Autonomous agents
Lecture 12, 20160229

Applications

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Today’s learning goals

- After this lecture you should be able to
  - Exemplify and describe some applications of autonomous systems (robots and vehicles)

No lecture on Thursday

- Please note that there will be no lecture on Thursday.
- That lecture is normally not used – instead, you'll have some extra time to work with HP2.

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Exam information

- A practice exam has been posted on the course web page.
- Please download and go through the problems in the practice exam.
- The actual exam will take place on **March 15, 14.00-18.00, M.**

Fourth quarter preparations

- **NOTE (Important!):** It is mandatory to attend the lecture next Thursday (10^{th}). At this lecture, groups will be formed for the work in the 4^{th} quarter.
- *Those who do not attend will simply be placed in a group, without the possibility to choose group members*.

Robot application: Indoor navigation

- For an application involving decision-making in autonomous robots, see Example 2 from the previous lecture, and read the paper available at
- http://www.intechopen.com/books/recent-advances-in-mobile-robotics/reliable-long-term-navigation-in-indoor-environments
- Here, two other classes of applications with be considered: Autonomous vehicles and intelligent (software) agents.

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Autonomous vehicles

- In recent years, the vehicle industry has developed a great interest in autonomous vehicles (and autonomous driver support functionality).
- Thus, the methods and approaches developed in the field of (mobile) robots (over the last 3-4 decades) has become highly relevant in the vehicle field as well.
- Here, I will describe some projects related (directly or indirectly) to autonomous vehicles.

Vehicles or robots?

- Vehicles get more and more in common with robots!

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Autonomous vehicles: An example

- Komatsu have developed a set of autonomous dumpers (for mining operations).
- They have been deployed at the Rio Tinto's West Angelas mine in Australia.
- The vehicles used a truly huge: They are capable of hauling around 300 tonnes of material.

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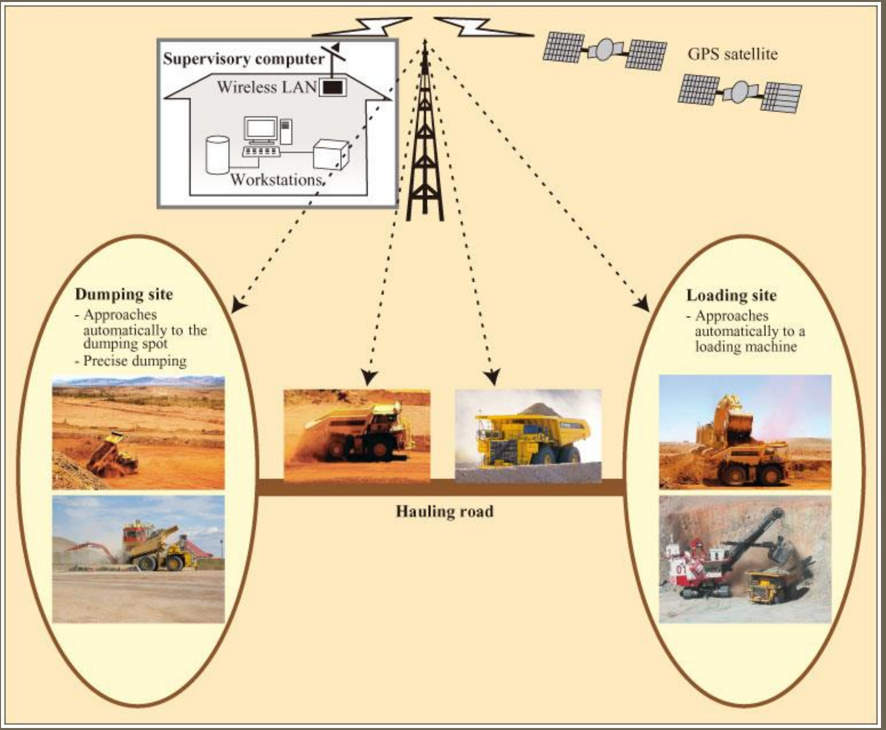
Autonomous vehicles: An example

- The dump trucks are autonomous and are monitored from a remote operations center.
- The trucks have motion controllers, a positioning system (using GPS), and are capable of obstacle avoidance. They are also equipped with a wireless network.
- Loading, navigating, and dumping all occur autonomously.
- A safety system prevents collisions with other trucks, as well as collisions with people.

Autonomous vehicles: An example



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Autonomous vehicles: An example

Our projects (with Volvo)

- Multivehicle path planning (2013-2015), continued 2015-2018
  - Autonomous construction vehicles (e.g. dumpers)
  - Dynamic multivehicle path planning, using AI-methods.
- Platooning (2014-2017):
  - Longitudinal control of road trains, using AI-methods.
- Autonomous work yards (-2017):
  - Driver-to-autonomous transformation at work yards.
- Image-based autonomus driving: (2015-2018):
  - Lateral control and positioning.

Overall description

- Most of our work concerns *artificial intelligence applied to the topic of autonomous vehicles*.
- We are more focused on high-level aspects (platooning, map generation, path planning, site management, obstacle avoidance etc.) rather than low-level vehicle control.
- We apply methods that are often inspired by biological systems, and that have (in some cases) been used earlier in robotics.
- In particular, we are interested in the biologically more plausible concept of *satisficing* (rather than error-minimization).

Satisficing vs. optimizing

- In classical control, one often formulates problems in the form of error minimization.
- For example, an autonomous vehicle might be steered in such as way as to minimize the difference between a pre-defined reference trajectory and the vehicle's actual trajectory.
- However, this is *not* the way humans steer a vehicle!
- Instead, a human driver will take action only when needed. Satisficing!

Multivehicle path planning

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Multivehicle path planning

- The project aims to develop a platform for autonomous vehicles. The demonstrator will be an autonomous dumper, hauling material between two points at a construction site.
- One of our tasks is to generate a multi-vehicle dynamic path planner for use in (for example) applications involving mines or construction sites.
- For this project (and other, related projects) we are writing a general-purpose simulator for autonomous vehicles.

Multivehicle path planning

- Then, in the next phase, a fleet of dumpers will be considered.
- The dumpers should be able to operate autonomously, but should also handle situations where some vehicles are driven by human drivers.
- The dumpers must not only navigate safely, but must also be able to reach their target (in order to deliver whatever they are carrying) at specific times.

Multivehicle path planning

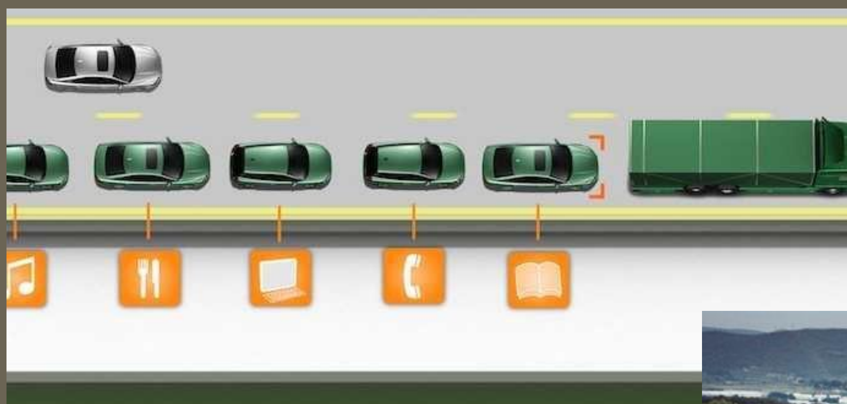
- Problem formulation:
  - Given a set of *N* vehicles, find a navigation algorithm such that vehicle i (v_i) will arrive at a target location at time t_i, without any collision with other vehicles, and with minimum fuel consumption.
  - The problem is dynamic, since (i) vehicles may deviate from their intended paths (so that recalculation is needed, (ii) vehicles may break down or encounter unforeseen obstacles, (iii) new vehicles may be added at any time, and (iv) new target locations are set whenever a target has been reached.

Multivehicle path planning

Platooning

- Platooning refers to a configuration of the form:
  - A lead vehicle following a given speed profile.
  - A set of followers that use a platooning algorithm to follow closely behind the vehicle in front.
- Aims:
  - Save fuel,
  - Increase efficiency,
  - Increase safety.

Platooning



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Platooning

- Platooning will have several advantages
  - Drag reduction => lower fuel consumption
  - Reduced road congestion
  - Possibility for drivers to carry out other tasks than driving!
- In our research, we consider platoons consisting only of trucks.

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Platooning

- Baseline case (standard platooning):
  - Lead vehicle uses cruise control (CC) with constant set speed.
  - Followers use adaptive cruise control (ACC), a well-defined algorithm for maintaining a certain gap to the truck in front.
- Research question:
  - Can one do better than CC + ACC from a fuel consumption perspective?

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Platooning

- Two research issues
  - Optimizing the speed profile for the lead truck.
  - Optimizing the platooning algorithms used by the followers.
- Both topics are considered in our research.
- Here, however, only the lead truck speed profile optimization will be presented.

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Platooning

- Our project is aimed at optimizing (truck) platoons over varying topographies (i.e. hilly roads).
- As a part of that project, we have considered speed profile optimization for (single) trucks.

Speed profile optimization for trucks

- The standard way of driving a truck is to use cruise control, in which the driver assigns a set speed that the vehicle then maintains.
- Problem: If the truck is driving over a hilly road (with many ups and downs) maintaining a constant set speed might not be optimal regarding fuel consumption.

Speed profile optimization for trucks

- The question, then, is whether one can find, for a given road, an optimal (varying) set speed, i.e. a speed profile.
- Method (assumes road profile available, e.g. from GPS)
  - Before starting the truck, run a simulated truck (with the same configuration as the real truck) over a certain distance (the next 10 km, say), and measure the fuel consumption.
  - Objective: Find the speed profile that minimizes fuel consumption.
  - Then, drive according to this profile while optimizing the next 10-km stretch etc.

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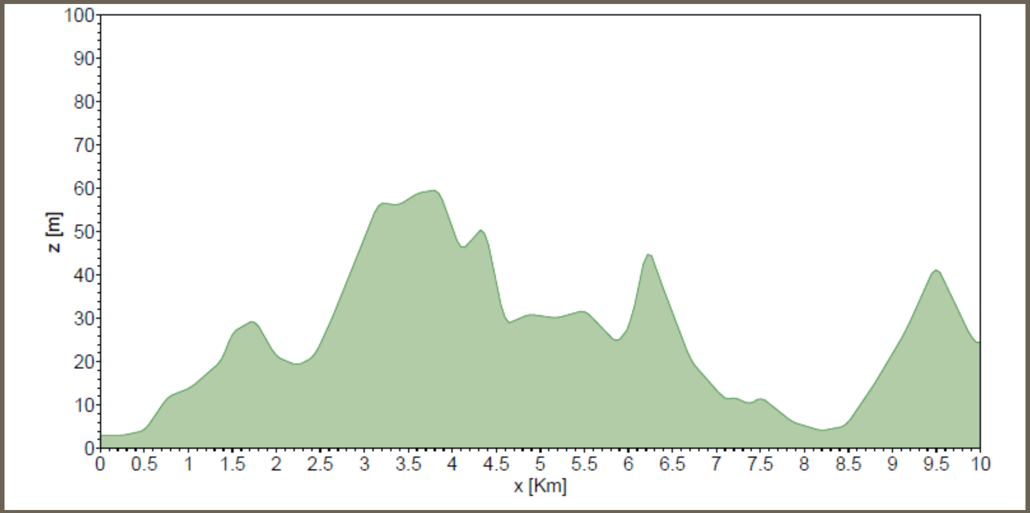
Road profile

- In this particular case, we generated a set of 10 km road profile from the E6 between Göteborg and Malmö.
- Example: (exaggerated a factor 100 on the y-axis)



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Truck model

- Longitudinal motion (essentially Newton’s second law):

$$m(G)\dot{v} = F_{\rm e} - F_{\rm b} - F_{\rm d} - F_{\rm r} - F_{\rm g}$$

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Truck model

- Air resistance equation:

$$F_{\mathrm{d}} = \frac{1}{2} c_D A \rho_a \Phi(d) v^2$$

- For a single vehicle (the case considered here), $\Phi = 1$.

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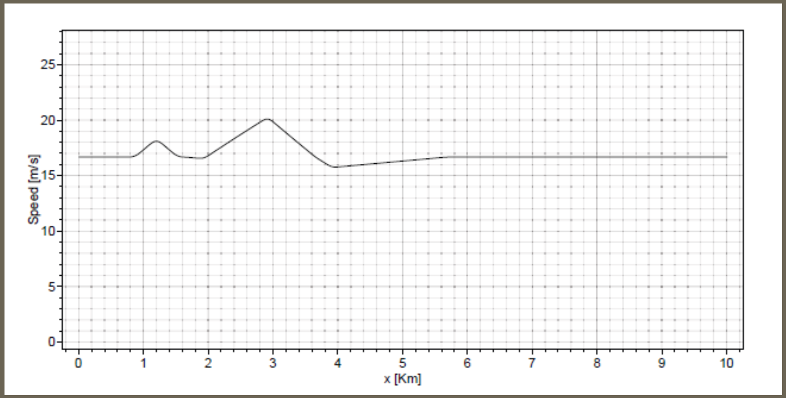
Optimization

- The speed profile was optimized using a simple GA
  - Starting from a flat speed profile (cruise control).
  - The speed profile was randomly tweaked (linear tweaking around a center point:



Optimization

- If better (lower fuel consumption), the new profile is kept.
- Otherwise, it is discarded, and a new profile (new tweaking) is generated.

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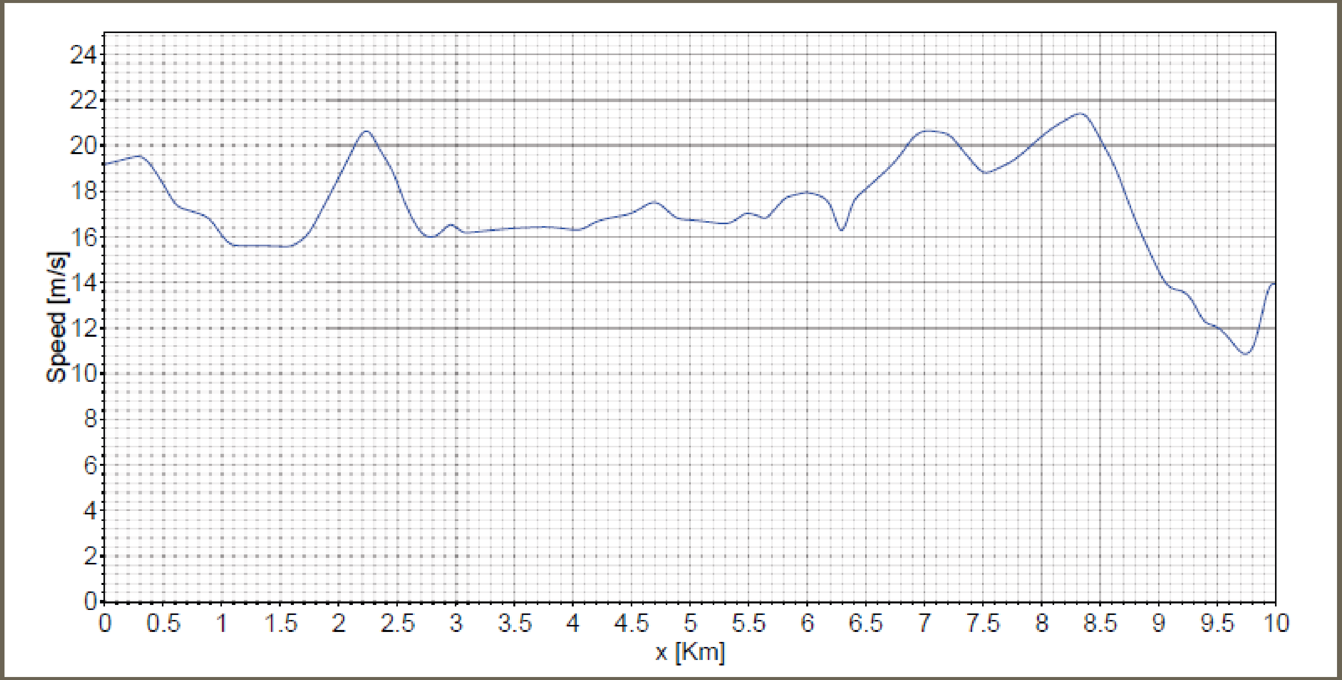
Results

- Final speed profile (example)



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Results

- The best optimized speed profile greatly reduce the fuel consumption of the trucks.
- Reductions range from around 12% to almost 20% (average 15.8%).
- The results are currently being implemented in real trucks.
- Further work on platooning algorithms is underway.

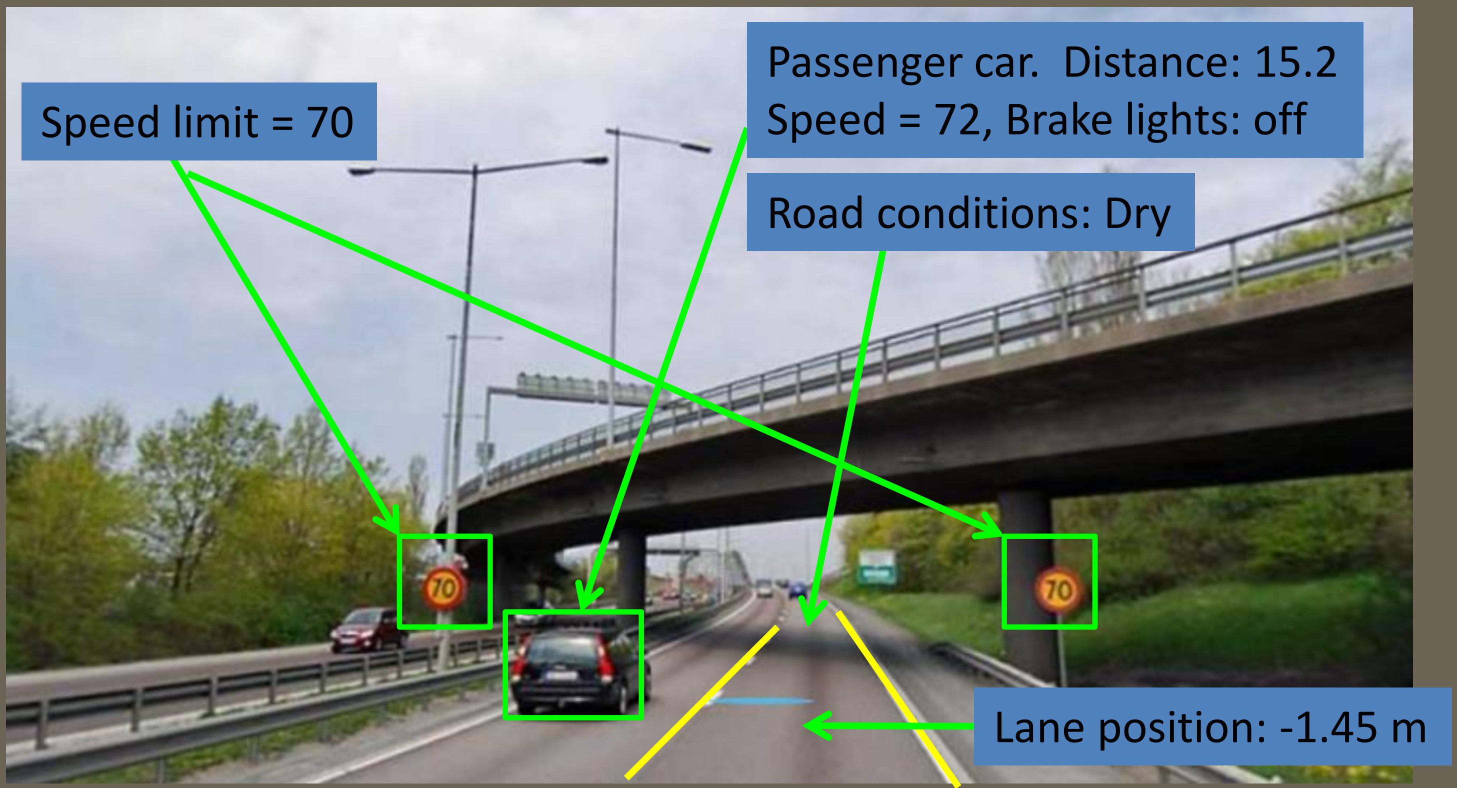
Work yards

- Project aimed at autonomous functionality (in trucks) at (for example) delivery sites and logistics centers.
- Our work involves positioning and mapping (using GPS, LRFs, vision etc.)

Image-based autonomous driving

- Project aimed at lateral vehicle control (for which the accuracy of (normal) GPS is insufficient).
- Our work will mostly involve robust (and very fast) image processing.
- Using image recognition for safe driving,
  - Requires (limited) scene interpretation,
  - Must handle various weather conditions etc.,
  - No shortage of data – unlimited amounts can be collected and stored.

Image-based autonomous driving



Intelligent software agents

- In addition to the vehicle projects, we are also involved in the development of intelligent software agents.
- An intelligent software agent is a computer program capable of rapidly acquiring and processing vast amounts of data, in order to provide either decision support for human users, or taking decisions autonomously.
- Such systems have many different applications in, for example, health care and finance (and many other fields).

Intelligent software agents

- We are currently working on two kinds of software agents:
  - Partner agents for elderly care (and for helping the visually impaired)
  - Financial agents (for decision support during trading).

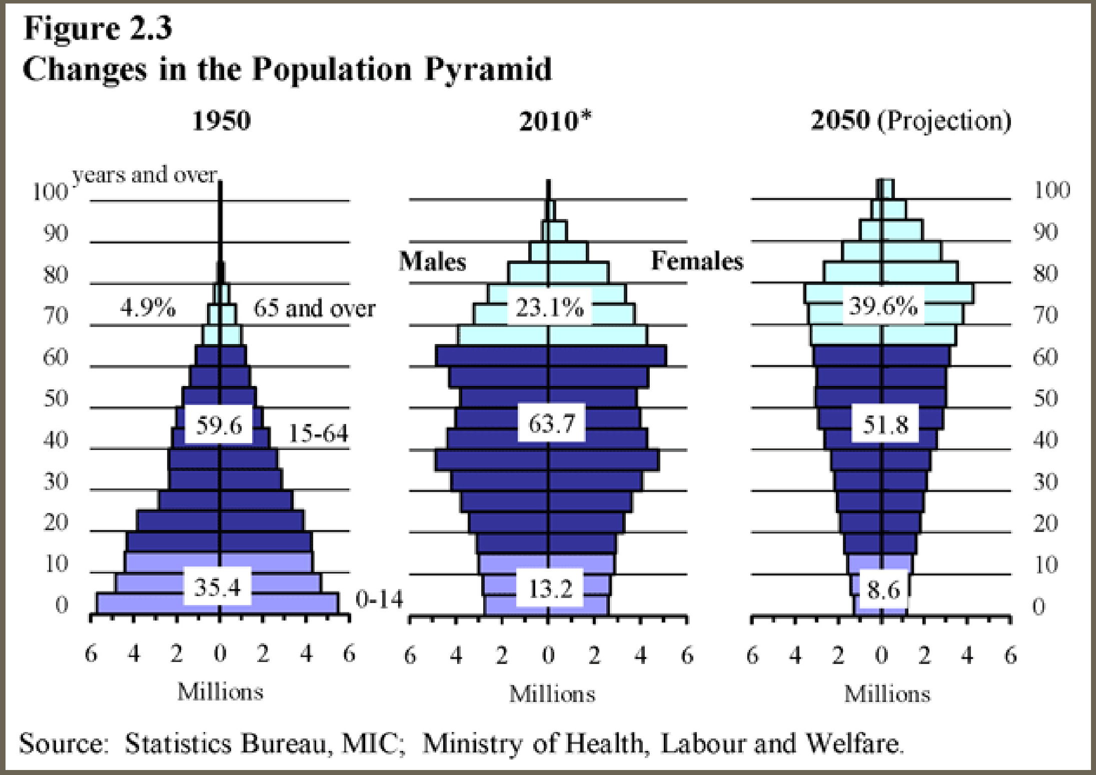
Intelligent software agents

- The aim is to develop agents with (among other things)...
  - ... natural means of communication (touch, voice, gestures)
  - ... realistic dialogue capabilities (within limits),
  - ... rapid processing and compilation of large amounts of data,
  - ... artificial emotions (e.g. empathy).

Intelligent agents in elderly care

- The fraction of elderly people in the population increases rapidly in the developed world.
- For example, in the EU, the fraction of people aged 65 and over is expected to increase from around 17% (2010) to 30% in 2060.
- The fraction of people aged *80* and above is expected to increase from 5% (2010) to 12% (2060).

Intelligent agents in elderly care



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Intelligent agents in elderly care

- Great pressure on the health care system, in the form of rapidly rising costs and staff shortages.
- Many of these problems can be solved, at least partially, using technology, for example partner robots, partner agents, and smart homes.

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Intelligent agents in elderly care

- When using partner agents in elderly care, one must take into account that the users typically...
  - ...have very little experience of computers and smart phones.
  - ...may have various physical impairments (visual, for example).
  - ...expect to be able to interact with the agent in a very natural way.

Intelligent agents in elderly care

- Thus, one must design the systems carefully, i.e. with...
  - ...a strong degree of robustness
  - ...various natural modes of interaction
  - ...efficient error handling – easily finding one's way back after getting lost in a dialogue etc.

Intelligent agents in elderly care

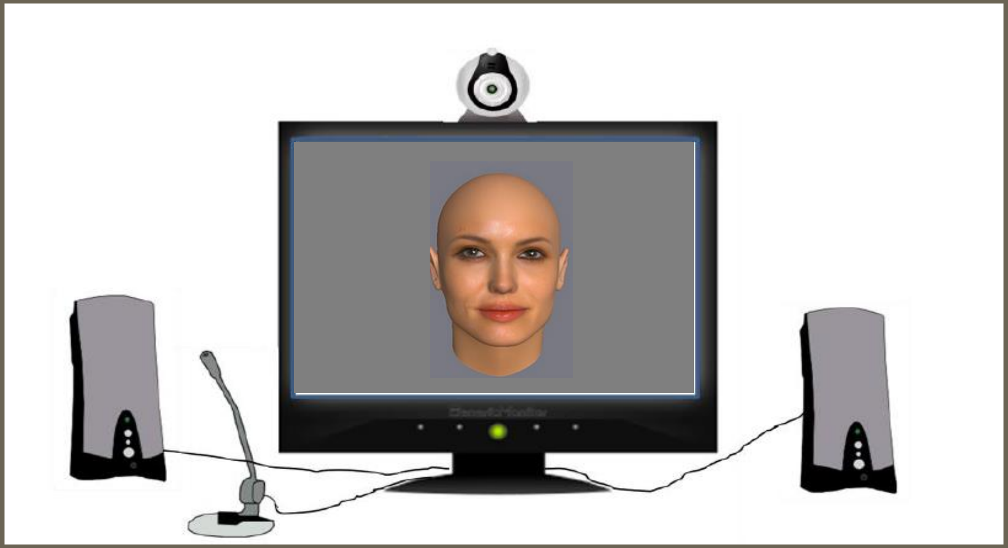
- Even though a lot of work is being done on robots in various health care applications, in some applications, particularly those that are focused on human-machine interaction, it is not always necessary to have a *mobile* robot.
- Furthermore, it might be difficult to capture some aspects of behavior (e.g. facial expressions) in a robot.
- An alternative is to use a partner agent, i.e. an animated face on the screen.

Intelligent agents in elderly care

- We first developed a robotic head…
- …but found that the users (elderly people) found its facial expressions to be too limited.

Intelligent agents in elderly care

- We have therefore switched to using an intelligent software agent, including a face shown on a screen:



Intelligent agents in elderly care

- The project involves many aspects of applied artificial intelligence, e.g. speech recognition, speech synthesis, dialogue modelling, decision-making, image processing, gesture detection, facial expression detection etc. etc.
- One of the most difficult aspects is to generate a (non-annoying and natural) system for human-machine dialogue.

Example 1: Gesture recognition

- Consists of several parts:
  - (dynamic) subtraction of the background
  - Identification of limbs (arms, hands, fingers...)
  - Detection of the actual gesture (either static or dynamic).
- In the first version, we implemented simple gesture recognition using a standard web camera.
- Currently, a method based on a Kinect (depth) camera is being developed, which is capable of handling dynamic gestures.

Example 1: Gesture recognition

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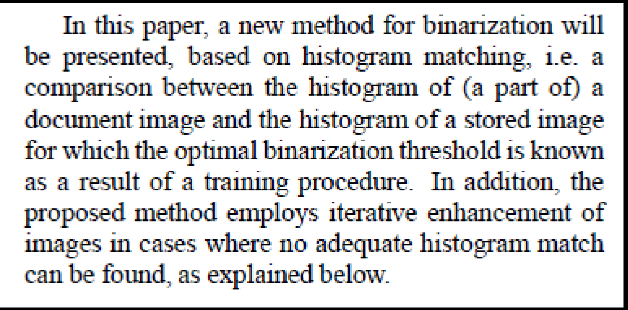
Example 2: Reading text in images

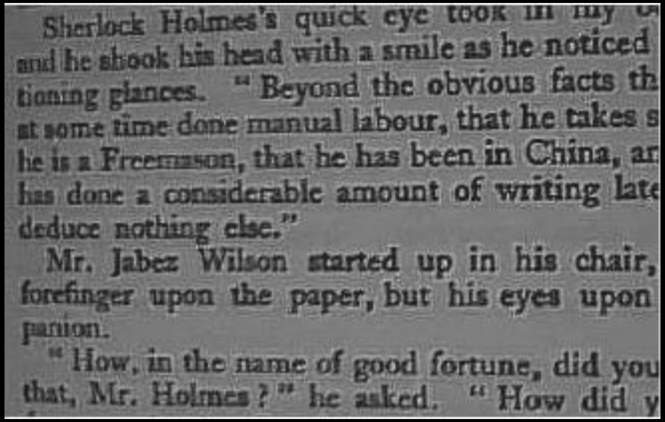
- Text extraction from images has many different applications, for example
  - ...helping the visually impaired to read signs, letters etc.
  - ...reading license plates on vehicles.
  - ...reading labels (on groceries, for example).
- The problem can be considered on different levels ranging from optical character recognition (OCR) of scanned, typed text (easiest) to completely general text extraction from an arbitrary image (difficult).
- An important intermediate case: reading text from a letter (or similar) held in front of a camera.

Example 2: Reading text in images



In this paper, a new method for binarization will be presented, based on histogram matching, i.e. a comparison between the histogram of (a part of) a document image and the histogram of a stored image for which the optimal binarization threshold is known as a result of a training procedure. In addition, the proposed method employs iterative enhancement of images in cases where no adequate histogram match can be found, as explained below.

In this paper, a new method ... etc.



Sherlock Holmes's quick eye took in my o
and he shook his head with a smile as he noticed
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has done a considerable amount of writing late
deduce nothing else."
Mr. Jabez Wilson started up in his chair,
forefinger upon the paper, but his eyes upon
panion.
"How, in the name of good fortune, did you
that, Mr. Holmes?" he asked. "How did y

Sherlock Holmes's quick eye...

King's Cross 10
SCANIA

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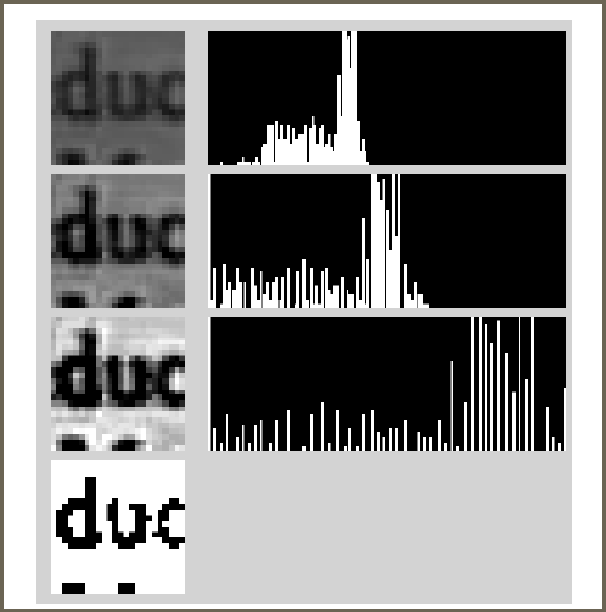
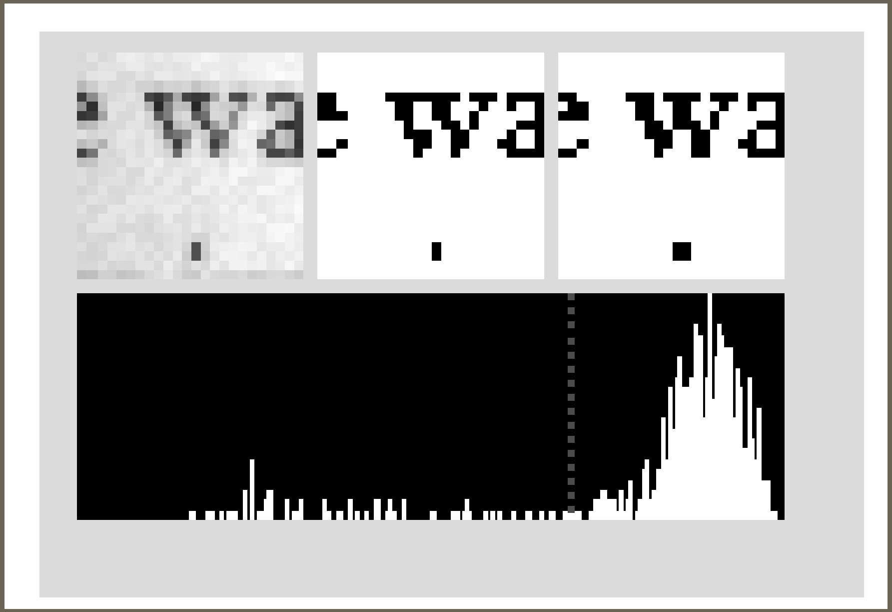
Example 2: Reading text in images

- We developed a robust method for extracting textual information from a poor-quality web camera image.

Example 2: Reading text in images

Table 2: A comparison of the average binarization performance, measured as the PSNR value obtained when comparing the binarized image generated from the binarizer to the corresponding noise-free image.

Method	Average PSNR
Otsu	6.457
Niblack	8.027
Sauvola	13.72
Proposed method	14.41

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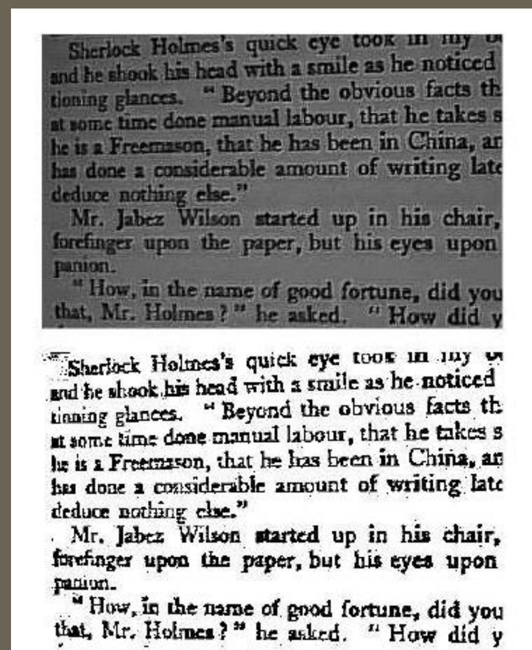
Example 2: Reading text in images

- Proposed method applied to actual (live) camera image: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Today's learning goals

- After this lecture you should be able to
  - Exemplify and describe some applications of autonomous systems (robots and vehicles) ✓

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