TUTORIAL: Designing and Evaluating



Part I: Introduction to the Technical Committee

Tom Carlson, PhD

Lecturer, Aspire Create
University College London



What is shared control?



What is shared control?

See no evil, hear no evil

(1989)



Important Elements

Design Evaluation



Important Elements

Design

Evaluation

- Communication
- Feedback
- Timing
- Modalities (speech, haptics, ...)
- Perception
- Situational Awareness
- Learning / Adaptation
- Authority



Important Elements

Design

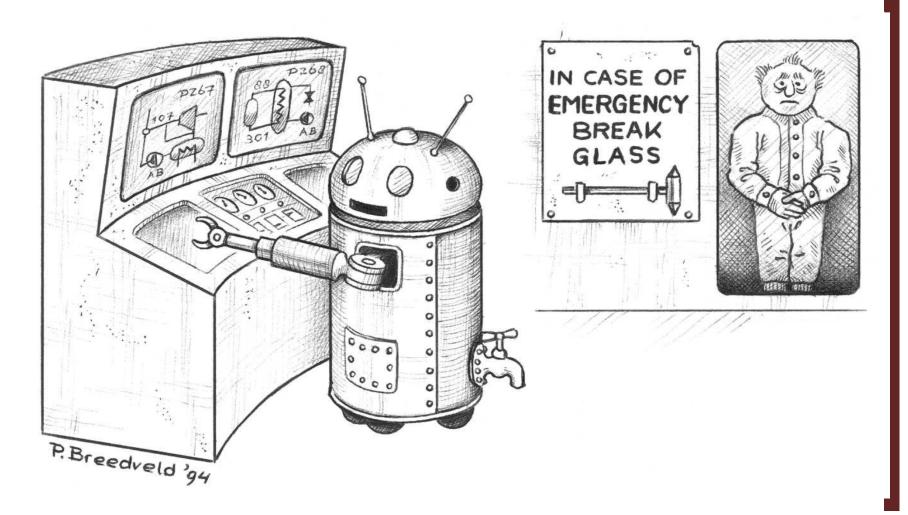
- Communication
- Feedback
- Timing
- Modalities (speech, haptics, ...)
- Perception
- Situational Awareness
- Learning / Adaptation
- Authority

Evaluation

- What is performance?
- What is effort?
- What is efficiency?



Common Human-Automation Interaction







vehicles or tools that:

- are aware of their environment, and keep the user aware as well



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- have a good idea what the user wants to do in that environment



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Vehicles







Robots





vehicles or tools that:

- are aware of their environment, and keep the user aware as well
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- communicate their intentions, but can be easily overruled

Vehicles







Robots



Task-dependent: different robots -> different design goals



A metaphor?



[Flemisch et al., 2003]



A metaphor?





[Flemisch et al., 2003]



A metaphor?

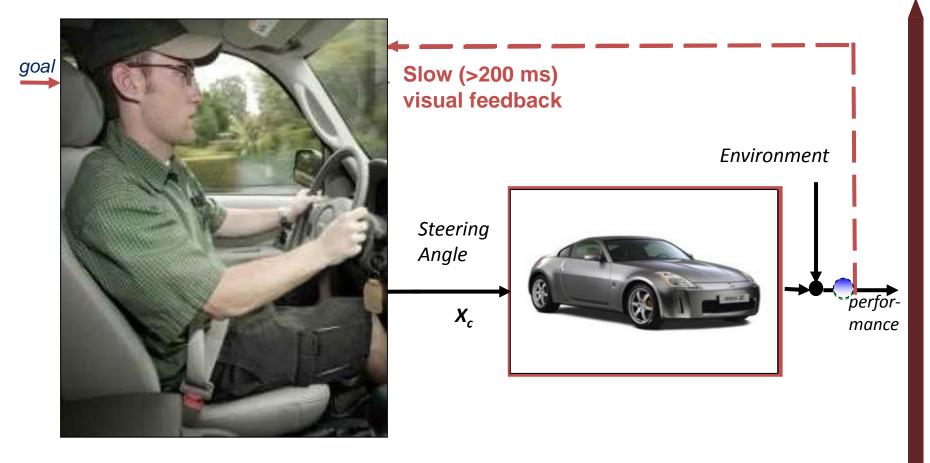






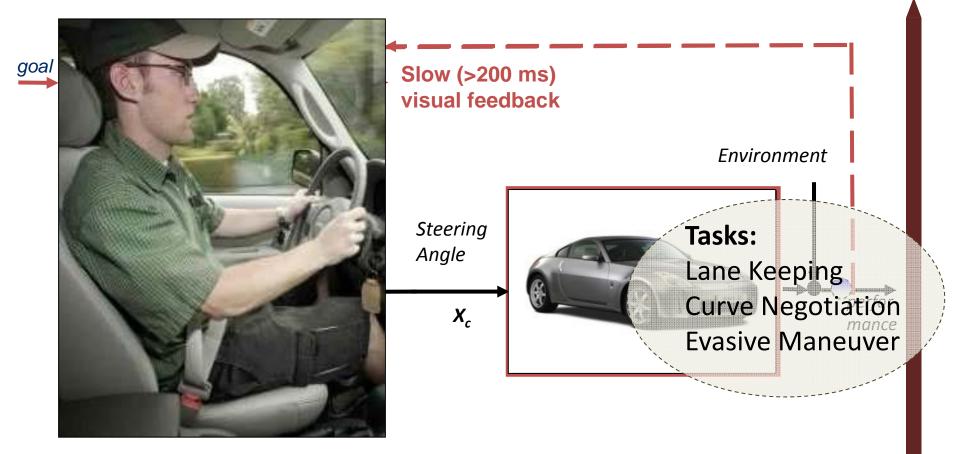
[Flemisch et al., 2003]

Manual Control



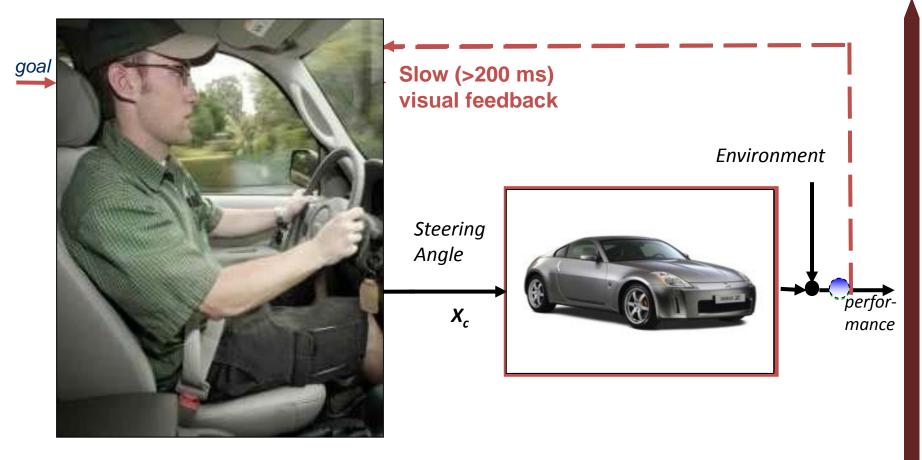


Manual Control



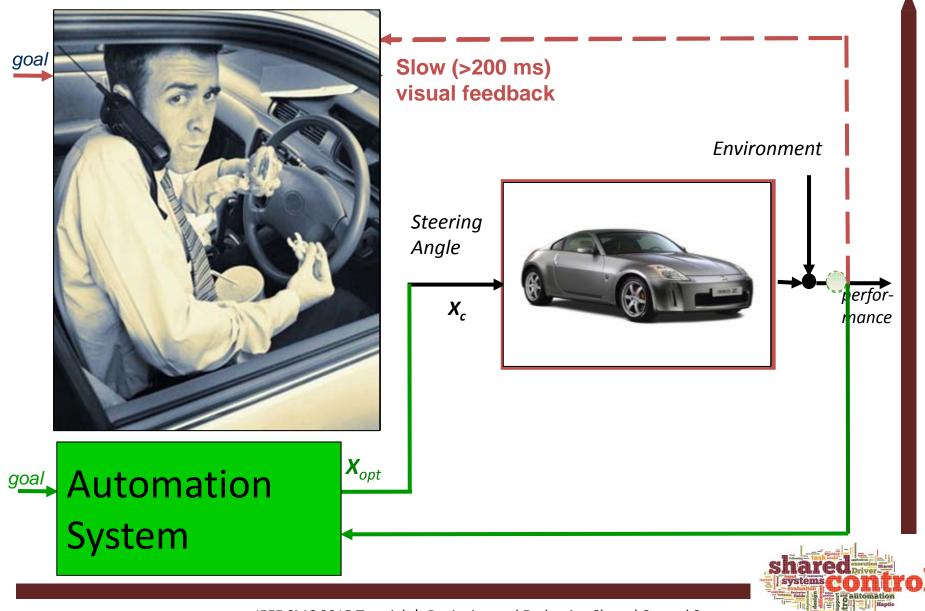


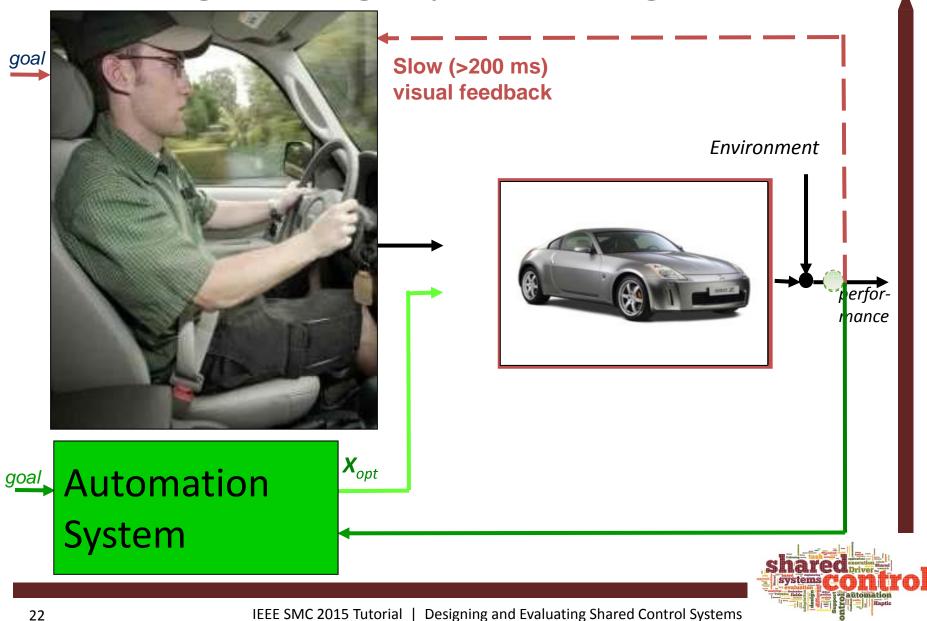
Manual Control

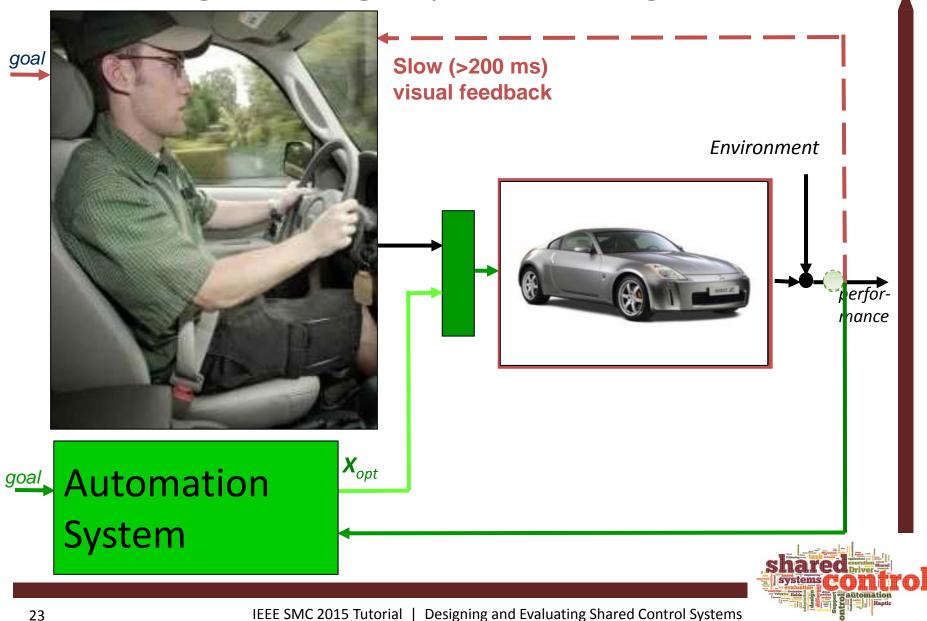


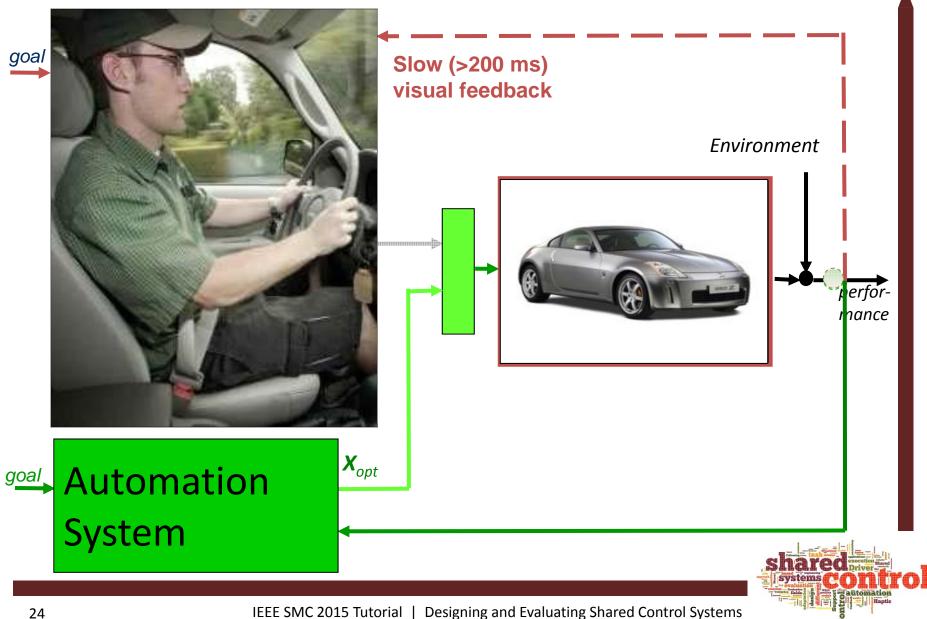


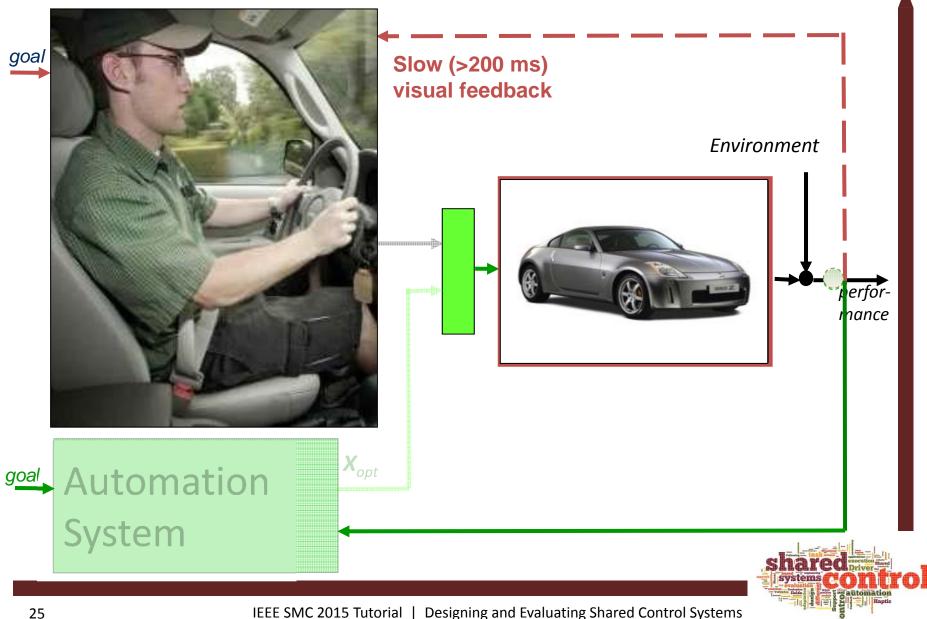
Full Automation



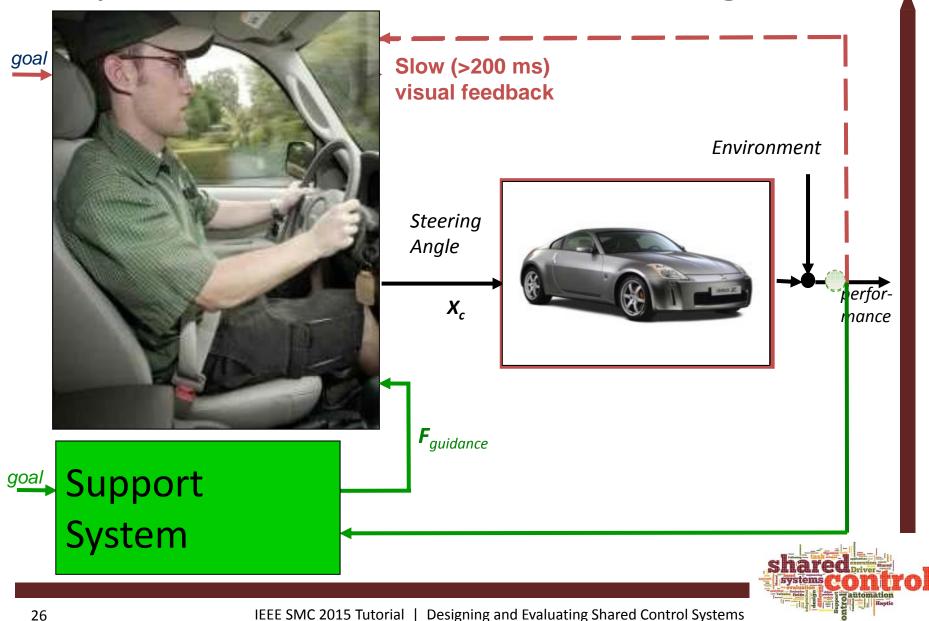








Haptic Shared Control for Steering



When human and automation share tasks...

... there is need for human-machine interface

Good interface is hard to design and evaluate



When human and automation share tasks...
... there is need for human-machine interface
Good interface is hard to design and evaluate

Issue 1. Does human understand automation?

Automation boundaries & Detected system failures



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Good interface is hard to design and evaluate

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Automation boundaries & Detected system failures

Current human-machine interface

- Communicate through visual or auditory warning signals



When human and automation share tasks...

... there is need for human-machine interface

Good interface is hard to design and evaluate

Issue 1. Does human understand automation?

Automation boundaries & Detected system failures

Current human-machine interface

Communicate through visual or auditory warning signals

Issue 2. Does automation understand human?

Desired trajectories, safety boundaries, strengths & limitations



When human and automation share tasks...

... there is need for human-machine interface

Good interface is hard to design and evaluate

Issue 1. Does human understand automation?

Automation boundaries & Detected system failures

Current human-machine interface

Communicate through visual or auditory warning signals

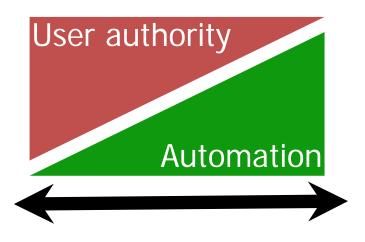
Issue 2. Does automation understand human?

Desired trajectories, safety boundaries, strengths & limitations

Current human-machine interface:

- User can only switch on/off (binary)
- User can only provide some set-points for automation

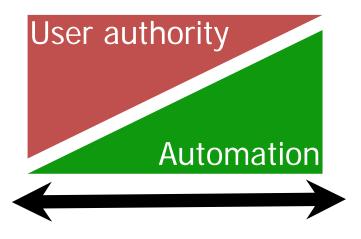






Tasks change over time

- Spatio-Temporal Constraints may change over time
- Shifts in authority may be required



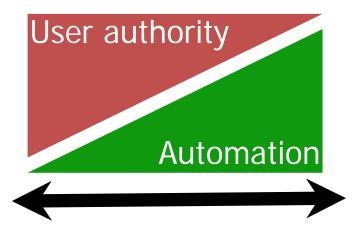


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Each user is different

- Individual skills and capabilities
- Individual needs and desires





Tasks change over time

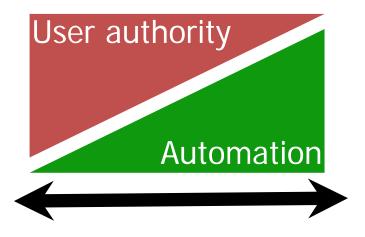
- Spatio-Temporal Constraints may change over time
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Each user is different

- Individual skills and capabilities
- Individual needs and desires

Users change over time

- Individual Tolerances change over time
- Attention / motivation / perception may change over time
- Learning / adaptation / skill-loss





Technical Committee: A brief history

Founded in 2012, 2 years after initial discussions



Mark Mulder



David Abbink



Tom Carlson



Current TC Co-Chairs



Makoto Itoh



Tricia L. Gribo

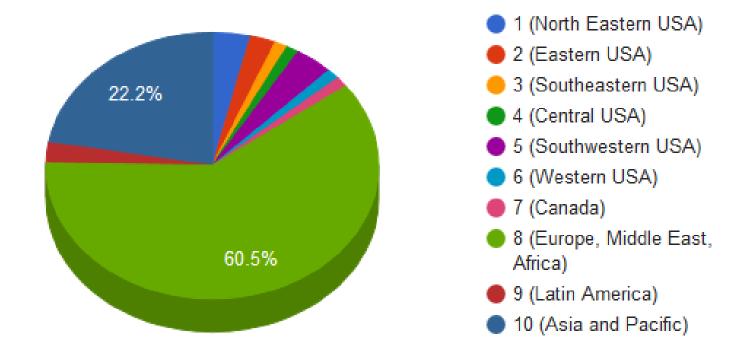


Erwin R. Boer



Technical Committee Members

SMC TC on Shared Control: Members by IEEE Region



Currently 77 Members and growing!



SMC Sessions & Workshops 2011-2014

Lectures by Keynote speakers



Hands-on Demo's





Discussions in work groups



Special Session BMI-B09

Sunday 11th 10:20-12:20

Location: AC3 6th Floor, Room 209

- How to measure and model users?
- How to assist when user and environment are not tightly coupled?
- How to deal with conflicts?

Poster Session 5: Sunday 11th, 15:10 - 16:40

Location: AC3#6/F - Pre-function Area (outside Wong

Cheung Lo Hui Yuet Hall)



Today's Plan

- 1. Intro to TC + Shared Control overview (Tom)
- 2. Haptic Shared Control (Tricia)
- 3. Dealing with Conflict (Makoto)
- 4. Application Areas
 - Driving (Makoto); UAV, Teleoperation (Jan); Other Areas (Tricia)
- 5. Evaluation principles (David)

Break

Interactive Session

- Demo
 - Tricia's demo FF vs Stiffness communication about authority / criticality
 - Tom's demo on adaptation and secondary tasks splat the rat
- Break out + group presentations
 - Feedback (bi-directional communication)?
 - Dealing with conflict?
 - Adaptation when and how?
 - Over-dependence / de-skilling / lack of Situational awareness
- Wrap-up (David)



TUTORIAL: Designing and Evaluating

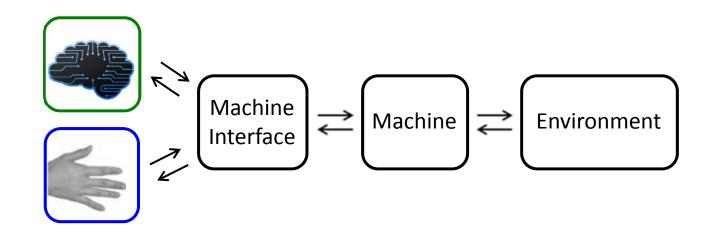


Part II: Haptic Shared Control Approaches

Tricia Gibo

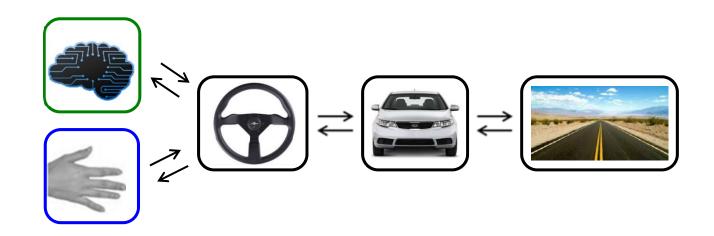
Postdoctoral Researcher at Delft Haptics Lab Delft University of Technology





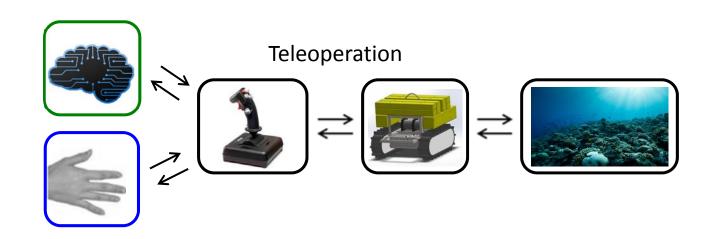
"... the human utilizes the haptic sensory modality to share control of the machine interface with an automatic controller."





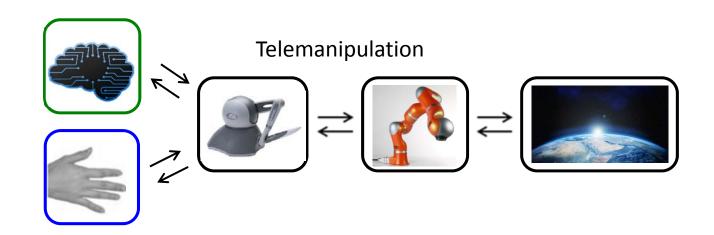
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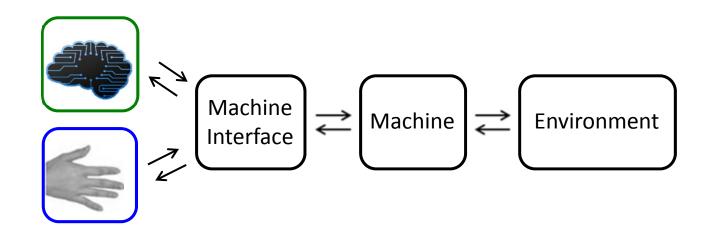
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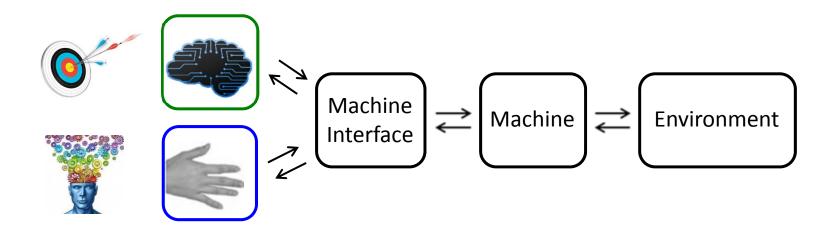


"... the human utilizes the haptic sensory modality to share control of the machine interface with an automatic controller."

Keep human-in-loop

Human can override

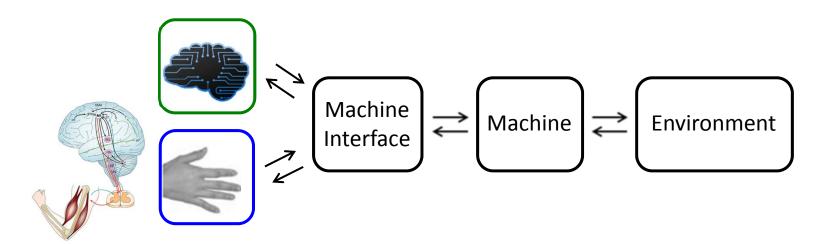




"... the human utilizes the haptic sensory modality to share control of the machine interface with an automatic controller."

Strengths of man + machine





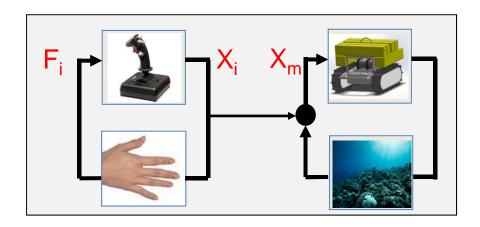
"... the human utilizes the haptic sensory modality to share control of the machine interface with an automatic controller."

Directly perceptible

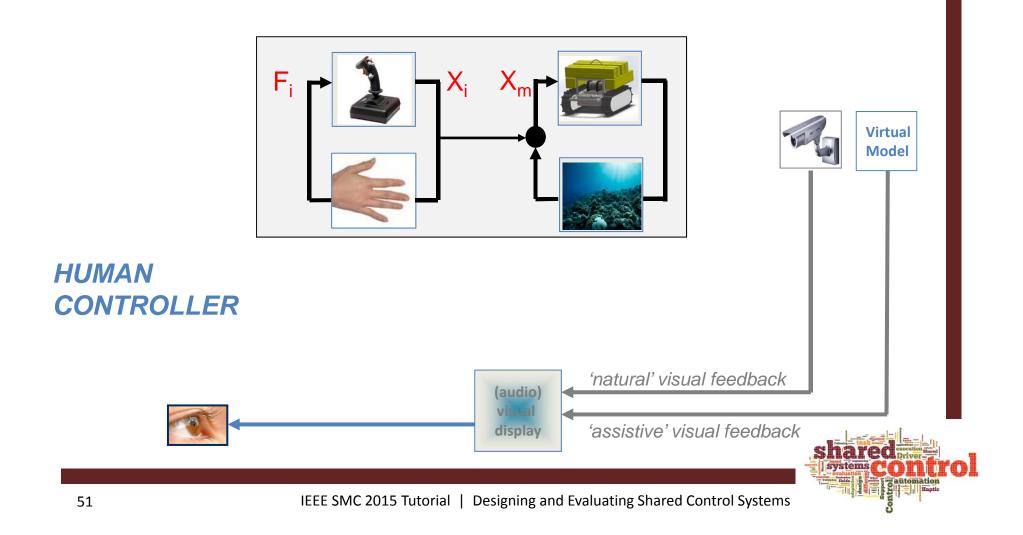
Intuitive

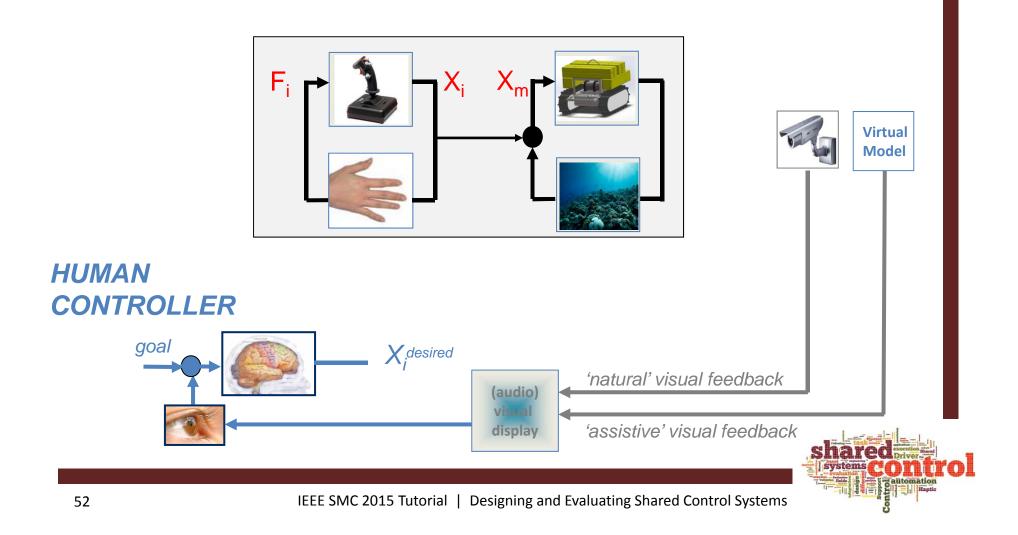
Reduced response time delay

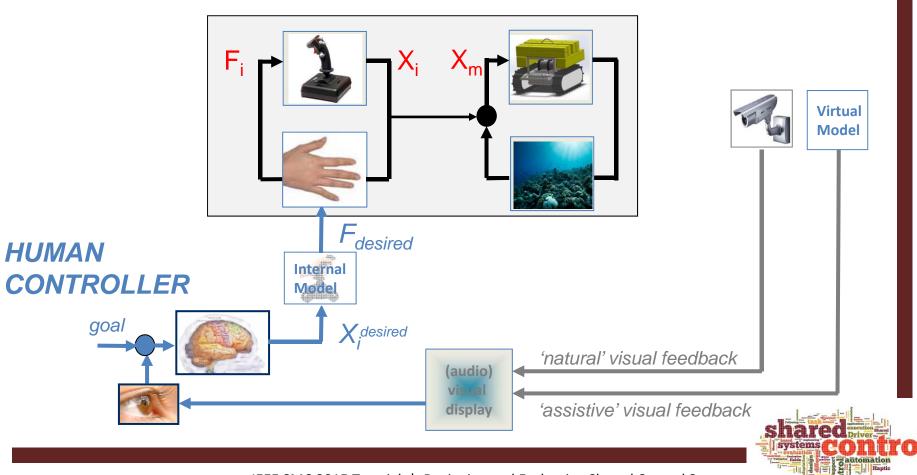


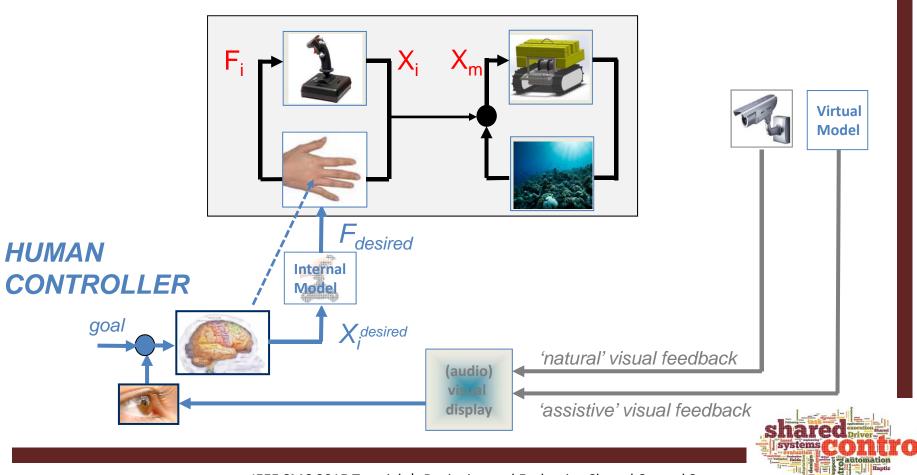




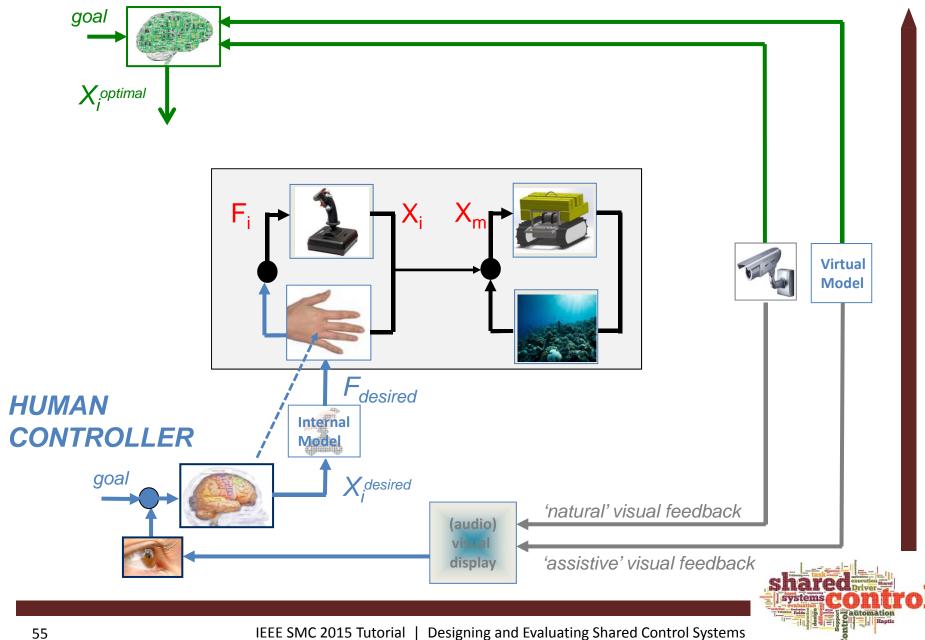




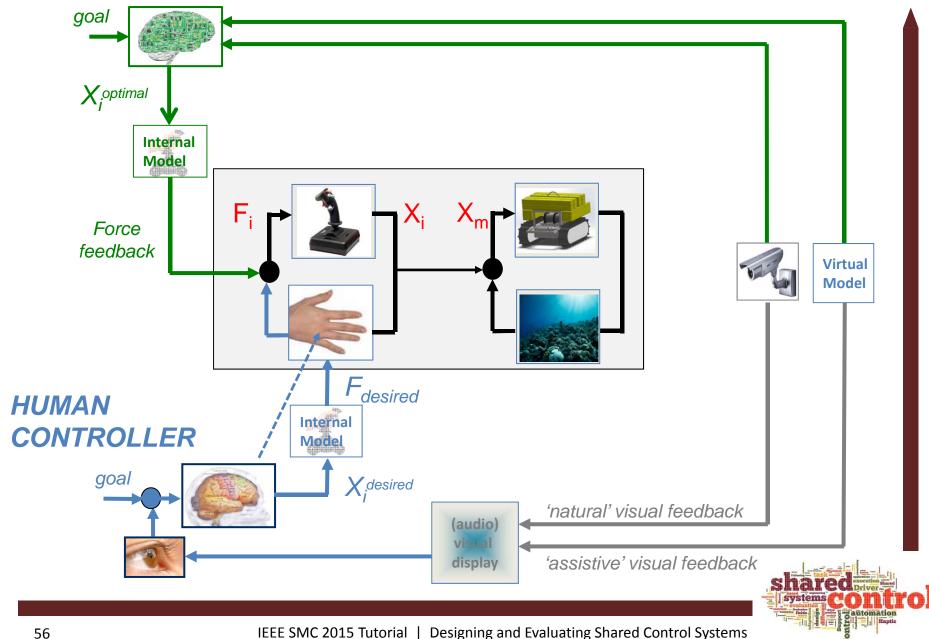




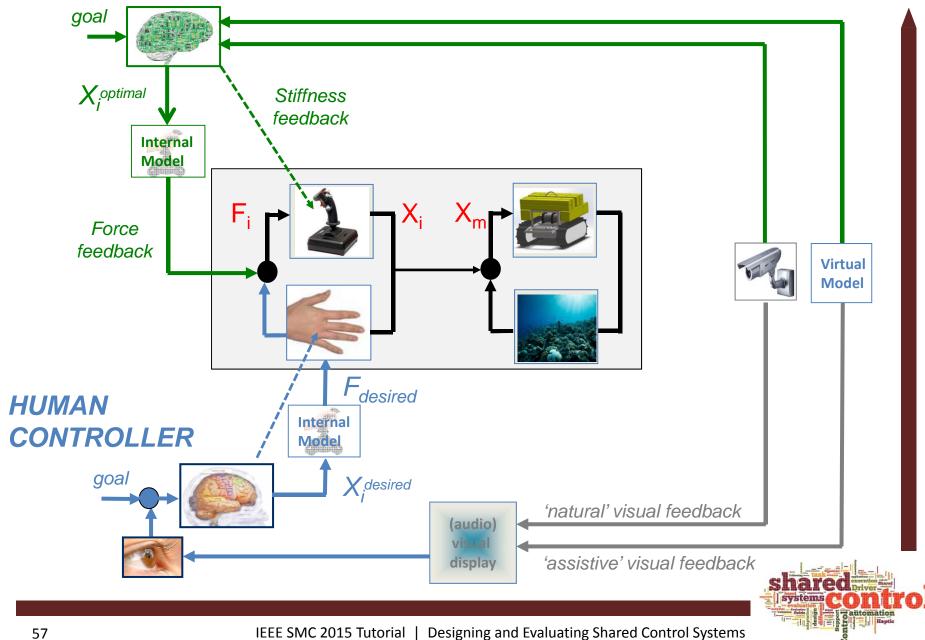
HAPTIC SHARED CONTROL



HAPTIC SHARED CONTROL



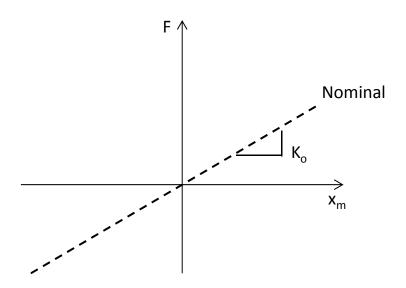
HAPTIC SHARED CONTROL



Design parameters

$$F_{total} = K_o x_m(t)$$

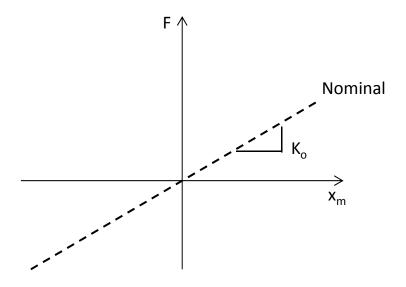






Design parameters: force

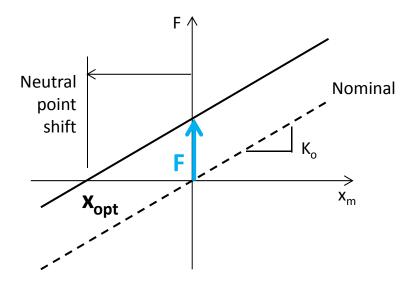
$$F_{total} = K_o x_m(t) + \underbrace{K_f x_{opt}(t)}_{\text{Force feedback}}$$





Design parameters: force

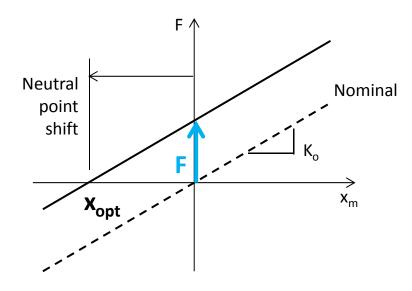
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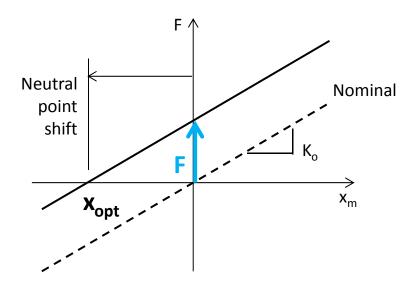
Tune K_f

- depends on H/M impedance
- too low: sloppy control
- too high: instability



Design parameters: force + stiffness

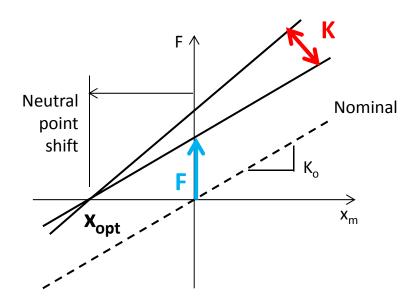
$$F_{total} = K_o x_m(t) + \underbrace{K_f x_{opt}(t)}_{\text{Force}} + \underbrace{K_s | e(t)| \left(x_m(t) - x_{opt}(t)\right)}_{\text{Stiffness}}$$
feedback
Stiffness
feedback





Design parameters: force + stiffness

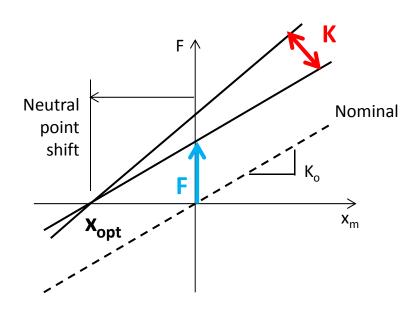
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feedback
Stiffness
feedback





Design parameters: force + stiffness

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Stiffness feedback



Tune K,

- ↓ deviations from x_{opt}
- determine authority

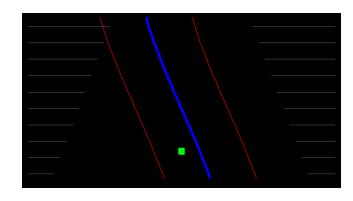


DEMO: HSC force + stiffness feedback

Custom 1-DOF "GEMINI" device

Tracking task

- No HSC centering stiffness only
- Force feedback different levels
- Additional stiffness feedback different levels







Proof of concept: Nuclear reactor maintenance

Transparency: direct control (DC)

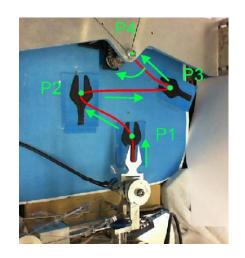
(realism) telemanipulation with FF (FF)

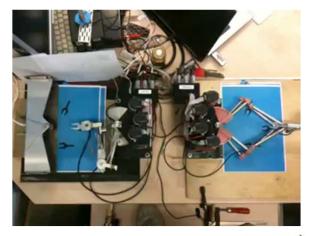
telemanipulation without FF (NoFF)

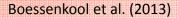
HSC: guide position & orientation

Design of HSC: a priori path from environment model

trial-and-error parameter tuning









Proof of concept: Nuclear reactor maintenance

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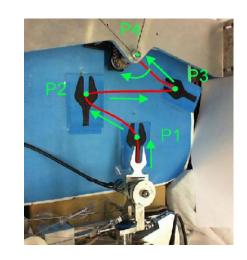
(realism) telemanipulation with FF (FF)

telemanipulation without FF (NoFF)

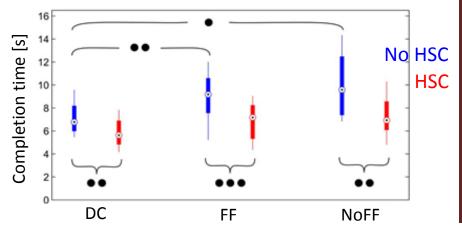
HSC: guide position & orientation

Design of HSC: a priori path from environment model

trial-and-error parameter tuning



HSC can improve task execution, independent of haptic feedback quality



Boessenkool et al. (2013)

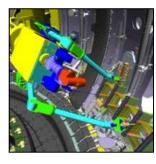


Factors to consider in SC design

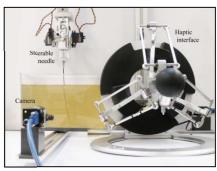
- Human
 Adaptibility, intuitiveness
- Machine
 Position vs. rate control
- EnvironmentVariability/uncertainty
- Task
 Guidance vs. avoidance, position vs. force
- Conflicts

 Level of authority, errors









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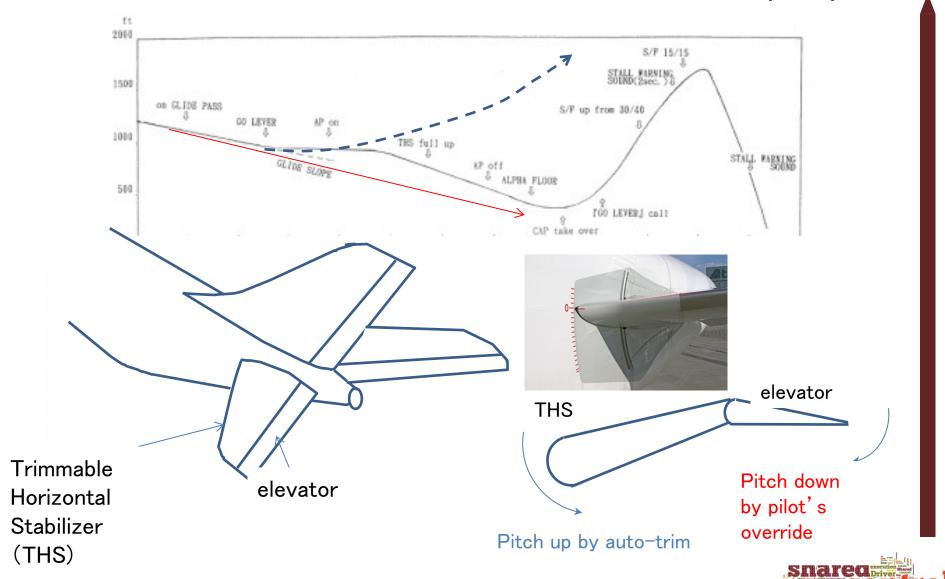
Part III: Dealing with conflicts

Makoto Itoh

Professor, Faculty of Engineering, Information and Systems, University of Tskuba, Japan

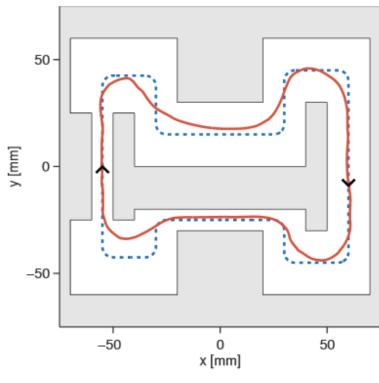


China Airlines Crash at Nagoya Airport ('94)



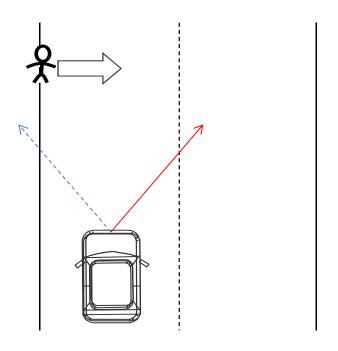
Varieties of conflicts

Trajectory conflicts
- too left or too right



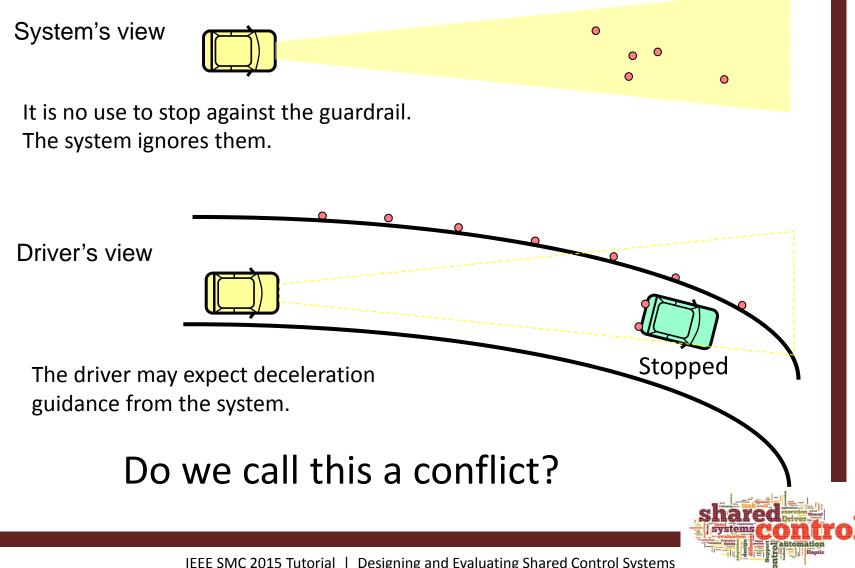
(de Jonge et al., 2015)

Direction conflicts
- go right vs go left



(Tanaka et al., in press)

No guidance: Adaptive Cruise Control



Possible categories of conflicts

Trajectory

- The trajectory is too right, or too left.
- The guidance is too strong.

Direction

- The guidance is opposite to the maneuver of human operator.
- The intention is the opposite to each other.
- No (less) guidance
 - No (less) guidance is given even when the human operator expected.

Is a conflict bad?

Yes

 The guidance given to the human is the disturbance. It is impossible or at least difficult for the human to do something he/she wants.

No

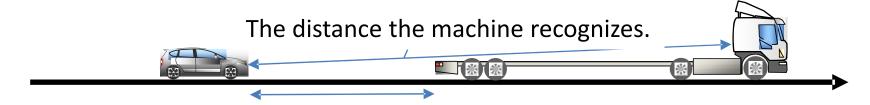
- The human is stupid, the guidance saves the human.

The human may be wrong, but the human may be right.



A bad conflict: Opposite guidance given

The system proposes to reduce the distance.



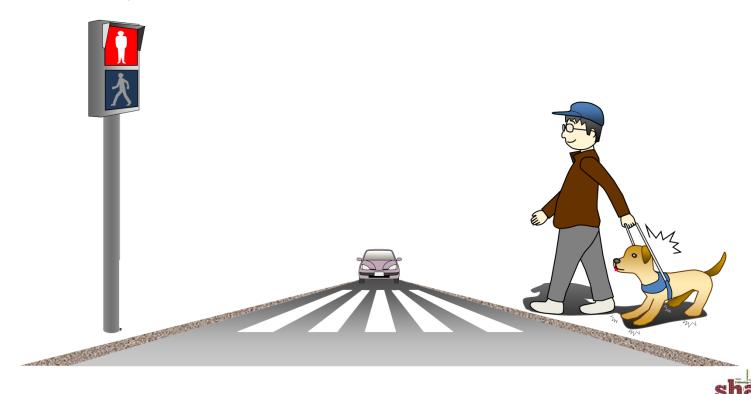
The actual distance.

The driver does not want to reduce the distance.

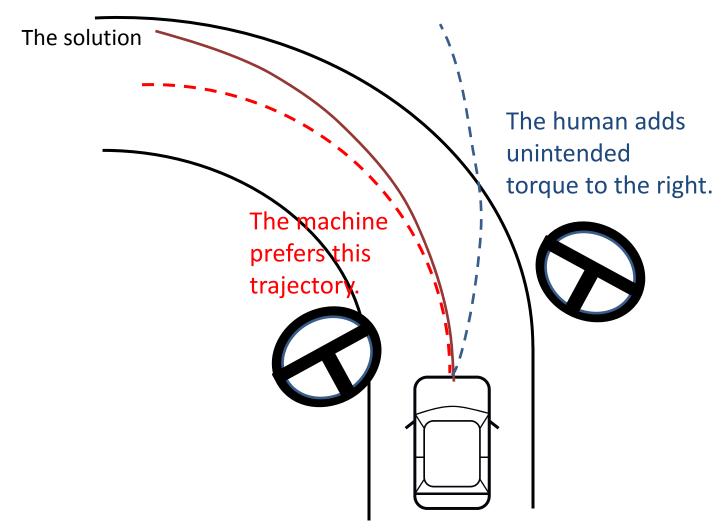


A Good Conflict: "Intelligent disobedience"

- A blind man is crossing the road, the signal is in red.
- A guide dog recognizes the red signal, and he/she disobeys the order of the blind man.



A good conflict: When the driver is drowsy...





Similar issue at the Special Session.

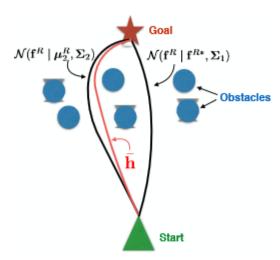


Fig. 3: One global autonomy optima at \mathbf{f}^{R*} and a safe autonomy mode at μ_2^R through some obstacle field. The ope predicted trajectory at $\bar{\mathbf{h}}$ is safe .

Will be presented at the special session on Shared Control.

Trautman (2015)

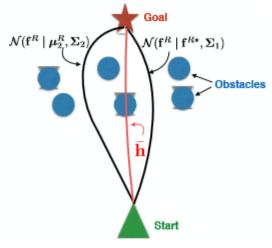
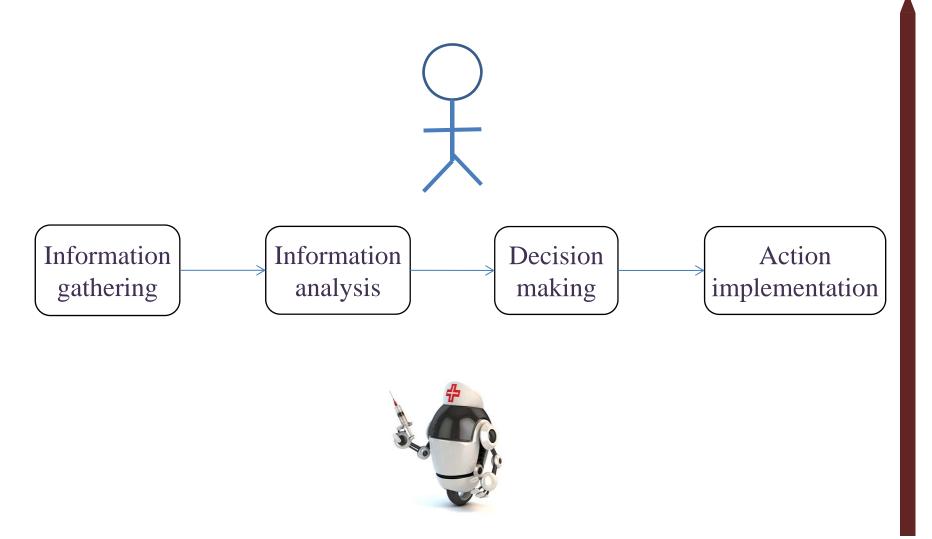


Fig. 4: One global autonomy optima at \mathbf{f}^{R*} and a safe but suboptimal autonomy mode at μ_2^R through some obstacle field. The operator's unimodal predicted trajectory at $\bar{\mathbf{h}}$ is *unsafe*.

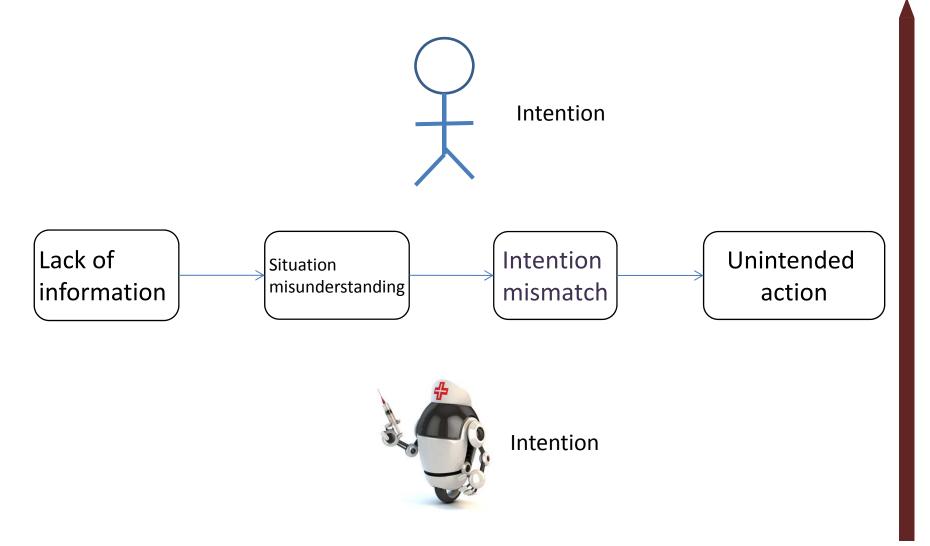


Sources of conflicts





Sources of conflicts





How to solve conflicts?

- The principle of human-centered automation (Billings, 1997)
 - The human must bear the authority.
 - The system adapts to the human.
- Adaptive automation (Inagaki, 2003)
 - There are cases where the human cannot handle the situation but the system can. In those cases, the system may be allowed to have the authority.
 - Faults in information acquisition and analysis.
 - Time criticality

How much the system should be intelligent to have the authority?

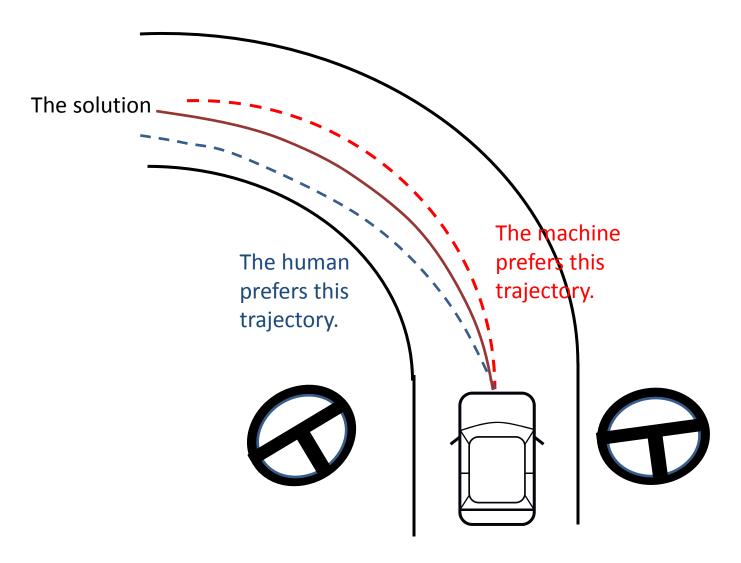


What is a "conflict" between human and machine?

"Even when desired trajectories are similar but not identical between operator and shared controller, repetitive small trajectory conflicts can occur between human operator and haptic shared controller." (de Jonge at al., 2015)



Conflict between human and machine



Is the solution optimal or at least acceptable?



TUTORIAL: Designing and Evaluating



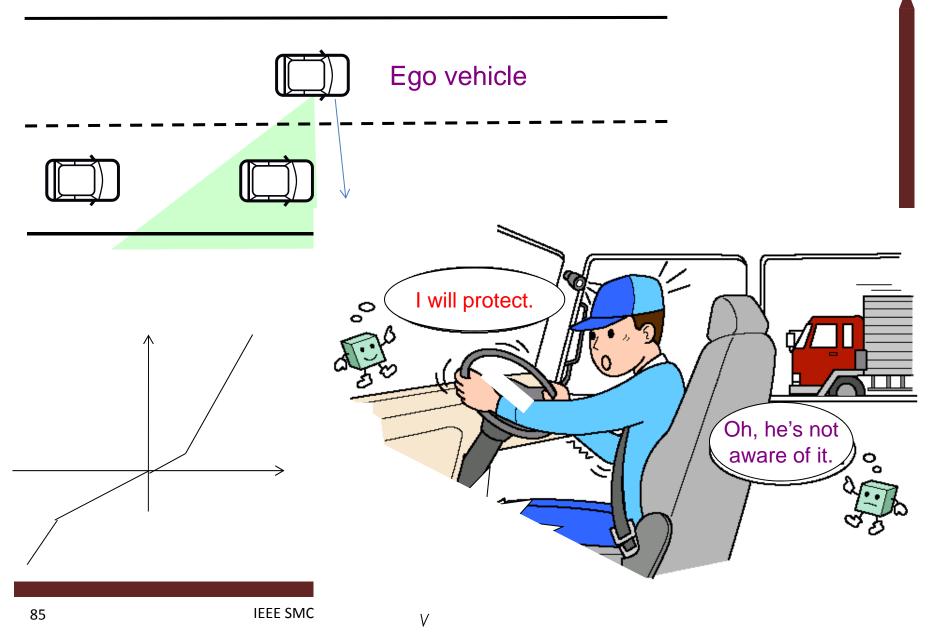
Part IV: Automobile

Makoto Itoh

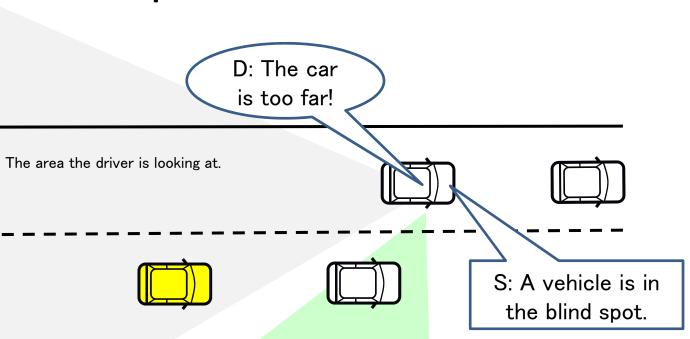
Professor, Faculty of Engineering, Information and Systems, University of Tskuba, Japan



Soft protection (Itoh, Inagaki, 2013)



A complicated conflict



The area the system is looking at.

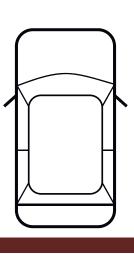
If the system is pretty sure, the system may have the final authority.



Pedestrian avoidance

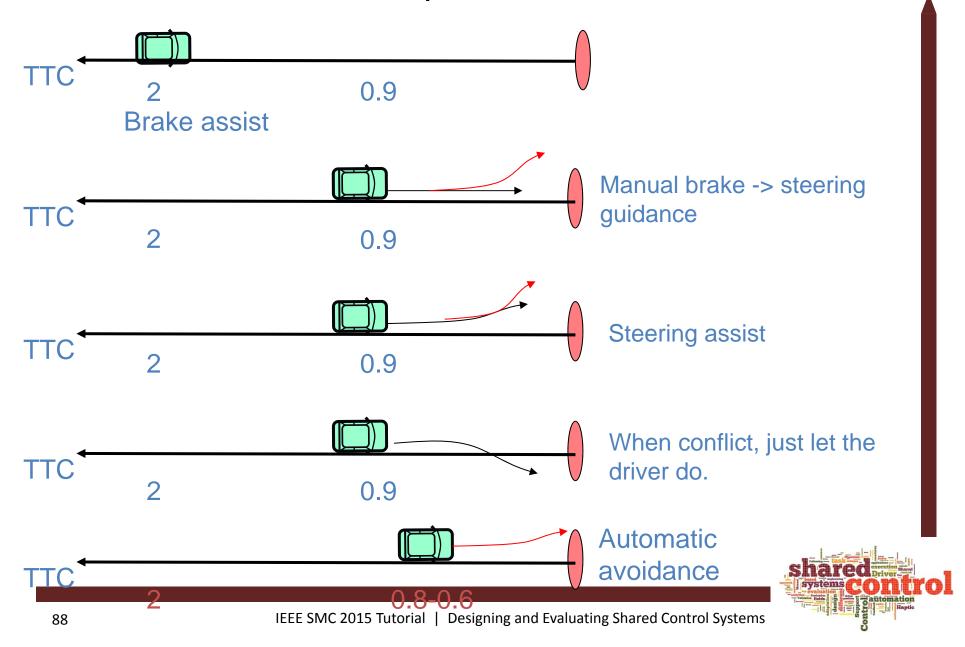




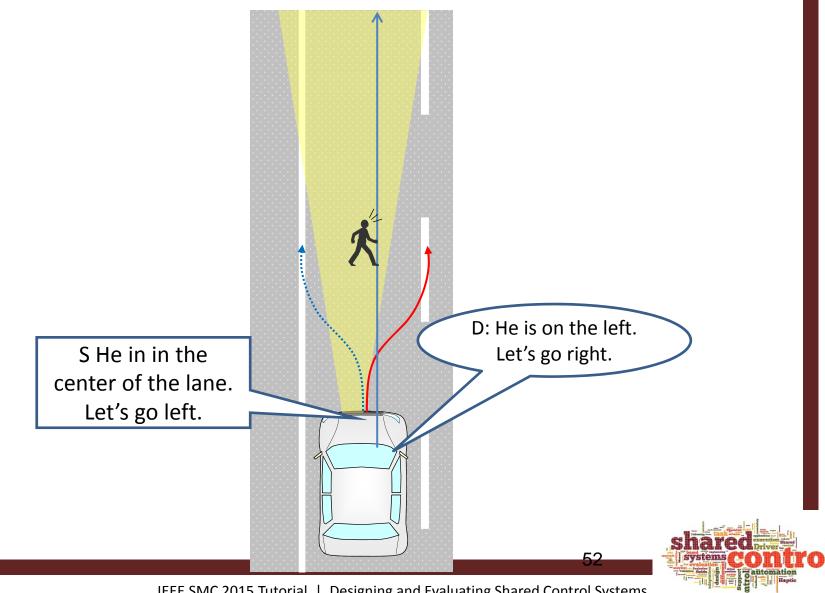




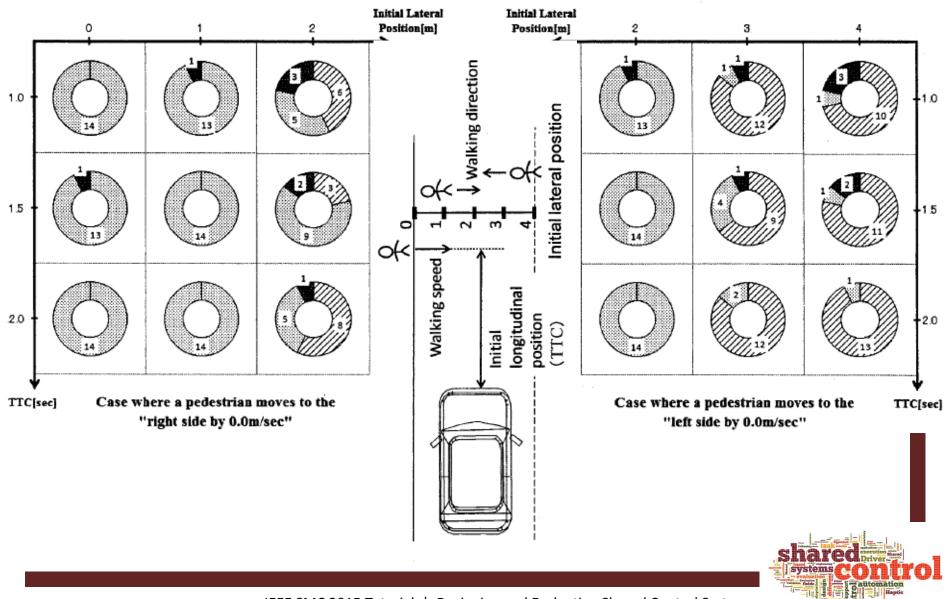
Collision avoidance system (Itoh, Horikome, Inagaki, 2014)



Conflict again: Both are correct but...



Driver's choice



Implication

Human and Machine

The situation interpretation of the driver is different from the one of the system.

The human may be right, but the human may be wrong.

Environment

The situation may change very dynamically.

Task

It could be guidance or avoidance depending on situation.

Conflicts

Depends on the level of intelligence of the system. Partly due to misunderstanding of situation, but partly because due to the difference in intention.



Part IV: Dealing with conflicts – User adaptable HSC

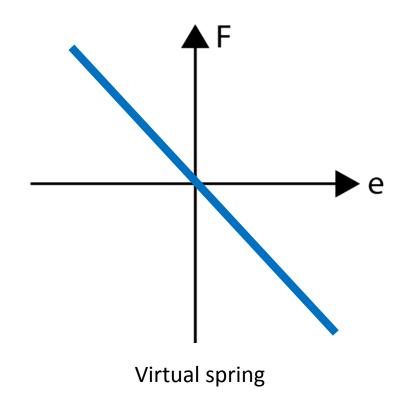
Jan Smisek

PhD candidate at Delft University of Technology Robotics Engineer at Telerobotics & Haptic lab, European Space Agency



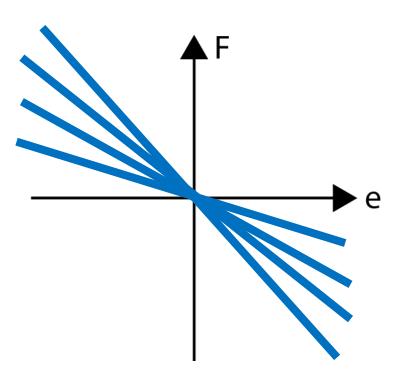
How is the authority divided?





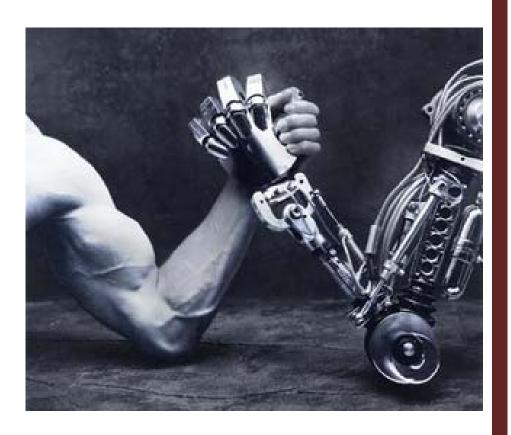


How strong should the system be?



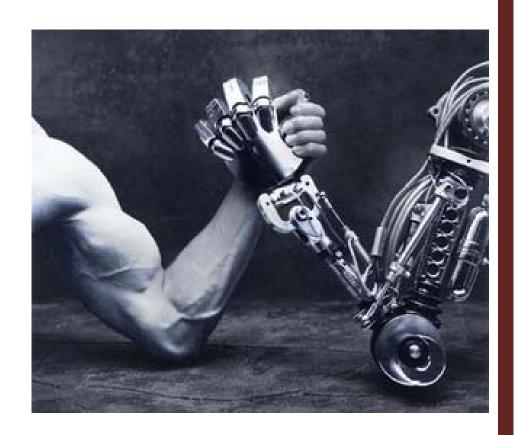


How strong should the system be?





How strong should the system be?



So how can we tell?

- Tune for performance [Lam et al. (2007), Marayong et al. (2004)]
- Tune to match human NMS [Abbink et al. (2010), Smisek et al. (2013), Sunil et al. (2014)]

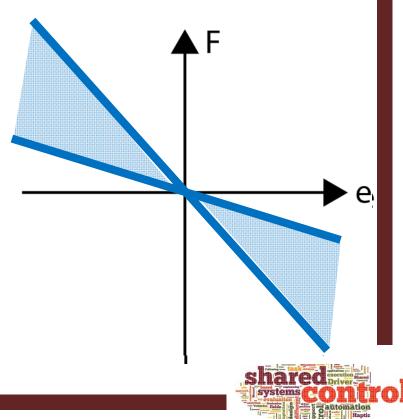


Assume that we managed to tune for a nominal situation...



Adapting HSC authority based on:

- Task performance [Passenberg et al. (2013)]
- Criticality [Lam et al. (2009)]
- Conflict between operator and HSC [Passenberg et al. (2011)]



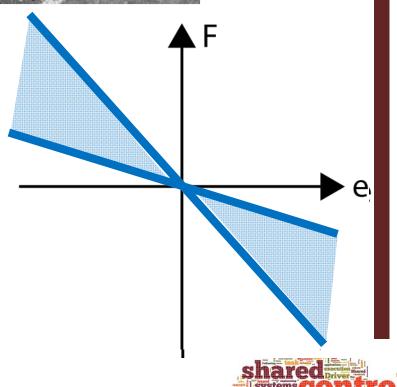
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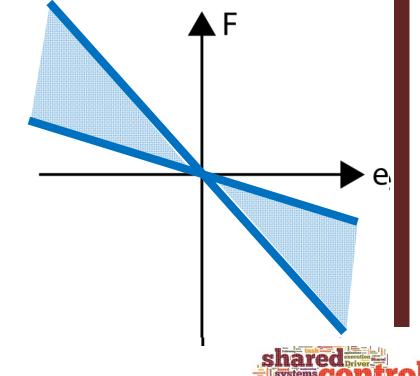


Assume that we managed to tune for a nominal situation...









Machine decides on its own authority!

Is there a natural way to change the tuning?

HSC

Operator





Is there a natural way to change the tuning?

Sign of difficulty increase support

HSC







Is there a natural way to change the tuning?

Sign of difficulty increase support

Sign of conflict decrease support

HSC

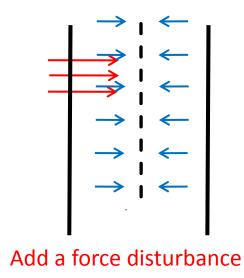
Operator



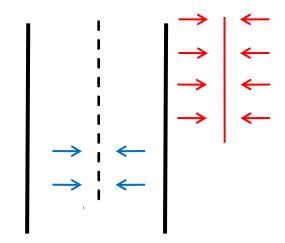


HIL study: How to evoke specific user response?

Sign of difficulty increase support



Sign of conflict decrease support

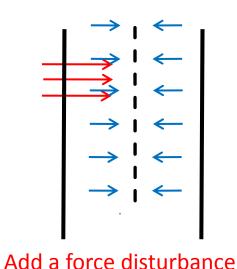


Add a reference disturbance

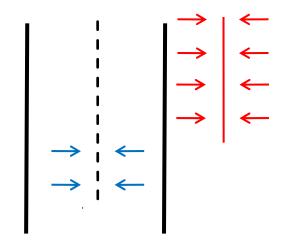


HIL study: How to evoke specific user response?

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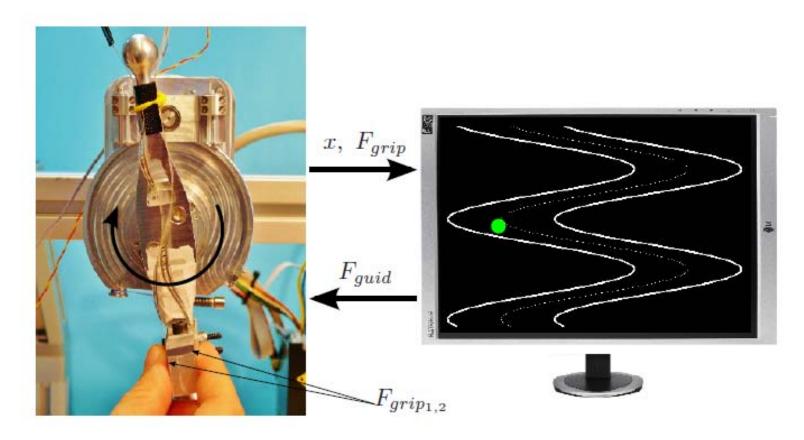


Add a reference disturbance

Two opposite HSC strategies (with increased stiffnesses increase / decrease support)



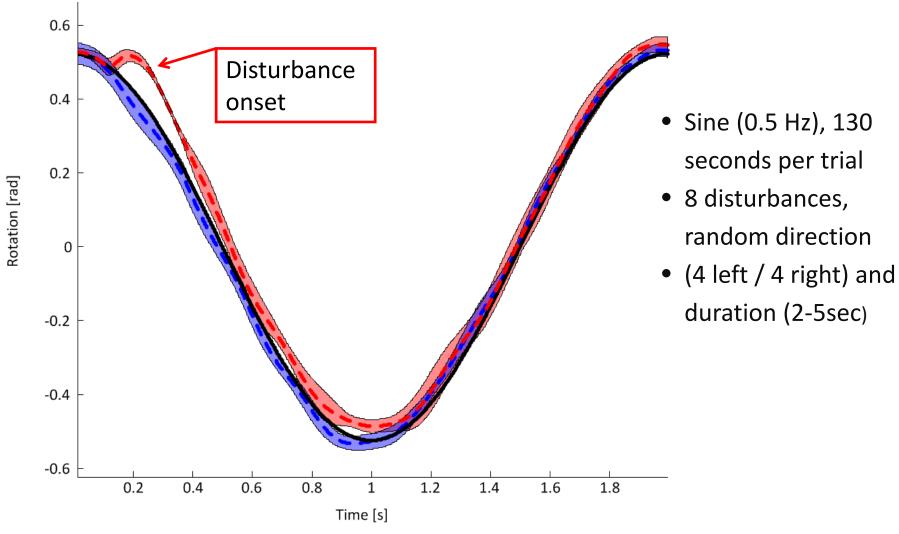
HIL study: Setup and conditions



- 1. HSC controllers $(\mathbf{G}_{increase}, \mathbf{G}_{decrease}, \mathbf{G}_{weak}, \mathbf{G}_{strong})$
- 2. Disturbances (force and reference)
- 3. Compare **performance** and **control effort**

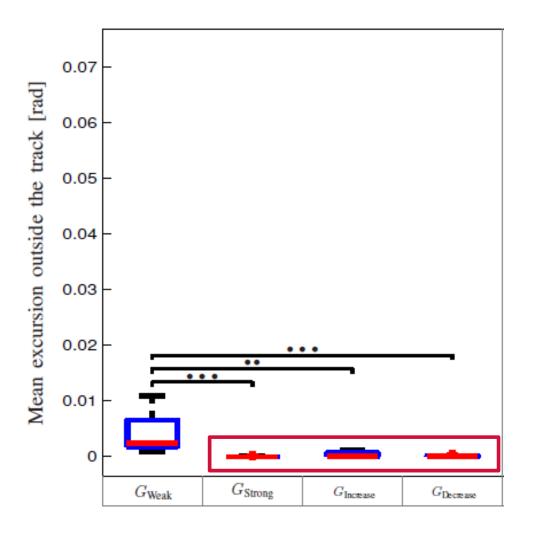


Results: Nominal vs Disturbed data





Results: Performance (mean off track error)

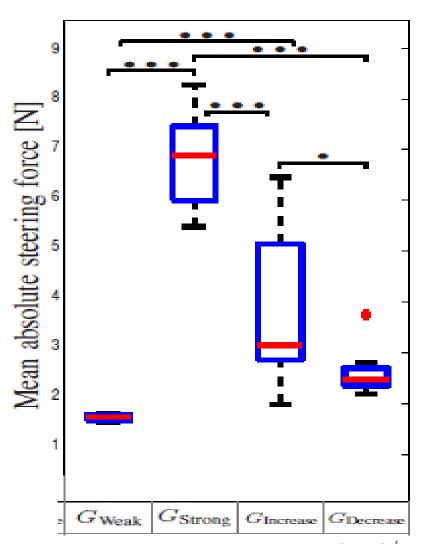


- Performance comparable wit strong guidance
- Allows improvement over "under-tuned" HSC



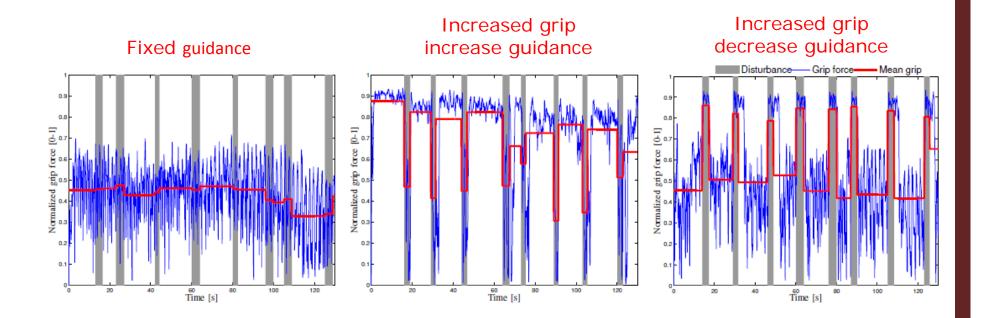
Results: Control effort (mean steering force)

- Force disturbance stronger guidance helps more
- o Reference disturbance lower effort





Results: Control effort (grip force)





Factors to consider in SC design

- Human
 Adaptability, intuitiveness
- Machine
- Environment

 Disturbances
- Task

 Guidance
- Conflicts

 Level of authority, errors in HSC





Thank you for you attention! (jan.smisek@esa.int)

Dealing with conflicts: User adaptable HSC

Jan Smisek

PhD candidate at Delft University of Technology Robotics Engineer at Telerobotics & Haptic lab, European Space Agency



TUTORIAL: Designing and Evaluating



Part IV: Robot-Assisted Surgery

Tricia Gibo

Postdoctoral Researcher at Delft Haptics Lab Delft University of Technology



Robot-assisted surgery: Motivation

Surgical procedures demand both dexterous motor and cognitive skills

Robotic systems can assist existing procedures and enable new procedures not previously possible



Strengths

Adaptable

Good judgment

Dexterous (at human scale)

Robot Accurate and precise

Resistant to radiation

Limitations

Prone to tremor and fatigue

Limited dexterity (outside natural scale)

Susceptible to radiation

Poor judgment

Limited dexterity

Howe & Matsuoka (1999)

Human



Autonomous approaches limited

- Complex procedures
- Dynamic environment
- High risk
- Low acceptance of systems



Paul et al. (1992)

Potential of human-robot collaboration

da Vinci Surgical System

(Intuitive Surgical)



Sensei Robotic Catheter System

(Hansen Medical)



Steady-Hand Eye Robot

(Johns Hopkins University)



RIO Robotic Arm

(MAKO Surgical Corp.)

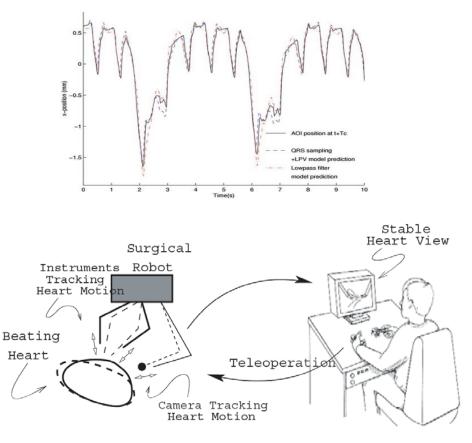


COOPERATIVE MANIPULATION

Input-mixing: Research example

Active robotic compensation of physiological motion





Riviere (2006), Gangloff & de Mathelin (2003-2008), Cavusoglu (2005-2008), Ortmaier (2005)



Haptic virtual fixtures

Software-generated forces

- Guide user through path-specified task (active)
- Prevent user from entering designated forbidden region (passive)



Rosenberg (1993), Abbot et al. (2007)



Virtual fixtures: Clinical example

Forbidden region VF based on implant shape

- Robotic precision + surgeon intuition and "feel"
- Gravity compensation + forbidden region



RIO Robotic Arm (MAKO Surgical Corp.)



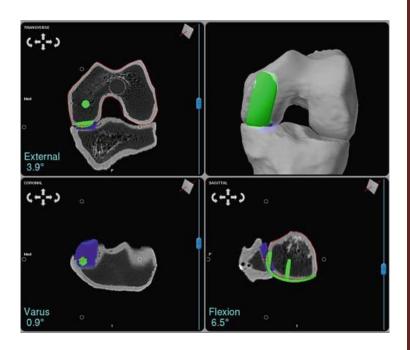


Hagag et al. (2010)



Virtual fixtures: Clinical procedure

Preoperative imaging & planning

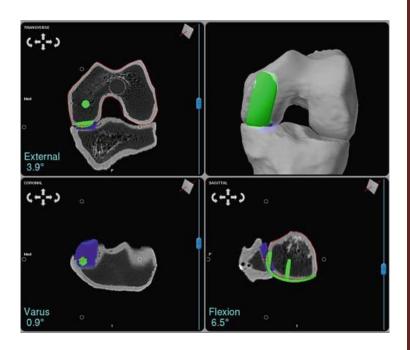


Hagag et al. (2010)



Virtual fixtures: Clinical procedure

- Preoperative imaging & planning
- Setup & registration



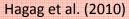
Hagag et al. (2010)



Virtual fixtures: Clinical procedure

- Preoperative imaging & planning
- Setup & registration
- Operation
 - Visual, auditory & haptic feedback
 - Automatic safety shut-off of burr





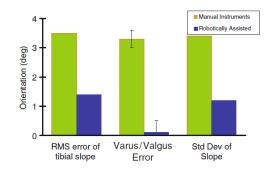


Results of unicompartmental knee arthroplasty (UKA)



Results of unicompartmental knee arthroplasty (UKA)

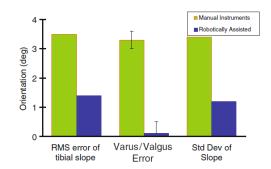
- Decreased alignment error and variance
- Lower depth of resection

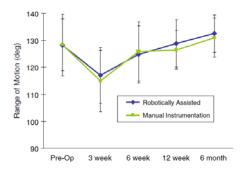




Results of unicompartmental knee arthroplasty (UKA)

- Decreased alignment error and variance
- Lower depth of resection
- More patients go home day of surgery, but no significant difference in range of motion, pain, use of assist devices
- Lower two-year revision rate

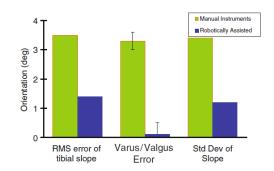


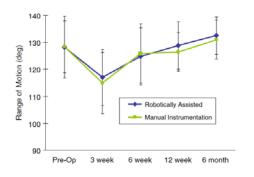


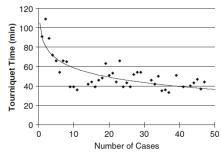


Results of unicompartmental knee arthroplasty (UKA)

- Decreased alignment error and variance
- Lower depth of resection
- More patients go home day of surgery, but no significant difference in range of motion, pain, use of assist devices
- Lower two-year revision rate
- Learning curve of approx. 14 surgeries







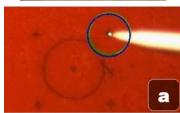


Virtual fixtures: Research examples

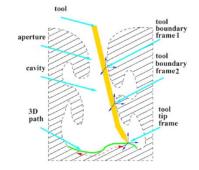
Assist challenging sensorimotor and spatial reasoning tasks:

- Protect delicate tissues
- Maneuver around intricate anatomical structures
- Control complex mappings/kinematics of robotic instruments

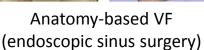


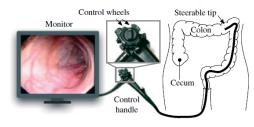


Real-time VF from microscope video (opthalmic microsurgical surgery)

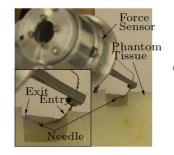








Real-time VF from endoscopic camera (colonoscopy)



VF from multiobjective constraint optimization (suturing)

Becker et al. (2013), Li et al. (2007), Reilink et al. (2011), Kapoor et al. (2005)



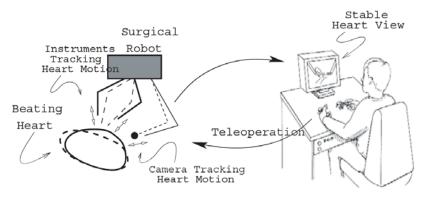
Factors to consider in SC design

- Human
- Machine
- Environment

 Variability/uncertainty
- Task

 Guidance vs. avoidance
- Conflicts

 Level of authority







TUTORIAL: Designing and Evaluating



Part V: Shared Control Evaluation

David Abbink

Associate Professor at Delft Haptics Lab Delft University of Technology



What is a good shared control system?

- Good task performance (what is task performance?)
- Good effort (what is effort?)



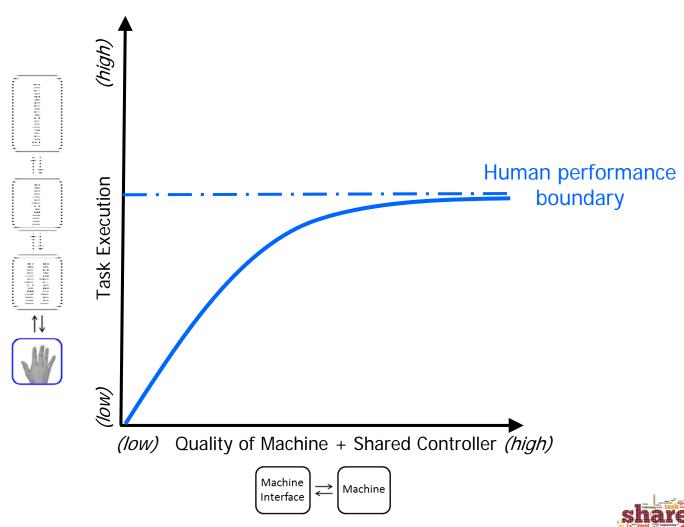
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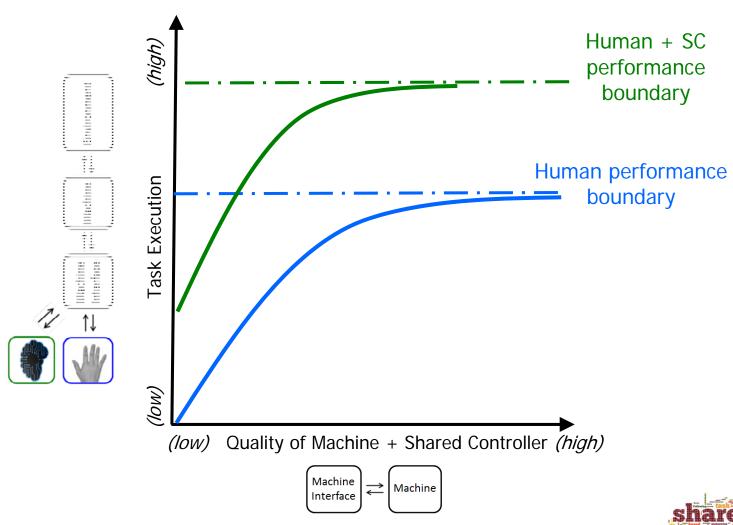
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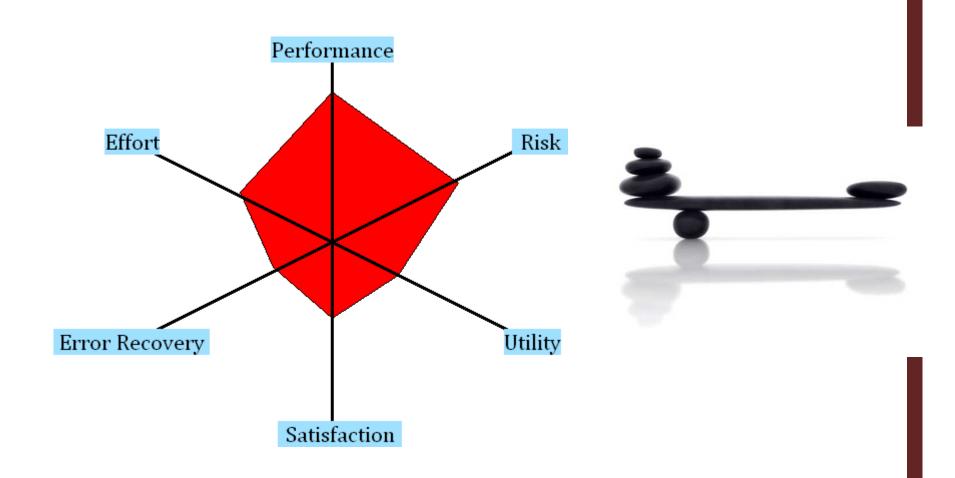
How to evaluate shared control?



How to evaluate shared control?

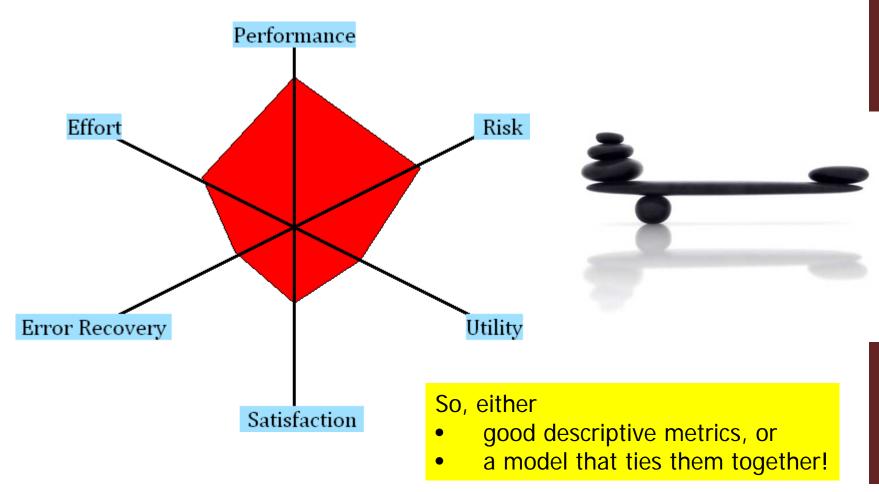


Complicating Factors - Trade-offs



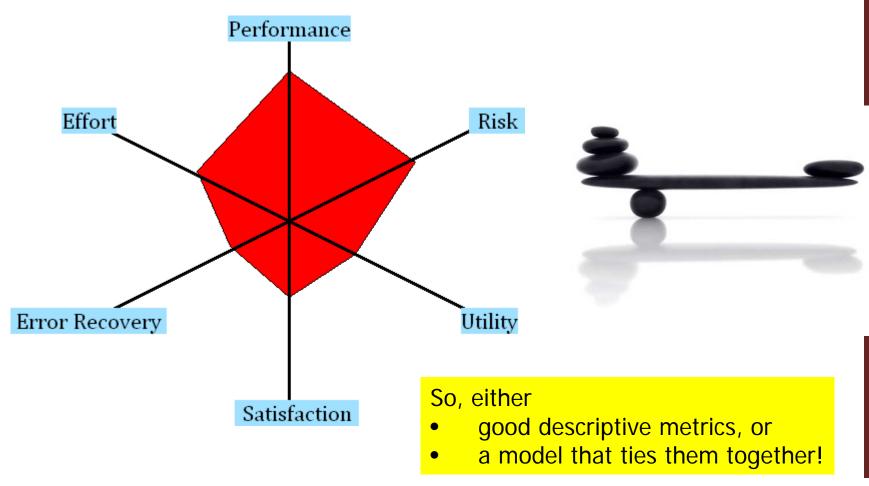


Complicating Factors - Trade-offs

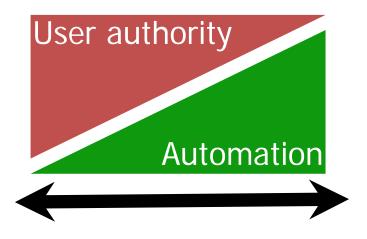




Complicating Factors - Trade-offs



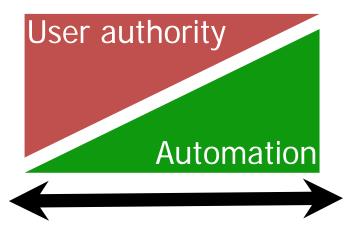






Tasks change over time

- Spatio-temporal constraints may change over time
- Shifts in authority may be required



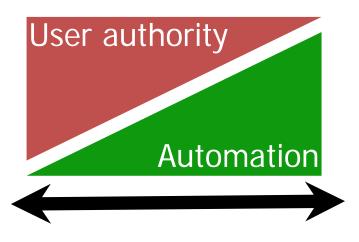


Tasks change over time

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Each user is different

- Individual skills and capabilities
- Individual needs and desires
- Indivual trade-offs





Tasks change over time

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Each user is different

- Individual skills and capabilities
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User authority Automation

Users change over time

- Individual Tolerances and Trade-offs may change over time
- Attention / motivation / perception may change over time
- Learning / adaptation / skill-loss



Complicating Factors: influence of system design

Display Augmentation

Aug environment Aug state

Aug system

System Alterations

Alter control

Alter system

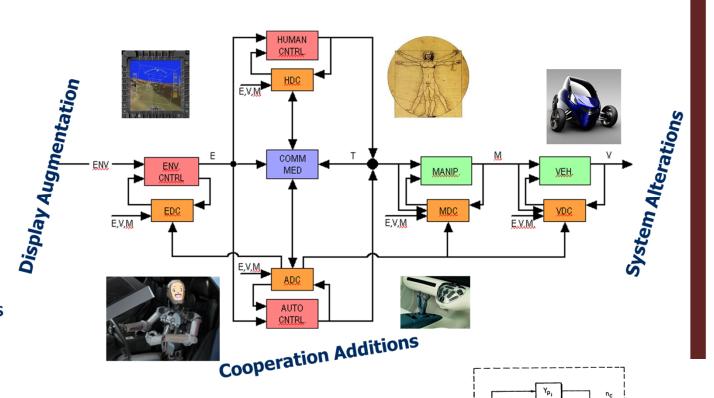
Alter feedback

Cooperation Additions

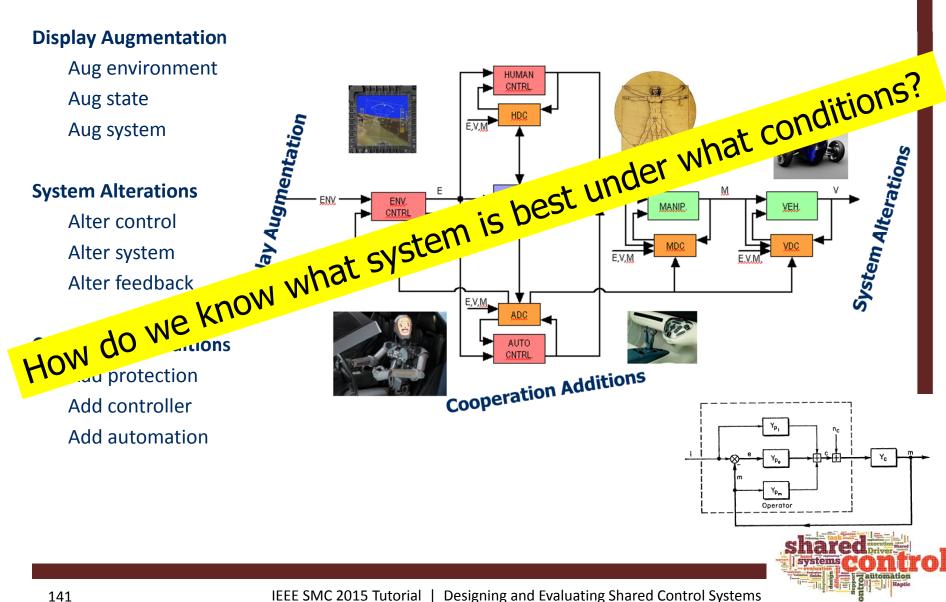
Add protection

Add controller

Add automation



Complicating Factors: influence of system design



Whose Performance? Experimentor or Participant?



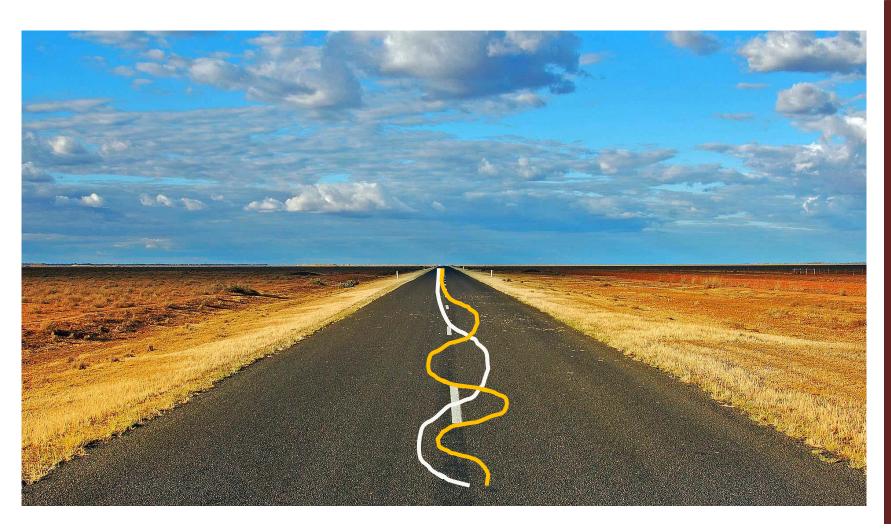


Whose Performance? Experimentor or Participant?



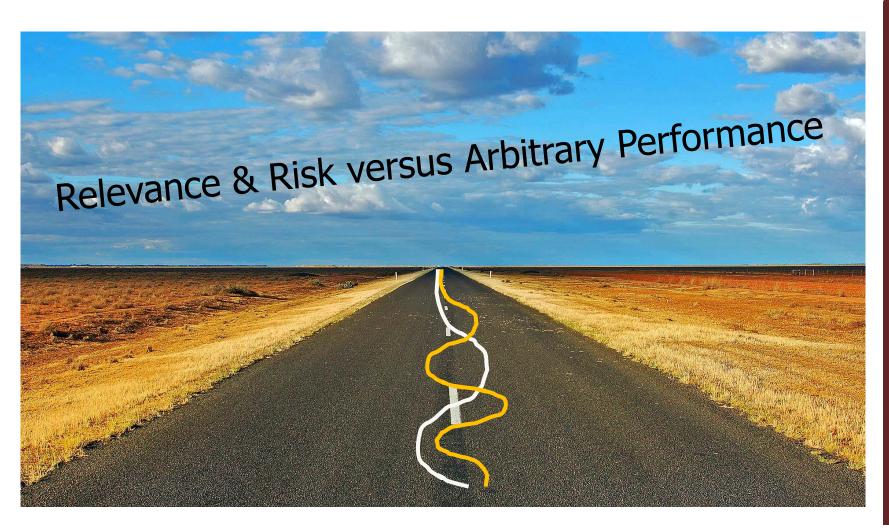


Whose Performance? Experimentor or Participant?



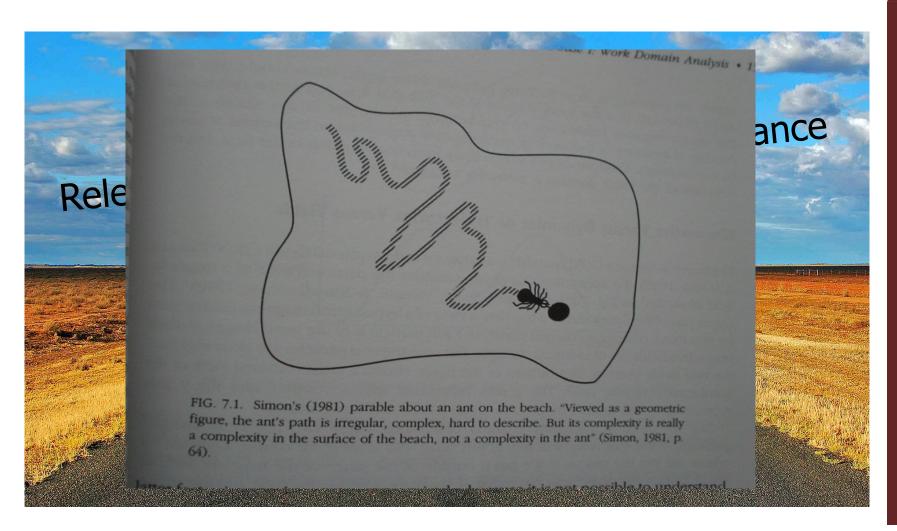


Whose Performance? Experimentor or Participant?





Whose Performance? Experimentor or Participant?

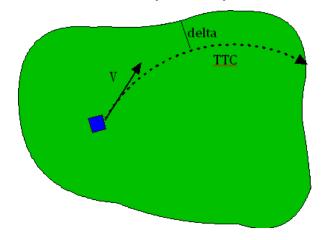




Performance is ... tolerance management?

- When task space contains relevant constraints that should not be exceeded
 - Spatio-temporal constraints
 - System dynamic constraints
- Risk can be defined as a combination of the
 - Current proximity to these constraints
 - Rate of change in this proximity

- Keep state (blue) within established boundaries (in green field).
- □ Potential Risk and Actual Risk based on V, delta, and TTC.

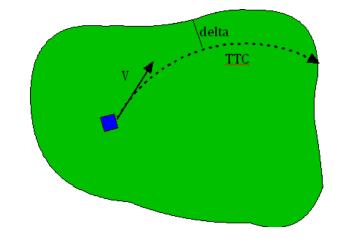




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Control activity

Mental load & visual attention



- Control activity
 - Magnitude, frequency, amount
 - Statistics of control inputs
 - Smoothness (well-matched to dynamics)
 - Steering wheel reversals
 - Physical Load
 - Forces on control interface, EMG
- Mental load & visual attention



- Control activity
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 - Not too high, not too low
 - Dual tasks
 - Eye-tracking



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 - Dual tasks
 - Eye-tracking
- Also Subjective!
 - Questionnaires
 - NASA TLX







Mulder, Abbink & Boer (2012) - Sharing Control with Haptics - Seamless Driver Support from Manual to Automatic Control - Human Factors

Tested 3 driver groups (from young and unexperienced, to old and experienced), during curve negotiation in a fixed-base driving simulator.

Goal: compare manual control, to shared control, to hands-free driving



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Performance increased

Control effort decreased

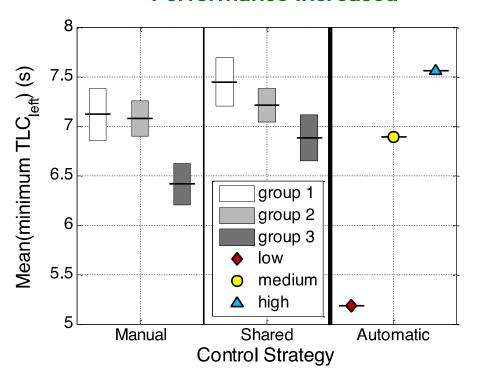


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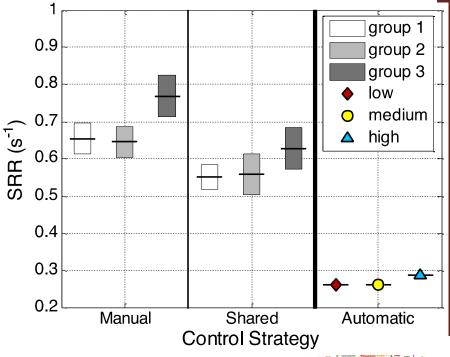
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Performance increased

8 Mean(minimum TLC_{left}) (s) 7.5 6.5 group 1 group 2 group 3 low 5.5 medium high 5 Shared Manual **Automatic** Control Strategy

Control effort decreased



Evaluation in non-nominal conditions

Method: Test automation errors of a curve negotiation support system that would fail just before the onset of a sharp curve

Conditions

with full automation (red lines) that allowed manual override

with haptic shared control (green lines)

Flemisch et al (2008)



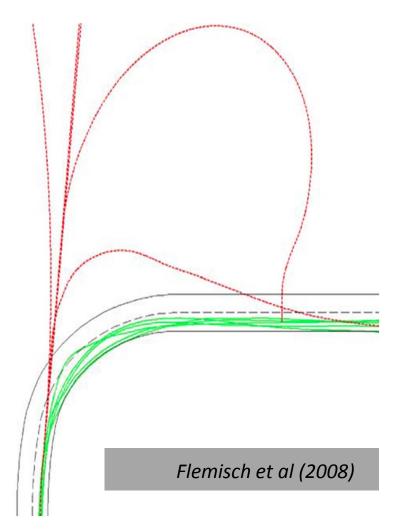
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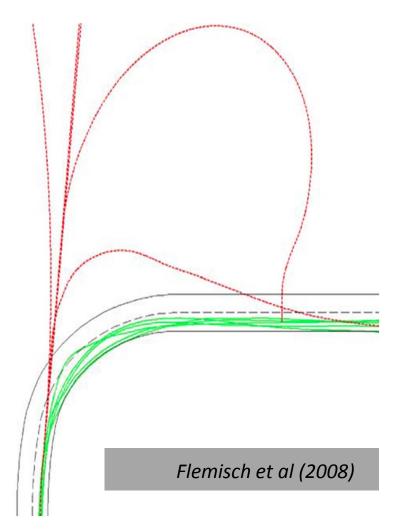
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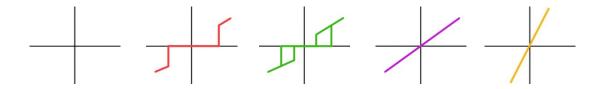
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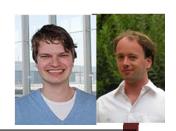


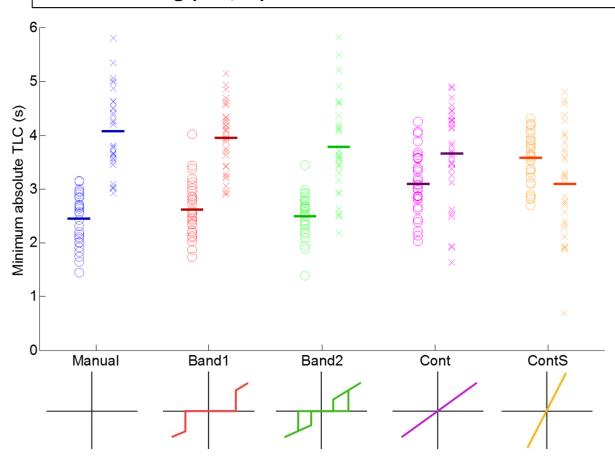






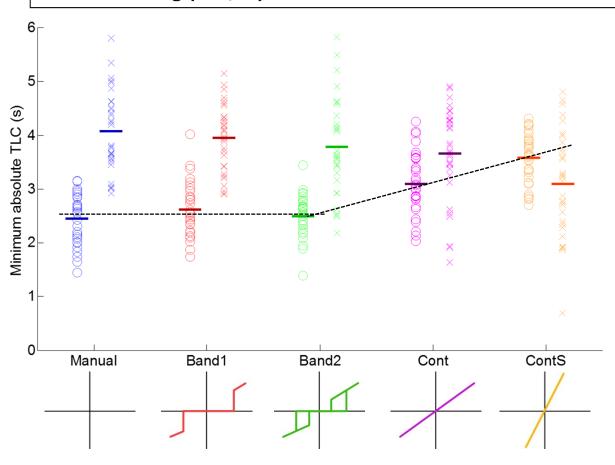




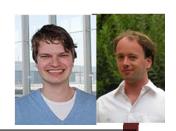


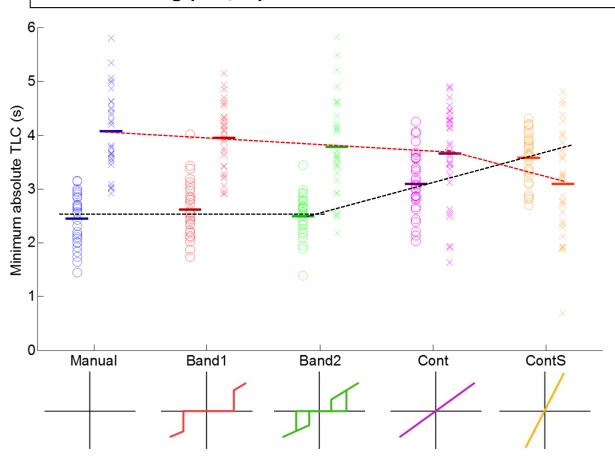








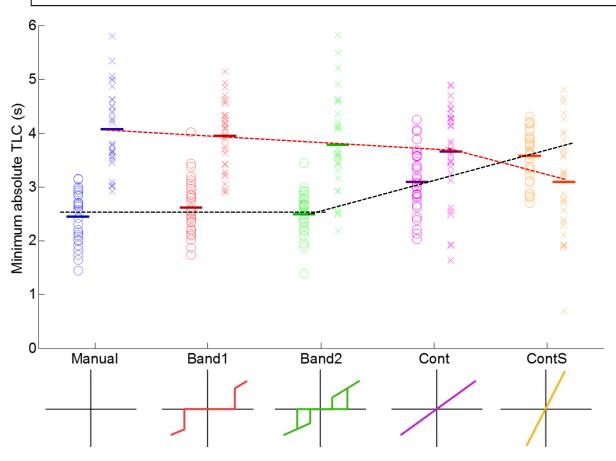








Goal: Compare 4 different HSC designs to manual control nominal driving (left,---) vs sensor failure before a curve (right,---);



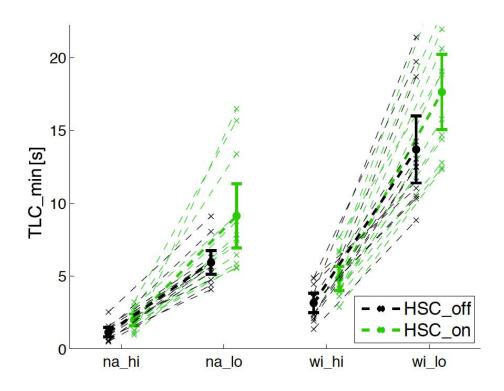


Human Factors Prize 2014

Petermeijer, Abbink, de Winter (2014) "Should drivers be operating in an automation-free bandwidth?"

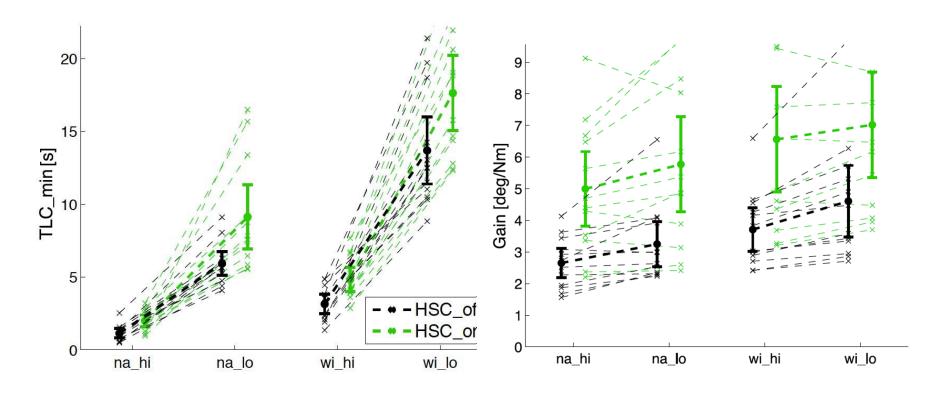


Complicating Factor - Users Adapt! - In different ways





Complicating Factor - Users Adapt! - In different ways





Adapt Shared Control Assistance

• Assess the user's cognitive state [Saeedi et al. SMC, 2012]



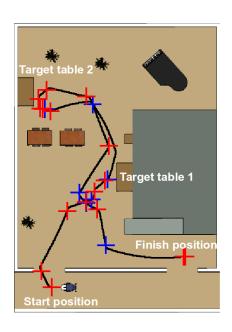
Adapt Shared Control Assistance

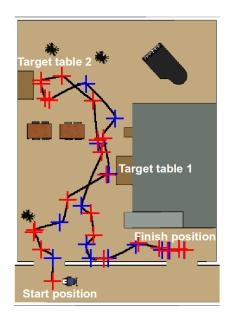
- Assess the user's cognitive state [Saeedi et al. SMC, 2012]
- Use online performance metrics
- Always provide emergency safety layer
 - > When performing **badly**, gradually **increase** assistance
 - > When performing well, gradually decrease assistance
- Define assistance modulation factor (AMF)
 - ➤ What do we usually use in the evaluation?



Online performance metrics definition

- Online performance metrics
 - > Number of blocked commands
 - Commands per metre travelled

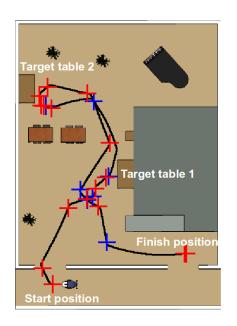


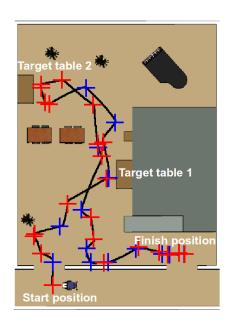


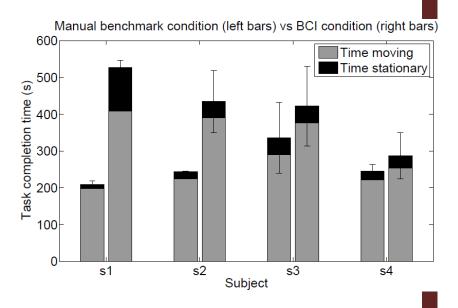


Online performance metrics definition

- Online performance metrics
 - > Number of blocked commands
 - > Commands per metre travelled
 - Ratio of time spent stationary to time moving







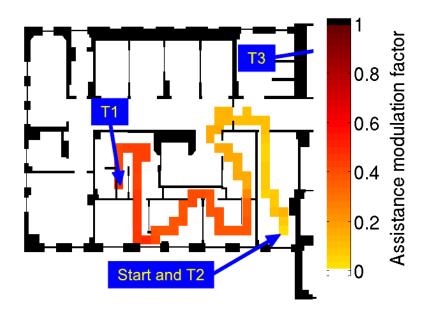
- Assistance modulation factor (AMF) is a weighted sum
- Leaky integrator



Results: AMF variation along trajectories

Driving Only

- A low level of assistance is required
- More is provided at tight parts of the trajectory





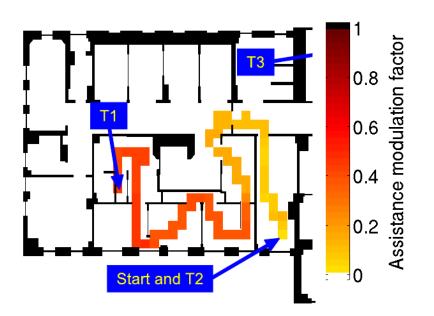
Results: AMF variation along trajectories

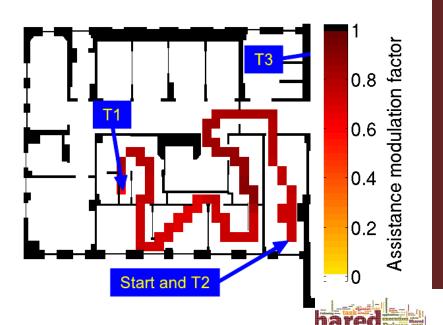
Driving Only

- A low level of assistance is required
- More is provided at tight parts of the trajectory

Driving + Secondary Task

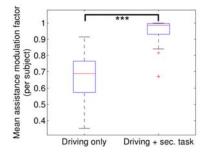
- Workload significantly increased
- Significantly more assistance is required (and provided)



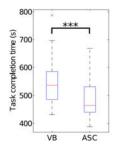


Evaluation of adaptive shared control

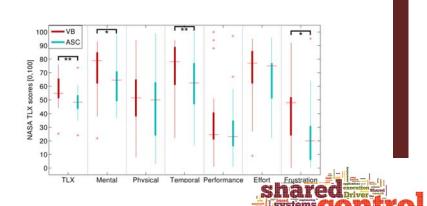
 Assistance modulation factor (AMF) indirectly captured workload



 Task performance improved with adaptive shared control (ASC)



 Participants preferred adaptive shared control (ASC)



TUTORIAL: Designing and Evaluating



Part VI: Interactive Session

David Abbink

Associate Professor at Delft Haptics Lab Delft University of Technology



Interactive Session

- Demo's (15 min)
 - Tricia's demo FF vs Stiffness communication about authority / criticality
 - Tom's demo on adaptation and secondary tasks splat the rat
- Break out (15 min) + group presentations (15 min)
 - How to realize feedback (bi-directional communication)?
 - How to deal with conflicts between user and automation?
 - How to deal with user adaptation when and how?
 - How to deal with over-dependence / de-skilling / lack of situational awareness?
- Wrap-up (David)



TUTORIAL: Designing and Evaluating



Part VII: Wrap-up

David Abbink

Associate Professor at Delft Haptics Lab Delft University of Technology



Want more?

Special Session BMI-B09: Sunday 11th 10:20-12:20

Location: AC3 6th Floor, Room 209

Topics

- How to measure and model users?
- How to assist when user and environment are not tightly coupled?
- How to deal with conflicts?

Poster Session 5: Sunday 11th, 15:10 - 16:40

Location: AC3#6/F - Pre-function Area (outside Wong Cheung Lo Hui Yuet Hall)



Want even more?

Special session on shared control:

IFAC Conference – Kyoto, Japan

Next year's special session at SMC?

IEEE SMC '16 - Budapest, Hungary



Can't get enough? Join us!

Join SMC Technical Committee on Shared Control

Come to HMS Recruitment Reception

- Free drinks and fingerfood!
- Saturday 10 October, 2015 6:30 pm 9:30 pm
 City Top Western Restaurant 9/F Amenities
 Building, City University of Hong Kong

Or sign up now!

