Adaptive User-centered Neuro-symbolic Learning for Multimodal Interaction with Autonomous Systems

Amr Gomaa, Michael Feld
amr.gomaa@dfki.de, michael.feld@dfki.de
German Research Center for Artificial Intelligence (DFKI)
& Saarland Informatics Campus (SIC), Germany

Overview & Methodology

- **Problem**: Existing machine learning-based autonomous systems perceive and comprehend objects and their environments in a perceptual subsymbolic manner (i.e., a mostly data-driven approach)
- **Proposed Solution**: Use a hybrid learning approach that combines both symbolic and subsymbolic learning to allow autonomous systems to understand objects and their environments more conceptually and symbolically through explicit and implicit feedback (see Figure 1).

Research Questions

- **Agent World View (RQ1):** Which features of the agent (i.e., autonomous system) and the context (i.e., human behavior) can be used to detect and classify user interaction situations, and which devices are available to provide them efficiently (e.g., investigating user behavior as in [1])?
- **Multimodal Interaction (RQ2):** What aspects of system and interface design can be utilized of the given modalities in terms of fusion techniques, temporal dependencies, and learning models to achieve optimal performance (e.g., reference detection as in [2] and estimation of mental workload in [3, 4])?
- **Neuro-symbolic Adaptation and Continual Learning (RQ3):** How can the system adapt to the performance of user-specific tasks [2, 4]? How can the system be designed to continuously gather feedback from the user (both implicitly and explicitly) to guarantee constant development and enhancement of the underlying algorithms? How would that affect the system's reliability and user trust?

Approach

- Select the right level of granularity and fusion of subsymbolic data (e.g., sensors) to combine with symbolic prior knowledge (e.g., through clustering) **(RQ1)**.
- Investigate several input and output channels to achieve optimal interaction performance through continuous user monitoring **(RQ2)**.
- Utilize existing lifelong learning approaches (see Figure 2), such as transfer learning, incremental learning, and online learning techniques, to continuously adapt the interface to current user behavior **(RQ3)**.

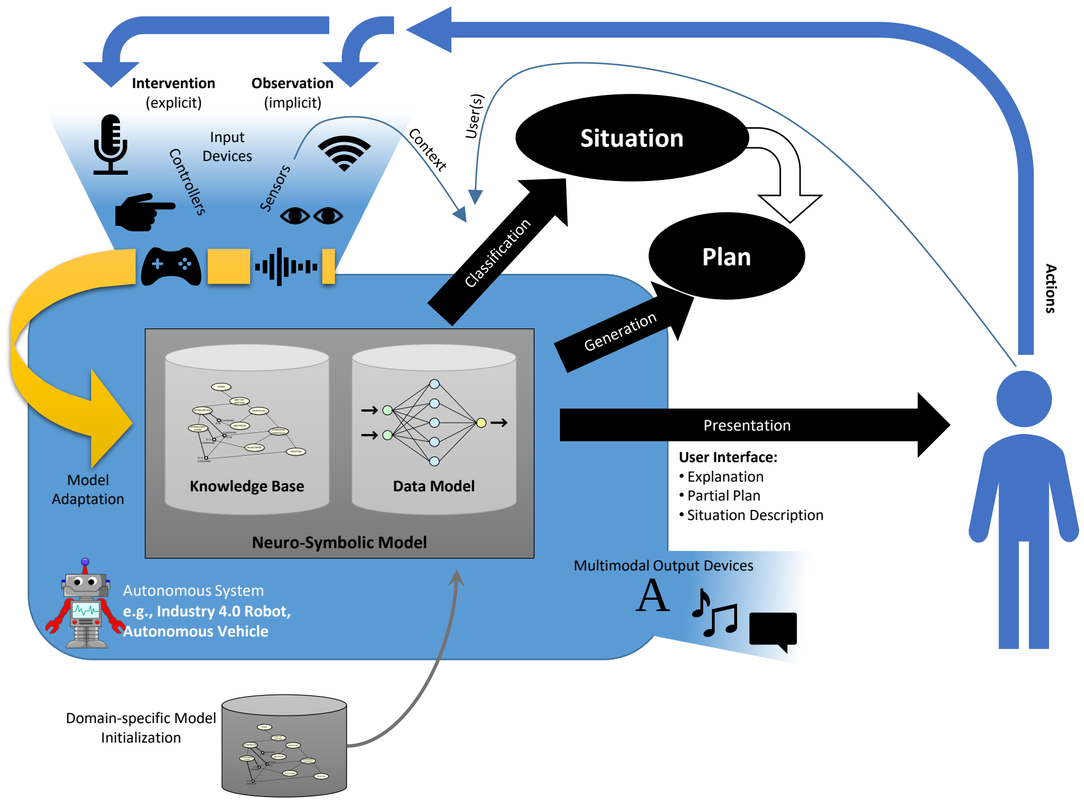

Figure 1: Overview of the envisioned user-centered neuro-symbolic human-in-the-loop learning system.

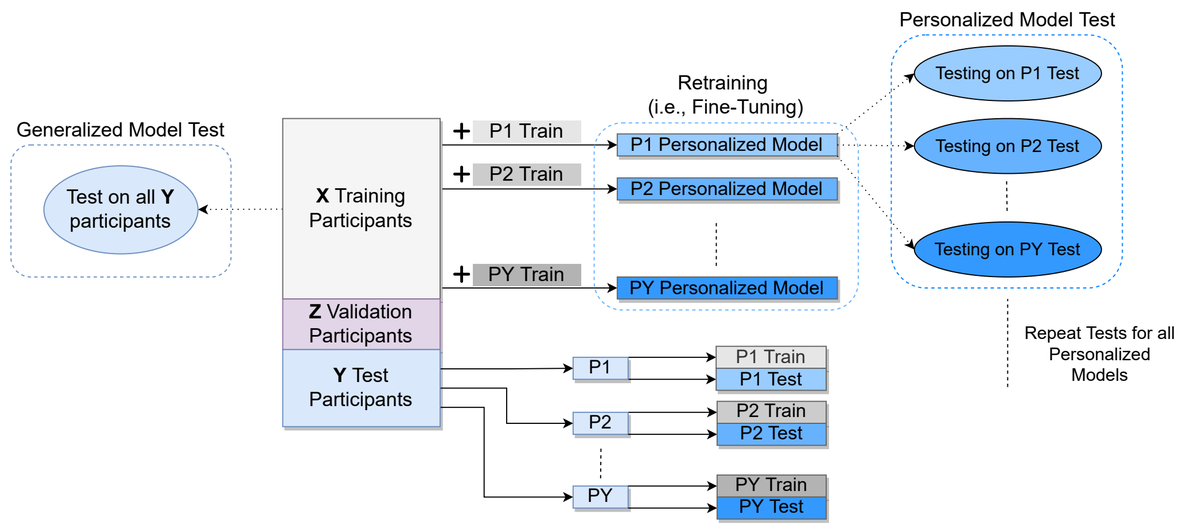

Figure 2: Proposed approach for model adaptation to generate personalized models through transfer and incremental learning techniques.

Discussion & Conclusion

This position paper highlights important considerations for future studies focused on human-centered artificial intelligence and trustworthy interfaces. In particular, we emphasize the importance of continuous learning and hybrid learning approaches to enable a user-centered design that enhances the user experience. By following these guidelines, researchers can develop personalized and adaptive interfaces that respond to individual user needs and behaviors, ultimately improving their satisfaction and engagement with the system. Furthermore, future research in this area should focus on developing frameworks and methodologies to assess user-specific interfaces' effectiveness and explore these technologies' ethical and societal implications.

References

[1] A. Gomaa, G. Reyes, A. Alles, L. Rupp, and M. Feld, "Studying person-specific pointing and gaze behavior for multimodal referencing of outside objects from a moving vehicle", in Proceedings of the 22nd international conference on multimodal interaction (Oct. 2020), pp. 501–509.

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