

Registration form (basic details)

1a. Details of applicant

- Name, title(s): **Zeljko Obrenovic, Dr.**
- Male/female: **Male**
- Address for correspondence: **Kruislaan 413, 1098 SJ Amsterdam**
- Preference for correspondence in English: **yes**
- Telephone: **020 592 4202 (office), 06 45 21 3280 (mobile)**
- Fax: **020 592 4312**
- E-mail: **Zeljko.Obrenovic@cwi.nl**
- Website (optional): **<http://www.cwi.nl/~obrenovi/>**
- Doctorate (date, dd/mm/yy): **26/05/2005**
- Use of extension clause: **no**

1b. Title of research proposal:

A DESIGN THEORY FOR INFORMATION PRESENTATION UNDER PERCEPTUAL CONSTRAINTS

1c. Summary of research proposal

Designers of information presentation systems have to account for the overwhelming number of factors to make presentations universally accessible. Information is available in heterogeneous formats, accessed in different contexts through devices that have different requirements and presentation capabilities. Users vary in terms of language, knowledge, age, gender, cultural background and (dis)abilities. Universally accessible presentation of information has to account for all these parameters. However, existing design support, such as accessibility guidelines, does not address such diversity, and knowledge about these important factors is itself not easily accessible. As a consequence, designers are often unaware of important human and situational factors, building systems accessible only for a "typical" user in a specific context.

Our main goal is developing a design theory to aid designers in creating information presentation systems for a broader set of users and situations. The theory is envisioned around the metaphor of perceptual constraints: the presentation context is described in terms of constraints on user perception, and interfaces in terms of their perceptual requirements. By combining these two types of descriptions, we can deduce recommendations about an optimal form of context sensitive presentation. Our hypothesis is that such recommendations enable designers to create accessible interfaces more quickly and more easily. The primary innovation of our work is a unified treatment of presentation context, what provides an economic advantage over existing approaches that "handcraft" solutions for all possible users and situations, which is expensive, time consuming, and often produces several incompatible versions of content.

Our method will combine case studies and evaluations of user interfaces. Based on the theory, we will develop a design decision-support system, and evaluate it against the design of prototype applications. We will observe how the theory influences the decisions of designers, and evaluate implemented applications to see if they are more widely accessible.

Key Words: Human information processing; Information interfaces and presentation; Multimodal interaction; Human factors in software design; Multimedia information systems.

1d. NWO Council area:

- EW: 'Exacte wetenschappen' (Physical Sciences / Computer Sciences)

1e. Host institution

- CENTRUM VOOR WISKUNDE EN INFORMATICA (CWI), AMSTERDAM

Research proposal

2. Description of the proposed research (1956 words)

2a. Research topic

Although computer science has achieved significant progress in last decades, human-computer interaction (HCI) progresses at much slower pace [Turk00]. There is no Moore's Law for user interfaces, and HCI has not changed fundamentally for nearly two decades. Developers of interactive systems have to be "equipped" with the knowledge that goes beyond computing, including numerous human, social and environmental factors, as HCI cannot progress by simply improving the performance of computing systems hardware.

Developers of interactive systems, however, have to deal with an overwhelming number of factors. The "data explosion" produces vast amount of information content in heterogeneous formats including text, images, audio, video or three-dimensional scenes. Users access this information through internet-enabled cell phones, PDAs, desktop, laptop, and wearable PCs. All of them have very different requirements and presentation capabilities. Devices are used in different contexts, including offices, corridors, homes, streets, or transportation. Users vary in terms of language, knowledge, age, gender, cultural background and (dis)abilities. Universally accessible presentations have to account for all of these parameters. Existing design support, such as accessibility guidelines [WAI], however, do not address such diversity, and knowledge about these important factors is itself not easily accessible: it is present in a diverse set of sources and not interconnected. As a consequence, designers are not aware about many important non-computing factors, building systems accessible only for a "typical" user in a specific context. Most existing information presentation systems are optimized for a limited set of users, mainly aimed at desktop computers used in office environments. This isolates not only disabled users, but also users who use the system under suboptimal conditions, from a growing number of information sources. The number of people that are excluded from information society is significant: according to the UN report¹, more than 500 million people have some kind of disability. On the other hand most reports suggest that only a small percentage of information sources are accessible for people with disabilities². There is also a growing number of mobile users, where existing desktop metaphors cannot be applied.

2b. Overall Aim

This project will develop a novel design theory, supporting design of information presentation systems accessible for a more diverse set of situations and users. Existing tools, such as accessibility guidelines [WAI], help avoiding making inaccessible information presentation systems, but they cover a limited range of situations, solving only most acute problems, e.g. providing alternative speech output for blind users. However, many users require support not covered by current guidelines, while there are various other factors that can influence information perception [Milne05].

Designers are often not aware of all potential problems and constraints that new interaction contexts and users have. For example, unattended speech, which is often present in public spaces (e.g. passenger conversation in a train, news on the radio), causes information to be removed from short-term memory [Baddeley90]. Information presentation that requires recall of information or usage of short term memory (such as when a user has to keep in mind the structure of the presentation, or switch between two windows), may completely fail in environments where a user or talks or listens speech. Similar problems occur with disabilities: users with short-term memory impairments have similar problems even when they are not in a noisy environment. *These facts are not obvious and often surprising for*

¹ <http://unstats.un.org/unsd/demographic/sconcerns/disability/>

² According to the yearly survey from Accessibility.nl, only 4% of the government sites in the Netherlands currently supported basic accessibility level.

developers [Karl93, Buxton95]. Encapsulating this knowledge and communicating it in a form of design recommendations is the primary aim of our design theory. As the space of possible combinations is enormous, designers need tools that can support them to rapidly generate multiple alternatives, and explore the implications of design decisions at early stages of design [Chevalier03, Shneiderman02]. Our theory, implemented as a design-support system, will facilitate designers to access design recommendations early in the development stage, when most of the fundamental design decisions are made.

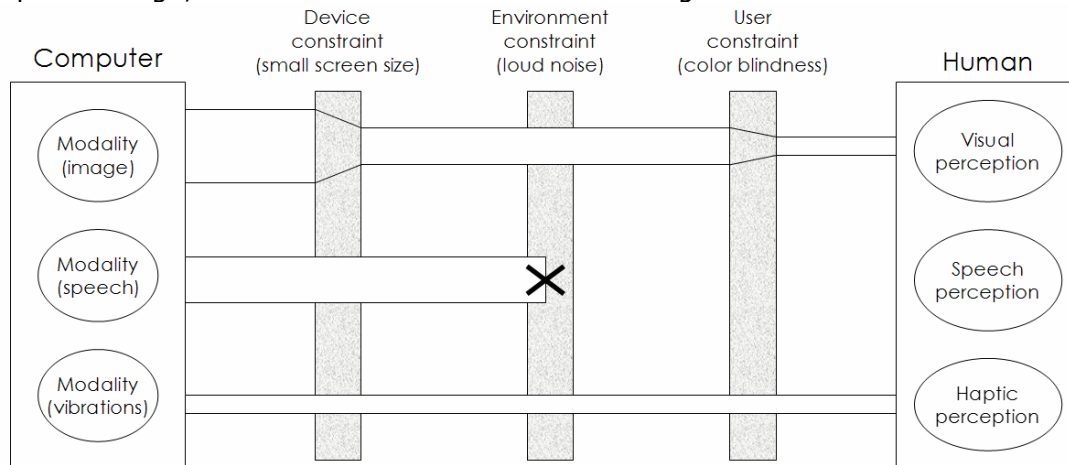


Figure 1. An example of perceptual constraints. Presenting information through images is limited when the screen size is small and a user has a color disability. Speech may not be perceived in very noisy environments. Using vibrations, such as a on mobile phone, is not affected by the device screen size, environment noise or user color blindness, although has limited information bandwidth.

The theory is envisioned around the metaphor of *perceptual constraints* [Obrenovic07b]. We define a perceptual constraint as a restriction on information presentation introduced by device limitations, environmental conditions, or users' (dis)abilities (Figure 1). Designers formally model presentations, using descriptive logic, in terms of modalities (such as text, image, or speech) that try to engage different elements of the human perceptual system. Perceptual constraints, introduced by the device (e.g. screen size), environment (e.g. noise), and user (e.g. disability), may reduce or stop information transfer. The theory will define a method where developers can formally describe the interaction context in terms of perceptual constraints, and be supported by support of reasoning framework with recommendations for modalities appropriate for that context.

The proposed approach and metaphor has advantages for developers and researchers. From a developer's point of view, one advantage is that it is possible to design more flexible and more reusable solutions, aimed for a broader set of situations. Most of the previous work concentrated on a specific set of users or on specific situations. Considering the great diversity of user abilities and situations (such as increased number of mobile users), development and maintenance of such systems is rather complex. With our approach, developers can concentrate on more generic perceptual concepts.

Another important advantage is that our framework enables treating different situations in the same way. As user abilities are described in the same way as device and environmental characteristics, it is possible to re-apply solutions for disabled users in situations that limit the interaction in a similar way. In addition to providing more universal solutions, this could also solve some of social problems because design is not concerned with disabilities (recognizing that the term "disability" often creates negative reactions), but with various perceptual requirements and their constraints.

2c. Approach (Method)

Our approach will combine case studies and evaluations of user interfaces, and build on existing theoretical work in human computer interaction and knowledge modelling. We plan

to work in an *iterative and structured way*, similar to that proposed in [Barnard00], gradually improving our design theory based on observations and the results of evaluations. More specifically, we plan to:

- *Construct a method for quantification of perceptual constraints and requirements.* We will develop a knowledge formalization method based on descriptive logic, where we will define modelling primitives and constraints for checking the consistency of the collected facts. We will build on our previous work on modelling user interfaces [Obrenovic04a, Obrenovic07b].
- *Use the method to gradually build a knowledge base about human perception,* from surveys of existing work and empirical studies which observe the influence of selected context on information perception. The knowledge base will include vocabularies of human perceptual functionalities, as well as description of perceptual constraints of common interaction contexts and perceptual requirements of common presentation modalities. As a starting point, we will use existing vocabularies, such as *The International Classification of Functioning, Disability and Health (ICF³)* and *The Foundational Model of Anatomy (FMA⁴)* [Obrenovic07a]. We will also provide interfaces that enable designers to extend the knowledge base, and share it with other designers [Basili99].
- *Develop a decision-support reasoning framework,* structured around the perceptual constraint metaphor. The framework will take as an input the knowledge base about human perception, enable a designer to describe the interaction context in terms of perceptual constraints, and output recommendations for the combinations of modalities that optimally present the information in the given interaction context. The framework will also support exploratory search of the knowledge base [Löwgren92, Marchionini06].
- *Evaluate a theory by applying it to the design of multimodal user interfaces,* where the main task of the designer is presenting rich multimedia data in desktop and mobile environments, with a subset of perceptual constraints. The basic measure of success of our theory would be showing that our decision-support system provides useful guidance in a design process, and that designers are capable of building information presentation systems accessible for a broader set of situations and contexts. We will organize case studies that observe how our decision support system influences the decisions of the designer [Fjermestad00], especially for less experienced designers at early stages of design, and evaluations of implemented systems to see how accessible they are [Chevalier07]. Evaluations will include testing of implementations in different situations with users of different abilities, as well as usage of accessibility evaluation tools⁵.

2d. Scientific Background

Our theory builds on observations from the domain of perceptual user interfaces (PUIs), which investigates how natural human capabilities of communication, motor, cognitive and perceptual skills can be combined with computer devices, machine perception and reasoning [Turk00, Reeves00]. By using these results we will identify key factors of human information perception, going into more formal ways of description of perceptual experience and influences that various contextual factors can have on this perception. Here, we also build on some of our previous work, where we emphasized the importance of formal modelling of multimodal user interfaces [Obrenovic04a, Obrenovic04b], and the benefits of combining these descriptions with descriptions of accessibility issues [Obrenovic07a, Obrenovic07b]. We also plan to reuse ideas from other areas, such as cognitive and performance models [Newell90] applied in human computer interaction applications, including Fitts' law [Fitts54, Accot97], GOMS family of models [John96], and cognitive architectures including Soar [Wray05] and ACT-R (Adaptive Control of Thought--Rational)

³ <http://www3.who.int/icf/onlinebrowser/icf.cfm>

⁴ <http://sig.biostr.washington.edu/projects/fm/>

⁵ <http://www.w3.org/WAI/eval/>

[Anderson96]. Most of these theories and models are, however, applicable only at low levels of interaction, such as the key stroke level, and cannot be used to reason over higher-level properties of interaction, such as user perception. In our approach we aim at supporting analysis of higher-level perceptual effects.

We plan to apply semantic web techniques for modelling and reasoning over knowledge [Antoniou2004] to realize the proposed modelling and reasoning frameworks. In this way we are able to reuse existing tools and build on the experience of applications of semantic techniques to similar problems in other domains.

2e. Originality and Innovation

The main innovative element of the proposed topic is in using perceptual constraints as a unifying metaphor. Most of the previous work on designing solutions concentrated on a specific set of disabilities, or on specific situations. By treating different task, user, environment and device presentation factors in the same way, we can facilitate the design of generic solutions applicable in broader set of situations. We also enable a higher-level perceptual view on information presentation, in contrast to existing theories that cover only low-level interaction. Usage of standard knowledge modelling techniques and tools will allow the reuse of existing tools and experiences from other fields, and communication of the results to a wide audience.

2f. Significance (potential contribution for science, technology, and society)

Our main contribution to science and technology is in developing an aid in coping with the complexity of the design of information presentation. Our theory enables design of more flexible and reusable solutions, aimed for a broader set of situations, addressing the growing number of users that access information in new context (i.e. through mobile devices), and the needs of disabled users. Given the great diversity of situations and user (dis)abilities, our design theory will provide a general economic advantage over existing solutions that try to "handcraft" solutions for all possible users (dis)abilities and situations [Gurminder04].

A significant contribution of our anticipated result to society includes improved design of interfaces for information access by disabled people.

2g. Plan of work

	Year 1	Year 2	Year 3
Survey (and user studies)			
Requirements specification			
Building the theory			
Applying the theory			
Evaluation and feedback to the theory			
Reporting and publishing			

During our project we will collaborate with several other research groups, including:

- Stichting Bartimeus Accessibility⁶, Utrecht, The Netherlands; we plan to work together on topic of evaluation of information presentation applications with disabled users.
- Human-Computer Studies Group (HCS), Informatics Institute of the University of Amsterdam; we plan to work together on application of proposed design theory in a mobile context.
- Laboratory for Human Computer Interaction for Special Needs, San Sebastian, Spain; work together on evaluation methods for identification of perceptual constraint on the Web.
- K-Space IST Network of Excellence⁷; working together on semantic (semi-) automatic annotation of multimedia content in terms of perceptual constraints.
- World Wide Web Consortium (W3C) Web Accessibility Initiative (WAI) group⁸; giving feedback on guidelines for multimedia content on the Web.

⁶ <http://www.bartimeus.nl/>, <http://www.accessibility.nl/>

⁷ <http://www.k-space.eu/>

⁸ <http://www.w3.org/WAI/>

2h. Literature references

- Accot97 Accot, J., Zhai, S. (1997). Beyond Fitts' Law: Models for Trajectory-Based HCI Tasks. Proceedings of CHI '97, Atlanta, Georgia, ACM Press.
- Anderson96 Anderson, J. R. (1996). ACT: A simple theory of complex cognition. American Psychologist, 51, 355-365.
- Antoniou04 Antoniou, G. and van Harmelen, F. 2004 A Semantic Web Primer. MIT Press.
- Baddeley90 Baddeley, A. (1990). Human Memory: Theory and Practice. London: Lawrence Erlbaum
- Barnard00 Barnard, P., May, J., Duke, D., and Duce, D. 2000. Systems, interactions, and macrotheory. ACM Trans. Comput.-Hum. Interact. 7, 2 (Jun. 2000), 222-262.
- Basili99 Basili, V.R., Shull, F., and Lanubile, F. Building knowledge through families of experiments. IEEE Trans. Software Engineering 25, 4 (Apr. 1999), 456--473.
- Buxton95 Buxton, W. (1995). Speech, Language & Audition. Chapter 8 in R.M. Baecker, J. Grudin, W. Buxton and S. Greenberg, S. (Eds.) (1995). Readings in Human Computer Interaction: Toward the Year 2000, San Francisco, Morgan Kaufmann Publishers.
- Chevalier03 Chevalier, A. and Ivory, M. Y. 2003. Web site designs: influences of designer's expertise and design constraints. Int. J. Hum.-Comput. Stud. 58, 1 (Jan. 2003), 57-87.
- Chevalier07 Chevalier, A. and Bonnardel, N. 2007. Articulation of web site design constraints: Effects of the task and designers' expertise. Comput. Hum. Behav. 23, 5 (Sep. 2007), 2455-2472.
- Fitts54 Fitts, P.M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology, 47, 381-391.
- Fjermestad00 Fjermestad, J. and Hiltz S.R. Group support systems: A descriptive evaluation of case and field studies. Journal of Management Information Systems 17, 3 (Mar. 2000), 113--157.
- Gurminder04 Gurminder Singh, "Content Repurposing," IEEE MultiMedia, vol. 11, no. 1, pp. 20-21, January/March, 2004.
- John96 Bonnie E. John , David E. Kieras, "The GOMS family of user interface analysis techniques: comparison and contrast", ACM Transactions on Computer-Human Interaction (TOCHI), v.3 n.4, p.320-351, Dec. 1996
- Karl93 Karl, L., Pettey, M. & Shneiderman, B. (1993). Speech versus Mouse Commands for Word Processing: An Empirical Evaluation, International Journal of Man-Machine Studies, 39(4), 667-687.
- Löwgren92 Löwgren, J. and Nordqvist, T. 1992. Knowledge-based evaluation as design support for graphical user interfaces. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Monterey, California, United States, May 03 - 07, 1992). P. Bauersfeld, J. Bennett, and G. Lynch, Eds. CHI '92. ACM, New York, NY, 181-188.
- Marchionini06 Marchionini, G. 2006. Exploratory search: from finding to understanding. Commun. ACM 49, 4 (Apr. 2006), 41-46.

- Milne05 Milne, S., Dickinson, A., Carmichael, A., Sloan, D., Eisma, R., and Gregor, P. 2005. Are guidelines enough?: an introduction to designing web sites accessible to older people. *IBM Syst. J.* 44, 3 (Aug. 2005), 557-571.
- Newell90 Allen Newell, *Unified Theories of Cognition*, Cambridge, MA: Harvard University Press, 1990.
- Obrenovic04a Z. Obrenovic, D. Starcevic, "Modeling Multimodal Human-Computer Interaction", *IEEE Computer*, Vol. 37, No. 9, September 2004, pp. 65-72.
- Obrenovic04b Z. Obrenovic, D. Starcevic, B. Selic, "A Model-Driven Approach to Content Repurposing", *IEEE Multimedia*, Special Issue on Content Repurposing, Vol. 11, No. 1, January-March 2004, pp. 62-71.
- Obrenovic07a Z. Obrenovic, R. Troncy, L. Hardman. "Vocabularies for Description of Accessibility Issues in Multimodal User Interfaces", In *Workshop on Multimodal Output Generation*, Aberdeen, Scotland, January 25-26, 2007
- Obrenovic07b Z. Obrenovic, J. Abascal, D. Starcevic, "Universal Accessibility as a Multimodal Design Issue", *Communications of the ACM*, Vol. 50, No. 5, May 2007, pp. 83-88.
- Reeves00 Reeves, B. and Nass, C. 2000. Perceptual user interfaces: perceptual bandwidth. *Commun. ACM* 43, 3 (Mar. 2000), 65-70. Byron Reeves, Clifford Nass, *The media equation: how people treat computers, television, and new media like real people and places*, Cambridge University Press, New York, NY, 1996
- Shneiderman02 Shneiderman, B. 2002. Creativity support tools. *Commun. ACM* 45, 10 (Oct. 2002), 116-120.
- Turk00 Turk, M. & Robertson, G. (Eds.), 2000. "Perceptual user interfaces," *Communications of the ACM* (special issue), 43(3), 32-70.
- WAI Web Accessibility Initiative (WAI) - home page, <http://www.w3.org/WAI/>
- Wray05 Wray, R.E., Jones, R.M. An introduction to Soar as an agent architecture. In, R. Sun (ed), *Cognition and Multi-agent Interaction: From Cognitive Modeling to Social Simulation*, Cambridge University Press, pp 53--78, 2005.

Cost estimates

3a. Budget

NOTE: We will also use existing hardware equipment (including PCs, mobile devices, and cameras), existing software, and other facilities and logistic support at CWI.

	2008	2009	2010	TOTAL
Staff costs: (in k€)				
Applicant	65,8	67,9	70	203,7
Support staff	0,0	0,0	0,0	0,0
Non staff costs: (k€)				
Equipment	2,0	0,0	0,0	2,0
Consumables				
Travel and subsistence	5,0	5,0	5,0	15,0
Other				0,0
TOTAL	72,8	72,9	75,0	220,7

3b. Indicate the time (percentage of fte) you will spend on the research

- 100% (1,0 fte)

3c. Intended starting date

- 01/07/2008

3d. Have you requested any additional grants for this project either from NWO or from any other institution?

- NO

Curriculum vitae

4a. Personal details

Title(s), initial(s), first name, surname: **Dr. Željko Obrenovic**

Male/female: **Male**

Date and place of birth: **3/3/1976, Sisak, Croatia**

Nationality: **Serbian**

Birth country of parents: **Croatia (father), Bosnia and Hercegovina (mother)**

4b. Master's ('doctoraal')

University/College of Higher Education: **University of Belgrade**

Date (dd/mm/yy): **25/05/2002**

Main subject: **Optimization of Multimodal Communication for Time Critical Applications**

4c. Doctorate

University/College of Higher Education: **University of Belgrade**

Starting date (dd/mm/yy): **01/06/2002**

Completion date (dd/mm/yy): **26/05/2005**

Supervisor ('Promotor'): **Dusan Velasevic and Dusan Starcevic**

Title of thesis: **Designing User Interfaces using Unified Model of Human-Computer Interaction**

4d. Work experience since graduating

(per appointment: fte, tenured term ('vast') / fixed-term ('tijdelijk')).

- *2006 - present, researcher (1.0 fte, fixed-term)*
Centre for Mathematics and Computer Sciences (CWI)
Amsterdam, The Netherlands
- *1999 - 2005, researcher (1.0 fte, tenured term)*
The Center for Command Information Systems
Belgrade, Serbia
- *2004 - 2005, assistant professor (0.2 fte, tenured term)*
Computer Science Department, Technical Military Academy
University of Belgrade, Belgrade, Serbia
- *2002 - 2004, lecturer (0.2 fte, fixed-term)*
Computer Science Department, Technical Military Academy
University of Belgrade, Belgrade, Serbia
- *2000 - 2002 lecturer (0.2 fte, fixed-term)*
School of Business Administration
University of Belgrade, Belgrade, Serbia
- *2000-2001, teaching assistant (0.2 fte, fixed-term)*
College of Electrical Engineering
Belgrade, Serbia and Montenegro.

4e. Man-years of research

- 2 years and 7 months

4f. Brief summary of research over last five years

I have been doing multidisciplinary research in areas of human computer interaction, universal accessibility, and software engineering. In my PhD thesis I proposed a novel approach for designing user interfaces based on a unified model of human computer interaction. This model represents a formal description of basic concepts and relations

among concepts of interest to the development of user interfaces. Using the unified model as a starting point, and by applying principles of model-driven development, I explored various design approaches, applying them in the development of user interfaces and education [3, 4, 5, 15, 17]. As part of this research, I also conducted experimental evaluations of designed user interfaces [6, 18, 25]. The results of the research have been applied in the applications such as presentation of biomedical data and interactive television [2, 7, 8, 9]. In collaboration with other research groups, I have developed a conceptual link between the areas of multimodal interface design and universal accessibility, showing that awareness of these links can help both disciplines [1, 24]. My recent work goes toward improving a design process of complex interactive solutions for less experienced developers and end-users, and in the development of interactive ambient objects, such as interactive "cushions" [23].

4g. International activities

- Participant of K-Space — a European Commission Network of Excellence (FP6-027026) in semantic inference for semi-automatic annotation and retrieval of multimedia content (<http://www.k-space.eu/>).
- Participant of the European ITEA Passepartout project (ITEA 04017).
- Member of the World Wide Web Consortium (W3C) Multimedia Semantics Incubator Group (<http://www.w3.org/2005/Incubator/mmsem/>)
- Program committee member or reviewer for international conferences:
 - ACM Conference on Human Factors in Computing Systems – CHI (2008)
 - International Cross-Disciplinary Conference on Web Accessibility – W4A (2007)
 - International Workshop on Semantic-enhanced Multimedia Presentation Systems (2006)
 - International Workshop on Task, Models and Diagrams for UI Design – TAMODIA (2006)
 - IFIP Conference on Artificial Intelligence Applications & Innovations – AIAI (2006, 2005, 2004)
 - Conference on Articulated Motion and Deformable Objects (2006)

4h. Other academic activities

- Visiting Lecturer, Laboratory of HCI for Special Needs, University of the Basque Country, San Sebastian, Spain, Fall 2004

4i. Scholarships and prizes

- June 2006 - Recognized as a multimodal interface "guru" by SIMILAR, European Network of Excellence (FP6-507609) dedicated to multimodal interfaces (<http://www.similar.cc/>)
- January 2000 – January 2002 – M.S. scholarship grant (first in rank) from The Ministry of Science, Research, and Technology, The Government of Serbia

List of publications

5. Publications:

- International (refereed) journals

1. **S. Ž. Obrenovic**, J. Abascal, D. Starcevic, "Universal Accessibility as a Multimodal Design Issue", *Communications of the ACM*, Vol. 50, No. 5, May 2007, pp. 83-88.
2. **Ž. Obrenovic**, D. Gašević, "Open-Source Software: All you do is put it together", *IEEE Software*, IEEE Software, Vol. 24, No. 5, Sept/Oct, 2007, pp. 86-95.
3. **S. Ž. Obrenovic**, D. Starcevic, "Adapting the Unified Software Development Process

for User Interface Development", *Computer Science and Information Systems*, Vol. 03, No. 01 (June 2006), pp. 33-52.

4. **S. Ž. Obrenovic**, D. Starcevic, "Modeling Multimodal Human-Computer Interaction", *IEEE Computer*, Vol. 37, No. 9, September 2004, pp. 65-72.
5. **S. Ž. Obrenovic**, D. Starcevic, B. Selic, "A Model Driven Approach to Content Repurposing", *IEEE Multimedia*, Vol. 11, No. 1, January-March 2004, pp. 62-71.
6. **Ž. Obrenovic**, "Experimental evaluation of user performance in a pursuit tracking task with multimodal feedback", *Yugoslav Journal of Operations Research (YUJOR)* 14 (2004), Number 1, pp. 99-115.
7. E. Jovanov, D. Starcevic, A. Samardžić, A. Marsh, **Ž. Obrenovic**, "EEG analysis in a telemedical virtual world", *Future Generation Computer Systems* 15 (1999), pp. 255-263.

- Books, or contributions to books

8. **S. Ž. Obrenovic**, D. Starcevic, E. Jovanov, "Multimodal presentation of Biomedical Data", in Metin Akay (Editor): *Wiley Encyclopedia of Biomedical Engineering*, Wiley, 2006, ISBN: 0-471-24967-X, DOI: 10.1002/9780471740360.ebs1325.
9. **Ž. Obrenovic**, D. Starcevic, E. Jovanov, "Virtual Instrumentation", in Metin Akay (Editor): *Wiley Encyclopedia of Biomedical Engineering*, Wiley, 2006, ISBN: 0-471-24967-X, DOI: 10.1002/9780471740360.ebs1265.
10. **Ž. Obrenovic**, *Human-Computer Interaction*, FON: TEMPUS, Belgrade, 2004, ISBN 86-7680-027-8, (in Serbian, adapted PhD Thesis).
11. **Ž. Obrenovic**, D. Starcevic, "History of Human-Computer Interaction", In Devedžić, V. (ed.) *Intelligent System Technologies*, FON – School of Business Administration & TEMPUS, Belgrade, 2004, pp. 73-90, ISBN 86-7680-026-X (in Serbian).
12. D. Starcevic, E. Jovanov, V. Radivojevic, **Ž. Obrenovic**, A. Samardžić, "Virtual medical devices for telemedical applications", in P. Spasic, I. Milosavljevic, M. Jancic-Zguricas (Eds.), *Telemedicine*, Academy of Medical Sciences of Serbian Medical Association, Belgrade, Yugoslavia, 2000, pp. 218-244.
13. D. Starcevic, V. Radivojevic, **Ž. Obrenovic**, E. Jovanov, A. Samardžić, "Technological breakthroughs in neurophysiology: Virtual medical devices for EEG analysis", in Ilankovic (Ed.): *Consciousness, sleeping, dreams*, Belgrade, 1999, pp. 145-158.

- International (referred) conference papers

14. **Ž. Obrenovic** and Jacco van Ossenbruggen, "Web Browser Accessibility using Open Source Software", in *Proceedings of International Cross-Disciplinary Conference on Web Accessibility (W4A) 2007*, May 07-08, 2007, Banff, Canada. Co-Located with the 16th International World Wide Web Conference, pp. 11-20.
15. **S. Ž. Obrenovic**, Nestor Garay, Juan Miguel López, Inmaculada Fajardo, Idoia Cearreta, "An Ontology for Description of Emotional Cues", in Jianhua Tao, Tieniu Tan, Rosalind W. Picard (Eds.): *Affective Computing and Intelligent Interaction, First International Conference, ACII 2005*, Beijing, China, October 22-24, 2005, Proceedings. Lecture Notes in Computer Science 3784 Springer 2005, pp. 505-512.
16. **Z. Obrenovic**, "A flexible system for creating music while interacting with the computer", In *Proceedings of the 13th Annual ACM international Conference on Multimedia* (Hilton, Singapore, November 06 - 11, 2005). MULTIMEDIA '05. ACM Press, New York, NY, pp. 996-1004.

17. **S. Ž. Obrenovic**, D. Starcevic, Vladan Devedzic, "Using Ontologies in Design of Multimodal User Interfaces", in M. Rauterberg, M. Menozzi, and J. Wesson (Eds.): *Proceedings of the Ninth IFIP TC13 International Conference on Human-Computer Interaction - INTERACT '03*, IOS Press & IFIP, 2003, pp. 535-542.
18. **Ž. Obrenovic**, D. Starcevic, E. Jovanov, "Experimental Evaluation of Multimodal Human Computer Interface for Tactical Audio Applications", *Proceedings of IEEE International Conference on Multimedia and Expo - ICME 2002*, Lausanne, Switzerland, August 26-29 2002, Volume 2, pp. 29-32.
19. **Ž. Obrenovic**, D. Starcevic, E. Jovanov, Vlada Radivojevic, "An Agent Based Framework for Virtual Medical Devices", In *Proceedings of the First international Joint Conference on Autonomous Agents and Multiagent Systems: Part 2* (Bologna, Italy, July 15 - 19, 2002). AAMAS '02. ACM Press, New York, NY, pp. 659-660.
20. M. Markovic, Z. Savic, **Ž. Obrenovic**, A. Nikolic, "A PC Cryptographic Coprocessor Based on TI Signal Processor and SMarch Card System", In *Proceedings of the IFIP Tc6/Tc11 international Conference on Communications and Multimedia Security Issues of the New Century* (May 21 - 22, 2001). R. Steinmetz, J. Dittmann, and M. Steinebach, Eds. IFIP Conference Proceedings, vol. 192. Kluwer B.V., Deventer, The Netherlands, 3.
21. E. Jovanov, D. Starcevic, A. Marsh, **Ž. Obrenovic**, V. Radivojevic, A. Samardzic, "Multi modal presentation in virtual telemedical environments", In *Proceedings of the 7th international Conference on High-Performance Computing and Networking* (April 12 - 14, 1999). P. M. Soot, M. Bubak, A. G. Hoekstra, and B. Hertzberger, Eds. Lecture Notes In Computer Science, vol. 1593. Springer-Verlag, London, pp. 964-972.
22. E. Jovanov, D. Starcevic, A. Marsh, A. Samardžic, **Ž. Obrenovic**, V. Radivojevic, "Multimodal Viewer for Telemedical Applications", in *Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Volume 3, 29 Oct-1 Nov 1998, pp. 1254 - 1257.

- Other publications

International (refereed) workshops

23. Nack, F., Schiphorst, T., **Obrenovic, Z.**, KauwATjoe, M., de Bakker, S., Rosillio, A. P., and Aroyo, L. 2007. "Pillows as adaptive interfaces in ambient environments". In *Proceedings of the international Workshop on Human-Centered Multimedia* (Augsburg, Bavaria, Germany, September 28 - 28, 2007). HCM '07. ACM, New York, NY, 3-12.
24. **S. Ž. Obrenovic**, Raphaël Troncy and Lynda Hardman. "Vocabularies for Description of Accessibility Issues in Multimodal User Interfaces", In I. van der Sluis, M. Theune, E. Reiter, E. Krahmer (Eds.): *Proceedings of the Workshop on Multimodal Output Generation*, Aberdeen, Scotland, January 25-26, 2007, CTIT Workshop Proceedings Series WP07-01, pp. 117-128.
25. **Ž. Obrenovic**, D. Starcevic, E. Jovanov, "Toward Optimization of Multimodal User Interfaces for Tactile Audio Applications", Chapter in N. Carbonell, C. Stephanidis (Eds.): *Universal Access Theoretical Perspectives, Practice, and Experience - Lecture Notes in Computer Sciences 2615* (Proceedings of the ERCIM Workshop User Interfaces For All), Springer, 2003, pp. 287-298.
26. **Ž. Obrenovic**, D. Starcevic, E. Jovanov, Vlada Radivojevic, "Implementation of Virtual Medical Devices in Internet and Wireless Cellular Networks", in *Proceedings*

of the IFIP Tc6/Wg6.4 Workshop on internet Technologies, Applications and Social Impact (October 10 - 11, 2002). W. Cellary and A. Iyengar, Eds. IFIP Conference Proceedings, vol. 232. Kluwer B.V., Deventer, The Netherlands, pp. 229-242.

27. **Ž. Obrenovic**, D. Starcevic, E. Jovanov, V. Radivojevic, "An Implementation of Real-time Monitoring and Analysis in Telemedicine", *Third IEEE EMBS Information Technology Applications in Biomedicine – Workshop of the International Telemedical Information Society ITAB-ITIS 2000*, Arlington, Virginia, November 2000, pp. 74-78.

National (refereed) journals

27. **Ž. Obrenovic**, D. Starcevic E. Jovanov, "Optimization of Multimodal Communication for Tactical Audio Applications", *InfoM*, Vol. 1, No. 1.
28. M. Merdžanovic, N. Ostojic, **Ž. Obrenovic**, "An application for supporting military sport competitions", *Military technical journal*, Vojnoizdavacki zavod, Belgrade, No. 2, Vol. 2003, pp. 182-183.
29. Z. Savic, **Ž. Obrenovic**, "Protecting Data in the State Agencies' Networks", *INFO science*, 1-2 (2000), pp. 41-45.
30. D. Starcevic, **Ž. Obrenovic**, E. Jovanov, D. Karron, "Tactical Audio Training System based on Virtual Reality", *INFO science*, 6/99 (1999), pp. 4-7.

National (referred) conference papers

31. D. Starcevic, **Ž. Obrenovic**, V. Radivojevic, "Multimodal Neural Feedback", *XXX Yugoslav Symposium of Operational Research - SYMOPIS 2003*, Herceg Novi, Serbia and Montenegro, 30. September - 03. October 2003.
32. **Ž. Obrenovic**, V. Jovanovic, I. Martic, "Selective Access to SQL Server databases: An Integrative Approach", *XVIII Information Technology Conference - InfoTech 2003*, Vrnjacka Banja, Serbia and Montenegro, 26-30. May 2003.
33. V. Štavljanin, M. Minovic, D. Starcevic, **Ž. Obrenovic**, "Applying WAP 2.0 technologies in banking", *XVIII Information Technology Conference - InfoTech 2003*, Vrnjacka Banja, Serbia and Montenegro, 26-30. May 2003.
34. D. Gašević, **Ž. Obrenovic**, "An Approach to Integration of Structured Data Sources Based on Metamodel Transformations ", *YUINFO Conference 2003*, Kopaonik, Serbia and Montenegro, 10-14. March 2003.
35. **Ž. Obrenovic**, D. Starcevic, V. Štavljanin, V. Batalov, "Applying WAP/SMS Technologies in Banking", *X Telecommunications Forum - TELFOR 2002*, Belgrade, Serbia and Montenegro, 10-14. March 2003, 26-28. 11. 2002.
36. N. Ostojic, **Ž. Obrenovic**, M. Merdžanovic, N. Dulanovic, Z. Ružic, "Web-based Information Support of SYMOPIS 2001 Conference: Lessons Learned", *XXIX Yugoslav Symposium of Operational Research - SYMOPIS 2002*, 10-14. March 2003, Tara, Serbia and Montenegro, 09. - 12. October 2002, pp. VI-5 - VI-8.
37. M. Merdžanovic, **Ž. Obrenovic**, D. Hinic, "Web-based Information Support of Sport Competitions", *XXIX Yugoslav Symposium of Operational Research - SYMOPIS 2002*, Tara, Serbia and Montenegro, 09. - 12. October 2002, pp. VI-13 - VI-16.
38. **Ž. Obrenovic**, D. Starcevic, E. Jovanov, "Experimental Evaluation of Multimodal Interfaces for Tactical Audio Applications", *XVII Information Technology Conference - InfoTech 2002*, Vrnjacka Banja, Serbia and Montenegro, 17-21. June 2002.

39. D. Starcevic, **Ž. Obrenovic**, E. Jovanov, Vlada Radivojevic, "Virtual Medical Devices in Internet and Wireless Cellular Networks", 6th Balkan Conference on Operational Research, Thessaloniki, Greece, May 2002.
40. **Ž. Obrenovic**, D. Starcevic, E. Jovanov, V. Radivojevic, "Virtual Medical Devices for Monitoring and Analysis of EEG signals based on Internet and Cellular Network Technologies", *XVI Information Technology Conference – InfoTech 2001*, 19-22. June 2001, Vrnjacka Banja, Serbia and Montenegro, ISBN 86-82831-07-4.
41. V. Batalov, V. Štavljanin, **Ž. Obrenovic**, "Mobile Counter", *XVI Information Technology Conference – InfoTech 2001*, 19-22. June 2001, Vrnjacka Banja, Serbia and Montenegro, ISBN 86-82831-07-4.
42. G. Barac, Ž. Stankovic, **Ž. Obrenovic**, S. Novakovic, I. Martić, N. Novakovic, "Developing Military Human Resources Management Information System: Lessons Learned", *XVI Information Technology Conference – InfoTech 2001*, 19-22. June 2001, Vrnjacka Banja, Serbia and Montenegro, ISBN 86-82831-07-4.
43. **Ž. Obrenovic**, D. Starcevic, E. Jovanov, V. Radivojevic, "A Web-based Solution for Real-time EEG Monitoring and Analysis", *YUINFO Conference 2001*, Kopaonik, Serbia and Montenegro, 19-23.03.2001.
44. **Ž. Obrenovic**, D. Radovic, "A Web-based Solution for Acquisition, Analysis and Presentation of Metrological Data", *VIII Telecommunications Forum - TELFOR 2000*, Belgrade, Serbia and Montenegro, 21-22.11.2000, pp. 29-32.
45. **Ž. Obrenovic**, N. Ostojic, M. Živanovic, M. Đurašinovic, "Information Support of Marathon Competitions: A Web-based Approach", *YUINFO Conference 2000*, Kopaonik, Serbia and Montenegro, 2000.
46. N. Ostojic, **Ž. Obrenovic**, Milorad Živanovic, Dragan Strelic, Mladen Đurašinovic, "Web Based Information Processing Support for Sportsmen Competitions", *5th Balkan Conference on Operational Research, Banja Luka, Bosnia and Hercegovina, May 2000*.
47. E. Jovanov, **Ž. Obrenovic**, D. Starcevic, D.B. Karron, "A Virtual Reality Training System for Tactical Audio Applications", *In Proceedings of SouthEastern Simulation Conference, SESC'99*, Huntsville, Alabama, Oct 1999, pp. 149-154.
48. **Ž. Obrenovic**, N. Ostojic, M. Đurašinovic, Đ. Vojnovic, "Information Support of Shooting Competitions: A Web-based Approach", *XLIII ETRAN Conference 1999*, Zlatibor, Serbia and Montenegro, 20-22. September 1999.
49. N. Ostojic, **Ž. Obrenovic**. . . , "Information Support of Shooting Competitions: Lessons Learned", *XLIII ETRAN Conference 1999*, Zlatibor, Serbia and Montenegro, 20-22. September 1999.
50. **Ž. Obrenovic**, "An approach to server activities monitoring based on distributed software agents", *VI Telecommunications Forum - TELFOR'98*, Belgrade, Serbia and Montenegro, 24-26. Novembar 1998, pp. 350-353.
51. E. Jovanov, D. Starcevic, V. Radivojevic, **Ž. Obrenovic**, A. Samardžić, "Visualization and Sonification of Biomedical Data", *Conference on Informatics in Medicine, Pharmacy, and Social Protection - IFM'98*, Arandelovac, Serbia and Montenegro, 19-23. May, 1998, pp. 19-24 (pozvano predavanje).

-
52. **Ž. Obrenovic**, "The Software System for Supporting Email Access to Internet Services", *V Telecommunications Forum - TELFOR'97*, Belgrade, Serbia and Montenegro, 25-27. novembar 1997, pp. 337-340.
53. **Ž. Obrenovic**, "Preparing Email Messages for Accessing Internet Services", *SINFON Conference 1997*, Zlatibor, Serbia and Montenegro, 14-17. novembar 1997, pp. 33.
54. **Ž. Obrenovic**, "An Object-oriented Approach to Development of Graphical Interface for Information System Modeling", *SINFON Conference 1996*, Zlatibor, Serbia and Montenegro, 8-11. novembar 1996, pp. 10.
55. **Ž. Obrenovic**, M. Majstorovic, B. Milovanovic, "Development of the System for Evaluation of Artillery Actions: An Object-Oriented Approach", *XXIII Yugoslav Symposium of Operational Research - SYMOPIS 1996*, Žabljak, Serbia and Montenegro, 1996, pp. 969-972.

Signature

I hereby declare that I have completed this form truthfully:

Name: **ŽELJKO OBRENOVIC**

Place: **AMSTERDAM**

Date: **January 7, 2007**

ALWAYS POST THIS PAGE TO NWO

Post to NWO

In order to counter check electronic submissions, please complete the form below and post a print-out of this page together with any relevant documents to NWO to arrive no later than the submission deadline. Always post this page before the deadline, even when no other paper documents have to be sent.

I, the undersigned declare that I have today posted (tick relevant documents):

Official declaration that my thesis manuscript has been approved

(compulsory for applicants for Veni grants who have not yet received their doctorates, to be sent by post or as pdf using the Iris system)

Institutional guarantee from Board ('Inbeddingsgarantie College van Bestuur')

(to be sent by post, optional for Veni during the application procedure)

Address list of 'non-referees'

(to be sent by post before the submission deadline, optional for all applicants, maximum 3 names, see Notes)

• 1st • 2st • 3st Veni application

Name of applicant: Željko Obrenovic

Place: Amsterdam

Date: 07/01/2007

Postal address: Kruislaan 413, 1098 SJ Amsterdam

NWO Council area: EW

Send the documents to:

NWO/Vernieuwingsimpuls
Council area: **EW**
P.O. Box 93138
2509 AC The Hague
(The Netherlands)

Laan van Nieuw Oost Indië 300
2593 CE The Hague