University of Bremen

Avoiding Mode Confusion in Service Robots

The Bremen Autonomous Wheelchair “Rolland” as an Example from Rehabilitation Robotics

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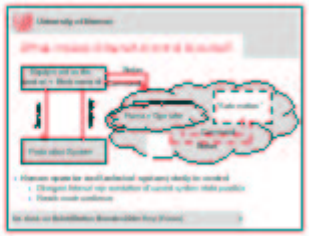
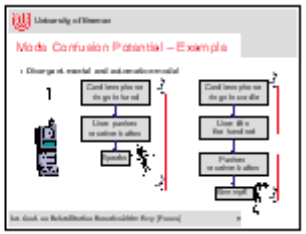
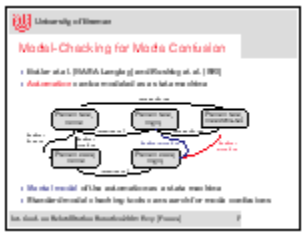
Outline of the Talk

Intro



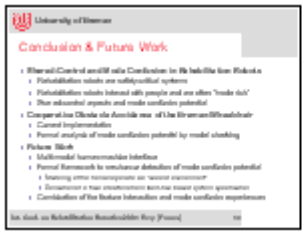
Mode Confusion





Rolland

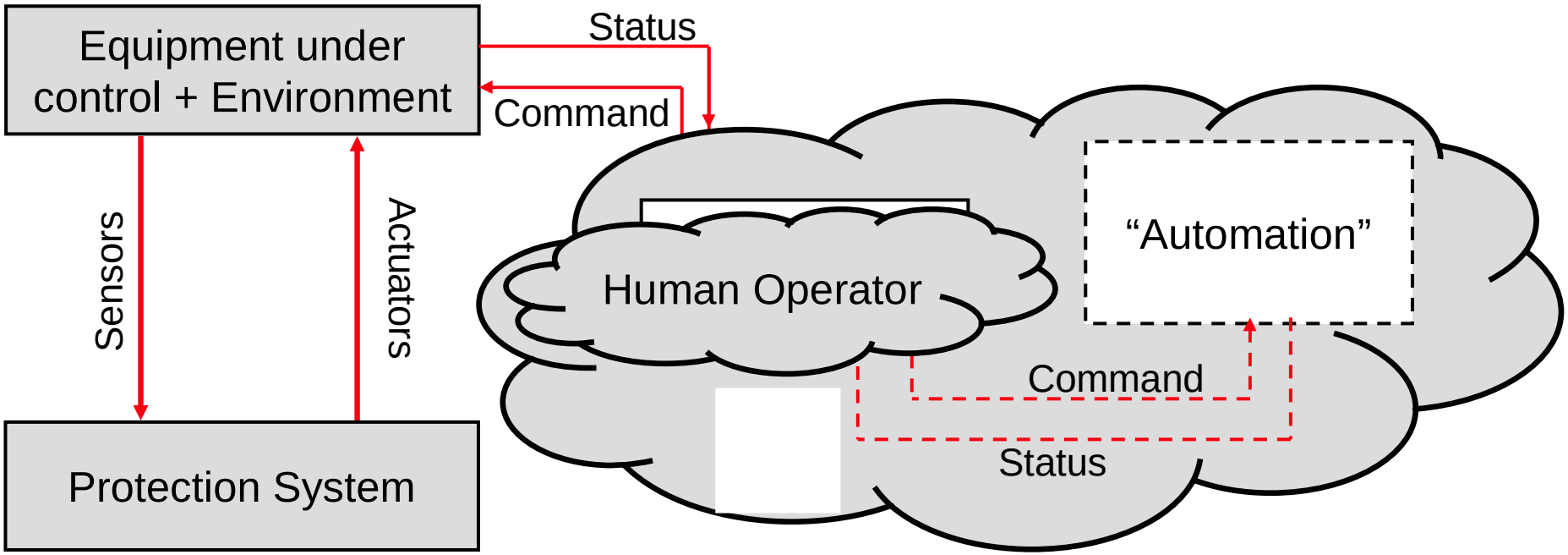
Results



Rehab-Robots: Safety-Critical Systems

- **Persons more and more depend on the machine**
  - User, e.g. the driver of a wheelchair robot
  - People in the surroundings, e.g. passengers in an airport building
- **Designing a rehabilitation robot is designing a safety-critical system**
  - Malfunctions can cause severe harm to people
  - Formal approach to design, verify and test

What makes Shared-Control Special?



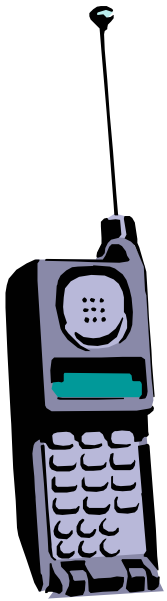
- **Human operator and technical system jointly in control**
  - Divergent internal representation of current system state possible
  - Result: *mode confusion*

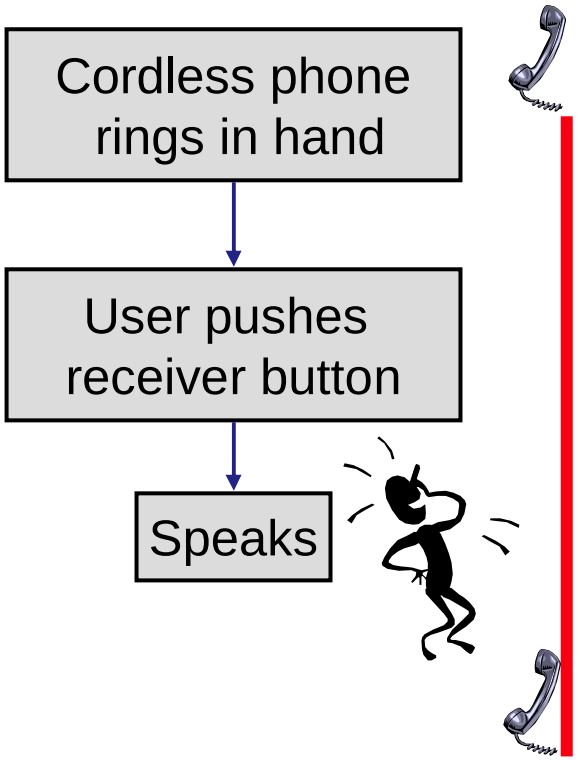
Mode Confusion

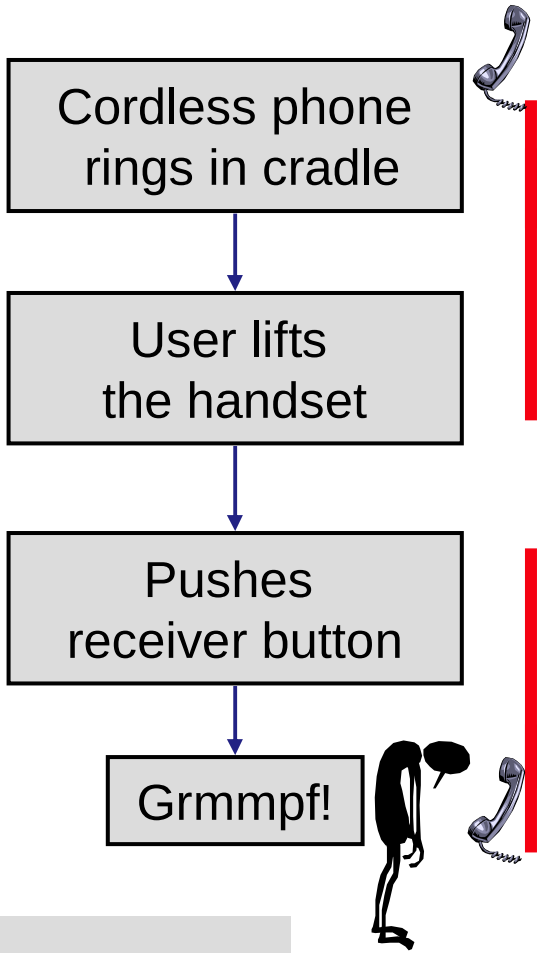
- **What and where is mode confusion**
  - Divergent assumption about current system state
  - Shared-control with varying prioritization between operator and automation
- **Primary sources for mode confusion (Butler et al., 1999)**
  - Opacity
  - Complexity
  - Incorrect mental model
- **Error categories (Leveson et al., 1997)**
  - Interface interpretation error, operator authority limit
  - Lack of appropriate feedback, indirect mode change
- **Close relation to feature interaction (Cameron et al., 1994)**
  - Checking for inconsistencies in telecommunication contexts

Mode Confusion Potential – Example

- **Divergent mental and automation model**

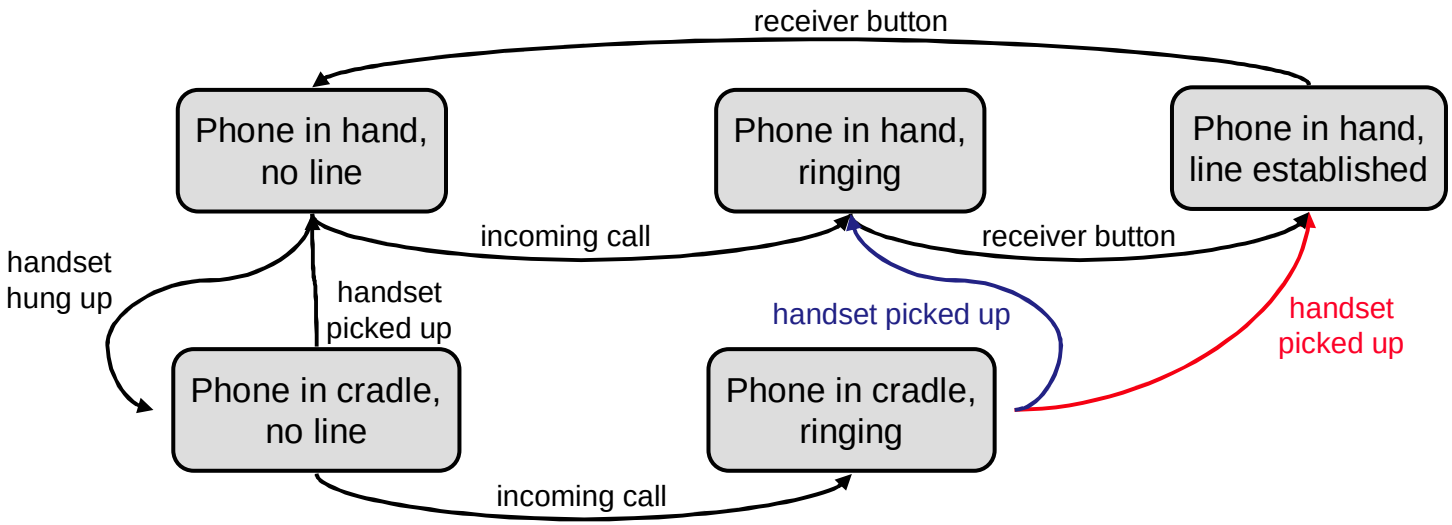






Model-Checking for Mode Confusion

- **Butler et al. (NASA Langley) and Rushby et al. (SRI)**
- **Automation can be modeled as a state machine**

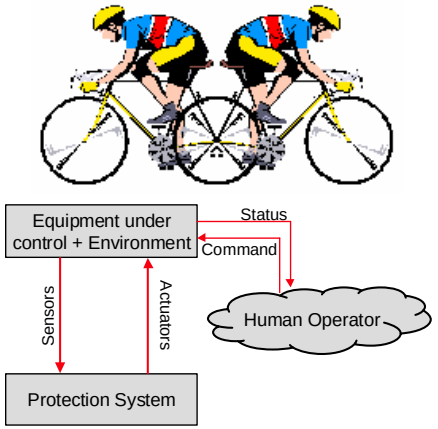


- **Mental model of the automation as a state machine**
- **Standard model checking tools can search for mode confusions**

Mode Confusion in Rehab-Robots

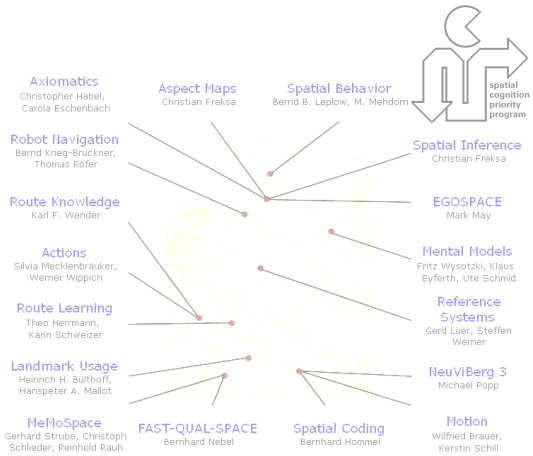
- **Human-machine interface**

- **Shared-Control**

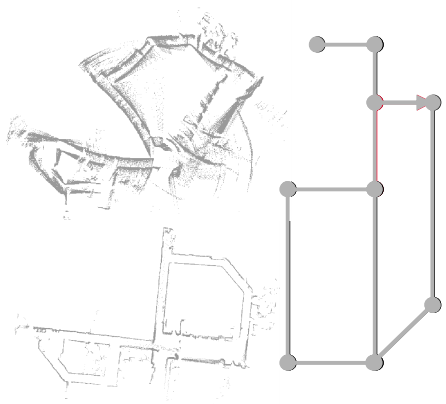


- **Adaptability to specific needs of each particular user**
- **Mode rich**
  - Making use of a variety of sensors/actuators and interfaces
  - Probably many levels of support
- **Example: Bremen Autonomous Wheelchair “Rolland”**

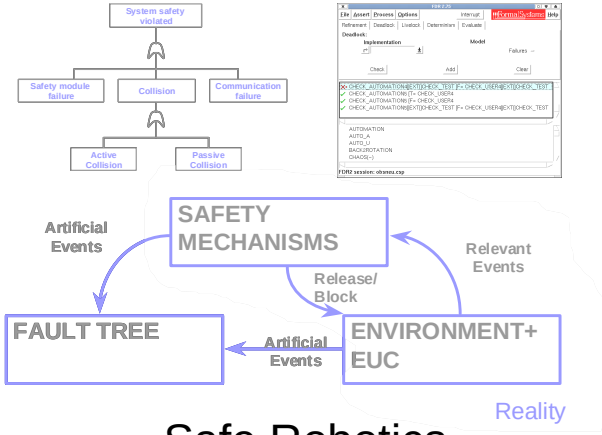
Working Group “Cognitive Robotics”



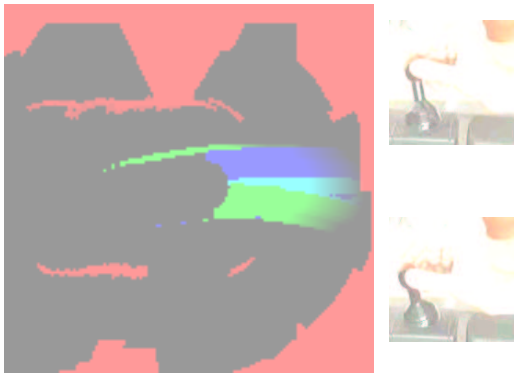
Spatial Cognition



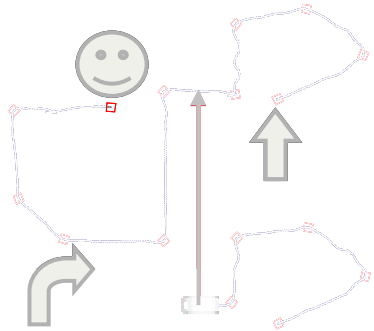
Navigation



Safe Robotics



Driving Assistant



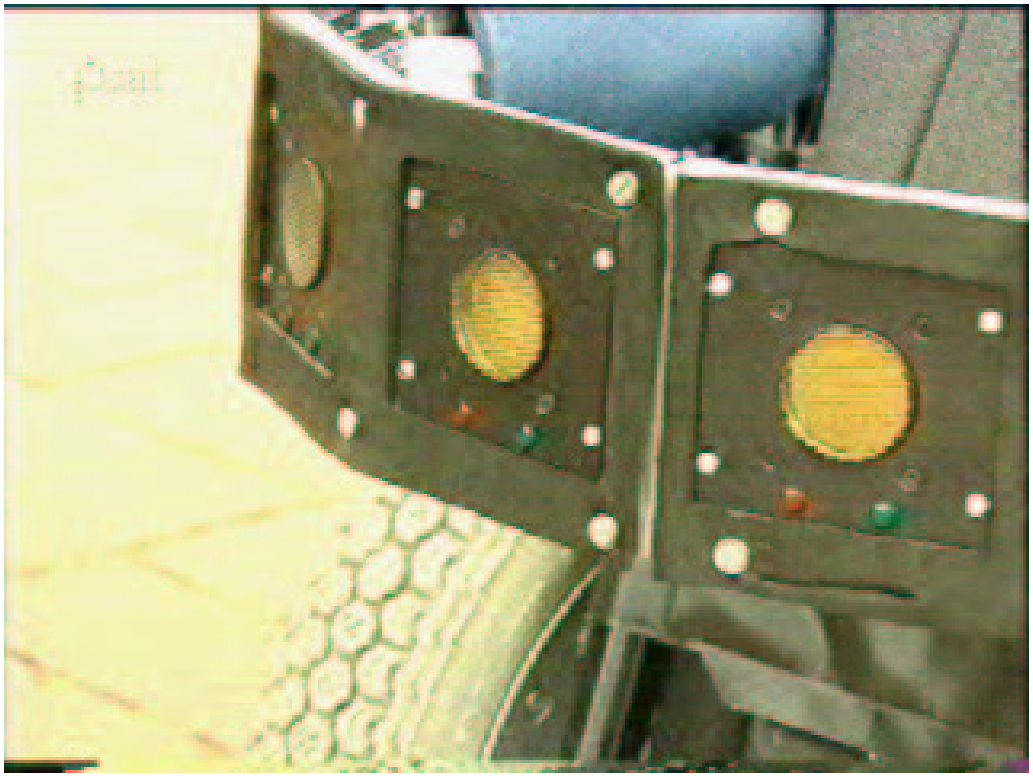
Route Assistant

Navigation Assistant

Bremen Wheelchair “Rolland”

- **The wheelchair robot**
  - Model “Genius 1.522” by Meyra
  - Maximum speed 84 cm/s
  - Communication via two serial links
- **Sensors**
  - Internal (speed/steering angle)
  - 27 sonar sensors (Nomadic)
  - SICK laser range finder
- **Computing power**
  - Industrial-PC (Pentium III 600)
  - QNX (real-time OS)

Cooperative Obstacle Avoidance



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Analysis I - Modeling

- **Specification of both models in CSP (Hoare, 1985)**

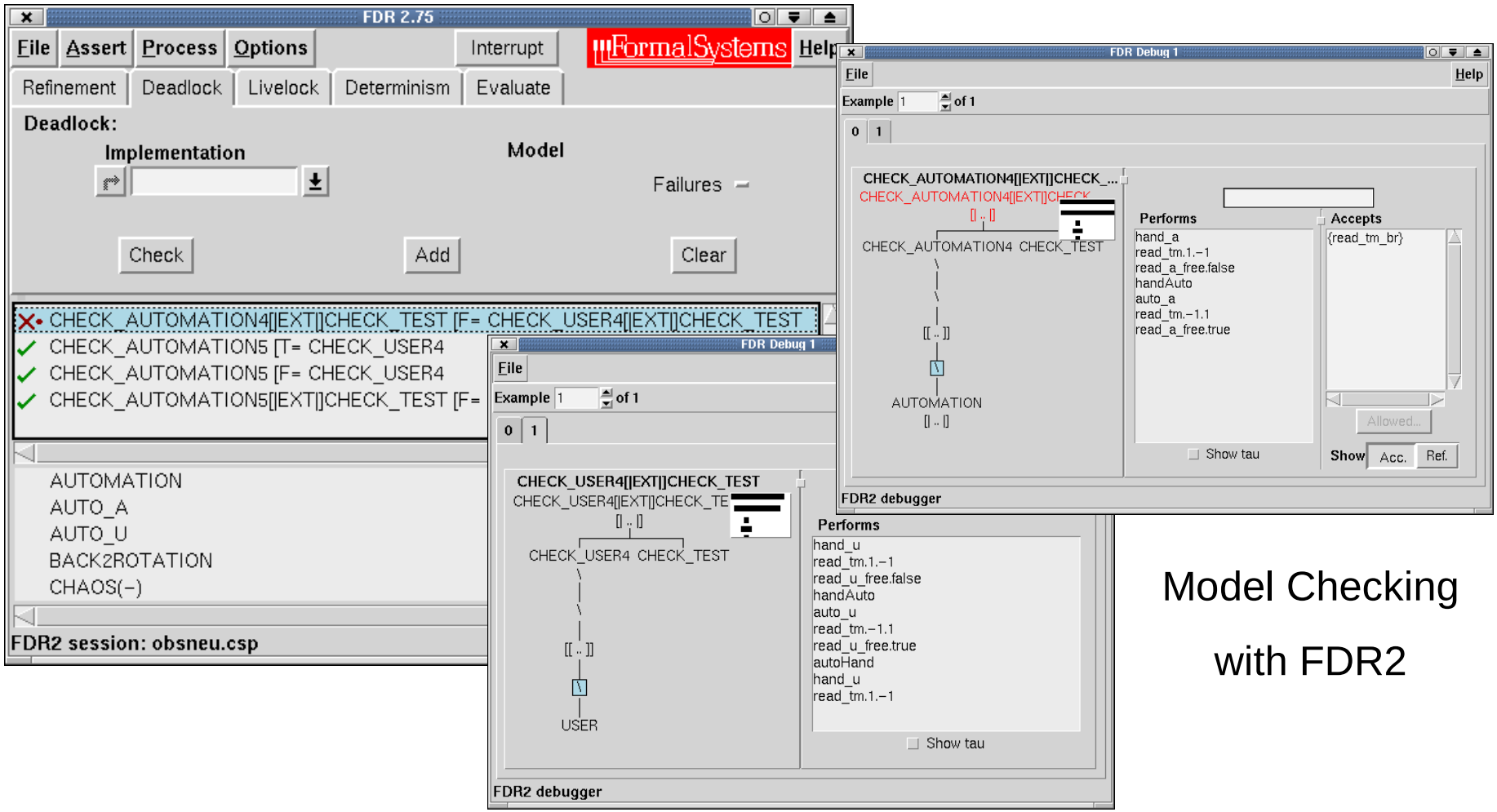
USER

```
HAND_U = hand_u -> read_tm?v_t.r_t ->
       if (v_t == 0) then
         handStop -> STOP_U
       else
         read_u_free?free ->
         if (free == true) then
           HAND_U
         else
           handAuto -> AUTO_U
```

AUTOMATION

```
HAND_A = hand_a -> read_tm?v_t.r_t ->
       if (v_t == 0) then
         handStop -> STOP_A
       else
         read_a_free?free ->
         if (free == true) then
           frameTick -> HAND_A
         else
           writeOriginalRadius!r_t ->
           readCurrentOrientation?co ->
           writeTargetOrientation!co ->
           handAuto ->
           AUTO_A
```

Analysis II - Divergence Check



Model Checking with FDR2

Conclusion & Future Work

- **Shared-Control and Mode Confusion in Rehabilitation Robots**
  - Rehabilitation robots are safety-critical systems
  - Rehabilitation robots interact with people and are often “mode rich”
  - Shared-control aspects and mode confusion potential
- **Cooperative Obstacle Avoidance of the Bremen Wheelchair**
  - Current implementation
  - Formal analysis of mode confusion potential by model checking
- **Future Work**
  - Multi-modal human-machine interface
  - Formal framework to mechanize detection of mode confusion potential
    - *Modeling of the human operator as “second environment”*
    - *Derivation of critical situations from fault-tree based system specification*
  - Integration of the feature interaction and mode confusion experiences

For details, references, demos,
(these) slides, jobs, etc.,

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