From Teleoperators to Robots

Development of machines and interfaces
Teleoperation

History and applications
Definition

- **Teleoperation** means simply to operate a vehicle or a system over a distance.
- Distance can vary from tens of centimeters (micro manipulation) to millions of kilometers (space applications).
The 1\textsuperscript{st} mobile machines without human onboard were teleoperators \rightarrow the first pre-stage of a robot

How to control a vehicle over a distance?

Phased development from mechanical manipulation to high level supervisory control

Today both closed loop teleoperation and high level communication are needed
Robot teleoperation

- Basically every mobile robot is a teleoperated machine and most of the teleoperated machines are mobile robots, only level of autonomy varies
- → Robot HMI = teleoperation interface
- Fully autonomous robots ??
Forestry Man & Washing Harvester

Man & Horse Harvester

Man & Tractor Harvester

Wheel Track Based Harvester

Time:

- 1950
- 1970
- 2010

Automation/Intelligence

Autonomous forestry worksite

Autonomous thinning and brushing robot societies

Remote operated multi-machine forest harvesting worksite

Autonomous for warder

Teleoperated wheel track or leg based harvester

Wheel Rack Based Harvester

FC

Re
The earliest type of teleoperation?
What is the difference between using a tool and teleoperation (remote manipulation)?
Tool or Teleoperation

- Tool – to improve the work task, to make something possible
- Teleoperation – to avoid hostile environment, usually neither the quality nor the efficiency of the work is improved
Development

- manipulation
- vehicle (submarine) control
- space
- Semiautonomous vehicles
- “Autonomous” vehicles (no closed loop teleoperation needed)
### Terminology

- **Teleoperation**: to operate a vehicle or a system over a distance

- **Operator**: human operator is the person who monitors the operated machine and makes the needed control actions

- **Teleoperator**: is the teleoperated machine. A sophisticated teleoperator can also be called as *telerobot*

- In *supervisory control* remarkable part of the control is delegated to the teleoperator end (compare coordinated teleoperation)
Terminology

- **Robot**: Any automatically operated machine that replaces human effort, though it may not resemble human beings in appearance or perform functions in a humanlike manner. The term is derived from the Czech word *robota*, meaning “forced labor.” [Encyclopedia Britannica]
Definitions

- Mechanical manipulation
  - The control commands are transmitted mechanically or hydraulically to the teleoperator. Visual feedback can be straight or via monitor.
  - This is typical for manipulation of dangerous materials as well as micro manipulation
Definitions

- Remote operation/control:
  - The operator has most of the time straight visual contact to the controlled target. Control commands are send electrically by wire or radio
Definitions

- “Normal or standard teleoperation”
  - Wireless control and visual feedback via camera – monitor system
Definitions

- **Closed loop control (Direct teleoperation):** The operator controls the actuators of the teleoperator by direct (analog) signals and gets real-time feedback. This is possible only when the delays in the control loop are minimal.

- **Coordinated teleoperation:** The operator again controls the actuators, but now there is some internal control - remote loop - included. However, there is no autonomy included in the remote end. The remote loops are used only to close those control loops that the operator is unable to control because of the delay.
Example: Arska

- Commercial ATV
- Servo actuators in
  - throttle
  - steering
  - brake
  - gear
- Computer control
- Teleoperation over radio modem
- Today all control via computer!!!
In *supervisory control* [Sheridan, 1992], the remarkable part of the control is to be found in the teleoperator end (compare coordinated teleoperation). The teleoperator can now perform part of the tasks more or less autonomously, while the operator mainly monitors and gives high-level commands. The term *task based teleoperation* is sometimes used here, but it is more limited than "supervisory control".
Closed loop/Supervisory control
History

- The first *modern* master-slave teleoperators were mechanical pantographs.
- These manipulators were developed by the group of R. Goertz in the late 1940s at the Argonne National Laboratory where Enrico Fermi developed the first nuclear reactor.
History

- The mechanical manipulators were soon replaced by electro mechanical servos.
- In 1954 Goertz’s team developed the first electro mechanical manipulator with feedback servo control.
- After this the teleoperation of manipulators and vehicles spread out rapidly to new branches where advantages of teleoperation techniques could be utilized.
Applications

- Submarines (ROV)
Applications

- Space
  - Perfect for teleoperation: safety and costs
  - Problem very long delay => “move and wait”
Applications

- Military
  - underwater
  - ground
  - air
  - semiautonomous / closed loop control

- Anti terrorist
  - typically closed loop control
Applications

- Medical
  - Endoscopic surgery
    - ~ (micro) mechanical manipulation (is this teleoperation??)
    - minimal damage, smaller risks
  - Telesurgery
    - Specialists can operate over distances
Applications

- Industrial – Mining
  - Resque operations
  - Mining in unsafe areas
Industrial applications

- Why to teleoperate if there is no danger??
- Semiautonomous work machines with part time teleoperation!!
- All possible work is done autonomously
- Difficult tasks and exceptions are teleoperated
- This will be the future!!
Technology

- Mechanical manipulators, (good feedback)
- Electrical servos – TV, (closed loop)
- Radio control – Video, (closed loop, supervisory)
Problems

- Video transmission
  - Big amount of data
  - Need for digital transmission
  - Delay, delay, delay, delay, delay, ...

- Control transmission
  - Fast response for control actions
  - Delay, delay, delay, delay, delay, delay, ...
DELAY

- signal speed max. 300 000km/s
- Shannon theory: measuring frequency > 2 x system frequency
- In practise (mobile machines) < 0,1s => perfect, < 0,5s = > easy
- In long delay systems “move and wait” task based teleoperation
Delay

- There are always delays in a teleoperation loop
- Every part of the system has some delays
- Digital systems increased the delay
Long delay teleoperation

- No possibilities for closed loop control
- because of the mission it’s difficult to increase the autonomy
- => move and wait teleoperation
- models of robot and environment, operator loop in control → “operator loop”