Assistive Systems

Assistive Robots

Human Computer Interaction Group (HCI)

Institute of Visual Computing & Human-Centered Technology,
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Under partial use of scripts of Hochschule Furtwangen, Prof. Dr. Christophe Kunze

Content

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Introduction – Sequence of Course

I. Demarcation and Definitions

- Umbrella term AAL
- Technical Aids vs. Assistive Systems

II. Active User Interface (HCI)

- Active Support

III. Assistive Robots – Added Movement

- **Human Robot Interaction (HRI)**

IV. Sensors – are entering the living area

- Safety and Support

V. Ethics, Law and Economics

VI. Requirements Analysis and Evaluation

Objectives

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- Get to know and understand the technical basics and state of the art of research and development in Assistive Robotics
- To get to know applications and limitations of using robots as Assistive Systems
- Learn how to evaluate robots and to assess and handle risks

Robots, what is this about?

Topic: Assistive Robots (AR), Societal change, Self-determined living

Robots? Can come in different forms

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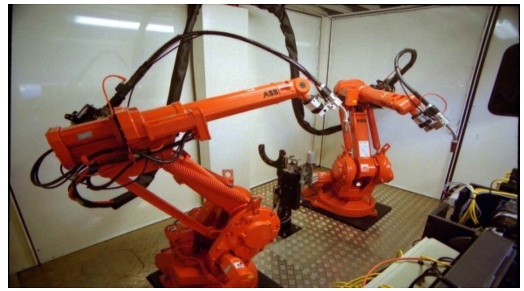

Industrial robots
Domestic robots
Mobility robots
Rehabilitation robots
Surgery robots
…

A robot is a mechanical or virtual agent, usually an electro-mechanical machine that is guided by a computer program or electronic circuitry.

How do you picture a robot?
Very often as work robot (industrial robot)
Or an intelligent, human-like robot like in SF movies
Meanwhile a wide range of robots exists, but not all are used as standard

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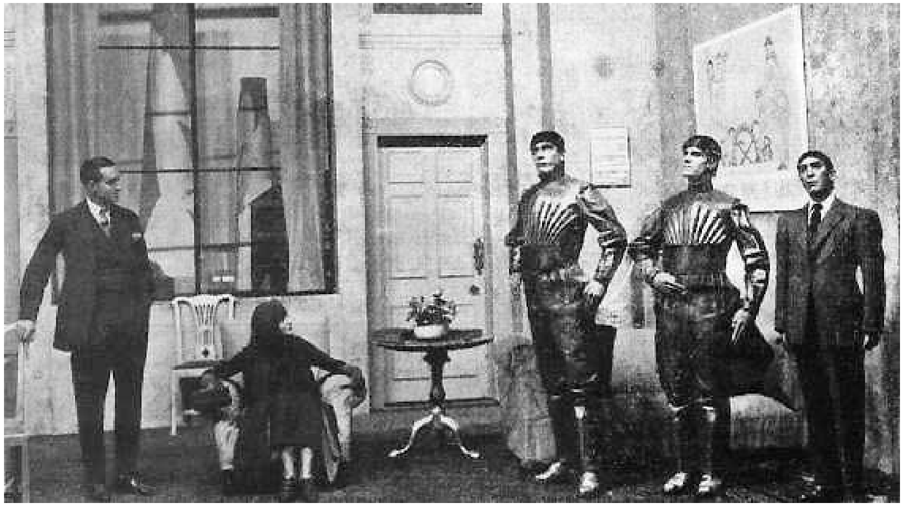
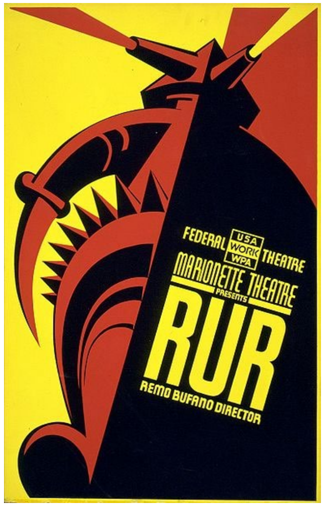
Robotics / Robots: Definition

- The term Robotics / Robots is not exactly defined
- Robotics is the science of development and construction of robots
- Most often robots (mobile or stationary) denote machines for managing different tasks, where **movement or moving objects** is important
- Robotics comprises **HW+SW**: parts of informatics (esp. A*rtificial intelligence)*, electronics and mechanical engineering
- Artificial Intelligence denoted technologies for enabling computers to autonomously solve problems (pattern recognition, classification, knowledge based systems, …)
- With increasing use of **sensors** the differentiation from „simple“ machines becomes more difficult

Robots: History

The name „Robots“ and respective descriptions of „machine humans“ appear long before technical realisations in *Science-Fiction* literature. The term was invented in 1920 in the theatre play „RUR“ of Karel Capek for human-like **worker** machines.





For long robots had a „futuristic“ touch, meanwhile they have become common.

AAL Robots: Attempt for definition

A **robot** in general

- Is a computational intelligent system
- With input and output (data, actions …)
- With a set of algorithms (initially) designed by humans
- With a (potential) ability to adapt and learn based on data and earlier decisions
- Can be regarded as “autonomous” within a given domain or environment (which might change) as long as they can accomplish their tasks
- May appear “alive”
- Should be safe, reliable and trustworthy
- Is a “work assistant”

AAL Robots: Attempt for definition

An **AAL robot** is a robot that:

- assists the target group of older users including users with disabilities.
- supports the target group during daily life or work.
- improves or maintains the independent living of the target group.

A robot is a *mechanism* that has *sensors and actuators*, makes *sensor- or knowledge-based decisions* in order to fulfil its aims and is capable of *visible motion* in *two or more axes*.

Source: benefit study on „Potential of Robotics for AAL“ 2015

Types of robots

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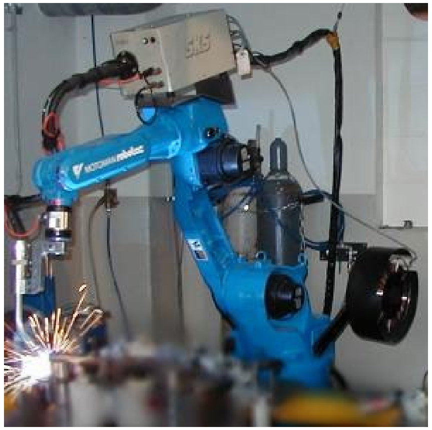
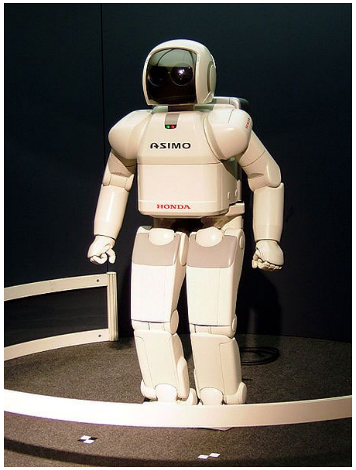
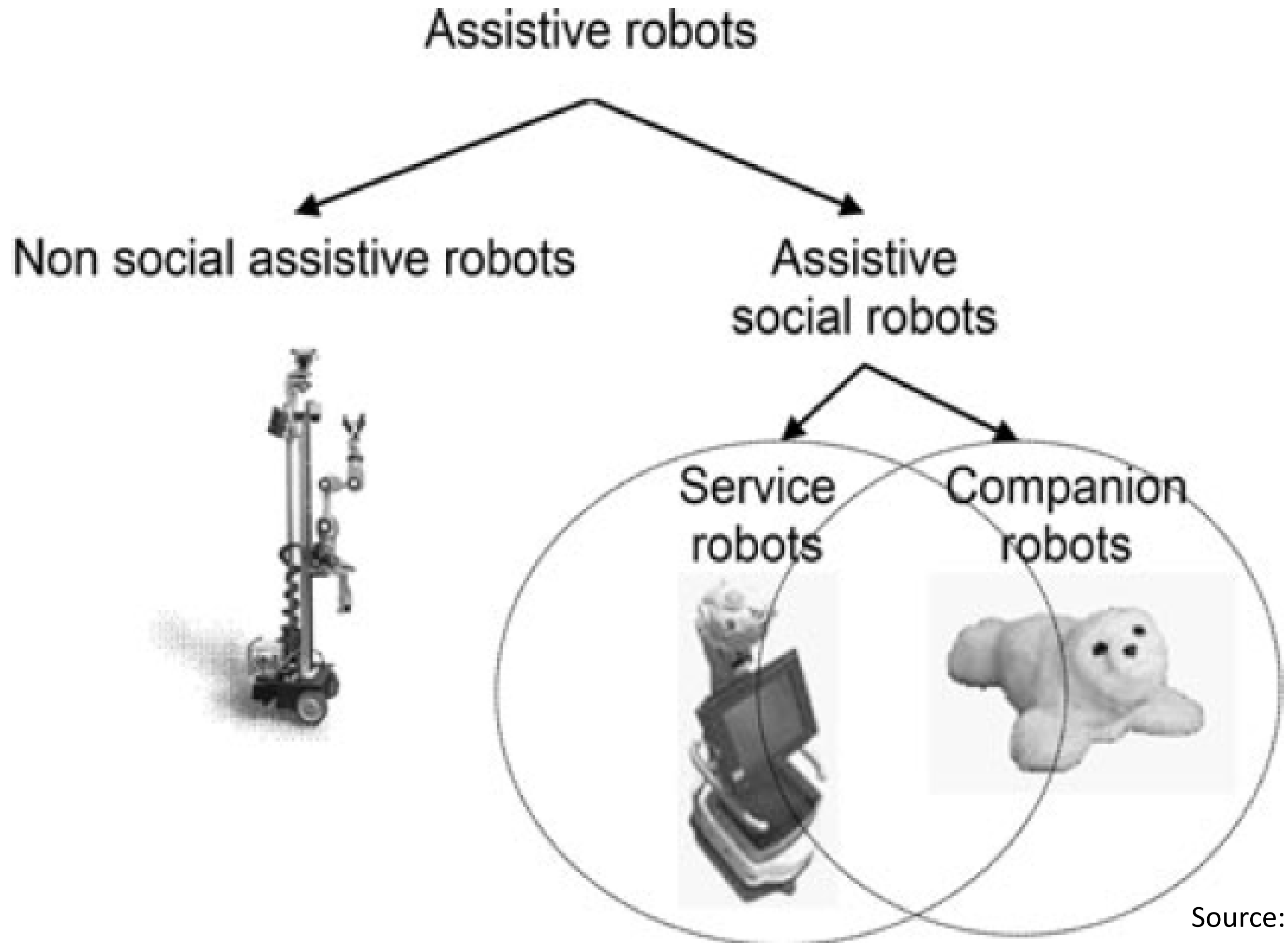
- **by application area**:
  - Industrial robots (e.g. welding robots, typically not mobile, isolated)
  - Service robots (services aside from production)
  - E.g. AAL robots
- **by construction**:
  - E.g. humanoid robots (human-like robots, typically walking machines or on wheels)
  - E.g. driverless transportation devices





Acting in shared / separated spaces with humans

Service robots - Assistive robots

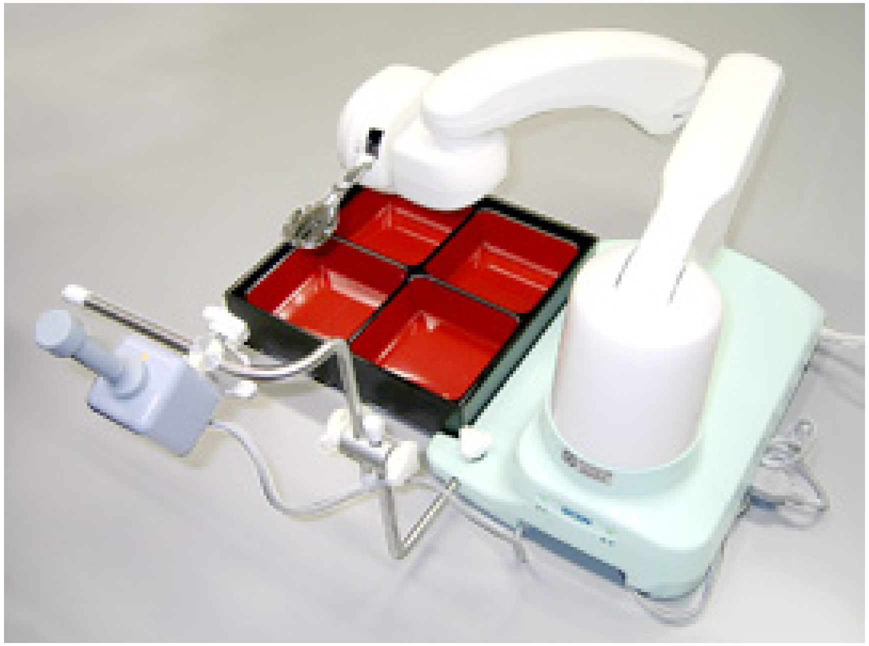


„Assistive robots“ is an umbrella term
Social or just „functional“ is the first differentiation
Further differentiation according to manipulation and communication features

Source: M. Heerink et al. (2010) Assessing Acceptance of Assistive Social Agent Technology by Older Adults: the Almere Model, J of Social Robotics, vol. 2, no. 4, pp.361 - 375.

Non-Social Assistive Robots

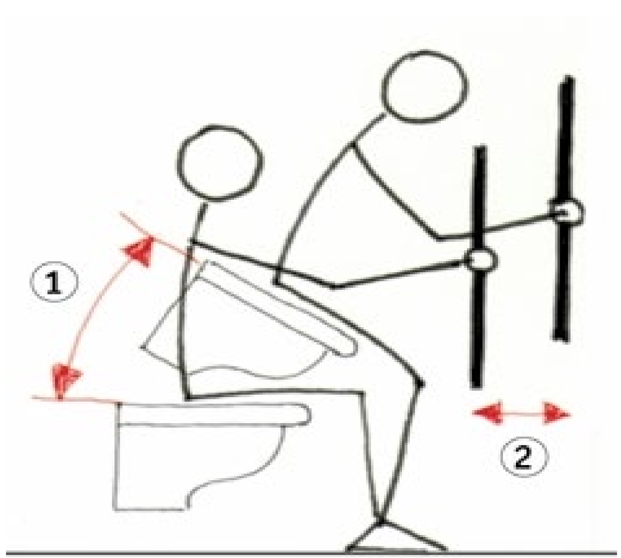
Example: My Spoon robot

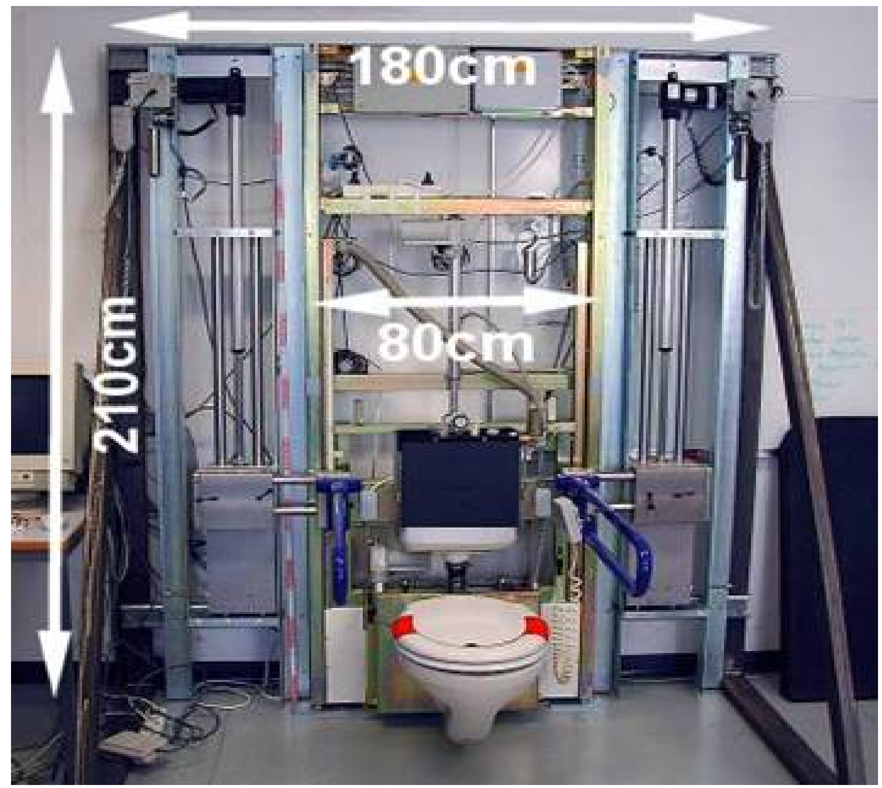


Example of a non-social robot: My spoon robot
https://www.focalmeditech.nl/en/meal-supports

Non-Social Assistive Robots

Example „Intelligent“ toilet “robot”





Example of a non-social robot: Intelligent Toilet („Friendly Rest Room“ project)
Height adjustable, tilt adjustable, speech control, RFID for automatic setting of individual preferences, extensive field tests in Vienna
http://www.is.tuwien.ac.at/fortec/reha.e/projects/frr/frr.html

Assistive and Social Robots

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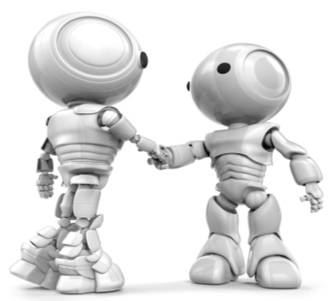
Assistive (service) robots

compensate for disabilities

- grasping difficulties, mobility, monitoring and comprehension
- for autonomy of old persons or persons with disabilities
- physical manipulation capability (of objects)
- direct physical interaction with user



Social (companion) robots

- communicate with the user, information at a distance to caregivers, physicians, family and others
- social interaction and communication by bridging distances for homebound person
- for lonely and dependent people
- little or no physical manipulation capability

Assistive and social robots can take many forms. Most often no direct contact with user -> special robotics problem

A lot of definitions

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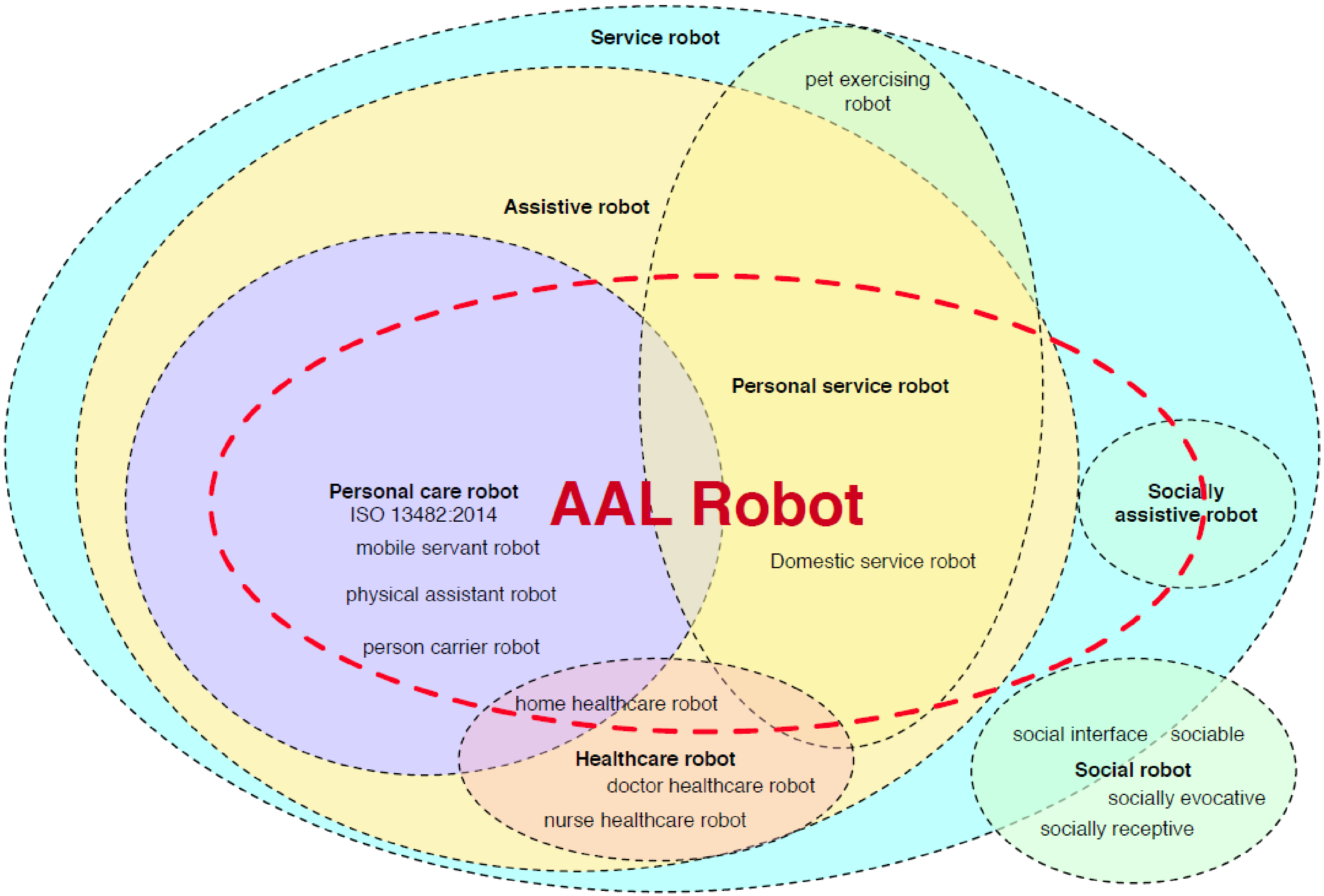

From benefit study „Potential of Robotics for AAL“ 2015

Examples of robots

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Hector - Pepper – Romeo – Alias - Care-O-bot-3/4 – Nao
Kompai – Reem-C – Tiago – Medisana - Hobbit 1/2
3 of these robots: Kompai, Nao, Hobbit, have been developed or used in own research projects
Interaction with user in the center. If stability is called for (wide) platforms on wheels are used

Typical examples per category

				
Robotic Mobility Aid Friend II	Fetch & Carry Support Botlr	Robotic Manip. Aid Asibot	Rehabilitation Robot Auto Ambulator	Telepresence Robot Giraff
				
Personal Care Robot Bestic	Household Robot Scooba	Companion Robot Hector	Emotional Robot Paro	Entertainment Robot Ifbot

From benefit study „Potential of Robotics for AAL“ 2015

Usage of service robots – professional and domestic

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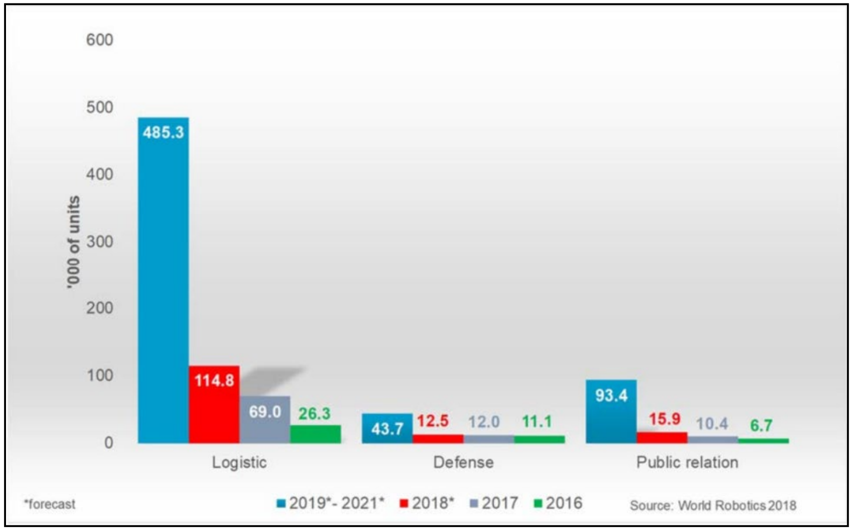
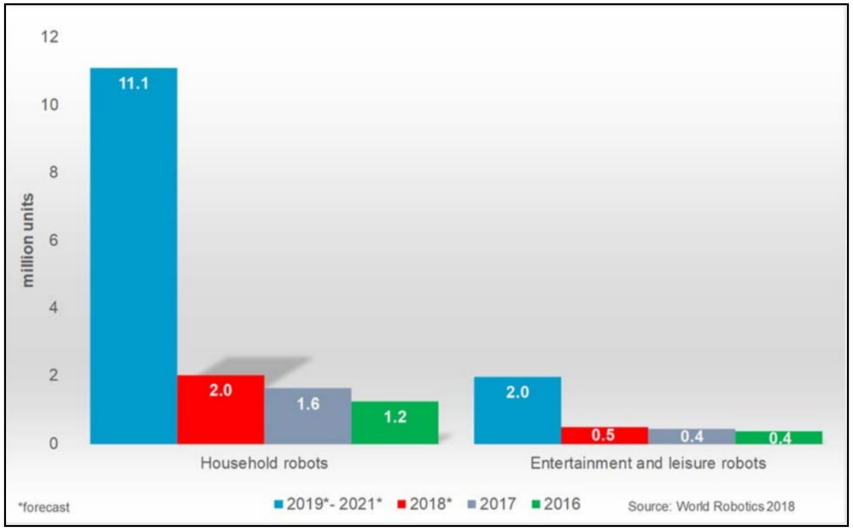


Service robots for professional use in main applications. Unit sales 2016 and 2017, forecast 2018 and 2019-2021.



Service robots for personal/domestic use. Unit sales 2016 and 2017, forecast 2018 and 2019-2021.
Ca. 25+% growth.

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Service robots in domestic sector

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Useful under certain conditions

On the market

Lawn mower robot

Beispiel: Bosch indego

Vacuum robot

Beispiel: iRobot Roomla

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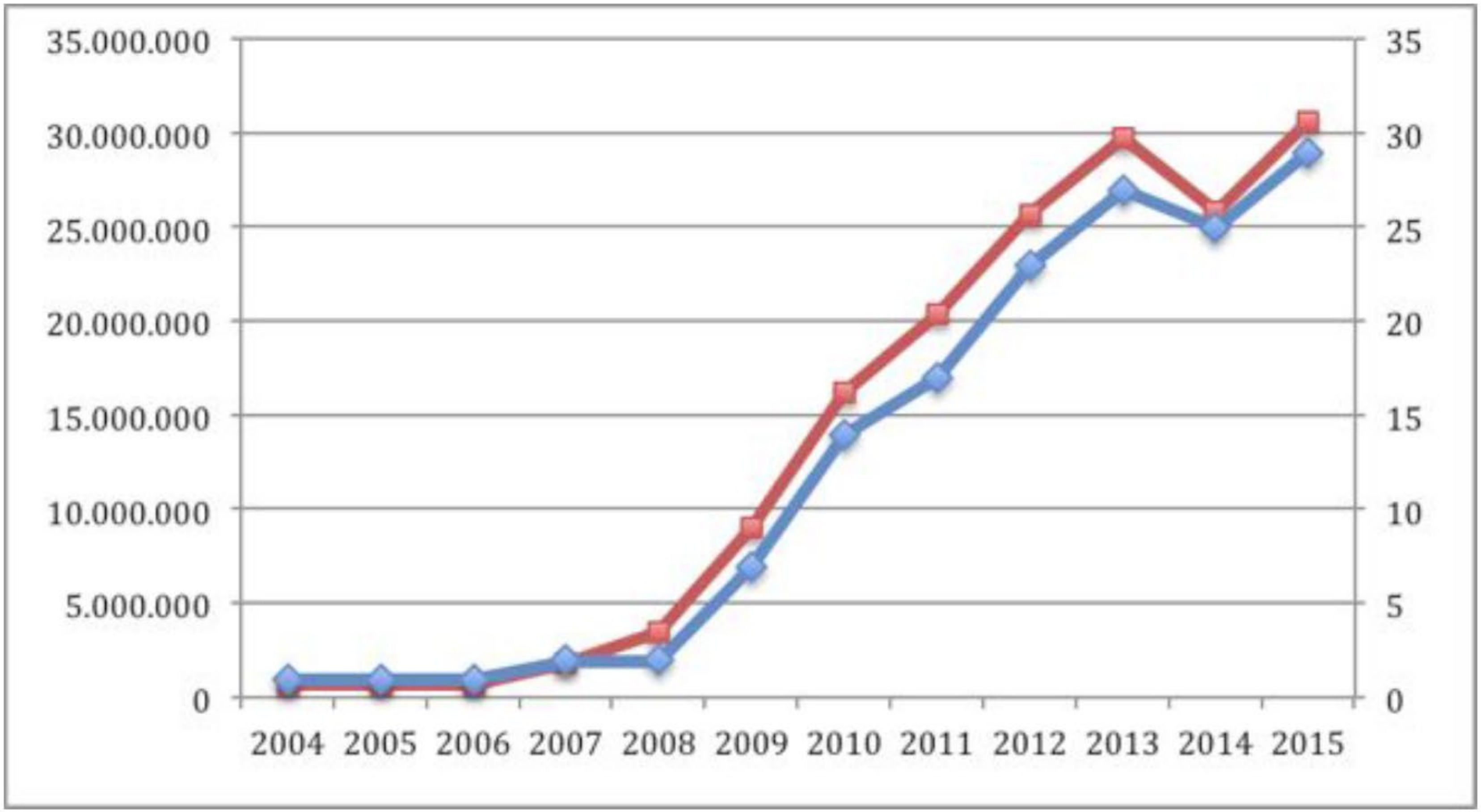
AAL Robotics research projects

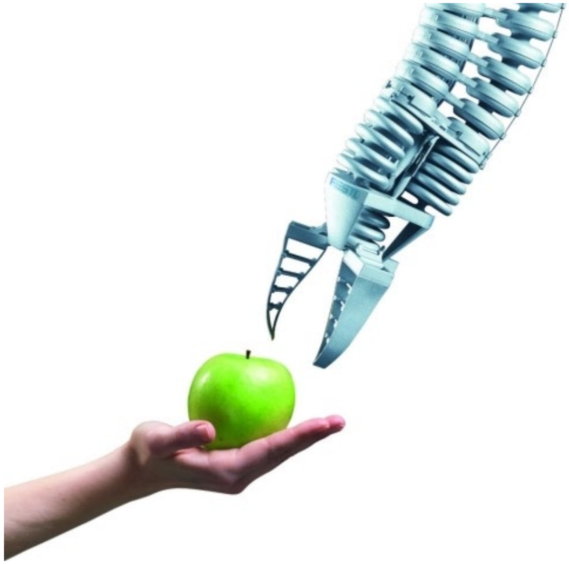


Investment per annum (€) into AAL robotics research projects (red - left) and the number of ongoing research projects in the field per year (blue - right)
From benefit study „Potential of Robotics for AAL“ 2015

Current state: lightweight robots

By low weight and small forces safe interaction with humans
- or by sensor skin

Example: kuka LBR



Example : Festo Bionischer Handling Assistent

Example : BDR AirSkin

Current state: Low cost robot platforms, „service robotics for all“

„TurtleBot3“ – 500-2500€	„Beam“ – ca. 2100€	„PR2“ – ca. 200-400k€
	SUITABLE TECHNOLOGIES	Willow Garage
General robot base	Tele-presence robot base	Manipulation robot base
Research, simple	Research, helping clients	Research

Current state: Low cost robot platforms, „service robotics for all“

Aldebaran / Softbank Mobile

NAO - Pepper - Romeo

60 - 120 - 140 cm

~8400€ ~1400+Abo €100/m?

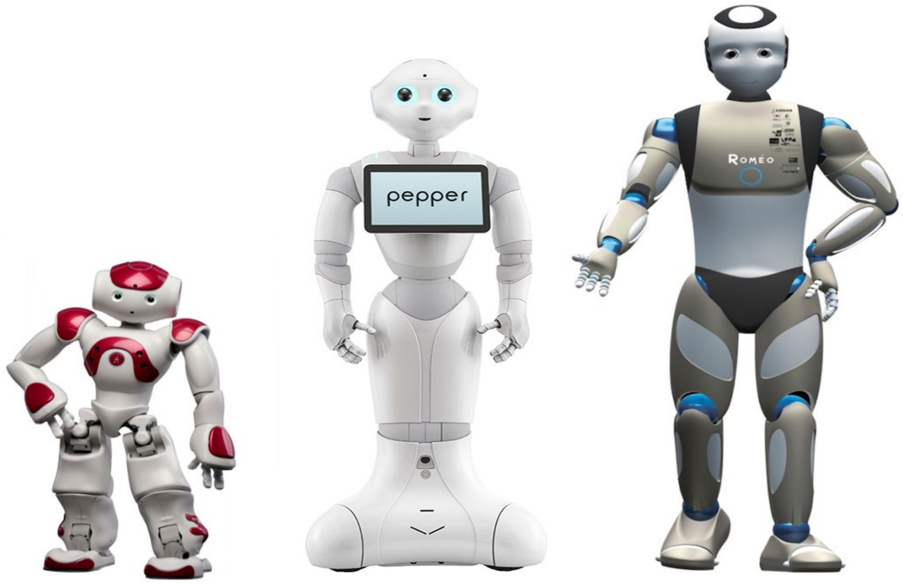
~20000€

Medisana

Home Care Robot

120cm?

2990€ Q2/2020



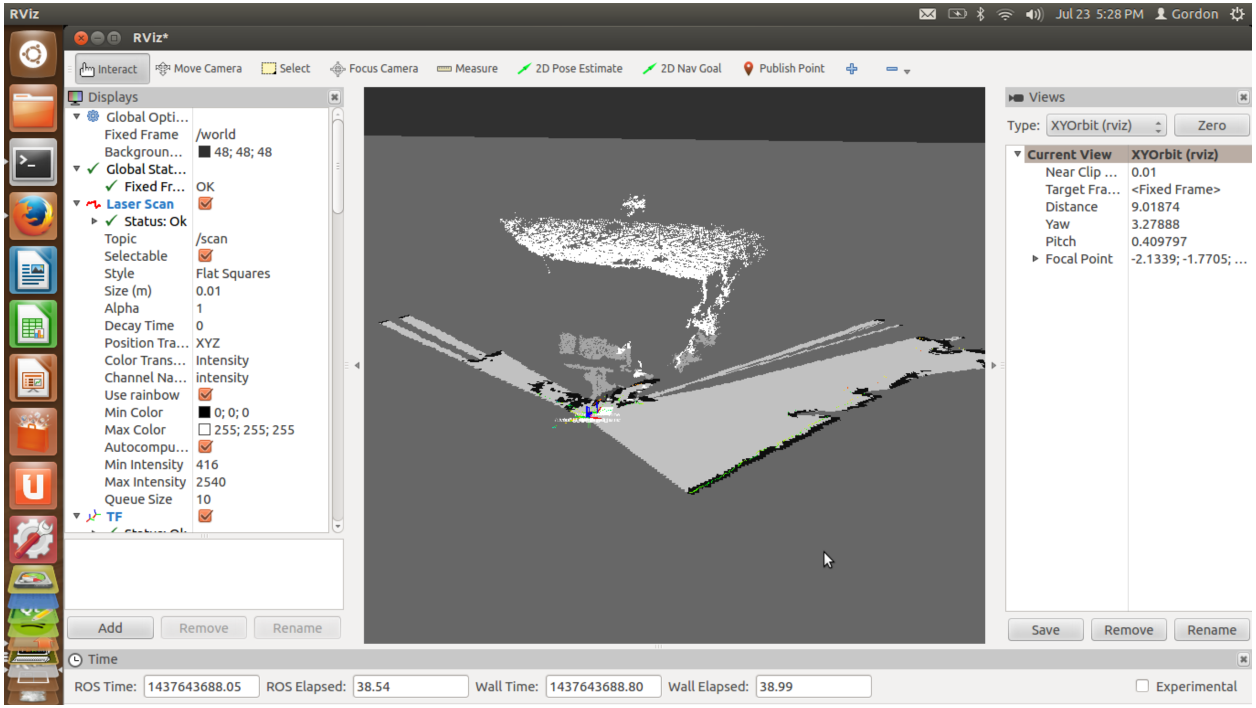
Pepper video: https://youtu.be/tYY3RCzuwBA

Nao video: https://www.youtube.com/watch?v=4uYN_3gL4_Y

Medisana video: https://www.youtube.com/watch?v=gQ97Mlow4jo

Current state: Open source software and runtime environments

ROS: Software library for environment recognition, movement control, visualisation



https://www.ros.org/

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Current: Learning robots „Programming by demonstration“

Robots learn how to cook

Roboter lernt Kochen aus Youtube-Videos

vorlesen / MP3-Download

Roboter lernen Kochen aus Youtube-Videos (Bild: www.darpa.mil)

Roboter sollen sebstständig Arbeitsschritte aus YouTube-Kochvideos wiederholen und die korrekten Geräte handhaben -- das verspricht eine von Forschern der University of Maryland entwickelte Technik

Source: heise, 2015

Limiting factors

The application of service robots in the domestic area is still limited, mostly by

- High costs
- Low performance (for ADLs)
- Acceptance
- Unresolved service structure

Could there be application scenarios for care?

Application scenarios for robots

Scenarios of robot application

- Domestic robots
- Driverless transport machines
- „Toy/emotional robots“ for Dementia therapy
- Communication / Telepresence
- Mobility aids (instrumented wheelchairs, …)
- Service robots in professional care
- Lifting- and repositioning
- Rehabilitation

Application in healthcare: Driverless transport systems

Die Übernahme eines Speisecontainers erfolgt in der Versendestation in der Küche.

01→

Auf dem Weg zum Fahrziel wählt das System automatisch einen geeigneten Aufzug und aktiviert ihn per Funkkommunikation. Türen im Verlauf der Strecke werden automatisch geöffnet.

02→

Nach Anlieferung des Containers auf die Bettenstation erfolgt die Verteilung der Speisen durch das Stationspersonal.

03→

Auf der Rückfahrt von der Bettenstation wird ein bereitstehender leerer Container wieder mitgenommen. Dadurch wird die Anlage optimal ausgelastet.

04→

Nach Anlieferung und Entladen des Containers kann dieser gegebenenfalls zu einer Waschanlage gebracht werden.

05→

Das Fahrzeug steht nun für den nächsten Fahrauftrag zur Verfügung oder parkt in der Ladestation zum Nachladen der Batterien.

06

Source: swisslog

Application scenario: Communication / Telepresence

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Telepresence robot (Panasonic)

Source: CompanionAble

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Application scenario: Assistance for drinking water

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Source: FhG IPA Care-O-Bot 3

Source: ieee FhG Care-O-Bot 4

Care-o-bot 3 brings water: http://www.youtube.com/watch?v=tdmh-1Ohw4c&feature=related (starting 00:35)
Successor Care-o-bot 4: http://video.golem.de/wissenschaft/15122/care-o-bot-4-auf-der-hannover-messe-fraunhofer-ipa.html

Application scenario in care/nursing: Lift/reposition

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Source: Riken (Riba II), Prototyp

The follow up version is called ROBEAR

Application scenario in care/nursing: Lift/reposition

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Source: Panasonic Transfer Assist Robot, Prototyp 2011

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Application scenario in care/nursing: Lift/reposition

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Source: Toyota Partner Robot,

http://www.toyota-global.com/innovation/partner_robot/family.html

http://www.diginfo.tv/v/11-0239-r-en.php

Source: Attris R2D2 Aufstehhilfe,

https://www.attris.de/produkte/aufstehhilfe/aufstehhilfe-r2d2-und-r2d2-v

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Application scenario in care/nursing: Lift/reposition

Source: Robotic Bed, Panasonic

Application scenario: Hair washing

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(Prototype, Panasonic)

Application scenario: Mobility aids

Source: DFKI, Forschungsprototyp

Displayed at the 39th Tokyo Motor Show 2007

Source: Toyota, Design-Studie

Application scenario: Mobility aids

Source: Toyota Partner Robot,
http://www.toyota-global.com/innovation/partner_robot/family.html

Source: Murata Systems

Application scenario in care/nursing: Tele-/Rehabilitation/Therapy

Source: hocoma AG

Source: hocoma AG

Application scenario: Telepresence and more

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VictoryaHome
http://www.victoryahome.eu

VGo telepresence robot
http://www.vgocom.com/

Medisana Home care
https://www.medisana.de/thehomecarerobot.html

Application scenario: Assistance for eating/feeding

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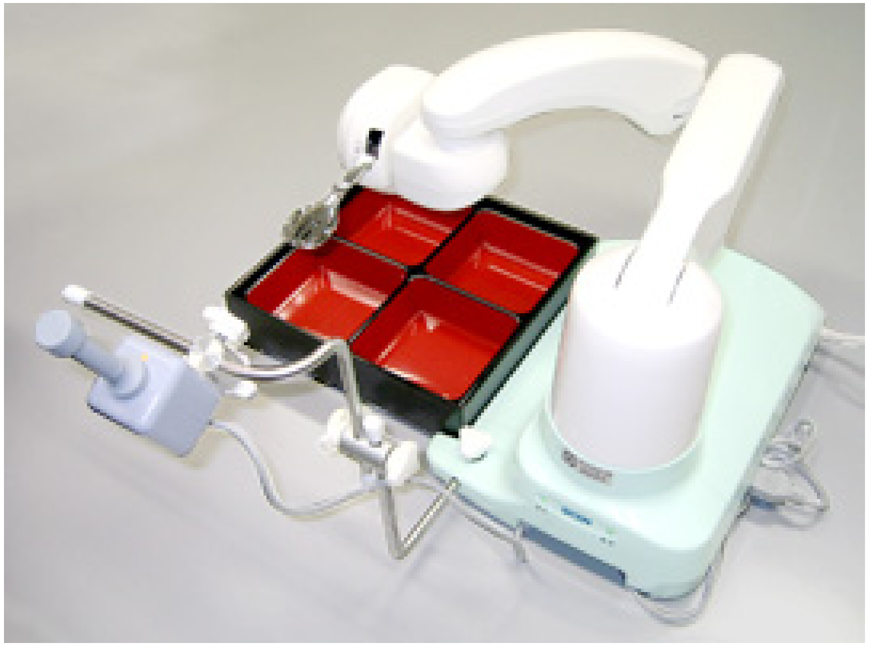

My spoon robot
https://www.focalmeditech.nl/en/meal-supports

Application scenario in care/nursing: Emotional activation: PARO/Lizzy

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http://www.parorobots.com

Video https://youtu.be/agia0O8ms84

Video https://www.youtube.com/watch?v=gIdLhgAWnUM

Source: Maternus Kliniken AG

Source: Joy for all / Hasbro

Care robotics framework for care of old people (example)

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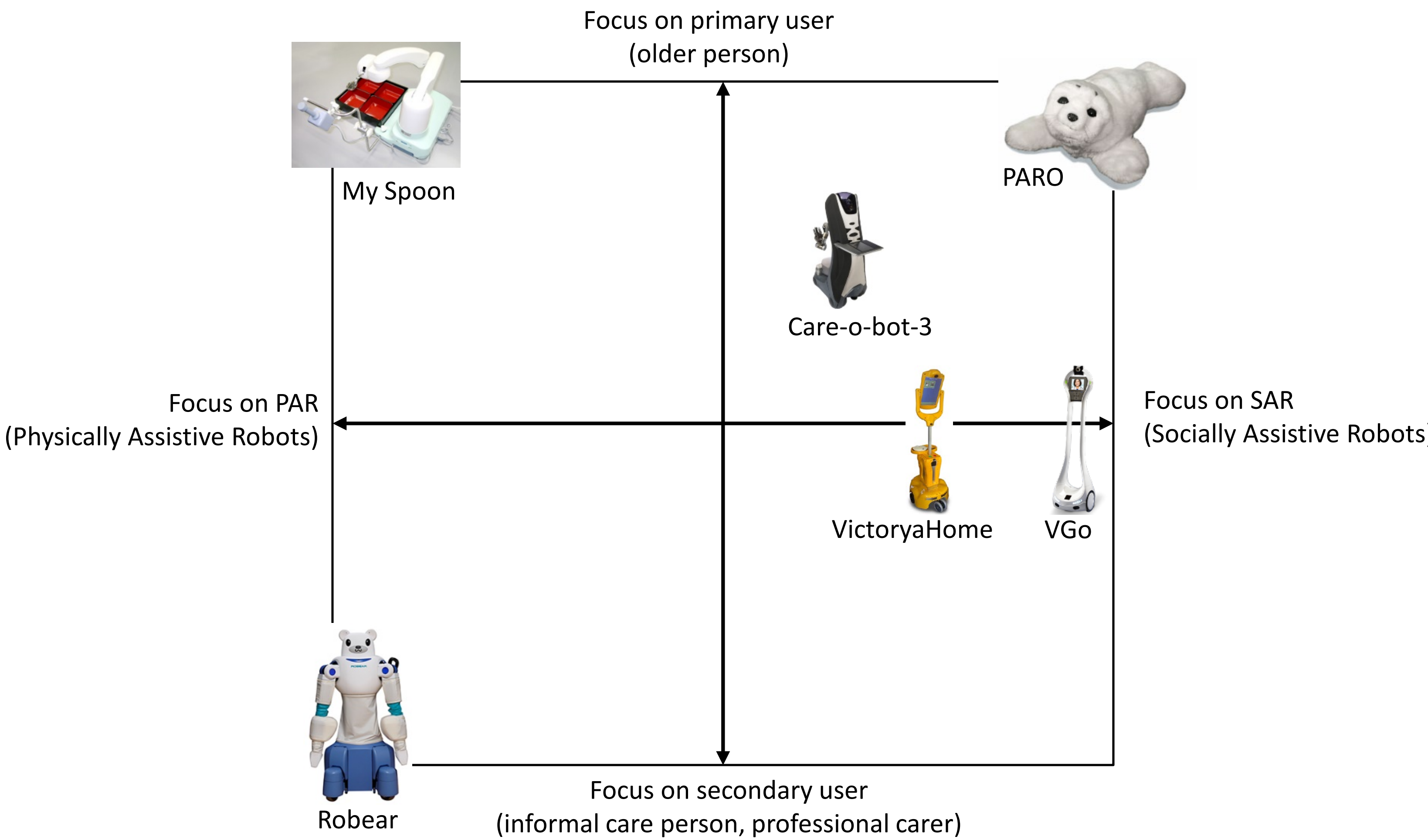

Based on Source:
Bedaf S. et al. 2017 Robots supporting care for elderly people, in Encarnacao P. et al. (eds) Robotic assistive technologies, pp 309-332

Summary

Robots have big potential in support for humans

- in industrial environment (production) robots are meanwhile widespread in use
- „Service robotics“ is seen as important future application segment
- There is lots of research and prototypes

but

- Still there are only few systems suitable for interaction with humans
- Complex tasks are still difficult for robots
- Costs often are (still) not within marketable range

Robots as Assistive System
Benefits of Movement

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What are Assistive Robots already capable of?

- (Tele-)communication / information ✓
- Tele - medicine /therapy ✓
- Reminders ✓
- Detection of emergencies (falls) ✓
- Manipulation/transport?

What does a robot transform into a „system“?

- Autonomous action e.g. patrolling
- Adaptation to changing environment
- Networking with other systems
- Detection of emergencies and context

Building blocks for robots

Manipulation / control of movement

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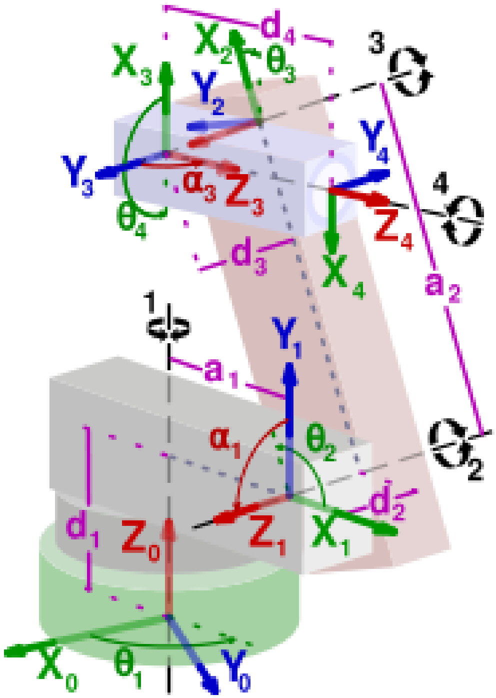
Robot kinematics

- Typically system with several independent (translatoric, rotatoric) axes (x degrees of freedom)
- Elaborate mathematical modelling of robot movements, e.g. by coordinate transformations (forward / backward)
- Differentiation of static and dynamic behaviour
- Problem field grasping of objects



Sensing the environment / recognition of situation

Robots have to detect and recognise objects in their vicinity

- Machine vision (image recognition / object recognition)
- Depth information
  - Stereoscopy
  - Laser-Scanner
  - Radar
  - …

Typical building blocks

Mobility: Mobile platform or legs
GUI: Touchscreen or beamer
Emotions: Head or face
Handling: Tray for carrying objects
Manipulation: Gripper, arm
Sensors: localization, navigation, collision detection
Speech: ASR (Speech recognition), Distress Sounds and TTS (Text To Speech)
Vision: Face and gesture recognition
Remote Control/Call

Robots, functions

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- Movement, most important function
  - Robot comes to user
  - Robot can go to other rooms/charging
- Transport and carry
  - Robot carries load
  - Robot serves as support for user
- Manipulation
  - Grasping and moving of objects
    - From floor - from user
    - From table - to user
    - From shelves - liquids

Robots, functions of HCI

- HCI output
  - Display
  - Speech output
  - Gestures, movements
- HCI input
  - Touchscreen
  - Speech recognition, calling
  - Gestures
  - Extra call button
- Sensors (Awareness)

Considerations in construction

Base

Size/space needed

- Little space in flats of old users
- Stability against tilting
  - User could use it as support!

Motor

- fast, silent, efficient

Power supply

- runtime, autonomous charging

Construction is made from typical components depending on application

Types of locomotion

- Wheels
  - Number
  - Arrangement
  - => Degrees of freedom
- Tracks
  - Good in terrain, bad for floor
- Feet
  - Extra complexity because of stability and coordination

Types of wheels

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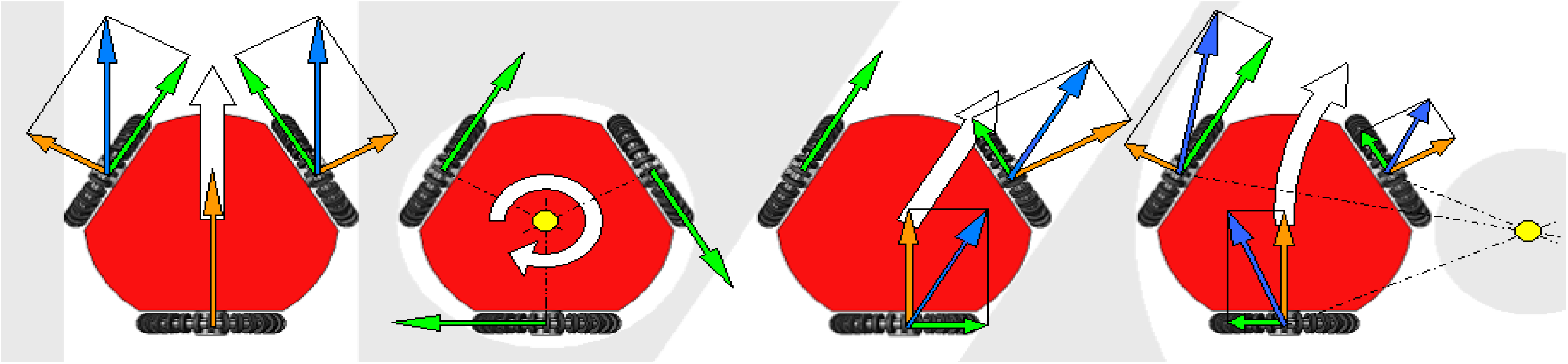
Omni directional

Mounted rings as tread

All-side-wheel 90 degrees, not so quiet run, low load capability



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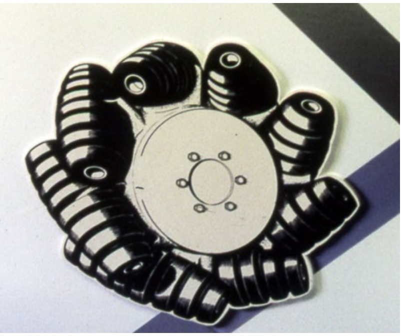
Types of drives

Omni directional:
Mecanum, 45 degree rollers,
Bearings sophisticated
Video: https://www.youtube.com/watch?v=_tmiu1wpp_E



Omni directional:
Drive-turn-module,
Sophisticated construction

Types of drives, DOF

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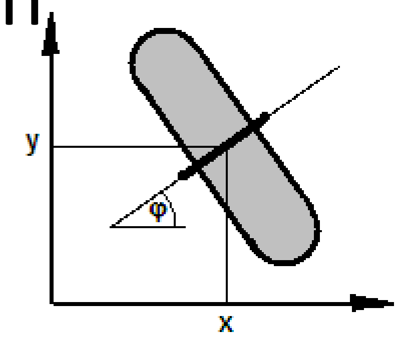
DOF of a mechanical systems

a robot is **holonomic** if the number of controllable DOFs is equal to their total number

Example: wheel from position to position:

3 DOFs „in total“ (in space)

But non-holonomic roll pre-condition



=> only 2 DOFs

(2x turning) „in operation“

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Types of drives

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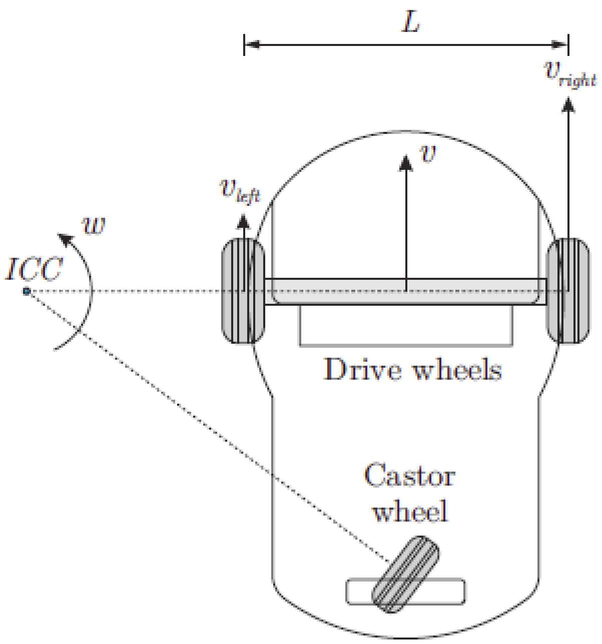
2 wheel drive, differential drive:
+ Caster/Castor wheel, overrun, in tow



Center of rotation – space needed for turning

Types of drives

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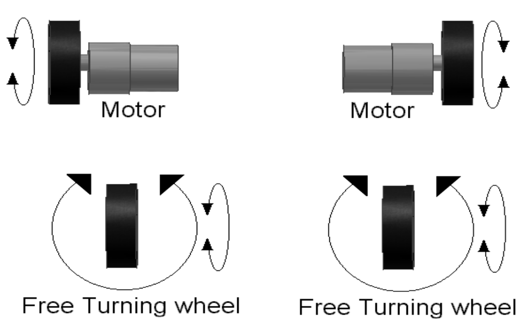
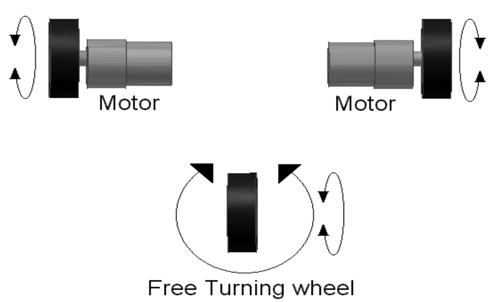
2 wheel drive with castor wheels

Stability against tilting (4-point) , definedness (3-point) on non-flat floor





Fixed 4 wheel arrangement, tanks - shearing

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Drive

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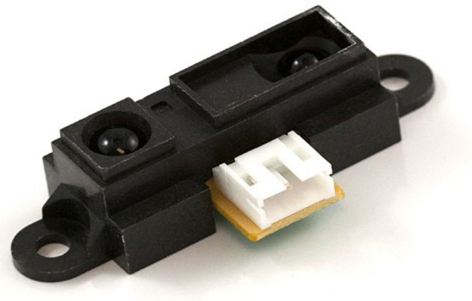
Typical problems (in principle manageable)

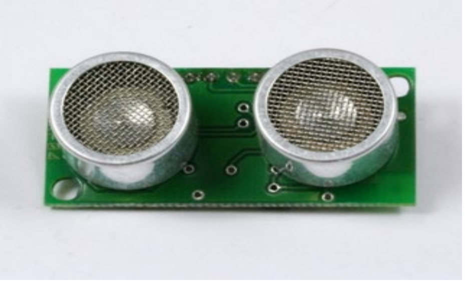
- Drive over door steps ~ 3cm
  - Wheels big enough
- Space needed for direction change
  - Turning on spot before driving
  - Circular/round shape
- Mostly sensors in front
  - Only drive forward or turn in place
- Timely braking/stopping
  - Drive “on sight”, depends on distance
- Avoid “getting stuck” (bottlenecks)

Most important sensors

Odometry

wheel path from rotations – slip!





Distance

IR, US

Small angle, short range

Laser scanner (most 2D), LIDAR

Wide angle (270 Grad) and range, were expensive, big, now smaller in cars

Radar (from automobile area)

becomes affordable

Most important sensors

3D

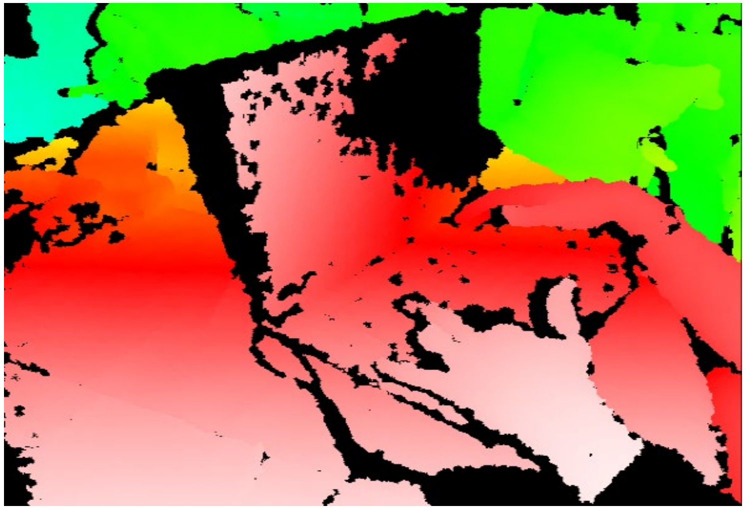
TOF Camera (Time of Flight)

time until reflection

Kinect 1

Pattern

(Structured light)



Small angle (50 Grad), Minimum distance (> 0,5m), illumination dependent (sun)

Future: vision based like autonomous cars

Collision bumper – last resort, emergency stop

Safe reaction? Move away in which direction?

Viewing angle and dead/blind angle

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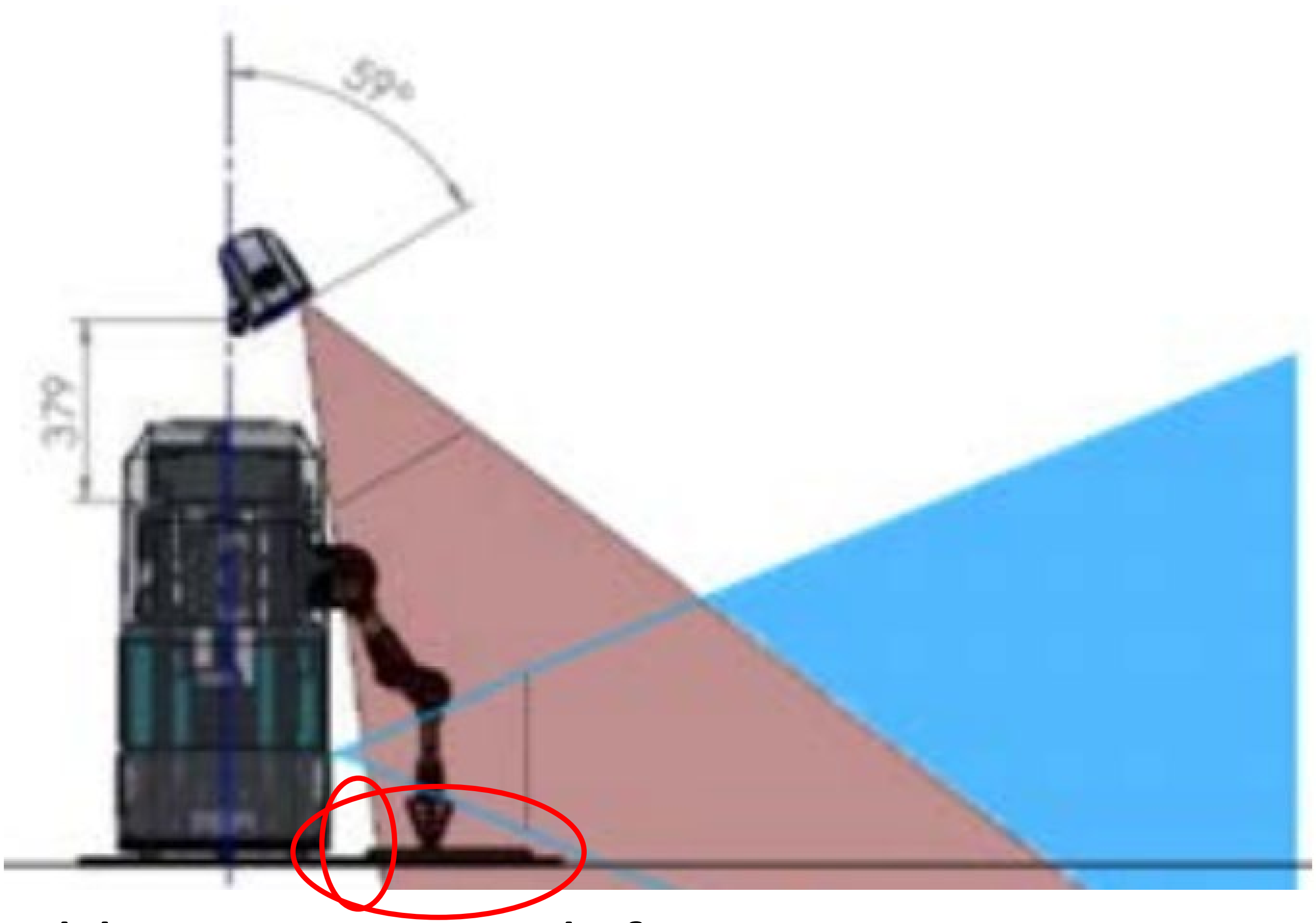
Near distance and low height critical (feet)



- Problem in approach for interaction

VO Assistive Systems

Navigating, localising

VC&HCT

- SLAM (simultaneous localization and mapping) particle filter and probability distribution for location
- Map of environment with fixed obstacles
- Special targets (charging station)
- Lost Robot Problem (Start position)
- Solved by “look around”, often turning on spot

VO Assistive Systems

Self localising by turning

In the beginning unclear position, estimated by measuring distance to fixed obstacles in map

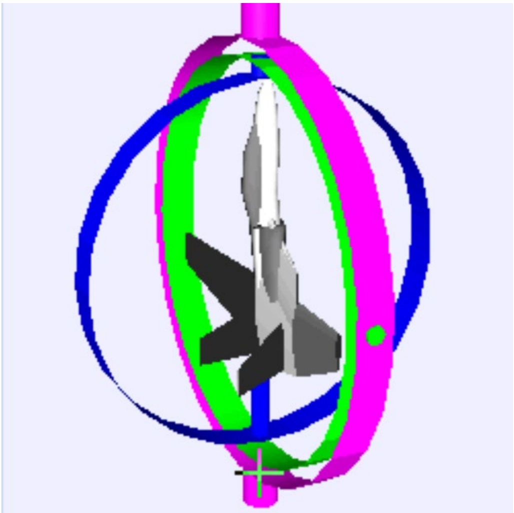
Improvement after 1 resp. 2 rotations
Also good anytime if viewing angle is limited, but doesn‘t look very smart

Pose, Transformation

Pose or spatial position
Combination of

- Position (x,y,z)
- Orientation (turning angles)

Generally in 3D, often 2D: x,y,w



(Wikipedia „gimbal lock“ – original yaw blocked)

Transformation of Poses by translation and rotation, nowadays computing is no problem

- Euler angle (Roll, Pitch, Yaw 3x3 Matrix)

-> Problem at ±90° Pitch (gimbal lock)

- or better Quaternion – rotation axis and rotation around it (x, y, z – axis and w – rotation angle)

Pose: State - Change

Coordinate system:

- World system (static environment, map, navigation, global path planning)
- Robot centric system (shape, manipulator, local path planning, obstacle recognition, collision avoidance)

Static transformations - translation plus rotation

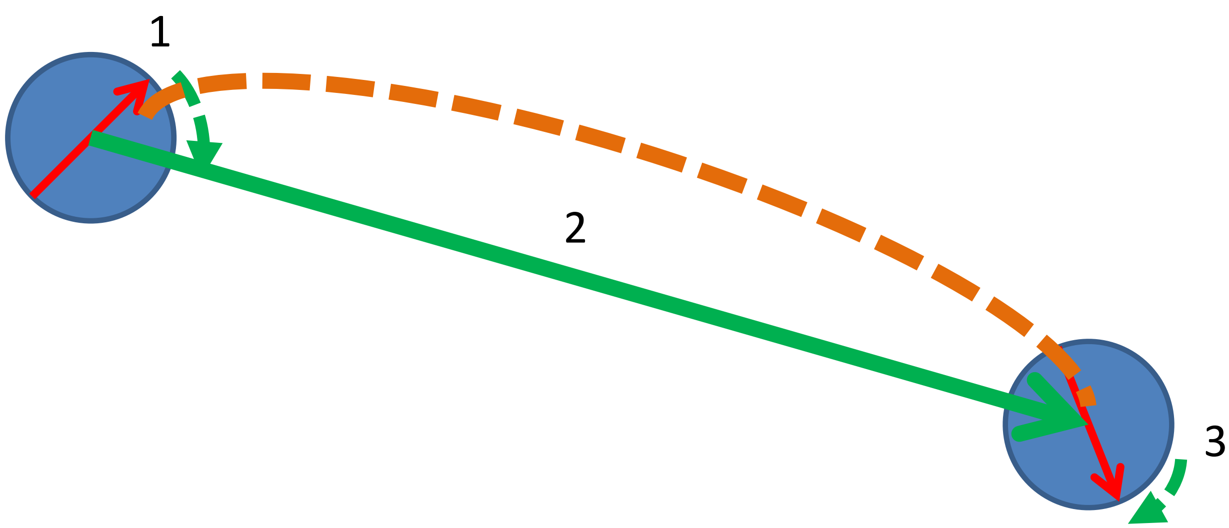
Change of Pose in 2D:
Linear speed v,
Rotary speed ω

Is my robot free to go?

- Shape of base determines free drive range
- Do not enter „bottlenecks“ – think ahead
- Extended manipulator changes contour
- Sensor geometry decides speed and direction – all forward space covered
- Obstacles (moving user) must be updated regularly and avoided
- Sometimes the user is an obstacle , sometimes the goal -> special situations approach, follow/lead
- Map changes moving chair, user, doors
- Charger is a special goal which is touched, not avoided
- Doors are bottlenecks, sometimes even closed

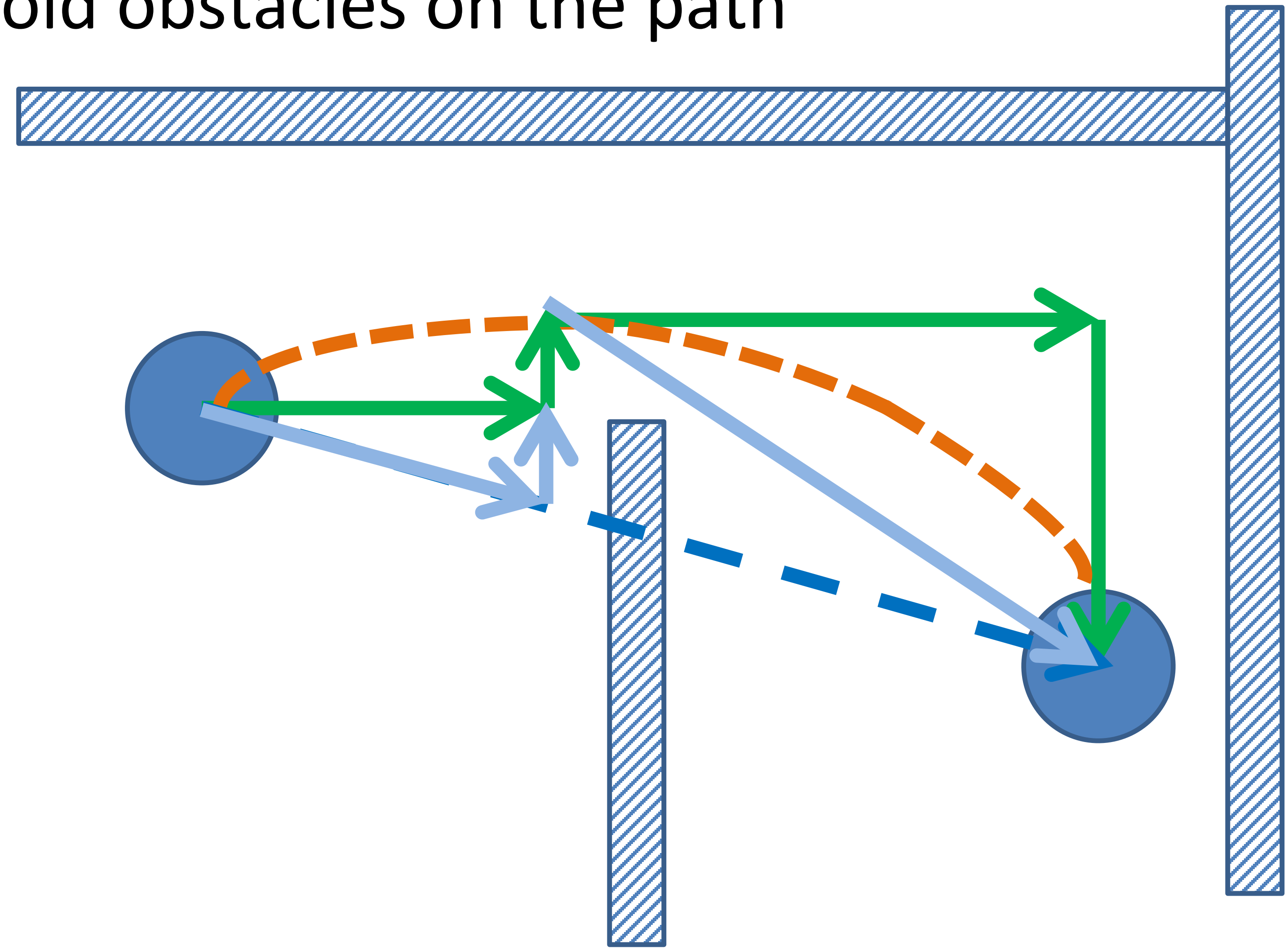
Path planning simple - elegant

Turn to face goal+ straight line + turn at goal = simple, but inelegant



Path planning simple - elegant

Avoid obstacles on the path



Dead end – depends on shape

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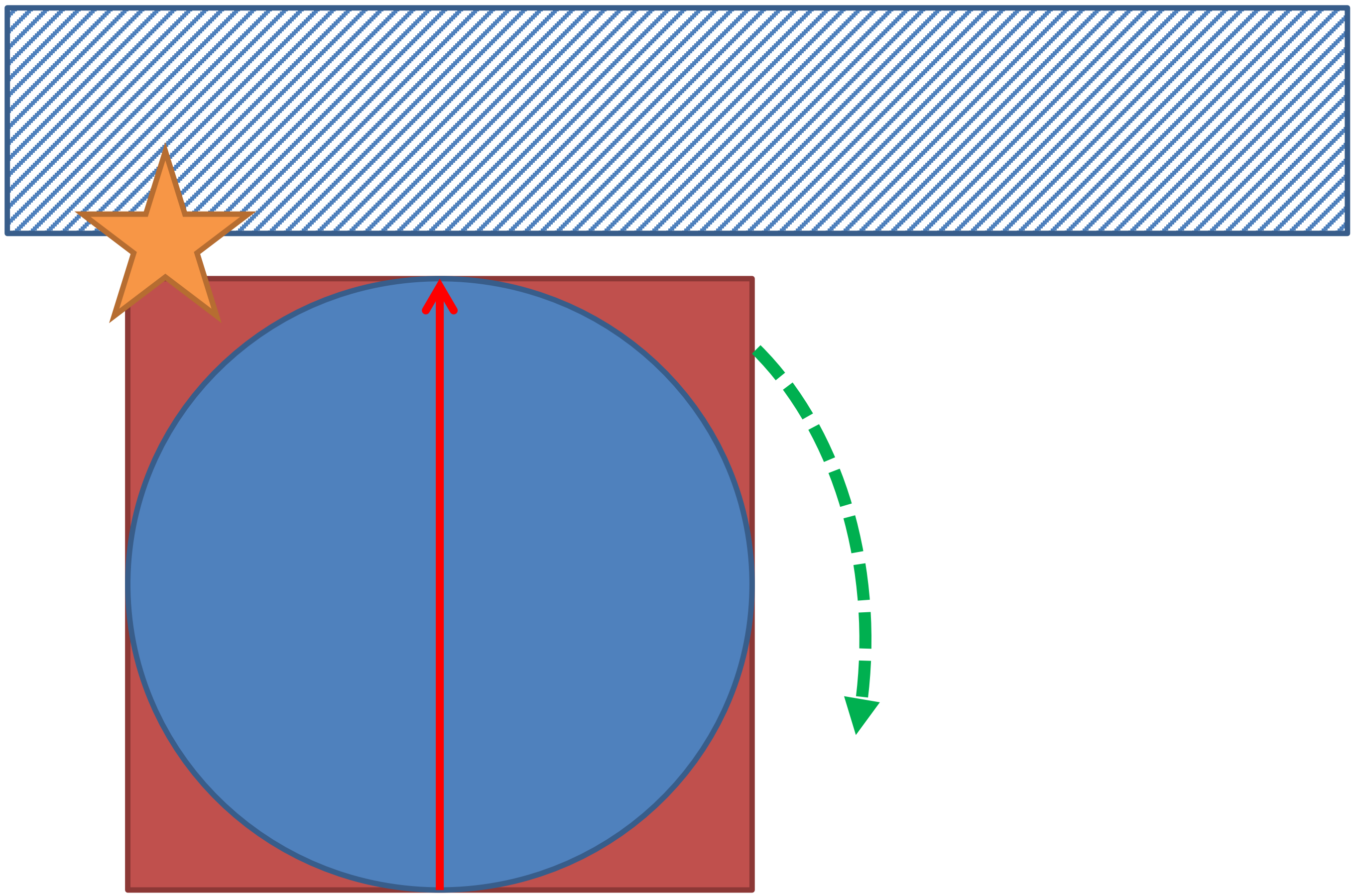
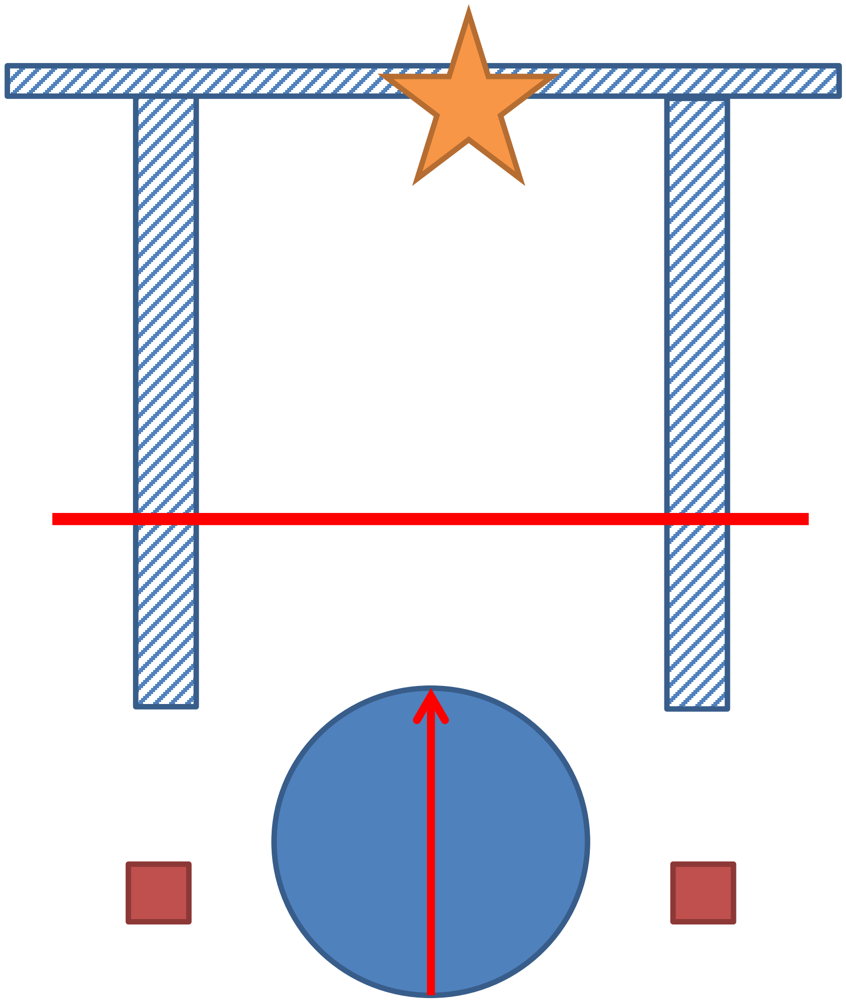
Such positions should not be driven to – reversing / turning can be problematic



VO Assistive Systems

2D map: collision with table top



Laser scan in one height

2D map -> no obstacle

Navigation, localising

VC&HCT

- Why a map is needed?
  - Orientation – where am I, relative and absolute
  - Path planning – to goal
- Why 2D?
  - Simple projection to floor, like Laser scanner
  - Computing power, memory
  - Avoid problem spots in all heights (tables)
- Problem spots?
  - Doors *) /passages/bottlenecks/narrows
  - Tables (roll-under furniture)
  - Dynamic obstacles (chair, door, user)

Note: *) often doors are expected to remain always open

Robot OS requirements

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- As independent as possible from underlying OS resp. available for most
- Including drivers from OS or own
- Central communication structures (secured)
- Logging
- Visualisation

Robot OS, ROS

ROS

http://www.ros.org/

- ROS is a frequently used Software Framework for personal robots under Open Source BSD license
- Another example is Microsoft Robotics Developer Studio (Microsoft RDS, MRDS)
- In this context also other Open Source tools for simulations (Gazebo) or for some sensors (OpenNI) exist

Robot OS ROS Characteristics

- Packages, Manifests
- Central ROS master, parameter server
- Process control (launch, kill nodes)
- Communication channels:
  - Services (1:1, blocking)
  - Topics (1:n, subscription)
    - Actions(lib): goals with callbacks
- Bags (saved communication)
- C++ and Python
- Tools

ROS simple example

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TOPIC Publisher

```
ros::init(argc, argv, "talker");
ros::NodeHandle n;
ros::Publisher chatter_pub = n.advertise<std_msgs::String>("chatter", 1000);
ros::Rate loop_rate(10);

while (ros::ok())
{
    std_msgs::String msg;
    msg.data =  „Hello“;
    ROS_INFO("%s", msg.data.c_str());
    chatter_pub.publish(msg);
    ros::spinOnce();
    loop_rate.sleep();
}
```

ROS Visualisation

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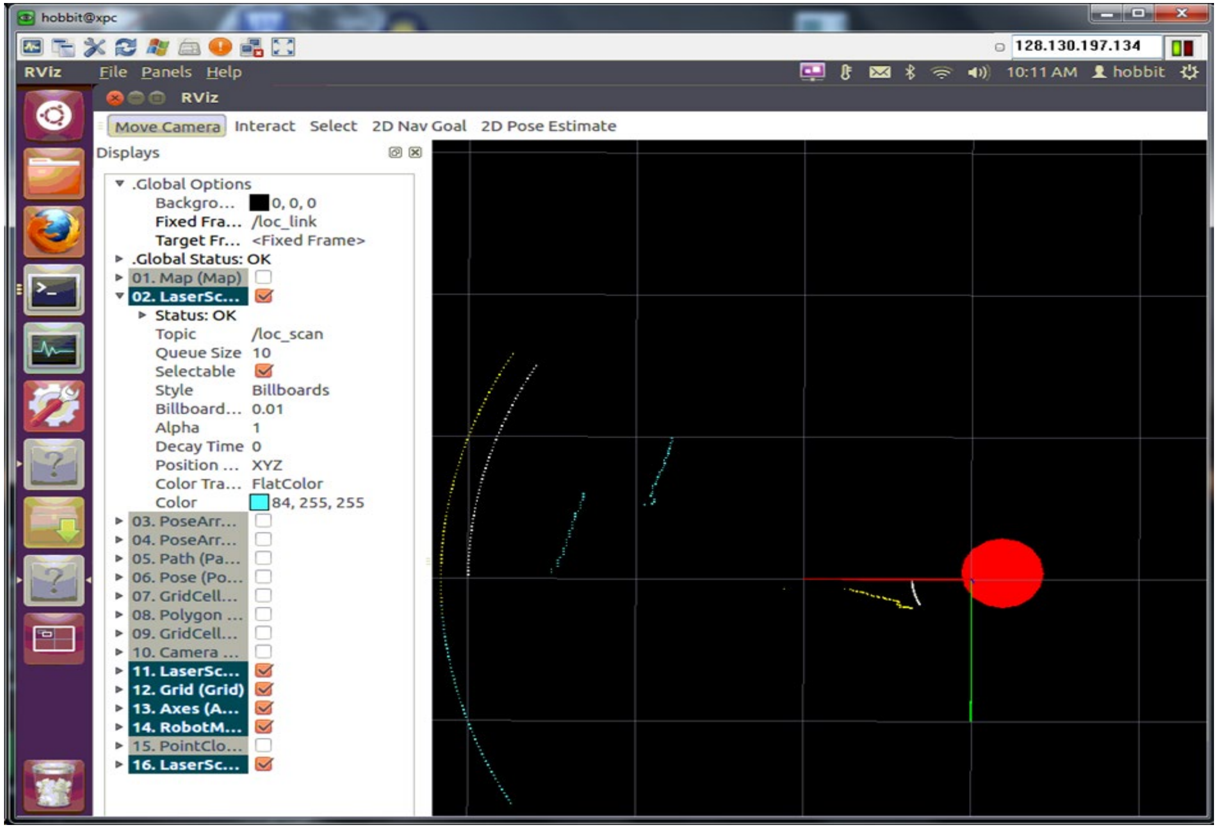
Visualisation: rviz, based on topics



ROS State Machines

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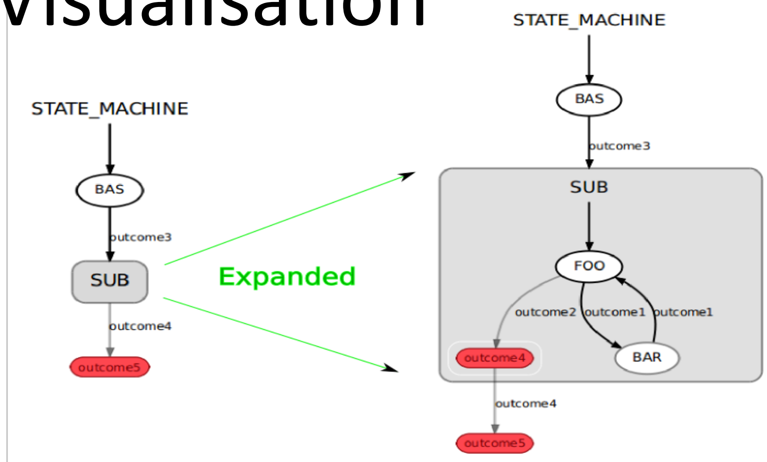
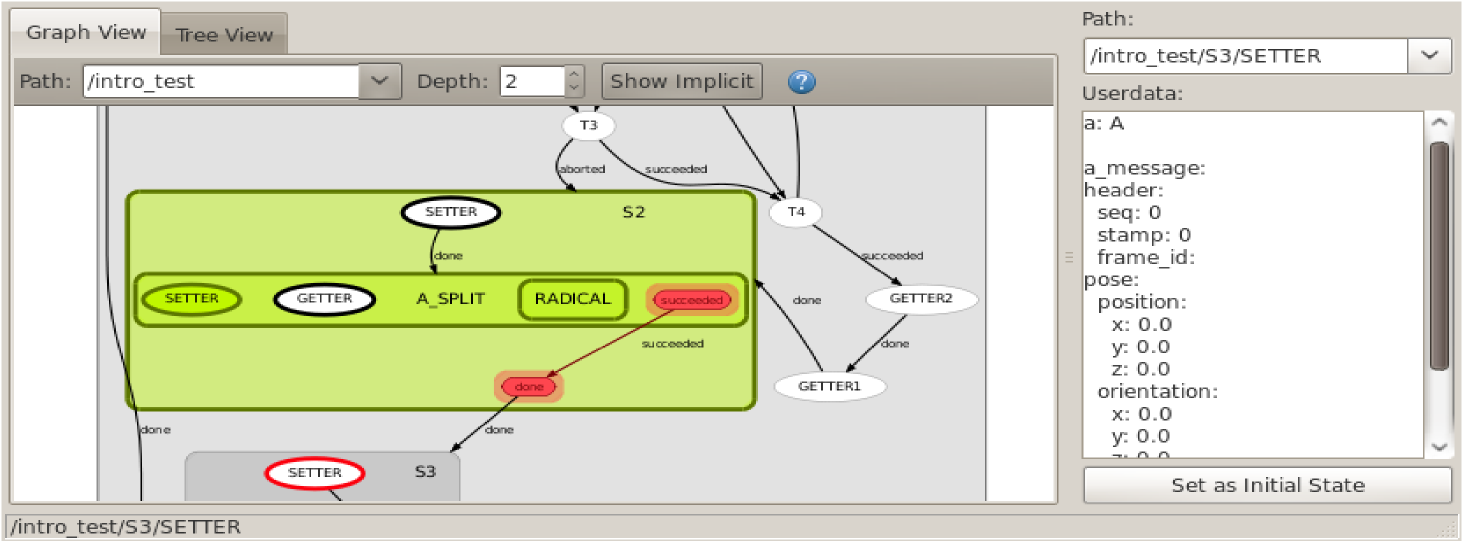
Smach, state machines, Visualisation





HCI -> HRI

Aspects

Acceptance models and factors

Common acceptance models: **UTAUT** [Venkatesh2003], **TAM** - TAM3 [Venkatesh2008], special for Assistive Robotics - **Almere** model [Heerink2010].

- **Functionality (Usefulness and perceived usefulness)** – whether or not the robotic device solves a user's need(s).
- **Usability (Ease of use)** – the degree to which one believes that using the system would be free of effort.
- **Robotic behaviour and appearance** – The robotic behaviour including interaction with humans (HRI) and the robots appearance and general design.
- **Safety** – operational safety as defined in ISO13482:2014 (safety requirements of personal care robots).
- **Costs and financing** – The cost-efficiency and affordability by the target group.

…

Acceptance factors continued

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- **Ethical aspects** – Including friendship and possible relations with robots, becoming dependent on technology and stigmatization
- **Legal aspects** – Legal and regulatory aspects solving e.g. who is liable in case the robot causes harm
- **Social aspects** – Social influence of people who are important to the users and their opinions regarding the use of AAL robots.
- **Privacy** – Data protection and security.
- **Psychological aspects** – such as the users' attitude towards technology, anxiety towards robotic solutions and initial effects of excitement.

From benefit study „Potential of Robotics for AAL“ 2015

Human-Robot Interaction (HRI)

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Goals of HRI: understand, design, and evaluate robotic systems for or with people.

Interaction categories:

- Distant interaction:
  Human and robot are separated spatially or temporally (extreme example Mars Rover).
- Close interaction:
  Human and robot together (e.g. service robot in same room with user).

cf. Goodrich & Schultz: Human–Robot Interaction: A Survey, Foundations and Trends in Human–Computer Interaction, Vol. 1, No. 3 (2007) 203–275

Human-Robot Interaction (HRI)

The HRI problem is to understand and shape interactions between human(s) and robot(s).

Factors that designers can influence:

- Level and behaviour of autonomy,
- Nature of information exchange,
- Structure of the “team”,
- Adaptation, learning, and training of people and the robot, and
- Shape of the task.

cf. Goodrich & Schultz 2007: „Interaction, *the process of working together to accomplish a goal,* emerges from the confluence of these factors. The designer attempts to understand and shape the interaction itself, with the objective of making the exchange between humans and robots beneficial in some sense.”

HCI vs. HRI

Main differences HRI and HCI?

Most important differences are:

- Two autonomous actors in “shared space”
- Mobility of HCI
- Distance and proximity
- Robot personality – “uncanny valley” if too “human-like”
- …
- Power supply/charging (robot autonomy)

Transition HCI -> HRI

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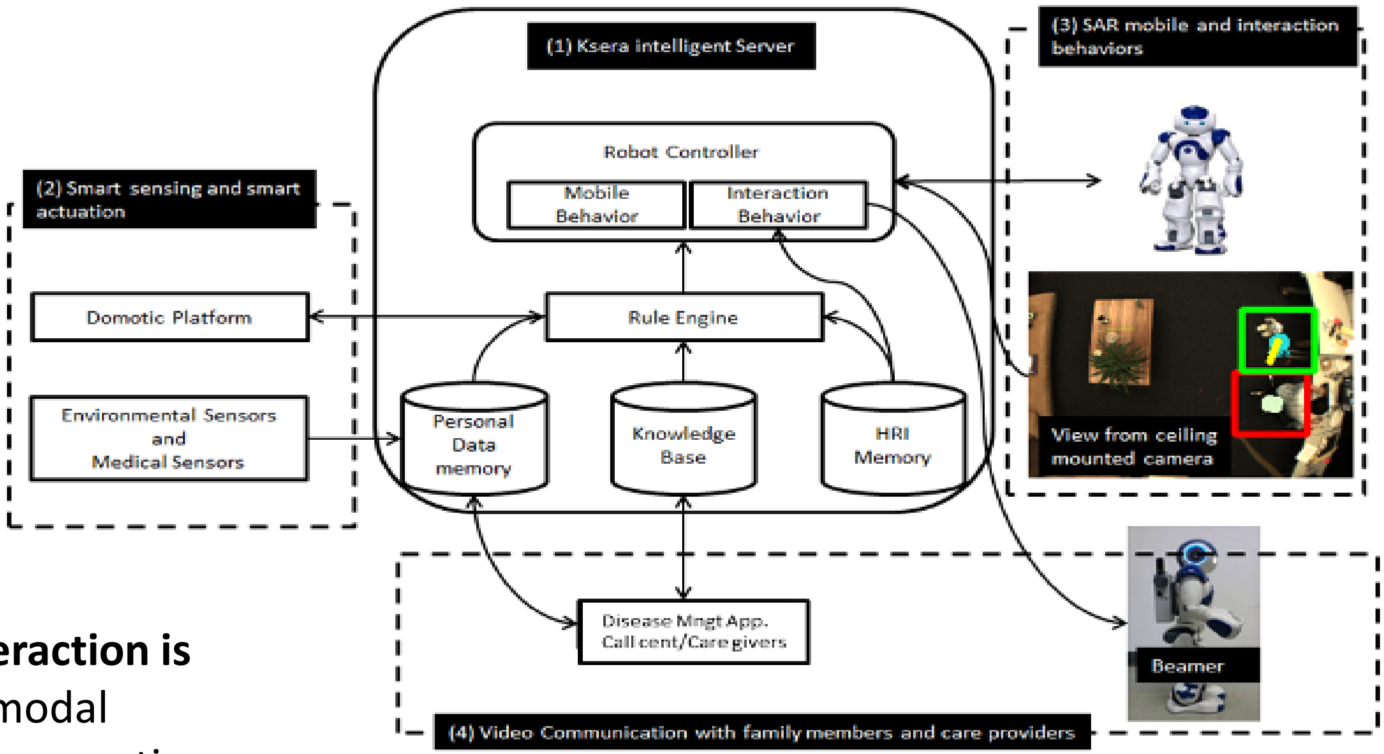
From KSERA project



Social interaction is

- Multi-modal
- Contains emotions
- Synchronises with physical action
- Context based
- Task oriented

Human Robot Interaction/Interface as special category

- Autonomy leads to dynamic
- Perception as „personality“
- Manipulation, mobility enables „working together“
- Sensors and behaviour

Interaction over varying distance

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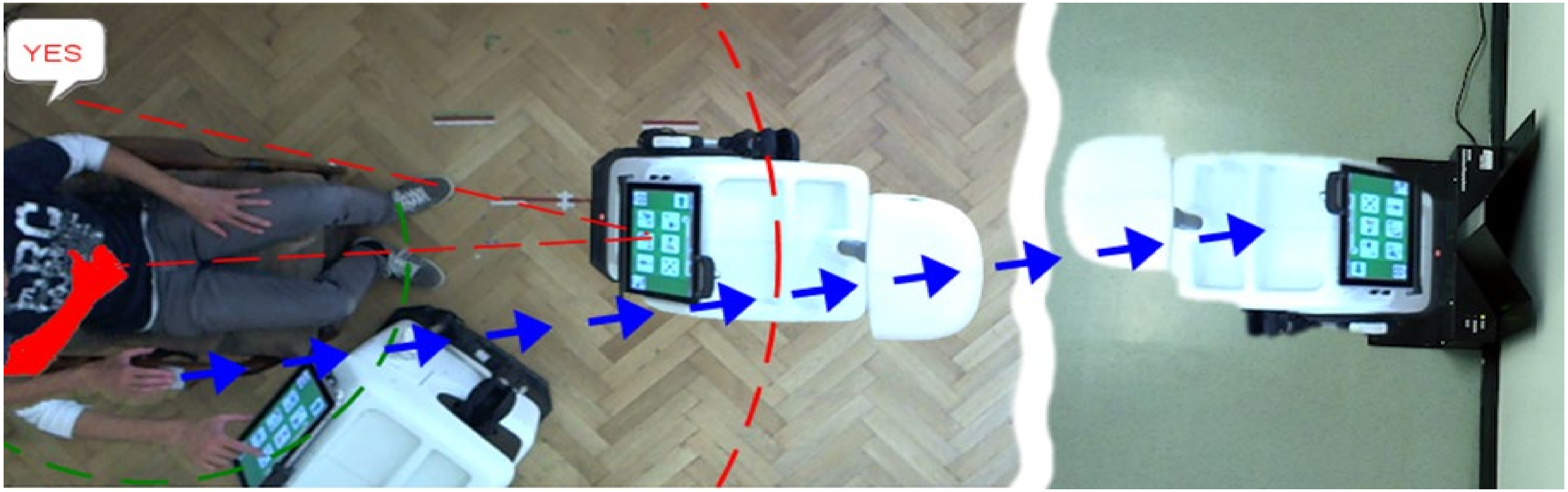

Close < 1m Medium < 3..5m Far

Important: Indicate when/if ASR and GR are available and "immediate" feedback

Interaction parties moving with respect to each other – minimum and maximum distance!
Ranging from arm range (Touch), ASR and gesture to calling from other room (RF)
User needs to know when a command is possible and if it has worked
Theoretically there can be problems with contradictory commands from different modalities

Interaction in different distances

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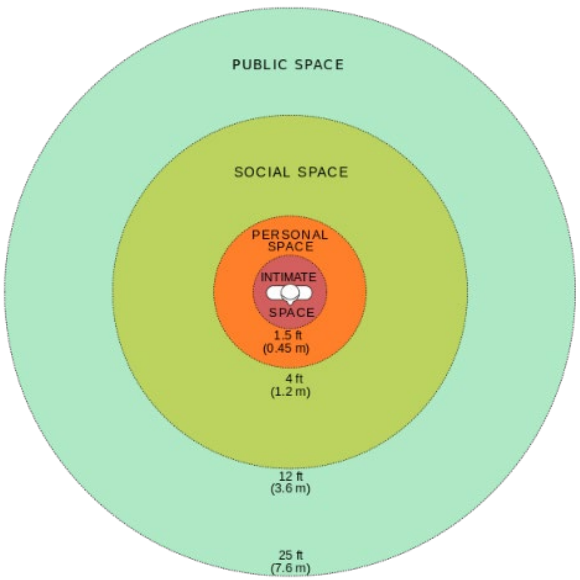
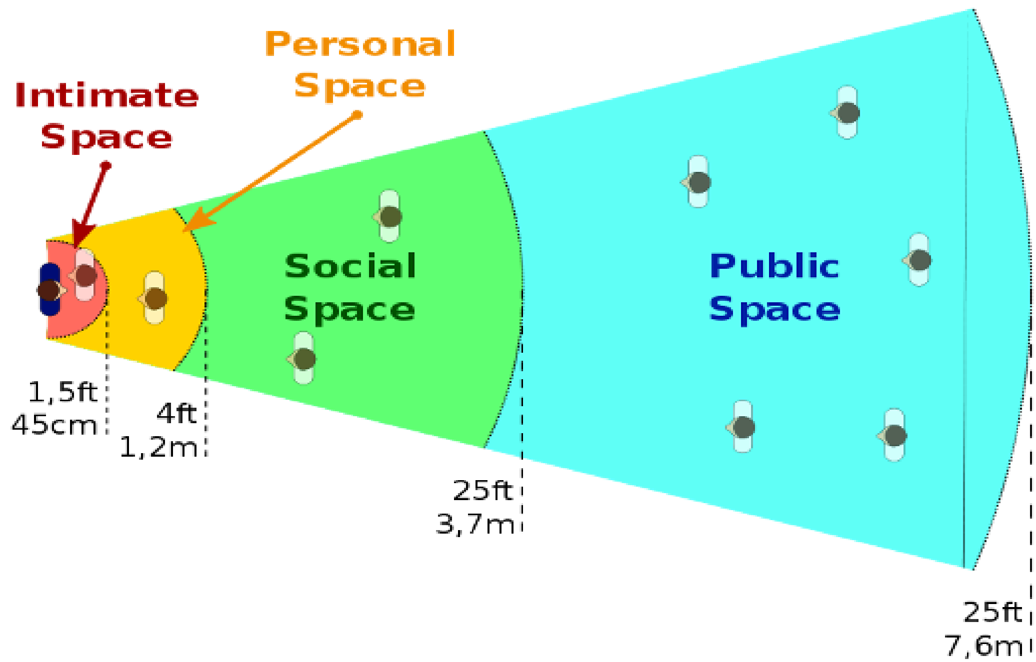
Proxemics – social aspects of distance





Hall's personal space zones, cited from Wikipedia
Different proactivity levels, communication styles

“personality” (introverted <-> extroverted)

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Robot ActiveMedia Pioneer 2-DX used by Tapus et al. and typical test scene (Robot and test person) in „social distance“. source: [Tapus et al., 2008]

Parameters according to Tapus et al.

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	Introverterted Robot		Extroverted Robot	
	Quality	Value range	Quality	Value Range
Voice (pitch)	Low		High	
Volume	Low		High	
Content	encouraging	I know it is hard, but keep in mind, it is good for you. Very well, just continue this way.	demanding	You can do it! Concentrate on the task!
Interaction distance	distant	1,2 – 2.2 m typ. 1,7	closer	0,7 – 1,7 m Typ. 1,2 m
Speed	slower	0,1 – 0,2 m/s Typ. 0.15 m/s	faster	0,1 – 0,3 m/s Typ. 0,2m/s

Tapus et al.

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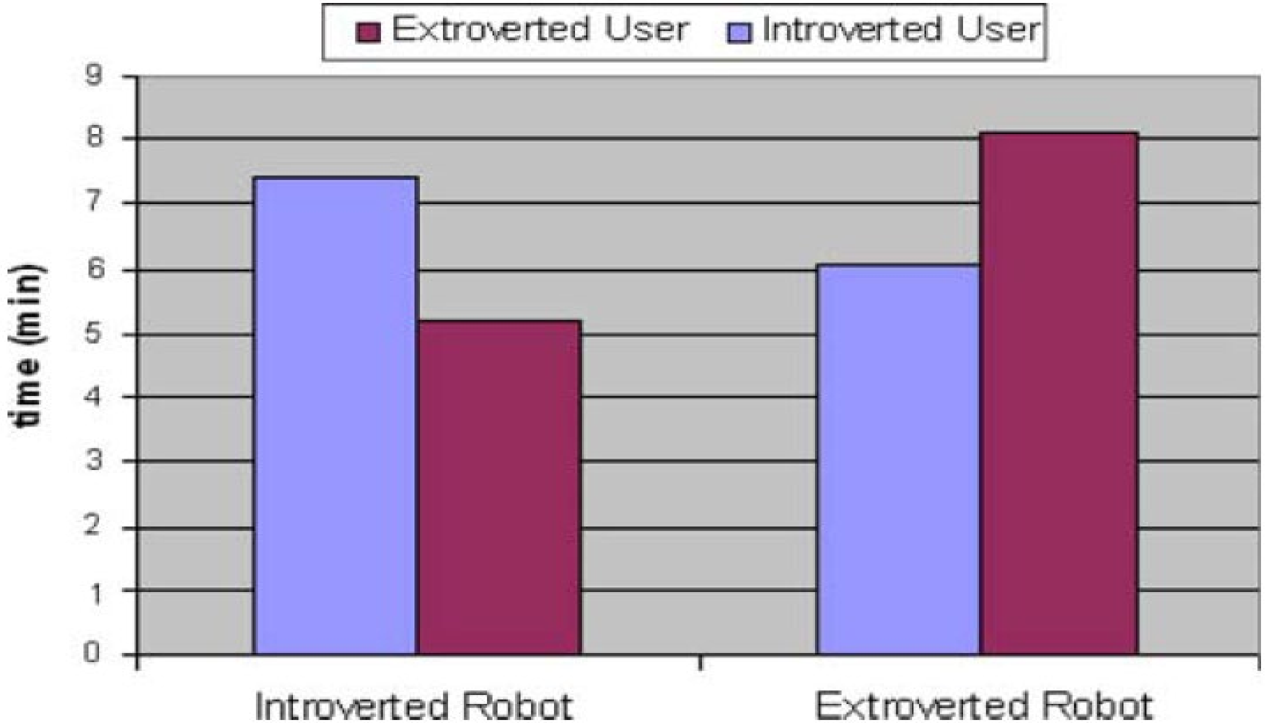
The average interaction time (minutes) spent by introverted/extroverted users with introverted/extroverted robots, respectively – **other studies came to opposite results**



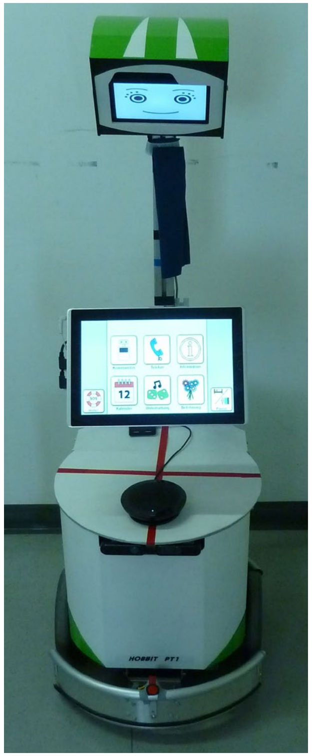
Source: Tapus, A., Tapus, C. and Mataric, M.J.: User - robot personality matching and assistive robot behaviour adaptation for post-stroke rehabilitation therapy, Intel Serv Robotics 1, 2008, pp. 169-183.

Study on personality modelling

personAAL: Small study with n=13 persons on the influence of personality for same functionality.

Hypothesis: **it makes a difference / is recognised?**

„introverted“



„extroverted“

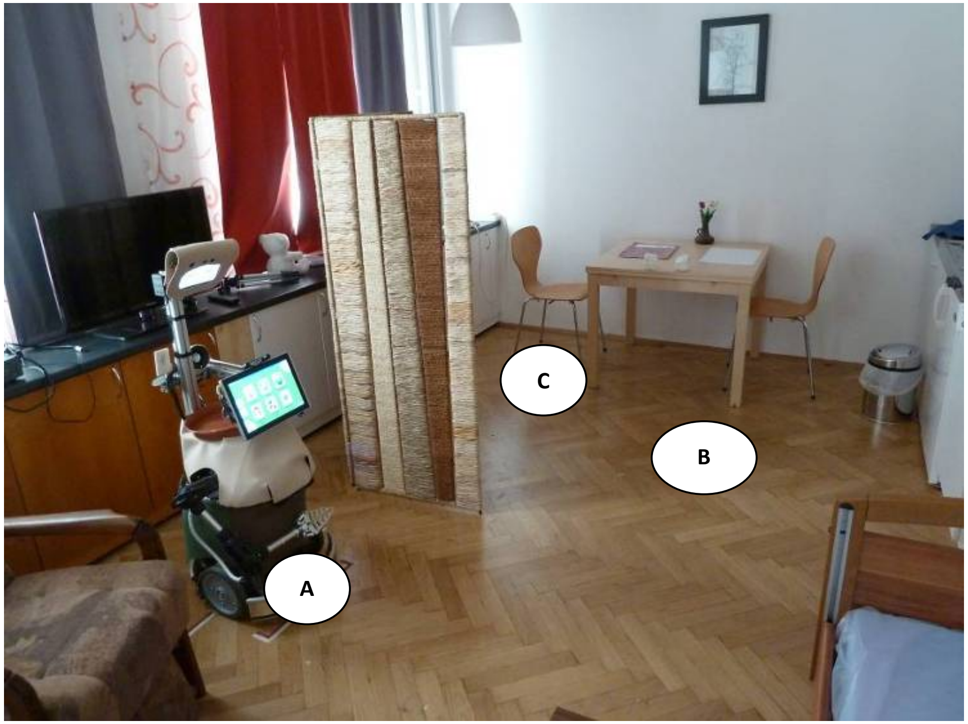
personAAL Study

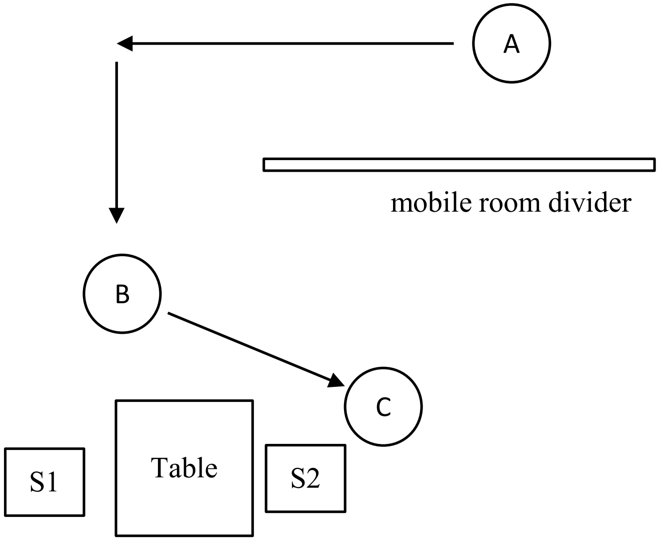
VC&HCT

Robot behaviour	Calm – INTROverted (i)	Lively - EXTROverted (e)
Robot speaks	slow, low pitch, low volume	fast, higher pitch, high volume
sentences	Short sentences	Longer sentences
Lip movement	Shows no lip movement	Shows lip movement
Viewing direction at speaking	Downwards gaze while speaking	Looks at user while speaking
Start of speaking	Speaks only after arriving	Partly starts speaking while still driving
Robot mimics:	Same fixed face	Blinks and smiles from time to time
Rest position	In idle position looks downwards	Small moves of head and body
Announcing behaviour	Doesn‘t announce itself	Announces that it will start or arrive
Pro-activity	Waits until user looks in its direction	Proposes proactively to do something, (e.g. call somebody on phone, play music)
Mode of addressing	Uses German „Sie“	Uses German „Du“ and first name
Speed of movement, Interaction distance	Drives more slowly and uses more distance robot.speedfar= 0.15m/s robot.speednear=0.10m/s robot.distance=1.0m	Drives faster and closer robot.speed.far=0.30 m/s robot.speed.near=0.20 m/s robot.distance=0.8m (20cm closer)
Appearance:	Small blue tie	Big red bow tie

personAAL interaction study

VC&HCT





personAAL interaction scene

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Study on personality modelling

VC&HCT

personAAL: Small study with n=13 persons on the influence of personality on same functionality.
2 behaviours assessed with Godspeed questionnaire.

Wilcoxon test for paired samples with level of significance of 5% shows:
For „Antropomorphy“ (p=0.07) and „Liveliness“ (p=0.04) and total assessment (p=0.02) significant differences in perception. For „sympathy“ no significant difference, also „safety“ more or less rated equal .
Spearmans correlation coefficient self assessment <-> preferred personality: no significant correlation.

Results

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	Yes	No
Noticed a difference in behaviour of robot?	12	1

	introverted	extroverted	neither nor, depends….
Which robot is preferred?	1	9	3
Self assessment(introverted, extroverted)	6	7	-

Conclusion: Behaviour of robot should be adaptable to individual preferences → can increase acceptance

Context of interaction

»context and content (or activity) cannot be separated. Context cannot be a stable, external description of the setting in which activity arises.
Instead, it arises from and is sustained by the activity itself.«

Autonomy, situated dialogue, context awareness

Context as 'embodied interaction' (Dourish, 2004)

What does this mean for a moving, autonomously acting user interface?

Multi-modal interaction channels

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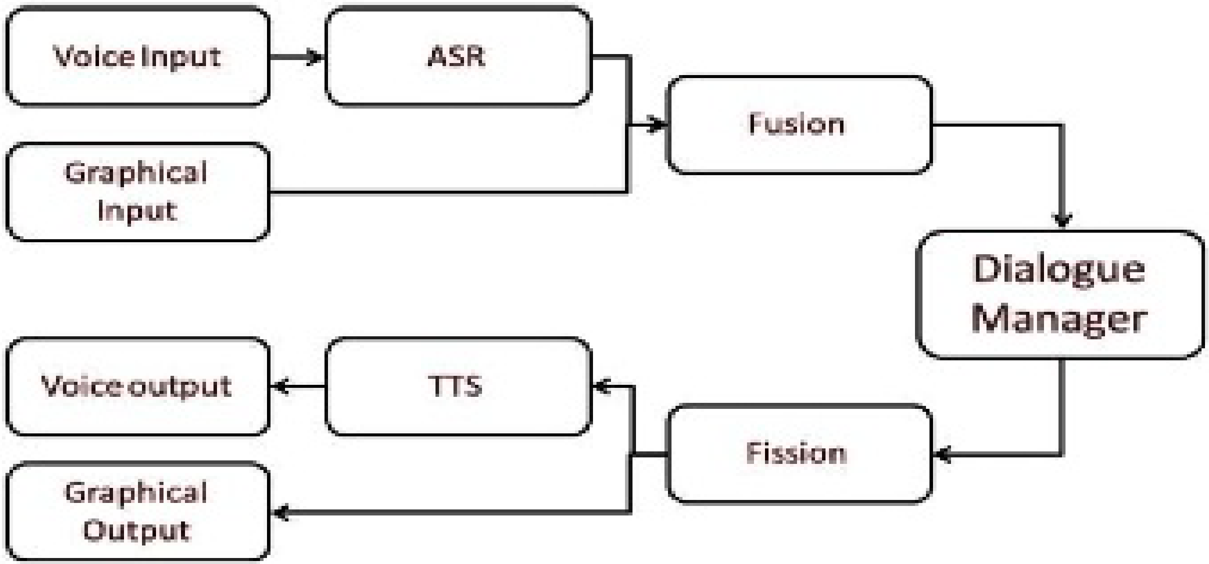
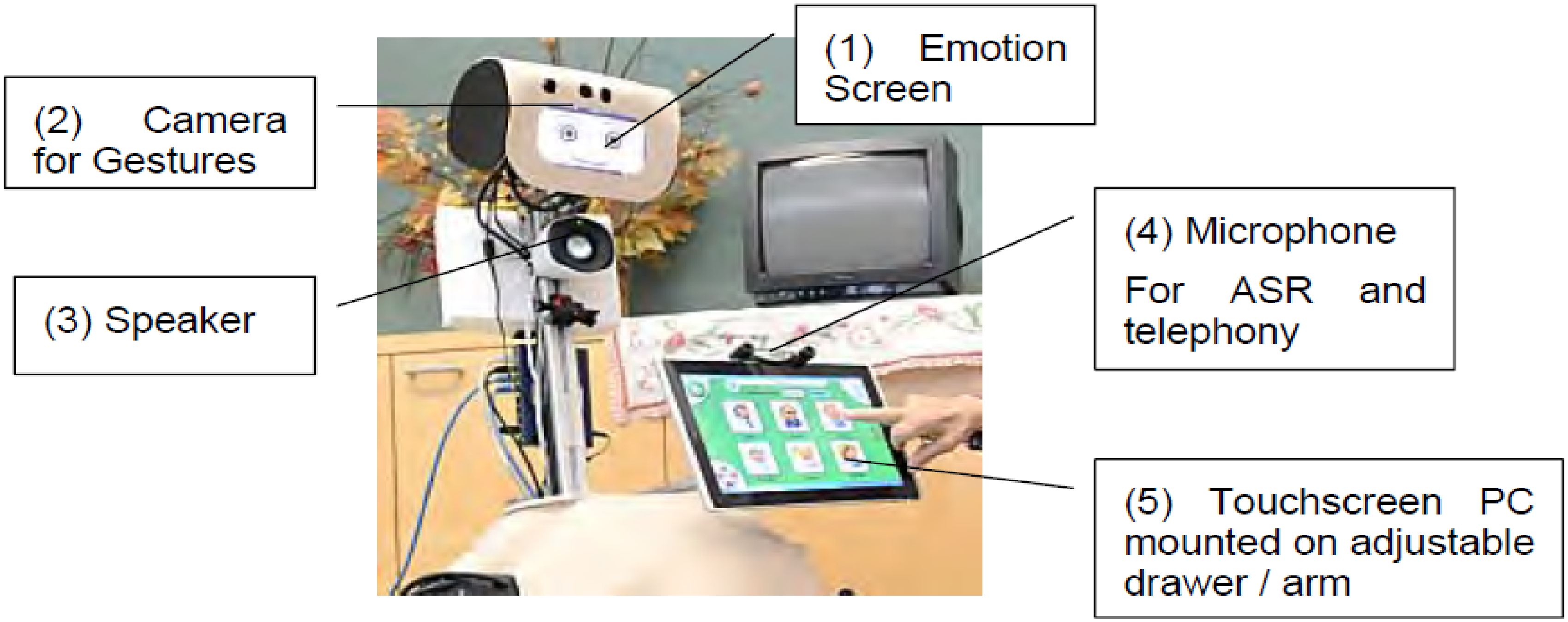


+ Context, intelligent/AAL environment:
Movement, door, window, light, temperature, water, actuators, switches …
=> channels

Human robot interaction/ interface as special category
- Gesture, speech (ASR+TTS), touch/visual, remote control

Multi-modal channels have to be synchronised. Preferences for channels also depend on distance and context
The intelligent/AAL environment also works as i/o channel

Elements of a multi-modal UI/HRI



Intuitive use – without special instructions

Self-explaining, in form of a dialogue

Example from first prototype of Hobbit robot (spring 2013)
D. Fischinger et al.: Hobbit - The Mutual Care Robot, Assistance and Service Robotics in a Human Environment Workshop in conjunction with IEEE/RSJ Intern. Conf on Intelligent Robots and Systems, 2013
Additionally: emergency button on 30 cm above floor (for fallen user)

GUI – variants of robots, like any HCI

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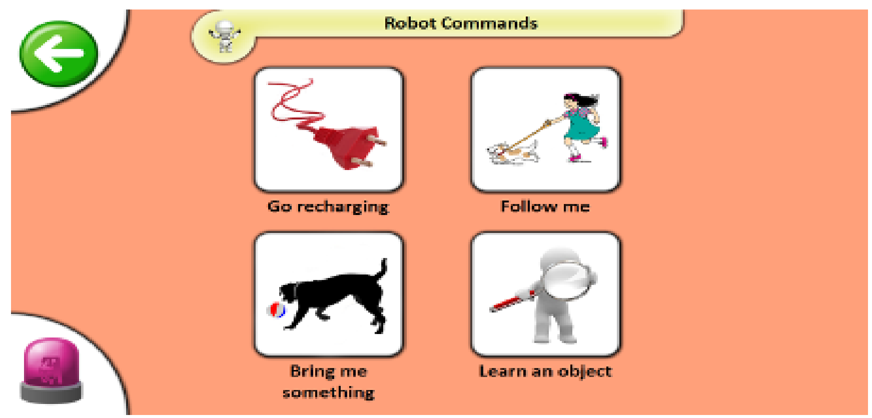

Commonalities? Icons and/or text, different styles, sizes
Domeo – alias
Companionable - Hobbit
User group and mobility (distance) call for bigger elements

Position of touchscreen

A touchscreen has to fit in height and tilt:

- Suitable for sitting and standing interaction
- Range of (preferred) arm and distance of feet must be appropriate
- Provide place to rest hands on
- No protruding parts
- Antireflection coating
- Size of elements appropriate for free-handed use

Design & Implementation: Hobbit

Hobbit home page: http://hobbit.acin.tuwien.ac.at/
First prototype (with and w/o cover), final prototype, ca. 1.20m

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Standards

Safety

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- In general requirements as for all other electronic products wrt:
  - Electrical safety, radio interference
- CE marking
- Additional requirements regarding minimising risks from mechanical (movement) impacts on user
- „Inherently safe design“
- STANDARDS are no laws and no full safeguard!

Safety

- EN ISO 13482:2014 Robots and robotic devices -- Safety requirements for personal care robots – Non-medical domestic and assistive robots
- Up to this robots had to be „locked away" and needed an emergency stop (=> industrial applications). Now consideration of robot autonomy.
- MDR (since 2018) (if applicable) requires still more rigorous checks, medical advice only by qualified staff/certified devices.

ISO 13482 purview

Applies to

- **mobile servant robots**
- physical assistant robots (exo-skeletons)
- person carrier robot (wheelchair robots)

Does not apply to

- robots travelling faster than 20 km/h
- robot toys
- swimming robots and flying robots
- industrial robots, which are covered in ISO 10218
- robots as medical devices
- military or public force application robots

Safety

VC&HCT

Risk factors with assistive robots:

- Material, emissions, electrics
- **+Collisions**
  - Mass
  - Velocity
  - Manipulator!
- **+Tilting**
  - Stability (even if caused by user)
  - Avoid „grips/handles“ and corners
- **+Blockage**
  - Empty battery, pushing out of way

Application area ISO 13482

The scope of ISO 13482:2014 is limited primarily to human care related hazards but, where appropriate, it includes domestic animals or property (defined as safety-related objects), when the personal care robot is properly installed and maintained and used for its intended purpose or under conditions which can reasonably be foreseen.

Safety – how to handle risks?

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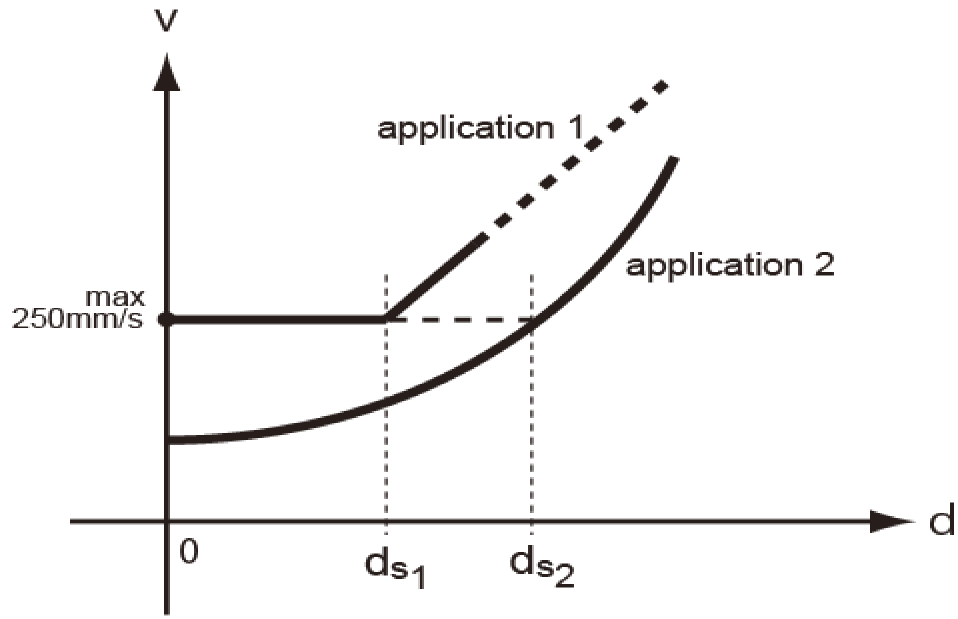
Risk factors, „hazard" identification and treatment according ISO 12100/22100 e.g. speed:



Safety distance and maximum relative speed in the proximity

Safety – how to assess risks?

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Methods for risk assessment:

– A: Visual inspection

– B: Practical test

– C: Measurement

– D: Observation during operation

– E: Examination of circuit diagrams

– F: Examination of software function blocks and/or software documentation

– G: Review of task based risk assessment

– H: Examination of layout drawings and relevant documents

Risk level assessment: **hazard severity and likelihood**

ISO 12100/22100 Safety of machinery

Handling of risks: <u>2 main actions/strategies</u>

1) **Assessment** - 2) **Reduction**

1) Assessment

Determine limits
↓
Identify hazards
↓
Estimation of risks

2) Reduction

Inherently safe construction
↓
Protective measures
↓
User information (Safe use)

Other important standards

Safety distances and approach speeds:

- ISO 13854 - Minimum gaps to avoid crushing of parts of the human body
- ISO 13855 - Positioning of safeguards with respect to the approach speeds of parts of the human body
- ISO 13857 - Safety distances to prevent hazard zones being reached by upper and lower limbs

Other new standards

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- ISO 18646-1 Robots and robotic devices -- Performance criteria and related test methods for service robot -- Part 1: Locomotion for wheeled robots
- ISO 18646-2 Robots and robotic devices -- Performance criteria and related test methods for service robot -- Part 2: Navigation
- ISO 9283 Manipulating industrial robots -- For evaluating the characteristics of manipulators

How to test assistive robots?

Evaluation

of a complex system

The evaluation

Evaluation goals

- Functionality – lab tests (+safety!)
- Usability,
- Social acceptance,
- User experience,
- and societal/economic effects

How to test HRI continuously without

- Full function in early phases
- Needing to simulate full complexity
- Long term testing

Evaluation of HRI can be tedious
Which principles?

… Example workshop: comparison

Different robots with 2 different implementations provide experts with something to score

Or: comparison with/without robot

… Expert workshop

… To compare benefit: “added value”

Different quality of audio and video

- Video shows current situation and emotional state of user better than audio alone (also in emergency communication)

Reminders

- For physical exercises
- Motivation to social communication

Comparison NAO robot with Kompai robot from DOMEO project

Experts can speak for their own work situation and for their clients

… AAL Lab

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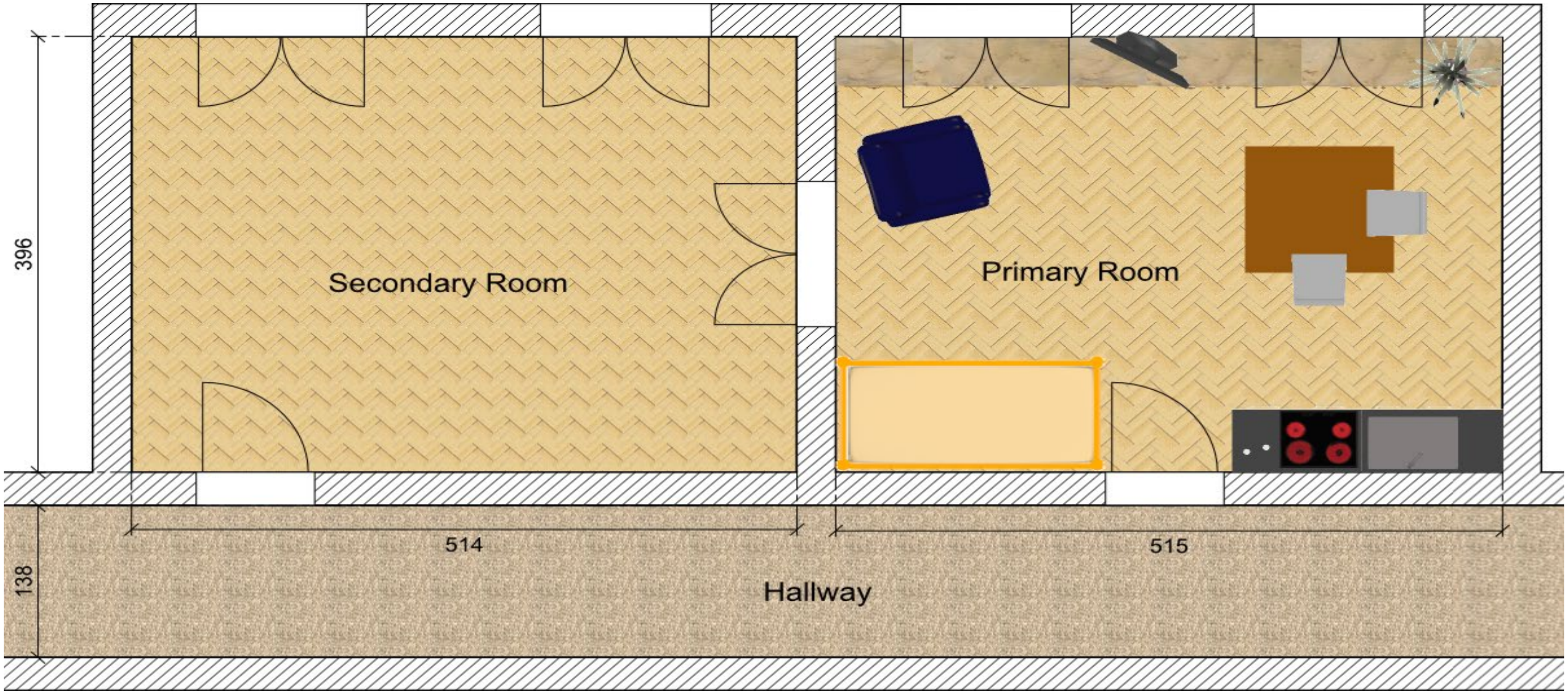
Testing/observation under “real life” conditions: room, furniture, sit, stand, lie, cooking …



Mimics a real living environment for demonstrations and user testing. The primary room has areas for cooking, eating, living, sleeping. The two adjacent rooms can be used for moving around (navigation) of the robot and for observation.
P Mayer et al.: A Social Assistive Robot in an Intelligent Environment, in: Abstract Book BMT2013 Graz, Biomedizinische Technik, pp.219-220.

… AAL room/ AAL lab

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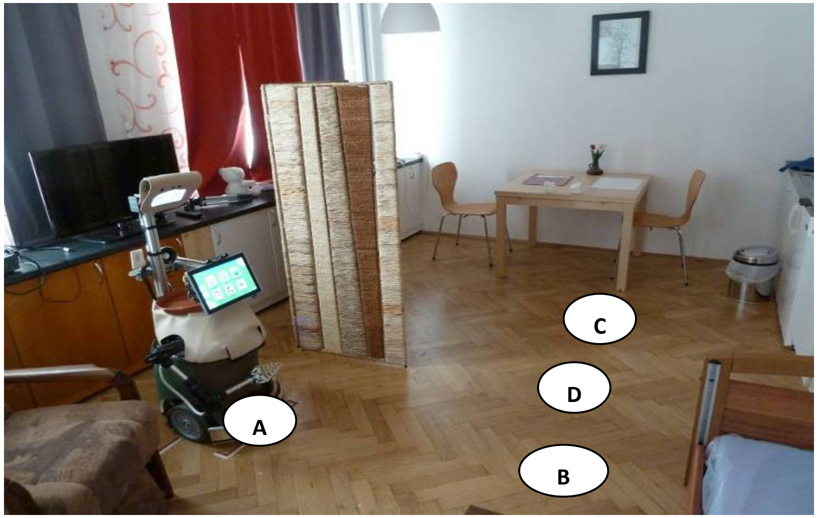

Example: Setting for a Wizard of Oz test (FP7 Hobbit project)

… AAL room/ AAL lab

Cameras in the ceiling monitor interaction – important for Wizard of Oz !

Wizard of Oz - operator in adjoining room

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Wizard of Oz - Monitors
At start and during interaction

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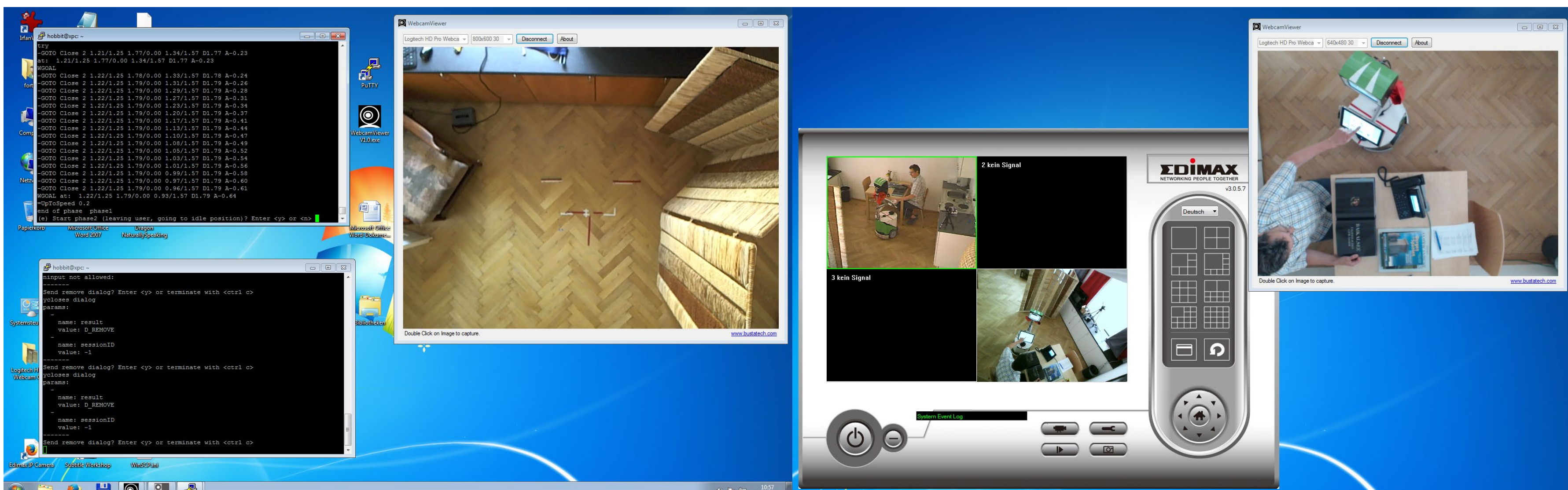

VO Assistive Systems

Interaction

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… Demonstration as tool

Communication of vision (of the complex system) to stakeholders

- off-line video production
  - with actor keeping to defined character
  - with functionality, e.g. interaction

- Wizard of Oz (simulation of system, real user)

All intermediary steps in development are recorded on video.
Used for communication with stakeholders and for expert tests

Heuristic Evaluation

=> heuristic evaluation similar to Usability Heuristics by Nielsen:

1. Sufficient information design
   just enough information
2. Visibility of system status
   keep users informed
3. Appropriate information presentation recognition over recall
4. Use natural cues
   concepts familiar to user

Edward Clarkson and Ronald C. Arkin 2007
Inspired by Nielsen, Goodrich & Olsen

Heuristic Evaluation ctd.

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5. Synthesis of system and interface
   the interface is an extension of the system, the user and by proxy, the world.
6. Help users recognize, diagnose, and recover from errors
7. Flexibility of interaction architecture
   the interface should support the evolution of system capabilities,
8. Aesthetic and minimalist design

Edward Clarkson and Ronald C. Arkin 2007
Inspired by Nielsen, Goodrich & Olsen
See also: USUS framework Weiss et al

User centered iterative approach

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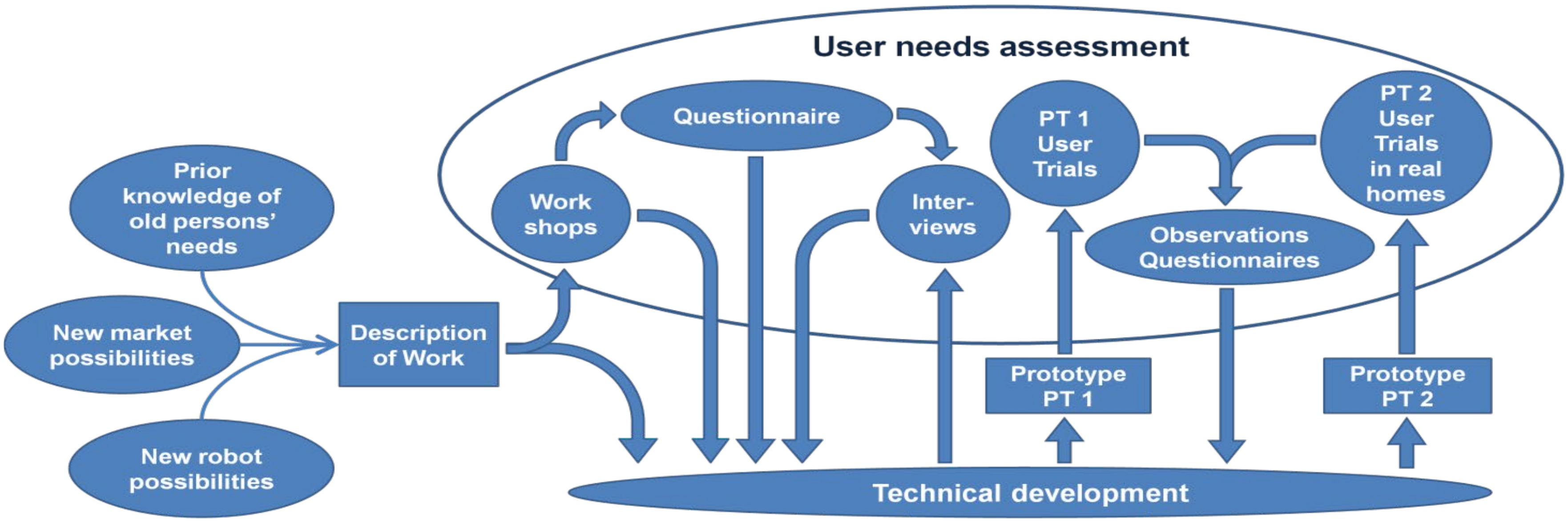
Example from project



The user-centred methodology and the technical developments of the Hobbit project are connected at all stages and constant feedback loops influence both. Prior knowledge of old persons' needs was brought in, as well extensive experience of user-centred design methods for diverse target user groups, technology design for older people, design for all, universal access and e-inclusion.

Workshop results HOBBIT

- Austria, Greece, Sweden with users > 70 years and professional carers/relatives

- -> human like but not too tall
- -> soft (but easy to clean)
- -> safety while being alone (falls)

- Often wanted but not possible: assistance in housework/chores

A lot of peculiarities to be considered for this user group

-> Special Considerations: Users

- Assistive Robot users are not the typical “consumers” buying a robot themselves
- The users are unfamiliar with touch screens and miss the haptic feedback
- The users are not aware of e.g. ASR limitations and do not “comply” to UI rules
- The users are tiring quicker and forgetful
- The users are more vulnerable in general
- The users might have impairments (hearing, vision, dexterity…)

-> Special Considerations: Other

- Interaction is from (some) distance while standing, not at desktop, in hands
- Robot is not always there, in same place, might leave for a task
- Social distance must be observed by robot because the robot itself is moving
- Privacy and ethics
- Liability, safety standards
- Strictly non-medical, otherwise medical product standards apply

Challenges in design

- Small but mechanically stable (e.g. also for stand-up and walking support)
- Not too tall but space for the UI
- Costs vs. functionality
- Foreseeable behaviour but not boring
- Goal oriented but not annoying
- User always must feel to be in control
- Consistent behaviour but with fun
- ….

Metrics for evaluation

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- Functionality – lab tests (+safety!)
- Usability,
- Social acceptance,
- User experience,
- Societal/economic effects,

- Affordability, cost effectiveness – business plan

Iterative evaluation of these criteria needed.
Because design and implementation decisions have to be taken frequently it is important to permanently make corrections in order to achieve goals.

Conclusions

- AR and HRI have <u>a lot in common</u> with classical HCI
- <u>Additional dimensions</u> are added e.g. by <u>mobility</u>, varying <u>distances</u>, <u>personality</u>
- A user centred iterative design process promises good results
- Heuristic and demonstration based methods are important because of complexity
- Ambitious goal: evaluation at home of users (real test environment)

Videos (1)

VC&HCT

- Domeo – Kompai robot
  https://www.dropbox.com/s/yfj3sk7pdnyu9q6/kompai_short_untertitel.wmv?dl=0
- KSERA – Nao robot with LED projector
  https://www.dropbox.com/s/szti8qwyvi336cn/LED-Projektor-video.mkv?dl=0
- Pepper robot (Aldebaran / Softbank)
  https://www.dropbox.com/s/07d5v2u1mj1d09x/Interview%20with%20Pepper%20the%20robot.mpg?dl=0
- Pepper
  https://www.dropbox.com/s/qmo0f2der9hkuro/Pepper-Robot.mp4?dl=0
- https://www.youtube.com/watch?v=WI0IGAM489k
- Pepper robot interaction demonstration https://youtu.be/tYY3RCzuwBA
- PARO (Robbe)
  https://www.youtube.com/watch?v=mxej6oscYQk&t=9s (Wien)
  https://youtu.be/agia0O8ms84 (Deutschland)

Videos (2)

VC&HCT

- Hobbit (demos)
  - Hobbit delivers stove reminder when leaving (demo) https://www.dropbox.com/s/de0zrkj28w3q1vq/AAL_stove_reminder_when_leaving.ts?dl=0
  - Hobbit robot shows 2 different behaviours / personalities when delivering a reminder
    - more functional https://www.dropbox.com/s/mivd472gfhwbj0o/behaviour_reminder_more_functional.ts?dl=0
    - more social https://www.dropbox.com/s/22upllahg9cfjo4/behaviour_reminder_more_social.ts?dl=0
  - HOBBIT Erprobung im Alltag Wien 2015 https://www.dropbox.com/s/jvtpyagfvmajbb8/HobbitAtHome.mp4?dl=0

Outlook, next lectures:

- IV. Sensors – are entering the living area
  Safety and Support
- V. Ethics, Law and Economics
- VI. Requirements Analysis and Evaluation

Assistive Systems - Literature

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Encarnação, Pedro and Cook, Albert (2017) Robotic Assistive Technologies: Principles and Practice, CRC Press, 382 pages, ISBN 9781498745727

Payr, Sabine, Werner, Franz and Werner Katharina (2015) Potential of Robotics for Ambient Assisted Living - IKT der Zukunft, https://iktderzukunft.at/resources/pdf/potential-of-robotics-for-ambient-assisted-living-final-report.pdf

Bendel, Oliver (Hrsg.) Pflegeroboter, Springer Gabler, Wiesbaden, Germany, 2018, ISBN 978-3-658-22697-8, 267 Seiten, online: https://www.springer.com/de/book/9783658226978 (open access)

Assistive Systems - Abbreviations

VC&HCT

AAL	Active and Assisted Living (Ambient Assisted Living)
AS	Assistive System
ASR	Automatic Speech Recognition / Spracheingabe
AT	Assistive Technologie
GUI	Graphical User Interface
HCI	Human Computer Interaction
HRI	Human Robot Interaction
IKT	Informations- und Kommunikationstechnik
ICT	Information and communication technology
MDD	Medical Device Directive
MMI	Man machine interface / Mensch Maschine Interface
MPG	Medizinproduktegesetz
OS	Operating System / Betriebssystem
ROS	Robot Operating System
TTS	Text to Speech / Sprachausgabe
UI	User Interface / Benutzerschnittstelle