Modeling Decision Making on the Use of Automation

Junya Morita (JAIST, Japan), Kazuhisa Miwa, Akihiro Maehigashi, Hitoshi Terai (Nagoya University, Japan), Kazuaki Kojima
(Waseda University, Japan), Frank E. Ritter, (Penn State, USA)

Goal: construct a model that makes decision of using an automation system through interaction with a task environment

Result: success to simulate the use of automation with the utility update mechanism of ACT-R

1. Background

- Ironies of Automation (Bainbridge, 1983)
  - Machines will not completely substitute for human cognition even if it is highly developed
  - Monitoring and decision making about automation using are always needed
- Irrationality of automation using (Parasuraman & Riley, 1997)
  - Over-trust: A tendency to trust too much in automation
  - Distrust: A tendency to trust too little in automation
- Need to understand the process of decision making about automation using

2. Previous study - Extended Decision Field Theory

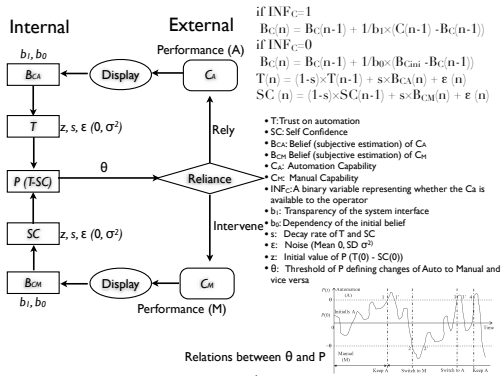
Extended Decision Field Theory (EDFT model)

- Reliance of automation is determined by the relation between self-confidence (SC) and trust (T)
- T and SC dynamically changes in cyclic computation reflecting Capabilities of auto (Ca) and manual controls (Cm)

Limitations: Abstract mathematical model

- No interaction with a task environment
- No prediction of human performance

Gao, J., & Lee, J. D. (2006). Extending the decision field theory to model operators' reliance on automation in supervisory control situations. IEEE Transactions on Systems Man and Cybernetics, 36 (5), 943-959.



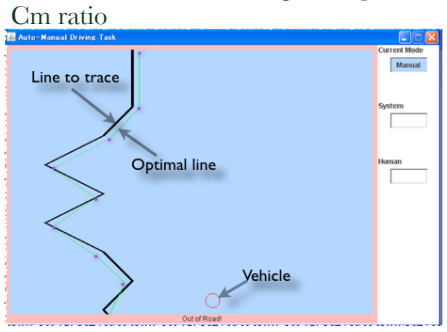
$$\text{if } INF_C=1:\ B_C(n) = B_C(n-1) + 1/b_1\times(C(n-1) - B_C(n-1))$$
$$\text{if } INF_C=0:\ B_C(n) = B_C(n-1) + 1/b_0\times(B_{Cini} - B_C(n-1))$$
$$T(n) = (1-s)\times T(n-1) + s\times B_{CA}(n) + \varepsilon(n)$$
$$SC(n) = (1-s)\times SC(n-1) + s\times B_{CM}(n) + \varepsilon(n)$$

- T: Trust on automation
- SC: Self Confidence
- B_{CA}: Belief (subjective estimation) of C_A
- B_{CM} Belief (subjective estimation) of C_M
- C_A: Automation Capability
- C_M: Manual Capability
- INF_C: A binary variable representing whether the Ca is available to the operator
- b_1: Transparency of the system interface
- b_0: Dependency of the initial belief
- s: Decay rate of T and SC
- ε: Noise (Mean 0, SD σ^2)
- z: Initial value of P (T(0) - SC(0))
- θ: Threshold of P defining changes of Auto to Manual and vice versa

3. Task - Line tracing task

- Two modes of control
  - Manual mode: An operator presses the left and right arrow keys to move the vehicle
  - Auto mode: An automation system moves the vehicle
- Changing modes: Press the space bar
- Capability of auto / Capability of manual
  - Ca and Cm are success rates of control (keys do not always work)

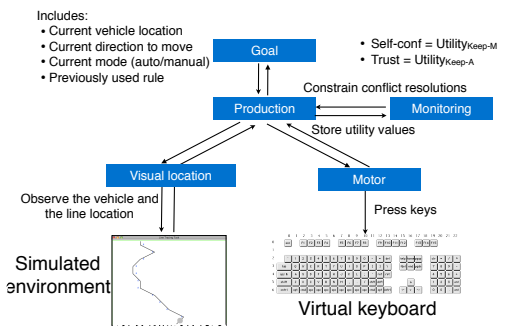
An artificial task for manipulating Ca/Cm ratio



4. Model

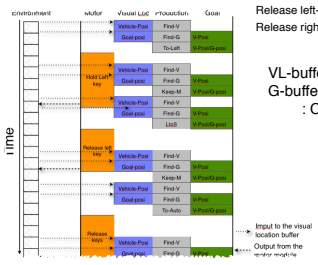
4.1 Architecture

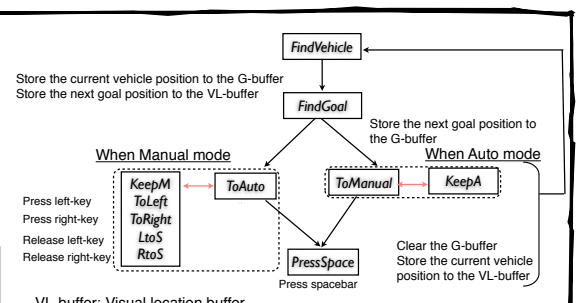
- Implementation of the EDFT model in ACT-R 6 architecture
- Visual and motor modules allow the model to interact with a simulated task environment
- Trust and Self confidence are represented as utilities of productions in ACT-R architecture



4.2 Productions

- 11 productions consist perceptual and motor cycle
- The delays in perceptual and motor modules causes manual disadvantages

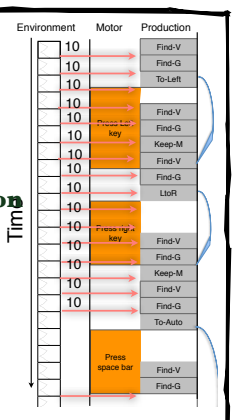




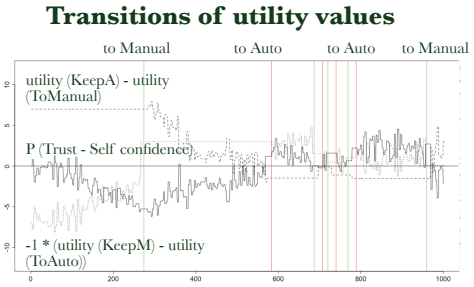
4.3 Learning and decision

- Reward triggers
  - Every screen updates except during mode switches (from firing ToAuto/ToManual until finishing key press)
  - All rules fired since previous trigger receive rewards
- Reward values
  - When the vehicle is on the line: 10
  - When the vehicle is off the line: 0
- Initial utility values
  - KeepM, ToLeft, ToRight, LtoS, RtoS, KeepA: 10
  - ToManual, ToAuto: 3
- The utility values of mode switching correspond the threshold in the EDFT model

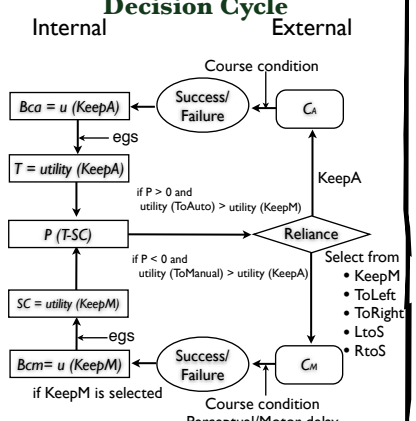
Gaps between rewards and production



Transitions of utility values

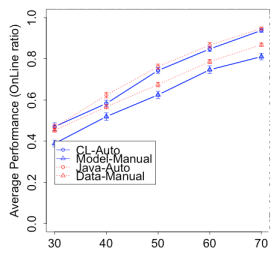


Decision Cycle



5. Baseline Simulation

- Model
  - Run the auto mode in the simulated task environment (100 runs)
  - Run the manual mode model in the simulated task environment (100 runs)
- Data
  - Run the auto mode in the actual task environment (65 runs)
  - Participants executed the task only with manual mode (n = 65)
- Performance increases with higher Ca / Cm levels
  => Confirms the manipulations
- The auto controls are better than the manual controls
  => Confirms human factors



[Auto] r2 = .994, [Manual] r2 = .996

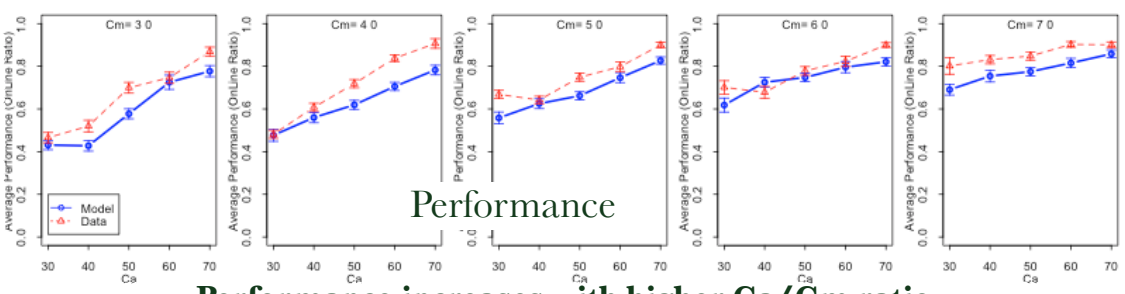
6. Simulation of the use of automation

- Aim
- To simulate the choice of the auto mode
- Variables
  - 5 levels of Ca (30-70) × 5 levels of Cm (30-70)
- The model and the participants could chose the auto or manual mode during the task

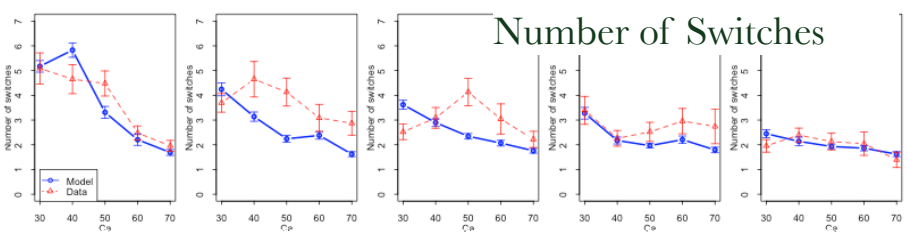
Ca \ Ca	30	40	50	60	70
30	40 sec	40 sec	40 sec	40 sec	40 sec
40	40 sec	40 sec	40 sec	40 sec	40 sec
50	40 sec	40 sec	40 sec	40 sec	40 sec
60	40 sec	40 sec	40 sec	40 sec	40 sec
70	40 sec	40 sec	40 sec	40 sec	40 sec

× 50 runs in random order [model]

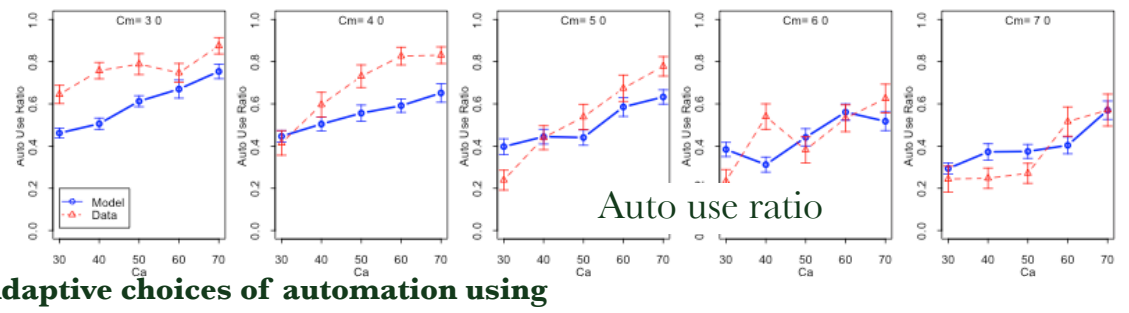
× 23 participants in random order [data]



Performance increases with higher Ca/Cm ratio



Decrease with Ca / Cm levels



Adaptive choices of automation using
Increase with increase of Ca level / Decrease with increase of Cm level

Significance

- ACT-R modeling of time critical field (include meta-level decision making)
- Predict Performance (Performance and decision interact with each other)