

# Robots and DSP methods: History and perspectives

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## Outline

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Therm "Robot"

## Where the term "robot" comes from?

### R.U.R. Rossum's Universal Robots

- The term "robot" was invented by the Czech painter Josef Capek who died in the Bergen-Belsen concentration camp
- The word first appeared in the play R.U.R. published in 1920 by his brother writer Karel Capek.
- This fantastically-visionary work takes place on an island somewhere in the middle of the ocean. On island is the central factory of Rossum's universal robots. These Robots are being sold to the world as cheap labour force.
- At the end of the play the only surviving men - master builder Alquist is waken up by two Robots, who are like humans. Unlike the other Robots they have feelings, they sense love, are sensitive. He sends them excitedly into the whole wide world as a new Adam and Eve.

## A Brief History of Robotics

### Manhattan Project

- In 1942, the United States embarked on a top secret project, called the Manhattan Project, to build a nuclear bomb.
- One of the first problems that the scientists and engineers encountered was handling and processing radioactive materials
- One suggested mechanism was a force reflecting telemanipulator, a sophisticated mechanical linkage which translated motions on one end of the mechanism to motions at the other end.

From telemanipulator to robotic arm

# The ancestor of robotic arm

## A Model 8 telemanipulator



# Cybernetics

## From telemanipulator to robotic arm

- After World War II, many other countries became interested in producing a nuclear weapon and in exploiting nuclear energy as a replacement for fossil fuels in power plants
- The need to mass-produce nuclear weapons and to support peaceful uses of nuclear energy kept pressure on engineers to design robot arms which would be easier to control than telemanipulators.
- After WWII, pioneering work by Norbert Wiener allowed engineers to accurately control mechanical and electrical devices using cybernetics.

## An industrial manipulators

### Industrial manipulators and automatic guided vehicles

- Robot arms began being introduced to industries in 1956 by Unimation (although it wouldn't be until 1972 before the company made a profit)
- An industrial manipulator is a reprogrammable and multi-functional mechanism that is designed to move materials, parts, tools, or specialized devices
- Automatic guided vehicles are intended to be the most flexible conveyor system possible: they doesn't need a continuous belt or roller table.

## A black factory

### Hopes

- A black factory is a factory that has no lights turned on because there are no workers
- Computers and robots were expected to allow complete automation of manufacturing processes, and courses in "Computer-Integrated Manufacturing Systems"

### Two unanticipated trends undermined industrial robots

- First, industrial engineers did not have experience designing manufacturing plants with robots
- The second trend was mass customization. The lack of adaptability and difficulties in programming industrial robot arms and changing the paths of AGVs interfered with rapid retooling

## A space robotics

### A man on the moon

- On May 25, 1961, President John F. Kennedy announced that United States would put a man on the moon by 1970
- The need for devices, which could do the tasks difficult for astronauts to perform, have appeared
- Planetary rovers were a possible solution
- The Dartmouth Conference was a gathering hosted by the Defense Advanced Research Projects Agency(DARPA) in 1955 of prominent scientists working with computers or on the theory for computers
- NASA introduced the notion that AI robots would have to integrate all forms of AI (understanding speech, planning, reasoning, representing the world, learning) into one program

# Rovers Left: The lunar rover Right: Sojourner Mars rover

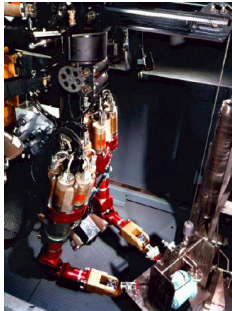


## Teleoperation

### Controlling a robot from a distance

- The operator and robot have some type of master-slave relationship
- The teleoperator cannot look at what the remote is doing directly, either because the robot is physically remote (e.g., on Mars) or the local has to be shielded (e.g., in a nuclear or pharmaceutical processing plant hot cell).
- Therefore, the **sensors** which acquire information about the remote location, **display** the display technology for allowing the operator to see the sensor data, and **communication link** the communication link between the local and remote are critical components of a telesystem

# Teleoperation



## Teleoperation task characteristics

### Teleoperation is best suited for applications where:

- The tasks are **unstructured and not repetitive**
- The task workspace cannot be engineered to permit the use of industrial manipulators
- Key portions of the task intermittently require **dextrous manipulation**, especially hand-eye coordination
- Key portions of the task require object recognition, situational awareness, or other **advanced perception**
- The needs of the display technology do not exceed the limitations of the communication link (bandwidth, time delays)
- The availability of trained personnel is not an issue

## Autonomous device and semi-autonomous control

### Two flavors of semi-autonomous control:

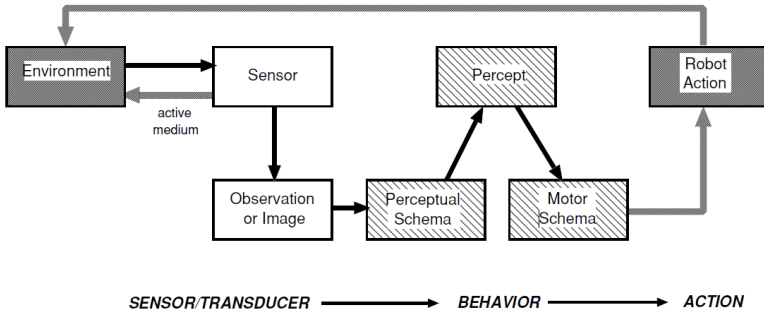
- continuous assistance, or **shared control**. The teleoperator can either delegate a task for the robot to do or can do it via direct control. If the teleoperator delegates the task to the robot, the human must still monitor to make sure that nothing goes wrong
- control trading. The human initiates an action for the robot to complete autonomously. The overall scheme is very much like a parent giving a 10-year old child a task to do. A difficulty with most forms of shared control is that it is assumed that the human is smarter than the robot.
- Autonomic devices performs complex tasks. They depend on development of artificial intelligence

## The Seven Areas of AI

### Main areas of robotic AI:

- **Knowledge representation.** How does the robot represent its world, its task, and itself.
- **Understanding natural language.**
- **Learning.** Imagine a robot that could be programmed by just watching a human, or by just trying the task repeatedly itself.
- **Inference.** Inference is generating an answer when there isn't complete information.
- **Search.** In AI terms, search means efficiently examining a knowledge representation of a problem (a "search space")
- **Vision.** Vision is possibly the most valuable sense humans have. much of problem solving abilities stem from the ability to visually simulate the effects of actions

# A model of sensing



## Sensors classification

### Passive and active

- **Passive sensor** rely on the environment to provide the medium for observation - a camera requires a certain amount of ambient light to produce a usable picture
- **Active sensor** put out energy in the environment to either change the energy or enhance it. A sonar sends out sound, receives the echo, and measures the time of flight.

### Physical and logical

- **A logical sensor** is a unit of sensing or module that supplies a particular percept. It consists of the signal processing from the physical sensor and the software processing needed to extract the percept; it is the functional building block for perception

## Sensors classification

### Internal and external navigation systems

- Aircraft, submarines, and missiles use **inertial navigation systems** which measure movements electronically through miniature accelerometers. As long as the movements are smooth, and the samples are taken frequently, an INS can provide accurate dead reckoning to 0.1 percent of the distance traveled. The cost of an INS is prohibitive; units run from \$50,000 to \$200,000 USD. The cost is due in part to having to stabilize the accelerometers with gyroscopes, as well as the nature of precision electronics.
- **GPS**, or Global Positioning System, is becoming more common on robots, especially those used to automate farm equipment (an effort called precision agriculture).

## Sensors classification

### Proximity Sensors

- **Sonar** refers to any system for using sound to measure range. In practice, reactive robots need to respond to obstacles in the 0.3 to 3 meter range.
- **Infrared sensors** are another type of active proximity sensor. They emit nearinfrared energy and measure whether any significant amount of the IR light is returned. IR sensors have a range of centimeters to meters, depending on what frequency of light is used and the sensitivity of the receiver. These often fail in practice because the light emitted is often washed out by bright ambient lighting or is absorbed by dark materials (i.e., the environment has too much noise).

## Sensors classification

### Bump and feeler sensors

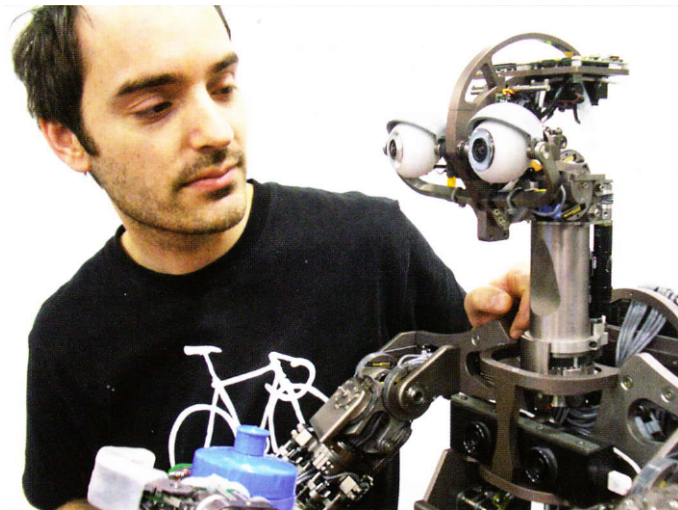
- In theory, the sensitivity of a **bump sensor** can be adjusted for different contact pressures; some robots may want a "light" touch to create a signal rather than a "heavier" touch. In practice, bump sensors are annoyingly difficult to adjust.
- **Feeler sensors** are whiskers or antennae, only not as sensitive as those on animals. Contact of a whisker and an object will trip a binary switch, whereas there is reason to believe that an insect or animal can extract much more information. Bump and feeler sensors are actually tactile sensors since they require the robot to be touching something in order to generate a reading.

## Sensors classification

### Computer vision

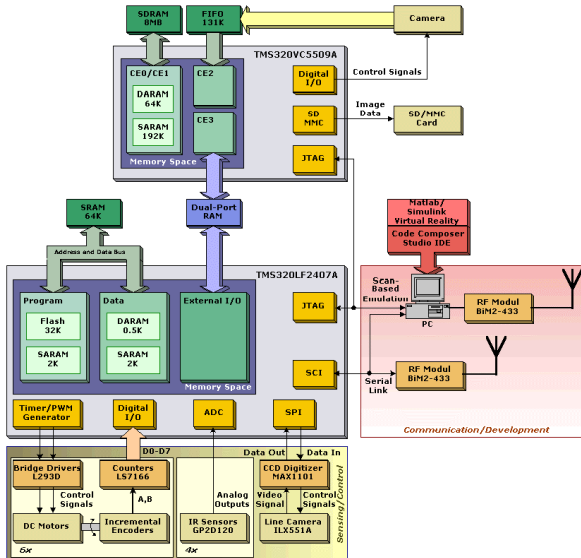
- **Computer vision** includes cameras, which produce images over the same electromagnetic spectrum that humans see, to more exotic technologies: thermal sensors, X-rays, laser range finders, and synthetic aperture radar. Computer vision is a separate field of study from robotics, and has produced many useful algorithms for filtering out noise, compensating for illumination problems, enhancing images, finding lines, matching lines to models, extracting shapes and building 3D representations. Reactive robots tend not to use those algorithms. Most of the algorithms, especially those that remove noise, require many computations on each pixel in the image; until recently, the algorithms were too computationally expensive to run in real-time.

# Computer vision

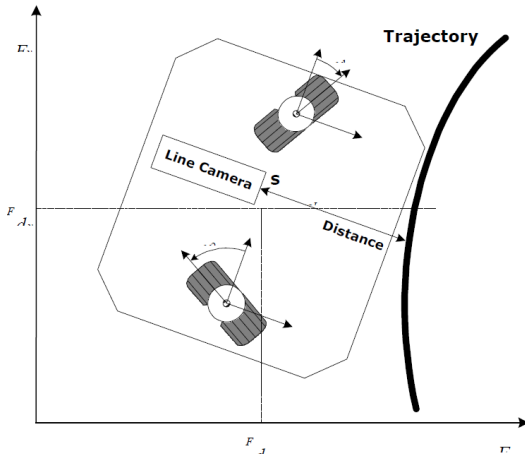


DSP applications

# Communication in multi-DSP environment with interfaces to robot subsystems



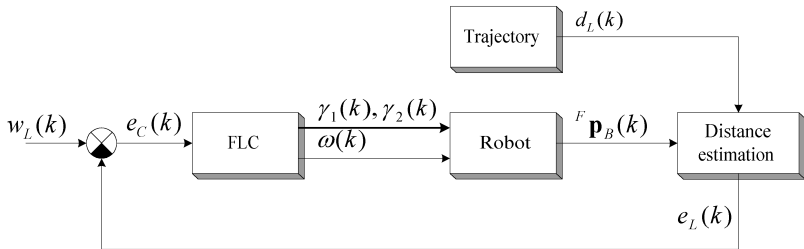
# A neuro-fuzzy controller for the path following



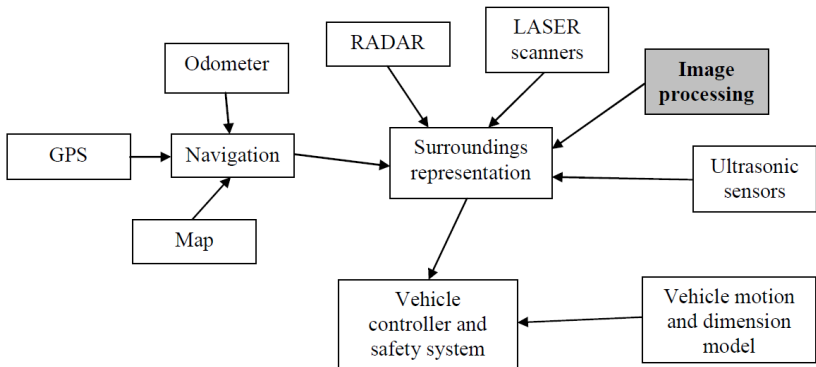
## A neuro-fuzzy controller for the path following

### FLC

fuzzy logic controller (FLC) of Takagi- Sugeno type. It represents physical sensor fusion into logical sensor. Input value is back propagated trajectory error, this value is processed by neural network, output value is path correction.



# Road recognition

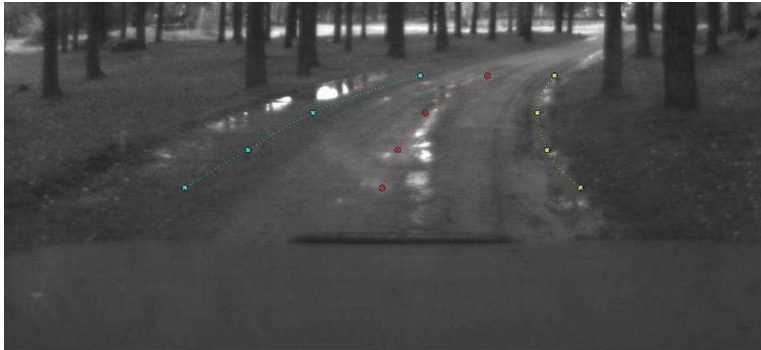


# Road recognition

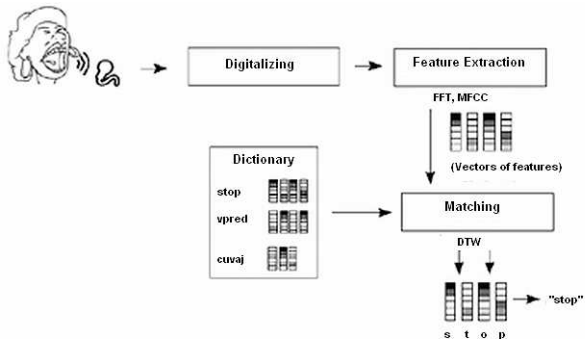
## Algorithm

- Cutting of not important parts of image (engine bonnet and scenery above horizon)
- Selecting 5 rows of the image in  $1/6$ ,  $2/6$ ,  $3/6$ ,  $4/6$  and  $5/6$  of image height
- Comparing these rows with ideal road width using cross-covariance
- Finding maxima of the cross-covariance and projecting it to the image width
- Polynomial approximation of selected points

# Road recognition



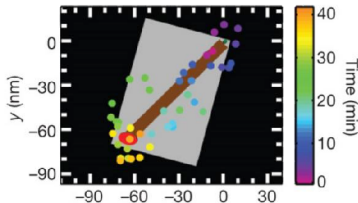
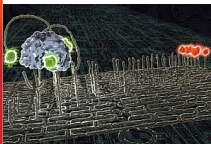
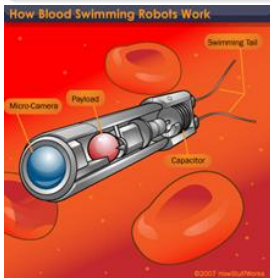
# Voice control



Urgent need for fast online DSP and AI algorithms

## Perspective areas of development

- Military (the biggest financial resources, the biggest demand)
- Health care - surgery robots, rehabilitation robots, assistant robots, nanorobots
- Agriculture - automate farm equipment (an effort called precision agriculture)



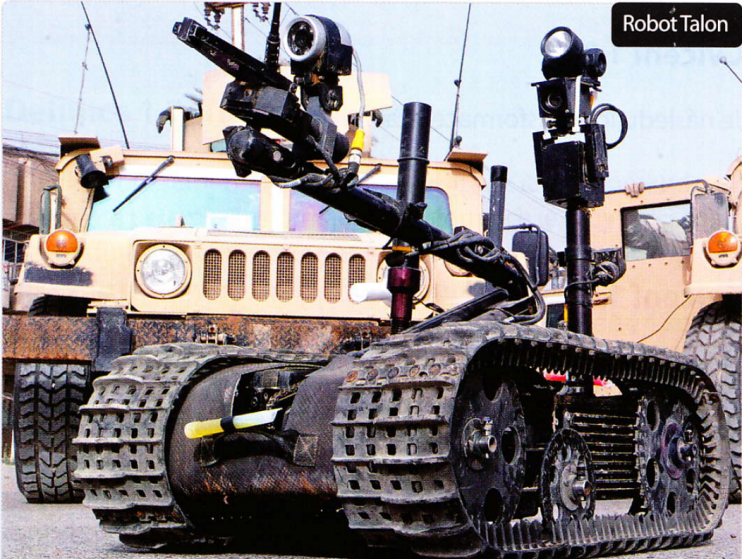
Military robots

## Spy and investigational robots



Military robots

# Spy and investigational robots



# Combat robots

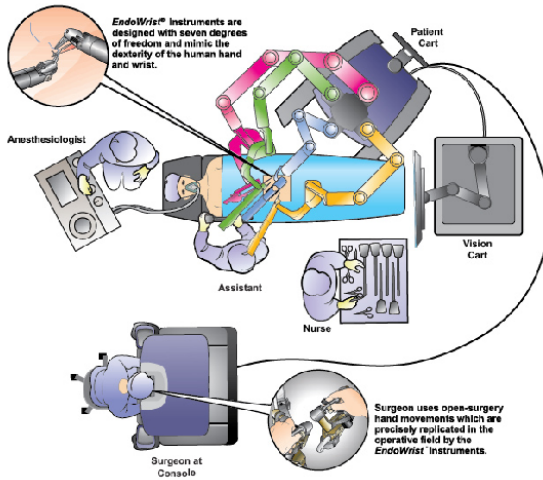


Příslušník 25. pěší divize US Army v novém typu polního stejnokroje trénuje odhoz Ravenů

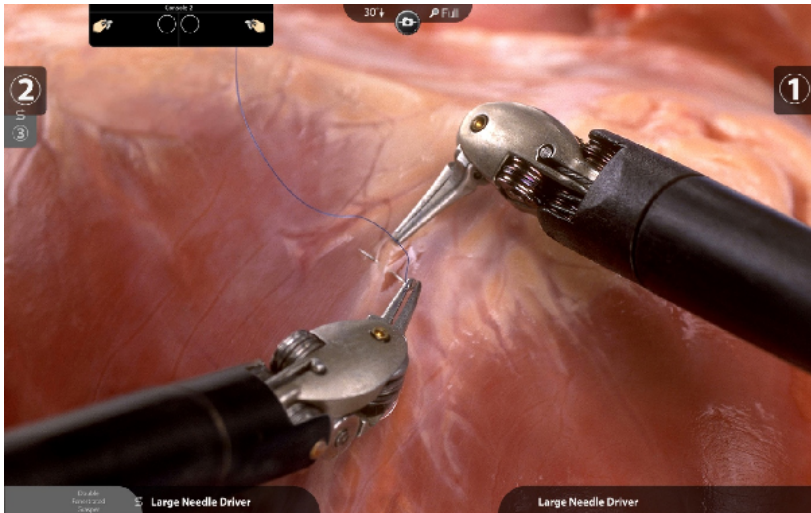
# System Da Vinci



# System Da Vinci



# System Da Vinci



Thank you for your attention

