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TNO report

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ETP Modelling
Intuitive User interaction
Overview 2011-2014

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Summary

Mention Project leader with contact details and picture
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Summary including highlights.
Intuitive User Interaction aims to develop the next generation user interfaces required to grant experts and laymen access to complex models and large amount of data in design and decision processes and therewith to contribute to the ambition to broaden the applicability of models. Important topics include advanced methods to visualize multidimensional data and data with uncertainty and innovative ways to interact with data based on eye movements and brain signals. Results include both basic knowledge on visualisation of uncertainty made available through a visualization toolbox, and use cases in which we show that including eye-movement information can potentially speed up inspection of model output by a factor ten and developed a 3D visualisation for TNO's GeoTOP model that allows the presentation of 3D data including uncertainty.

Contents

1 Introduction

1.1 Background and motivation

Models are not decision makers in themselves but a tool to support scientist, designers and decisions makers. The success of these tools depends on their user-friendliness: if the user cannot interact with the model and understand the outcomes, the model will not be used or –even worse– will be used in the wrong way or lead to suboptimal decisions. This project focuses on innovations in the user-system interaction (more specifically the visualisation of and interaction with big data and complex models) enabling models to be used to their full potential.

1.2 Objectives

Our aim is to develop the next generation user interfaces required to grant experts and laymen access to large amounts of data and complex models in design and decision processes. This includes advanced methods for visualization and interaction of 3D and 4D data and of data with uncertainty. We aim to verify these methods in human subjects experiments.

1.3 Core methodologies and technologies

Our core methodologies are from Human Factors Engineering and include user-centred design, physiological computing, and human-subject studies. The project worked along the following research lines:

- Multimodal Interaction: the user interaction is not restricted to visual information presentation. To create a more intuitive way to interact this research line investigated methods and models for tangible and immersive interaction.
- Advanced visualisation: plain, static 2D representation on a computer monitor may not be optimal for data and model output that is often complex, multidimensional and has for instance a certain amount of uncertainty. In this line of research we develop new visualisation tools to display uncertainty or to employ 3D visualisation techniques.
- Brain and eye-based interaction: advances in user interaction allows to use eye-movement and brain-based signals above and beyond explicit user control. This line of research developed new methods to use these physiological measures to check the validity of model output and to investigate and optimise dashboard designs.

2 Methods, models, tools

2.1 Tool to speed up model output checking by experts.

Contact person: Peter-Paul van Maanen, peter-paul.vanmaanen@tno.nl

2.1.1 *Description*

Due to the expected increase in dataflow of models and user demands, the development of (semi-)automated quality control systems is becoming crucial. For this purpose capturing model errors as seen from the expert viewpoint is of increasing interest. However, this is a time-consuming process that requires efficiency improvements to remain feasible. We envision the use of eye gaze and brain signal information to support and speedup detection of errors in models. This tool potentially speeds up this process by a factor 10. Model anomalies can be identified based on the expert's implicit behavior much faster than the expert's conscious decision. To show this, the tool has been implemented for quality control of a 3D geological voxel model of the upper subsurface of the earth. Experiments show that: 1) attended areas as determined from experts' gaze data largely match with errors as indicated by the experts using a mouse, and 2) a substantial part of the match can be reached using only gaze data from the first few seconds of the time the experts spent to search for errors. These results open up the possibility of more efficient model quality control. Other potential avenues of application are in the improvement of models themselves or in the development of independent assessment methods for the focus and expertise level of experts.

2.1.2 *Technical description*

Gaze is used as input for an attention model that results in `attended areas' for parts of the output of the model that needs to be validated. In the case of the 3D geological model, 2D slices of the 3D model were used for this. In order to acquire an attention model that performs well, multiple eye movement and brain signal datasets of experts are used to train the different model parameters. This improved attention model is then used to predict model errors in new output of model being validated. This can be done by using just several seconds of expert data per model output part. Future research will focus further improving the used attention model, applying it to other domains, and exploring the possibility to develop tools that do not require a human in the loop at all.

2.1.3 *IP*

A journal and conference paper has been published, one journal paper is being submitted and the work has been presented on an international geosciences conference in Vienna. In addition, new fundamental work on fixation related brain potentials that formed a necessary requirement for the applied case has been presented orally at two conferences and was published in a conference proceeding paper.

2.2 Dashboard evaluation tool

Contact person: Ward Venrooij, Ward.venrooij@tno.nl.

2.2.1 Description

The application of dashboards in the field of management and science is increasing rapidly. Due to the developments in ICT, the technical effort to create dashboards is getting less every day. However the current ease of building, the quality of dashboards can often be improved. Research shows that most mistakes made in dashboard design are caused by the lack of insight of designers in perceptual and cognitive abilities of the users. Examples are the inadequate organisation of the data, overuse of highlighting and the application of incorrect chart types. Currently validated empirical measures for the quality of dashboards are lacking. The Visualisation Performance Tool (ViP) will ultimately serve this goal.

ViP is based on a set of new methods to empirically validate design choices in dashboards on both efficiency and effectiveness through integrating (scan path entropy) eye movements, attention models and measures of workload. The tool is developed in cooperation with the Utrecht University. Parts of the ViP are currently validated in a human-subject study with six simple dashboards which fully met the content criteria. The dashboards differed in the type of charts used to display the data. Respondents were asked to conduct two tasks in each dashboard. Eye-tracking data and questionnaire results were used to validate a new measure to empirically test the quality of each dashboard.

ViP is very useful for various companies and organizations (outside TNO) that wish to evaluate their own dashboards and assist their designers in the development process. Dashboard software vendors could use the ViP as an add-on to assist their users in developing higher quality dashboards.

2.2.2 Technical description

We define a dashboard as “a visual display of the most important information needed to achieve one or more objectives that has been consolidated on a single computer screen so that it can be monitored and understood at a glance” (Few, 2004). Visualisation Performance Tool (ViP) evaluates whether a dashboard meets the two major criteria mentioned above.

1. CONTENT: Does the dashboard contain the most important information needed to achieve one or more objectives. The content criteria can be expressed in the percentage of objectives which can be achieved with the information presented on the dashboard.

2. QUALITY: Does the dashboard enable the user to monitor and understand the information at a glance. This criterion is assessed with a newly constructed empirical method. It relies on eye tracking data (gaze points and pupil size) and questionnaire results and measures the extent to which users get accurate situational awareness in a minimal amount of time, with minimal amount of effort.

The fundamentals and basic validation of the ViP are developed in this project. Additional research can further improve and validate the workload measures and visual attention models.

2.2.3 *IP*

To be decided together with Utrecht university. Currently, we foresee publication in a scientific information visualization journal (ready in December).

2.3 Method to visualize uncertainty in traffic models

Contact: Simeon Calvert, simeon.calvert@tno.nl

2.3.1 *Description*

Traffic is a system in which a large amount of fluctuations exist in many areas. Driver behavior lies at the heart of many of these fluctuations and by definition causes a great deal of uncertainty in traffic flow. Although developments in traffic modelling are beginning to consider these stochastic fluctuations, most models still do not. A reluctantness to consider or even ignore uncertainty in models comes from a lack of understanding and cognitive ability to communicate the outcomes of such uncertainty. In general, visualizations of results from aggregate models, known as macroscopic traffic models, already contain two to three dimensions. This results in a challenge how to apply additional dimensions conveying information on uncertainty variables such as probability, impact or sensitivity.
This method concerns visualizing uncertainties in regular macroscopic traffic models, such that a user is clearly able to comprehend and act upon the results given. Created visualizations are designed such that they cater for two different user groups, namely: decision makers and operational traffic managers.

2.3.2 *Technical description*

The developed approach makes use of innovative and tested visualization forms integrated in the existing model environment and extending existing model visualizations. The importance of starting from a familiar model environment limits the cognitive effort required by a user when interpreting additional features.
The developed visualizations can be defined as static or demand. The static visualizations attempt to add information by expanding the current dimensionality of the given information.

This is performed by working with gradations, multiple colour charts, highlighting, and additional visual features. The dynamic visualization form includes the possibility of including time-dynamic motion of results and the ability to make use of additional user definable context graphs for additional and detailed information. Dynamic visualizations are designed here to offer the user a wide range of flexible interaction and the possibility to 'pick-and-choose' what information is relevant to the decisions that are to be made. Implementation of the dynamic visualizations are carried out in TNO's CommonSense visual interaction package, which allows for easy use and interaction with an interactive table [SOURCE CommonSense].
The dynamic approach is in general more geared to operational traffic purposes as it allows for a greater amount of interaction, while the static approach is designed to be applicable for policy-makers and usable for use in technical reports.

2.3.3 IP

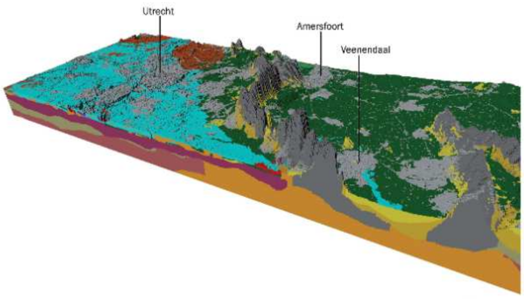
Not applicable.

2.4 TNO visualization toolbox.

Contact: Maurice van Beurden, maurice.vanbeurden@tno.nl

2.4.1 Description

This toolbox contains a set of visualization guidelines based on insights and results from the various 'Intuitive user Interaction' projects and other relevant projects. These guidelines will support TNO colleagues involved in visualizing data. Included is a list of relevant literature and example projects that could serve both as inspiration and explanation of the guidelines. A special and unique focus is on visualizing uncertainty in both 2D and 3D data. Data from models is often a prediction based on assumptions and therefore contains uncertainty.
When communicating model outcomes it is important to communicate results from the models together with the uncertainty of the data while this is typically an area with a lack of proper visualization guidelines.
Keeping the above in mind, the TNO (Utrecht) GeoTOP model (on geological data of the subsurface of The Netherlands) was selected as use case. The model data consists of a regular grid of millions of voxels, each presenting the most likely available lithoclass (e.g., sand, clay, gravel) based on borehole data. Since these models are stochastic in nature the model uncertainty can be quantified and visualized. In the current project, we visualized uncertainty in these 3D datasets without losing information in terms of lithoclass. To fully benefit from the third dimension the visualizations are developed and presented on 3D display technology (e.g., 3D display and head-mounted display). Validation is done through feedback from experts within TNO.



2.4.2 Technical description

The toolbox will only be made available for TNO internal use though TNO City / Stepping Stone and comparable internal platforms. By the end of the project, the toolbox will contain the momentary state of the art, but it is the explicit intention to maintain the tool in the coming years. Within the ETP project, a new visualization expert group was started (including experts from Groningen, Delft, Soesterberg) that agreed to adopt and maintain the toolbox.

2.4.3 IP

Not applicable (internalu se only).

3 Publications

Journal papers

Brouwer, A-M., Reuderink, B., Vincent, J, Van Gerven, M.A.J., & Van Erp, J.B.F. (2013). Distinguishing between target and nontarget fixations in a visual search task using fixation-related potentials. Journal of Vision, 13(3):17, 1–10.Haas, E. & Van Erp, J.B.F. (2014). Multimodal warnings to enhance risk communication and safety. *Safety Science, 61*, 29-35.

Hancock, P.A., Mercado, J.E., Merlo, J., & Van Erp, J.B.F. (2013). Improving target detection in visual search through augmenting multi-sensory cues. *Ergonomics, 56(5)*, 729-738.

Houtkamp, J.M., Toet, A. & Bos, F.A. (2012). Task-relevant sound and user experience in computer-mediated firefighter training. *Simulation & Gaming, 43(6)*, 778-802.

Steen, M., Arendsen, J., Cremers, A., De Jong, J. & De Koning, N. (2013). Using interactive model simulations in co-design: An experiment in urban design. *CoDesign, 9 (1)*, 2-16.

Tak, S., Toet, A. & van Erp, J.B.F. (2014). The perception of visual uncertainty representation by non-experts. *IEEE Transactions on Visualization and Computer Graphics, 20(6)*, 935-943.

Tak, S., Toet, A. & Van Erp, J.B.F. (in review, minor changes). Public understanding of visual representations of uncertainty in temperature forecasts.

Toet, A. & van Schaik, M.G. (2012). Effects of signals of disorder on fear of crime in real and virtual environments. *Journal of Environmental Psychology, 32(3)*, 260-276.

Toet, A. & van Schaik, M.G. (2013). Visual attention for a desktop virtual environment with ambient scent. *Frontiers in Psychology, 4 (883)*, 1-11.

Toet, A., Houtkamp, J.M. & van der Meulen, R. (2013). Visual and auditory cue effects on risk assessment in a highway training simulation. *Simulation & Gaming, 44(5)*, 732-753.

Toet, A., van Schaik, M.G. & Theunissen, N.C.M. (2013). No effect of ambient odor on the affective appraisal of a desktop virtual environment with signs of disorder. *PLoS ONE, 8(11)*, e78721.

Van Erp, J.B.F., Toet, A. & Janssen, J. (2015). Uni-, bi- and tri-modal warning signals: effects of temporal parameters and sensory modality on perceived urgency. *Safety Science, 72*, 1-8.

Van Maanen, P.-P., Busschers, F.S., Brouwer, A.-M., Van der Meulen, M.J. & van Erp, J.B.F. (in press). Quality Control of Geological Voxel Models using Experts' Gaze. *Computers & Geosciences*.

Popular papers, book contributions, theses

Van Raalte, M. (2011). Affective appraisal and thermal sensation in actual and simulated thermal environments. Stageverslag UU Utrecht

Werkhoven, P.J. & Van Erp, J.B.F. (2013). Multimodal perception and simulation. In: Chubb, C., Dosher, B.A., Lu, Z.-L., Shiffrin, R.M. (Eds): Human information processing: Vision, memory, and attention. Decade of behavior, (pp. 227-242). Washington, DC, US: American Psychological Association.

Willemse, C.J.A.M. (2013) An Exploratory Study on the Effects of Multimodal Feedback in Bimanual Interaction with Active Tangible Interfaces. Master thesis Eindhoven University

Conference papers

Brouwer, A-M., Brinkhuis, M.A.B., Reuderink, B., Hogervorst, M.A.J., & Van Erp, J.B.F. (in press). Fixation-related potentials: Foveal versus parafoveal target identification. Graz BCI conference 2014.

Brouwer, A.-M., Vincent, J., Van Gerven, M. & Van Erp, J.B.F. (2013). Distinguishing between target and non-target fixations in a visual search task using fixation-related potentials. *Proceedings of the Fifth International Brain-Computer Interface Meeting 2013*, 2-7 June 2013, Asilomar, CA. Graz, Austria: Graz University of Technology Publishing House, DOI:10.3217/978-4-83452-381-5/065.

Busschers, F.S., van Maanen, P.-P. & Brouwer, A.-M. (in press). Quality control of 3D Geological Models using an Attention Model based on Gaze. *EGU General Assembly 2014*.

De Jong, A.P.J., Tak, S. Toet, A. Schultz, S. Wijbenga, J.-P. & Van Erp, J.B.F. (2013). Subjective usability of speech, touch and gesture in a heterogeneous multi-display environment. In: *Proceedings of ACHI 2013: The Sixth International Conference on Advances in Computer-Human Interactions*. Pp 53-56. IARIA. XPS Press.

De Valk, W., Rypkema, J. & Van Erp, J.B.F. (2014). Facilitating Planning with Sensators: Tangible Objects Offering Multimodal Feedback and Support for Off-loading. In: *proceedings of EuroHaptics 2014*. Berlin: Springer Verlag.

Houtkamp, J.M. & Toet, A. (2012). Who's afraid of virtual darkness: Affective appraisal of night-time virtual environments. Digital Landscape Architecture 2011/2012: GeoDesign and Teaching, (pp. 508-515). Offenbach, Wichmann Verlag.

Tak, S. & Toet, A. (2013). Towards interactive multisensory data representations. Proceedings of the 4th International Conference on Information Visualization Theory and Applications (IVAPP 2013), pp. 558-561). Barcelona, Spain: SciTiPress.

Tak, S. & Toet, A. (2013). Towards interactive multisensory data representations. Proceedings of the 4th International Conference on Information Visualization Theory and Applications (IVAPP 2013), (pp. 558-561). Barcelona, Spain: SciTiPress.

Tak, S. & Toet, A. (2014). Color and uncertainty – it is not always black and white. In N. Elmqvist, M. Hlawitschka & J. Kennedy (Eds.), Proceedings of the IEEE Information Visualization Conference InfoVis 2013.

Tak, S., & Cockburn, A. (2012). Enhanced Spatial Stability with Hilbert and Moore treemaps. *InfoVis 2012*.

Tak, S., Brouwer, A.-M., Toet, A., & Van Erp, J.B.F. (2013). Exploring the potential of neurophysiological measures for user-adaptive visualization. 1st International Workshop on User-Adaptive Visualization (WUAV). *UMAP 2013 Extended Proceedings*. Rome, Italy, 10-14 June.

Van Erp, J.B.F., Willemse, C.J.A.M., Janssen, J.B. & Toet, A. (2014). Active multisensory tangibles for multi-touch devices: On the development of Sensators. In: *proceedings of EuroHaptics 2014*. Berlin: Springer Verlag.

4 Strategic collaboration

4.1 (Endowed) Professorship

No direct endowment, but links to the chairs of prof. F van Geer (UU) and J. van Erp (UT).

4.2 MSc projects

Micha van Raalte, 2011, UU. Affective appraisal and thermal sensation in actual and simulated thermal environments.
Christian Willemse, 2013, TUE. An Exploratory Study on the Effects of Multimodal Feedback in Bimanual Interaction with Active Tangible Interfaces.
Daniel Azulay, 2014, UL. Visualisation of uncertainty in complex traffic models.
Manje Brinkhuis, 2013, UU. (Para)foveal fixation locked ERPs.
Joris Vincent, 2011, UCL. Combing eye fixations and brain signals. (BSc).

5 Handover to market

User interaction and visualization are archetypally enabling for many products and services and seldom the sole end result of a project. This is substantiated in the visualization expert group initiated in this project that currently consists of more than 10 TNO experts from Delft, Groningen and Soesterberg. These experts transfer and apply the ETP knowledge on a daily basis in a multitude of knowledge development and market projects. The enabling character of user interaction expertise is also reflected in the contribution to four use cases within the ETP model: chemical plant of the future, reservoir management, bridge life span demonstrator, and traffic models. Main market outlets are through Information Society (Robbert Kooij, Henk Jan Vink); Oil and Gas (Ida Rust); Defence, Safety and Security (Adelbert Bronkhorst, Rick Meesen); TNO Geological Survey (Michiel van der Meulen); Mobility (Jan Burgmeijer); example projects include: Police Resilience Project (dashboard to gain insight in the psychological resilience of Dutch Police officers), Military Cognitive Overload (visualisation that enabled military staff to gain insight in the cognitive workload of soldiers during an operation), Psychosocial cost modelling (visualisation for policymakers to gain insights in the predicted costs of psychosocial aftercare of military deployment), Smart city dashboards (two dashboards to enable policymakers on local level to monitor the status of the projects and their effect on higher level goals), SPITS LIVE (mobility), development of Core Probability Models (CPM) in the Probabilistic Modelling project (mobility), and Praktijk Proef Amsterdam(apps Super Ticket and Super Route).

6 Concluding remarks and outlook

User interaction is enabling for products and services containing advanced models or big data and in some case even critical to their success. We expect that the rate of development in modelling and big data and their ever increasing complexity will further drive the demand for innovative user interaction tuned for specific applications and adjusted to the task and capabilities of individual users, whether experts or laymen.

The project had the ambition to contribute to “increasing applicability” of models and started with a broad scope. After initiation and through interaction with the think tank and the steering group, the focus was brought in line with the knowledge questions posed by the themes. This implied the termination of research lines that were either of limited interest within the themes or were considered too futuristic. Research on advanced visualization and for instance the knowledge on visualization of uncertainty are acknowledged for their current and future importance and are expected to be continued in the upcoming strategic period, amongst others through the use cases initiated within the ETP, and for instance the collaboration with CBS on the topic Smart Cities. The current group of more than 10 visualization experts affiliated to the project indicates that the project succeeded in its ambition to contribute to the valorisation of TNO’s data and models.