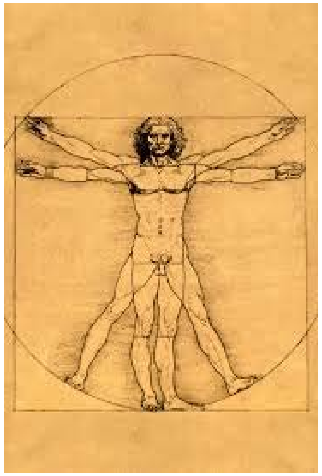
WB2306 The Human Controller
Class 1. General Introduction



"Adapt the device to the human, not the human to the device!"

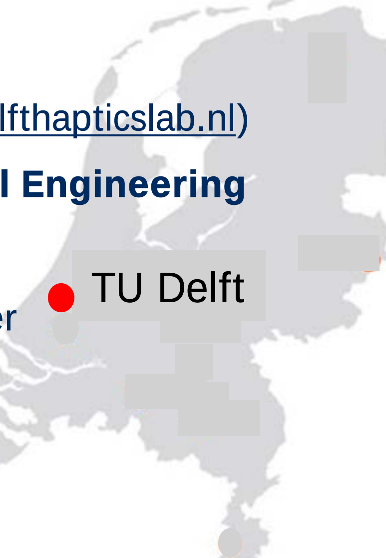
Teacher:

- David ABBINK
- Assistant professor at Delft Haptics Lab (www.delfthapticslab.nl)
- BioMechanical Engineering, Delft University of Technology, The Netherlands
- d.a.abbink@tudelft.nl

Personal Background

Lecturer

- David Abbink, PhD - Assistant Professor at Delft Haptics Lab (www.delfthapticslab.nl)
- **Delft University of Technology, Faculty of 3mE, BioMechanical Engineering**



Team includes:

Mark Mulder, Rene van Paassen, Erwin Boer

prof. Max Mulder, prof. Frans van der Helm

5 PhDs, 3-5 master students/year

Industrial Partners

Nissan (2002 – present), Boeing (2007 – present), several Dutch companies

Academic Partners (joint research, publications, exchange students)

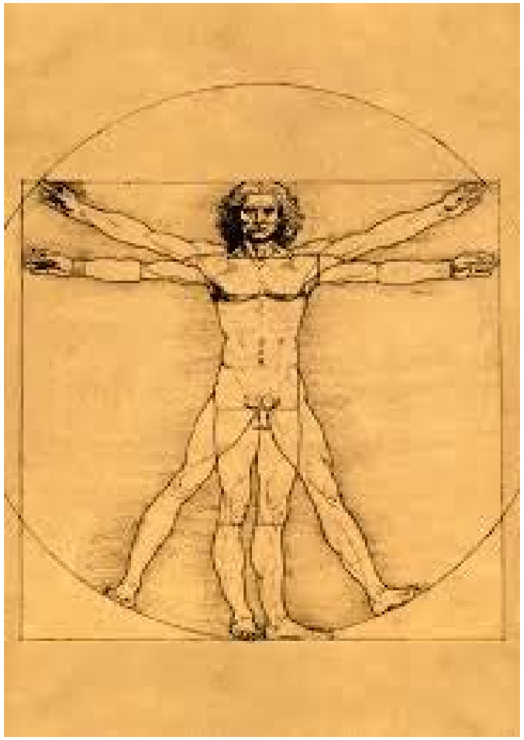
Erwin Boer (EC inc.), Frank Flemisch (DLR), Ken Goodrich (NASA), Max Planck Institute

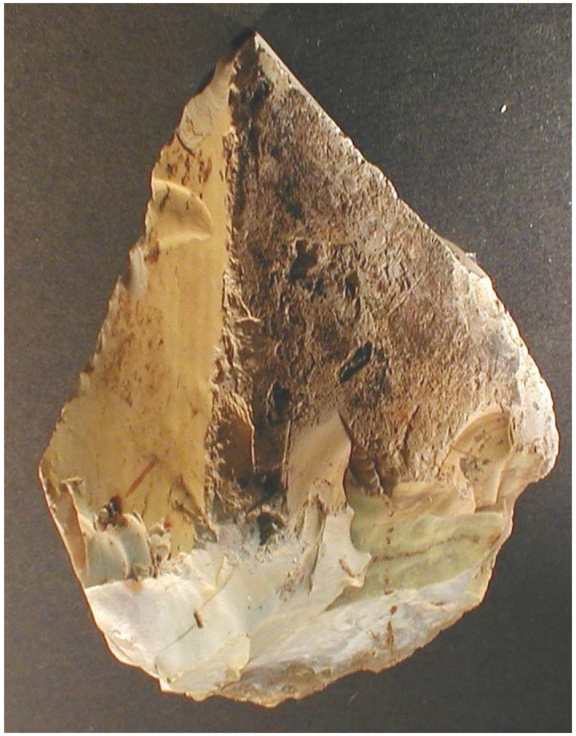
University of Tokyo, Kobe University, Leiden University, NorthWestern University

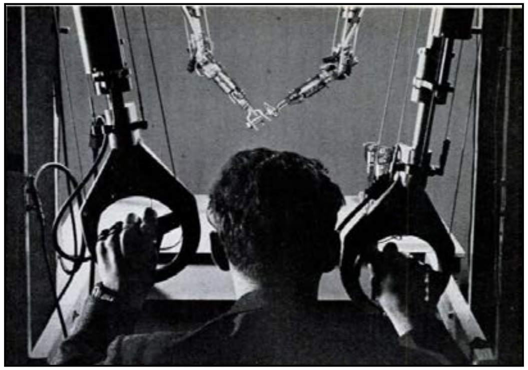
Research interests: human factors, haptics, driver support systems, neuromuscular control

What is this class about?

Humans and the tools they make





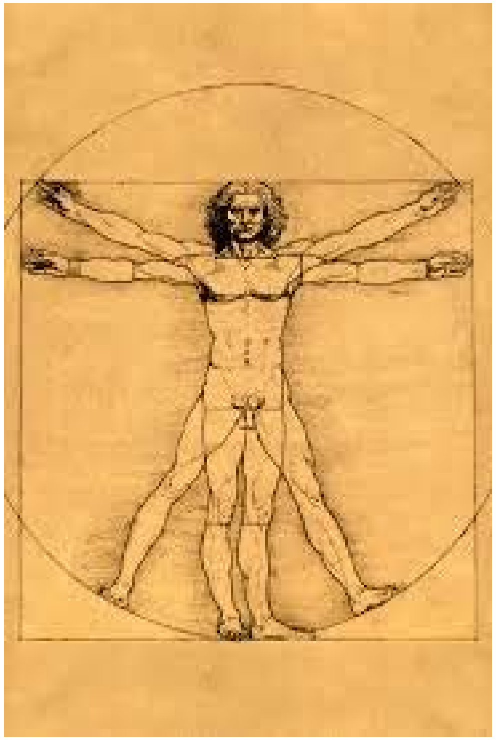


You will learn about:

1. **Human (manual) control behavior**
   "Perception-action couplings"

2. **State-of-the art methods to measure and model human control behaviour capabilities and limitations**

3. **How to use this knowledge when evaluating human-machine interaction**
   Practical assignments for driving and telemanipulated control



After this class you can:

Reproduce important concepts
on the physiology behind human perception, cognition and action

Apply existing techniques to measure and model human behavior when interacting with vehicles or tools

- apply McRuer's crossover model to a simple manual control task, and reflect on the pro's and con's of this modeling approach
- reflect on the balance between an operator's performance of a task and the control effort to realize that performance; and measure/model such interaction

Critically reflect

- on different ways to measure and model human behavior
- on different roles of humans when interacting with machines
- on short term vs long term effects of support systems
- on how knowledge of human behavior help design of new human-machine interfaces

General Information

Coordinator: David Abbink

- E-mail: D.A.Abbink@tudelft.nl

Course Information (see schedule on blackboard)

- Check Blackboard regularly for updates & announcements!!

Assessment and Examination

- Written exam on July 1 2014, re-exam in August 2014
- 30% of the grade is from three practical assignments

For OpenCourseWare Students

- only one practical assignment possible, no online support available!

Motivation for this class

Two types of motivation

Humans controlling technical systems:

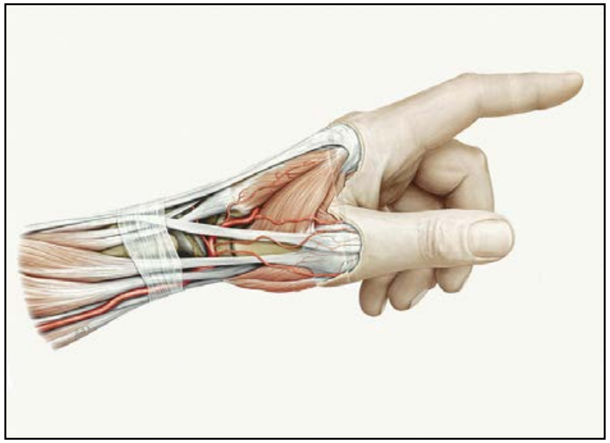
- Curiosity: How do humans control them?
- Engineering: How can we make this better?

Planes

Cars

Robots

Own Limbs



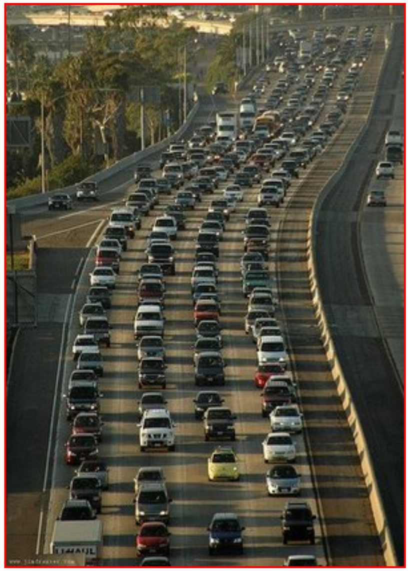
Why is this class necessary?

To engineer good human-machine interaction is

difficult, but essential

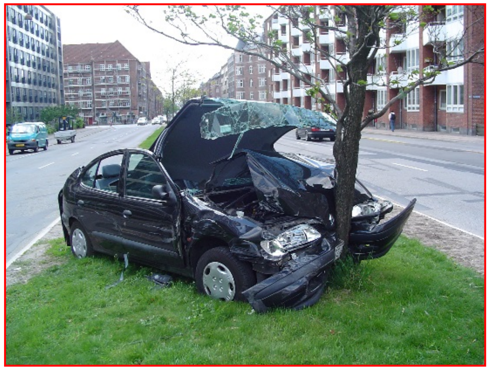
to deal with challenges of the near future!!

Why important? – an example



Road Congestion

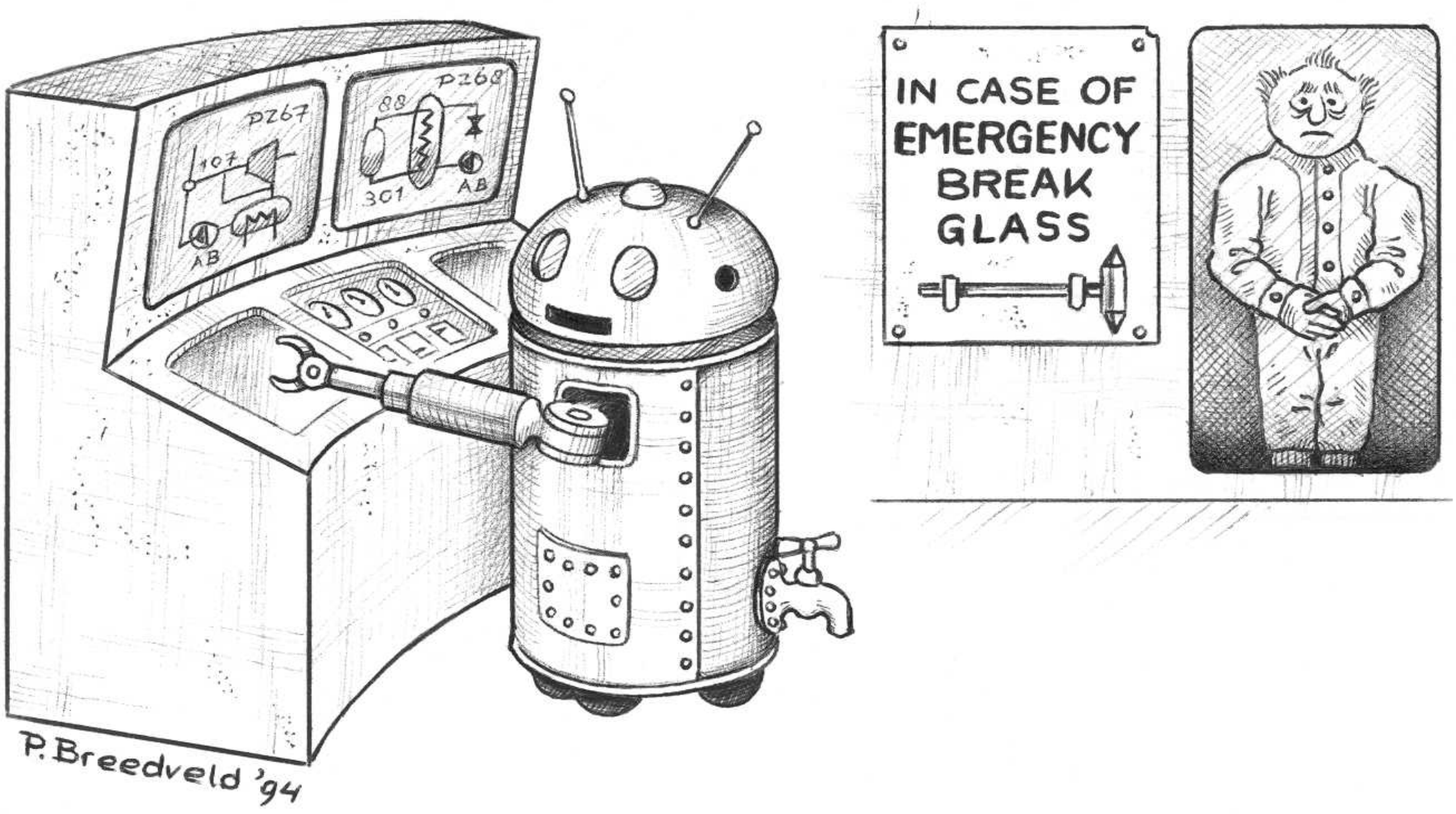
- EU cost: €50 billion / year



Road accidents

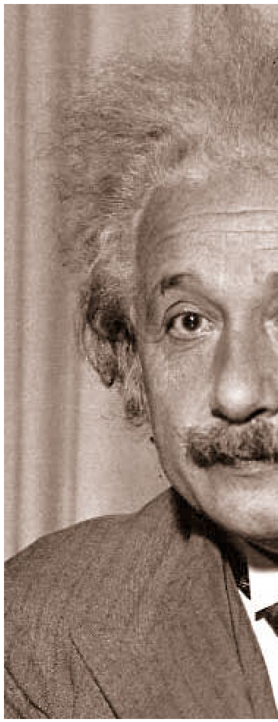
- EU cost: €160 billion / year
- 1.7 million injuries / year
- 40,000 deaths / year

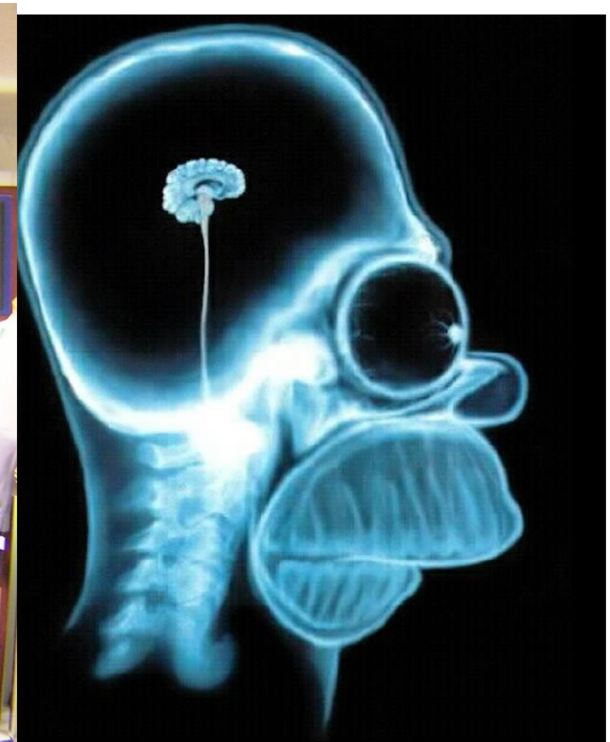
Why important? – an example



Why difficult?

Deals with Humans





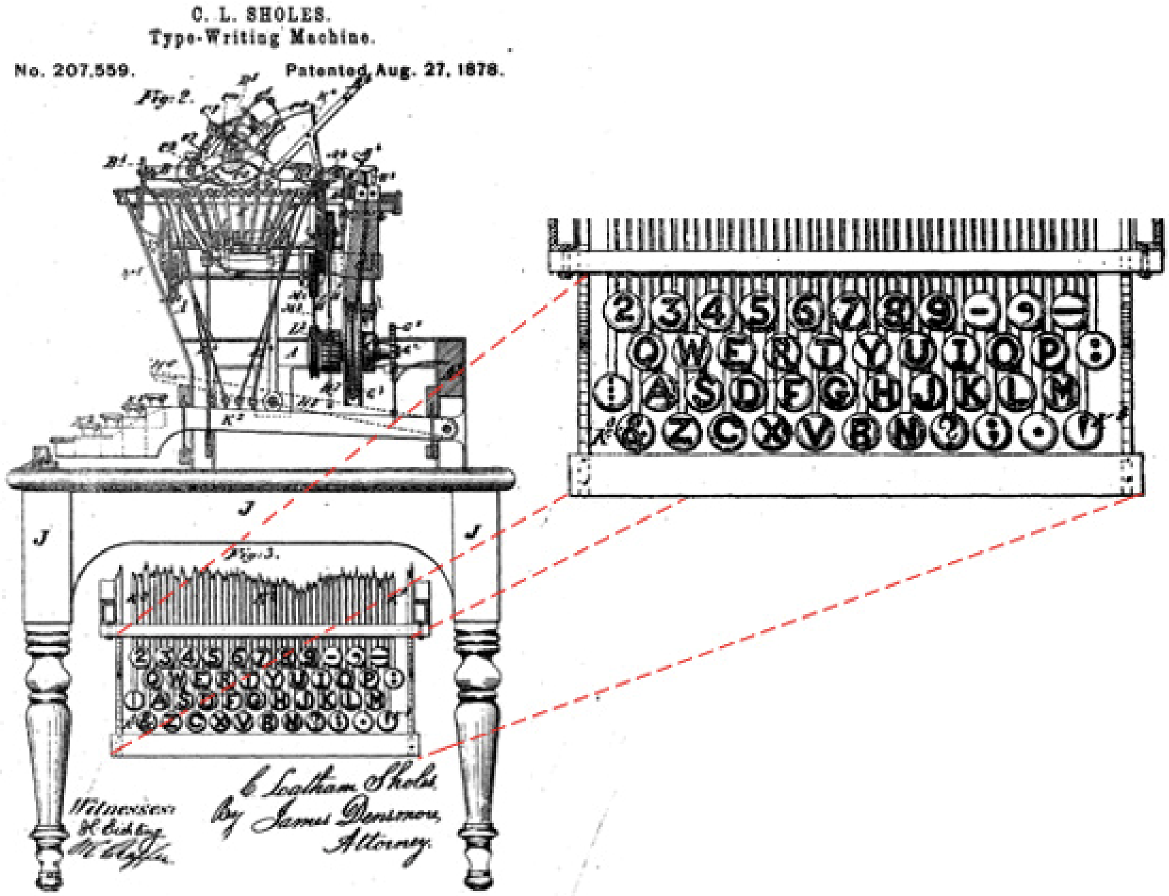
Humans adapt!

Human are very, very good at adapting

Great ability!

Excuse for bad design?

Humans also adapt to sub-optimal designs!



Patent for first typewriter (1868)

'Lifted' (2006) by Pixar

What if human-machine interface is *not* optimal?

From this cartoon we see many important concepts:

- If interface is not easy, operator makes mistakes
  - Maybe dangerous for him/herself
  - Maybe dangerous for other humans or things
  - Costs a lot of time
  - Is frustrating

- A very skilled human can still operate such a machine

- It is difficult to display information to human

What would be a good way for us engineers
to help the little alien?

Basic idea about this class

A human-controlled technical device can only function well when both the device and the human-machine interface are optimized!

Past:
technology was a limiting factor in design

Now:
almost infinitely many designs are possible, but...

What is optimal?

Knowing what's optimal requires…

knowing about controlled system

- Kinematics and Dynamics (how things move)
- Signal Analysis (time domain and frequency domain)
- Control Engineering (stability, disturbances)
- Situated Task and Environment

knowing about humans

- Sensing (information from outside or inside body)
- Acting (move limbs, exert force)
- Cognition and perception-action couplings
- Capabilities, limitations, preferences, adaptation

Knowing how to measure, model and evaluate

Let's think about driving....

Final design goals:

- Safe
- Effective
- Comfortable
- Intuitive

Break

What does a driver need to do for safe and comfortable driving?

1) Perceive

- Road
- Road users
- Motion cues
- Steering forces
- Status of the car

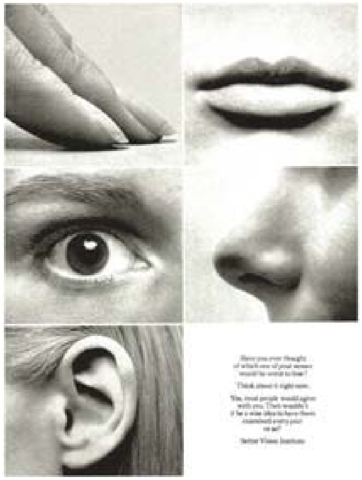
2) Act (do)

- Steer
- Brake / Gas Pedal
- Clutch / Stick shift
- Operate secondary controls

3) Predict & Know

- Traffic rules
- Intention of other road users
- Navigation
- Road condition / Weather conditions

2. From Perception…



Sensing
- Visual
- Auditory
- Vestibular
- Proprioceptive / Tactile

Perception is not perfect!
- Just Noticeable Differences
- Perception Thresholds

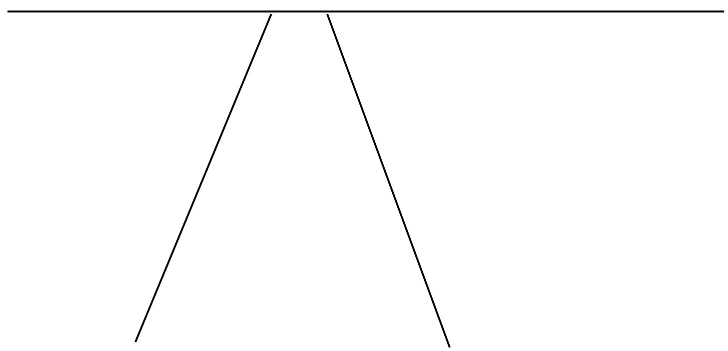
Making Sense
- Sensory integration & illusions

More in Class 2

Example – speed perception

Suppose we design driving simulator

- What do we need to include to give a good speed perception?

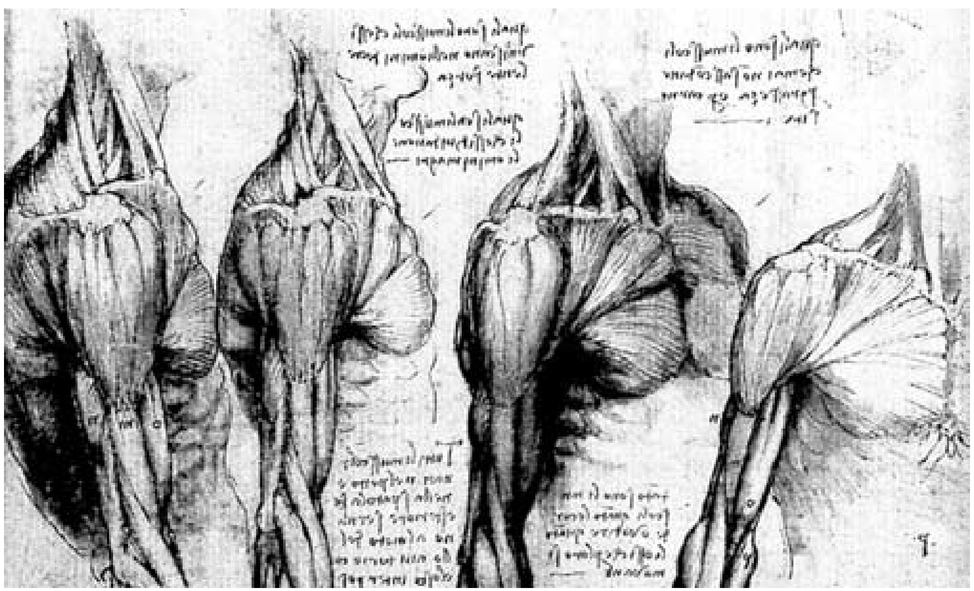


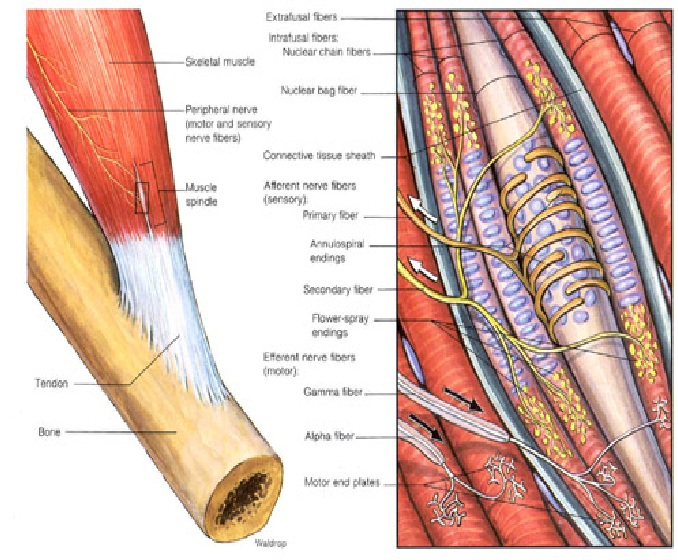
- Include:
  - Visual cues: side poles, trees, textures
    - Use speed indicator to overcome bad speed perception
  - Auditory cues: engine and wind noise
  - Haptic cues: seat vibration, forces on the wheel
  - Vestibular cues: accelerations by a motion-base

3 ...to action

Human Motion Control

- Feed-forward control (plan)
- Feedback control (correct)
  - Muscles
  - Reflexes





More in Class 3

4-5-6. From Perception to Action:
Measuring and Modeling Human Controllers

Design and evaluation methodologies

In dynamic tasks, what is good performance?
How is performance balanced with control effort?

4. Evaluating the Human Controller
(By dr.ir. Erwin Boer)

Important factors for system designer:

- Performance (human + system)
- Control effort and Mental load of human operator

Several methods to measure

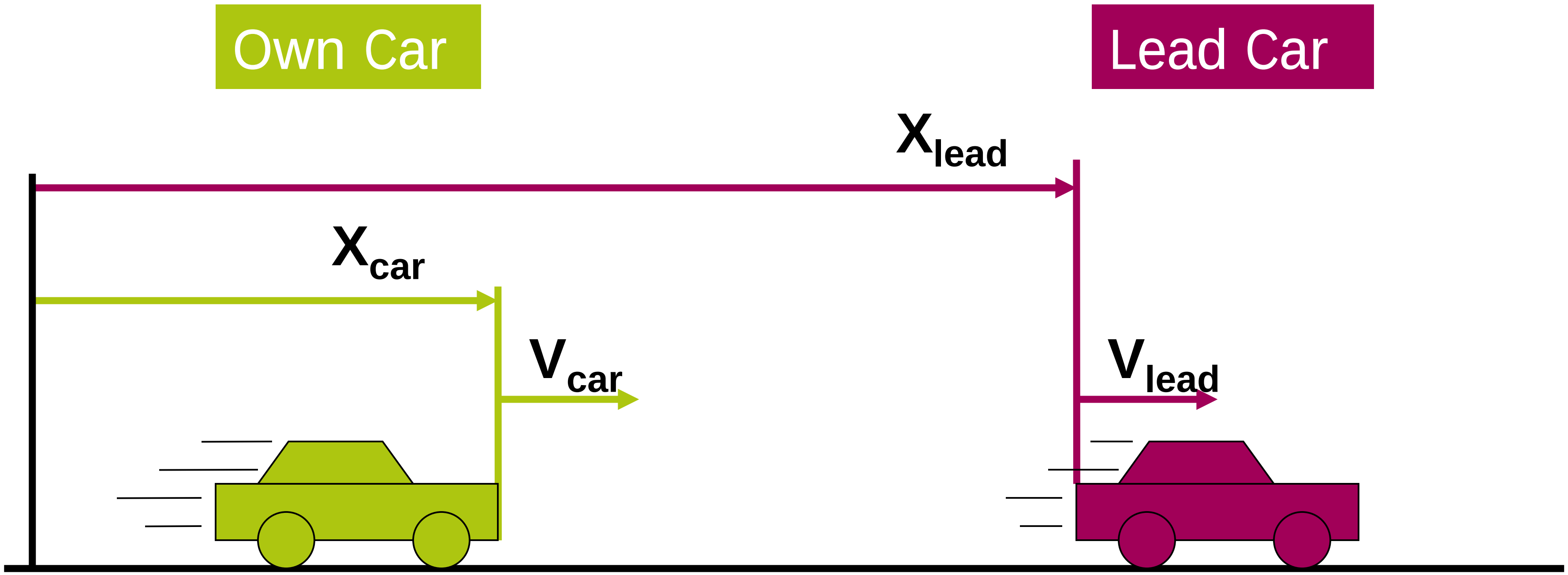
- Performance (how well is the task performed?)
- Control effort (how much effort does it take the human?)
  - Physical effort
  - Mental load

Evaluation issues and examples from Nissan Collaboration

- Empirical vs modeling approach
- Optimizing vs satisficing
- What is important to humans?

More in Class 4

Example: Measuring and Modeling Car Following



$X_{rel} = X_{lead} - X_{car}$
$V_{rel} = V_{lead} - V_{car}$

Separation States

THW = Xrel / Vcar
TTC = X_{rel} / $-V_{rel}$

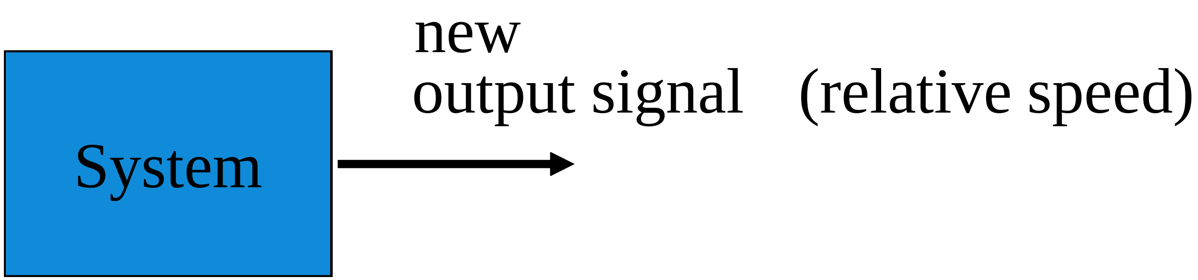
Conventional System Optimization

Measure the impact of a new system by determining

- Statistical analysis (mean, std, CDF) of a dynamic signal
- Change in performance metric for different systems (tunings)

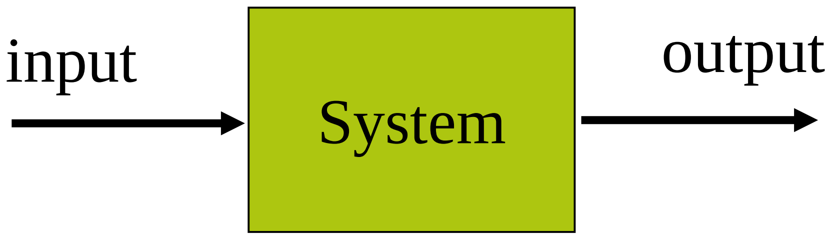
Shortcomings

- Time consuming
- Descriptive, but not predictive (hard to generalize)
- Many ways to achieve the same performance metric, unclear what situations cause change in the metrics, or interaction between them



5. Alternative: use modeling!

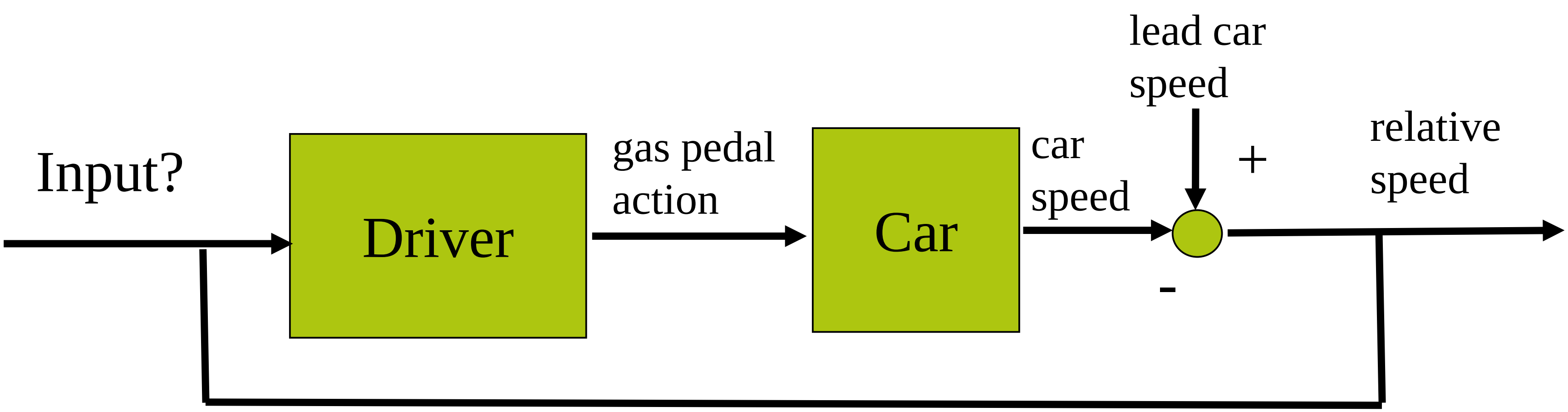
Use System Identification Techniques to determine (causal and dynamic) relationships between input and output



$$\text{System} = \frac{\text{output}}{\text{input}}$$

5. Cybernetic Modeling!

Cybernetics: describing a human
in control engineering terms (gains, time delays, noise)



5. Cybernetic Modeling!

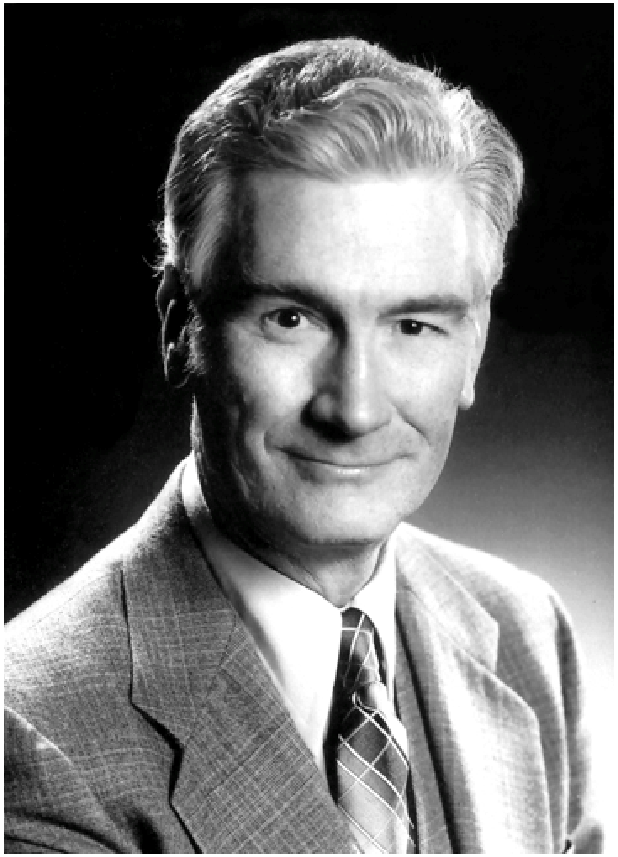
Example: McRuer's Crossover Model

Advantages of this evaluation method:

- Quantitative -> objective
- More information -> better understanding
- Gives Predictive Models

Needed

- Understanding of Control Engineering
  - Bode plots
  - Fourier Analysis



More in Class 5,6

6. Practical Assignment 1

Experience with McRuer's Crossover Model

Form groups of 5 students (for all 3 assignments!)

Perform measurements together

- Download software from Blackboard
- Download assignment from Blackboard
- Perform experiment in groups of 5 students

Assessment

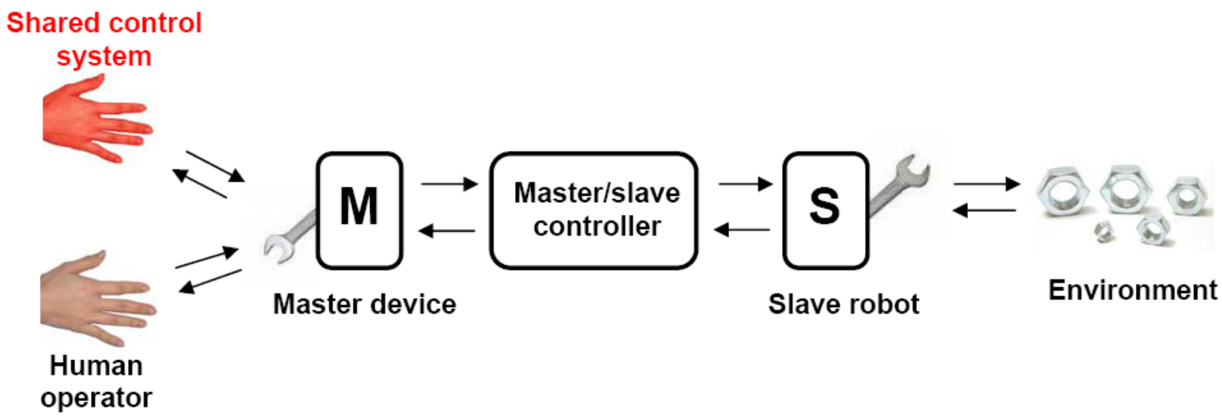
- Presentation in Class 12

Class 7 – Monday 19th – Free!

Well... no classes, but you should work on:

Practical Assignment 2: Modeling the human controller

8-9. From Perception to Action: Haptic Applications

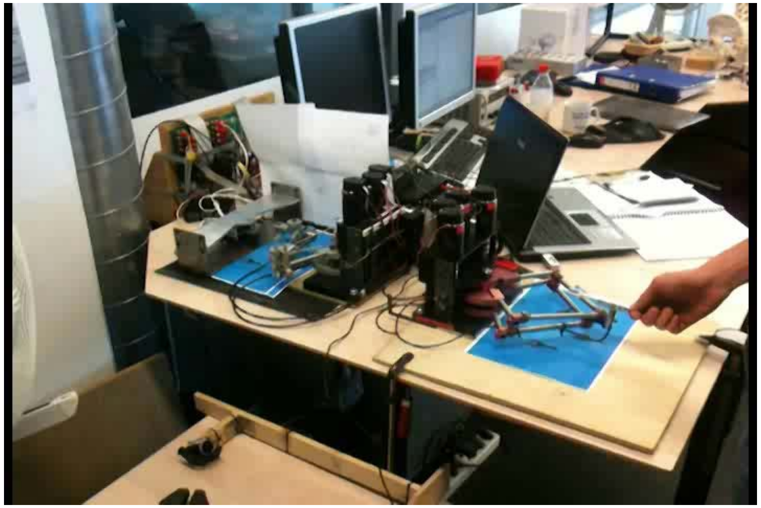


10. Haptic Shared Control

11. Practical Assignment 3

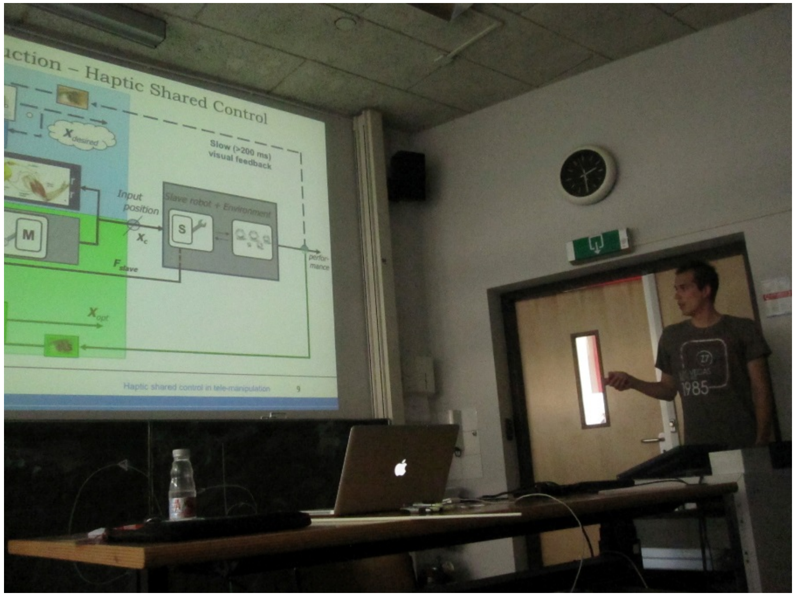
A Human controlling a car

B Human controlling a teleoperator



12-13. Presentations & Discussions

12: Present PA 1	**By you!**
13: Present PA 2 + 3	**By you!**



14. General Discussion
What is good/bad, what do we want?

What should be the future role for humans and machines?

Philosophy, confusing remarks, discussions

Take Home Message

Exam

Open-book exam, with 7 open questions

- we will give examples of exam questions at the end of most of the classes

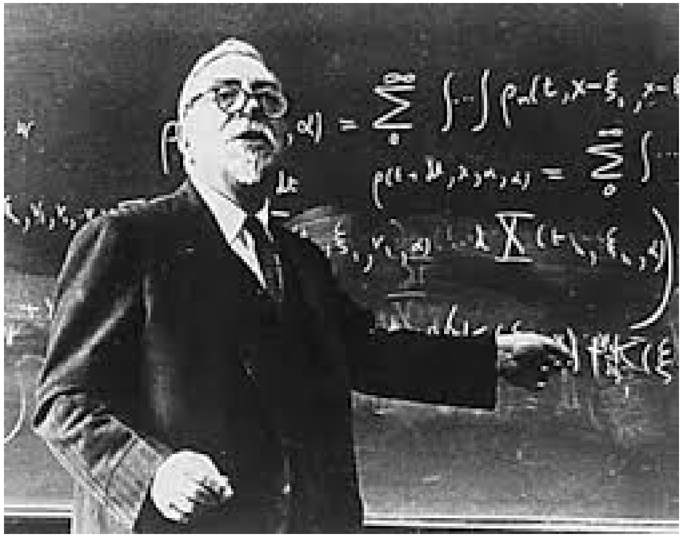
Relationship to other 3mE courses

Human Movement Control – studies humans controlling their own limbs, not machines

Man-Machine Systems – studies humans in a supervisory control loop, not a direct control loop

Human Factors & Ergonomics?

'Cybernetic' Ergonomics



Norbert Wiener (1948) *"Cybernetics is the scientific study of control and communication in the animal and the machine"*

Take Home Message

Today you have learned:

1. That this class is about humans controlling devices

2. The planning of the coming classes and relevant topics

3. That humans have strengths and limitations, and are very adaptable

4. That designing and evaluating good human-machine interaction is difficult, but very important to avoid confusion, unncecessary effort or even dangerous situations!

Questions?