Robotics

The future of robotics

@ G. Gini 2014
robots

Remote

*Teleoperation*: extends the reach of the human hand to remote, hazardous, unreachable environments

Virtual

*Simulation*: enables humans to touch geometric and dynamic computer-based data and models

Real

*Autonomous Robot*: independently explores and manipulates real objects to accomplish tasks
Do we need interdisciplinarity?

This is an interdisciplinary program in which physics students try to hit psychology students with pendulums. Promising!

My professors had an ongoing competition to get the weirdest thing taken seriously under the label "interdisciplinary program."
• **The market**
• Robots for the internet
• Robot games
• Robots as appliances
• Robots for personal mobility
• Robots for body repair
• …
About 16,400 **service robots** for professional use were sold in 2011. The sales value increased by 6%.

**Main applications: Defence and milking robots**

With about 6,600, service robots in defence applications accounted for 40% of the total number of service robots for professional use sold in 2011.

Unmanned aerial vehicles seem to be the most important application as their sales increased by 11% to more than 5,000 units. The value of defence robots was about US$ 748 million, 3% higher than in 2010.

The total number of field robots - mainly milking robots - sold in 2011 was about 5,000 units, accounting for a share of 31% of the total unit supply of professional service robots.
Considerable growth potential of logistic systems and medical robots

About 2,100 logistic systems (logistic systems, which were mainly automated guided vehicles for factories) were installed in 2011, 3% less than in 2010, accounting for 13% of the total sales of professional service robots.

Sales of medical robots increased by 13% compared to 2010 to 1,051 units in 2011. The most important applications are robot assisted surgery and therapy. Other professional service robots with lower units sales are construction and demolition systems, robots for professional cleaning, inspection and maintenance systems, rescue and security robots, mobile robot platforms and underwater systems. Underwater systems are among the most valuable professional service robots with a unit price of about US$ 850,000.
• **About 2.5 million service robots for personal and domestic sold in 2011**
  • mainly in the areas of domestic (household) robots, which include vacuum and floor cleaning, lawn-mowing robots, and entertainment and leisure robots, including toy robots, hobby systems, education and research.
  • In 2011, it was estimated that 1.7 million domestic robots were sold. As for entertainment robots, about 841,000 units were counted in 2011, 12% more than in 2010. The total value of the 2011 sales of entertainment robots amounted to US$ 166 million.
  • It is estimated that about 15.6 million units of service robots for personal use will be sold between 2012 and 2015.

• **Handicap assistance robots have not taken off to the anticipated degree**
  • Robots for handicap assistance aim to help people who have a disability with everyday activities or to provide therapy in order to improve physical or cognitive function.
Frito-Lay and Wynright Put Robots on the Docks

• “While much of the warehouse has benefitted from automation, the loading dock is still primarily a manual operation”

• Wynright produced its Robot Truck Loader (2011) and more recently its Robot Truck Unloader.

• The machine is an arm over a wheeled base. It can automatically scan barcodes.

• It is slower than humans but an operator can supervise 3 of them, boosting case loading rates from 500 cases per labor-hour to over 1,100.

• Important for the huge deliveries from the internet market
Robot surgeon

- Da Vinci system – artery bypass, laparoscopy, …
- more than 1.5 million surgeries performed globally
- As of March 31, 2012 a total of 1957 da Vinci Surgical Systems were installed in the United States
- A da Vinci Surgical System costs between $1 million and $2.3 million and more than $100,000 a year to maintain
Home cleaning

- Vacuum cleaning
- Pool cleaning
- Lawn mower
During the wars in Iraq and Afghanistan, the U.S. Army spent more than $730 million on unmanned ground systems that conducted missions such as bomb disposal and detection, route clearance and reconnaissance.
NASA on Mars
• Moon – Lunabotic mining competition - mine resources on Asteroids as well as Mars
- The market
- **Robots for the internet**
- Robot games
- Robots as appliances
- Robots for personal mobility
- Robots for body repair
- …
Internet of things

- Intelligent sensors and actuators in the internet (IP protocol)

- More objects are becoming embedded with sensors and gaining the ability to communicate. The resulting information networks promise to create new business, improve business processes, and reduce costs and risks

- M. Chui, M. Loffler, R. Roberts 2010
Information and analysis

1. Tracking behavior
   Monitoring the behavior of persons, things, or data through space and time.
   Examples:
   - Presence-based advertising and payments based on locations of consumers
   - Inventory and supply chain monitoring and management

2. Enhanced situational awareness
   Achieving real-time awareness of the physical environment.
   Example:
   - Sniper detection using direction of sound to locate shooters

3. Sensor-driven decision analytics
   Assisting human decision making through deep analysis and data visualization
   Examples:
   - Oil field site planning with 3D visualization and simulation
   - Continuous monitoring of chronic diseases to help doctors determine best treatments
Automation and control

1. Process optimization
   Automated control of closed (self-contained) systems
   Examples:
   - Maximization of lime kiln throughput via wireless sensors
   - Continuous, precise adjustments in manufacturing lines

2. Optimized resource consumption
   Control of consumption to optimize resource use across network
   Examples:
   - Smart meters and energy grids that match loads and generation capacity in order to lower costs
   - Data-center management to optimize energy, storage, and processor utilization

3. Complex autonomous systems
   Automated control in open environments with great uncertainty
   Examples:
   - Collision avoidance systems to sense objects and automatically apply brake
   - Clean up of hazardous materials through the use of swarms of robots
SENSORPEDIA

- (http://www.sensorpedia.com)
- initiated by Oak Ridge National Laboratory to utilize Web 2.0 social networking principles to organize and provide access to online sensor network data and related data.
  - Sensorpedia networks users based on mutual information interests.
- Sensorpedia is a Web-based application consisting of 2 parts:
  - 1. a Google Maps interface where users can search and explore published sensor data.
  - 2. Architecture that supports it
• The Sensorpedia API uses Web services designed to accept and publish data using established standards (AtomSyndicationFormat and GeoRSS).

Sensorpedia also relies on open data portability standards (OpenSocial, OpenID, and OAuth) to ensure current and future interoperability with other Web-based software applications.
Smart sensors

- Most commercially available sensor networks today are based on proprietary communications protocols.
- **IEEE 1451.4** marks a huge advance:
- All parameters needed for measurement and validation are “local” to the sensor.
  - The heart of 1451.4 is the use of a ROM chip embedded in the analog sensor that stores the sensor's electronic data sheet, as well as information identifying the sensor.
  - When hooked up to a 1451.4-enabled data acquisition system, the ROM chip transmits the data to the system.
- It offers a standard interface and protocol by which a sensor can describe itself over a network.
Robots on the internet

• Integrating robotic applications with Internetscale sensor networks

Telegarden, Gratz, 2004

Distributed robotic garden, MIT
Based on the Gibsonian principle of defining objects by their function, "affordances" have been studied extensively by psychologists and visual perception researchers, resulting in the creation of numerous cognitive models.

AfNet (theaffordances.net).
AfNet uses three types of affordance features. Structural and material together form functional affordances. While structural affordances hold the key to object class recognition in visual perception systems, material and semantic affordances accelerate recognition.

- Structural affordance corresponds to inferred knowledge about the 2D/3D shape of the object.
  - For example, detection of a cylindrical or circular shape indicates a 'Roll-ability' affordance.

- Material affordance corresponds to deduced knowledge about the material properties of an object based on the local visual features.
  - A good example is the shiny color of a metallic object which results in an inference of high strength and 'dur-ability' of the object.

- Semantic affordances define the Subject-Object relationships for functional affordances.
- The current ontology contains 25 structural and 10 material
• An example for affordance features is the 'Contain-ability' structural affordance feature. This feature is exhibited by objects that provide the functional ability to contain a solid or liquid within its geometry.

• AfNet describes unique geometric mappings for each affordance feature. Contain-ability is defined using geometric mapping of 'high convexity'. Mugs, cups, beakers, bowls, bags and pots exhibit this functional affordance and hence form a 'Conceptual Equivalence Class'.
example

- Distributed robotic garden (MIT)
- iRobot Create mobile base, a CrustCrawler4-DOF robotic arm and gripper with force feedback sensor, a LynxMotion servo control board, a Logitech Webcam, a water storage system and pump, and an Intel Duo notebook.
- The robot should execute watering, estimating plant status, cleaning
- The pots serve the plant as an interface to the robots by providing additional sensing (humidity), actuation (turning on an infrared beacon), and storing data about the life cycle of the plant
- The market
- Robots for the internet
- **Robot games**
- Robots as appliances
- Robots for personal mobility
- Robots for body repair
- …
• Games can open the road to more demanding solutions.
• Example: the kinect is now used in most of the robotics research systems
• New gadgets hitting the market …
Takara Tomy is introducing AutoMee, a $20 smartphone and tablet-cleaning robot. Recognizing edges, AutoMee just keeps spinning and rotating around the surface and has a lens-cleaning paper on its underside to enable cleaning.
Using three powerful servos driving three replaceable bristle brushes, the Grillbot can navigate all over the grill scrubbing as it goes and regulating it's speed and direction. Grillbots will be available early summer for $70.
Desk Pets has added Tankbots to their line of inexpensive robotic-like toys. The $30 Tankbot can navigate mazes, avoid obstacles and be remotely controlled with a smartphone or tablet.
SmartLab Toys has released ReCon 6, a programmable rover selling for $70. It can be programmed to fetch items and speak recorded messages. It's intended to be an instructional device for kids to learn programming.
sphero

- A robot ball dog resistant and water resistant
- You control it from smartphone
- Sphero is releasing an augmented reality application. Instead of the ball being a ball, it comes to life as a beaver named Sharky. The ball costs $130 and the app is free.
index

- Robots for the internet
- Robot games
- **Robots as appliances**
- Robots for personal mobility
- Robots for body repair
- …
Position and orientation using camera phones

- Indoor environment
  - No available signals, **only rely on images**
  - Eventually wifi
- Outdoor environment
  - GPS signal
  - Rely on a set of geotagged photos
Case 1: Indoor


- Use images to find landmarks
- Find the camera pose through matching landmarks to given maps
  - A building server holds map and makes computation, the client communicates wifi
- Take image, extract features (SIFT), estimate location, find correspondence between image features and the map (RANSAC, 2 sec), compute the camera position and orientation, display the result
- Use wifi location to prune the search
steps

- Entire cycle: 10 s
- Error under 30 cm
Case 2: Outdoor


Use an online collection of geotagged photos collected using mobile phones
  - Each image has location GPS, viewing direction, and name of landmark

- Automatically solve camera orientation and correct poor GPS readings using vision
- Rank landmarks by popularity and images by salience
- Cluster images with views of the landmark
- Rasterize the world in grid cells of 30x30 meters georeferenced (loixel)
Orientation

• Using magnetic compass and tilt sensors find the real orientation of the device
  ▪ 2-axis tilt measures pitch and roll

• When the user points to an object in the world, the phone transmits the position and orientation sensors reading to the server that identifies the area of interest

• accepted error are: 1 m for GPS, 1° for angle

• 3D GIS
The user indicates a path
- Loxelize the path
- Determine visible landmarks in a 3x3 loxels area
- Select a cluster
- Find best cluster for vicinity to the path, and best cluster according to alignment to the direction of motion
- Print arrow on the map
1. Keep walking straight, Gates Hall will be to your front left

2. Turn right here, Gilbert Hall will then be to your front left

3. Keep walking straight, past Gilbert Hall to your left

4. Keep walking straight, past Herrin Labs to your left

11. Keep walking straight, past Main Quad Math Corner to your left

12. Keep walking straight, toward West Gate

13. Keep walking straight, into West Gate

14. Keep walking straight, Hoover Tower is in the distance
• The market
• Robots for the internet
• Robot games
• Robots as appliances
• **Robots for personal mobility**
• Robots for body repair
• …
Self driving cars

- The robotic vehicle Stanley from Stanford University won the 2005 DARPA Grand Challenge
- Google is developing the self driving car
- permitting the operation of driverless cars in Nevada, Florida and then California
Personal mobility

• Honda – wearable assisted walking gadget - to support bodyweight, reduce stress on the knees. To be used by workers in auto factories

U3-X
Mobility in town
• The market
• Robots for the internet
• Robot games
• Robots as appliances
• Robots for personal mobility
• Robots for body repair
• …
exoskeletons

- Robot therapist
- Body support
Prosthesis – lower limbs

• Active prosthesis

“I imagine a future so advanced that we could rid the world of disability.”

Hugh Herr
Prosthesis – upper limbs

- Estetic prosthesis
- Active prosthesis
- Many problems for upper limb
Personal assistance and help

• Home assistance (dressing, food preparation, eating, moving around…)
• - the available solutions are few and with reduced capabilities
• Care centers – monitoring (only in NY state in 10 years more than 1000 deaths from accidents as drowning and suffocation)
• - the available solutions can be better used
Up to present day... what happened?

- 2006 Minsky complained:
  - central problems, like commonsense reasoning, neglected
  - majority of researchers pursued commercial applications
    - e.g. commercial applications of neural nets or genetic algorithms

"So the question is why we didn't get HAL in 2001?

I think the answer is I believe we could have"