Title: Gaze-contingent displays: Multi-scale interaction with complex immersive 3D visualizations

INRIA and UR-Lorraine topics and challenges addressed by this project::
National scientific challenges:
5 'Combining simulation, visualization and interaction', and 2 'Develop multimedia data processing'
National priority topics:
Within challenge 2: human-computer dialogue (multimodality), human-computer interaction (flexibility and robustness)
Within challenge 5: new devices for interacting with multi-scale visualizations in immersive virtual reality environments

UR-Lorraine priority topics and scientific challenges:
- Theme 1 'Towards mastering natural language automatic processing and multimodal communication' ("multimodal data integration … to communicate with computers.")
- To a lesser degree, theme 2 'Combining simulation and visualization' ("taking account of… interactivity")

- Workplace: Research Unit INRIA-Lorraine

- Job title: post-doctorate

- Environment:
- Related project: MErLIn
- Advisor: Noëlle Carbonell

- Objectives:
The main objective of this project is to tailor displays, especially displays of complex data sets on large and 3D displays, so that the most informative details are generated at the point of gaze and degraded nicely at the periphery of the field of foveal vision.
To be efficient, gaze-contingent display algorithms have to rely on knowledge of human vision, both for anticipating gaze movements, and for defining the shape and size of the high resolution area and the way resolution will be degraded beyond the user's current field of foveal vision. In addition, these changes of display precision should not interfere with the pace and comfort of users' visual exploration.
Research on gaze-contingent displays is developing rapidly. See (Duchowski, 2003, pages 211-217) for a review of recent research in this area which has been mainly focused on defining the optimal size of the screen area where maximum visual information is displayed (Parkhurst et al., 2000), and assessing the ergonomic quality (i.e., visual comfort) of available techniques for progressively degrading the precision of the displayed information (Loschky, McConkie, 2000).
Main scientific objectives and expected results are twofold: to increase knowledge of human vision in the context of realistic scene exploration activities, and to enrich human-computer interaction modalities by implementing gaze as an efficient pointing modality that could replace the mouse for interacting with graphical software.
Potential application areas include:
- Interaction with complex distant visualizations or animations in cases when image compression techniques prove insufficient for achieving satisfactory display speed and reactivity;
- Interaction with virtual reality environments such as Reality Centres or Caves where gaze represents a more natural, usable and efficient input modality for remote pointing and designation than hand or finger gestures.

At present, accurate point of gaze detection can only be achieved using specific equipment. Eye trackers that do not restrict freedom of movement are still somewhat cumbersome. However, this constraint is about to disappear thanks to rapid progress in miniaturization techniques. It is now possible to attach eye trackers to spectacles. A head-mounted eye tracker (ASL 501, http://www.a-s-l.com/) is available at LORIA, and the MErLIn project has developed appropriate dedicated software for recording and processing interactions with virtual reality applications. We have also developed a robust real-time algorithm for computing fixations.

- Activities:
1. First, a few techniques for degrading visual information will be selected, implemented and tested. Their efficiency (i.e., information reduction rates) and acceptability (i.e., users' visual comfort) will be assessed experimentally with potential users. The technique yielding the best visual comfort will be retained.

The shape and size of the display area corresponding to the field of foveal and parafoveal vision will also be determined experimentally. The solution yielding the best trade-off between efficiency (reduction of the high resolution area) and acceptability (visual comfort and task efficiency) will be selected.
During this initial stage, the post-doctoral researcher will be trained to the eye tracker operation and the software designed to process eye tracking data.
2. The MErLIn research group has developed an operational gaze-contingent display prototype (C++, Linux). The post-doctorate researcher will improve this prototype using the results and conclusions obtained in the course of step 1, and the experience of the MErLIn research group in analyzing and modelling human strategies for visual exploration. Such knowledge is crucial for controlling the spatial and temporal evolutions of the display satisfactorily, that is, according to utility and usability requirements. Necessary knowledge of visual perception will be obtained through collaboration with psychologists at the IMASSA-CERMA Cognitive Science Department (Paris).
3. The last stage will consist in participating in the design and realisation of the ergonomic evaluation of the resulting prototype by users interacting with complex visualisations displayed on the screen of the Reality Centre at LORIA. The ergonomic evaluation of the prototype will take the form of an experimental study the design of which represents a scientific and methodological challenge. First, the evaluation must combine objective measures and subjective judgements. Secondly, the choice of the tasks that participants will have to carry out is a crucial issue. The performances of the new version of the prototype (i.e., accuracy and reactivity of the display) will also be extensively tested during this last stage.

- Minimum qualifications:
PhD in computer science or artificial intelligence or software engineering. Knowledge and experience in image processing highly appreciated. Interest in the psychological aspects of visual perception, and motivation for engaging in multidisciplinary scientific collaborations most welcome.

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- Extra information:
Some useful references:
- (Duchowski, 2003, pages 211 à 217) for a survey of research on gaze-contingent displays.
- (Parkhurst et al., 2000) for information on the appropriate size of the high resolution screen area corresponding to the foveal and parafoveal visual fields.
- (Duchowski, 2000 ; Loschky, McConkie, 2000) for information on blurring techniques reproducing the evolution of visual acuity which decreases as eccentricity increases.

A.T. Duchowski (2000). Acuity-Matching Resolution Degradation through Wavelet Coefficient Scaling. *IEEE Transactions on Image Processing*, 9(8), 1437-1440.

A.T. Duchowski (2003). *Eye Tracking Methodology: Theory and Practice*. Springer, 250 pp.

L.C. Loschky, G.W. McConkie (2000). User Performance with Gaze Contingent Multiresolutional Displays. In *Eye Tracking Research and Applications Symposium (ETRA)*, Palm Beach Gardens, FL, November 6-8, pp. 97-103.

D. Parkhurst, E. Culurciello, E. Niebur (2000). Evaluating Variable Resolution Displays with Visual Search: Task Performance and Eye Movements. In *Eye Tracking Research and Applications Symposium (ETRA)*, Palm Beach Gardens, FL, November 6-8, pp.105-109.