Analysis of Cognitive Models to Evaluate User Interfaces

Jeronimo Dzaack (jeronimo.dzaack@zmms.tu-berlin.de)
Research Training Group prometei, MoDyS, Technische Universität Berlin
Jebensstraße 1, J2-2, 10623 Berlin, Germany

Usability-evaluation of user interfaces can be done by empirical, criteria oriented and model based methods (e.g., interview study, checklist, and cognitive model). Model based methods enable more detailed predictions of quantitative parameters, for example error rates, times and sequences of actions compared to empirical and criteria based methods – even without an existing prototype. This allows applying model based methods in early phases of system-development processes, to detect usability-problems and to change the examined user interface. Integrating these aspects, cognitive models additionally take into account the cognitive abilities and characteristics of humans (Newell, 1990). Complex paradigms (e.g., dual-tasking, decision-making, and time-estimation) that are important in present user scenarios are hardly to observe with classical usability-methods because of their complexity and the insufficient representation of internal processes. The formal description of cognitive architectures (e.g., ACT-R, Anderson et al., 2004) and the derived models allows observing these paradigms in simulations that can be easily repeated and evaluated. The potential of cognitive architectures and its cognitive models is known in research and development related to usability. Nevertheless this method is seldom used in both fields because of insufficient support of analyzing and modeling cognitive models. Focus of this research is the analysis of cognitive models.

Analysis of cognitive models

In most of the observed simulation experiments time-based relations are used to analyze the model and its fit to empirical data. Because of the psychological theories implemented in low-level architectures (Salvucci & Lee, 2003), it is possible to consider a more detailed analysis. Detecting fine-grained cognitive patterns composed of cognitive interaction primitives (e.g., for visual search: move eye, process information, encode information etc.) is another possibility to enrich the explanatory power of cognitive models. The interpretation of these cognitive patterns enables a better classification of interaction processes and the corresponding user interface in comparison to time based analysis. For example the arrangement of elements can be evaluated by a cognitive model regarding eye-movement and decision-making. Then the design can be adjusted to outcomes of the analysis (e.g., predicted fragmentary/complete interaction patterns, errors).

Concept

To support the analysis and the following evaluation of user interfaces by cognitive models the simulation data has to be preprocessed and to be provided conveniently. For this purpose cognitive interaction primitives are derived from psychological theories (e.g., visual perception and processing) and specified in a general-purpose format for complex, hierarchical structured data (XML-schema). The simulation data of cognitive models in ACT-R is transferred in this specification and forms the basis for a general algorithm based analysis of the interaction processes. Two levels of abstraction have to be observed: the macro- and the microstructure (Gray, Sims & Schoelles, 2006). For the macrostructure aspects of the models overall performance are integrated (e.g., times, errors, and transition-matrices of areas of interest). The microstructure can be indicated by the sub-processes of the cognitive model, that is repeated cognitive patterns (e.g., short sequences of action).

Outlook

First macrostructure algorithms are implemented and tested for transition-matrices and local viewing paths. Additional micro- and macrostructure algorithms will be implemented on the base of interaction primitives. The algorithms will be provided as part of an integrated workbench for cognitive modeling developed by this workgroup. To validate the algorithms and the findings, the analysis of model data and empirical data has to be compared and measured by means of ratios. The analysis of model data, provided in the workbench, will help to close the gap between modeling and the difficulties using models for usability evaluation.

Acknowledgments

This PhD project is funded by Deutsche Forschungs-gemeinschaft (research training group GRK 1013 prometei).

References

Anderson, J. R., Bothell, D., Byrne, M. D., Douglass, S., Lebiere, C., & Qin, Y. (2004). An integrated theory of the mind. *Psychological Review, 111*, 1036-1060.

Gray, W. D., Sims, C. R. & Schoelles, M. J. (2006). Musings on Models of Integrated Cognition: What Are They? What Do They Tell Us that Simpler Approaches Cannot? How Do We Evaluate Them? In *Proceedings of the 7. ICCM*, 12-13. Mahwah, NJ: Lawrence Erlbaum.

Newell, A. (1990). *Unified Theories of Cognition*. Cambridge, MA: Harvard University Press.

Salvucci, D. D. & Lee, F. J. (2003). Simple Cognitive Modeling in a Complex Cognitive Architecture. In S. Ashlund, K. Mullet, A. Henderson, E. Hollnagel & T. White (Eds.), *Human Factors in Computing Systems: CHI 2003 Conference Proceedings*, 265-272, New York, NY: ACM.