robot

An actuated mechanism programmable in two or more axes with a degree of autonomy (moving within its environment, to perform intended tasks)

Mobile robot

A robot able to travel under its own control

Service robot

A robot that performs useful tasks for humans or equipment excluding industrial automation applications

Autonomy

An ability to perform intended tasks based on current state and sensing, without human intervention

Personal care robot

A service robot that performs actions contributing directly towards improvement in the quality of life of humans, excluding medical applications

Mobile servant robot

A personal care robot that is capable of travelling to perform serving tasks in interaction with humans, such as handling objects or exchanging information

Physical assistant robot

A personal care robot that physically assists a user to perform required tasks by providing supplementation or augmentation of personal capabilities

Restraint type physical assistant robot

A physical assistant robot that is fastened to a human during use. This includes wearable suits or non-medical physical assistance exoskeletons.

Restraint-free type physical assistant robot

A physical assistant robot that is not fastened to a human during use. This allows free holding/releasing of the robot by the human in order to control or stop the physical assistance. Examples include power assisted devices and/or powered walking aids

Person carrier robot

A personal care robot with the purpose of transporting humans to an intended destination

Protective stop

An interruption of operation that allows an orderly cessation of motion for safeguarding purposes

3 Service robot market

Service robot market is starting to grow in double digits number and now is good time to enter market. Opportunity window is now open, technologies are mature enough and component prices are falling. Also open source robotics is growing strongly enabling fast market entry.

3.1 Areas of Service robots

Service robots can be divided to following areas

- Elderly care
- Medical
- Agriculture
- Transportation
- Education
- Entertainment
- Security
- Defense
- Maintenance

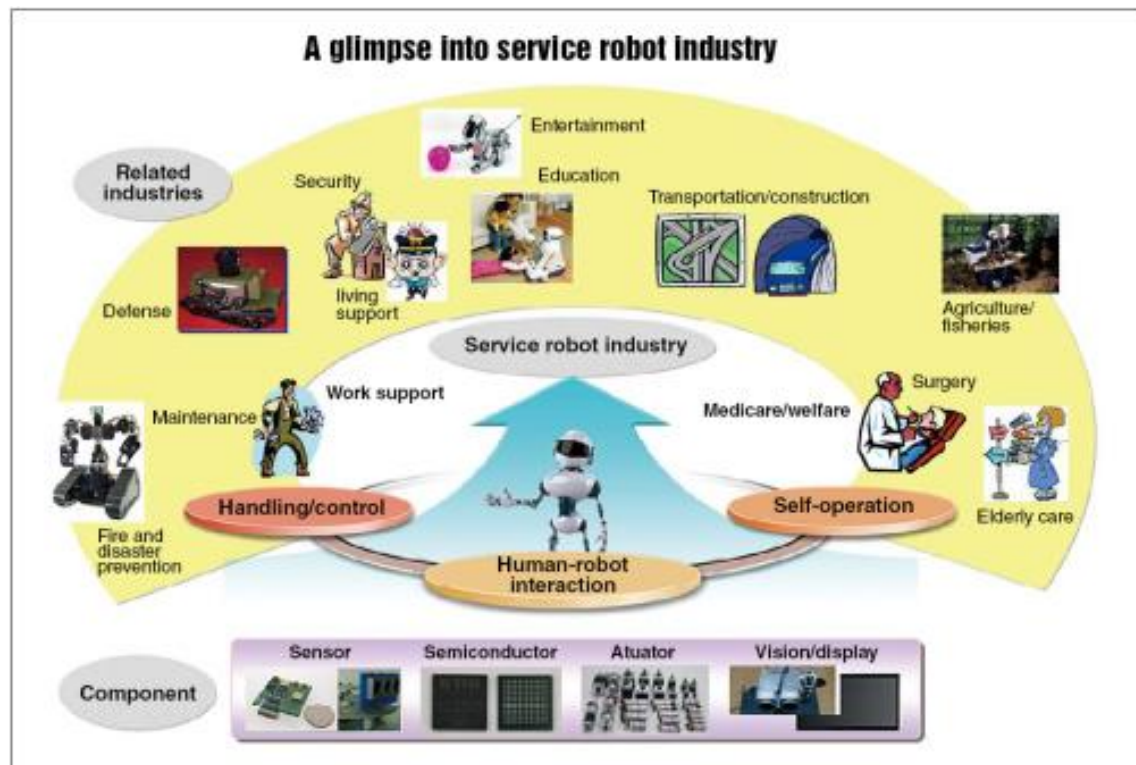


Figure 1. Different areas of Service robots (2)

3.2 Service robot market

Service robot market is growing rapidly and it is also growing faster than other robotics area. This is mainly because factory robot market is mature i.e. those factories which could have been robotized, have been robotized. Other reason is that a lot of investment is put on service robot market.

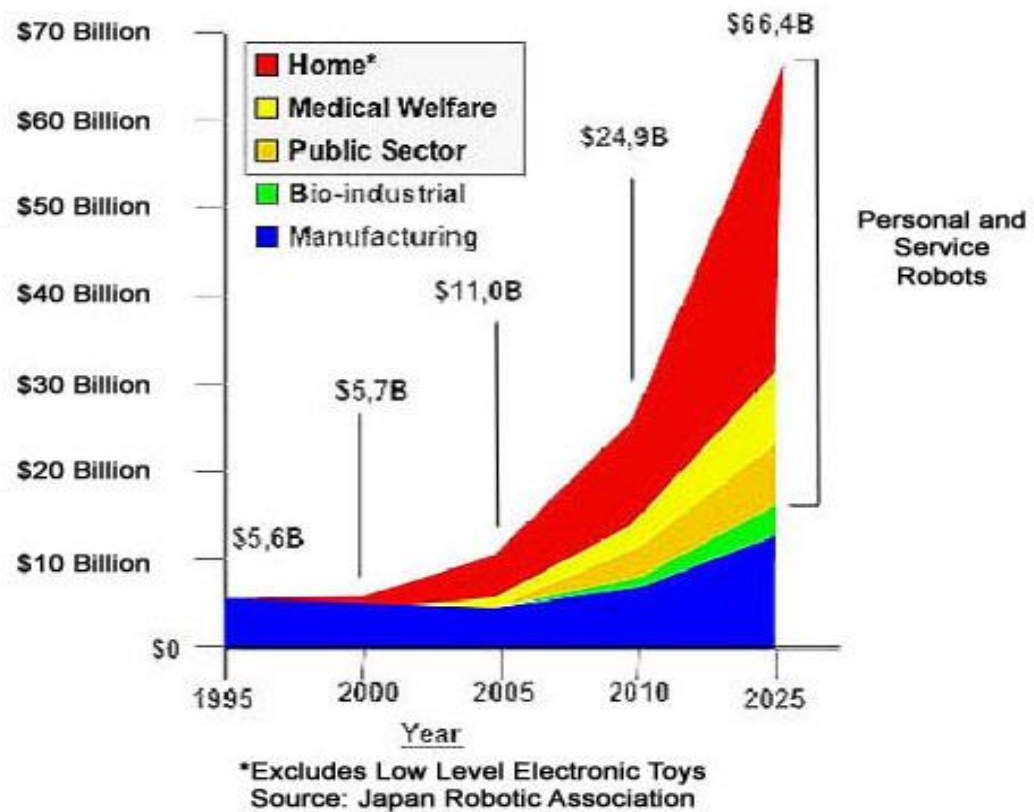


Figure 2. Service robots, total market growth (3)

3.3 Gartner hype Cycle

Gartner Consulting Company creates yearly a Hype Cycle for Emerging Technologies. It usually used to see on which phase different technologies are. It is named as Hype cycle because it has seen that all technologies go to hype phase in some time in their lifecycle. Below is Hype Cycle for Emerging Technologies from year 2015. Main areas affecting service robots are marked with red ellipses, most are about machine – human interaction and other about sensing and navigation

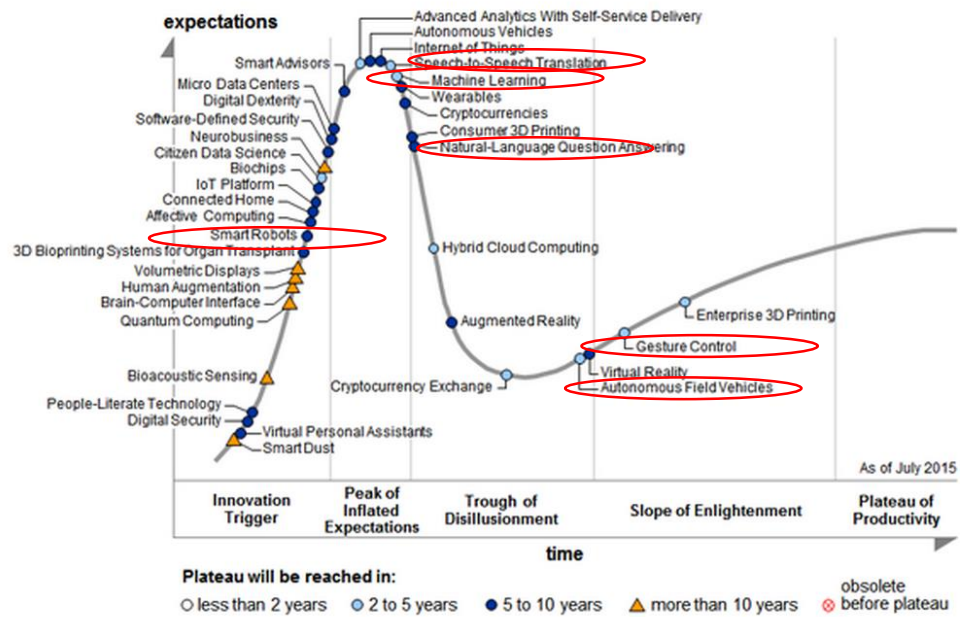


Figure 3. Hype Cycle for Emerging Technologies. (4)

3.4 Mapping of service robots

Here is market mapping for currently available service robots. There are multipurpose robots like Nao and Zeno. Then there are single task service robots like Bestic and TUG. Some are very simple but creating strong emotions like Paro

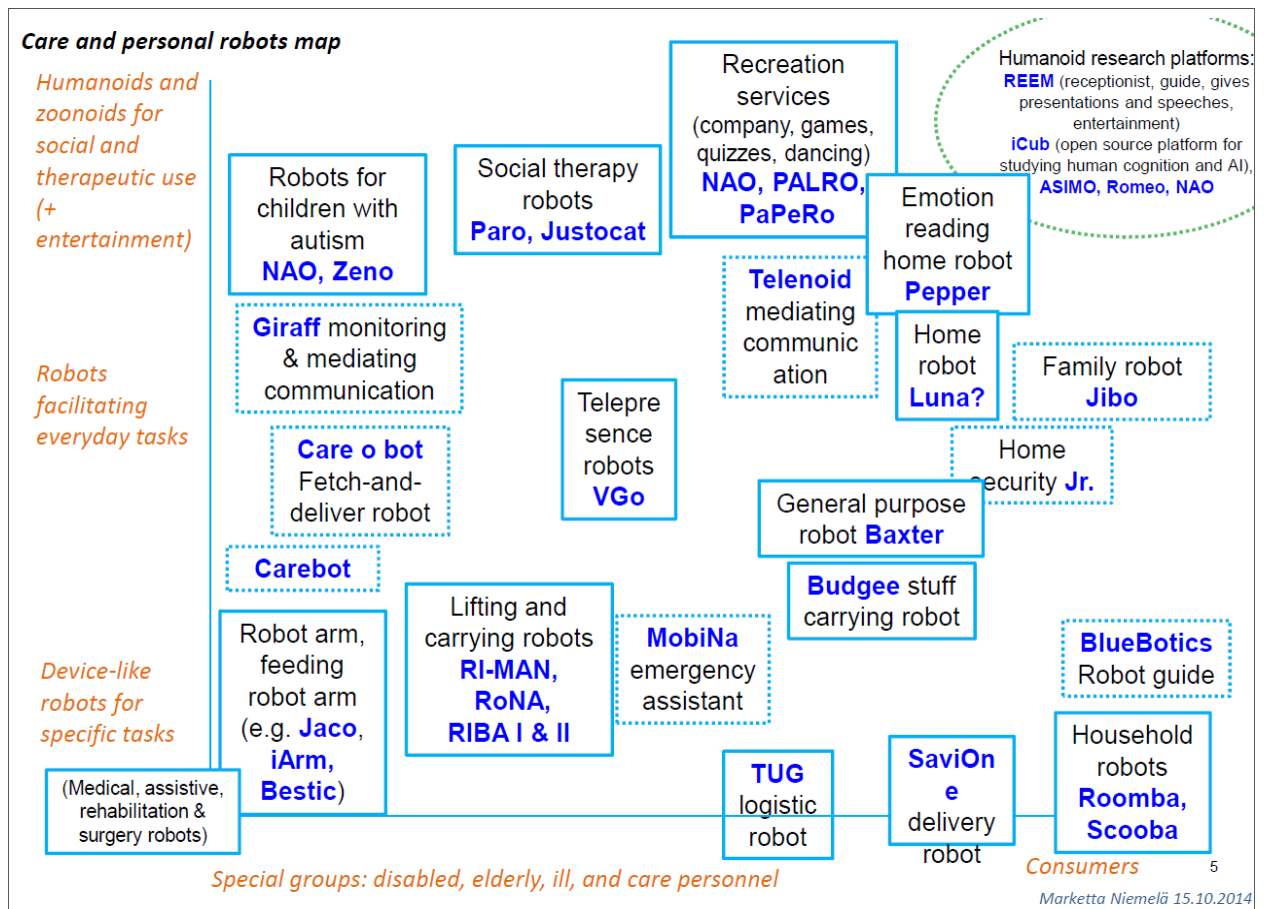


Figure 4. Market mapping for currently available service robots (5)

4 Designing Service Robot

4.1 Areas of design

Main areas of designing service robot can be divided as following

- Navigation
- User interface
- Manipulation
- Safety

- AI

Designing service robot is a multidisciplinary effort. I.e. following expertise are needed: sensor knowledge, user experience, mechanical, linguistics and algorithms

4.1.1 Navigation

Currently most of navigation is done by 2D navigation, but now 3D navigation is getting to mainstream. 3D navigation is one of the most significant challenges in the area of dexterity and mobility. Presently, most localization, mapping, and navigation systems rely on two-dimensional demonstrations of the realm. These representations are usually maps of city streets or plans of building floors. As robots are used in more and more normal life unstructured environments, which are also highly populated, and there is less control of environment, these all creates challenge for robot navigation. Currently used 2D navigation, which work only in in one plane, is not enough to get needed information of these complex surroundings, and therefore support proper navigation of robot. It is clear that 3D navigation is needed to cope in these environments. 3D navigation creates multi-level plane of surroundings and therefore enables proper robot navigation.

It is noted that these three dimensional depictions should not only contain the geometry layout of the world, but they should also contain task relevant semantic information about different objects and features of the environment. Present robots are decent at understanding where things are located in the environment, but they have tiny or no understanding of what located things really could be or are. When robot mobility is performed in service to manipulation, mapped environmental representations need also contain object affordances. In other words, knowledge of what the robot can do with object or what could it be used for. Achieving accurate semantic 3D navigation will need new methods for sensing, affordance recognition, mapping, perception, localization, object recognition, and planning.

Thera are promising technologies towards semantic three dimensional mapping, which are using sensors, new different kinds, mapping a building. Presently in order to a robot to create a map of surroundings and also learning building map, a high accurate laser rangars or stereo cameras are used. This mapping requires simultaneous localization and mapping algorithms, which same time when moving, maps environment and then move again and then maps environment again. This requires almost real time computing.

If digital cameras are used then are Visual SLAM algorithms used. Nowadays these digital RGB cameras are relatively cheap, availability is good and they are mechanically proven. Their performance is sufficient for almost real time usage, so they are good choice for robot navigation. The overall and ultimate target for robot mobility is that it can move in crowds safely and error free.

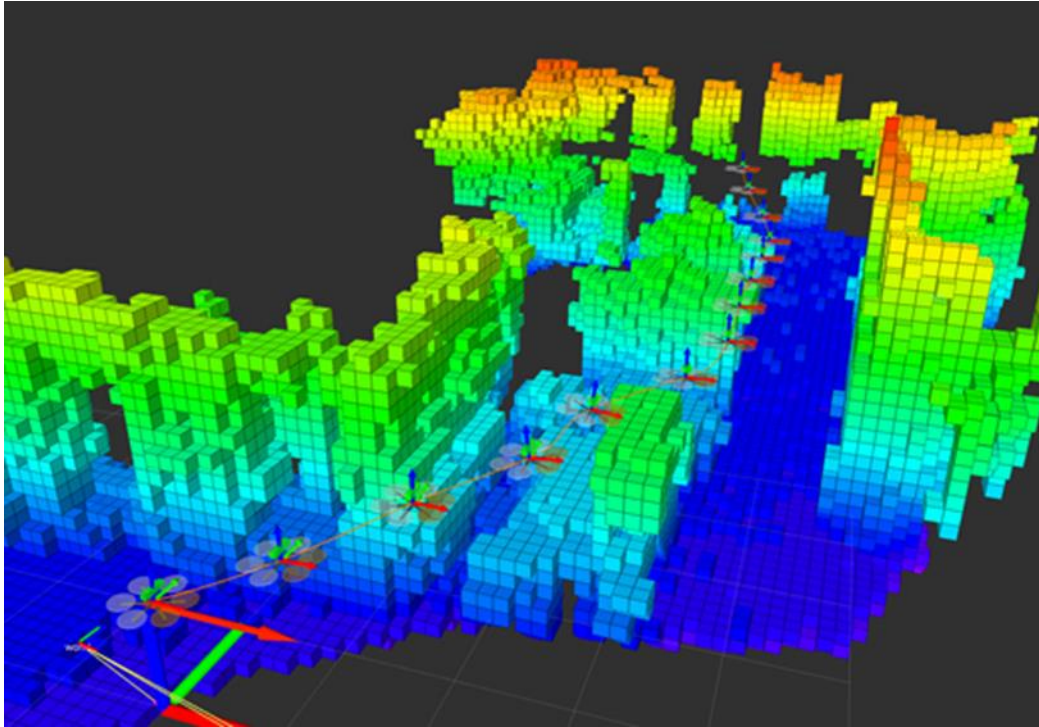


Figure 5. 3D mapping by laser

4.1.2 Human-Robot Interaction (HRI)

Human - robot interface is one of the most important aspects of usability. Set the ultimate goal of deploying dexterous and mobile robots in surroundings of human to enable co-operation and coexistence, considerable development emphasis is required in the area of human-robot interaction.

As discussed in the previous subsection, these important interactions should also become an essential component in an overarching methodology for robust humanoid robot behavior. Robots could learn new interaction skills from their communications with humans. Although under all situations, a robot need to be aware of the normal characteristics and requirements when communication with humans.

Normal communication modes like nonverbal, verbal, facial expression and gesture are usually enough, but also following significant topics; social relationships, emotions like recognition, social emotional cognition/modeling, presentation, trust and engagement are needed. An deep understanding of these facets of human-robot communication should lead to an automatic constituting of the interactions between humans and robots. Humanoid robotic systems' ability to operate autonomously rises or falls automatically as both the task and the human supervisor's interaction with the system modifications.

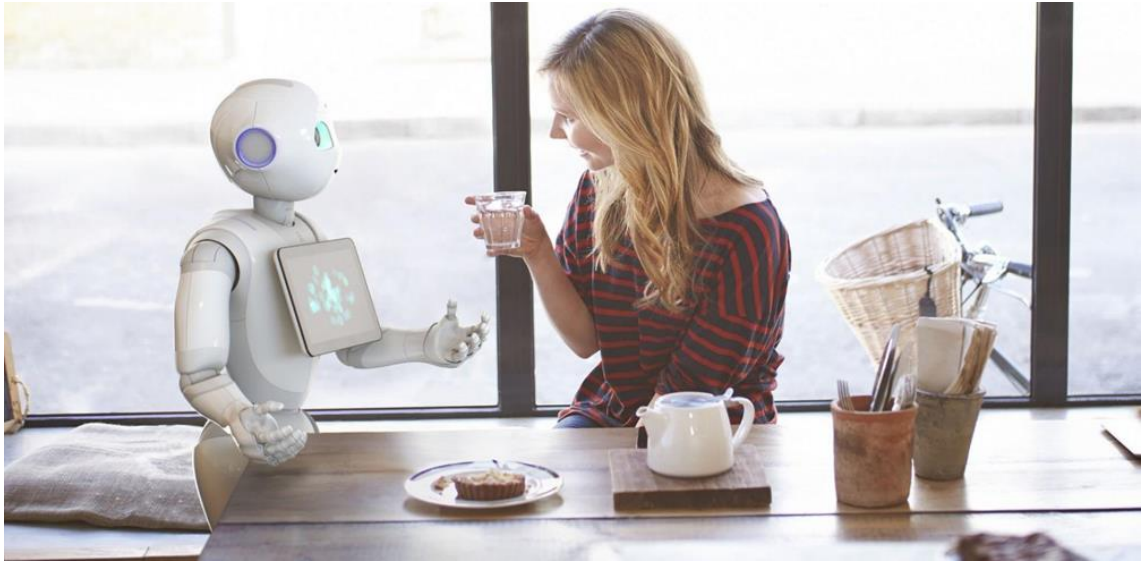


Figure 6. Example of Pepper, a companion robot interface.

4.1.3 Manipulation

Manipulation of objects creates substantial challenge currently. Considerable development in operation is required for almost all of the service/care robots. These areas of applications require a service/care robot to act together tangibly with its surroundings by picking up objects, opening doors, devices and operating machines. Presently, self-governing manipulation systems work well in highly controlled surroundings and carefully engineered, such as assembly cells and factory floors. Challenges are in handling the environmental ambiguity and variability associated with dynamic, open, and unstructured surroundings.

Preceding information and models of the surroundings should be used whenever possible. This enables a robot to do error free and accurate grasping and manipulation, even the environment is unstructured, open and can be challenging. Because all real environments are dynamic so beforehand done plans are usually not enough, so robot needs to be designed to handle new, unknown situations, either by trying different pre-set options or given control to human.

As a consequence, really automatic independent manipulation will be contingent on the

service/care robot's capability to obtain acceptable, relevant to task, environmental representations in that case that are not accessible. This also creates need for move from nowadays dominant planning and control paradigm, to more perception based ad hoc environment analysis to support better and dexterous manipulation.

When developing truly autonomous service/care robot tactile sensing is needed and also high representative and physically lifelike simulators are needed. It is also noted that for most humanoid service/care robot requirements a capable, pick and place, operations could deliver appropriate functional design base.



Figure 7. Example of 3 finger manipulator. With 3 finger you can get almost same dexterity as 5 fingers but less complexity

4.1.4 Sensing and perception

A service/care robot needs to understand it's environment. Novel sensing types, as well as further, lower cost, advanced and higher-resolution, versions of existing types of sensors. There are lot of new types of sensors, which support robots movement and manipulation. Most prominent are dense three dimensional range sensing sensors, using laser, called LIDAR, or stereo or machine learning RGB-D cameras. The requirements for sensing and perception is accuracy and robustness in extensive type of surroundings. What are also coming sensor market are tactile sensors used in robot hand, which look alike human skin and also works in same ways as i.e. sense of touch. What also are coming to shelves are presence and depth sensors for sensing in short range

Additional sensors, for example SONARs, acoustic sensors and specific sensors for safety, like micro switches, could be used. Also special sensors like heat or range sensing to detect the attendance of humans could be used. If needed to detect unexpected contact between the service/care robot and its environment or human, a

distinctive torque sensors could be used in actuating mechanics. There is also available Human skin-like sensors which cover whole robot's body and this can be used to detect human touch and act accordingly.

In complex and greatly dynamic surroundings, a near real time mathematical algorithms are needed for to process data coming from different sensors. These conditions also change frequently, so data processing and analytics needs work fast enough to guide robot. Also changes in lightning, like daytime, dusk and nighttime and light reflections from windows, mirrors and other reflecting surfaces, which are very difficult to predict, create challenges for accurate sensing. To overcome these challenges it is needed to use multiple sensors together, like laser ranging, sonar ranging, infrared ranging, tactile and camera with RGB sensor, and then use fusion algorithm to combine and process incoming data.

Specific task algorithms that can be integrated with algorithms created in planning and study dynamic somatic constraints needs to be developed. For example, in human surroundings to perform a task and dexter manipulation, algorithms for affordance recognition needs to be developed. Creating perception algorithms for situation conscious contextual models is also needed for mobile robot. When integrating all these sensors and algorithm, they enable a service/care robot sense and perceive it's environment.

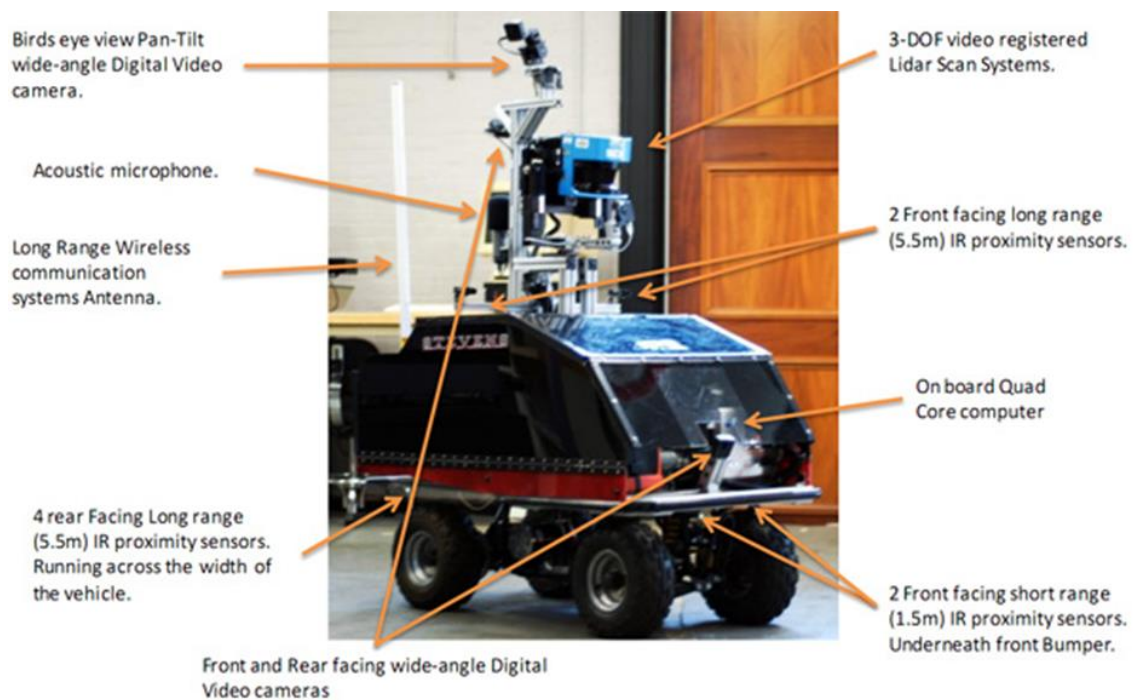


Figure 8. Example of robot equipped with multiple sensors.

4.1.5 Safety

In human surroundings, safety is utmost most critical design aspect for service/care robot. A Service/Care robot cannot create any risk for human injury or in worst case death.

In order to increase general acceptance of robots and robotics, in daily life, it is needed fundamentally safe robots. Different modes of robot-human communication, could also support this target. This also would create positive view to robot, as helper, not as threat.

Fundamentally safer motors and mechanisms with improved strength to weight ratio would represent an important enabling technology for safer robot. In such mechanisms, variable compliance would be a required property. The concept of adjustable compliance refers to a mechanisms ability to adjust its behavior to reaction forces when contacting the environment and also to go to safety stop.

These different forces of reaction can be mixed for diverse jobs. When working together with humans, these kind of mechanisms allow operations which are safe and intuitive. Also these different forces of reaction allow robust, flexible, and capable motion when in interaction with the surroundings. Moreover, high efficiency of energy is recognized as a critical apprehension for applications in many types. Service/Care robots needs to operate without external power for stretched time periods. This means also careful planning for battery lifetime extension algorithms.

To conclude, new or improved motion modes, further than wheels, are needed to enable reliable and safe operation in mixing environments, like in outdoor and indoor locations. Outdoor surroundings usually consist of highly variable environment properties. In typical outdoor scenario there can be ladders, ramps, stairs, elevators or escalators, and all these create a challenge for robot safety. Design needs to be addressed to power- and force-limited robots, low-inertia servo motors, elastic actuators and also to safe enclosure design



Figure 9. Example of Frida, a collaboration robot, safety feature

4.2 Artificial Intelligence (AI)

Service robots can go long way with what-if-then–else ladder logic. People feel still that it is somehow natural conversation even robot don't really understand what human means. Also most movements and manipulation can be handled with what-if-then-else logic. But if really environment change adaption and natural conversation is needed then is AI needs to be used.

The fundamental problems of AI research include knowledge, reasoning, planning, learning, perception, natural language processing (communication), and the ability to move and manipulate objects. General intelligence is still among the field's long-term goals, but it is also criticized that it is really realistic to try to achieve it, but to concentrate to more practical applications. Presently popular approaches include machine learning, statistical methods, computational intelligence and traditional symbolic AI. (6)

There are a large number of different tools used in AI. Containing versions of search and mathematical optimization, ladder logic, methods based on probability and economics, and many others. The AI field is interdisciplinary, in which a number of sciences and professions converge, including computer science, psychology, mathematics, linguistics, neuroscience and philosophy, as well as other specialized fields such as artificial psychology. Figure 10 shows different areas of AI, in this study we don't go more deeply to those areas.

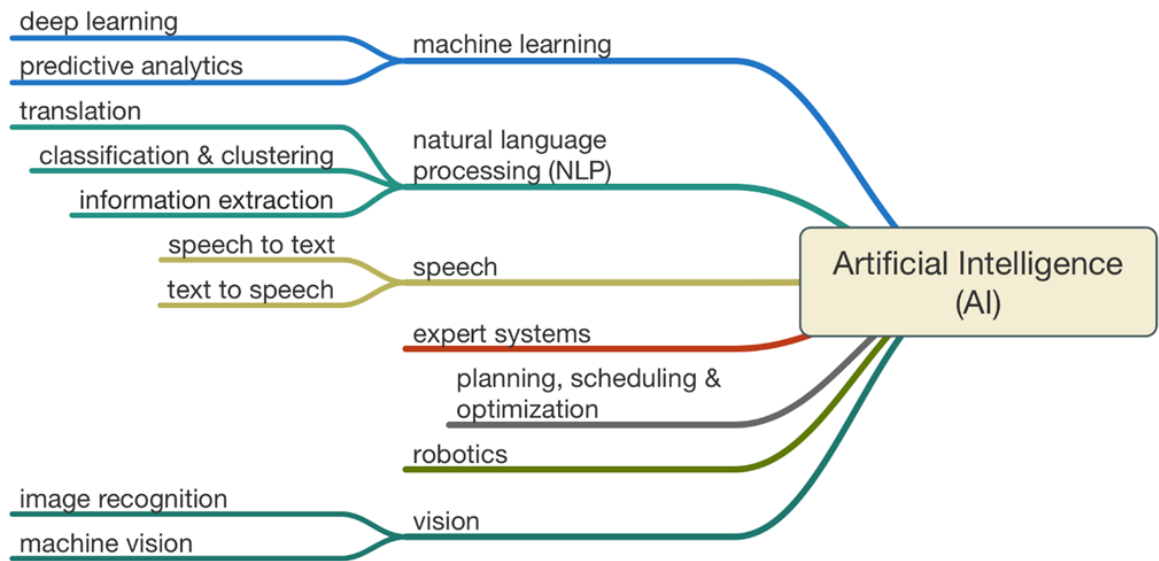


Figure 10. Different areas of AI (7)

5 Standards

International Organization for Standardization ISO has made to standard which needs to followed when designing a Service robot, Other on is ISO 13482:2014(en) for Care robots and other one is ISO/TS 15066:2016(en) for Collaborative robots

5.1 Safety requirements for personal care robots (ISO 13482:2014)

A personal care robot shall be designed according to the principles of ISO 12100 for all hazards identified for its application, comprising the following:

- a) inherently safe design;
- b) protective measures;
- c) information for use

5.1.1 Examples of operational spaces for personal care robots

Mobile autonomous person carrier (person carrier robot)

A person carrier robot of 200 kg is moving autonomously around in a museum. The walls of the rooms define the maximum space. The floor plan of the working area of the robot has been prepared from the museum floor plan. The robot has a work volume and movable, extending, robot arm parts that should not touch walls. This defines the restricted space.

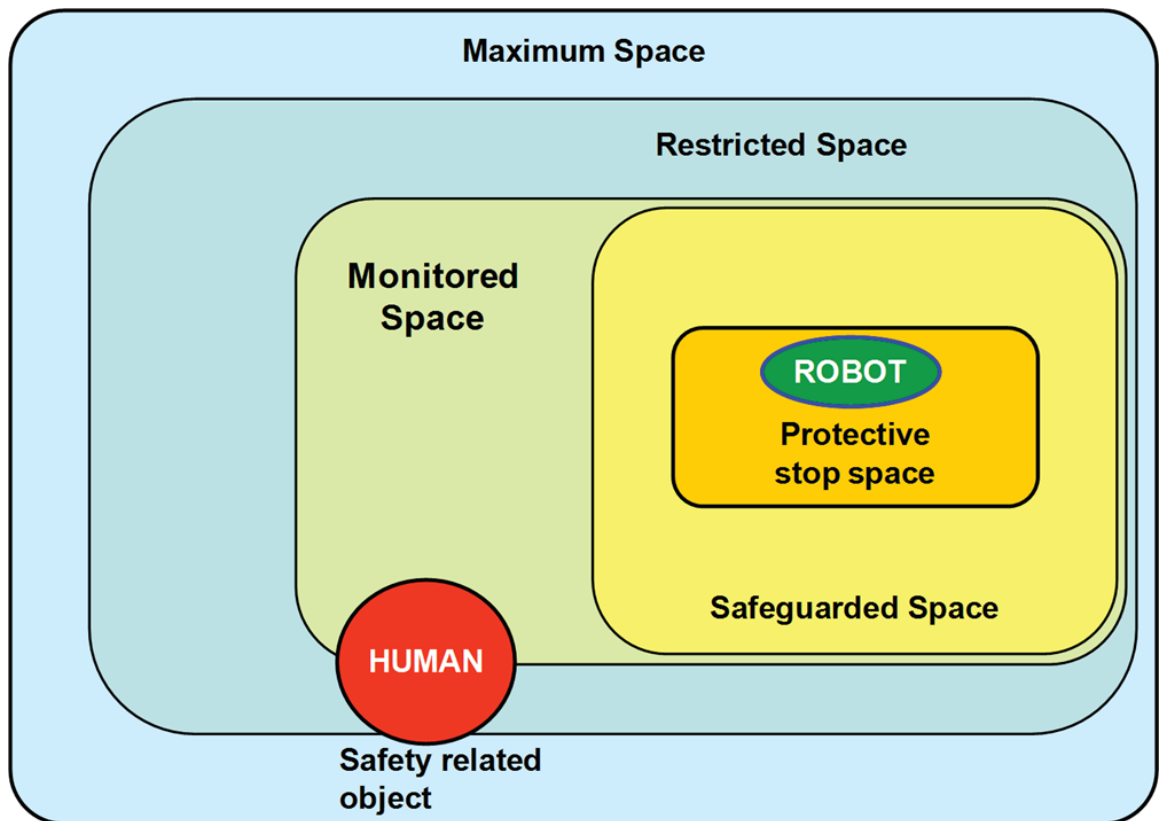


Figure 11. Different safety regions

The robot is only allowed in the central area of the rooms and doorways. While the robot moves autonomously, it observes the environment with its on-board sensors and via facility-mounted sensors defining the dynamic monitored space.

a) While the robot moves about the room, it dynamically updates its safeguarded space and its protective stop space. As soon as a safety-related object enters the safeguarded space, the robot will reduce its speed depending on actual velocities of the robot and safety-related objects in its environment, thus maintaining safe margins to any safety-related object.

b) If a safety-related object enters into the protective stop space, the robot comes to a protective stop. For this type of robot, it is important that the monitored space overlaps and covers at least the safeguarded space to ensure that the robot has all required information to plan its motions such that no collisions or dangerous situations arise.

c) If a safety-related object is suddenly moving into the safeguarded space of the robot, the robot path planner issues a robot command to react immediately by recalculating a path around the moving safety-related object or stops the robot dependent upon their relative velocities. (8)

5.2 Safety requirements for Collaborative robots ISO/TS 15066:2016(en)

The objective of collaborative robots is to combine the repetitive performance of robots with the individual skills and ability of people. People have an excellent capability for solving imprecise exercises; robots exhibit precision, power and endurance.

To achieve safety, robotic applications traditionally exclude operator access to the operations area while the robot is active. Therefore, a variety of operations requiring human intervention often cannot be automated using robot systems.

A comprehensive risk assessment is required to assess not only the robot system itself, but also the environment in which it is placed, i.e. the workplace. When implementing applications in which people and robot systems collaborate, ergonomic advantages can also result, e.g. improvements of worker posture. (9)

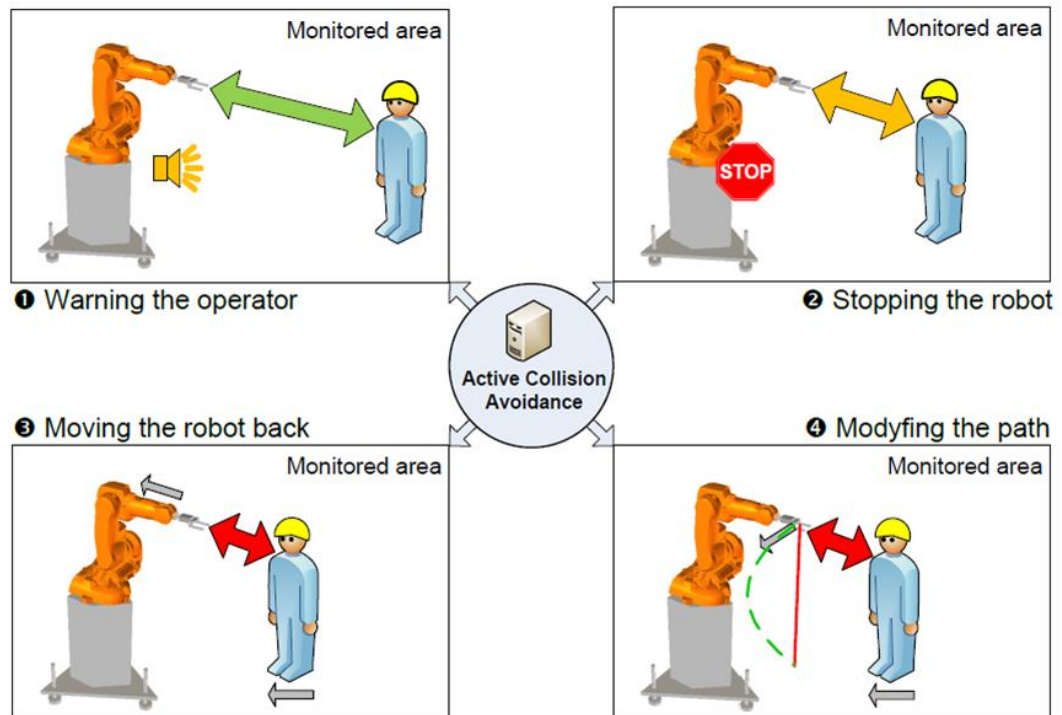


Figure 12. Human robot collaboration safety. (10)

6 Robot Operating systems (ROS)

Robot Operating System (ROS) is a collection of software frameworks for robot software development. It is providing operating system-like functionality on a heterogeneous computer cluster. It can be also understood as middle ware, acting between hardware and sensors and operating system.

ROS offers regular operating system services, OSS, such as low-level device control, hardware abstraction, implementation of commonly used functionality, message-passing between processes, and package management. In shortly ROS enables developer to concentrate on developing end users requirements and let ROS take care the basic operations, like standing.

ROS-is based on processes and when running sets of those, they are represented in a graph architecture. Processing takes place in nodes that may post, receive and multiplex

sensor, control, state, planning, actuator and multiple other messages. Despite the importance of reactivity and low latency in robot control, ROS, itself, is not a Real-time OS, though it is possible to integrate ROS with real-time code (11)

ROS Ecosystem software can be separated into 3 groups:

- Packages containing application-related code which uses one or more ROS client libraries
- Language-and platform-independent tools used for building and distributing ROS-based software
- ROS client library implementations such as roscpp, rospy, and roslisp

ROS Package application areas will include:

- Segmentation and recognition
- Perception
- Gesture recognition
- Face recognition
- Egomotion
- Motion tracking
- Structure from motion (SFM)
- Motion understanding
- Motion
- Stereo vision: depth perception via two cameras
- Control
- Mobile robotics
- Grasping
- Planning

ROS ecosystem has gained a lot of user and it's repositories are growing rapidly. Following diagram shows ROS repositories growth.

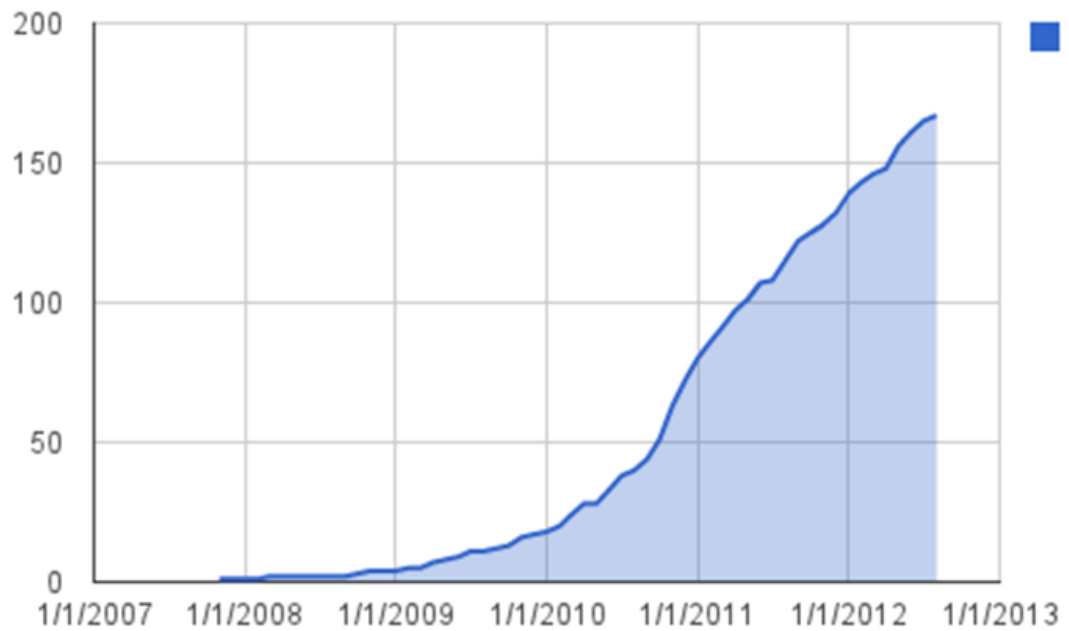


Figure 13. ROS repositories growth 2007-2013. (12)

7 Collaborative robots, as known as Cobot

Cobots are robots which are designed to work with human, for example in electronics assembly or in medical lab. They share most same design principles with service robots like safety and user interface but they usually are not mobile. Cobots are seen a way to get production back from China, this might be true but of course a factory with Cobots doesn't need so many people than factory without them. Most well-known Cobots are Yumi from ABB and Baxter from Rethink Robotics.



Figure 14. Yumi, a collaborative robot from ABB.

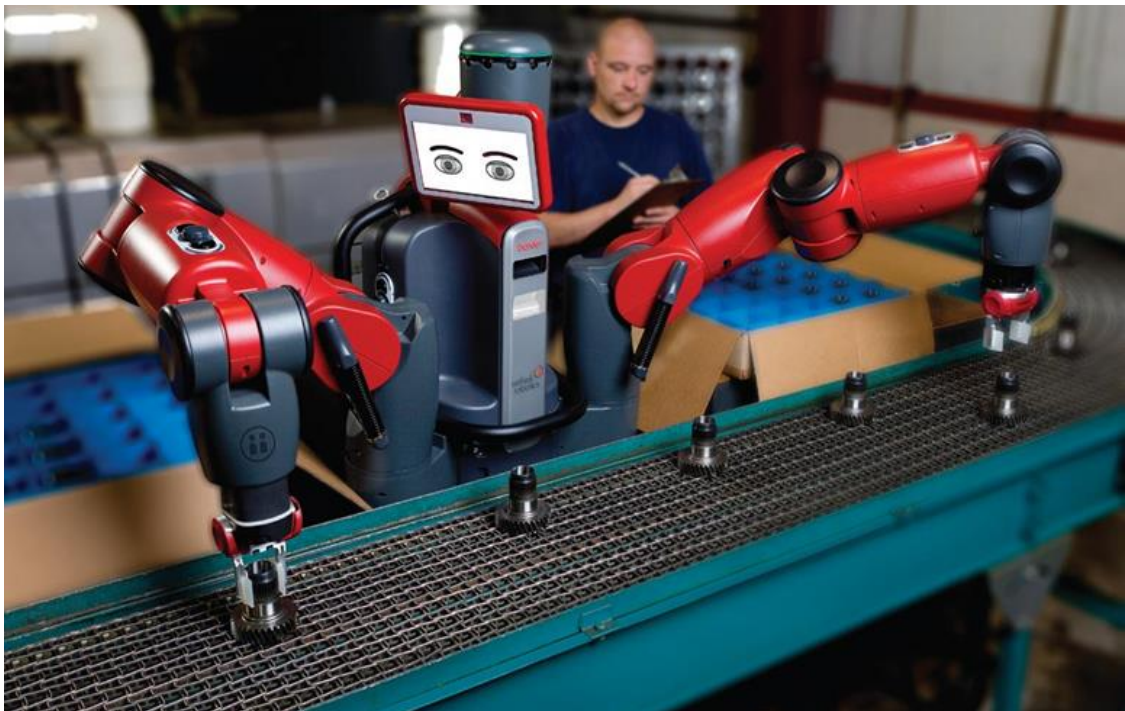


Figure 15. Baxter, a collaborative robot from Rethink Robotics.

In following table Yumi and Baxter are compared by key specifications.

Table 2. Comparison table between Yumi and Baxter.

Item	Yumi	Baxter
Degrees of freedom	14	14
Payload (kg)	0.5	2.2
Weight (kg)	38	75
Maximum Reachus (mm)	559	1210
Accuracy (mm)	0.02	5
Price \$	40 000	20 000
Dexterity	+++	++

Comparison shows that Baxter is more like workhorse and Yumi like ballet dancer, so they are designed for different application areas.

8 Care robots

8.1 Care robot design principles

Care robots can be divided to two main categories by location: 1. Facility i.e. Hospitals/Nursing homes 2. Homes. Care robot design is almost opposite in these two categories, see table below for comparison.

Table 3. Comparison between .facility and home robot design

Design item	<i>Home</i>	Notes	<i>Facility</i>	Notes
Price	€	Personal use, very limited budget unless subsidized or shared	€€€	Shared by many so can cost more
Movement/navigation	+	Changing environment, floor plan cannot be designed for robot usage	+++	Static environment, floor plan can be designed for robot usage
Size	+	Small space, also space can change	+++	Wide space, although space can also change

8.2 Care robots at elderly home care

In this study we concentrate to care robots at homes.

Following problems were identified in questionnaire to care professionals

1. Home care personnel don't have enough time for a patient, max 20 minutes, no time for small talk
2. Many different care person visit patient, care persons also change
3. Elderly living at home feel very lonely
4. Elderly with mild dementia are held at home care
5. Not enough exercise
6. Not enough control on medicines
7. Difficult to go toilet (13)

Also one quote about problems in current elderly home care “We go three times with dementia patient’s triangle: bed – toilet- dining table. After visit we leave him/her to arm-chair, where next care person usually finds her/him” (14)

So there are lot of problems in elderly home care. One of biggest problems are loneliness and not enough exercise. There is also vicious cycle called “Exercise spiral”: when elderly person is not moving enough, then less appetite, which can lead to malnutrition, then the quality of sleep at night will deteriorate, which can lead more nap during a day, which can lead more time in bed, and altogether can result less exercise, spiral is ready and at end of spiral it will affect to health of that person. How to stop this vicious cycle? How care robots can help on this? A table below shows different possibilities.

Table 4. Human incapability – robotics

Capability	Explanation	Robot solution	Price	Technology maturity	Total
Loneliness	No enough communication , for a reason or another	Talking	€	+++	YES
Cognitional problems	Not enough brain “exercise”	Cognitive trainings	€	+++	YES

Movement problems	Difficult to walk	Exoskeleton	€€€	+	Not yet
Memory problems	Forgetting everyday tasks	Reminder	€	+++	YES
Staying inside	Can be fear not to go outside, can be memory problem fear, can be physical fear	Exoskeleton	€€€	+	Not yet
Too little exercise	No trainer	Training program	€	+++	YES
Cannot go to toilet	Limited movement	Exoskeleton	€€€	+	Not yet
Cannot go to shower	Limited movement	Exoskeleton	€€€	+	Not yet

Most of these problems are related to each other and there are some key problems and if they are solved with robotics, it can also solve multiple problems. Like solving loneliness problem helps on many other problems. The final solution will be human like robot, a humanoid, but before that it can be done, a robot that helps a lot.

8.2.1 Opinions about elderly home care robots

When I told about my thesis, this work, in “Vanhustenhoidon nykytila” Facebook group, roughly half of people commented that they don't want robots to take of them when they are old or their current old parents. This is quite common first reaction, but when you ask more detail you can find out that it is not all robots what they don't accept and also this varies from people to people what robots they accept and what not. Also in multiple robot pilots have been noticed that elder accept robots, but their relatives don't.

Table 5. Different attitudes against care robots

Class	Attitude
Robo Luddites	Do not accept any robots
Just do work	Do not accept all robots, but if does the work then ok
Robo lovers	Accept all robots, prefer some to human

One key principle is: It doesn't matter if cat is brown or black, if it gets rat i.e. it doesn't matter if robot or human is doing work if end result is same. So if person feel less alone when talking with robot then let the robot do the work

8.2.2 Why care robots to home?

There are multiple reason why there is need care robots in homes. Here are listed most common ones.

- Population will get older, more and more people over 65 years
- No new retirement homes, even less
- People will live longer
- People are healthier, no immediate need for facility care
- “Home sweet home, no, it is a prison”

Home care professionals stay roughly 20 minutes per customer, robot can be 24/7, see table below for full comparison. What is best usage for robot in this scenario?

Table 6. Comparison between Human and robot in home

Item	Human	Robot
Time in home	20 min	24h
Speech recognition	Excellent	Average
Humor	Understands	Don't understand
Repetition	No time	Excellent
Memory	Average	Excellent
Patiently	Average	Excellent

Vision: Care robotics will enable people to live a full and rich life at their own home!

Specification for a feasible care robot which can deliver most for it's price can be seen table below

Table 7. A feasible home care robot specs.

Feature	Solves	Notes /price
Cognitive exercises, games	Cognitive problems	
Reminder	Memory problem	
Small talk	Loneliness	
Reads news, papers, magazines	Loneliness	What you would like to read?
Recognizes peoples in photos, can store photos	Loneliness	Remember this person in this photo?

Physical training	physical problems	Raise your arm!
TV control	Support	What you would like to watch?

Other features

- Needs to be height above table
- Legs are too expensive, need to use wheels
- No arms, don't add enough value
- Price under 1000€

Care robot have to be, also

- Safe to use
- Intuitive UI
- Monitor itself for preventive maintenance
- Failsafe mode

8.2.3 Said about care robots

"No machine will ever replace human touch or the warmth of human love. When our loved ones are at their most vulnerable, those are the elements that are most needed for their wellbeing. As with most things, balance and caution should be used if we are to successfully blend robotic assistance with human care. " (14)

"They are also looking into the potentially troubling implications of a patient developing an emotional connection to a robot. "This is a very vulnerable group, very frail," said Espingardeiro. "What happens if they get attached to these machines?" (15)

9 Nao robot programming

9.1 What is Nao robot?

Nao, humanoid robot, is an autonomous, programmable robot. It is designed to meet most of humanoid robot researcher's and developer needs. It is first affordable full featured humanoid robot and currently it is most popular in the market

A French robotics company, Aldebaran Robotics, has developed Nao, Their main office is located in Paris. Development of humanoid robot begun at year 2004 and development project got a name, Nao. Nao was so successful humanoid robot that replaced Aibo, a robot dog by Sony. in the RoboCup. RoboCup is an international robot soccer competition and Nao competed in the Standard Platform League (SPL). Nao joined RoboCup completion also in years 2008 and 2009, and also 2010, new platform version, V3R, was used to compete in SPL.

Because of different needs, several versions of the Nao robot have been released since 2008. The Nao Academics Edition was developed for universities and laboratories for research and education purposes. It was released to institutions in 2008, and was made publicly available by 2011. More recent upgrades to the Nao platform include the 2011 Nao Next Gen and the 2014 Nao Evolution.

Nao robots have been used for research and education purposes in numerous academic institutions worldwide. As of 2015, over 5,000 Nao units are in use in 50+ countries. (17)

9.2 Features

Nao is designed to be offer all basic and advanced features of humanoid robot. The various versions of the Nao robotics platform feature either 14, 21 or 25 degrees of freedom (DoF). A specialised model with 21 DoF and no actuated hands was created for the Robocup competition. All Nao Academics versions feature an inertial measurement unit with gyrometer, accelerometer, and four ultrasonic sensors (sonars) that provide Nao with stability and positioning within space. The legged versions included eight force-sensing resistors and two bumpers. The most recent version of the robot, the 2014 Nao

Evolution, features stronger metallic joints, improved grip and an enhanced sound source location system that utilizes four directional microphones.

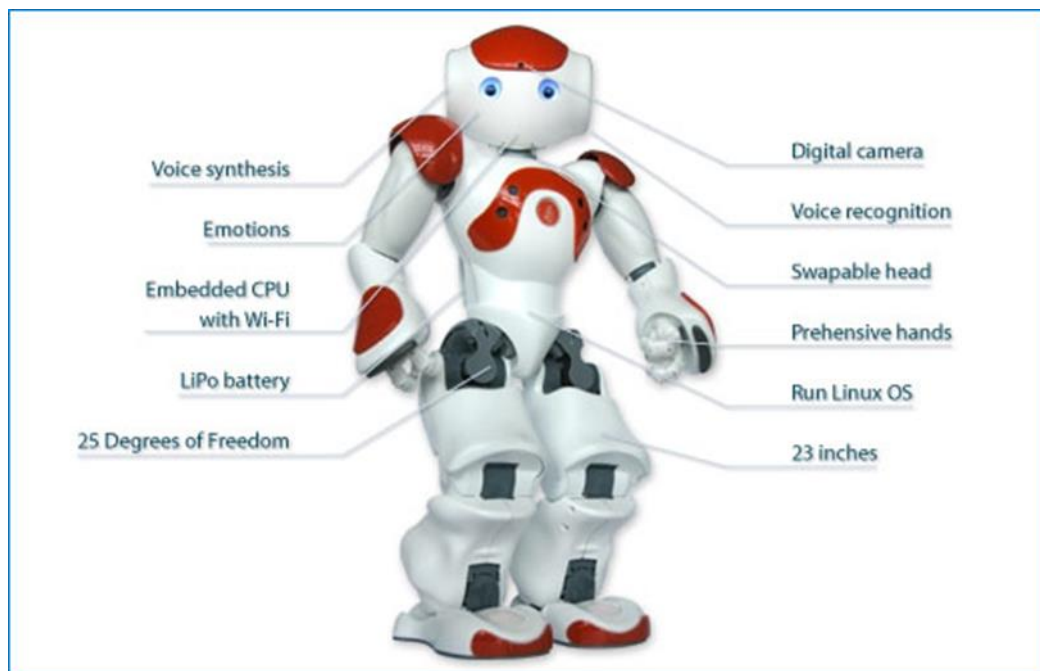


Figure 16. Nao features

The Nao robot is controlled by a specialised Linux-based operating system, dubbed NAOqi. The OS powers the robot's multimedia system, which includes four microphones, for voice recognition and sound localization, two HD cameras, for computer vision and including facial and shape recognition and also two speakers, for multilingual text-to-speech synthesis. The robot also comes with a software suite that includes a graphical programming tool "Choregraphe", simulation software and a software developer's kit. Nao is furthermore compatible with the Cyberbotics Webots Microsoft Robotics Studio and the Gostai Urbi Studio. (18)

9.3 Specifications

Nao V5 Evolution (2014)

Height 58 centimeters

Weight 4.3 kilograms

Power supply	lithium battery providing 48.6 Wh
Autonomy	90 minutes (active use)
Degrees of freedom	25
CPU	Intel Atom @ 1.6 GHz
Built-in OS	NAOqi 2.0 (Linux-based)
Compatible OS	Windows, Mac OS, Linux
Programming languages	C++, Python, Java, MATLAB, Urbi, C, .Net
Sensors	Two HD cameras, four microphones, sonar rangefinder, two infrared emitters and receivers, inertial board, nine tactile sensors, eight pressure sensors
Connectivity	Ethernet, Wi-Fi
Price	6000€

(13)

9.4 Coregraphe

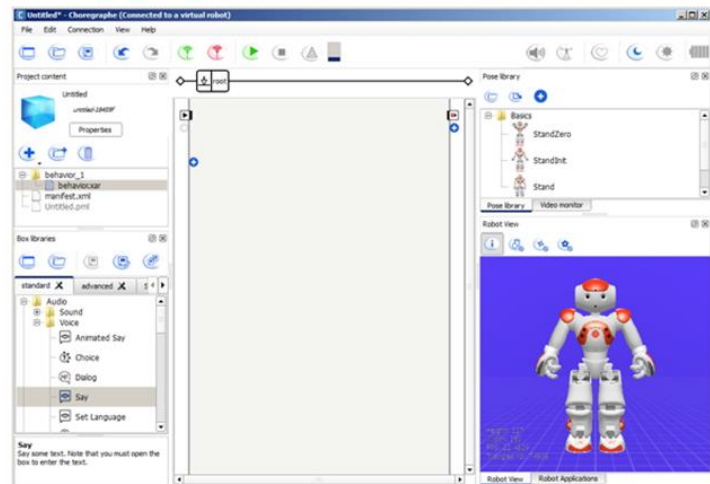
Choregraphe is a multi-platform desktop application, allowing you to:

- Create animations, behaviors and dialogs
- Test them on a simulated robot, or directly on a real one
- Monitor and control you robot
- Enrich Choregraphe behaviors with your own Python code

Choregraphe allows you to create applications containing Dialogs, services and powerful behaviors, such as interaction with people, dance, e-mails sending, without writing a single line of code

Main window

At startup, the following interface is displayed.

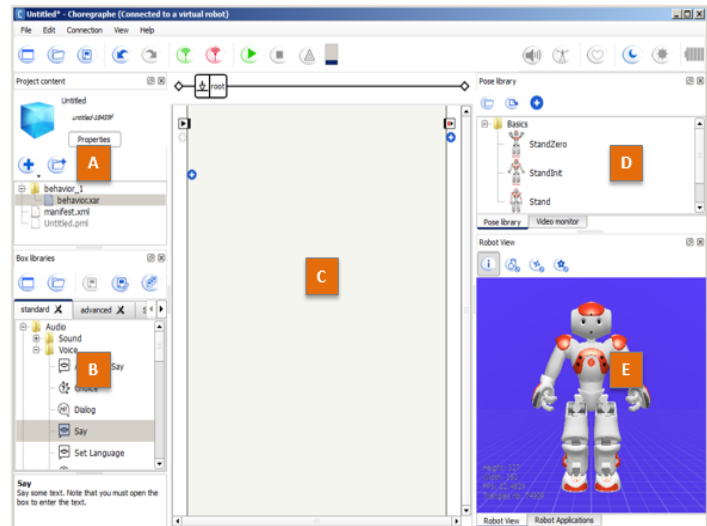


This interface contains a **Menu Bar**, a **Toolbar** and several **Panels**.

Figure 17. Choregraphe main window

Panels

By default, the following panels are displayed:



Part	Name	Part	Name
A	Project content panel	D	Pose library panel and Video monitor panel
B	Box libraries panel	E	Robot View and Robot applications panel
C	Flow diagram panel		

Figure 18. Choregraphe panels

Toolbar



These buttons are shortcuts to actions you will often need while creating behaviors. Note that keyboard shortcuts are also available.

Button(s)	Function
	Create a New project , Open or Save a Project .
	Undo and Redo last actions made in the diagram.
	Connect , Disconnect or Try to reconnect your Aldebaran robot. For more information about the connection, see Connection Management .
	Play or Stop the opened Behavior.
	See the warnings and the errors that can occurs during the execution of your behavior.
	Progress bar that indicates the behavior loading when you click on Play. This indicator can be: <ul style="list-style-type: none"> Mainly grey: the behavior is not loaded. Moving up and down: the behavior is loading. Blue: the behavior is loaded.
	Enables you to set the volume of NAO's speakers.

Figure 19. Choregraphe toolbar 1






	<p>Activate / deactivate the Animation Mode which enables you to easily manipulate your Aldebaran robot and store its position.</p> <p>For more information, see Getting started with the Animation Mode.</p> <p>This button can be:</p> <ul style="list-style-type: none"> ■ Green: the Animation Mode is deactivated. ■ Orange: intermediate state where the animation mode is either loading or unloading. ■ Red: the animation mode is activated.
	<p>Turns on and off the Autonomous Life on the robot. For further details, see: ALAutonomousLife.</p> <p>If you play a Behavior while the Autonomous Life is turned on, Choregraphe plays it using ALAutonomousLifeProxy::switchFocus().</p>
	<p>Rest button. Sets the Stiffness off.</p> <p>If your Aldebaran robot is standing, before setting the Stiffness off, he goes to the Crouch posture.</p>
	<p>Wake Up button. Sets the Stiffness on.</p> <p>Additionally, if your Aldebaran robot is crouched, he also goes to the StandInit posture.</p> <div data-bbox="448 645 1441 701" style="background-color: #f0f0f0; padding: 5px;"> <p>Warning Do not touch your Aldebaran robot during a wake up; or the Active diagnosis may return false positive results.</p> </div>
	<p>Indicate the level of NAO's battery.</p> <p>This indicator can be:</p> <ul style="list-style-type: none"> ■ Green: the level of the battery is almost at its maximum. ■ Orange: the level of the battery is medium. ■ Red: the level of the battery is very low and your Aldebaran robot is going to shutdown in a few minutes if you do not plug it in.

Figure 20. Choregraphe toolbar 2

9.5 Programming Nao

9.5.1 Programming exercise: Hello world

Target was to create Hello world code which would make Nao to say “Hello world”

Let's do it

Step	Action
1.	Start Choregraphe .
2.	Click the Connect to button and connect Choregraphe to your robot.

For further details, see [How to connect your NAO](#).
Your robot appears in the **Robot view**.

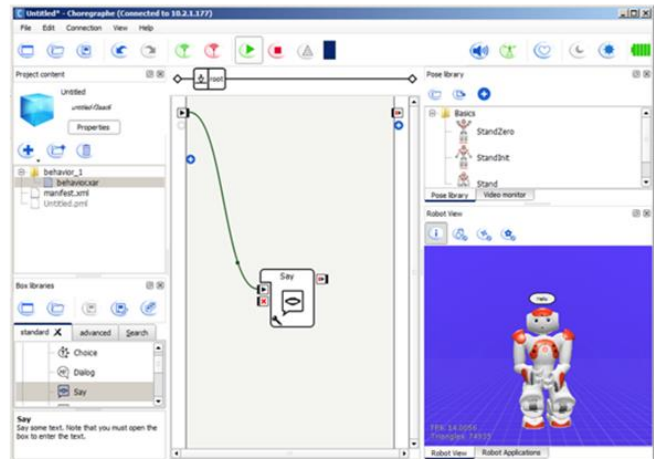
Figure 21. Connecting to Nao

3.	Drag the Audio > Voice > Say box on the grey area.
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Figure 22. Drag Say box

Result

Your robot says "Hello". In the meantime, the **Robot view** displays the message.



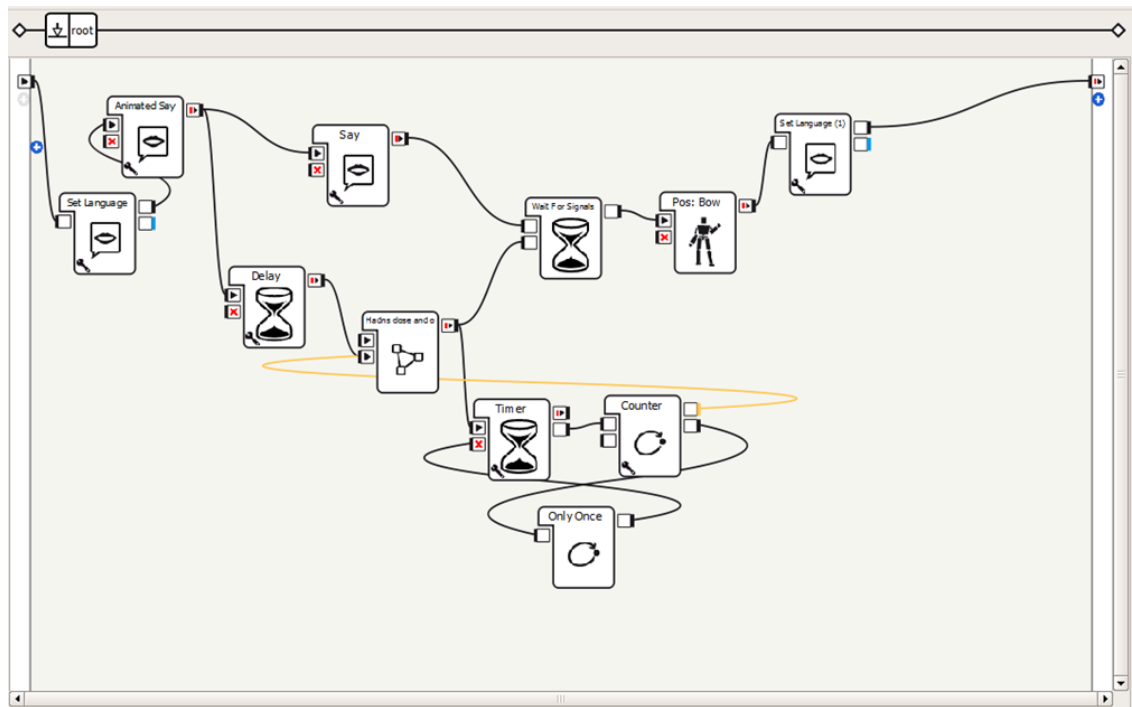
How it works

- The **Connect to** button allows you to define on which robot you will send your program.
- Dragging and dropping a box creates a ready-to-use copy of a predefined program.
- The **Play** button has a 2-in-1 function: it uploads the program on the robot and starts its execution.
- The execution automatically starts the box linked to the **onStart** input.

Figure 23. Nao says "Hello world"

9.5.2 Programming exercise: what-if-loop

Target was to what-if-loop in Choregraphe. Following program was created using drop down boxes and then doing local editing. It contains simple what – if loop with timer



9.5.3 Findings

It is easy to start Nao box programming and user can create a lot of functions especially when combined with move recording tool. Nao can be used easily as elderly care robot, but its price is too much for every home usage. It can be used as shared resource in homes or in facilities. Dropping prices with right feature combination could make Nao even more useful.

A Belgian company made new very intuitive UI to Nao and renamed it as Zora. Now they are selling it with price 20 000€, when Nao price is 6000€. This is a good example how to create new services from current platform

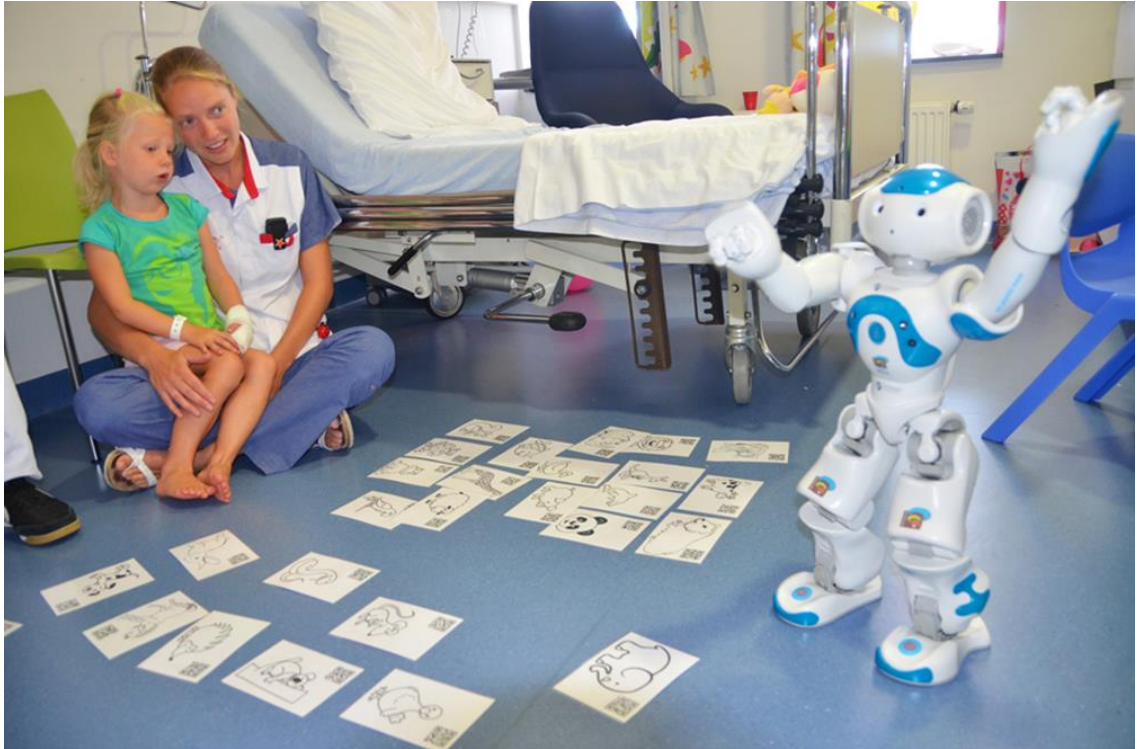


Figure 24. Zora in action.

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