Introduction to Automated Planning

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Objectives

Specific Objectives

- To understand what AI Planning is
- Where Planning can be applied
- Understand Planning as a search process

Source

- Stuart Russell & Peter Norvig (2009). Artificial Intelligence: A Modern Approach. (3rd Edition). Ed. Pearsons
- Ghallab, Nau &Traverso (2004). Automated Planning: Theory & Practice. The Morgan Kaufmann Series in Artificial Intelligence

Outline

- **Introduction**
- Application domains
  1. Satellite operations
  2. Workflow systems
  3. Robotics
- A brief history
- Solving Planning Problems
- Conclusions

Introduction

- Automated planning: area of Artificial Intelligence (AI) that studies the deliberation process computationally
- Planning is the reasoning side of acting
- In our everyday activities we are always acting, and we do anticipate the outcome of our actions, even if we are not fully aware of anticipating
- We act much more frequently than we explicitly plan our actions
- We are not often conscious of performing an explicit deliberation process prior to acting
- A purposeful activity requires deliberation when it addresses new situations or complex tasks and objectives or when it relies on less familiar actions

Motivation

- Practical
  - Designing information processing tools that give access to affordable and efficient planning resources
  - There are jobs where complex and changing tasks involve demanding safety and/or efficiency requirements
  - I.e. Rescue operation
- Theoretical
  - An important component of rational behaviour
  - If one purpose of AI is to grasp the computational aspects of intelligence, then the reasoning side of acting, is a key element in such a purpose

Forms of Planning

- Path P.: synthesis of a geometric path from a starting position to a goal
- Motion P.: takes the model of the environment and the kinematic and dynamic constraints (control actions for dynamic systems)
- Perception P.: involves sensing actions identifying the current state of the environment
- Navigation P.: combines previous motion and perception in order to reach a goal or to explore an area
- Manipulation P.: concerned with handling objects
- Communication P.: arises in dialog and in cooperation problems between several agents, human or artificial

Definition (I)

- Planning: selects a sequence of activities that meet one or more goals and a set of constraints imposed by the domain

- Scheduling: resource allocation and start times of activities, obeying the temporal restrictions on the activities and the capacity limitations of shared resources
  - An optimization task where limited resources are available throughout the time between activities
  - Activities can be run in serial or in parallel according to different objectives

Definition (II)

- Planning
  - Based on predicates and objects
  - It uses a first-order language (FOL) containing predicates and functions to describe the domain
  - The functions are a set of parametrized operators of the available transitions domain
- Scheduling
  - Not use of predicate or specific language
  - Represents activities and resources by numbers in an input file

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Example I: Satellites operations (I)

- Scheduling ground operations in HISPASAT
- Spanish satellite communications operator, leader in the distribution of content in Spanish and Portuguese
- 25 years of experience, with an important presence on Spain & in Latin America (4th satellite operator), is in charge of:
  - National communications needs
  - Capacity for digital TV in Europe, America & North Africa
  - TV image
  - Defence purposes
- Operations follow engineering instructions: work to accomplish

Example I: Satellites operations (II)

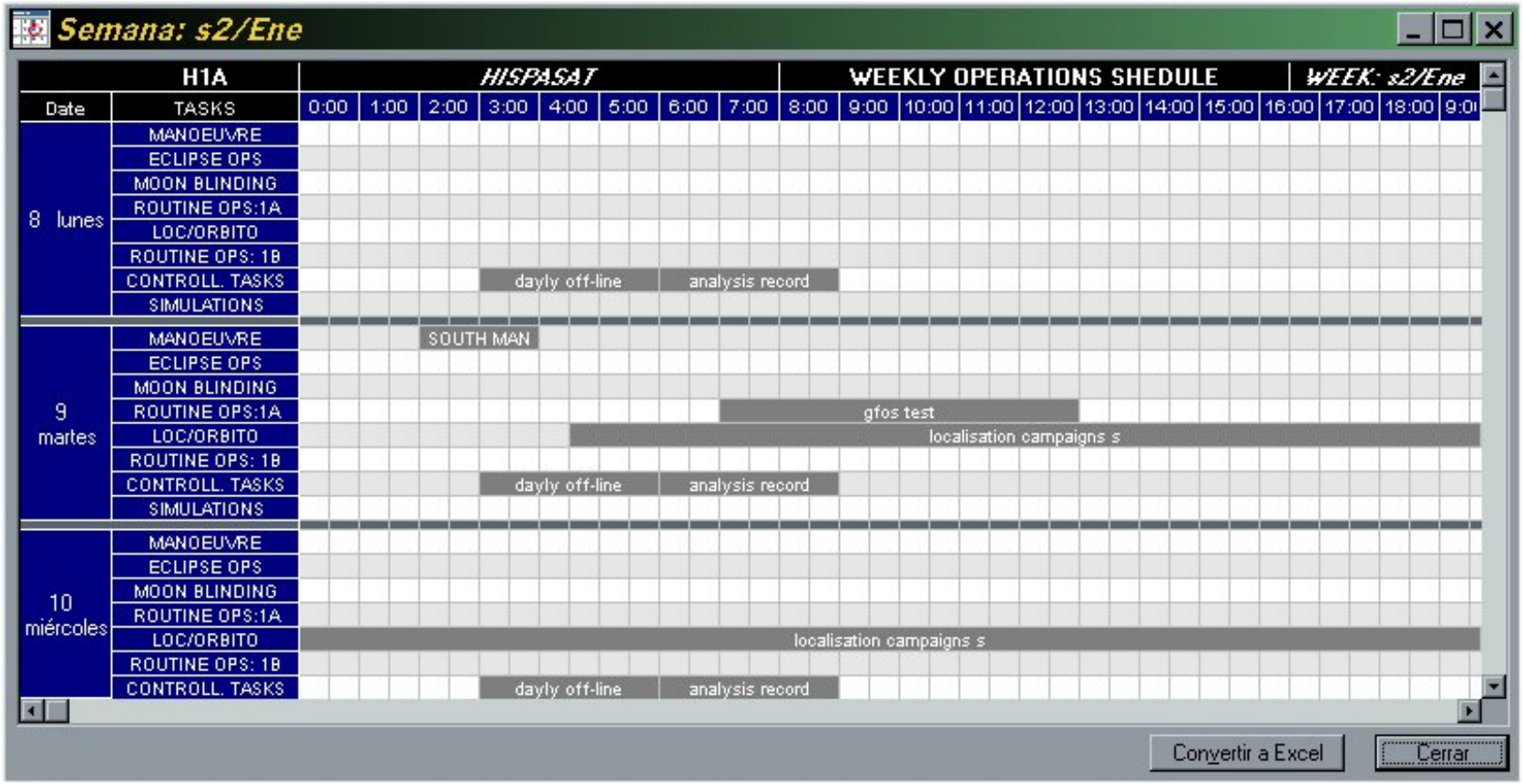
- Operations
  - Follow engineering instructions:

    By Hand & On Paper
  - Depend on external factors
  - Scheduled around Manoeuver
  - Related to the use of batteries & tanks
  - Maintenance

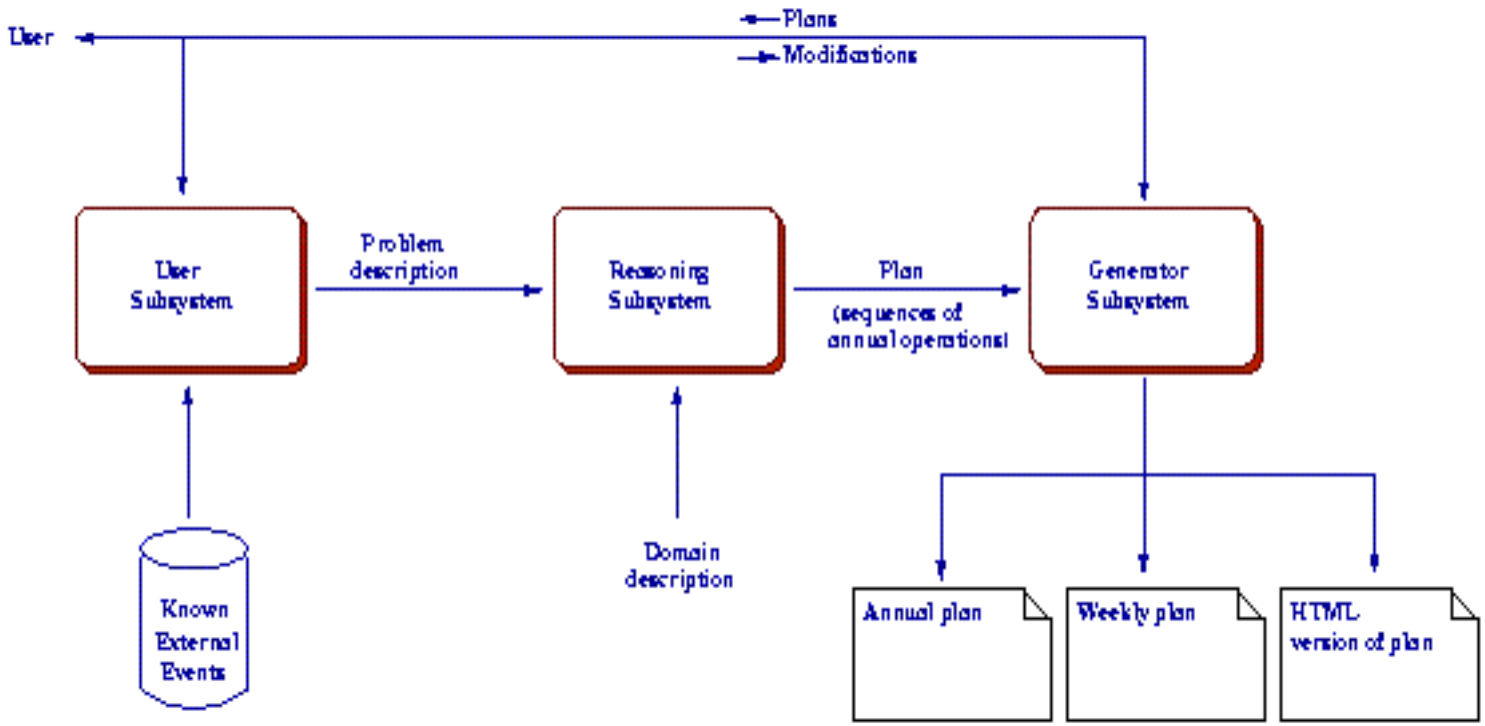
Example I: Satellites operations (III)

- Types of operations (hard vs. soft):
  - Driven by external events and fixed time as Moon blinding
  - Fixed days with some flexibility as Manoeuvres
  - Wide period of time as Antenna Maintenance

Example I: Satellites operations (IV)



Example I: Satellites operations (V)



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Example II: Workflow Systems (I)

- Business Process Management (BPM): a discipline that view business as a set of processes
- Examples:
  - A bank manager rejecting a loan application is a step in a business process
  - A manager approving a purchase order is is an activity in a process
- Involves combination of modelling, execution, control, measurement and optimization of business activity flows
- There are tools to help in defining & simulating models (manually generated)

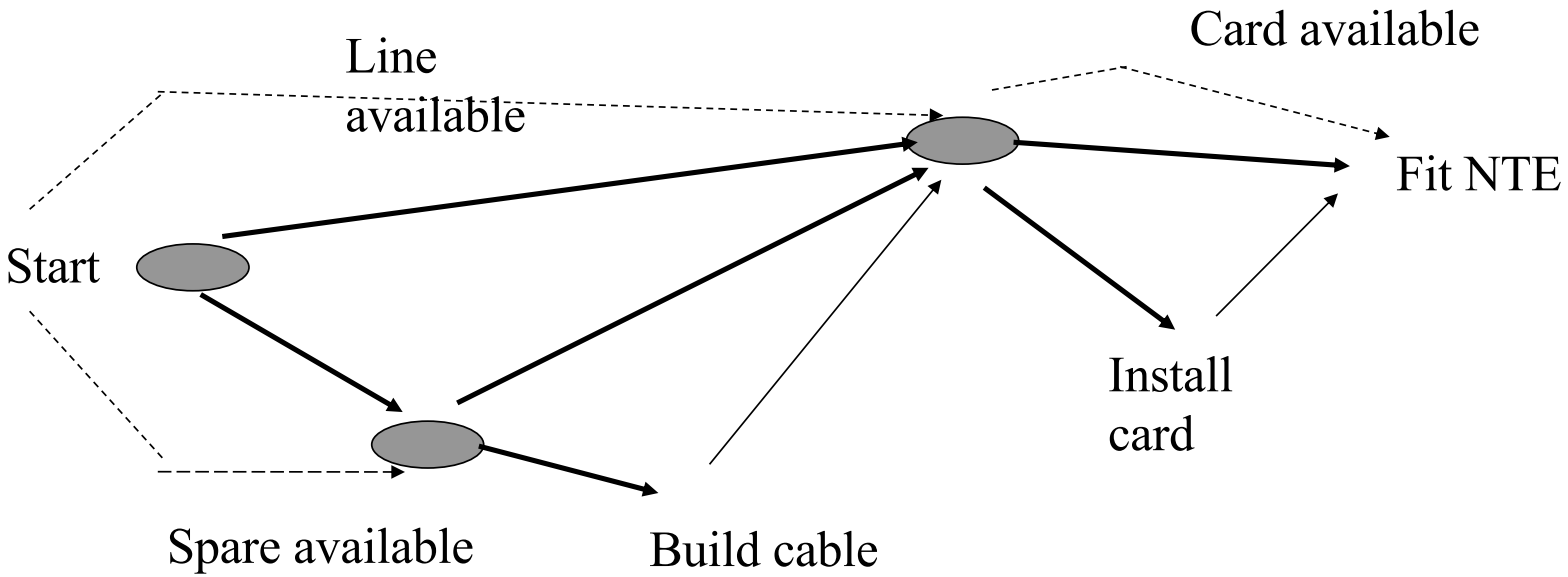
Example II: Workflow Systems (II)

- BPM at BT in UK for lines provision
- COMOSS
  - BP starts when the user calls
  - Gather information and passed to COSMOSS as a job
  - Job is decomposed into activities (Target time)
  - Activities have conditions to be met: questions to be answered
  - The SW will construct a schedule
  - Job & Activities are assigned to agents

Example II: Workflow Systems (III)

- A customer contacts BT for a line and it could:
  - She has already one line (spare pair of wires is available from the house to make a connection from the DP).
  - She is asking for a line for the 1st time (if not new cable must be build)
- Check there is a spare line card available in the exchange (if not, installation may be arranged)
- Contact the customer to fit a new NTE
- Test the line end to end and install NTE
- Allocate the telephone number to the new line an update the exchange, line and customer records

Example II: Workflow Systems (IV)



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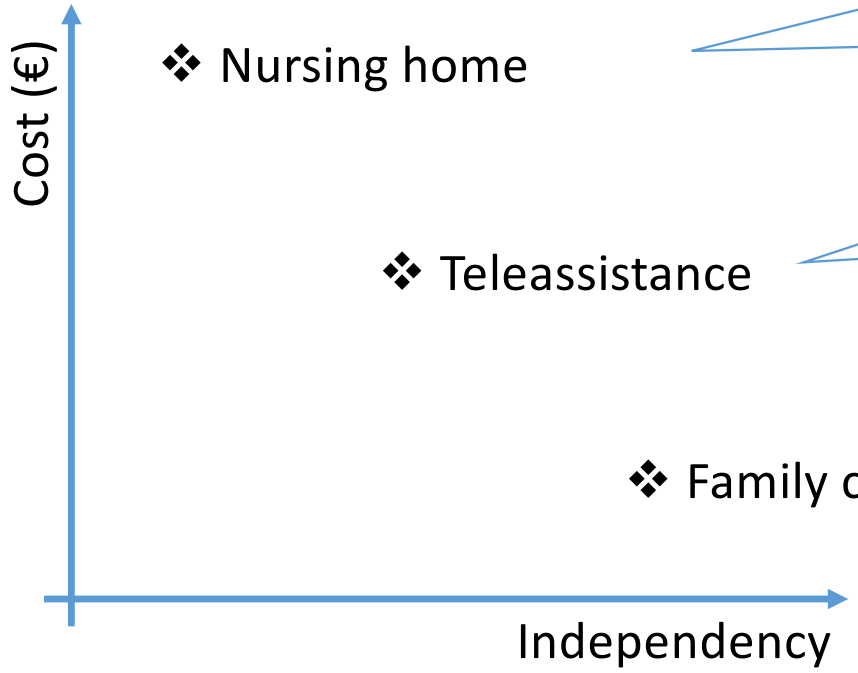
Example III: Robotics (I)

- Robots to support ageing people: LARES system
- Ageing often reduces:
  - Mobility
  - Mental capabilities
- Older and handicap adults often require caregiving:
  - Family cares
  - Nursing homes
  - Teleassistance

Example III: Robotics (II)



- Nursing home
- Teleassistance
- Family cares

Pros:
- 24/7 assistance
- Professional cares

Cons:
- Expensive
- Psychological impact

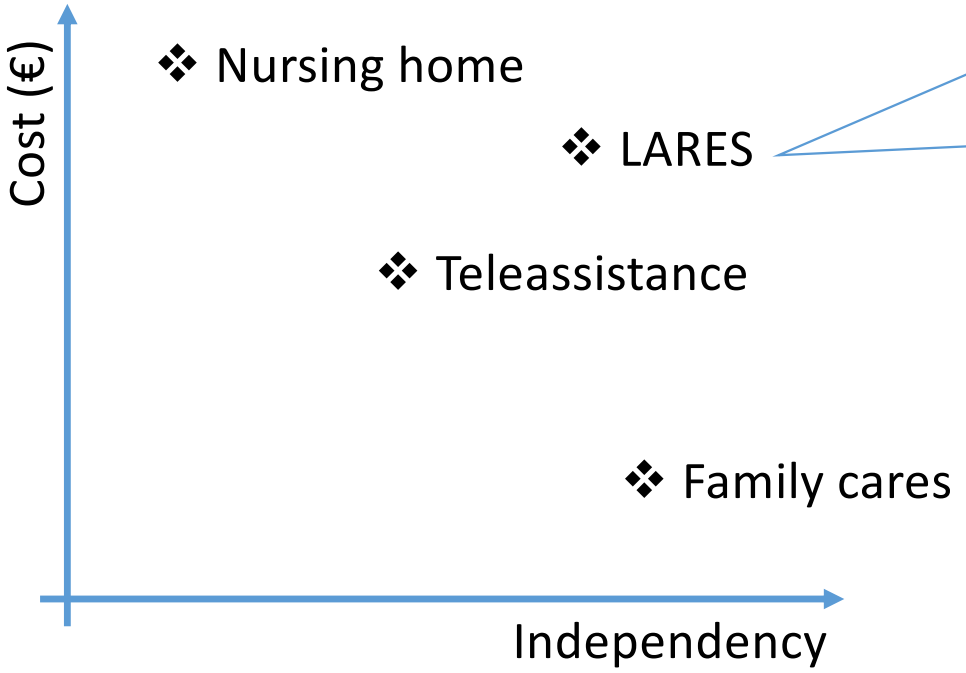
Pros:
- 24/7 assistance
- Adopted at dependent home

Cons:
- Psychological impact
- Require user cooperation

Pros:
- Independency
- Family is close

Cons:
- Family stress
- Hard to cover 24/7

Example III: Robotics (II)

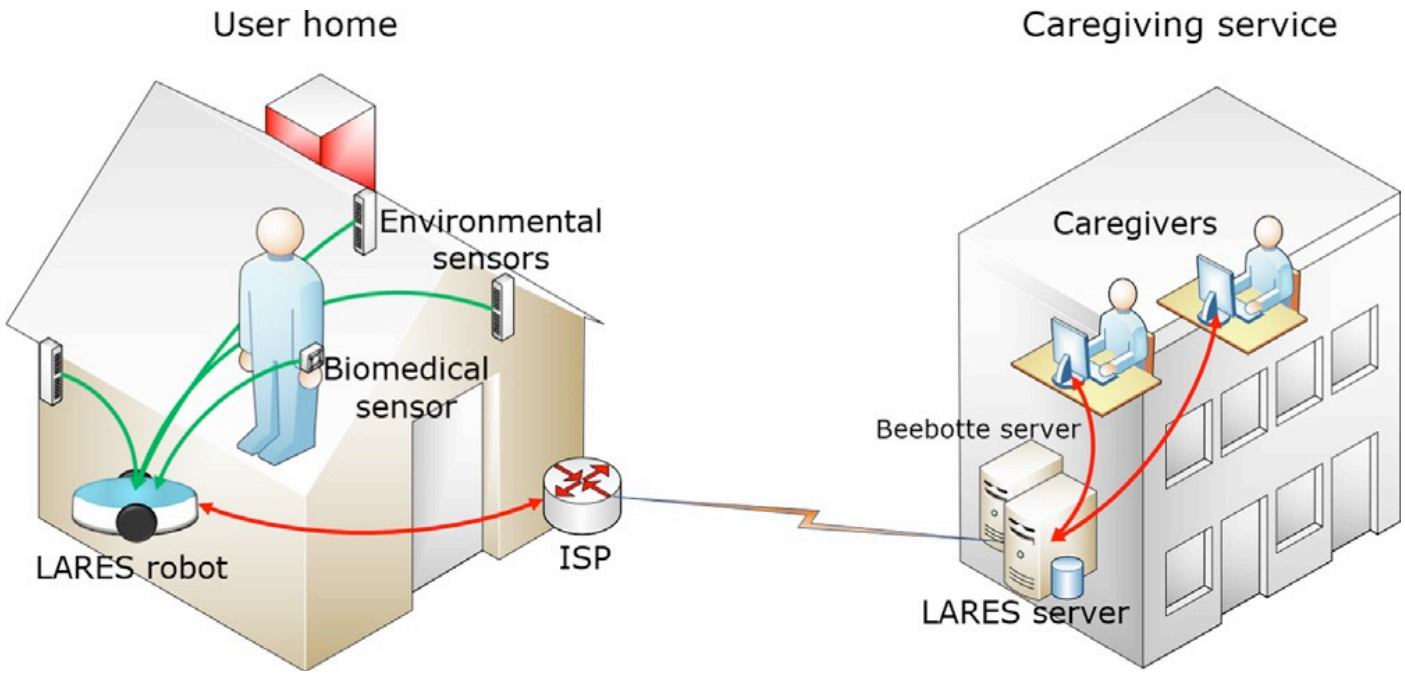


Pros:
- 24/7 with intelligent alarms
- Independency
- Less family stress

Cons:
- Still a prototype
- Deployment requires a technician

Example III: Robotics (III)

Components



Example III: Robotics (IV)

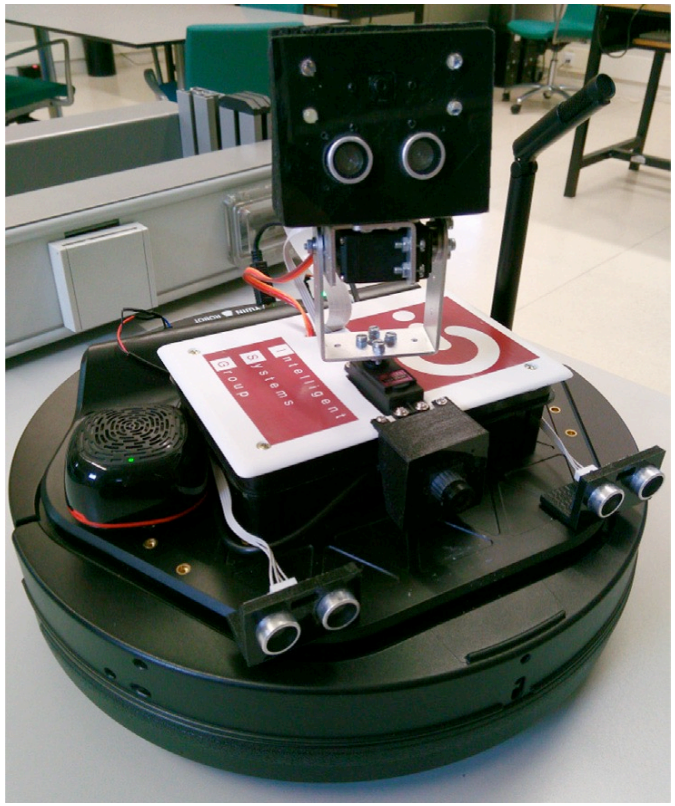
Components

- Wireless Sensors Network
- Low consumption IoT sensors
  - Luminosity
  - Temperature
  - Humidity
  - Presence
- XBee communication
- ~2 months battery operation

Example III: Robotics (IV)

Components

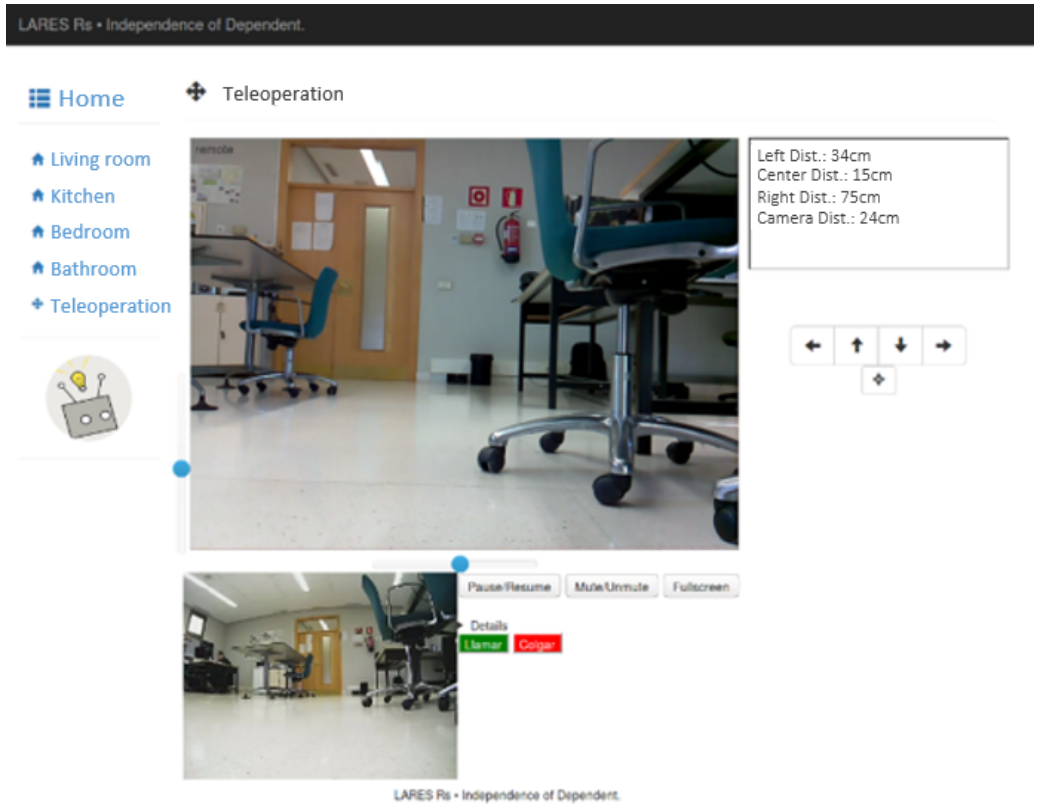
- Autonomous tele-operated robot
- Sensor data assessment
- Teleoperation on-demand
- Autonomous navigation:
  - From dock to alarm location
  - Return to dock
- Video from house to caregivers
- Bidirectional audio



Example III: Robotics (IV)

Components

- **LARES frontend**
  - Recent history
  - Teleoperation frontend



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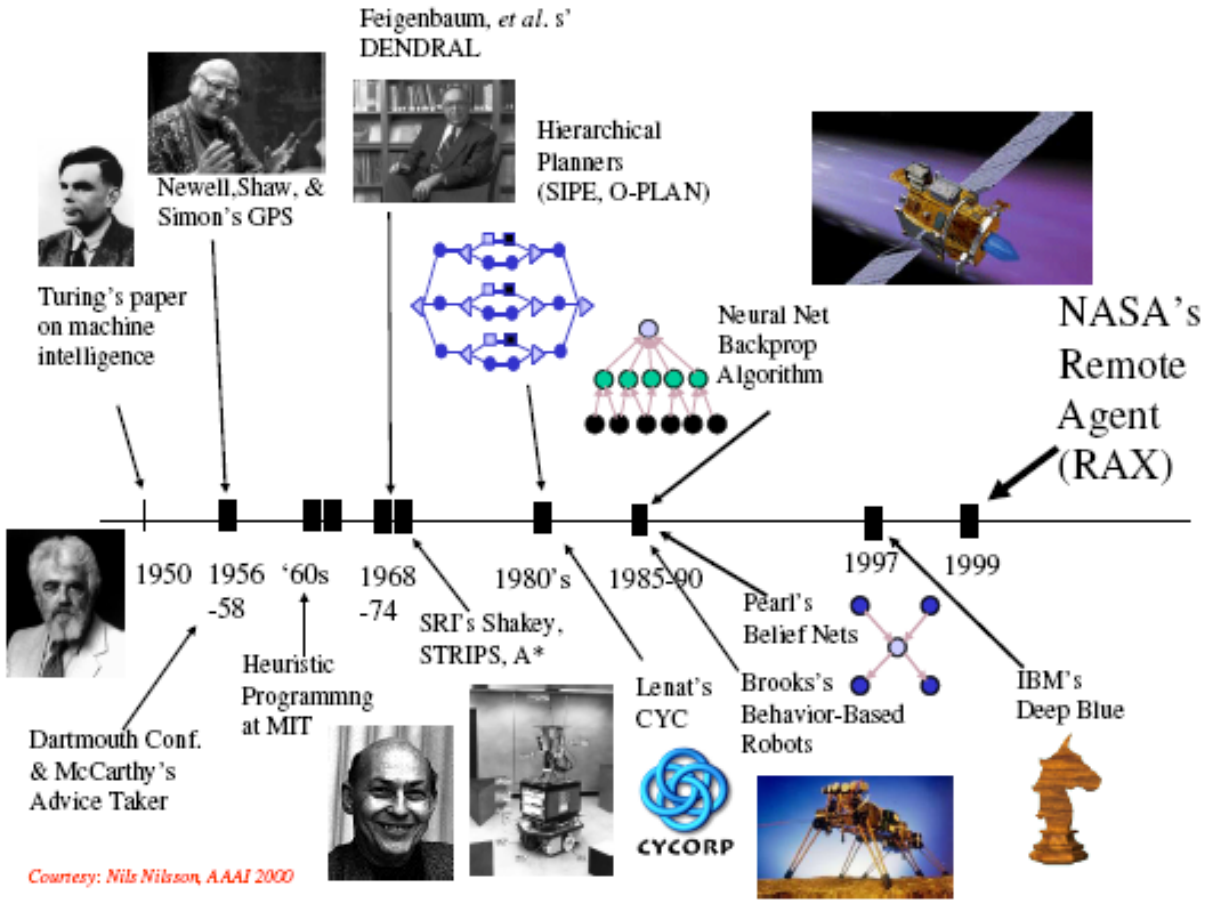
A brief history



A brief history

- 1971-74: Shakey Robot, STRIPS, A*
- 1991: During the Gulf War, US forces deployed an AI logistics planning and scheduling program that involved up to 50,000 vehicles, cargo, and people
- 1995: No hands across America
- 1999: NASA's on-board autonomous planning program controlled the scheduling of operations for Deep Space-1
- 2003-2007: Robot driving in DARPA grand challenge
- 2019: Cooperation Robot Challenge (AlphaPilot)

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Solving Planning Problems (I)

- Domain dependent-planning: address each problem with the specific representations and techniques adapted to the problem
  - Predictive models for the type of actions to be planned for and for the states of the system in which they take place
  - Computational tools for running these models, in order to predict and assess the effects of alternate actions and plans in various situations, exploit the specifics of the domain
  - For example, geometry, kinematics, and dynamics are the tools needed for motion or manipulation planning. Mathematical programming and optimization techniques are the tools widely used in various forms of economic planning

Solving Planning Problems (II)

- Disadvantages of domain-dependent planning:
  - Some commonalities to all these forms of planning are not addressed in the domain-specific approaches. The study of these commonalities is needed for understanding the process of planning
  - It is more costly to address each planning problem anew instead of relying on and adapting some general tools
  - There are not satisfactory for studying and designing an autonomous intelligent machine. Its deliberative capabilities will be limited to areas for which it has domain-specific planners, unless it can develop by itself new domain-specific approaches from its interactions with its environment

Solving Planning Problems (III)

- Domain-independent approaches
  - It takes as input the problem specifications and knowledge about its domain
  - It is not meant to be opposed to domain-specific planning techniques, just as automated reasoning is not intended to replace every arithmetic and floating-point calculus
  - It relies on abstract, general models of actions
  - These models range from very simple ones that allow only for limited forms of reasoning to models with richer prediction capabilities
- Forms of models and planning capabilities:
  - Project Planning: reduced to temporal & precedence constraints (plan edition & verification)
  - Scheduling: include also constraints on the resources to be used
  - **Plan synthesis**: include also the conditions for the applicability

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Conclusions

- Classical planning is a branch of AI
- It is related to decision-making
- Consist of a a set of tasks performed by the robots or computer programs to achieve a specific goal
- We can apply it to any problem when (automate) generation of activities is needed
- We will focus on Plan synthesis
- Knowledge on search algorithms is **REQUIRED**