Communication and Dialogue in HRI


Seminario per il corso di ELN 2003/04

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Summary

- An explanation of what is Human-Robot Interaction
- A survey to understand the attitude of people towards robots
- HRI issues
- Dialogue in Human-Robot Interaction

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Definition of robot and robotics

- A “robot” is:

  "A programmable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of task" (*definition by the Robot Institute of America, 1979*).

- “Robotics” is:

  “The science of robots."

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What is a robot

- Some are machines that do tasks in factories and hospitals. Some are life-like toys. In the future, autonomous, mobile robots will assist people in many environments. Robots could help the elderly and caretakers, assist with work around the home, act as guards, and perform tasks that are repetitive, boring, or dangerous in nursing homes, hospitals, military environments, disaster sites, and schools.

- The study of HRI concerns in particular the Social Robots.

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Pearl: a mobile assistant robot for the elderly

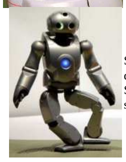
Social Robots (1)

Aibo: the Sony's dog

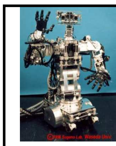
- **Service Robot** or **Assistive Robot** = mobile robot designed to work with humans.

- **ISR** = Intelligent Service Robot: a mobile platform that can perform cleaning and transportation tasks in a domestic setting. In addition it may be used as a dextrous assistant to handicapped and elderly.

Minerva's face with a 'happy' expression. Carnegie Mellon University.

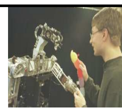


Sony has developed the SDR-4X that can sing and dance.



Wendy: S. Sugano Laboratory Waseda University.

Social Robots (2)



The newest version of Cog, developed at MIT AI laboratory.

- Humanoid robot = anthropomorphic robot designed to emulate some subset of the physical, cognitive and social dimensions of the human body and experience.

Hadaly – 2: Humanoid Project Waseda University.

- Ultimately, humanoids might prove to be the ideal robots designed to interact with people. These robots will interact socially with people in typical everyday environments and will be designed to act safely alongside humans, extending our capabilities in a wide variety of tasks and environments.

Social Robots Tasks

Ursula, an entertainment robot developed by Florida Robotics to amuse crowds at Universal Studios.

- To an increasing extent, robots are being designed to become a part of the lives of ordinary people.

- Their tasks may range from entertainment or play, to assisting humans with difficult or tedious tasks. In these kinds of applications, the robot will interact closely with a group of humans in their everyday environment (home, offices, factories, hospitals). This means that it is essential to create models for natural and intuitive communication between humans and robots.

Human-Robot Interaction (1)

- "The study of the humans, robots and the ways they influence each other" (*definition by the 10th International Symposium of Robotics Research, November 2001, Australia*).

- HRI regards the analysis, design, modeling, implementation and evaluation of robots for human use.

- HRI represents an interdisciplinary effort that addresses the need to integrate social informatics, human factors, cognitive science and usability concepts into the design and development of robotic technology.

Human-Robot Interaction (2)

- This area includes the study of human factors related to the tasking and control of social robots. How will we communicate efficiently, accurately, and conveniently with humanoids?
- Another concern is that many humanoids are, at least for now, large and heavy. How can we insure the safety of humans who interact with them?
- Much work in this area is focused on coding or training mechanisms that allow robots to pick up visual cues such as gestures and facial expressions that guide interaction.
- Lastly, this area considers the ways in which humanoids can be profitably and safely integrated into everyday life.

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HRI and HCI (1)

- So, before developing and integrating in our society intelligent robots, the researchers need to pay attention to the nature of human-robot relationship and to the impact of this relationship on our future.
- A good starting point is the study of HCI (= Human Computer Interaction).

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HRI and HCI (2)

- HRI is strongly related to Human-Computer Interaction (HCI) and Human-Machine Interaction (HMI).
- HRI, however, differs from both HCI and HMI because it concerns systems (robots) which have complex, dynamic control systems, which exibit autonomy and cognition and which operate in changing, real-world environments.

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HRI: a distinctive case of HCI

- People seem to perceive autonomous robots differently than they do with respect to most other computer technologies (anthropomorphic robots).
- Robots are ever more likely to be fully mobile, bringing them into physical proximity with other robots, people and objects.
- Robots make decision, that is, they learn about themselves and their world and they exert at least some control over the information they process and actions they emit.

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Attitudes of people towards ISR

- Many studies were made to investigate people's attitudes towards an intelligent service robot in the areas of HRI.
- The whole idea of robots seems to have started in **Science Fiction** (SF) in various forms like literature, movies, television, which makes it an important source for understanding humans in their relation to robots.
- Some examples are: "Frankenstein", "R2D2" and "C-3PO" (Star Wars), "Terminators", ...
- Movies, film and media have influenced the images of robots strongly, which is emphasized by a fear manifested in a kind of "Big Brother-is-watching-you-syndrome" and the "robot-running-crazy-syndrome" which are the most common negative views on robots.

Why surveys are important?

- Important factors in the definition of usability are:
  user acceptability, utility, ease of learning and reliability.

- User acceptability is based on the physical design as well as the system's functionality. It is furthermore dependent upon the extent to which the system satisfies the users' needs by performing the wanted tasks.

Questionary survey (1)

1. How are robots perceived by humans in general?

2. How can robots be used for service purposes in the household?

3. What should the robot look like?

4. How should the robot behave or be?

Questionary survey (2)

5. From where have humans conceived their ideas and images of robots?

6. Who is the potential user of a robot? Which categories do these potential users fit into?

7. What should a robot not do in a household, i.e. which functions and tasks are not wanted in a household?

8. How should the communication between a human and a robot be conducted? Through which media channels or modes of communication?

Survey result (1)

- **Tasks for robots:**
  a person actually wants a robot to help or conduct these tasks: polishing windows, cleaning ceilings and walls, cleaning, moving heavy things and wiping surfaces clean. The least wanted were: baby sitting, watching dog/cat and reading aloud.
- **Communication with robots:**
  - speaking with the robot (82%),
  - writing a command (45%),
  - showing on a touchscreen (63%),
  - gesticulating (51%).

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Survey result (2)

- **Robot's voice:**
  - humanlike voice instead of synthesized voice,
  - masculine and feminine voice, neutral towards gender specification,
  - young or old persons voice, neutral specification of age.
- **How the robot should indicate problems**
  - by a sound signal (64%)
  - by coming to you and tell you (60%)
  - showing it on a screen (65%)

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Survey result (3)

- **Language used with a robot:**
  Samples of instruction sequences:
  1. *Ulla, could you get the blue bowl with the hazel nuts please.*
  2. *Kalle, pick up and bring the red bowl on the table in front of the sofa to me in the kitchen.*
  3. *Listen!, get the bowl on the table in front of the sofa! give it to me! the kitchen!*
  4. *Robot, get, the bowl, sofa table, to me, now.*
  5. *Hugo!, to the sofa table, take the 30cm bowl!, bring 30 cm bowl to me!, release in my hands!*
  6. *Kalle, give me the bowl.*

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Survey result (4)

- **The image of a robot :**
  - Appearance
  robot with machine-like appearance but personally designed, somewhat colorful, round-shaped and quite serious.
  - Size: height and breadth of a robot
  important factors that are decisive are the empty (free) space in a home, meaning that people are worried about having congested homes and do not want the robot to take unnecessary space. The preferred size of the robot is exemplified in a suggestion by an interviewee: "a robot should be small enough to fit inside a wardrobe (or placing itself in the wardrobe)".

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Survey result (5)

- Speed

adjustable speed is preferred and walking speed should be the normal pace of a robot.

- Preferred description of a robot

ISRs primarily as a domestic device with abilities to help and assist in various tasks.

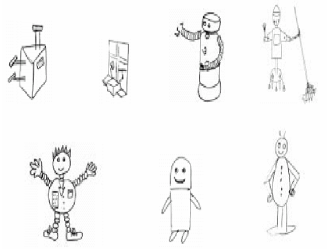
- The independence of a robot

the option of a programmed robot is preferred indicating that people do not want a robot to be too smart, but more or less have the capacity to conduct limited actions according to its programs.

Survey result (6)

- **Robotdrawings:**

What generally can be said about these images is that they either have human features such as eyes, hands, feet, head and a body or that they are more mechanical devices with only subtle human attributes.



We focus on…

- two little-understood aspects of service robots in society:

  1. The design and behavior of service robots.

  2. The ways that humans and robots interact.

1. Design of service robot

- The analysis of the interaction between human and robot and the models to be used in design should be based on an understanding of the context where the robot is to be used. (group of people involved, their goals and activities, the shared physical environment).
- More, ethical and social consideration surrounding this context.

Robot as partners

- A robot is commonly viewed as a tool: a device which performs tasks on command. As such, a robot has limited freedom to act.
- Moreover, if a robot has a problem, it has no way to ask for assistance.
- It seems clear that there are benefits to be gained if humans and robots work together.
- Treating a robot not as tool, but rather as a partner, we can achieve better results.

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Collaborative control

- The “division of labour” between human and robot is rarely given in beforehand, but may vary depending on the context. Users may prefer to do certain tasks themselves while they need assistance with others. In other cases, users may be expected to assiste the robot on its missions to compensate for limitations of autonomy (*Collaborative Control).*
- A human and a robot work as partners collaborating to perform tasks and to achieve common goals.
- The human and the robot engage in *dialogue* to exchange ideas, to ask questions and to resolve differences.

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Conseguences of Collaborative Control

- The robot can decide how to use human advice: to follow it when available and relevant; to modify it when inappropriate or unsafe.
- The robot doesn’t become “master”, it has more freedom in execution and can better function when the human is unavailable.
- The most significant benefit, however, is that if the human is available, he can provide direction or assist problem solving; but, if he is not, the system can still function.

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Key issues of Collaborative Control

- Since the robot is free to use the human to satisfy its needs, the robot must have *self-awareness* (in what it can do and what the human can do).
- The robot must have *self-reliance*. The robot should be capable of avoiding hazards and monitoring its health.
- The system must have the *capacity for dialogue.* The robot and the human need to be able to communicate effectively. Dialogue is two-way and requires a richer vocabulary.
- The system must be *adaptive.* The robot has to be able to adapt to different operators and to adjust its behavior.

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2. Communication and Interaction with robots

- The range of communication and interaction systems that users are experienced with and use skillfully, include face-to-face, mediated human-to-human and man-machine communication and interfaces. This prior knowledge will be of importance in evaluating the robot's characteristics and perceived usability of expressiveness.
- In face-to-face communication people use spoken language, gestures, and gazes to convey an exchange of meaning, attitudes and opinions. As typical properties, human communication is rich in phenomena like ellipses, indirect speech acts, and situated object or action references. The ambiguities incorporated in a human-to-human conversation needs to be carefully thought and designed for in HRI.

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HRI issues

1. Design and integration of the sensors and actuators necessary for enabling a robot to sense in, and act on, its environment in a human-like way.
2. Realization of a control structure that allows a robot to generate useful and goal-directed behaviors.
3. Development of communication and interaction behaviors to enable the robot to communicate intelligently and to display a user-friendly and cooperative attitude.

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1. Designing robots for human environments (1)

- The problem:

  a service or personal robot shall perform its tasks in environments where humans work and live, in apartments, offices, laboratories, restaurants or hospitals.

CERO

- The solution:

take human as a design model (human centered approach, in the sense that the goal of technology is to satisfy the human needs, instead of robot centered approach). So, this means to enable the robot to adapt itself to the environment.

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Designing robots for human environments (2)

- Shaping the robot according to an anthropomorphic model and equipping it with human-like sensor (vision, touch and hearing) and motor skills will avoid subsequent and expensive changes of the infrastructure and make the robot, in principle, suited for any environments humans normally work and live in.

Actroid

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Designing robots for human environments (3)

- Service robots will have to interact, and to communicate, with humans. If a robot has a humanoid form and exhibits human-like behavior, humans are able to interact with it in a more natural way.
- Movement of an anthropomorphic robot can more easily be predicted even by humans who are not interested in robot technology.
- Humanoid size and shape of a robot can be advantageous for its representation of knowledge of the environment in such as a way that it may easily be accessed by, and shared with, humans as a basis for communication.

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2. Controlling a Humanoid Service Robot

- The problem:

  controlling a robot with many degrees freedom in actuation and sensation.
- The solution:

  to ground the system on a behavior-based architecture, that is the architecture now generally accepted as an efficient basis for autonomous mobile robots.

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Behavior-based system architecture

- The main principle is the achievement of desired goals by activating an appropriate sequence, or combination, of behaviors that are selected from a repertoire of predefined behaviors.
- The key problem in designing this kind of architecture is the question how to choose at each moment the most appropriate behavior.
- One solution could be to base this decision on a multitude of factors that represent the “situation”.

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What means “situation”?

- The concept of “situation” includes not only the objects in the environment and their state of motion, but also higher-level goals of both the human and the robot, overall tasks, and behavioral abilities of the robot.
- The situation on which the robot bases its behavior selection is only the robot’s internal image of the actual situation. Due to imperfect sensing or knowledge, this image may sometimes differ from the true situation, which will then result in a suboptimal or even grossly inappropriate behavior of the robot.

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3. Communicating and Interacting with Service Robots **(1)**

- The problem:

  A user-friendly interface is a prime prerequisite for service robots that are aimed to help us in various activities in daily life.

  1) human and robot have to agree upon a suitable communication mode,

  2) communication and interaction have to be grounded on a common understanding or reference frame.

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Communicating and Interacting with Service Robots (2)

- The solution:

  1) Since natural language is the easiest and most desiderable mode of communication for a human it is desirable to integrate speech recognition and output into most service robots. The robots must not only have the ability to understand perfectly clear and complete commands, but they must also resolve ambiguities and complement missing information that is inherent in human conversation.

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Communicating and Interacting with Service Robots (3)

- Two approaches:
  - Robot should use the current situation as a relevant context,
  - Robot may evoke additional information from the human through a dialogue.

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Communicating and Interacting with Service Robots (4)

2) In general, robots do not have the perceptual abilities of humans and therefore might not be able to detect the features of the environment a human would like to refer to during communication.

The solution is a situation-oriented approach: since man and machine are sensing and acting in a common environment, they will perceive their current situation in a similar way.

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Interaction Modalities

- Speech
- Gesture
- Facial expressions
- Gaze
- Proxemic and kinesic signals
- Haptics
- Multi-modal interfaces are supposed to be beneficial due to their potentially high redundancy, higher perceptibility, increased accuracy, and possible synergy effects of the different individual communication modes, if taken in together.

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Dialogue: communication and conversation (1)

- Dialogue is the process of communication between two or more parties.
- Depending on the situation (task, environment,..) the form or style of dialogue will vary. However many properties of dialogue (initiative taking and error recovery) are always present.
- The common interface models for human-robot dialogue are: *command languages*, *form-filling*, *natural language (speech or text)*, *question-and-answer*, *menus* and *direct-manipulation (graphical user interfaces)*.

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Dialogue: communication and conversation (2)

- Dialogue is controlled by four factors:

  1. *Linguistic competence*: the ability to construct intelligible sentences and to understand the other's speech.

  2. *Conversational competence*: the pragmatic skills necessary for successful conversation.

  3. *Nonverbal skills*: such as gestures, are used to add coherence to a dialogue and provide redundant information.

  4. *Task constraint*: can determine the structure of dialogue (restricted vocabulary, domain specificity, economical grammar e. g., acronyms)

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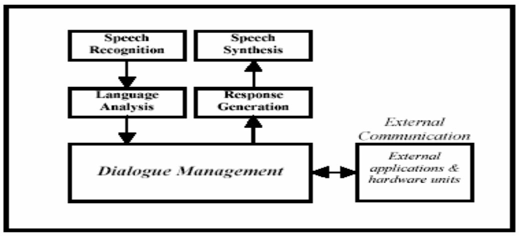
Spoken Dialogue Systems

- SDSs allow users to interact with robots by means of spoken dialogues in natural language.
- There are a lot of fields involved in spoken dialogue systems. These include speech recognition and speech synthesis, language processing and dialogue management.



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SDSs architecture

- The architecture:

  the speech input is first processed by a *speech recognizer*, which convert it to a written form. This is then passed to the *language analyzer*, which construct a logical representation of the user's utterance. Using this representation, information on the previous discourse, and knowledge of the task to be performed, the *dialogue manager* may then decide to communicate with an external application or device, or convey a follow-up message to the user. In the latter case, a logical representation of the message is passed to *response generator*, which generates an appropriate response in written form and passes it to the *speech synthesizer*.

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Speech Recognition (1)

- The formal definition of speech recognition is:

  "the recognition of speech input from the user by the system."
- **Problems of speech recognition**

  1. The complexity of language is a barrier to success.

  2. Background noise can interfere with the input, masking or distorting the information.

  3. Speakers can introduce redundant or meaningless noises into the information stream by repeating themselves, pausing or using words like "Uhmm" and "Errr".

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Speech Recognition (2)

4. Another problem is caused by the variations between the voices of people. People have unique voices and systems can only be successful if they are tuned to be sensitive to minute variations in tone and frequency of the speaker's voice. New speakers can be a problem sometimes, because they present different inflexions to the system, which will fail to perform as well.

5. A more serious problem is caused by regional accents, which vary considerably. This strong variation upsets the trained response of the recognition system.

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Speech Recognition (3)

- **A promising future for multi-modal interaction**

  Considering speech recognition from the point of view of multi-modal interaction, there is no doubt that it offers another mode of communication that may in some contexts be used to supplement existing channels or become the primary one.
- Another advantage is that it can be an alternative means of input for users with visual impairment, physical disabilities or learning disabilities like dyslexia.

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Speech Synthesis (1)

- Complementary to speech recognition is speech synthesis.
- Speech synthesis is the process of automatic generation of speech output from data input, which may include plain text, formatted text or binary objects.

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Speech Synthesis (2)

- **Problems of speech synthesis**

  there are as many problems in speech synthesis as there are in recognition.

  The most difficult problem is that we are highly sensitive to variations and intonation in speech. We are so used to hearing natural speech that we find it difficult to adjust to the monotonic tones that are presented to us by speech synthesizers.

  In order to decide what intonation to give to a word the system must have an understanding of the domain. Therefore, an effective automatic reader would also need to be able to understand intonations in natural language. Especially for synthesized speech, this is not easy to accomplish.

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Dialogue Management

- The basic function of dialogue management is to translate user requests into a language the robot understands and the system's output into a language that the user understands.
- In addition, dialogue management must be capable of performing a variety of tasks including adaptation, disambiguation, error handling, and role switching.

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Dialogue management techniques

- Spoken dialogue systems can be classified into three main types, according to the methods used to control the dialogue with the user.

  1) Finite state-based systems
  2) Frame-based systems
  3) Plan-based systems

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State-based technique (1)

- **State-based**: represents the possible dialogues by a series of states; at each state the system may ask the user for specific information, it may generate a response to the user, or it may access an external application. The structure of the dialogue is predefined, and at each state the user is expected to provide particular inputs. This makes the user's utterances easier to predict, leading to faster development and more robust systems at the expense of limited flexibility in the structure of the dialogues.

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State-based technique: an example

- A simple example:
  System: What is your destination?
  User: Amsterdam
  System: Was that Amsterdam?
  User: Yes
- If the answer of the user is negative, the system will repeat the question, as can be shown below:
  System: What day do you want to travel?
  User: Friday
  System: Was that Sunday?
  User: No
  System: What day do you want to travel?

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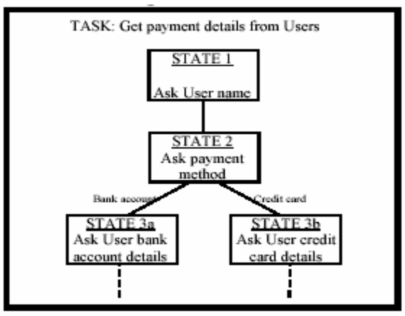
State-based technique: another example



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State-based technique (2)

- For simple tasks, state-based techniques are often the most practical solution. In complex tasks, however, state graphs become extremely large and difficult to maintain, and they lead to long dialogues that users may find irritating.

- There are a lot of commercial spoken dialogue systems which use this form of dialogue control. The system maintains control of the dialogue, produces prompts at each dialogue state. Next to this, it recognizes (or rejects) specific words and phrases in response to the prompt. After this, it produces actions based on the recognized response.

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State-based technique (3)

- It should be clear that one important property of this kind of system is the fact that the user input is restricted to single words or phrases. The system always gets responses to carefully designed systems prompts. A major advantage of this form of dialogue control is that the required vocabulary and grammar for each state can be specified in advance, resulting in more constrained speech recognition and language understanding.
- Unfortunately, there is also a disadvantage. These systems restrict the user's input to predetermined words and phrases, making correction of misrecognized items difficult. A second disadvantage is that the user has very little or no opportunity to take the initiative and ask questions or to introduce new topics.

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Hygeiorobot

- Hygeiorobot is a project whose goal is to develop a mobile robotic assistant for hospitals.
- Hygeiorobot uses a state-based approach.
- The SDS allows users to deliver a medicine or message to a specific room or patient. The users can also ask for information about the patients, such as the phone or room number of a patient.

[H] – Hello, this is Hygeiorobot. Please state your action and priority.
[U] – Medicine delivery at high priority please.
[H] – Please select the room number for the delivery
[U] – 911.
[H] – You have selected room number "911". Is this correct?
[U] – Yes.
[H] – Would you like to give the recipient name?
[U] – Yes. DeForest Kelley.
[H] – So you want me to deliver to room "911" to the person by the name of "DeForest Kelley".
[U] – Yes.

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Frame-based technique (1)

- **Frame-based:** uses frames instead of series of states. In this case, each frame represents a task or subtask, and it has slots representing the pieces of information that the system needs in order to complete the task. The system formulates questions to fill in particular slots that remain empty but the user may get the initiative of the dialogue and provide more information than asked. This additional information is used to fill in more slots, saving the user from having to answer subsequent questions, and leading to shorter dialogues compared to state-based approaches. On the other hand, user utterances become less restricted and, hence, harder to predict, compared to state-based techniques, which increases the time needed to develop a robust system.

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Frame-based technique: an example (1)

- In a frame-based system, the user is asked questions that enable the system to fill slots in a template in order to perform a task. An example of this is to provide train timetable information.

  System: What is your destination?

  User: London

  System: What day do you want to travel?

  User: Wednesday
- In this example the user provides one item of information at a time and the system performs rather like a state-based system.

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Frame-based technique: an example (2)

- It is also possible that the user provides more than the requested information. As can be seen in the example below, the system can accept this information and check if any additional items of information are required before searching the database for a connection.

  System: What is your destination?

  User: London on Friday around 10 in the morning

  System: I have the following connection…

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Frame-based technique (2)

- Frame-based systems function like production systems, taking a particular action based on the current state of affairs. Some form of natural language is required by frame-based systems to permit the user respond more flexibly to the system prompts.

  This is a great difference compared to finite state based systems.

- Natural language is also required to correct errors of recognition or understanding by the system.

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Plan-based technique

- **Plan-based:** concentrates on identifying the user's plan and determining how it can contribute towards the execution of that plan. This is a dynamic process, whereby new information from the user may force the system to modify its initial perception of the user's plan and its possible contribution. Plan-based techniques typically allow for greater degrees of user initiative in the dialogues, compared to previously mentioned approaches, and have proven to be particularly well suited to problems where the pieces of information or actions that are needed to perform a task are hard to predict in advance. The implementation and maintenance of plan-based systems, however, is far more complex, compared to systems based on the previous approaches.

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Plan-based technique: an example

- Below we can see an example dialogue between the user and the system.

  User: I'm looking for a job in the Calais area. Are there any servers?

  System: No, there aren't any employment servers for Calais. However, there is an employment server for Pas-de-Calais and an employment server for Lille. Are you interested in one of these?

- Here it is obvious that the system is trying to be more cooperative than with frame-based or finite state-based systems.

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Conclusions (1)

- The tasks that most mobile assistants are expected to perform typically require only a limited amount of information from the users.
- These points argue in favour of simple dialogue management approaches, namely state- or frame-based techniques, rather than more complex, plan recognition mechanisms.

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Conclusions (2)

- Robotic assistants often have to operate in noisy environments (offices, hospital corridors,…) where they need to interact with many casual users.
- This calls for speaker-independent speech recognition and robust language processing.

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A service robot: HERMES (1)

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A service robot: HERMES (2)

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A robot assistant: PEARL

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