Designing Safe and Robust Human-machine Interactions with Fuzzy Mental Models


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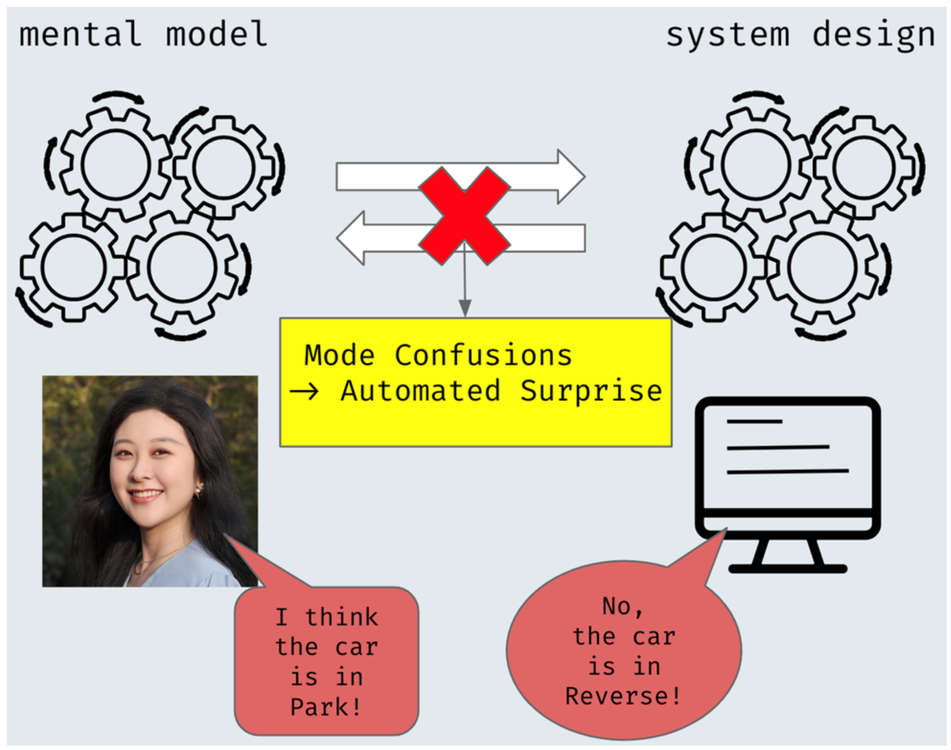
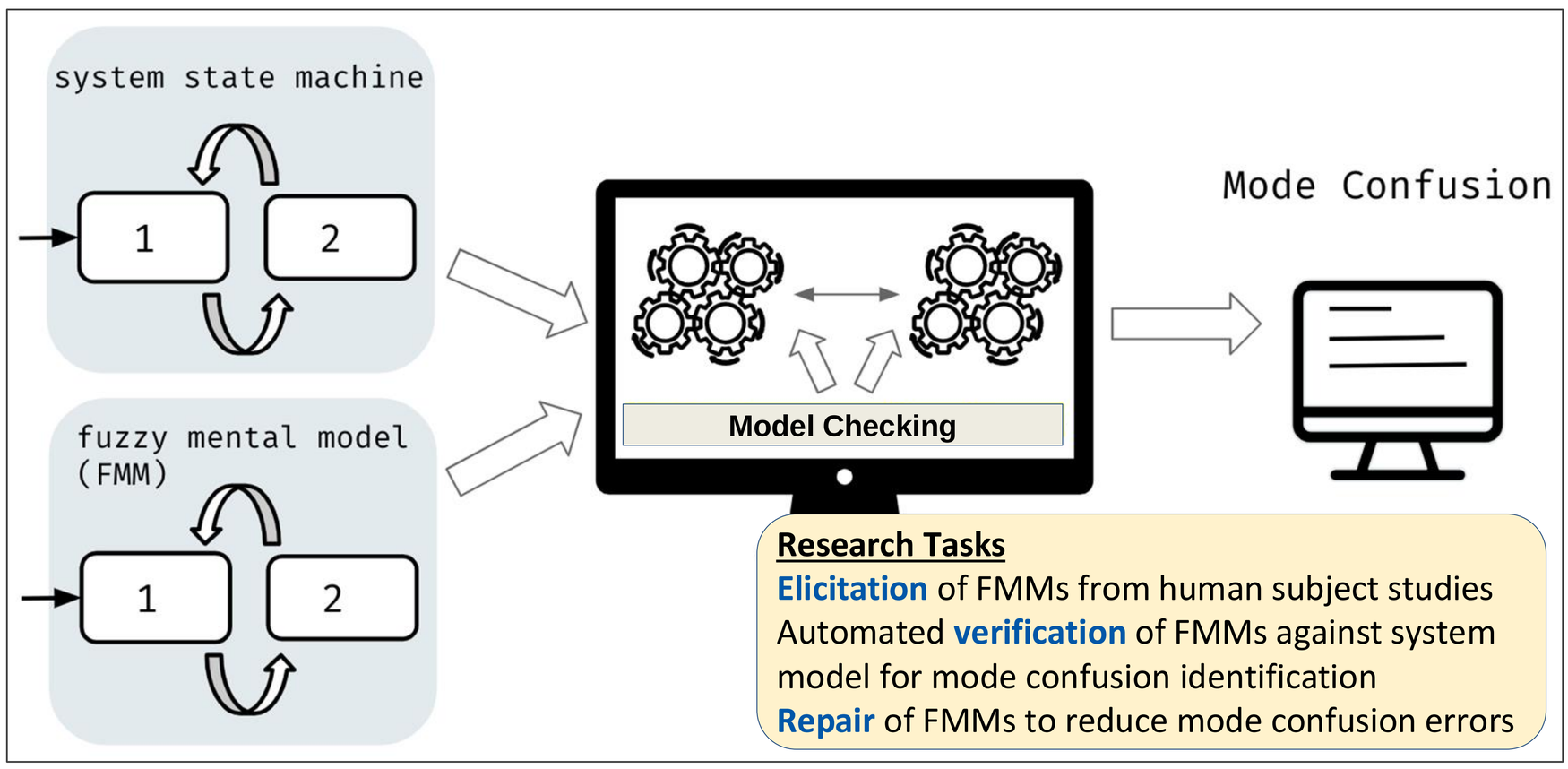
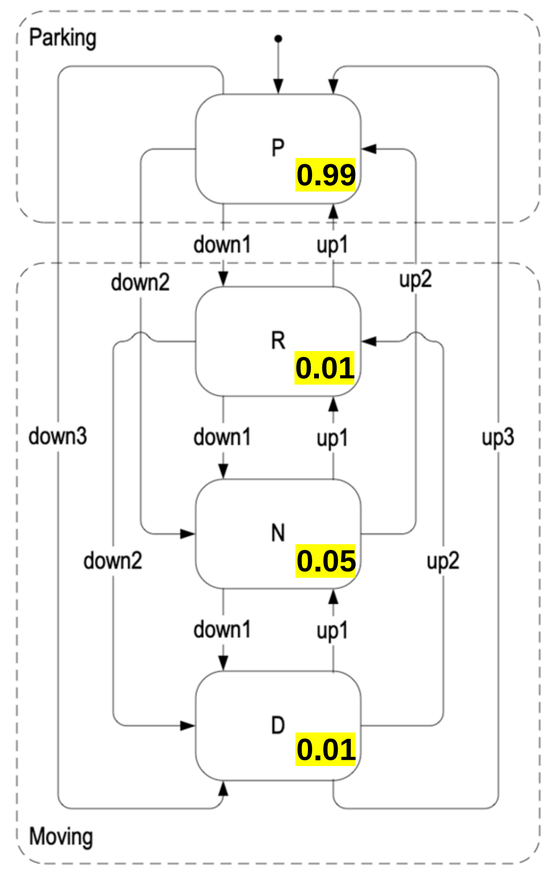


Mode Confusions in Human-Machine Interfaces

- Humans use a **mental model** to keep track of the system state and predict the effect of an action
- Mismatch between mental model vs. system design can cause **mode confusion errors**
- Prior works: Modeling & verification of mental models as finite state machine (FSMs)
- Conventional FSMs fail to capture **vagueness** in human cognition and errors that arise from it





Approach: Fuzzy Mental Model State Machines (FMMs)

- **Fuzzy logic**: Degree of memberships (DoM) between 0 to 1
- **States**: A vector of membership degrees in possible states
- **Transitions**:
  - Input action & resulting state both fuzzified into DoM vectors
  - Compute the next state DoM vector through fuzzy operations
- **Mode confusion error types:** Conditions over **(DoM vector, actual system state)**
  - **Dominant error state**: State with highest DoM ≠ system state
  - **Non-deterministic state confusion** Multiple states with DoM > threshold
  - **Vacuous state confusion**: No states with DoM > threshold

Case Studies: Gear shifters, cruise control, aviation interfaces, medical devices

Scientific Impacts

- **Formal methods**: New techniques for verification & repair with fuzzy logic
- **Human factors**: New methods for modeling human errors due to vagueness; catalog of mode confusion errors and design guidelines

Broader Impacts

- **Society**: Reduce human errors and accidents in safety-critical systems
- **Education**: Support for multiple PhD and REU students from underrepresented groups