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Navigace lidí s omezenou schopností orientace

Navigation of People with Limited Orientation Capabilities

Summary

The ability to explore the neighborhood independently and to travel to a desired destination is required for satisfactory level of quality of life and of self-confidence. Unfortunately visual or motor impairment primarily restrict the ability of person to move freely and independently. It has been observed that 30% of visually impaired people never leave their homes alone. Moreover, almost no blind person travels alone to unknown places. The percentage of visually impaired people who never travel alone has remained constant over decades. One of the key aspects seems to be a significantly higher stress level observed by the visually impaired persons while traveling independently. I will present results of long lasting research (5 years, more than 100 visually impaired participants) focused on investigation of assistive technologies for visually impaired people while navigating in unknown areas. We proposed dialogue based navigation system, which tries in maximum extent to exploit the abilities of visually impaired users. During conducted experiments an interesting correlation between specific stress situation and cognitive performance was discovered. This can be used for modeling of human behavior and improvement of navigation aids.

Souhrn

Pro udržení uspokojivé úrovně kvality života je nezbytné moci samostatně prozkoumávat svoje okolí a cestovat. Bohužel zrakové či motorické postižení primárně omezuje možnost volného a samostatného pohybu. Studie opakovaně potvrzují, že 30% zrakově postižených osob nikdy samostatně neopouští svůj domov. Navíc téměř žádný nevidomý necestuje samostatně na neznámá místa. Podíl zrakově postižených lidí, kteří nikdy necestují sami, se po desetiletí nemění. Jedním z klíčových aspektů se zdá být významně vyšší hladina stresu, kterou pozorujeme u zrakově postižených osob při samostatném cestování. V přednášce představím výsledky dlouhodobého výzkumu (5 let, více než 100 zrakově postižených účastníků) zaměřeného na zkoumání asistivních technologií pro zrakově postižené lidi při navigaci v neznámém prostředí. Navrhli jsme dialogový navigační systém, který se v maximální míře snaží využít schopnosti zrakově postižených uživatelů. Během těchto experimentů jsme zaznamenali zajímavou korelaci mezi specifickou stresovou situací a kognitivním výkonem. Tento poznatek může být použit pro modelování lidského chování a pro zlepšení navigačních pomůcek.

Klíčová slova: Uživatelský výzkum, navigace pomocí orientačních bodů, zrakové postižení, asistivní technologie, kognitivní výkon, stres.

Keywords: User research, landmark-based navigation, visual impairment, assistive technologies, cognitive performance, stress.

Contents

1 Introduction

The efficiency of navigation and orientation of a human is determined by his/her abilities and the environment where the navigation takes place. A fireman moving in burning and smoky building has very limited possibilities to use visual feedback and must utilize natural (e.g., walls, handrails) or artificial (e.g. fire hose) physical guiding lines and specific landmarks explorable by touch (e.g., niche in the wall, special shape of door knob). Similar situation can be identified by visually impaired person who is trying to navigate from the underground station to the office to acquire a new passport. This person will mainly rely on audio and tactile feedback (mainly provided by a white cane). He/she looks for physical guidelines, tries to orient his/her self by means of specific sounds coming from the environment (e.g., moving tram, sound of a passage). In our research we focus on navigation and orientation of people with visual impairment.

The ability to explore the neighborhood independently and to travel to a desired destination is required for satisfactory level of quality of life and of self-confidence. According to Golledge [14], visual impairment primarily restricts a person's mobility. Golledge et al. [16] show that restrictions on the mobility of visually impaired people significantly reduce their travel-related activities. Although visually impaired people undergo special training to learn specific navigation and orientation techniques and strategies, it has been observed that 30% of them never leave their homes alone [9,38]. Moreover, only a fraction of blind people travel independently to unknown places [15]. Interestingly, the percentage of visually impaired people who never travel alone has remained constant over decades, despite the fact that more and more assistive aids have become available. This leaves a space for research in the area of blind pedestrian navigation.

The level of mobility is influenced by the efficiency of the wayfinding process, which consists of two parts: immediate environment sensing (avoiding obstacles and hazards), and navigation to remote destinations [19]. Both parts of the wayfinding process can be supported by navigation aids that will assist the visually impaired. The basic criteria for evaluating navigation aids were defined by Armstrong [2] as safety, efficiency, and stress level.

It seems that the stress level experienced by the visually impaired people plays an important role. In a study by Wycherley and Nicklin [40], it was shown that visually impaired people experience a higher level of stress whenever they travel independently than sighted people.

This observation was verified by Peake and Leonard [25]. As it is also a demanding task for visually impaired people to use electronic devices, the usage of electronic navigation aids can further increase their stress level. According to a study by Folkman et al. [11], the stress level is determined by subjective processing of the whole situation (in our case including interaction with navigation aids). The complexity of relations between the navigation aids, environment, user personality and stress response is described in [13].

2 Navigation Problems and Current Approaches

In the following section I will summarize the problems that appear during pedestrian navigation and current approaches to solve them from three points of view:

- mobile navigation and the role of information and communication technologies (ICT),
- landmark based navigation vs. turn-by-turn navigation,
- interaction of pedestrian with navigation system by means of dialogue.

2.1 Mobile Navigation

Rapid development of ICT in mobile environment opened a space for designing pedestrian navigation systems. All major GIS systems (Google Maps, Apple Maps, OSM Maps, Nokia HERE Maps) are used on smartphones by various navigation systems including those targeted to pedestrians.

There are numerous navigation aids designed especially for visually impaired pedestrians. Some use special sensors to identify objects on the route, e.g. cameras [7], or an RFID based electronic cane [10]. Others are based on a concept described in [26], and rely on some kind of positioning system (e.g. GPS) in combination with the GIS system to identify objects and navigate the pedestrian, e.g. Ariadne GPS, BlindSquare, Microsoft GPS-enabled navigation headset. There have also been attempts to develop special interaction techniques for presenting navigation instructions, e.g. an auditory display [19] or a tactile compass [27].

However there are several issues that disqualify these navigation aids from real usage. ICT used for navigation of blind pedestrians often interferes with basic navigation aids and techniques, occupying ears or hands (see Figure 1) leading to disorientation of the person or necessity to release the white cane and stop moving. Some aids rely on very precise determination of location and orientation of the user, what is especially in urban area almost impossible. Usage of cameras for object recognition and position identification suffers from aiming problem of the camera and disturbs the privacy (reason of refusal of Google Glass).

Photo: The Guardian

Figure 1: Microsoft navigation headset on the left photo is bypassing the eardrum but still occupying audio channel what can lead to not hearing important environmental sound. Second it relies on very precise determination of location and orientation of the user. Smartphone navigation aids occupying hands on the right photo force the blind pedestrian to release the white cane and stop moving.

Common problem of many navigation aids is that they primarily try to recover missing or limited ability (in our case vision) what assumes deficiency [35] or inefficiency [34] of their cognitive functions. However currently the most promising theory of difference [14, 24] states that person with disability builds different cognitive strategies that do not have to be necessarily less efficient than those developed by not disabled. Thus these navigation aids can unfortunately lead to decrease of efficiency and passivity of the disabled people.

2.2 Landmark Based Navigation

For successful navigation and orientation in a space, we need to build up spatial knowledge about the given environment. According to Siegel and White [33], there are three levels of spatial knowledge: landmark knowledge, route knowledge, and overview knowledge.

It has been shown that landmarks (representing landmark knowledge) are by far the most frequently-used category of navigation cues for pedestrians [21] (unlike junctions, distance, road type and street names or numbers). A study conducted by Ross et al. [31] states that the inclusion of landmarks within the pedestrian navigation instructions increased user confidence, and reduced or eliminated navigation errors.

A very detailed study by Foo et al. [12] analyzed how routes are represented in cognitive maps, and concluded that as humans travel specific routes through a new environment, they do not appear to build up metric survey knowledge of the layout of target positions and that their knowledge cannot be characterized as a Euclidean cognitive map.

The fact that humans rely primarily on landmarks to navigate from point A to B is reflected in many experimental designs of navigation systems, e.g. the system of Millonig and Schechtner [23]. The system designed by Hile et al. [18] presents a set of heuristics for selecting appropriate landmarks along the navigation path.

However current navigation systems are ignoring the importance of landmarks and are turn-by-turn oriented. This is especially problem for blind pedestrians as they use different cognitive strategies from those used by sighted, based on egocentric frames [22] and the route knowledge has to be acquired on a declarative level [15]. This results in necessity to memorize large amount of information in a form of sequential representation, where the landmarks play crucial role.

Although there can be identified several attempts to tackle these problems by Openstreetmap community[1], they are either obsolete or not very systematically following some methodology like [39] for efficient navigation and orientation of visually impaired pedestrian.

Moreover the blind pedestrians use specific landmarks and attributes for navigation. These attributes can be categorized in three groups: tactile (like sidewalk surface, leading lines), auditory (like traffic sounds, echoes of passage), and olfactory (like a scent of a bakery or a river). These specific landmarks and attributes are missing in current GIS systems and are hard to gather by currently used techniques.

In addition, routing algorithms can encounter problems with nontrivial adjustments to the preferences and abilities of visually impaired people, e.g. their inability to cross open spaces (e.g. large squares).

[1] OSM for Blind Project, `http://wiki.openstreetmap.org/wiki/OSM_for_the_blind/`

2.3 Spoken Dialogue Based Navigation

For pedestrians the hands-free navigation would be the most suitable setup. For blind pedestrians it must be also eyes-free. In both situations the appropriate interaction modality would be voice communication.

Rehrl et al. [30] showed that voice-only guidance in an unfamiliar environment is feasible, and that participants clearly preferred landmark-enhanced instructions.

Building successful spoken dialogue based navigation system brings several issues that have to be solved. First it is creation of natural language description, which must be short but descriptive enough, clear and unambiguous. It is non-trivial problem to determine important landmarks and their attributes as this is strongly context dependent. In addition it is complicated to find appropriate segmentation of the route with respect to optimal pedestrian navigation. Second problem is the dialogue management especially when solving recovery from getting lost. The navigation task is a sequential decision making activity, the action effect of navigation instructions is uncertain, and when recovering from getting lost it is necessary to value actions that gather information. The model of the user is necessary to evaluate various dialogue strategies. According to [6] Partially Observable Markov Decision Processes (POMDPs) are suitable for designing such dialogue models. The problem of high computational cost seems to have promising solutions [41].

3 NaviTerier: Blind Pedestrian Navigation

NaviTerier [37] is a research project focused on the problems of blind pedestrians navigation in various environments. In our research we mainly focus on indoor and urban environments. In our investigation we try to understand their cognitive strategies and propose assistive technologies that support their specific abilities to achieve highest efficiency possigle while keeping them active. We have built an experimental navigation system (see Figure 2) and performed tens of experiments with more than 100 visually impaired persons.

In a study by Bradley and Dunlop [5] it has been shown, that in a situation of pre-recorded verbal navigation, the blind navigator navigated the blind traveler significantly faster than a sighted navigator. This interesting finding led us to conduct a series of experiments [3,36] where we have studied tele-assisted navigation based purely on verbal description of current location and knowledge of the environment. In

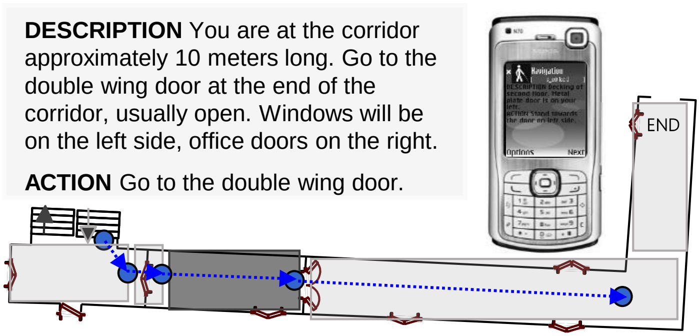

Figure 2: NaviTerier mobile navigation system. The route is split to several segments, based on the landmark distribution. The blind user is navigated from segment to segment.

these experiments we focused on the course of dialogue between the blind navigator and the blind traveler, the way of describing the environment, formulating navigation instructions and recovery from getting lost.

Based on experience gathered from the current state of art and our experiments we have designed data model for capturing the environment and algorithms for routing, route segmentation, and description creation. The data model and the algorithms are landmark based as this is the most efficient way of pedestrian navigation (see Section 2.2).

3.1 Landmark Based Routing

Our data model is split into two sub-models:

- Primary data model (see Figure 3), which is used for storage and update of environment data from multiple sources.
- Secondary data model (see Figure 4), which is used for efficient routing based on landmarks.

Primary data model consists of following classes: Landmark, LandmarkTag, WalkEdge, EdgePassability, WalkEdgePoint, and Observability. Landmarks represent the basic building blocks of the primary data model. We distinguish area landmarks and point landmarks that cover all necessary types of landmarks described in Section 2.2. Each landmark can have multiple tags – LandmarkTags – that carry additional information for generating multiple criteria values of routable networks and for building a route description. Two point landmarks can form a WalkEdge, which represents the smallest routable part. Each WalkEdge has a certain geometric shape and passability (EdgePassability). Point landmarks that are not forming WalkEdge are called WalkEdgePoints, and are used to describe important orientation cues along the route. Very important class is Observability, which allows us to model situations when Landmark or LandmarkTag is observable only from one direction.

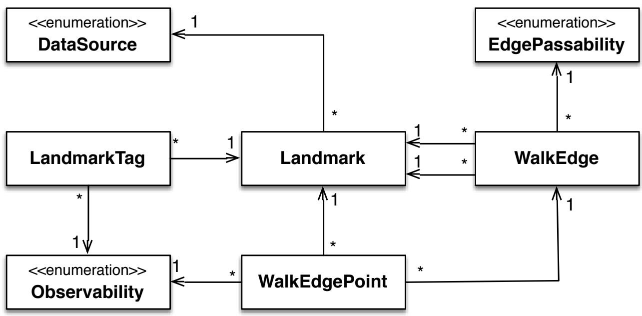

Figure 3: Diagram of the primary data model. This model is used to store and update environment data from multiple data sources.

To efficiently solve routing queries it is necessary to transform primary data model into a secondary data model that consists of routable network, data structure to identify source and target points of Dijkstra algorithm and data structure that contains spatial landmarks (see Figure 4). WalkEdges serve as the main source to build network topology for Dijkstra algorithm. Finding source and target point landmarks and spatial landmarks is a spatial search problem that can be efficiently solved by using R-Tree [1] data structure. To search for multiple routes, sort and present them based on user preferences, the cost vector is used. Cost vector is calculated from a distance between starting and end point of the route and LandmarkTags of Landmarks interfering with the route.

For each route we find all WalkEdgePoints and all intersecting spatial Landmarks. Then for each of these landmarks we fetch landmark tags. At this point we already know the direction of travel along the edge and landmarks and tags are filtered accordingly. By having all this information we can prepare a model for route description generation.

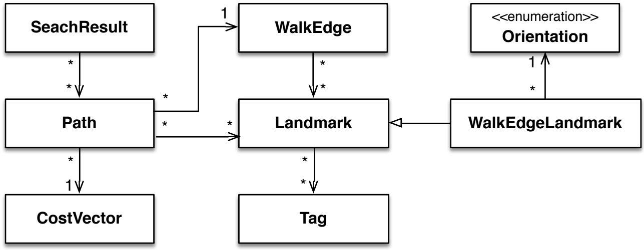

Figure 4: Diagram of the secondary data model. This model is used for efficient routing based on landmarks.

3.2 Generation of Route Description

Once we have the data model of the route we can start generating the description. For successful navigation it is important to provide user with clear and structured instruction and description of important landmarks. As the description can be longer than the user can remember, the description has to be split into several parts called segments [4,37].

The first of the problems to solve is the optimal length of the segments. Typically the segments starts and end at particular Landmarks, although this is not optimal solution if Landmarks are for example located on one straight line (see N0 – N1, N1 – N2, ..., N3 – N4 in Figure 5). In this case it is necessary to merge these segments and mention these Landmarks as being passed by, e.g. create one segment N0 – N4.

Another problem is whether to mention a landmark in the route description. For this purpose we use the Observability attribute and the direction in which the pedestrian travels.

Generated route description consists of three parts: description of current location based on surrounding landmarks, navigation instruction, and description of the segment of the route based again on surrounding landmarks. Optionally there can be description of imminent danger on the route. Description generated for the route in Figure 5 consists of following two segment descriptions:

1. You are at a corner of Zahoranskeho street and Na Zderaze Street. Go approximately 50 meters towards the corner of Na Zderaze street and Myslikova street. The building will be on your left hand side. You will pass traffic sign on your right hand side, entrance to the restaurant B1, traffic sign on your left hand side, entrance to the courtyard paved with cobblestones on your left hand side,

and second cobblestones. When approaching the corner you will hear sound from a busy street.

2. You are at a corner of Na Zderaze street and Myslikova street. Turn right 90° and cross the pedestrian crossing to the other side of Na Zderaze street.

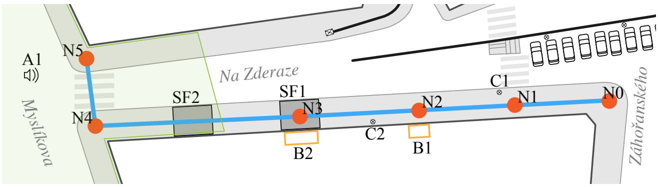

Figure 5: The illustration depicts a part of urban environment with selected landmarks: B1, B2 – restaurant, courtyard door respectively, Cx – traffic signs, SFx – cobblestones, green area A1 – sounds from a busy street, Nx – point landmarks connected by navigable edges. Solid poly-line (blue) represents a route found between N0 and N5.

Our experiments show that navigation based on this kind of description does not need any user localization and from the subjective point of view is very well accepted. As the mobile application can be controlled just by two buttons, it can be operated by one hand or simple voice commands and does not interfere with basic navigation aids like white cane.

4 Role of Stress in Navigation

As it has been already mentioned in the introduction (see Section 1) visually impaired people experience higher level of stress than sighted people whenever they travel independently, in our research we pay a special attention to the role of stress in navigation of blind pedestrians.

4.1 Remembering the Route

It seems that visually impaired people acquire superior serial memory skills. A study by Raz et al. [29] discovered that congenitally blind people are better than sighted people in both item memory and serial memory, and that their serial memory skills are outstanding, especially for long sequences. Moreover according to a study by Balata et al. [3], visually impaired people memorize relatively long routes at a very high level of detail.

In our experiments we studied the relation of the environment to the ability and way of remembering the route. Our observations revealed interesting finding, that in many cases the participant did not remember particular part of the route. There was no obvious relation to some specific segment of the route.

We have made an assumption that this may be caused by increase of stress level above certain level or by cognitive style of the person. The cognitive style cannot be identified by conventional psychological methods as all of them rely on visual stimuli. Thus we had to choose some characteristics that influence the cognitive style and check their correlation with the ability to remember the route. These characteristics were: gender, age, level of impairment, and time of getting blind.

First we have conducted several experiments where we tried to prepare a testing procedure which will allow us to measure which parts of the route are remembered by the participants and which not. Our first technique was based on reproductive methods – verbal description of the route and modeling the route into plasticine. This method turned to be very inconvenient for the participants as they struggled with the terminology and with the modeling technique. Moreover we were not sure why some route description was not mentioned – if they did not find particular description important or they really did not remember it. Finally we decided to let the participants to pass the route second time but without navigation aid and observed where they will get lost. In the first pass they were instructed to try to remember the path for eventual independent second pass.

In final experiment with more than 40 participants it was shown that there is a correlation between acute and short increase of the stress level (stress peak) and the ability to remember the route. There was no correlation between other characteristics studied in our experiment. The stress was indicated by two methods: derived from heart rate (HR), and from introspective evaluation of the participant. For statistical evaluation we used chi square test of homogeneity. For given confidence level $\alpha = 0.05$ we could refuse the null hypotheses (for introspection: $\chi^2 = 270.9, df = 1, p < 0.001$; for HR: $\chi^2 = 133.4, df = 1, p < 0.001$).

4.2 Cognitive shadow

Our experiment showed that the stress peaks are immediately followed by short recovery phase, where the participant will not remember the route with significantly higher probability. It seems that the stress peak causes a decrease of the cognitive performance immediately after its exposure is finished. As we did not detect any decrease of the cognitive performance during the stress peak, we can metaphorically say that the stress peak is casting a cognitive shadow on the participant performance.

As the process of spatial navigation includes the whole set of psychological processes (like learning, memorization), we cannot precisely determine if the decrease of the cognitive performance is given by decline of all processes or for example just by one process, which is so important that the overall performance is decreased. According to previous studies [8, 17] it is highly probable that the recovery phase has impact on more processes. Unfortunately there are currently no methods how to determine proportions.

However we can formulate possible explanations how the recovery phase influences the cognitive processes. Firstly we can say that during the stress peak the attention is increased and after the stress peak is over the attention is exhausted and this causes decrease of cognitive performance. Second explanation can be that the stress peak causes deviation of the attention to other topics not related to currently walked route segment.

We can also exclude explanations by means of the decrease of memory function. First the impact of stress has big latency [28] and cannot show up in short recovery phase (few seconds) immediately after the stress exposure. Second it seems that malfunction of memory (by means of processing spatial data) is observed during the stress exposure not in the recovery phase [32].

4.3 Elicitation and Measurement of Stress

One of the key problems while preparing our experiments was elicitation and measurement of the stress.

For measurement of the stress level there are several methods. We were restricted to non-invasive and fast methods able to detect acute and short increase of stress in few seconds. We performed several tests with measurements of skin conductance, heart rate variability (HRV), heart rate and subjective introspection. The skin conductance measurements appeared to be unreliable as the participants were on move

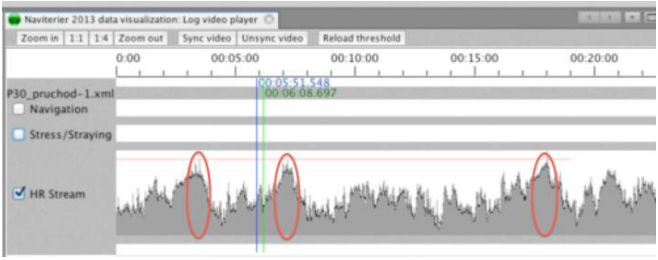

Figure 6: Objective measurement of stress peaks by means of heart rate. For each participant three highest peaks were selected and corresponding route segments were analyzed.

and often interfered with the measuring device. Their physical activity also negatively influenced the measurement precision. The HRV method seemed to be very promising as it is very robust method and in comparison to HR measurement it can eliminate the effect of physical activity. However the samples from this measurements must be processed in longer time frames (approximately 5 minutes frames) and we needed to detect approximately 15 seconds frames.

Finally we have chosen HR measurement as this can detect the increase of the stress level very fast. The physical source of stress was eliminated by carefully chosen testing route without varying physical load. We also used subjective evaluation by means of participant introspection of experienced stress.

For verification and analysis of gathered data we used our analytical tool IVE [20] which was of great help for us, as it was able to visualize various data sets (HRV, HR, introspection, videos, annotations) and synchronize them across time and participants (see Figure 6).

Second problem was elicitation of the stress. Our first attempt was to prepare artificial conditions which will evoke higher stress level (like navigation of participants through places where a reconstruction took place virtually), but this approach appeared not to work. We have observed that all participants went through moments with higher stress, but on very different places. Thus in our final test setup we did not evoke stress artificially and did not arbitrarily define any route segment were the stress should be higher. Based on measurement we have determined three most stressful segments for each participant.

5 Conclusion and Future Work

Our long lasting research of blind pedestrian navigation tries to propose assistive technologies that exploit in maximal extent the abilities of visually impaired users, keep them active during navigation and thus build their self-confidence.

Based on our research we have proposed data models and algorithms for routing and route description creation based on landmarks. We have proposed techniques for landmark filtering based on their observability and rules for segmentation of the route for more convenient route description. This description is then used in our landmark based navigation system NaviTerier. The robustness of our navigation system resulted in situation where the system does not rely on precise user localization.

We have investigated the problem of getting lost on the route and identified a significant role of stress. We have confirmed a hypothesis that immediately after the exposure to higher stress level the blind pedestrian gets more often lost than in other situations. We also came up with several possible explanation of this phenomenon.

Our previous research shows that optimal navigation system should behave similarly to tele-assisted navigation lead by experienced navigator. It was shown that blind navigators are more efficient than sighted ones in situation of verbal navigation only. This directs our future research towards exploration of blind-to-blind tele-assisted navigation [3] and to search for methods of replacing human navigator with a computer system. Here we see POMDP based control of navigation dialogue as a promising approach. Currently we are collecting data from blind-to-blind navigation sessions and trying to extract features for POMDP parametrization.

The knowledge of the role of stress in blind pedestrian navigation allows us to start designing adaptive features to navigation system, which will try to eliminate the negative effect of stress.

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Languages:	Czech (native), English (fluent), German (fluent), Spanish (basics), Russian (basics)

Education

2000–2007	PhD degree in Informatics and Computer Science, Czech Technical University in Prague
1991–2000	Master degree in Computer Science, Czech Technical University in Prague
1987–1991	Secondary school (computer engineering), Prague

Citations and Impact

Web of Science (2014)	h-index: 2
Scopus (2014)	h-index: 3
Google Scholar (2015)	h-index: 7, citations: 175, i10-index: 3

Professional History

2008–present	Assistant professor and researcher at the Department of Computer Graphics and Interaction, FEE CTU in Prague.
2005–2008	Assistant professor at Department of Computers, FEE CTU in Prague
2001–2008	Researcher at Department of Computers, FEE CTU in Prague
2000–2001	Researcher at the ZGDV e.V., Darmstadt, Germany (MUMMY project)

Research Activities

- IPC member of IEEE International Conference on Cognitive Infocommunication (2013, 2014)
- Organizing committee member of Eurographics (2007)

- Member of ACM, ACM SIGCHI, SIGCHI local chapter, IFIP TC13

Selected Journal Publications

1. Balata J., Franc J., Mikovec Z., Slavik P.: Collaborative Navigation of Visually Impaired. In Int. Journal on Multimodal User Interfaces. 2014, vol. 8, no. 2, p. 175-185. ISSN 1783-7677. [25%]

2. Maly I., Mikovec Z., Vystrcil J., Franc J., Slavik P.: An evaluation tool for research of user behavior in a realistic mobile environment. In Int. Journal of Personal and Ubiquitous Computing. 2013, vol. 17, no. 1, p. 3-14. ISSN 1617-4909. [16%]

3. Kunc L., Mikovec Z., Slavik P.: Avatar and Dialog Turn–Yielding Phenomena. In Int. Journal of Technology and Human Interaction (IJTHI). 2013, vol. 9, no. 2, p. 66-88. ISSN 1548-3908. [30%]

4. Mikovec Z., Cmolik L., Slavik P.: Beyond traditional interaction in a mobile environment: New approach to 3D scene rendering. In Int. Journal of Computers & Graphics. 2006, vol. 30, no. 5, p. 714-726. ISSN 0097-8493. [40%]

Selected Conference Publications

1. Balata J., Mikovec Z., Maly I.: Navigation Problems in Blind-to-Blind Pedestrians Tele-assistance Navigation, accepted at INTERACT 2015. [25%]

2. Balata J., Cmolik L., Mikovec Z.: On the Selection of 2D Objects Using External Labeling, In Proc. of CHI'14, 2014, p. 2255-2258. ISBN: 978-1-4503-2473-1. [25%]

3. Mikovec Z., Zuna V.: iDTV User Interface for Elderly Users Based on Simplified Navigation Scheme. In IEEE CogInfoCom'14, 2014, p. 209-214. [60%]

4. Vystrcil J., Maly I., Balata J., Mikovec Z.: Navigation Dialog of Blind People: Recovery from Getting Lost. In Proc. of the EACL Workshop on Dialogue in Motion, 2014, p. 58–62. [20%]

5. Balata J., Mikovec Z., Maly I.: Data Structures for Landmark-based Navigation of Blind Pedestrians, In Proc. of 2nd Conference on Mobile and Information Technologies in Medicine, 2014. ISBN: 978-80-01-05637-0. [40%]

6. Balata J., Mikovec Z., Novacek J.: Field study: How Blind People Communicate While Recovering From Loss of Orientation. In IEEE CogInfoCom'13, 2013, p. 313-317. ISBN 978-1-4799-1543-9. [30%]

7. Polacek O., Sporka A., Mikovec Z.: Measuring Performance of a Predictive Keyboard Operated by Humming. In Computers Helping People with Special Needs, 2012, p. 467-474. ISSN 0302-9743. ISBN 978-3-642-31533-6. [15%]

8. Polacek O., Mikovec Z., Sporka A., Slavik P.: Humsher: a predictive keyboard operated by humming. : In Proc. of ASSETS'11, 2011, p. 75-82. ISBN 978-1-4503-0920-2. [30%]

9. Polacek O., Mikovec Z.: Hands Free Mouse: Comparative Study on Mouse Clicks Controlled by Humming. In Proc. of CHI'10 EA, 2010, p. 3769-3774. ISBN 978-1-60558-930-5. [30%]

10. Polacek O., Mikovec Z.: Understanding Formal Description of Pitch–Based Input. In Proc. of In Human–Centered Software Engineering (HCSE'10), 2010, vol. 6409, p. 190-197. ISSN 0302-9743. ISBN 978-3-642-16487-3. [30%]

11. Maly I., Mikovec Z.: Web applications Usability Testing with Task Model Skeletons. In Human-Centered Software Engineering (HCSE), 2010, vol. 6409, p. 158-165. ISBN 978-3-642-16487-3. [20%]