Zbornik 19. mednarodne multikonference

INFORMACIJSKA DRUŽBA - IS 2016

Zvezek E

Proceedings of the 19th International Multiconference

INFORMATION SOCIETY - IS 2016

Volume E

Interakcija človek-računalnik v informacijski družbi
Human-Computer Interaction in Information Society

Uredili / Edited by
Bojan Blažica, Ciril Bohak, Franc Novak

http://is.ijs.si

11. oktober 2016 / 11 October 2016
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PREDGOVOR MULTIKONFERENCI INFORMACIJSKA DRUŽBA 2016

Multikonferenca Informacijska družba (http://is.ijs.si) je z devetnajsto zaporedno prireditvijo osrednji srednjeevropski dogodek na področju informacijske družbe, računalništva in informatike. Letošnja prireditev je ponovno na več lokacijah, osrednji dogodki pa so na Institutu »Jožef Stefan«.

Informacijska družba, znanje in umetna inteligenca so spet na razpotju tako same zase kot glede vpliva na človeški razvoj. Se bo eksponentna rast elektronike po Moorovem zakonu nadaljevala ali stagnirala? Bo umetna inteligenca nadaljevala svoj neverjetni razvoj in premagovala ljudi na čedalje več področjih in s tem omogočila razcvet civilizacije, ali pa bo eksponentna rast prebivalstva zlasti v Afriki povzročila zadušitev rasti? Čedalje več pokazateljev kaže v oba ekstrema – da prehajamo v naslednje civilizacijsko obdobje, hkrati pa so planetarni konflikti sodobne družbe čedalje težje obvladljivi.

Letos smo v multikonferenco povezali dvanajst odličnih neodvisnih konferenc. Predstavljenih bo okoli 200 predstavitev, povzetkov in referatov v okviru samostojnih konferenc in delavnic. Prireditev bodo spremljale okrogle mize in razprave ter posebni dogodki, kot je svečana podelitev nagrad. Izbrani prispevki bodo izšli tudi v posebni številki revije Informatica, ki se ponaša z 39-letno tradicijo odlične znanstvene revije. Naslednje leto bo torej konferenca praznovala 20 let in revija 40 let, kar je za področje informacijske družbe častitljiv dosežek.

Multikonferenco Informacijska družba 2016 sestavljajo naslednje samostojne konference:

- 25-letnica prve internetne povezave v Sloveniji
- Slovenska konferenca o umetni inteligenci
- Kognitivna znanost
- Izkopavanje znanja in podatkovna skladišča
- Sodelovanje, programska oprema in storitve v informacijski družbi
- Vzgoja in izobraževanje v informacijski družbi
- Delavnica »EM-zdravje«
- Delavnica »E-heritage«
- Tretja študentska računalniška konferenca
- Računalništvo in informatika: včeraj za jutri
- Interakcija človek-računalnik v informacijski družbi
- Uporabno teoretično računalništvo (MATCOS 2016).

Soorganizatorji in podporniki konference so različne raziskovalne institucije in združenja, med njimi tudi ACM Slovenija, SLAIS, DKZ in druga slovenska nacionalna akademija, Inženirska akademija Slovenije (IAS). V imenu organizatorjev konference se zahvaljujemo združenjem in inštitucijam, še posebej pa udeležencem za njihove dragocene prispevke in priložnost, da z nami delijo svoje izkušnje o informacijski družbi. Zahvaljujemo se tudi recenzentom za njihovo pomoč pri recenziranju.

V 2016 bomo četrtič podelili nagrado za življenjske dosežke v čast Donalda Michija in Alana Turinga. Nagrado Michie-Turing za izjemen življenjski prispevek k razvoju in promociji informacijske družbe bo prejel prof. dr. Tomaž Pisanski. Priznanje za dosežek leta bo pripadlo prof. dr. Blažu Zupanu. Že šestič podeljujemo nagradi »informacijska limona« in »informacijska jagoda« za najbolj (ne)uspešne poteze v zvezi z informacijsko družbo. Limono je dobilo ponovno padanje Slovenije na lestvicah informacijske družbe, jagodo pa informacijska podpora Pediatrične klinike. Čestitke nagrajencem!

Bojan Orel, predsednik programskega odbora
Matjaž Gams, predsednik organizacijskega odbora

FOREWORD - INFORMATION SOCIETY 2016

In its 19^{th} year, the Information Society Multiconference (http://is.ijs.si) remains one of the leading conferences in Central Europe devoted to information society, computer science and informatics. In 2016 it is organized at various locations, with the main events at the Jožef Stefan Institute.

The pace of progress of information society, knowledge and artificial intelligence is speeding up, but it seems we are again at a turning point. Will the progress of electronics continue according to the Moore's law or will it start stagnating? Will AI continue to outperform humans at more and more activities and in this way enable the predicted unseen human progress, or will the growth of human population in particular in Africa cause global decline? Both extremes seem more and more likely – fantastic human progress and planetary decline caused by humans destroying our environment and each other.

The Multiconference is running in parallel sessions with 200 presentations of scientific papers at twelve conferences, round tables, workshops and award ceremonies. Selected papers will be published in the Informatica journal, which has 39 years of tradition of excellent research publication. Next year, the conference will celebrate 20 years and the journal 40 years – a remarkable achievement.

The Information Society 2016 Multiconference consists of the following conferences:

- 25th Anniversary of First Internet Connection in Slovenia
- Slovenian Conference on Artificial Intelligence
- Cognitive Science
- Data Mining and Data Warehouses
- Collaboration, Software and Services in Information Society
- Education in Information Society
- Workshop Electronic and Mobile Health
- Workshop »E-heritage«
- 3st Student Computer Science Research Conference
- Computer Science and Informatics: Yesterday for Tomorrow
- Human-Computer Interaction in Information Society
- Middle-European Conference on Applied Theoretical Computer Science (Matcos 2016)

The Multiconference is co-organized and supported by several major research institutions and societies, among them ACM Slovenia, i.e. the Slovenian chapter of the ACM, SLAIS, DKZ and the second national engineering academy, the Slovenian Engineering Academy. In the name of the conference organizers we thank all the societies and institutions, and particularly all the participants for their valuable contribution and their interest in this event, and the reviewers for their thorough reviews.

For the fourth year, the award for life-long outstanding contributions will be delivered in memory of Donald Michie and Alan Turing. The Michie-Turing award will be given to Prof. Tomaž Pisanski for his life-long outstanding contribution to the development and promotion of information society in our country. In addition, an award for current achievements will be given to Prof. Blaž Zupan. The information lemon goes to another fall in the Slovenian international ratings on information society, while the information strawberry is awarded for the information system at the Pediatric Clinic. Congratulations!

Bojan Orel, Programme Committee Chair
Matjaž Gams, Organizing Committee Chair

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Bojan Blažica, Ciril Bohak, Franc Novak

11. oktober 2016 / 11 October 2016
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PREDGOVOR

Interakcija človek–računalnik v informacijski družbi je konferenca, ki jo organizira Slovenska skupnost za proučevanje interakcije človek–računalnik. Namen konference je zbrati raziskovalce, strokovne delavce in študente in ponuditi možnost izmenjave izkušenj in raziskovalnih rezultatov, kakor tudi navezave stikov za bodoče sodelovanje. Zadani cilj, da bi organizirali konferenco vsako leto, smo doslej le delno uresničili. Vendar pa kljub temu v Sloveniji narašča zanimanje za področje interakcije človek-računalnik, o čemer priča število prispevkov na letošnji konferenci in različne smeri opravljenih raziskav. Poleg že uveljavljenih tem, kot so uporabnostno testiranje, vizualizacija in snovanje grafičnih uporabniških vmesnikov, so predatavljeni tudi primeri aktualnih smeri, ki vključujejo nadgrajeno resničnost in aplikacije osnovane na množični mobilni komunikaciji.

FOREWORD

Human-Computer Interaction in Information Society is a conference organized by the Slovenian HCI community. The conference aims to bring together researchers, practitioners and students to exchange and share their experiences and research results, as well as to provide an opportunity for establishing contacts for collaboration. We have set ourselves the objective of organizing an annual event and have so far only partially succeeded. On the other hand, it is apparent that the interest in HCI in Slovenia is increasing as evidenced by the number of submitted papers to the conference this year and different areas of the reported research. Beside the established approaches such as usability testing, visualization or GUI design, examples from emerging topic areas including augmented reality and mobile crowd sensing are elaborated.

Bojan Blažica, Franc Novak, Ciril Bohak

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Remote Interaction in Web-Based Medical Visual Application

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ABSTRACT
In this paper we present a novel integration of four remote collaboration modalities into an existing web-based medical data visualization framework: (1) visualization data sharing, (2) camera view sharing, (3) data annotation sharing and (4) chat. The integration of remote collaboration modalities was done for two reasons: for getting the second opinion on diagnosis or for getting a diagnosis from the remote medical specialist. We present an integration of these modalities and a preliminary evaluation by the medical expert. In conclusion we show that we are on the correct track of integrating collaboration modalities into the visualization framework.

Categories and Subject Descriptors
H.4 [**Information Systems Applications**]: Miscellaneous; J.3 [**Computer Applications**]: Life and Medical Sciences

General Terms
Vizualization, Collaboration

Keywords
medical visualization, remote collaboration

1. INTRODUCTION
It is generally accepted fact, that collaboration yields better results in most of the fields. It is even more so for the case of medical diagnosis, where doctors are commonly looking for the second opinions of colleagues with more experiences or with different view on the problem. Since doctors with same expertise are often not in the same institution or even country the collaboration between them can be slow or requires lots of resources.

Medical collaboration applications have already been presented in different forms. Such cloud based solution is presented in [3] where authors claim, that such solution might reduce the storage costs of increasing volume of radiological data being produced on daily basis. While radiologists still need to transfer the data back to their devices for their examination it is the first step towards remote collaboration.

Early examples of remote collaboration in reviewing of ultrasound images using low-cost voice and video connections is presented in [1].

A collaboration system with broad specter of features is presented in [4]. The telemedicine system integrated many features of collaboration such as cooperative diagnostics and remote analysis of digital medical imaging data, audio-visual discussions as well as remote computing support for data analysis.

Where there are no radiologists available, hospitals can make use of remote diagnostic services. In such service the companies offer to make diagnosis based on radiological data at distance. In such case the hospital staff still has to send the data to the company which then makes a diagnostic process offline. Such example is a Canadian company Realtime Medical, which assures privacy, data security and fast processing of requests via their PACS/RIS-neutral workflow management platform DiaShare[1].

Another example of remote collaboration allows radiology specialists to guide and direct the technicians at the distance. Such system iMedHD2[2] was presented by Remote Medical Technologies and consists of two parts: (1) a wearable telemedicine device, a hands-free secure live HD streaming device, and (2) Tele-Ultrasound system, which provides multi-participant real-time sharing of images, annotations, snapshots and moreover, secure connection. The users can join the sessions in the web browser.

An image based viewer for tablets was presented by Khandheria [5]. Primarily the image viewer is intended for face-to-face consultation with colleagues, but offers a remote access to radiological images as well. The application integrates web-based PACS viewer and real-time audio/video teleconferencing with remote users.

Researchers have also investigated what is the acceptance of the Web-based distribution of radiology services. Such study for regional and remote centres of Western Australia is presented in [8].

This paper addresses different communication modalities for remote collaboration. In the next section we present the Med3D framework – a web-based framework for viewing me-

[1] `http://www.realtimemedical.com/`
[2] `http://www2.rmtcentral.com/tag/real-time-radiology/`

dical volumetric data. In section 3 we present the integration of novel remote collaboration modalities in the Med3D framework. Section 4 presents a preliminary evaluation of integrated collaboration modalities, followed by discussion in section 5. In last section we present conclusions and possible future work.

2. THE MED3D FRAMEWORK

A web-based visualisation framework Med3D [6], an adaptation of Java based visualization framework NeckVeins [2], was developed with purpose of platform independent tool for visualization of medical volumetric data. The framework is developed using WebGL 2.0 library for exploiting the hardware accelerated graphics rendering in the browsers. While currently the framework allows indirect visualization of volumetric data through the use of Marching Cube algorithm [7] for transformation to polygonal mesh model of the data, it is designed for integration of direct volumetric rendering algorithms such as ray casting as well.

Med3D also allows users to annotate the data they are viewing with 3D position based annotations and save the annotations for later review. We have also implemented a support for remote collaboration enabling specialists, mostly radiologists, getting second opinions form colleagues over the Internet or getting diagnosis from remote specialists at all. The data can be viewed locally by individual user it can be uploaded and shared with designated users of the framework, or it can be directly shared with an individual or group of users. The framework user interface is displayed in Fig. 1.

Figure 1: ***The Med3D framework with loaded 3D model of medical data. Figure also shows annotations pinned to the exact locations on the model.***

3. INTEGRATION OF REMOTE COLLABORATION

The main contribution of this paper is integration of remote collaboration in the web-based visualization tool Med3D. The remote collaboration includes four different modalities: (1) sharing visualization data, (2) sharing camera view, (3) sharing annotations and (4) integrated chat between connected users.

3.1 Visualization data sharing

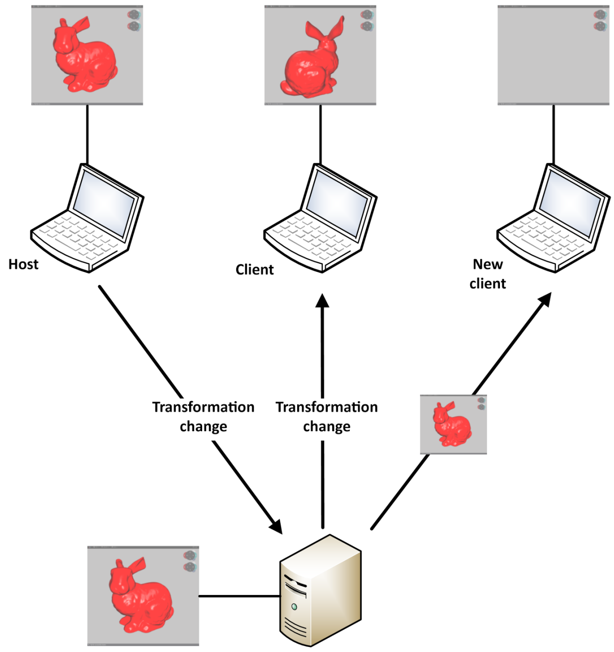

Figure 2: ***The communication schema during remote collaboration. In top left is the session host, who shares the scene with other users of Med3D application. The host in the schema has already synchronised the scene with the server (bottom right) and sends the updates of the shared scene, that is then sent to all the subscribers and updates the local copy of scene as well. In the top middle is the guest (subscriber) to she session, which has already transferred the scene from the server and is receiving updates from the host. Top right is the new client who transfers the most recent version of the scene from the server.***

The sharing of visualization data between users over network is not a novel idea. However, to the best of our knowledge, we do not know the implementation of the idea in such form. The data between users in Med3D can be shared in two ways. First option allows users to upload their data and make it available to other users of the framework. This is a common implementation done in multiple web-based collaborative applications. In this way the data is stored on the server and shared with selected users. The second approach, also implemented in our framework allows users to share data from current session. A user can share their session and define data sharing. Other users can connect to shared session and obtain the shared data in same form as original users has them. Such scheme is presented in Fig. 2.

3.2 Camera view sharing

While data sharing is quite common in many applications it is not very common to have an ability of sharing your view of the data as well. There are some examples of such collaborations in form of collaborative document editing (e.g. Google Drive). There are also applications that allow users to share their computer screen or single application window. But this still differs from our aim, where we wanted to enable user to have her own view on the data, but also have an option of seeing a view of a remote user.

We implemented this by sharing user's camera transformations with other users. Each user has an option to share her view and other users can attach to their shared view, thus sharing their viewing experience in real time, while still being able to switch back to their own view at any point in time. In our case this gives the users option to better explain their decisions and also to show which portion of the data they are currently studying.

Due to small amount of data being distributed between users there is no major latency between screen view synchronisation. The synchronisation speed is dependant on the latency of network itself between users and Med3D server. The distribution of camera transformations between users is also shown in Fig. 2.

3.3 Annotation sharing

Previously presented 3D position dependant annotations can also be shared with other users. Here we only share the content of the annotations and their anchoring position on 3D model, but not the position of actual annotation window in user interface. Each shared annotation is displayed in the middle of the screen upon its first display, but saves its position for individual user afterwards. This is done due to different sizes and aspect rations of individual screens (we do not want to put annotations outside the visible area for users with smaller screens).

Each user can decide whether she wants to share her annotations or not. In the future we will also implement the option of sharing individual annotation. List of local and shared annotations is displayed in left side of the Med3D user interface in Fig. 1.

3.4 Chat

Fourth collaboration modality is group chat integrated into Med3D framework. Such collaboration is not new but gives participating users option of communication. We implemented interactive chat because of low bandwidth consumption. The chat in framework is available to all the the participants in same session. An example of chat is displayed in Fig. 3 We are also planning on integrating voice and video conference support in later versions which were originally omitted due to their high bandwidth consumption.

4. EVALUATION

We have done preliminary evaluation with a medical expert who uses radiological data on everyday basis for diagnosis and preparations for medical procedures. The medical expert tried out the Med3D application and implemented workflow. He also tried out the presented remote collaboration features and pointed out that the implementation of collaboration is done well, but could use further improvements. First he missed integrated voice and video chat, the feature that is already planned for future implementation, and second, he missed an option of adding hand drawn annotations on desired view. This option allows doctors to better plan the procedure with visual annotations. We have added the proposed collaboration modalities to our list of future improvements.

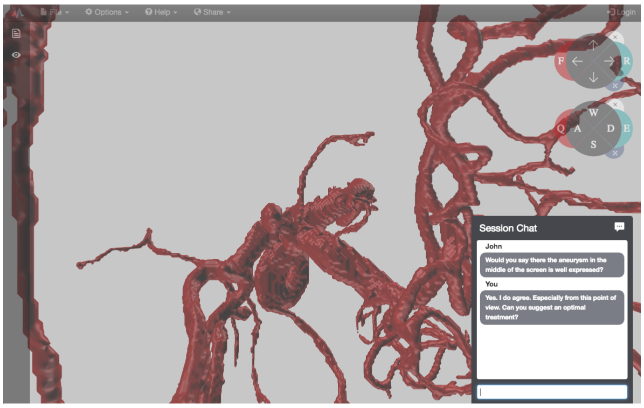

Figure 3: ***Integrated chat service for real-time discussions on displayed data.***

During the interview with a medical expert we got a good insight into desired workflow and features that allow doctors to improve their current work. The medical expert responded very positive to our implementation of remote camera synchronisation which enables collaborators in-depth study of the data from same point of view.

The medical expert has also pointed out that Med3D with well annotated data collection could also be used for educational purposes with support for students from experts with use of integrated remote collaboration modalities.

5. DISCUSSION

With integration of remote collaboration into medical visualization framework has proved as good idea according to the results of previous studies as well as from a positive feedback we got from the medical expert. We decided to integrate the remote collaboration option in an early stage of development of Med3D framework, which gives us the possibility of blending remote collaboration features with the single user workflow, making the features easier to learn and to use.

Our decisions were confirmed and supported with a preliminary evaluation interview with medical expert who gave us positive feedback with pointers on what and how to improve in the future. Medical expert also pointed out that the data visualization itself is very important and should be done well.

6. CONCLUSIONS AND FUTURE WORK

In this paper we have presented an integration of remote collaboration modalities into an existing web-based 3D visualization framework Med3D. We have presented each individual collaboration modality, presented results of a preliminary user evaluation and highlighted the pros and cons of presented collaboration modalities. The future work includes extension and specialization of each individual collaboration modalities, such as per user and per group permissions of collaboration options. We are also planning on introducing additional collaboration options in form of voice and video group calls between the users of the framework.

7. ACKNOWLEDGES

We would like to thank medical expert for great feedback on implemented features and guidelines for future improvements of the framework.

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3D serious games for Parkinson's disease management

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ABSTRACT
The aim of the article is to show how off-the-shelve equipment can be used to develop serious games for an affordable tele-medicine solution for Parkinson's disease management. Two games have been developed aimed at assessing and training patient's reach of upper limbs (using Kinect v2) and fine motoric skills of fingers (using Leap motion). The games collect player data in terms of score achieved and full kinematics of movement during gameplay. The data is stored online and made available to therapists and doctors through a secure connection. The games have been tested with patients within the Soča rehabilitation institute as well as at their homes.

Categories and Subject Descriptors
Categories and subject descriptors: H.1.2 [**User/Machine Systems**]: Human factors; J.3 [**Life and Medical Sciences**]: Health;

General Terms
Measurement, Documentation, Performance, Design, Human Factors.

Keywords
3D interaction, serious games, Parkinson's disease, rehabilitation, tele medicine

1. INTRODUCTION
Parkinson's disease (PD) is a long-term disorder of the central nervous system that mainly affects the motor system. It belongs to a group of conditions called motor system disorders, which are the result of the loss of dopamine-producing brain cells. The four primary symptoms of PD are tremor, or trembling in hands, arms, legs, jaw, and face; rigidity, or stiffness of the limbs and trunk; bradykinesia, or slowness of movement; and postural instability, or impaired balance and coordination. As these symptoms become more pronounced, patients may have difficulty walking, talking, or completing other simple tasks [1]. There are 10 million patients worldwide (1.2 million in the EU [2]). Their lives are dependent on others and there is no cure, we can only postpone the onset of symptoms or treat their severity. "The combined direct and indirect cost of Parkinson's, including treatment, social security payments and lost income from inability to work, is estimated to be nearly $25 billion per year in the United States alone. Medication costs for an individual person with PD average $2,500 a year, and therapeutic surgery can cost up to $100,000 dollars per patient." [2]

Given the above, it is no surprise that several research projects have been funded to advance our knowledge of PD (Rempark[1], Sense-Park[2], Cupid[3], Neurotremor[4]). The work presented in this article is part of the PD_manager project, which aims to build and evaluate an innovative, mHealth, patient-centric ecosystem for Parkinson's disease management. More specifically the aim of PD_manager is to:

1. model the behaviors of intended users of PD_manager (patients, caregivers, neurologists and other health-care providers),
2. educate patients, caregivers and healthcare providers with the focus on occupational and speech therapies and
3. propose a set of unobtrusive, simple-in-use, co-operative, mobile devices that will be used for symptoms monitoring and collection of adherence data (smartphone, sensor insole, smart pillbox, wristband with sensors for acceleration, heart rate, etc.) [5].

The games presented form a small subset of the devices used within the project for monitoring of patients and their adherence to treatment. As their main purpose is not entertainment, the developed games fall in the category of serious games [7].

2. REQUIREMENTS
The basic idea behind the presented systems is to (1) encourage patients with Parkinson's disease to put more time into rehabilitation through the use of gamification concepts, and (2) allow tracking the performance of individual patients that use the system. Performance tracking is created by recording of patient's activity both, at the rehabilitation center as well as at the patient's home.

The recorded performance track is also available to the doctors who have the possibility of tracking the progress of all patients that use the system via a web-based application. The web-based application is intended for doctors' use to asses and track individual patient's performance and plan his/hers rehabilitation remotely.

The system therefore consists of three parts: a client part application for patients, a server for gathering data and settings and a web-based client for doctors and caregivers. The client part

[1] http://www.rempark.eu/

[2] http://www.sense-park.eu/

[3] http://www.cupid-project.eu/

[4] http://www.car.upm-csic.es/bioingenieria/neurotremor/

is the most demanding in terms of system requirements, as it has to enable the smooth and comfortable use by the user as well as allow undisturbed capture of the data about patients' performance. The systems used in the presented work have the following specifications: Intel i7 – 4770R processor. 8 GB RAM, 120 GB SSD Hard Drive, Microsoft Windows 8.1, Microsoft Kinect V2, Leap motion, Mini PC form factor (GigaByte Brix and Zotac ZBOX used), mouse and keyboard for standard input at system boot. The system connects to any modern television with an HDMI input.

3. IMPLEMENTATION

The games have been developed with the Unity 3D[5] game engine, the choice of sensors to use was done according user specifications from Table 1.

Table 1: Sensor selection based on game requirements

Task	Reach	Fine motor skills
Requirements	Stimulate user to move hands above shoulder blades up and outwards	Stimulate user to use fine motoric skills of fingers
Sensor selected	Kinect v2	Leap motion
Relevant sensor specifications	3D tracking of 26 skeletal joints @30 Hz, seated mode, hand pose tracking (open, closed palm)	detailed 3D tracking of fingers@115 Hz

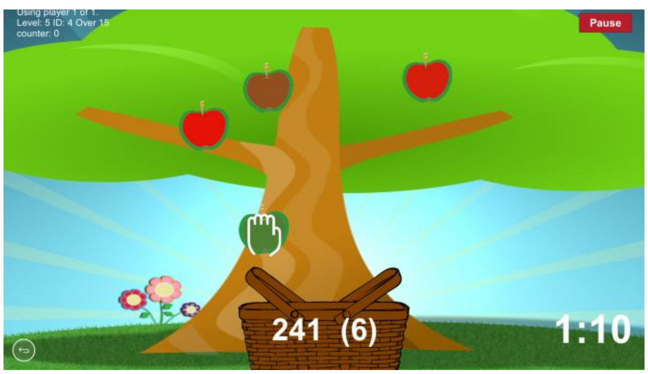

Figure 1: 'Fruit picking' game for exercising the reach above shoulder level.

The first game, aimed at preserving the range of movement of the patient's arms was developed with Microsoft's Kinect V2 sensor. The game consists of one scene in which the patient collects apples growing on a tree and puts them in a basket (Figure 1). Despite the game's simplicity its' development was not so straightforward. One of the most important aspects of such a game is the 'feeling' the user has when interacting, how smooth the interaction is, and the fidelity with which his movements are translated in the game. From a technical standpoint, this means filtering the raw input signal from the Kinect sensor and fine-tuning the filtering parameters. Additionally, with the health practitioners involved in the project we defined the physical interaction zone (PHIZ) of the game so it reflects the constraints that the domains of use imposes, i.e. mapping user movements relative to the users coordinate space (originating in the center of the user's torso) and translating the PHIZ above shoulder height (Figure 2). Difficulty levels were then defined based on how far the user needs to stretch to reach an apple; the higher the level, the more apart the apples are. The game progresses to the next level when a patient successfully collects 15 apples 3 times in a row. This protocol was defined after initial user tests. These test also revealed the possibility to cheat. The users could wait for an apple to fall near the basket, grab it then and put it in the basket, which defeats the purpose of the game (to reach out with the hands). This was corrected by making the apples not draggable once they start falling of the tree. Another issue raised from user testing was selecting the proper player as the sensor used can track 6 bodies simultaneously.

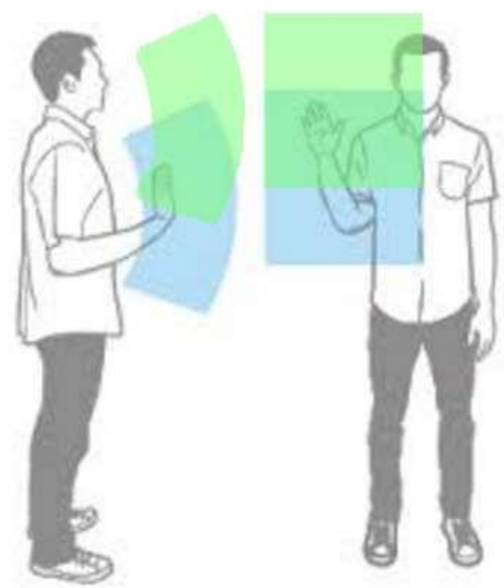

Figure 2: Original PHIZ (blue) and PD adjusted PHIZ (green) originating at the player's shoulder to stimulate proper exercising of upper limbs.

For the second game, focused on preserving the user's fine motoric skills, we decided to switch to the Leap Motion hardware as it would not be possible to achieve the desired accuracy with the Kinect sensor (some recent literature exist on how to process Kinect data to achieve accurate finger tracking [10], but the current available solutions proved to be too inaccurate for the task). The task of the user in the second game is to pick small cubes with his fingers and put them in a box (Figure 3). The result is the amount of blocks collected in two minutes and the time left in case he collects all boxes. Both games communicate with the server using secure SSL communication with self-signed certificates. Games settings, i.e. difficulty level, are retrieved from the server and controlled by the medical personnel remotely (Figure 4), while game results (score achieved and number of apples collected) and kinematic data of the user (rotation in Euler angles and quaternions and position of tracked joints) are anonymously stored online. The game also stores these data locally in case of problems with the internet connection at the patient's home.

[5] http://www.unity3d.com/

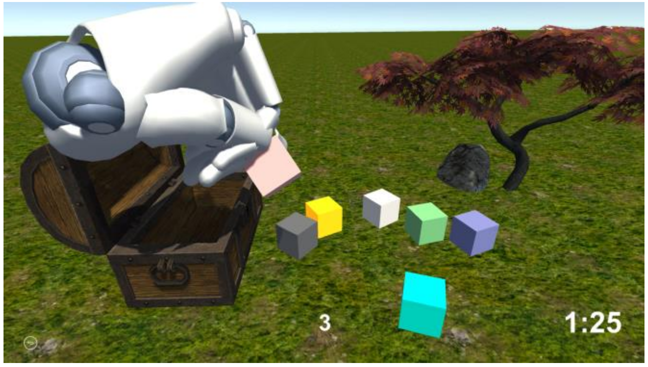

Figure 3: ‘10 cubes’ game for exercising fine motoric skills.

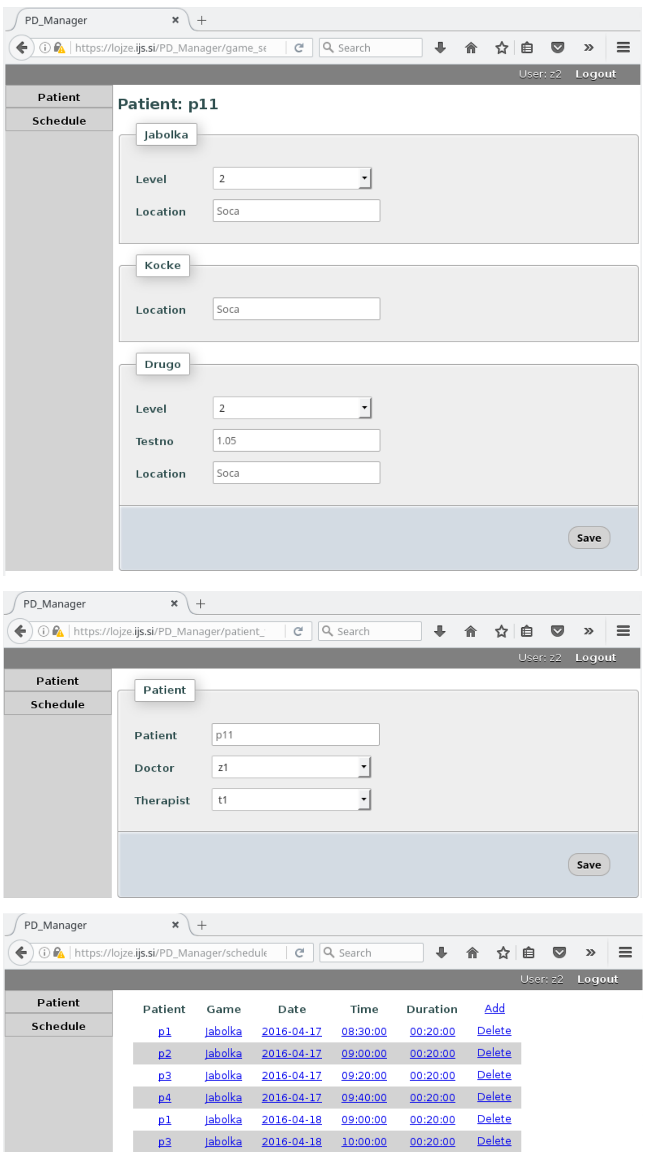

Figure 4: The interface for doctors and caregivers: patient-specific game settings (top), patient data (middle), exercises schedule (bottom).

3.1 PHIZ

While we could use the Leap motion SDK out of the box, we needed to make some adjustments when using the Kinect v2 sensor. The physical interaction zone (PHIZ) of the Kinect intended for normal use is defined as a cube originating in the player’s torso as shown in Figure 2 left, while the constraints that the domains of use imposes, imply a different PHIZ. The change demands the mapping of user movements in the original PHIZ to one translated above shoulder height as shown in Figure 2 right. Figure 5 shows the PD adjusted PHIZ in action during testing.

Figure 5 Testing with ‘Fruit picking’ game.

3.2 Kinematic data collected

In the first game, the data collected by the Kinect sensor is collected at 30 FPS and consists of the position vector (x,y,z) and quaternion orientation (w,x,y,z) of all joints of all detected players (layer). The recorded joints are: left ankle, right ankle. left elbow, right elbow, left foot, right foot, left hand, right hand, tip of the left hand, tip of the right hand, head, left hip, right hip, left knee, right knee, neck, left shoulder, right shoulder, base of the spine, middle of the spine, spine at the shoulder, left thumb, right thumb, left wrist, right wrist. See [6] for details.

The second game records kinematic data from the Leap motion controller data at 115 FPS. The data is described as follows: in each frame, there can be one or more hand objects. The hand object reports the physical characteristics of a detected hand. It includes a palm position and velocity; vectors for the palm normal and direction to the fingers; properties of a sphere fit to the hand; and lists of up to five attached fingers (identified by number, from 0 for thumb to 4 for pinky finger). The anatomy of each finger is further described with four bones ordered from base to tip, indexed from 0 to 3: 0 for metacarpal, 1 for proximal, 2 for intermediate, 3 for distal). Finally, each bone is described with its length, width, center position, orientation, next and previous joint [4].

For two minutes of gameplay, the data gathered amounts to approximately 5 MB and 100 MB for game 1 and 2 respectively.

4. DISCCUSION AND CONCLUSION

According to the review and the proposed classification of serious games for health presented in [8], our games can be classified as follows: *purpose* – for health, *application area* - motor, *interactive tool* – 3D cameras, *interface* – 2D/3D, *players* – single, *genre* - exergame, *adaptability* – yes, *progress monitoring*

– yes, *feedback* – yes, *portability* – yes, *engine* – Unity3D, *platform* – PC, *connectivity* – on. There were two other games mentioned in the review dealing with PD. One aimed at cognitive capabilities and the second for motor skills. The latter is comparable to our games with the exception that it does not provide feedback nor connectivity. Additionally, we can compare our games against the guidelines for serious games for PD described in [9]. We can see that most were met:

- *accuracy* – yes, the sensors used provide data that is accurate enough to be analyzed to evaluate the performance and progress of the patient,
- *home-based solution* – yes, the system is commercially available and affordable,
- *real-time biofeedback* – yes, the system gives feedback about how the patient is doing to therapists as soon as a session is finished (if connection is available),
- *customized games* – the games enable visual cues, and adjustable level of difficulty that can monitored remotely by the therapist,
- *PD rehabilitation protocol* – yes, the addition of new mini-games is possible,
- *automated system calibration* – yes, the Kinect sensor's skeleton tracking with the modified PHIZ acts as an automatic calibration system that matches the range of movement of the patient with the range of movement required by the virtual game player,
- *feedback/reward system* – yes, the games stimulate the user by constantly giving feedback on the progress of the game and after the game is finished to increase the engagement and involvement of the player with the game and reduce the risk of abandonment of the game and physiotherapeutic treatment.

4.1 Lessons learned

Connectivity is often overlooked. Two examples: first, the GigaByte Brix has no external WiFi antenna, which proved to be a problem when operating in the hospital as the room in which the therapy takes place has poor signal and second, PD patients are elderly people with often-outdated TV sets without HDMI input.

Other players of the system such as grandchildren must be taken in consideration. On the one hand, they make the whole tele-medicine experience nicer for the patients and can help with system adoption and troubleshooting but on the other hand can bring noise in the data collected if the system has no option to discriminate between patient and other player. This is why we introduced the warm-up mode of gameplay, where data is not recorded online.

Ease of use for both patients and therapists is equally important as both spend a lot of time with the system, but from a different perspective. For the patient, the ease of use is determined by how the game feels while playing, while for the therapist use of use is about the simplicity to set up the system, to switch between patients using the game and how much help the patients need when using the system at home.

Giving feedback is not always positive as some patients suggested that knowing that they are near the goal makes them anxious, which in turn makes it harder for them to actually reach the goal.

4.2 Future work – trials, evaluation

The virtual reality supported physiotherapy starts with inpatients and lasts for 4 weeks and each individual continues at home for additional 2 weeks. 18 inpatients, aged between 54 and 80, were recruited for testing and validation, 5 patients tested the system also in their homes after admission. Physiotherapists assess the patients' condition at the time of recruitment at the time of admission and at the end of home therapy. Although testing with additional patients and validation in a bigger pilot with 200 patients is subject of ongoing work, we can say that in general, the system is well accepted by patients.

5. ACKNOWLEDGMENTS

Our thanks to URI Soča rehabilitation center for their contribution during the development and testing of the system with real patients.

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Designing visual interface for nutrition tracking of patients with Parkinson’s disease

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ABSTRACT
In this paper, we describe the design of a visual interface of a mobile a mobile app for tracking nutrients and foods consumed by patients with Parkinson’s disease. The interface should enable the patients to recognize objects on the screen, easily perceive their function and interact with them thus providing an efficient way of entering the dietary intake data. The app has been validated by five patients and the preliminary results are encouraging.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Graphical user interfaces (GUI), Prototyping, User-centered design

General Terms
Design, Human Factors

Keywords
User interface, Design, Food and nutrition tracking, dietary assessment, mobile app, Parkinson’s disease.

1. INTRODUCTION
There exist different methods for dietary intake assessment, which are used to explore eating habits of individuals by measuring nutrients and foods. Information about dietary intake is needed for both risk prediction and dietary treatment of chronic diseases. Dietary assessment is possible using either open-ended surveys, such as dietary recalls or records, or closed-ended surveys including food frequency questionnaires.

Continued efforts have been done to improve the accuracy of these methods as inaccurate dietary assessment may be a serious obstacle of understanding the impact of dietary factors on disease. Recently, the technology for image detection and recognition by using Deep neural networks has developed significantly, enabling its application for automatic dietary assessment as well. The technology could not only provide automatic recognition of food and drinks but also enable estimation of volume and nutritional values.

While the need of tracking dietary intake is well recognized, the problem of acquiring the dietary intake data remains a challenge issue. In practice, it appears that patients with Parkinson’s disease, such as the older adults, often have problems handling electronic devices. Consequently, designing user interfaces for this population has been quite well researched topic. There are numerous studies addressing both interfaces on normal displays [1], [2] and touch-screens [3], [4] to name just a few.

Extensive and in-depth research of user design guidelines for smartphone applications for people with Parkinson’s Disease has been done by Nunes et al [5]. Their study featured literature review of disease symptoms, interviews with care-givers and usability testing experiments with (39) patients. They concluded that the patient’s interaction with smartphones may be directly influenced by their: motor symptoms (bradykinesia, rest tremor, muscle rigidity, postural instability and gait impairment), non-motor symptoms (sensory symptoms, cognitive disorders, dementia) and on/off phenomenon (the variety between the symptoms when the medication is acting in a great way and when not). They evaluated the performance of four touch gestures: tap – is accurate with the large target size; swipe – should be used without activation speed; multiple taps – are comfortably performed; drag – are not preferred (are better replaced with multiple tap controls). They furthermore constructed the information display guidelines, that included: the use of high contrast colored elements, carefully selected information to display, the presence of indication of location, the avoidance of time-dependent controls, the use of multi-modality and also the application of guidelines for older adults.

Another study [6] carried out pilot questionnaires to (22) patients with their caregivers – trying to understand requirements for designing the user interface for them. The PD-diary application for big touch-screens was designed based on assumptions about the patients concluded from the interviews. They suggested that most potential users are older than 60 years and are not computer-literate. Patients have been using only a few electronic devices (a mobile phone e.g.) and are not good with computer peripherals (such as mouse and keyboard) and may have negative associations with such equipment (because they don’t use it often). The answers indicated that it may be helpful to use the GUI logic that is well known to the patients (such as nine button numeric keyboard from the cash machine). The results also conformed with previously mentioned research guidelines in suggesting the use of large objects (buttons, labels, etc.), high contrast (bright objects on dark background and vice versa) and multi-modality (visual information combined with voice announcements and sound effects).

While previously mentioned research [5] included only testing of general touch gestures, recently also some usability testing of applications with a specialized purpose for PD patients has been done. For example, Barros et al [7] designed the medical application for patients' following their medical schedule based on the interviews with doctors, patients and care-givers. They performed usability tests with (12) patients that wasn't familiar with medication managing application. They used the application on a smartphone, while tactile information was being recorded and task performance was being observed. The results indicated that: there were some problems with tapping the buttons with icons placed very close to the boarders; swiping gestures on buttons with the arrows were observed; tapping on the check-boxes wasn't very accurate; patients did not always understand the additional step of confirming the input. Otherwise the researchers observed that recorded errors weren't severe, the patients grasped the main concept and quickly learned how to use the application.

Several studies researching the design of rehabilitative exergames (digital exercise based games) have been done (e.g. [8], [9]) and also the design of self-management applications for the patients to manage their diaries has been documented (e.g. [6], [10]). The mentioned research was taken into account when designing a mobile application for tracking the nutrition of patients – as part of PD_manager project, briefly presented in Chapter 2. While the previously described guidelines can here be seen applied in practice, the paper also presents new specific ways for making an application more user-friendly for the patients that interact with it. The focus of the study was how to make the visual language of user interface as easy to understand as possible for the focus group (Parkinson's disease patients). The results in form of design solutions, presented in Chapter 3, can therefore be useful for others designing user interfaces for patients with Parkinson's Disease (and also older adults in general).

2. NUTRITION TRACKING OF PATIENTS WITH PARKINSON'S DISEASE

In the European funded project PD_manager, we have developed a mobile app for tracking nutrients and foods consumed by patients with Parkinson's disease. The app provides two modules, which are used by experts and patients. The module for patients is simple and enables food recording based on images. Patients take photos of food, which are tagged by food names either in an automatic way or by the patients or their caregivers. Tagged images are uploaded on the server of the Open Platform for Clinical Nutrition (OPEN), where detailed analysis of the food diary is performed. The results of the analysis are sent to the PD_manager Decision Support System and to the patient's experts (dietitian, physician, logopedist), who perform education and, if needed, nutritional and logopedic therapy.

3. SPECIFIC VISUAL LANGUAGE

While establishing an information structure (that helps users understand the system) and designing an interaction (that makes it easy for them to finish a given task) were also a part of designing the user interface, this paper focuses on designing an adjusted visual language. The goal was to design it specificity in a way, that enables users to quickly recognize the objects on the screen – consequently making the whole experience more user-friendly.

Designed visual language provides an easy way for the patients to: locate interactive elements on screen, pay attention to the most important information, differentiate between input text and instructions, understand which functions are available to them and stay aware of the current activity that they are participating in.

Design choices not only incorporate previously described guidelines from the research of designing interfaces for patients with Parkinson's disease but are furthermore grounded in other design principles of graphical user-interfaces and visual communications.

We used color and shape in a way that utilizes specific characteristics of visual variables – selective and associative perception. We determined the same color for objects with the same functionality, making it easy for users to recognize, locate and isolate them – grouping them into categories (e.g. static and interactive objects). Within the main categories, we use the difference of shape to enable users to differentiate between sub-categories, while still preserving the perception of the main categories (e.g. icons of functions and input suggestions – both interactive objects). We established visual hierarchy by designing a few instances of different brightness of information and increasing the difference between them, making it easier for users to process them. Furthermore, we used semiotic principles to communicate different functions of buttons and provide the feedback of successfully completed tasks.

Designed visual language was unified and used throughout the whole app, which makes the interface predictable and consequently allows users to quickly learn how to use the app. It should be also noted, that the visual style differs from the ones usually found in mobile applications in its boldness, strong use contrast and the presence of clear, emphasized elements. At some points the aesthetic value was compromised for making sure that the interface as evident as possible for the users from the focus group, which may have problems with their sight.

3.1 Differentiation of interactive objects

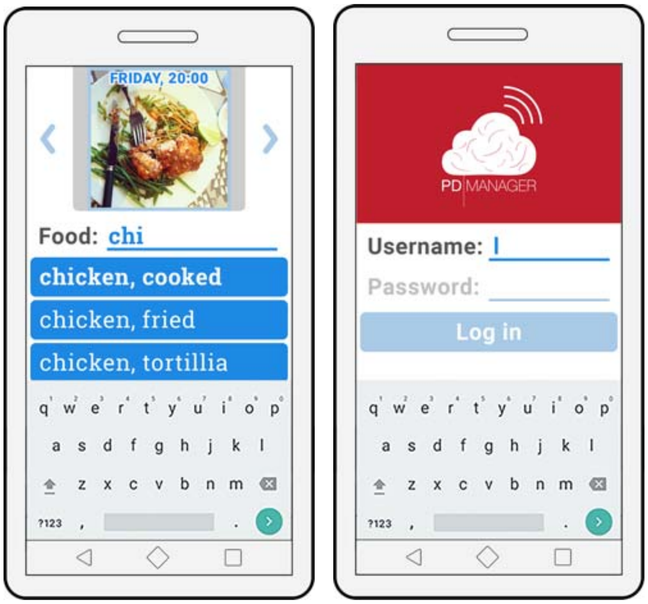
We enabled users to quickly see, on what they can tap on and on what not, by determining a distinctive color hue for interactive and static objects. We colored all the interactive objects blue and all the static ones gray. That means that all the buttons and input information are designed to have a blue color, while all the category titles and input field labels are gray. For example, the user can easily recognize every button by blue color and every field input label by gray color (Figure 1a).

3.2 Emphasis of prioritized information

We guided users' attention to parts of the screen, that are most important in given step by applying a bigger contrast to such parts. We determined two instances of brightness of the objects (for both the interactive and static ones) – we applied a lower brightness to objects with prioritized information and a higher brightness to others. For example, the user automatically focuses the attention first on the active row which is dark, while all the other passive text input rows are bright (Figure 1b).

3.3 Special text style for input

We made it easy for users to differentiate, which text is a label and which is an input, by choosing a different font (from the same typeface family) for each of them. We chose a serif font for text input (Roboto Slab) and sans serif for other information (Roboto). For example, the user can recognize every input text without reading it from observing a serif font alone and similarly he/she can recognize every field labels by a sans serif font (Figure 2a).

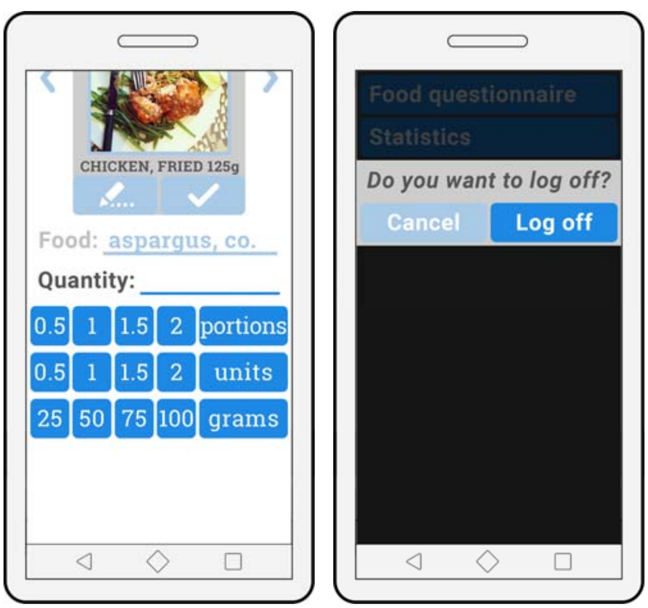


(a) (b)

Figure 1: (a) Example of button recognition, (b) example of guiding focus by higher/lower brightness

3.4 Special text style for instructions

We made it simple for users to recognize, which text is addressing them directly (instructions and questions) and which not, by choosing a different font (from the same typeface) for each category. We chose Italic font for the instructions and Regular font for other information. For example, the user can swiftly recognize the log out question without reading it by its Italic font and similarly he/she can recognize the buttons by their Regular font (Figure 2b).



(a) (b)

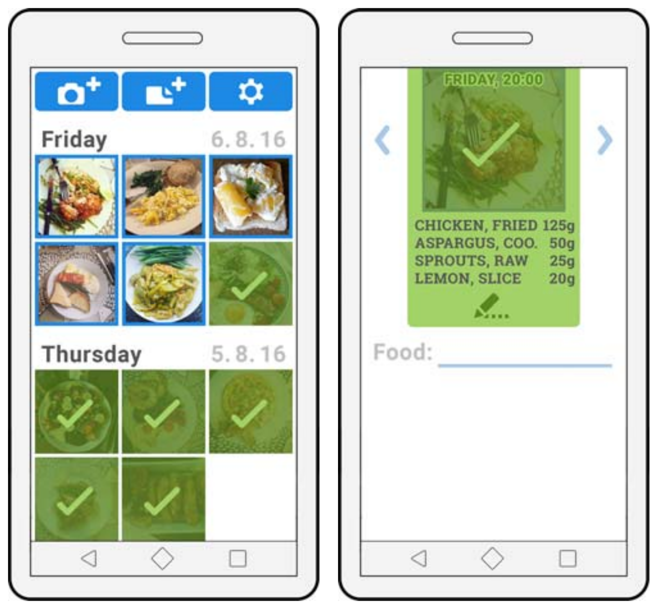
Figure 2: (a) Special text style for input, (b) special text style for instructions

3.5 Icons for functions

We helped users to perceive, what functionality provide certain buttons, by representing it in the form of pictogram icons. We designed icons of the functions to have minimal amount of details and a unified look amongst them. For adding a new meal with a photo we chose the plus sign in front of the camera and for adding a new meal without photo a plus sign in front of a blank page. For options we chose the icon of a gear, for switching between opened meals we used the icon of an arrow. For editing past input we chose the icon of a pencil and for completing the tagging process the icon of a check. For example, the user can understand in a moment (without reading any indicating text) that pressing the icon of plus and a camera will add a new photo in a gallery with meals (Figure 3a).

3.6 Feedback for task completion

We reassured that users know, when they have completed the task, by giving them visual feedback in the form of a green color. We indicated successfully finished tasks with a dark green background and a bright green check icon. For example, the user can be sure that he/she successfully performed all the steps of tagging the meal, when seeing the background of text turning green and the check icon appearing over the picture of the meal (Figure 3b).

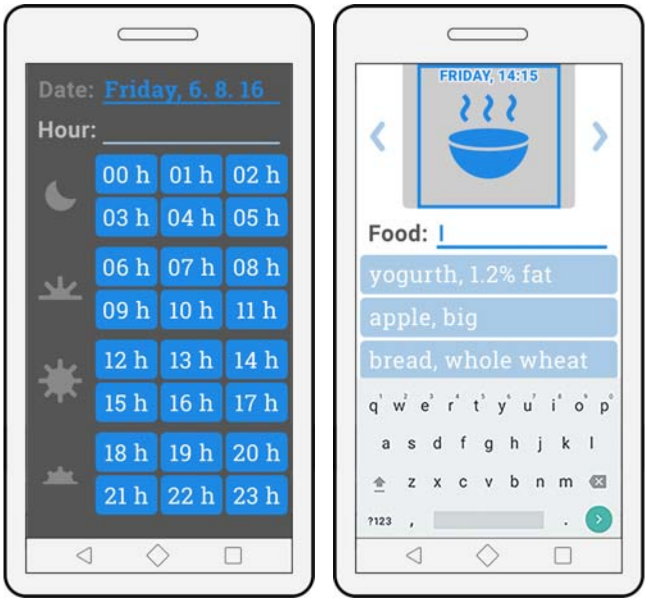


(a) (b)

Figure 3: (a) Example of pictogram icons, (b) example of feedback for task completion

3.7 Indication of current activity

We assisted users in recognizing, which task are they currently performing, by assigning a distinctive background color to different types of tasks. We chose a dark background for the task of adding a new meal (and also for viewing the options) and a bright background for the task of editing them. For example, a user can rapidly recognize that he/she is in the process of adding anew meal just by observing the dark background of the screen (Figure 4a). Similarly, he/she can recognize the process of tagging a meal by a white screen background alone (Figure 4b).



(a) (b)

Figure 4: Examples of indication of current activity

4. CONCLUSION

In this paper, we reviewed the literature on designing user-interfaces for patients with Parkinson's disease and presented the designed visual language for the interface of mobile application for tracking the nutrition of patients. The designed solution is based on: differentiating between interactive and static objects, emphasizing of prioritized information, differentiating between input information and instructions, communicating of available functions, giving feedback for task completion and indicating current activity. As it was designed in a way to make it easy for patients to recognize objects on the screen, perceive their function and know how to interact with them, the results can come in handy for others designing user interfaces for people with Parkinson's disease.

While not included in this paper, a specific information structure of application was also constructed (for enabling users to easily understand the system – by breaking tasks in several steps for example), and appropriate touch interaction was designed (for making it easy for users to effortlessly complete the tasks – by reducing the number of required taps for example). The studies were done as part of user-interface design for a mobile application for nutrition tracking of patients with Parkinson's disease (a part PD-manager project).

5. ACKNOWLEDGMENTS

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Redesign of Slovenian Avalanche Bulletin

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ABSTRACT

We present the redesign of the Slovenian avalanche bulletin, published regularly during the winter season to warn against avalanche danger and to provide specific information for advanced users. The former version included an estimation of danger on a scale from one to five with supporting text for the whole country, while the new one offers an additional graphical description, specified for several geographical regions. The redesign profoundly influenced the work of avalanche forecasters by introducing a new interface, additional input and database storage. At the same time, users welcomed the additional information, international comparability and user friendliness of the new bulletin.

Categories and Subject Descriptors

D.3.3 [**Information interfaces and presentation (e.g., HCI)**]: Miscellaneous

General Terms

Design, Standardization

Keywords

Avalanche bulletin; official warnings; risk communication; danger awareness; usability testing

1. INTRODUCTION

Depending on the snow and avalanche situation, avalanche bulletins are issued for the majority of the planet's mountainous terrain. Their purpose is to warn inhabitants and visitors of avalanche-prone areas of the current estimated danger and to provide them with additional information (e.g. type of avalanche, reason for triggering). As winter mountaineering and ski touring become more mainstream, they are increasingly accessible to less experienced people, whose lack of knowledge and skills can result in injury or death. Therefore, there is an increasing need for user-friendly, easily understandable warnings with a clear message of the dangers one is exposing himself to when visiting avalanche-prone terrain [1].

The avalanche warning services in Europe have followed this need (in accordance with their varying resources) by upgrading their bulletins [2, 3] and by agreeing on an international set of icons for danger level and avalanche situations [4].

The Slovenian Environment Agency publishes avalanche bulletins regularly throughout the winter season [5]. These are the official warnings for the entire Slovenian area. To improve service and adhere to international standards, a complete redesign of the bulletin was undertaken in winter of 2015/2016 with the new bulletin issued in test phase in the beginning of April 2016. The results from the test phase and user feedback will be used for additional improvements for the winter season of 2016/2017.

2. BULLETIN BEFORE REDESIGN

Before the redesign, the bulletin consisted of the danger level for the next few days and accompanying text describing in detail the snow conditions and danger situation along with the forecast for the next few days (Fig. 1).

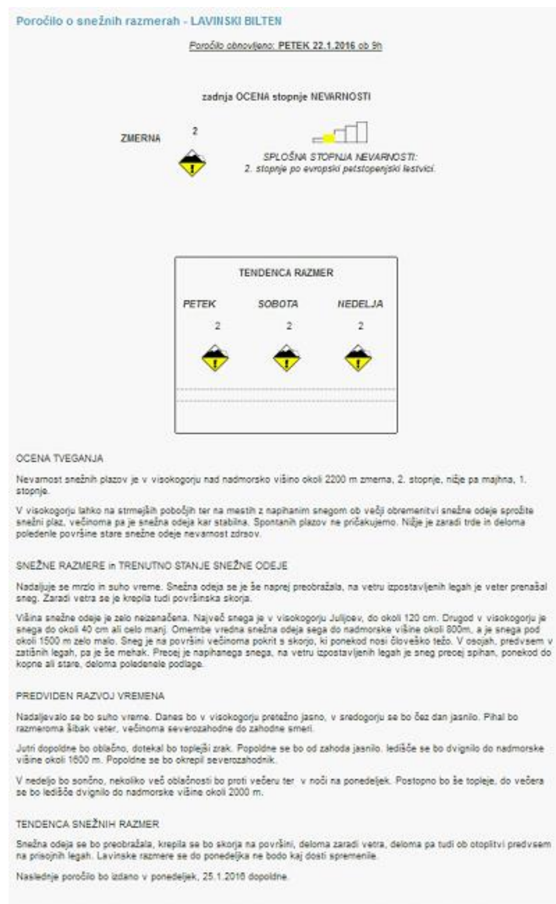

Figure 1: Bulletin before redesign

Although the text itself is very informative, usability testing indicated that it is more favored among experienced users, while novices have trouble comprehending the content due to lack of avalanche knowledge and experience. This predominantly textual form is also difficult for analyses and comparisons with previous seasons and other avalanche services from neighboring countries.

3. REDESIGNING THE BULLETIN

The **first step** of the redesign was an extensive study of other European avalanche bulletins as well as the bulletins on other continents, to find examples of good practice and examples of visualization options.

In the **second step**, the extent of the information to be presented in the new bulletin had to be decided. The bulletin needed to be as informative as possible while avoiding information overload and balancing the resources needed to provide the data, e.g. data availability and human resources needed to process the data.

Based on the agreed extent of information, several drafts of the new bulletin were prepared and user tested on several target groups.

To reach a final decision, we considered guidelines from previous work analyzed in step one with the addition of an online survey and usability testing based on initial paper prototypes (Fig. 2 - 4).

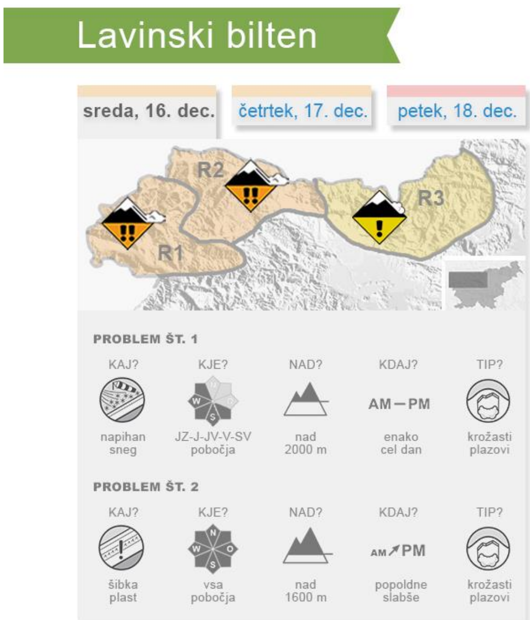

Figure 2: Graphical part of prototype no.1

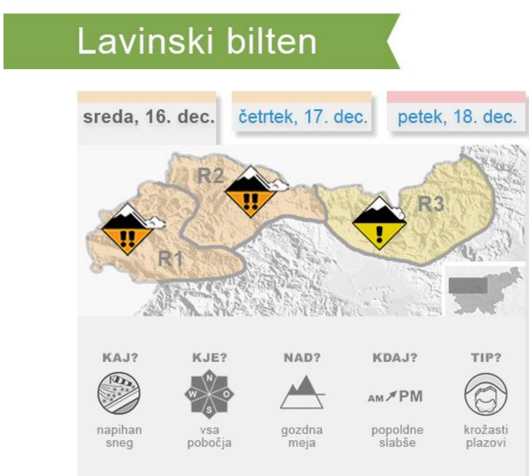

Figure 3: Graphical part of prototype no.2

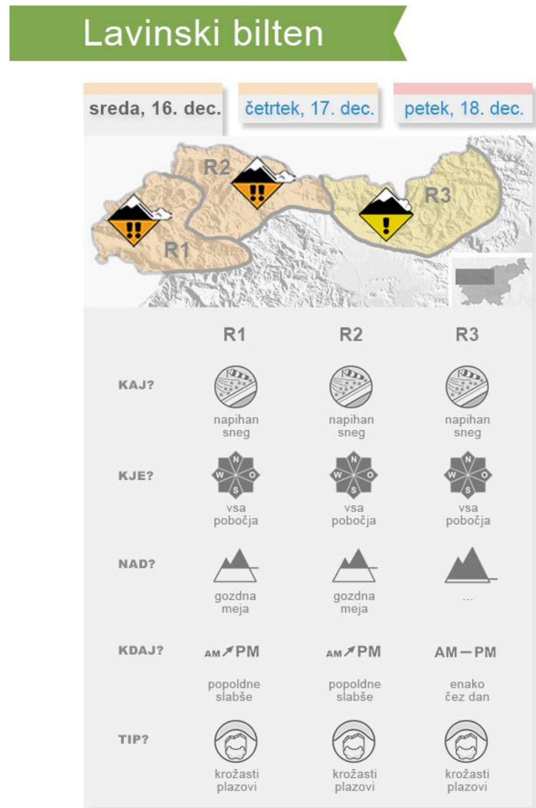

Figure 4: Graphical part of prototype no.3

User testing showed that users prefer prototype no. 3 because it presents the information for each region separately, although the table was not understood by everyone. Prototype no. 1 was confusing because it shows two problems at the same time while prototype no. 2 was well accepted. Therefore the new design is a modified prototype no. 2 with the possibility to select a particular region.

Other findings included:

- More experienced users rely more on the textual part and decide on the danger level themselves, while for novices the danger level is the most important information;
- The name “avalanche bulletin” does not stress enough that this is a warning against danger, particularly to novices;
- The danger level for the following days is not clearly presented;
- The entire scale for danger levels should be presented and the icons should also be numbered from 1 to 5;
- Regions should be named with proper names, not R1 – R3;
- The weather forecast is a useful piece of information, although it is not a always part of similar bulletins.

Based on usability testing, a near-final version was designed with the final set of information to be included in the bulletin. This was the necessary input for the third step.

The ***third step*** was to design a new database and interface to support forecasters' new workflow (Fig. 5). The interface was tested internally with the forecasters to achieve a user-friendly and effective design.

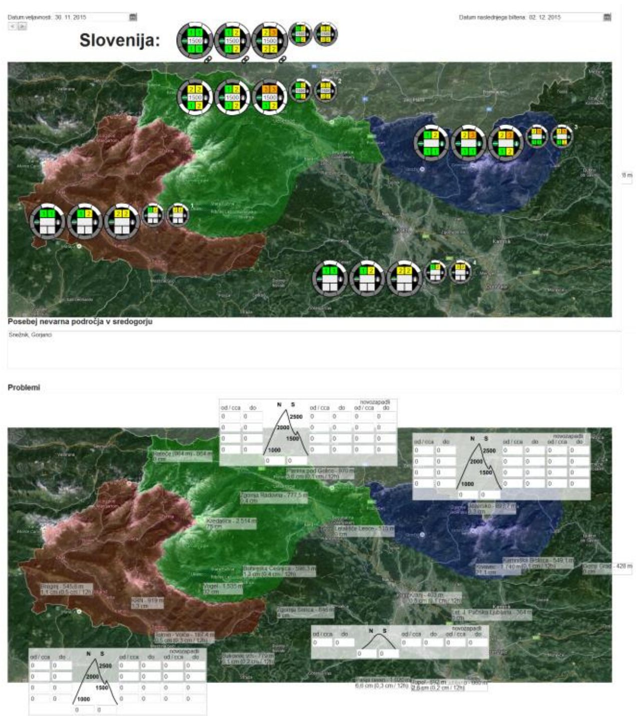

Figure 5: Two screenshots of the new interface for data input

Figure 6: Redesigned bulletin – more details in graphical part

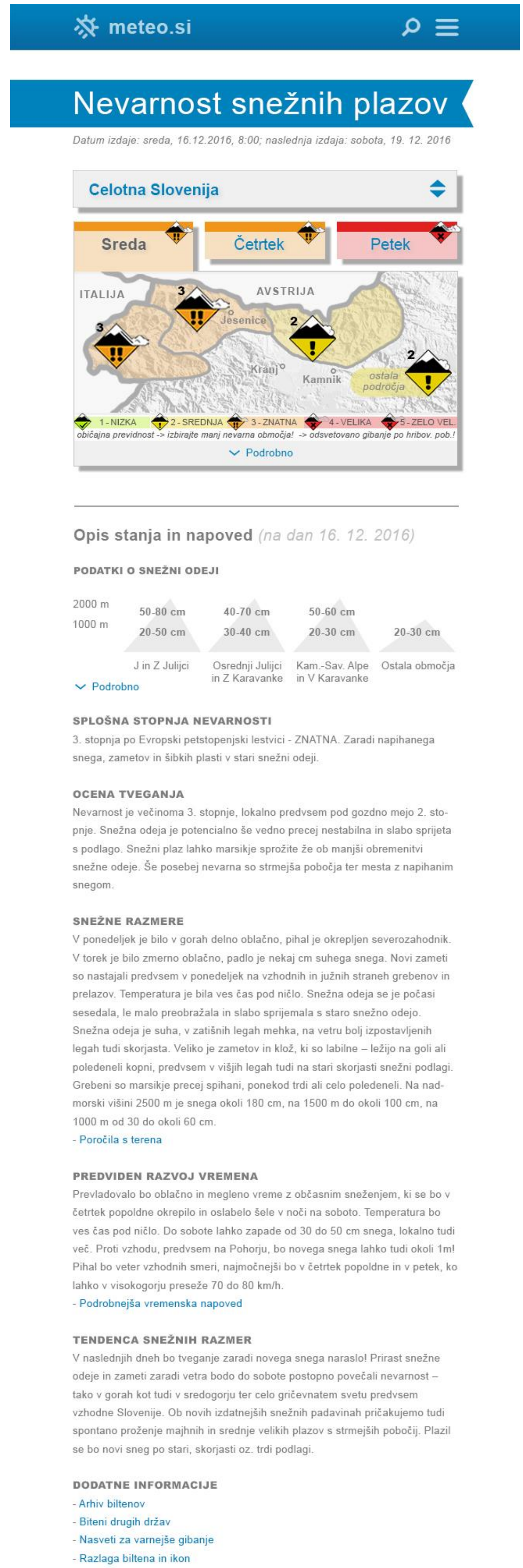

Figure 7: Redesigned bulletin – less details (main view)

The ***fourth step*** was to achieve further improvements by asking stakeholders (mountain rescue service, mountain guides, alpine association etc.) for comments on the near-final version.

The bulletin was issued in the new version for a test period in the last part of winter. The ***next steps*** will include fine-tuning based on the evaluation of the test period in terms of user acceptance and impact on the forecasters' workflow.

4. BULLETIN AFTER REDESIGN

The new bulletin (Figs. 6 and 7) puts more emphasis on graphical information for easier comprehension. The graphical content is presented for four geographical regions for the current and next two days. The avalanche situation is graphically explained with international icons (e.g. type of avalanche) and additional custom made icons (e.g. change of danger within the day). The new bulletin is more comparable to bulletins from other countries, which makes comprehension easier for foreigners as well as for Slovenians going abroad.

5. IMPACT OF THE REDESIGN

For the **Slovenian avalanche service**, the most important achievement is the improvement in the quality of their service when informing and warning the public. Additionally, the new database with more numeric information enables easier analysis of the season and the performance of the service as well as improved comparability with other services. The new interface was designed so that the number of geographical regions can be easily changed should the service decide for more (or less) detail. Similarly, the number of parameters can also be modified, making the bulletin adjustable. Although not yet in use, the data is prepared with improved dissemination in mind (xml format, widget). The presented graphical information also enables automatic translation of a large part of the information to other languages, which also remains to be implemented.

For **users**, easier dissemination and easier understanding mean increased awareness and consequently improved safety. This is particularly true for novices who had difficulty understanding the content of the previous bulletin. In the survey conducted after publishing the new bulletin in the test period, none of the 69 participants described the new bulletin as worse than before and the majority of users (65%) agreed that the bulletin has been significantly improved.

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[5] Slovenian avalanche bulletin.

http://www.meteo.si/pozor/plaz

Improving the usability of online usability surveys with an interactive Stripe scale

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ABSTRACT

The paper introduces Stripe, an interactive continuous scale for online surveys that makes it easy to compare multiple answers on a single screen. The Stripe is evaluated as an alternative to the n-point Likert scale, which is commonly used in online usability questionnaires like the System Usability Scale (SUS). The paper presents the results of a user study, which confirmed the validity of results gained with the proposed Stripe interface by applying both the Stripe and the Likert interface to an online SUS questionnaire. Additionally, the results of our study show that the participants favor the Stripe interface in terms of intuitiveness and ease of use, and even perceive the Stripe interface as less time consuming than the standard Likert scaled interface based on radio buttons.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]: Miscellaneous

Keywords

user interfaces, feedback gathering, human computer interaction, system usability score, user study, measurement scales

1. INTRODUCTION

Questionnaires are a common tool for usability evaluation in HCI research. For the purposes of our own usability testing, we developed Stripe, a more interactive and compact scale that fits on smaller screens and supports the comparison of answers across different questions. Knowing that the design of a user interface can affect the gathering procedure, and in some cases influence (or bias) the results [6, 8], we performed a user study that compared the validity of the newly proposed Stripe interface with the standard Likert scale.

The user study tested both user interfaces on the System Usability Scale (SUS) questionnaire for two well-known products. This gave us the ability to compare the SUS scores attained through both user interfaces to SUS scores reported by other studies. To further evaluate the potential of Stripe, we also performed a usability survey on both interfaces.

2. RELATED WORK

Usability is defined as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use [12]. There are many standard methodology tools available for measuring various usability aspects, ensuring the validity and comparability of results gained by a methodologically sound and well-structured approach. The tools vary in size and scope, but they all commonly use the Likert scale as the de facto standard for user-feedback gathering.

The NASA-Task Load Index (NASA-TLX) is a multi-dimensional scale designed to obtain workload estimates from a user performing a specific task [9, 10]. The ATTRAKDIFF questionnaire [11] is often used for qualitative evaluation of the pragmatic and hedonic aspects of a product or service. For measuring the usability aspects, the Software Usability Measurement Inventory (SUMI), Questionnaire for User Interaction Satisfaction (QUIS), System Usability Scale (SUS) and Usability Metric for User Experience (UMUX) are commonly used [13]. SUMI is a 50-item Likert scale questionnaire that measures five aspects of user satisfaction and scores them against expected industry norms. QUIS consists of a 27-item Likert scale and is similar to SUMI, but measures attitude towards 11 interface factors. SUS [2] is a 10-item Likert scale questionnaire measuring the usability and an overall satisfaction with a product or service. Finally, the UMUX [6] is a 4-item Likert scale questionnaire used for a subjective assessment of perceived usability.

For the purpose of testing new user interfaces for surveys, the SUS provides the right balance between length and precision with its 10 questions. Like other standard usability measurement methodology approaches, the SUS was carefully constructed from the beginning in order to achieve high reliability, validity and repeatability of results [2]. The result of the SUS is a single score, between 0 and 100.

2.1 Scales used in online questionnaires

Paper-based questionnaires have a long history of experimentation with different styles of rating scales, especially in the field of psychology. Visual analogue scales (VAS) appeared back in 1921 and were improved upon by graphic rating scales (GRS) in 1923 [4]. Both scales include an anchored horizontal line, with extreme values of the measured property listed at each end [4]. The user can place a mark anywhere along the continuous line.

In 1932 psychologist Rensis Likert introduced his own scale, which limits the number of available options to 5 in the original scale and no longer provides a continuum of choices along the line [5]. Since then, the Likert scale has been adapted to different types of questionnaires, including online versions that use standard HTML input radio buttons.

In contrast, continuous line-based scales have not been supported by the HTML standard until recently. HTML5 introduced a new "range" input type, which creates a slider scale with a handle that can be moved along the line to select a value[1]. The slider can be configured to support discrete steps or to act as a continuous scale. A potential problem with this approach is that the initial slider position can influence the response and can even lead to a different response distribution when compared to traditional scales based on radio buttons [7]. Luckily, the wide adoption of the JavaScript programming language in modern web browsers offers new opportunities for more interactive user interfaces that can bypass the limitations of standard HTML input types.

Research on online survey interfaces tends to focus on the validity of results and user performance (completion time), but fails to evaluate other usability aspects of alternative interfaces. For example, Couper et al. [4] compared online questionnaires that used VAS to ones with different styles of radio buttons and surveys with numeric input fields. Their experiment found that while VAS surveys took longer to complete and contained more missing data, they produced the same response distributions as other types. Cook et al. [3] compared a slightly different style of online graphic rating slider scales with surveys based on radio buttons and found that both provided reliable scores, but also noticed that sliders took a bit longer to manipulate. User satisfaction and subjective perceptions were not evaluated in these studies, which calls for more HCI research that takes a wider range of usability aspects into account when evaluating new interfaces for online surveys.

In the following Section we propose the Stripe, an alternative to the Likert scale that aims to take advantage of the benefits of continuous scales while offering a more compact interactive user interface that makes it easy for users to compare answers, even on a smaller screen.

3. THE STRIPE: A DYNAMIC INTERFACE

The Stripe is a user interface developed to provide an interactive and intuitive continuous-scale alternative to the standard multi-point scale interfaces. It is implemented as a canvas with one horizontal dimension (Figure 1). The dimension represents the presence of a variable, ranging between two extremes (e.g. negative/positive, absent/significantly expressed, completely disagree/agree). This is similar to the standard VAS scale. But unlike the VAS or the Likert scale, the Stripe interface accommodates drag-and-drop functionality for multiple labels, as well as annotation of multiple categories on the same canvas. In its simplest form, the user is provided with a set of labels describing different nominal values of the variable. By dragging the labels onto different positions of the canvas, the user marks their perception of each individual label on a continuous scale. The positions of placed items can subsequently be quantized to discrete values, if so desired. The amount of information retrieved by the Stripe interface is therefore at least equal to the amount of information gathered by a radio button matrix (for example, a set of 5-point scales) commonly used to capture similar information

[1]http://www.w3schools.com/html/htmlforminputtypes.asp

The Stripe and its extended version were already used in an online survey on multi-modal perception of music [14], and later evaluated in terms of usability, using a modified version of the NASA TLX questionnaire [15]. However, in order to fully evaluate the potential of Stripe, it is necessary to compare it with the standard multi-point Likert scale approach, typically used in online surveys.

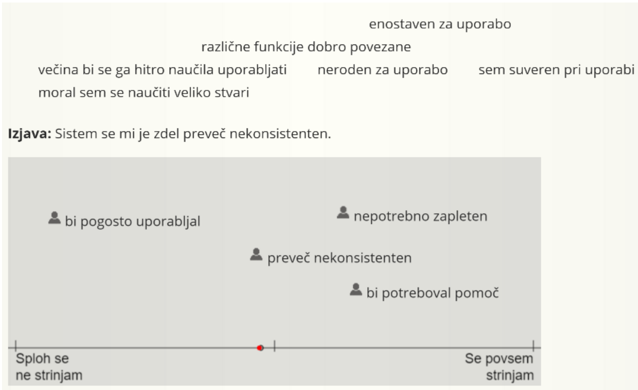

Figure 1: The Stripe interface. The statements are shortened into phrases for improved readability, but the full statement for each label is shown on 'mouse-over'.

4. EVALUATION

The goals of our experiment were: 1) to evaluate the validity of SUS scores gathered with the Stripe interface using the Likert scale as control and 2) to compare the usability of the Stripe interface with the usability of the standard Likert scale. The Stripe interface was designed for online questionnaires, so the experiment was conducted online. The user study was conducted on 2 different groups of participants, two months apart, to provide additional verification of the results.

4.1 Participants

A total of 68 participants, recruited from students and faculty members at the University of Ljubljana, fully completed the user study. Only participants with previous experience with the subject of the SUS were included in the survey, to obtain feedback from users with pre-existing experience and regular interaction with the chosen SUS subject.

For the first, Gmail survey, we collected feedback from 41 participants, 12 were male and 29 were female. Their average age was 29.4 years, with 7.1 standard deviation. For the second, Microsoft Exchange survey, we collected 27 responses from 21 female and 6 male participants. The average participant's age was 31.5 years, 7.9 standard deviation.

4.2 Experiment procedure

The user study was conducted online, with participants filling in all questionnaires on their own, using their own computers and their web browser of choice. At the beginning, each participant was asked to confirm their familiarity with the product being evaluated in the SUS: Gmail for the first group of participants and Microsoft Exchange for the second group. Participants that passed this initial step continued to filling is the SUS questionnaire twice. The formal Slovenian translation of the SUS questionnaire was used [1].

The website randomly assigned either the Stripe or Likert version of the SUS first, followed by the other version, displayed on a separate page. The user interface used in the SUS questionnaire was the independent variable, the two configurations were the Stripe interface and the 5-point Likert scale. The resulting SUS score was the dependent variable. This part of the experiment lasted on average approximately 7 minutes per participant, no time limits were imposed.

After the SUS evaluation, the participants were presented with 3 additional usability questions on a 7-point scale:

- By comparing both, the Stripe and the 5-point scale interfaces, which of the interfaces was more intuitive and comprehensible? (1 - 5-point scale, 7 - Stripe)
- By comparing both, the Stripe and the 5-point scale interfaces, which of the interfaces takes more time to fill-in? (1 - 5-point scale, 7 - Stripe)
- Is it easier or more difficult to express your opinion with the Stripe interface (due to the visual comparison of your answers)? (1 - easier, 7 - more difficult)

Basic demographic data (age and gender) of participants with optional written feedback was also collected during the final step. All questions were asked in Slovenian language.

5. RESULTS AND DISCUSSION

The scores of the SUS questionnaire for both groups of participants and both interfaces are shown in Table 1. For both experiments, results indicate consistent responses gathered with each interface. However, the standard deviation of responses gathered by the Stripe interface is smaller. This is due to the use of a continuous scale, which allows for a more fine-grained positioning of the labels, unlike restricted options on traditional n-point scales. When we performed a quantization of continuous responses into a 5-point scale (row 3 in Table 1), the scores were very similar for both interfaces. The average SUS score for Gmail was close to the average SUS score of 83.5 from [3], further confirming the roboustness of the SUS questionnaire and the validity of our results for both interfaces.

To further explore the consistency of results for both interfaces, we performed a two sample t-test for each question given in the Stripe and the 5-point Likert interface. The variances for all 10 SUS questions appear statistically consistent within each pair of variables for a given question. Thus, we rejected the null hypothesis of unequal variances for each pair of question variables for $\alpha = 0.01$. Consequently, we performed the analysis of variance for the cumulative scores. The variances for both services appear not to differ significantly. No group has marginal means statistically different from the other for $\alpha = 0.01$. The ANOVA shows no statistical differences between values gathered by both interfaces for both services, Gmail and Microsoft Exchange ($p = 0.32$). Furthermore, the ANOVA shows no statistical difference in variances between both services ($p = 0.44$).

The study also included questions on how both interfaces compare in terms of intuitiveness and comprehension, time perception and difficulty. The results showed that the participants found the Stripe more intuitive and comprehensible with the average values of 4.54 on a 7-point scale. In terms of time perception, the Stripe was rated as slightly less demanding than the 5-point Likert scale with an average value of 3.79 (Figure 2). Finally, the participants rated the Stripe interface as slightly easier for expressing opinions, with the average score of 3.42 on a 7-point scale (1 - the Stripe was easier than the Likert interface, 7 - the Stripe was more difficult than Likert).

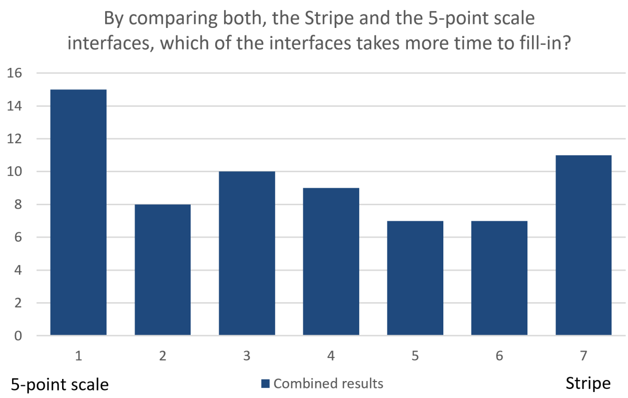

Figure 2: Comparison of the Stripe and Likert scale shows that the 5-point scale is perceived as more time consuming.

Overall, the results favor the Stripe interface over the 5-point Likert scale: mostly in terms of intuitiveness, slightly less in terms of simplicity of expressing an opinion. An unexpected result was the finding that participants found the 5-point Likert scale, which was implemented with standard radio buttons, as slightly more time consuming than the graphical and interactive Stripe interface. This result is at odds with research that shows that graphical scales take more time to fill-in than radio button scales, which leads us to the conclusion that the participants found the Stripe interface more enjoyable and engaging than the standard Likert scale interface.

6. CONCLUSION

Usability questionnaires like the SUS are still widely based on the traditional n-point Likert scale, which has also been adopted in online surveys due to its simple implementation with HTML radio buttons. And while there is some existing research that compares Likert scales with continuous scales, most research focuses on time performance and reliability of results. For this reason, we decided to conduct a user study that would also evaluate the usability of an alternative user interface for online usability surveys. In addition to providing the benefits of a continuous scale, the proposed

Table 1: Comparison of average SUS scores and their deviations for the 5-point Likert scale and Stripe interfaces.

	Gmail		Exchange	
User interface	Avg. SUS score	σ of SUS scores	Avg. SUS score	σ of SUS scores
(1) 5-point Likert SUS	79.88	18.03	72.03	20.32
(2) Continuous Stripe SUS	79.02	16.61	70.03	21.44
(3) 5-point Stripe (quantized)	80.55	17.27	70.37	22.36
Δ 1 vs. 2	0.86	1.42	2.00	1.12
Δ 1 vs. 3	1.67	0.76	1.66	2.05

Stripe scale also aims to provide a more compact alternative that could work well across different devices and smaller screens.

The results of the user study, which was conducted online on two separate groups of participants, show that both the Stripe and Likert scale interfaces provide consistent SUS scores, confirming the Stripe interface as a viable alternative. The Stripe interface was favored in terms of intuitiveness and chosen as easier for expressing opinions. The most surprising result was seeing the Stripe interface score slightly better in terms of perceived time. While surveys based on graphical interfaces like the Stripe usually take more time to complete, the participants in our study rated the standard 5-point Likert scale as taking slightly more time. Overall, our results show that the Stripe interface was the participant's favorite interface across all tested usability aspects.

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Evaluation of common input devices for web browsing: mouse vs touchpad vs touchscreen

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ABSTRACT

With the ever increasing connectivity to the Internet the use of the web has spread from static environments of desktop computers to mobile context where we interact with the web though laptop computers, tablet computers, mobile phones and wearable devices. Recent studies have shown that young people access the web using various devices and input techniques and spend on average more than 20 hours a week on the web. In this paper we plan to investigate which input technology is most usable or preferred for performing different tasks on the web. We decided to compare and evaluate the usability of the three most used input devices for web browsing, namely: a computer mouse and a touchpad on a laptop, and a touchscreen on a smartphone. For this purpose we have built a custom web page where users had to perform seven common tasks on web: open a URL address, copy/paste a URL address, copy/paste text, scroll up-down, scroll left-right, zoom in the context of a web page, and navigate a map. The results show that the mouse is still a preferred input device with shortest completion times, followed by the touchscreen interface even if it performed slower at some tasks compared to touchpad, which was marked as least preferred.

Categories and Subject Descriptors

H.5.2 [**Information interfaces and presentation**]: User interfaces—*Input devices and strategies (e.g., mouse, touchscreen)*

Keywords

input devices, performance, web browsing, evaluation

1. INTRODUCTION

Today, nearly half of the world's population is connected to the Internet[1]. According to Global Web Index, users spend up to 6 hours on the internet a day, of which 2-3 hours are spent on social networking sites [2]. These figures show that users spend a lot of time interacting with internet services, among which, the world wide web (WWW or web from hereon) is most prominent.

Browsing the web can be carried out on a wide range of computer-based products (e.g. smart phones, smart TVs, desktops, laptops, tablets, game consoles, e-book readers) and various input devices (e.g. mouse, touchpad, touchscreen, pointing stick, trackball, game and remote controllers). Users are facing different interaction modes with various input devices when carrying out the same tasks on different systems. As an example, let us assume that the we want to increase the size of the content displayed on the screen (zoom). On a computer we can achieve this with a mouse wheel or with a combination of keys on the keyboard. On the touchpad or touchscreen we can use a combination of fingers touching and moving on the surface (pinch gesture) of these input devices. Moreover, interaction is implemented with subtle differences on different operating systems, on different hardware solutions, and nonetheless, in different web browsers. Even if at first glance these slight differences look insignificant, they can lead to confusion and negative user experience.

The objective of the research presented in this paper was to evaluate and compare the three most commonly used input devices in carrying out the same tasks on the web using different computers systems. These three devices are a mouse, touchpad, and a touch screen. The aim of the research was to gain qualitative and quantitative information about user interaction while browsing the web, to determine which tasks are difficult to perform with a specific input device, which input device causes problems and why, and reveal areas where these devices could be improved to lead to better user experience.

[1] http://www.internetworldstats.com/stats.htm
[2] http://www.globalwebindex.net/blog/daily-time-spent-on-social-networks-rises-to-1-72-hours

2. LITERATURE REVIEW

The literature features an abundance of comparisons and evaluations of input devices for various computer tasks. An early comparison has looked at how mouse, trackball and stylus perform during pointing and dragging tasks [7]. The results show that pointing tasks produce less errors and are completed in less time than dragging tasks, stylus performed better when pointing, and mouse better when dragging when compared to the other two. Moreover, it has been shown that both tasks can be modeled by Fitts' law, which states that the time required to move to a target is a function of the ratio between the distance to the target and the width of the target [4].

It has been argued that target acquisition covered by Fitt's law is not the only performed task with input devices. We often perform trajectory based tasks (such as drawing, writing, and navigating hierarchical menus), which can been described and modeled by steering law [1]. The law is a predictive model predicting the speed as well as the time a user needs to navigate a pointing device through a confined path on the screen. Comparing input devices when performing linear and circular steering tasks has shown that for the overall performance the tablet and a mouse surpassed trackpoint, touchpad and trackball. However, depending on the nature of the tasks, some devices performed better than others [1].

Other tasks have also been investigated such as remote pointing input devices for smart TVs [6], operating input devices in 3D environments [3], or comparing mouse vs bimanual touch interaction on tabletops [5]. The latter has shown better mouse performance for single-user single-hand tasks, while touch has proved better for both-hand and multi-user interaction. Returning to everyday tasks, a recent study compared performance of three input devices (the finger, a stylus, and a mouse) in three pointing activities (bidirectional tapping, one-dimensional dragging, and radial dragging or pointing to items arranged in a circle around the cursor) [2]. The study confirmed that finger tapping is faster but more inaccurate with small targets than stylus and mouse. While the latter performed better in dragging tasks.

In contrast to the presented studies, our research focused on the real world tasks users often perform while browsing the web. For this purpose we have built a regular web site and logged users' performance in finishing predefined tasks. Additionally, our study focused on how users perceive the input devices and explores their opinions and preferences in using them.

3. METHOD

We conducted a study comparing three different input devices while performing common tasks when browsing the web. We selected most frequently used input devices as users are familiar with them: a mouse (connected to a HP ProBook 4530s laptop), touchpad (on a HP ProBook 4530s laptop) and a touch screen (on a Samsung Galaxy S6 Edge). For completing the tasks we used the latest Google Chrome browser (v 49.0.2623) for Windows 8.1 and Android 6.01 operating systems at the time of the study.

For the purpose of the study we have built a web page consisting of seven consequent tasks. Before starting each tasks, users had to read short instructions and had a possibility to train with currently selected input device. When they were comfortable enough they had to press on the *Start* button to start the task. The web page for each tasks was made in a simple linear fashion (with instructions, **Start** button, tasks content and the button for the next task following one another from top to bottom) for the web page to look as similar as possible on the wide screen of the laptop and on the phone's screen. We have thus not used any navigation (except for the button leading users onto the next task) or complex layout that would need responsive design and affect the layout of elements on the page. We have also used Boostrap[3] for the text to remain readable on both screen sizes. Because the page looked the same on both screens we did not have to build a separate page for each screen size in order to be able to compare the results and avoid that different designs affected users' performance.

The web page recorded task completion times. Each user completed all seven tasks with each input device. After finishing tasks with each device users filled in the questionnaire. The order of input devices was randomised.

The seven tasks users had to complete were: (i) open (click on, tap) a URL link, which opened within the page (iFrame), (ii) copy a URL of an image on the page and paste it into the text field on the page, (iii) copy the text on the page and paste it in a text box on the page, (iv) scroll a long text down and up again, (v) scroll a wide text left and right again, (vi) zoom in on an image as much as possible and zoom out to a normal size, (vii) and move from one location on a map (university's building) to another location (a well known park in the town) – both locations initially visible on the map – and zoom in on the park as much as possible.

We recruited 32 users (11 female and 21 male) with the snowball and convenience sampling. Participants were on average 28 years old, and had used: (i) a mouse on average 15.25 years, (ii) a touchpad on average 7.9 years, and (iii) touchscreen on average 4.9 years. The average number of years using touchscreen coincides with the mass emergence of these devices on the market. The number of years of using the mouse is higher than the number of years of using touchpad. This can be explained by the fact that users in primary and secondary schools do not need mobility provided by laptops. They buy their first laptop when they become students. Considering the average age of users (28), our average user became students 9 years ago. This coincides with the use of the touchpad (7.9 years).

4. RESULTS AND DISCUSSION

Mouse interface was ranked by users as the easiest and fastest interface among the three, whilst touchpad was rated as hardest (Figure 1 right). The majority of users highlighted that they have started using computers with the mouse and that mouse continues to be their main input device when working with computers which may be one of reason for such result. System Usability Scale (SUS)[4]

[3]`http://getbootstrap.com/`

[4]See `http://www.measuringu.com/sus.php`

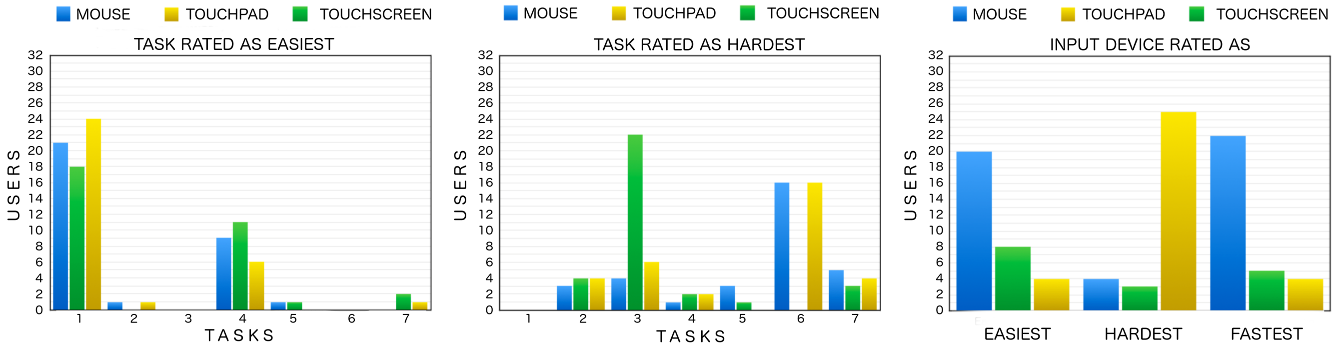

Figure 1: ***Left: tasks rated as easiest. Centre: tasks rated as hardest. Right: input devices rated as easiest, hardest, and fastest by number of participants.***

results partially confirm this trend (mouse scored 82.89%, touchscreen 80.31%, and touchpad 2.8 (64.92%) and highlight that only touchpad scored under the usability threshold of 68%. Touchpad was described as impractical, quite imprecise, slow and by 25 out of 32 users as the most difficult interfaces (Figure 1 right). The main reason for such a turnout is probably the fact that users do not use touchpads on their laptops as their main input device. Another reason can also be a capacitive sensing technology that requires stronger pressure (compared to touch screens) creating potential discomfort for casual touchpad users who are mainly using mouse and touchsreen interfaces. Moreover, users also stated that the size of touchpad is limited and does not allow for fine and precise interaction. Different manufacturers also implement touchpad's interaction differently (two users claimed that their touchpad works differently), which may lead to further confusion and the relatively bad results for the touchpad modality could be due to the specific implementation in the instrumentation used (HP Probook 4530s).

Users experienced most problems when completing Task 6 (zooming on an image) with mouse and touchpad interfaces and Task 3 with touchscreen (Figure 1 centre). Task 6 was rated hardest by 16 out of 32 users for both mouse and touchpad interfaces. It is interesting to note that no one of these 16 users used the mouse wheel to accomplish the task and that more than half of the users did not know about the zooming method with Ctrl Key and mouse wheel / two finger touchpad drag. This was observed despite the fact that users had the possibility to practice the task. Therefore, it appears that zooming functionality is not commonly used when browsing the web on personal computers.

On the other hand, zooming on mobile devices is more common due to small screen real estate on which desktop only websites are being browsed. Therefore, it is not surprising that users did not experience any problems while executing Task 6 with touchscreen interface. The hardest task for touchscreen was Task 3 (copying the text) which was also second hardest for touchpad interface (Figure 1 centre). Both touchscreen and touchpad were described as very imprecise and impractical and users claimed that certain tasks (e.g. copy/paste) are badly implemented (small buttons that lead to errors).

The easiest task for all three devices was Task 1 (opening the link) and Task 4 (scrolling the text up and down) as seen on the left in Figure 1. This confirms the results of previous studies described in literature review, which found that the pointing task is fastest performed on pointing input devices (finger, stylus), but not difficult with the mouse either (described as the most precise device of the three by users). The second easiest task was Task 4. This result can be attributed to the fact that scrolling is commonly performed; especially with sites such as social networking sites (SNS) that present the content on an "infinite" scrollable timeline. The fact that users spend between two and three hours a day on SNS also confirms the commonality of scrolling. Nevertheless, some users selected scrolling tasks as hardest, which we attribute to inexperience based on years of use of only one particular device.

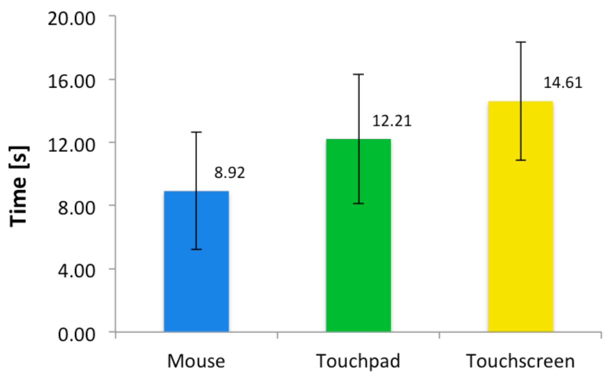

Figure 2: ***Average time completion with standard deviation for mouse, touchpad, touchscreen interface.***

The graph in Figure 2 shows that mouse is the fastest of the three interfaces, followed by touchpad and touchscreen interface. Comparing means presented on Figure 2 with repeated measures ANOVA with homogeneity of variances showed that at least one mean is significantly different ($p < 0.001$). Post-hock testing using the Bonferroni correction identified that actually all three mean values are significantly different (touchscreen vs mouse – $p < 0.0001$, touchpad vs mouse $p < 0.001$, touchscreen vs trackpad – $p = 0.002$). Compared to ranking results of task and device difficulty and speed (Figure 1 right) time results confirm dominance of mouse interface as it is identified as the fastest interfaces. However, contrary to previous result where users ranked touchscreen as less difficult to use and faster, time analysis showed touchpad was significantly faster than touchscreen interface.

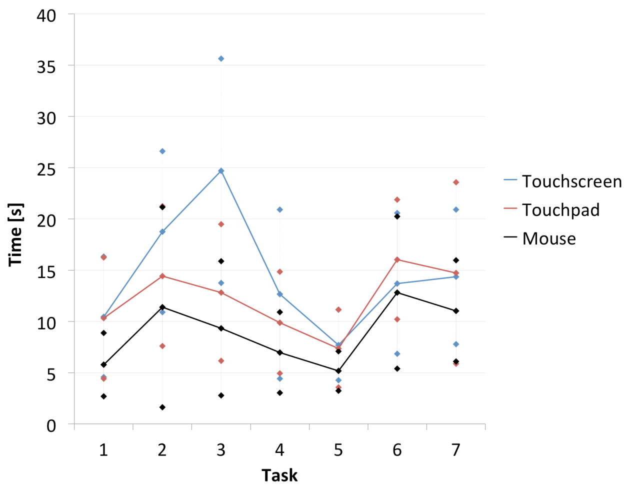

Figure 3: ***Average times in seconds for each task by input device.***

The average time completion in seconds for each individual task is shown in Figure 3. The graph shows that the touchscreen is the slowest interfaces in all but zooming tasks (Task 6 and 7) whilst mouse stays the fastest interface in all tasks. When analysing time completion of individual tasks ANOVA showed the differences between different interfaces are significant for all tasks except for Task 6 (zooming in on an image – p=0.158). For tasks with significant ANOVA score we run post-hock testing with Bonferroni correction. This test showed that significant difference between all possible pairs is not reached only in case of mouse vs. touchpad for Tasks 1, 2, and 7, and for touchpad vs. touchscreen in all but Tasks 3.

The graph on Figure 3 also shows that the major time difference happened in Task 2 (copying and pasting a URL), Task 3 (copying and pasting text), and Task 7 (navigating the map). Task 2 and Task 3 took longest on touchscreen and were also marked as the hardest to complete with touchscreen (see middle graph on Figure 1). One explanation for this observation is that these two tasks required precise interaction as well as the knowledge of the exact procedure of how to complete them.

The performance of mouse interface drastically drops in case of Tasks 6 and 7. This is in line with ranking results of task difficulty, where users marked task 6 and 7 as difficult to perform with mouse. In these two tasks touchscreen overtook touchpad interaction for the first time.

Despite the fact that the touchpad was faster than touchscreen for five out of seven tasks (only Task 6 and Task 7 took less time to finish on the touchscreen), users still preferred touchscreen. Additionally, Task 6 as the hardest task for touchpad did not take significantly more time than other two input devices. This shows that perceiving something as hardest, fastest, or easiest (comparing Figure 3 with Figure 2) is not only related to time spent for a certain task, but it depends on several factors such as perceived sense of quality, control over a device, responsiveness and other as mentioned by users in questionnaires.

5. CONCLUSION

In this paper we have explored difficulties users encounter using the three most common input devices (mouse, touchpad and touchscreen) when browsing the web. Similar to previous studies the results indicate a significant preference of using a mouse over other input devices [7, 1, 2]. However, as these input devices require different interaction for different tasks, it is inevitable that some tasks are faster performed on least preferred device (e.g. touchpad outperformed touchscreen in copy/paste tasks), or times are at least comparable with the most preferred device (mouse). This has also been the case mentioned in the literature [2]. It also seems that the preference depends on how familiar users are with a particular input device, which is where mouse leads. Other factor that may affected user preference is implementation of interaction for a particular task (e.g. touchpad and touchscreen are not precise enough when it comes to text selection or positioning the cursor), the perceived quality, responsiveness, etc. This work has singled out which of the commonly performed tasks are hard to complete on each input device. Since all these input devices are here to stay the community should look into ways of how to make certain tasks easier, and how to standardize interaction to improve usability of these devices.

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Wizard of Oz experiment for Prototyping Multimodal Interfaces in Virtual Reality

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ABSTRACT

In recent years the field of virtual reality has witnessed a rapid growth with significant investments in both hardware and software development. It has several potential applications for entertainment, education and enterprise where users benefit from being immersed into virtual worlds. VR headsets are available in several forms and price ranges from simple and inexpensive Google Cardboard to more complex products such as Oculus Rift. Nevertheless, designing fully operational virtual reality applications for researching new complex multimodal interaction possibilities (e.g. mid-air gesture, voice, haptics, etc.) may be difficult to implement, costly and time consuming. For this reason we have looked into ways of rapidly prototyping virtual reality interactions. Our approach consists of the Wizard of Oz experiment in which subjects interact with a computer system believing to be autonomous, but is in reality operated by researchers. The presented system allows non-technical designers to explore various multimodal interactions with rapid prototyping of VR environments.

Categories and Subject Descriptors

H.5.2 [**Information interfaces and presentation**]: Multimedia Information Systems—*Prototyping*

Keywords

Wizard of Oz, virtual reality, rapid prototyping, multimodal interaction

1. INTRODUCTION

The majority of big computer companies recently identified a big potential in Virtual and Augmented Reality (VR, AR) technology. This has lead to massive investments in hardware and software development, such as, Facebook takeover of Oculus Rift[1], Google's investment in MagicLeap[2] and Expeditions[3], Samsung's development of Galaxy Gear[4], and Microsoft's development of HoloLens[5].

Virtual reality offers immersion into virtual environments capable of producing a stereoscopic view into a virtual world that is usually coupled with audio. The stereo image is delivered by a head-mounted display (HMD) with sensors that track users' movements allowing the system to change the view accordingly. There are two types of HMDs: (i) the fully featured HMDs designed for use with gaming consoles or PCs and (ii) composite HMDs designed to hold a smart phone or a tablet computer. Fully featured devices are expensive and can cost between a couple of hundred to a couple of thousand euros excluding the cost of a console or PC. While in composite HMDs the mobile device (commonly accessible among the population) acts as a display and processing unit, which reduces the cost of HDMs bellow hundred euros.

Both types of HMDs offer various VR experiences with a varying degree of immersion. The latter partly depends also on the quality of the VR environment being projected on the screen and partly on other data produced for other senses. However the illusion most often remains incomplete, in that not all senses are catered for and natural ways of interacting in real world, such as with spoken and body language, are not supported. The work presented explores ways of supporting non-developeres to explore various multimodal interactions (including for example mid-air hand gestures, voice, haptics) in rapidly prototyped VR environments. For this purpose we designed and built a VR test-bead based on the Wizard of Oz (WoZ) metaphor. The test-bead enables screen sharing between desktop computer and HMD where the researcher acts as a wizard detecting and executing users' commands (e.g. hand gestures) on a desktop computer creating the illusion of a working prototype. In order to evaluate the test-bead the paper presents a short user study which was carried out using our fast prototyping

[1]https://www.oculus.com/
[2]https://www.magicleap.com/
[3]https://www.google.si/edu/expeditions/
[4]http://www.samsung.com/global/galaxy/gear-vr/
[5]https://www.microsoft.com/microsoft-hololens/en-us

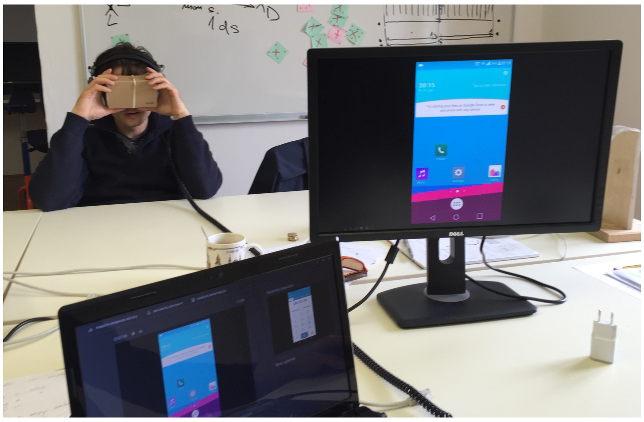

Figure 1: ***The conduct of the experiment. The experimenter controls the stream to the HDM based on participant's mid-air hand gestures or voice controls.***

technique.

2. LITERATURE REVIEW

The Wizard of Oz (WoZ) experiments in human-computer interaction have a long tradition and were pioneered in 1983 by Gould et. al. who simulated an imperfect listening typewriter to explore users' reactions when giving dictations [4]. The method was used in numerous studies since. It was for example used in prototyping speech user interfaces when AI agents were not so capable [5] or for studying a mixed reality application for enriching the exploration of a historical site with computer generated content [2]

WoZ is nowadays commonly used for rapid prototyping of systems that are costly to build, or as means of exploring what people require or expect from systems that require novel or non existent technology [8]. However, Maulsby et. al. have warned that researchers need to understand what limitations need to be implemented on the Wizard's intelligence, and need to base behavior and dialog capabilities on formal models in order to ensure consistent interaction, keep simulation honest, and to prevent inappropriate, optimistic results [7]. Nevertheless, as demonstrated by numerous studies employing WoZ, the observation of users' using such systems can lead to qualitative data that could not be otherwise acquired.

Furthermore, the HCI community has pointed out that there is a great need for easy to use, rapid prototyping tools (such as WoZ) [6, 3] and that any medium (including VR and AR) can reach its potential only when put into the hands of designers who can further develop it and define its popular forms. Such tools have already been developed to research AR usability and interactions [1]. Our contribution to existing work is providing an affordable, easy to use and intuitive set of tools and procedures for rapid prototyping user interfaces in VR. We evaluate the prototyping tool by running a small user study comparing voice and mid-air gesture interface while wearing HDM.

3. PROTOTYPE DESCRIPTION

There are three main hardware components used in our prototype: Android based smartphone, Google Cardboard, and a Windows based computer. The user interface is then streamed in real time to the phone from a desktop computer using TrinusVR[6] application as seen in Figure 2. Depending on the configuration, either the full screen or only the active window is streamed to the HMD device. The application was designed to transform any Android or iOS device into an affordable HMD to be used by gamers when playing 3D games on their computers. The application also features a lens correction system aimed to improve user experience by minimising distortion inducted by Google Cardboard's lenses. The communication between desktop computer and used mobile devices works both via USB cable or WiFi. The later is particularly interesting as it enables researcher to place the wizard into another room observing users via web cam and executing users commands.

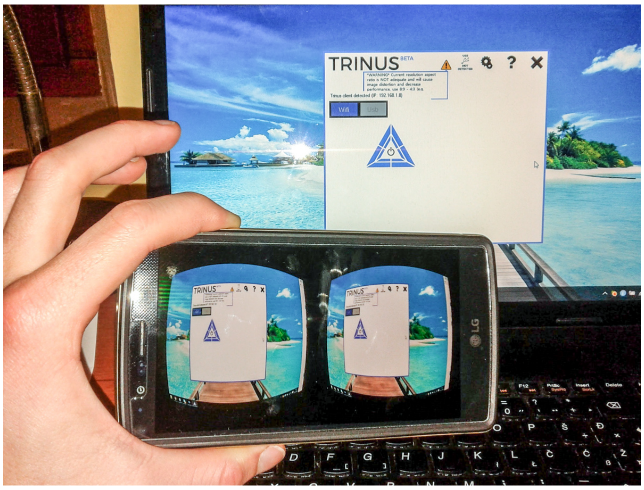

Figure 2: ***TrinusVR streaming the computer desktop to a mobile phone to be used in Google Cardboard.***

4. METHOD

To test our test-bed we have designed an interaction scenario comparing two different interaction techniques: namely mid-air finger gesture and voice based interaction. For this purpose we have created minimum viable product – two simple linear presentations in a presentation program. Each slide of the presentation featured a screenshot of the user Interface (UI) for a particular step towards completing a task. Users performed generic phone tasks such as initiate a call, take a picture, browse files. In order for the linear presentation to work in each step participants had only one possible option to choose from. In Figure 3 both gesture based (left) and voice based (right) user interfaces are displayed. In gesture based UI users had to bend the appropriate finger to trigger one of the available actions (e.g. bending pointer finger opened a folder named "Camera" as seen on the left in Figure 3) while in voice based UI users had to name available options visible on the screen (e.g. reading aloud the name of the folder "Camera" framed in red (right in Figure 3) opened it). After users initiated an action, the exper-

[6]http://trinusvr.com/

imenter switched to the next slide in the presentation in order to show the next screen on the HDM.

One of the issues we had to deal with is how to provide instructions for mid-air gesture interaction. The provision of gesture controls is almost indispensable at the beginning until users get familiar with interaction. This is also the case with current HDM controllers that come in sets of two (one for each hand) and each has several buttons and ways to control the VR worlds and tools. Until one gets accustomed to controls in a particular VR environment, the instructions can be overlaid over the controllers. In our study all available options were always visible on the screen. The limitation of our mid-air finger gesture set is bending five fingers only, which limited us to have five options only in each step. However, as w had a linear presentation with two options at most (back and forward) this was enough for our study. Users have also not had any troubles using the system and did not find instructions intrusive.

While mid-air (hand, finger) gesture interfaces are not so common (yet) on mobile devices, voice recognition and intelligent agents or personal assistants (such as Siri, Cortana and Alexa[7]) are a part of all major mobile operating systems and many users are accustomed to use them to complete certain tasks or services. Exploring natural language interactions thus did not present the same issues as mid-air gesture interactions. In our scenario users just had to read aloud the text on the screen or use controlling words such as “up”, “down”, “left”, “right”, “select”, etc.

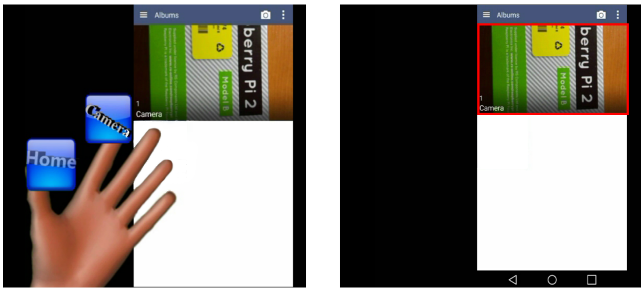

Figure 3: ***A sample screen from the scenario. Left: a mid-air finger gesture based interface where available options are visible over fingers and bending a finger with available option triggered the appropriate action. Right: a voice based interface where available options are framed in red and reading aloud their names triggered the appropriate action.***

We have used a convenience and snowball sampling to recruit participants. We have recruited 10 participants. The average age was 22.3 (SD = 3). All participants were either students (8 participants) or faculty members (2 participants) from our department. Each participant has tried both voice and gesture based interactions where the order was randomised. Before commencing the designed scenario participants tested each interaction mode in order to make sure they understood the principles of how to control each navigation. After completing the scenario of each interaction technique (see Figure 1) users had to answer SUS questionnaire.

5. RESULTS AND DISCUSSION

As mentioned, our scenario was a minimum viable study to test our test-bed. It involved handling the Android operating system UI by presenting users with sequence of images including browsing photos and controlling music player. We have thus not used a 3D virtual world, which is a limitation of our evaluation and which makes it difficult to generalize the results in context of virtual world interactions. Due to virtual representation of mobile device in our study, it is also not possible to generalize results in the context of mobile phone interaction. Nonetheless, the pilot provides practical insights into how the designed test-bed could be effectively used as a rapid prototyping tool for exploring different interaction possibilities within VR environments.

Since anything can be streamed from a desktop computer to the HDM, designers and non-technologists can use any available software to create such interactive environments. For example, navigating a 3D information environment can be simulated in non-linear and zooming presentation software such as Prezi[8], or 3D worlds could be simulated by creating them in computer-aided design (e.g. AutoCAD) or 3D computer graphics software (e.g. Blender[9]).

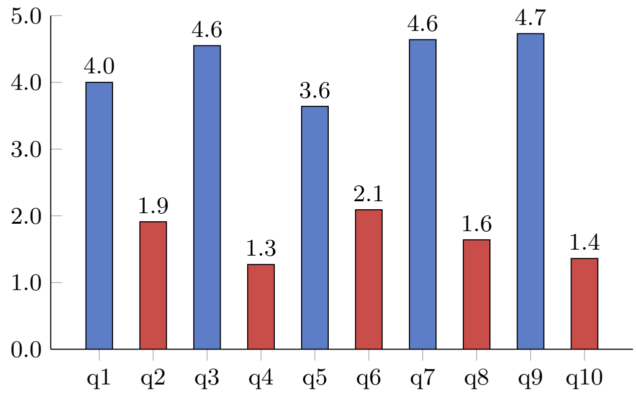

Figure 4: ***SUS scores by question for the gesture controlled interaction.***

The results of SUS questions[10] from our questionnaire for each interaction technique are visible in Figures 4 and 5. Even questions (colored in blue on the graphs) are about positive aspects of the system, while odd questions (colored in red on the graphs) regard negative aspects. We can see that in both cases negative aspects scored low while positive aspects scored high. Average SUS score for mid-air gesture interaction was 83.18 (SD 13.04), whilst voice interaction scored 81.46 (SD 8.08). Both scored above the threshold where users are more likely to recommend the product to friends. However, since this was just a minimum viable study we can just say that users were intrigued with how a phone’s UI can be interacted with and SUS scores are provided for informative purposes only.

[7] https://en.wikipedia.org/wiki/Intelligent_personal_assistant

[8] https://prezi.com/

[9] https://www.blender.org/

[10] See http://www.measuringu.com/sus.php

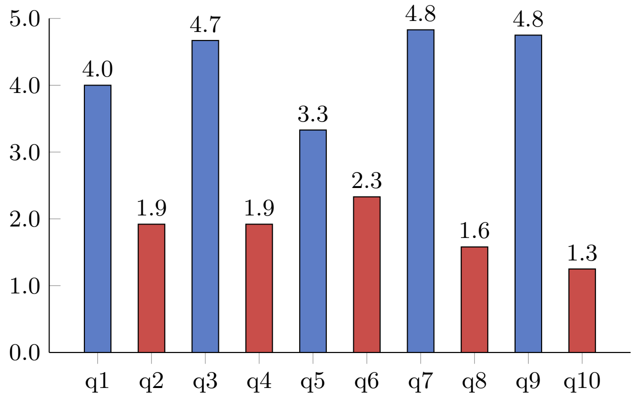

Figure 5: *SUS scores by question for the voice controlled interaction.*

Despite the fact, that we have not used a virtual world in our study, we have tested the prototype as a test-bed for VR interaction with a minimum viable product. We believe that our approach can open novel possibilities to explore, further develop and define popular forms of such medium since there is no need for designers to know any programming language except how to use designing software, which they should be familiar with already.

6. CONCLUSION

Mid-air gesture and voice interaction provide for richer experience than touch screen user interfaces (UI). Especially in virtual and augmented environments, where interaction with common paradigms (e.g. mouse + keyboard or touch screen) is challenging or inadequate. This introduced a need for new interaction metaphors designed particularly for these new worlds. One such example are mid-air gesture and voice interaction which can facilitate greater immersion into virtual environments. While there are fairly inexpensive depth camera and gesture sensors available for end users, programming for these can be challenging and time consuming particularly for non-technical people such as designers limiting their ability to contribute, further develop and define popular forms of such medium.

In this paper we present an affordable easy to use rapid prototyping tool for creating VR environment and explore different interactions with the Wizard of Oz (WoZ) experiment. With the introduction of wizard we remove the need for additional hardware setup such as wired gloves, depth aware or stereo cameras, gesture based controllers, etc. Experimenters can use any software designers are familiar with to create VR worlds, such as standard non-linear presentation, CAD or 3D graphics software. Or can simply create a sequence of UI screens that users can navigate through with interactions beyond mouse and keyboard. In the future we plan to further evaluate the test-bed (i) by running a user study in a 3D VR environment involving more participants, (ii) including other metrics such as timing tasks, interviews, coding transcriptions of filmed evaluations, etc. and (iii) by placing the wizard into a separate room creating a more convincing illusion of a working system.

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Towards the improvement of GUARD graphical user interface

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ABSTRACT
In this paper, we describe a case study of usability testing of the GUARD Control Desk graphical user interface, which is a part of the GUARD simulator and is used for exercise planning, execution and evaluation in soldier training. The usability testing was performed in the development phase of a new version of user interface.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Graphical user interfaces (GUI), Prototyping, User-centered design

General Terms
Design, Human Factors, Verification.

Keywords
Usability testing, user interface, military training system

1. INTRODUCTION
According to [1], usability is the extent to which a system, product, or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use. The latter terms are defined in [2] as follows; effectiveness represents the accuracy and completeness with which users achieve specified goals, efficiency refers to the resources expended in relation to the accuracy and completeness with which users achieve goals, while satisfaction reflects freedom from discomfort, and positive attitudes towards the use of the product. The importance of usability has been early recognized in different aspects. While Don Norman in his famous book The Design of Everyday Things [3] places usability side by side with aesthetic beauty, reliability and safety, cost, and functionality, Jakob Nielsen in his earlier work [4] focusses on the design of software systems and provides general usability guidelines.

The design of complex systems such as military training simulators requires careful analysis of customers' needs and requirements in order to provide tailor-made product fulfilling their expectations. For the GUARD simulation system referred in this paper, user-centered design approach is therefore imperative. In this paper we summarize our experience and results of the usability testing of a new version of graphical interface of the GUARD Control Desk.

2. GUARD SIMULATION SYSTEM
The GUARD simulation system is a military training system that allows photorealistic 360^0 VR environments, audio and visual effects accompanied by real-time weather and time-of-day changes. GUARD brings indoor training to the edge of real combat awareness and moves digital training borders towards real battlefield perception. The 3D real-time simulations reflect situations from the real word. Which objects take place in the 3D scene, what is the nature of the 3D scene and how the objects behave within the scene is a matter of the information recorded in the script.

Figure 1. GUARD Control Desk

The GUARD Control Desk (shown in Figure 1) is an all-in-one solution for instructors and trainees and can be added to any Guardiaris product. It is fully interoperable, interactive and features user-friendly interface for exercise planning, execution and evaluation. A large multi-touch screen and touch user interface guarantee efficient exercise planning and a best-in-class After Action Review procedure.

The simulator package includes four possible display modes of the interface. Each of them offers a different set of user controls and operations running on a specific type of device. The user interface in the editor mode, which is the subject of usability testing presented in this paper, offers the user several operations with maximum number of controllers and windows. Its task is to read, write, set and edit 3D scene. It is usually performed on developer computers with fairly strong hardware support.

3. USABILITY TESTING OF GUARD CONTROL DESK GUI

3.1 GUI description

The library of controllers written in C++ provides means for controlling objects that are included in a given scene. Each controller carries information about object dimensions, the relative or absolute location on the screen, and about (if any) graphical icons, symbols or text with a particular meaning for the user. The user interface is used to place objects in the 3D scene. Once placed in the scene the object becomes a part of the script. All kinds of physical properties, including the basic gravity, the speed of movement, etc., are associated with an object. The interface offers integration of operations between objects, classical processes for storing, loading, cleaning the scene and operational controls ("play", "pause", "stop"). Operations for introducing objects to a scene, hiding of certain types of objects, or excluding the possibility of selecting certain types of objects can be performed via user interface.

Previous interface, has been based solely on interaction via computer mouse and keyboard. Modern technologies require completely different approaches, dealing with multi-touch displays. and other devices that are able to run graphically demanding 3D environment, but do not use conventional computer input devices. Consequently, the new user interface should support multi-touch display and additional features such as the possibility of independent setting and editing scripts via an additional software package or a dedicated application. The new concept, generated through a series of brainstorming sessions and design iterations resulted in a new user interface, which has been evaluated with the performed usability testing. The working prototype of the new user interface is shown in Figure 2.

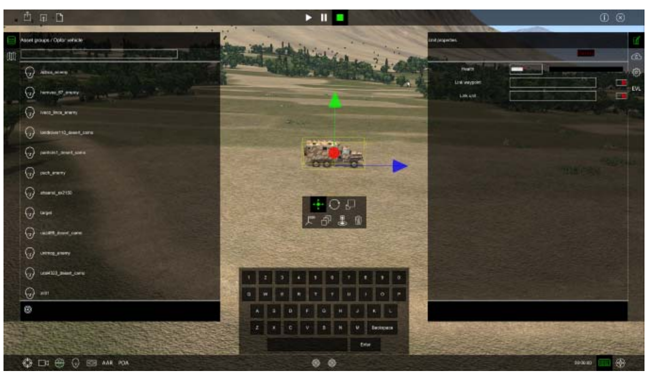

Figure 2. Working prototype of the new GUI

When setting up the concept of usability testing, we followed the methodology presented by J. Rubin, and D. Chisnell [5] which comprises three basic test techniques: exploratory (or formative), assessment (or summative), and validation (or verification) tests at a high level. The above tests are associated with specific points in the product life cycle. In our particular case, the exploratory phase has been performed by the above mentioned brainstorming sessions and design iterations. The actual usability tests have been performed on a fully functional prototype of the new user interface and can be regarded as a combination of assessment and validation tests. The implementation of usability testing followed the guidelines presented in [6].

3.2 Usability testing plan

The main goal of usability testing was to verify the adequacy of the conceptual design of the fully renewed appearance of the user interface. Consequently, the performed tests should check the ease of use, the perception of the individual sets of operations, the appropriateness of the composed sequence of operations, logic operations alone, feasibility of transformations on objects, as well as the ease of performing the actual flow of individual steps of the required test scenario. For this purpose, three step testing scenario (shown in Figures 3, 4 and 5) has been prepared.

Figure 3. First step of testing scenario

In the first step (Figure 3) the participant introduces objects in the scene. Their positions must be reasonably set into a whole. The participant thus gets acquainted with the concepts of lists of objects and groups, and with manipulator controller, which allows transformations (move, rotate, resize), and other operations (delete object, cloning facility, reset the position of the object in the initial position).

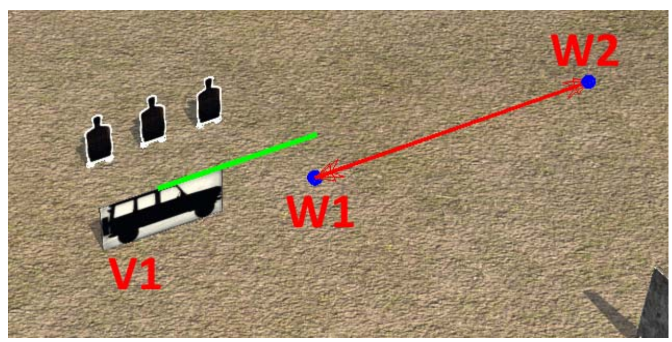

Figure 4. Second step of testing scenario

In the second step (Figure 4) the participant introduces new types of objects and becomes familiar with the operation of association between two objects. This enables integration of the "vehicle" object with the "waypoint" object, which in practice means that when the script starts, the vehicle heads towards the location of the "waypoint" object.

The main issue of the third step is the facility "trigger". The participant needs to properly connect all the objects among each other. In addition, in this step, certain attributes are assigned to the objects.

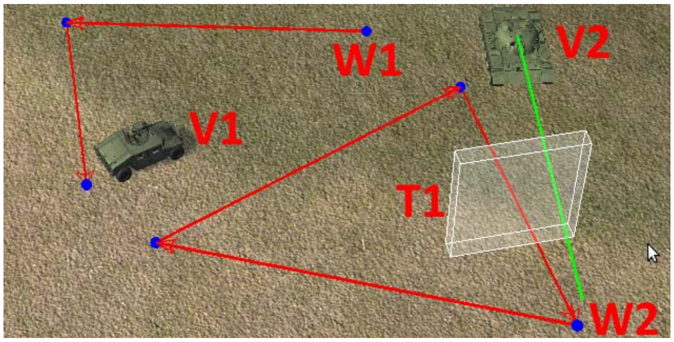

Figure 5. Third step of testing scenario.

Usability test plan and supporting documents were prepared following the usability test guidelines [6]. For the testing environment we used the room with a working station which is normally used for running and exercising the latest versions of software. The screen of the working station is shown in Figure 6, and the whole environment prepared for usability testing in Figure 7, respectively.

Figure 6. The screen of the working station used for usability testing

Figure 7. Usability testing environment

The selection and acquisition of participants whose background and skills are representative of those that will use the product is a crucial element of the testing process [5].. Selecting participants involves identifying and describing the relevant behavior, skills, and knowledge of the person(s) who will use your product. Within the company we managed to collect twelve participants, with different backgrounds that could be roughly categorized in three groups: a group from the hardware department, a group of participants of administrative nature, and a group originating from software industry with artists, designers and programmers. None of them have had any previous experience with the new version of the user interface, which was the subject of the usability testing.

3.3 Conducting the test sessions

Testing took place in one working day and passed without major concerns or complications. Implementation of each test, on average lasted about forty-five minutes. Occasionally it was necessary to restart the editor, because it stopped working due to unexpected gestures and touches of the participants. Fortunately, there weren't many cases like this. Yet, we carefully registered any jam and placed it on the list of future urgent or less urgent corrections.

3.4 Usability testing results

Test results were classified in four categories:

- Opinions about appearance, suggestions on improvements.
- Utilization, logical inconsistencies of the editor.
- Quality of the editor instructions
- Programming errors and bugs in the operation of the editor or in general of the interface kernel.

About ten mistakes, opinions or suggestions for possible improvement of the appearance or functionality of the editor referred to the first and second category. Almost all participants were disturbed by imperfect control of the camera with the particular gestures. We have found that it was not the problem with gestures or users, but in the program code.

Participants' comments also justified our concern about the manipulator controller. A quarter of the participants intuitively wanted to use it in a another (and always the same) way, different than the established one. This was not a malfunction of the software code, but the problem is in a completely different presentation of an operation in a 3D scene displayed on a 2D screen.

Most of the participants did not like the automatic display of menus. They would prefer more clever automatic solution, which somehow recognizes user needs and reacts accordingly.

In the last category, about fifteen problems have been identified. Some are minor in nature, such as the improper refreshing of certain components, while others will require a more thorough investigation. In most cases in this category we deal with functional errors, or rather the requirement to change the software code at the expense of the operations of the editor.

4. CONCLUSION

Usability Testing results have proven to be very useful. In addition to the detected bugs, comments of the participants on the existing design and suggestions for improvements were very valuable. In the future, more effort will be given toward systematic planning of individual phases of usability testing within the complete product life cycle. We are aware that the iterative nature of usability testing requires extending the product development life cycle however with proper scheduling of testing within the design phases the benefits will be prevail. Another issue is selection of participants. A well-known fact is that one should focus its efforts on recruiting participants who are representative of the product's target users. In our case, in-house personnel has been employed, which might have biased the results to some extent. Involving a wide range of representative users at the early stages of the development cycle is fundamental for early identification of usability problems.

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Towards affordable Mobile Crowd Sensing device

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ABSTRACT
In this paper, we describe first prototype of mobile crowd sensing device. The device serves as a source for signals in the potential crowd sensing studies. Presented device has no intention to compete with the existing mobile devices, such as mobile phones, but to complement them where they lack of the features like affordability, simple use and new opportunities in different segments of our lives. Our main goal was to develop a device, which can cover all aspects of mobile crowd sensing and at the same time to keep the device cost at very affordable level. The described device is capable of integration into most widely available sunglasses. The complete device consisting of two separate "lenses" forms distributed ecosystem serving as source for sound, light, acceleration and temperature signals while at the same time providing actuator function with integrated LED matrix display.

Keywords
Mobile crowd sensing, wearable interface, affordable electronics.

1. INTRODUCTION
Mobile crowd sensing (MCS) is a new paradigm [1]. The signals in the crowd sensing studies are transferred from pervasive mobile devices. The collected data serves as the source for numerous largescale applications, which can be classified into three groups: environmental, infrastructure and social. Each group has own requirements and operating conditions. Typical *environmental* mobile crowd sensing application is pollution monitoring [3]. The MCS application is a two-step process: to assign sensing tasks to users and to wait for results [3]. The interaction relies on active participation of each individual in the process loop, which can be sometimes cumbersome. Example of the *infrastructure* MCS application is use of the data in the emergencies where individuals try to support the actions of emergency services and volunteers, especially in time-critical situations [4].

Main obstacle in such situations is the availability of the existing infrastructure, which is usually compromised or even completely destroyed (in environmental disasters). Such situations void mobile phones useless. The *social* MCS applications enable individuals to share sensed information among themselves. The majority of the social MCS applications seem to be limited to social media and networks. There are applications where such applications improve the quality of life in elderly people by collecting biological sensor and activity data to adjust and gain the comfort condition [5]. The main issue in such application is limited use of smart phones with elderly people which prevents sensing possibilities.

Sensing individuals in a large group can be achieved by using existing smart phones and several sensors available in such mobile devices. The overview of some devices providing MCS applications is listed in Table 1. However there are several issues when using people-centric mobile phones as sensory devices: reliability of the sensed signals, lack of actuators and feedback, awkward use and lack of wider use due to relatively high cost of the currently available devices. In this paper we describe our first step towards many new opportunities in crowd sensing area, the affordable hardware platform which cover all three [2] groups of the mobile crowd sensing process: environmental, infrastructure, and social sensing. Our platform will try to overcome the two primary technical obstacles in mobile phone centric MCS: the noisy data and lack of useful and effective feedback to the MCS users. Same barriers were also identified with authors in [6], where they as such prevent the new applications to "advance quickly, acting as a disruptive technology across many domains including social net-working, health, and energy."

Table 1. Overview of some MCS application providers

Device	Inertial	Compass	GPS	Microphone	Camera	Proximity	Light	Affordable
iPhone 6	✓	✓	✓	✓	✓	✓	✓	
Asus Zenfone 3	✓	✓	✓	✓	✓	✓	✓	
Nexus 6P	✓	✓	✓	✓	✓	✓	✓	
HTC 10	✓	✓	✓	✓	✓	✓	✓	
MPS device [7]	✓	✓		✓			✓	
Our MCS device	✓	✓ (1)	✓ (1)	✓			✓	✓

(1) External module

Lack of affordable, low cost, almost disposable device enabling MCS applications encouraged us to develop new type of wearable interface. Our main goal was to develop a device, which can cover all three groups of mobile crowd sensing. At the same time our goal was to keep the device cost at very affordable tag, which can also be of paramount importance.

2. CROWD SENSING DEVICE
Development of new MCS device started with design requirement specifications. The complete list of requirements is shown in Table 2.

Our main goal was to develop small and affordable system, which can be integrated into existing environment. To keep the device affordable we were not able to add sensors for all signals listed in Table 1, however the device has all interfaces which can provide communication with external modules when needed, e.g. GPS, Bluetooth or WiFi module.

Table 2. List of design requirements

Scope	Details
Displaying messages	Display short text messages on the device surface
Detect activity	Motion detected with accelerometer sensor and/or GPS
Environment sensing	Integrated microphone, illuminance sensor and thermometer
Communication	Standard interfaces provided on-board
Low power	Power consumption limited with careful component selection
Affordability	Keep total cost of the device as low as possible

2.1 Integration into sunglass

The device was designed to integrate into existing sunglasses which are widely available at very low cost. After some investigation we concluded the almost all low cost sunglasses have same lens shape (Fig. 1). This and the fact that such sunglasses can cost a bargain motivated us to use the shape of such lenses for our base modules.

Figure 1. Most common "wayfarer style" sunglasses.

Another reason to use sunglasses was the ability to integrate the wearable display, providing personal interaction from one MCS device to another user.

Since the printed circuit board is not transparent we were faced with one obstacle: how to prevent the MCS device users to become blind when wearing such eyewear. One option was to use transparent substrate. Electronics can be integrated onto the glass substrate. This would definitely void the affordability goal. Another option was to drill array of holes into the substrate. After some experimentation we discovered the perforated substrate in front of the eye doesn't interfere with normal vision. Based on experiments on subjects at different ages and gender we defined the perforation parameters which are most acceptable for all users (Fig. 2). After short introduction time the subject became comfortable with the eyewear.

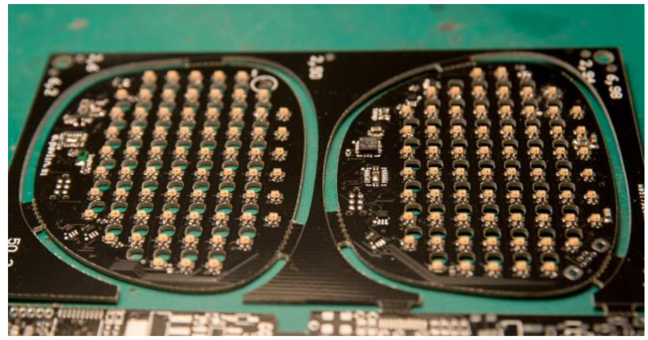

Figure 2. Perforated substrate of the MCS device used to replace the sunglasses lenses.

2.2 MCS Device

The device is divided into two modules: left and right "lens". Block diagram is shown in Fig. 3. Both modules communicate internally via I2C bus exchanging data from sensors and other peripheral devices.

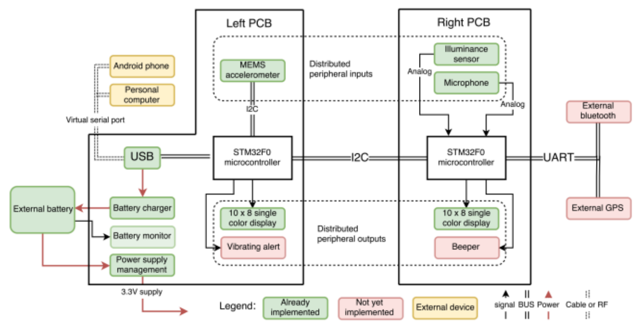

Figure 3. MCS device block diagram.

Lens from wayfarer style sunglasses were taken out of the frame and replaced by circuit boards with 69 LEDs on each. Every LED can be individually controlled much like pixels on 5×7 display. Both left and right circuit boards have a low power Cortex M0 micro-controller for driving the LEDs wired in a matrix. Among with the LEDs there are also other peripherals. The I2C bus enables both sides of the MCS device to communicate with each other. Programmable MEMS motion sensor (accelerometer) tracks head movements or other user motion activity. Tiny microphone detects environment sounds and provides MCS device to react on sound stimuli. Light sensor measures environment illumination. User can select modes of operation with one button. Device is powered by external lithium batteries residing on the frame. On-board LiPo/LiIon battery charger provides proper charging and is powered from micro USB connector, which also provides connectivity with personal computer or other mobile device applications. Finally, an extra ADC input is provided for experimenting with future sensors. External modules can be connected via USART interface such as Bluetooth or GPS.

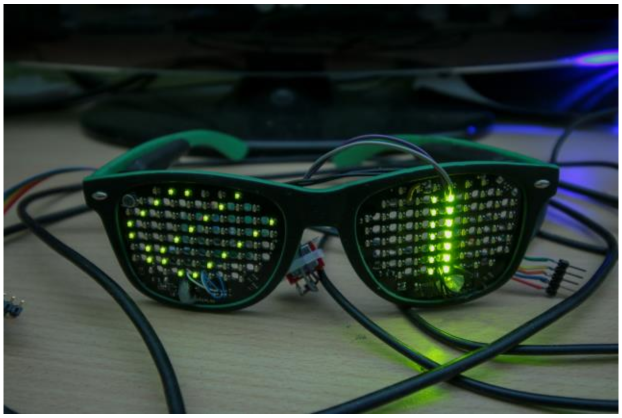

Figure 4. Working prototype of MCS device.

As expected few mistakes were made at designing the first prototype such as wrong component placement/connection and a faulty fabrication of the circuit board. After minor workarounds the MCS device became functional as expected albeit the initial design and fabrication mistakes. The first prototype looks very promising. A second version has already been designed.

2.3 MCS Device technology challenges

The perforated substrate leaves not much room for the components between the holes. The LED matrix which is placed on tiny bridges required smallest vias, tracks and tracks spacing. This can be derived from the mass market mobile phone production at very low expense. There are technologies providing micro vias and ultra-low design sizes, which could enable even larger holes in the substrate perforation. Unfortunately this would result in higher production costs. During first tests we found out there is no big issue with that and we could produce the MCS device with existing technology and geometry.

3. CONCLUSION

The field of mobile crowd sensing has recently evolved from the availability of vast sensing opportunities in modern mobile devices. Despite availability the existing commercial mobile devices lack of features in some aspects.

The paper presents the device to provide base for growing ubiquity of personal connected devices creating the opportunity for a range of applications which may fit into sensed signals and generated visual effects. The sensing requirements set by future applications will probably evolve over time very dynamically. The future expansion will depend on the evolving interest in different types of data gathered by presented MCS device based on different contextual factors. Hopefully the device will provide new approaches to modeling and programming multi-modal sensing applications with enhanced modularity and high affordability.

The presented MCS device is in no way limited only to the mobile crowd sensing, but can also provide some useful ways of use in everyday life at many levels. Display capability of the eyewear can e.g. provide new opportunity for disabled persons. One possibility is to provide personal contact with deaf(-mute) person when another person can't understand the sign language. The eye contact is more personal than e.g. writing or sketching on the paper or typing on the mobile phone screen. The experience could be completely different when "conversation" is held by maintaining eye contact.

Our hope is to spread the device to targeted crowds and use it as a tool for real world crowd sensing studies in this new and promising area.

4. ACKNOWLEDGMENTS

Our thanks goers to Texas Instruments and STM for providing us free samples of some components used in our project.

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I was here: a system for creating augmented reality digital graffiti in public place

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ABSTRACT

Since ancient times travelers and tourists try to leave their marks in places they visit. However, carving or writing on historic landmarks can cause irreversible damage on such sites. One possible solution are digital graffiti. These can for example be created through projection mapping where beams of light wrap the object with the digital graffiti created by users so everyone at the site can see them. However this may disturb other visitors being there at the same time. In this paper we explore an alternative solution for creating digital graffiti by utilizing Mobile Augmented Reality (MAR) technology. We developed a mobile application which allows users to: (i) select an object or a building, (ii) map a 3D mesh onto it in order to prepare its 2D plane , and (iii) draw a graffiti on this plane. After completing the drawing the application wraps the object or the building with a modified 2D texture creating an illusion of digital graffiti. In order to (i) evaluate the social acceptance of placing digital graffiti onto historic landmarks and to (ii) evaluate if the use of our prototype is socially acceptable in public spaces, we carried out a small reflective user study. We created a couple of simple graffiti on different historic buildings and posted them on social networking site Facebook. Despite amateur appearance, posted photos received attention and generated some positive responses and questions.

Categories and Subject Descriptors

H.5.1 [**Information interfaces and presentation**]: Multimedia Information Systems—*Artificial, augmented, and virtual realities*

Keywords

augmented reality, digital graffiti, public spaces, mobile interactions, handheld augmented reality

1. INTRODUCTION

Graffiti are a form of visual expression that can be carved or painted on walls or other surfaces. They can take many forms from simple written messages to elaborate drawings and are considered either as acts of vandalism [5] or admired as an art form [12]. They exist since ancient times [1, 2] and can carry political, social, artistic or any other message. Graffiti are primarily associated with different subcultures such as hip-hop youth or street art movements. However, there is a group of graffiti makers that is often forgotten – tourists.

Since ancient times travelers and tourist leave marks and writings on sites they visit. This is manifested across cultures and covers simple inuksuit built by Inuit peoples marking routes or sites for navigation and as a point of reference, to scribbled messages on the walls of ancient buildings denoting ones presence and appreciation of the site. The later form can be seen for example (i) on the walls of the Church of the Holy Sepulchre in Jerusalem scribbled by the crusaders and pilgrims, (ii) on the Mirror wall in an ancient village of Sigiriya in Sri Lanka featuring over 1800 pieces of prose, poetry and commentary written by ancient tourists between 600AD and 1400AD [2], or (iii) scribbled names of Greek and later Roman soldiers, merchants, and travelers in Egypt [8].

In a similar way, today's tourists also exhibit the tendency to leave their mark in places they visit. For example the breast of the statue of Juliet in Verona is showing prominent signs of wear by years of groping, or the Blarney Stone in Ireland that gets kissed by visitors. Even more personal example of expression is leaving a chewing gum (e.g. the Market Theatre Gum Wall in Seattle) or a D lock with declarations and messages on bridges in cities all over the globe (e.g. the Butcher's bridge in Ljubljana). While these are "socially accepted" marks and often become (together with local graffiti) tourist attractions themselves, some tourists also carry out unacceptable acts by today's standards. For example scribbling ones initials on a brick of the Roman Colosseum [9] or signing one's name on an ancient Egyptian's statue [13]. Both acts resulted in an outrage of masses on social media.

While ancient tourists' graffiti are a source for history research and debate such as searching for Herodotus signature [8], the majority of today's graffiti are not seen as art or valuable (except for studying them as a social phenomena [11]). One possible solution to prevent permanent marks on

Figure 1: ***This is screenshot of the mobile application projecting digital graffiti onto the wall of fortress in Split.***

historic landmarks is to allow tourists to leave their footprints in a digital form and project it on a desired location of the historic site [7]. However, this approach can disturb other visitors being there at the same time. Our idea includes placing a graffiti on a particular object or a building by Augmented Reality (AR) paradigm where only the user owning a device can see their graffiti when looking through the camera lens of their mobile devices, which can bee seen in Figure 1. This opens up interesting questions such as: is the process of making digital graffiti in public places and the end result placed on historic landmarks socially acceptable? To answer this questions we carried out a preliminary user study. Within the study we created a couple of simple graffiti on different historic buildings and posted them on social networking site Facebook to harvest the feedback.

In the next section a description of the prototype developed is presented, followed by a method section describing the process of the evaluation. Section 3 presents the results and includes the discussion of these. The paper finishes with conclusions and future work.

2. PROTOTYPE DESCRIPTION

Our prototype uses a mobile platform as a medium for Augmented Reality visualisation (AR) – the concept better known as Mobile Augmented Reality (MAR). Mobile devices have become ubiquitous in the last two decades and with the ascent of powerful smart phones coupled with quality cameras, AR for the first time emerged as consumer product. This development also enabled researchers to explore AR in various domains [4]. One of the advantages of MAR is that it can be visible to device owner only. We have used this fact in developing our prototype as digital graffiti visible to everyone (e.g. projection mapping of user generated digital graffiti on walls) may not be appreciated by everyone at the site.

We have built a mobile application prototype as a means to explore the feasibility of our idea. We have used the Metaio SDK[1] for tracking and rendering 3D objects. The interaction with the prototype can bee see in Figure 2 and 3 as a series of screenshots. Users are presented with four options as seen in the left most screenshot: three geometric bodies and a building. When selecting any of the three geometric bodies the applications expects markers to be placed under the objects for (i) marker based tracking (see Figure 2), and when selecting the building a (ii) markerless tracking (see Figure 3) also known as instant tracking is used. Marker based tracking was designed for drawing on smaller objects, whereas markerless solution was used for outdoor scenarios. Whilst markerless solution is obviously more flexible, due to the fact that it works in unprepared environments, it is prone to tracking failures, especially in cases when tracking surfaces are not optimal (varying illumination, no hard edges, low contrast, etc.)

[1]http://www.metaio.eu/

After selecting a body (and consequently the marker based tracking method) users are presented with the view of the camera and the virtual mesh of the selected body on previous screen. This virtual mesh needs to be adjusted to the surface of the selected physical object placed on the paper with markers. This is visible on the second screenshot from the right in Figure 2. Users have the possibility to expand or shrink the selected mesh in all directions by selecting the direction of size adjustment and pinch gestures (marked by two fingers on the screen in Figure 2). In our example we are adjusting the size of the cuboid mesh to the white cardbox placed in the centre of the paper with markers. All sides of the cuboid are marked with numbers, which becomes useful in the next step.

When the virtual mesh is wrapped around the physical object users can press the colour palette icon in the bottom left corner of the screen to start drawing. The drawing surface, visible on the second screenshot from the right in Figure 2, is a 2D texture that represents a 3D virtual object. The numbers on the sides of the virtual object are also visible in the 2D texture. This enables users to know where the graffiti will be drawn on the physical object. In our example the sides 1 and 2 are facing us, hence we decided to draw on these. However, we can draw on any side, although these might not be possible to visualise (e.g. the bottom side of the cuboid). The 2D texture features a simple drawing application where colours and the size of the brush can be selected. In addition, there are predefined drawings that can be placed on the surface.

When tapping on the green check mark on the screen, users get back to the AR view where the drawing made on previous screen is placed on the physical object. It is possible to take a picture of the graffiti or to return to the drawing screen. The markerless tracking can be seen in Figure 3. The sequence of screens is similar to the one with the marker. However, we do not need to place a paper with markers under selected physical object in order to track it.

3. METHOD

To answer our research questions (social acceptance of creating and created digital graffiti at/on historic landmarks) we run a reflective user study with the lead author. Such approach is often used to reflect upon the prototype developed, shed light on interactions details, provide a glimpse into the subtle affordances the prototype can offer [6], or when developing for a peak experience for a small number

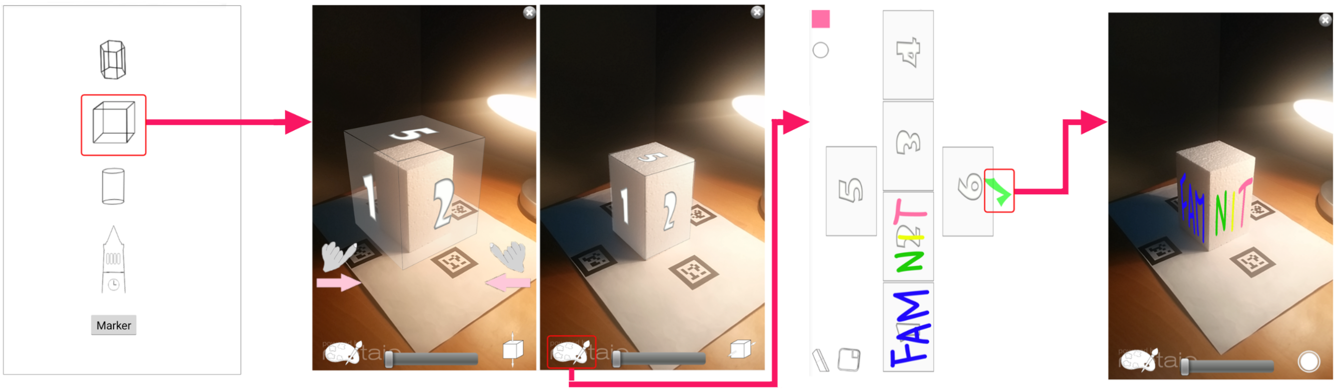

Figure 2: ***Prototype interface with marker-based tracking.***

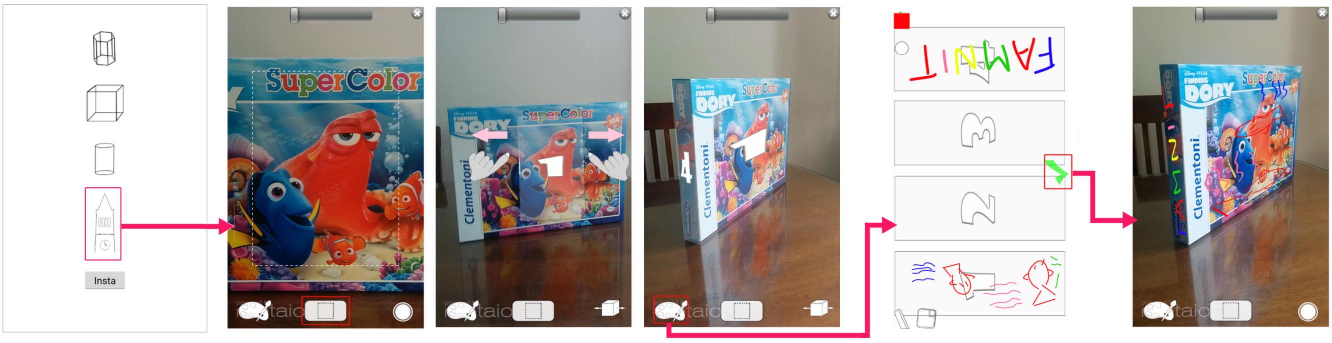

Figure 3: ***Prototype interface and interaction process with markerless tracking.***

of users (even a single user) [3]. Using the developed prototype the author created 10 digital graffiti on various historic sites in historic city of Split during high season when many tourists are visiting these attractions. He then posted some of his creations captured from various angles on his Facebook timeline. We chose social networking service site to reach a wider audience compared to sharing graffiti with (individual) contacts.

4. RESULTS AND DISCUSSION

The picture editor we used in our application allowed us to create simple drawings and captions only. Drawing on a 2D plane on a small screen proved difficult, especially as the developed prototype did not provide zooming functionality. In addition to this, currently implemented drawing tools are primitive and did not allow for drawing in multiple layers as all draw actions are fully opaque. As a result, only a couple of attempts ended with desirable results. However, to our surprise, the alignment of virtual mash to the 3D object was not as difficult as initially expected. The author quickly got a feel for it and managed to precisely map the virtual mesh to the real object as can be observed on third screenshot from the left on Figure2 and forth screenshot from the left on Figure3.

Another issue we wanted to look at was social acceptance of using the prototype in public. There are a couple of prominent examples of technology failures such as GoogleGlass[2], which may partly be blamed also on social acceptance . The key problem with GoogleGlass was caused by the visibility of the camera placed on the frame of glasses, which posed an obvious danger of intrusion into privacy of passers by or people being talked to. However, there are examples of successful camera based products, which continuously record users' surroundings. One such example are life-logging cameras usually worn around one's neck, such as Microsoft SenseCam [10], Vicon Autorgapher[3], and Narrative Clip[4] . Similar to mentioned products, in order to create digital graffiti one needs to point the phone's camera at historic landmarks, which may unintentionally record passersby or people in the vicinity. Our observations confirmed that despite the prolonged use of the phone's camera, during which the author created digital graffiti, none of the passersby or people in the vicinity seemed to be bothered by author's actions. This is probably due to the fact that so many people nowadays use their phones and tablet computers to take photos and film their undertakings on holidays, that holding up the phone for a prolonged amounts of time does not seem unusual.

The last part of our evaluation focused on exploring if placing digital graffiti on historic landmarks is socially accept-

[2] https://en.wikipedia.org/wiki/GoogleGlass
[3] http://www.autographer.com/
[4] http://getnarrative.com/

able. The author posted three curated digital graffiti images (such as seen on Figure 1) on his Facebook's timeline. Even if graffiti were of primitive nature (e.g. the graffiti were mainly composed of text and simple shapes) the published pictures attracted attention from author's social network. Comments were ranging from questions about the technology used, questions about the source of the pictures, to comments on the appeal of particular digital graffiti. Based on the fact that none of the comments in our pilot study highlighted that placing digital graffiti on historic landmarks is controversial or disrespectful, our preliminary study suggests that digital graffiti using MAR technology are socially acceptable. However, to make this conclusion final, a more comprehensive study including quantitative data capture would need to take place. Due to the fact that posted pictures did not cause a massive hype, we were not able to collect other statistically significant metrics such as number of likes, shares etc.

5. CONCLUSION

Whilst ancient graffiti are seen as a valuable window into the lives of past generations, many current graffiti made by tourists or travellers are considered as acts of vandalism. However, digital graffiti concept we presented in this paper may be able to provide sustainable means of fulfilling tourists' wish for marking a place they have visited. The concept is based on MAR technology as a method of generating and viewing digital graffiti. We implemented this concept into a prototype by building a mobile application that enables users to create digital graffiti on arbitrary objects of a predefined shape. By mapping a virtual mesh onto objects, the application can generate an appropriate 2D plane of the mesh on which users can draw digital graffiti.

In order to evaluate the feasibility and social acceptance of creating and placing digital graffiti on historic landmarks, the paper presents a preliminary self reflecting study. The study was based on creating digital graffiti of various historic landmarks, which we published on the authors Facebook timeline. The results show that: (i) due to primitive drawing functionality of the prototype only basic graffiti could be created, (ii) contrary to expectations author quickly became very skilled in mapping the virtual mesh to real objects, (iii) even after prolonged use in public space the application did not provoke unwanted attention or reactions from passersby, and (iv) despite amateur appearance, posted photos received attention and generated some positive responses and questions from author's social network. The results of preliminary study suggests that digital graffiti and the proposed concept are socially acceptable. Based on the results of the presented short self-reflecting study we are planning a more comprehensive study in order to confirm our findings. This will include more in-depth measuring of acceptance of digital graffiti through social reach (number of likes, shares on social networking sites, etc) and through downloads of the app in the app repository (Google Play). Before embarking this route, the current prototype also needs to be improved. For example the drawing interface needs to be expanded with zooming functionality, transparent layers, wider range of brushes, etc. Finally, transferring the graffiti in the digital domain allows for easy sharing which may provide indirect advertisement for local communities and promote touristic places to a wider public. How effective are such practices in this context should also be further studied in the future.

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Interactive Video Management by means of an Exercise Bike

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ABSTRACT
This paper describes the concept of virtual reality and the use of this technology in practice. The main part of the work is about reviewing the various stages of the development of a prototype system for interactive video management by means of an exercise bike. Systems, that are currently available on the market, are, due to their ease of use, closed units, for which upgrades are not possible or come at a great expense. The main advantage of the presented prototype, besides affordability, is a simple option to upgrade the system by adding sensors and/or modules; this allows us to extend the system in every stage of development. A low-cost computer (Raspberry Pi) is used as a processing unit, for calculating the speed of the wheel and sending this information to the control unit. The control unit processes the received data and sets the playback speed of the video clip accordingly. There is great potential for improvement on the developed prototype. Thus, ideas for further development are presented in the concluding section.

Categories and Subject Descriptors
H.5.1 [**Multimedia Information Systems**]: Augmented and virtual realities – *interactive video control*.

H.5.2 [**User Interfaces**]: Prototyping – *speed reading / video displaying prototype*.

General Terms
Algorithms, Management, Measurement, Performance, Design, Reliability, Experimentation, Human Factors.

Keywords
Raspberry Pi, exercise bike, virtual reality, open-source, Java.

1. INTRODUCTION
In the fast-paced life of a modern working man the time for recreation is very scarce. Not everyone can take the time to go outdoors, even going to a fitness can be either too expensive or too crowdy, and hence introduces unwanted stress. Hence, purchasing a piece of indoor fitness equipment (such as an exercise bike) seem to be the perfect solution for those who cannot afford to go to a fitness regularly or have no time or will to exercise outdoors.

On the other hand, cycling on an exercise bike while staring on a wall or even watching TV and/or listening to music, can become boring after some time. This happens because the indoor environment is static and, unlike cycling on an outdoor track, offers little or no “real” motion.

It is this lack of motion and motional feedback of the exercise bike that motivated us to develop a prototype of a system that would offer the user a more realistic experience. We got the idea from the field of virtual reality, where the aim is to offer the user the illusion of reality. In our case, to make cycling on an exercise bike look more like outdoor cycling.

For this purpose, we filmed a bike ride on an outdoor track and used a bike’s speed sensor to interactively control the playback time of the video that the user is looking at.

Next section introduces the reader to the concepts of virtual reality and its use in the field of indoor exercise. In section 3 the prototype system for interactive video management by means of an exercise bike is presented in detail – the first three subsections present its architectural, hardware and software parts, while the last, fourth subsection outlines its operation. Section 4 gives conclusions and lists possible directions for further work.

2. VIRTUAL REALITY
Virtual reality is a computer technology that uses software-generated realistic images, sounds and other sensations to replicate a real environment or an imaginary setting, and simulates a user's physical presence in this environment to enable the user to interact with this space.

Let us skip the history of virtual reality and just say that virtual reality is now in its mature years. The more and more affordable prices of computer hardware and other devices (sensors, embedded systems, …) make virtual reality appear nowadays in a wide variety of applications which include: architecture, sport, medicine, the arts, entertainment, and many more [15].

For the purpose of this paper, we focus on the application of virtual reality in sports. On websites that sell fitness equipment, we can find many indoor systems that enable interactive experience. The first such systems to appear on the market were adapted for exercise bikes. These virtual reality systems differ mainly in the way the user controls the video clip.

The first category consists of dedicated bike systems, adapted for use with virtual reality technology. Such systems are custom made and embedded in exercise bikes (in the gym) and upgrade the exercise bike with the necessary sensors that allow the user to control the video clip that is displayed on a pre-mounted display attached to the bike. An example of such a bike is shown in Figure 1.

Figure 1. A dedicated "virtual reality" indoor exercise bike (source [10]).

The second category of systems aims at bringing the cycling experience even closer to reality. This category includes devices designed for use with a real road bike. Such upgrade normally consists of two units: each one is placed under the rim of the wheel, as shown in Figure 2. The unit under the rear wheel is responsible for controlling the cycling speed and therefore the speed of video playback. At the same time, it acts as a resistor in cases where we want to simulate cycling uphill. The unit, which is mounted under the front wheel, can be reserved exclusively for ensuring the stability of the bike, the more advanced systems can record the angle of the steering wheel and, via a computer system, the image on the screen is shifted accordingly. More such bikes can be connected into the same network offering the possibility of multiplayer bike races [9] or a true VR headset can be connected to the system offering a more realistic experience [16].

Figure 2. A device under a real road bike (source [2]).

Both types of virtual reality systems for indoor cycling available on the market share the same two drawbacks: they are relatively expensive (prices ranging from several hundreds or even thousands of euro) and they are proprietary – that means they cannot be easily upgraded is need be. Our prototype system, described in detail in the next section, tries to overcome these drawbacks by being both relatively cheap (under hundred euro) and open-source.

3. THE PROTOTYPE

This section presents in detail the prototype system and all its parts. Subsection 3.1 is dedicated to the architecture, subsections 3.2 and 3.3 describe the hardware and software part of the system respectively. Subsection 3.4 presents how all the prototype parts work together.

3.1 Architecture

The architecture of the prototype system can be divided into four parts, namely the external or input unit, the processing unit, the control unit, and the display or output unit. Figure 3 depicts the block-schema of the system, showing the connections between the units. The external unit (the exercise bike with the speed sensor attached) is connected to the processing unit via a 2-wire cable (twisted pair) and sends 0/1 signals to it. The task of the processing unit (a Raspberry Pi computer) is to transform this signals to the actual speed of the bike's wheel. It then sends this speed data to the processing unit (a common laptop) via the Ethernet cable using TCP/IP protocol. The processing unit is responsible for controlling the speed of the video clip that is sent to the display unit (a computer monitor) via the HDMI cable.

The four units that make up the prototype system are described in more detail in subsection 3.2 Hardware.

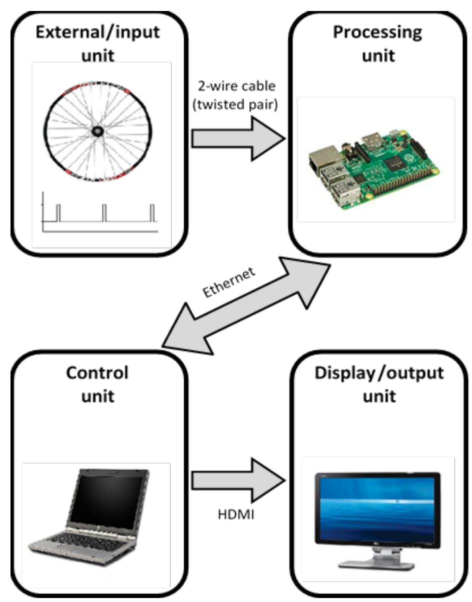

Figure 3. Block-schema of the prototype system architecture.

3.2 Hardware

In this subsection each of the four parts that make up the prototype system are presented in more detail. Thus, the following four subsubsections describe the external unit, processing unit, control unit, and display unit in that order.

3.2.1 External unit

The external unit (also called the input unit, because it provides the input signals to the system) is the exercise bike mounting a speed sensor. For presentation purposes we implemented this unit as an exercise bike simulator shown in Figure 4.

Figure 4. The exercise bike simulator.

The exercise bike simulator consists of a kids bike wheel (without the tire) integrated in the forks and mounted on a pedestal (a wooden plate). The speed sensor is a magnetic switch consisting of two parts. The stationary part of the sensor is the switch itself mounted on one of the forks. The moving part of the sensor is attached on one of the spokes of the wheel and consists of a small magnet with a constant magnetic field. The rotation of the wheel causes the magnet to pass near the switch and triggers it. The detailed operation of this type of magnetic switches can be found in [3].

The magnetic switch is connected to the processing unit (via a twisted-pair cable). For safety reasons and voltage adjustment of the switch a resistance of 4.7 kΩ is connected between it and the processing unit.

The task of the external unit is to generate repetitive electric pulses and sending them to the processing unit.

3.2.2 Processing unit

For processing the signal from the external unit and calculating the speed of the wheel we used the Raspberry Pi – a low-cost, credit card sized computer [14]. The reason for using this type of computer for our processing unit is its size and versatility.

We describe here just those parts of its operation that are relevant for the understanding of our prototype system functioning (a detailed description of the Raspberry Pi can be found in [11],[14]).

The Raspberry Pi comes in many flavors. In this project the Raspberry Pi 2 Model B [11] was used. This version of the Pi comes with a 900 MHz, 32-bit Cortex-A7 CPU with 256 KB of L2 cache, a 250 MHz, VideoCore IV GPU capable of decoding 1080p video, 1 GB of RAM that is shared between CPU an GPU. Its input/output include 4 USB 2.0 slots, a CSI-2 (Camera Serial Interface, Type 2) slot, an HDMI slot, a 3.5 mm composite 4-channel analog output slot, a MicroSD card slot, a network Ethernet slot, and 40 GPIO (General Purpose Input Output) pins that can be used to connect with all types of external devices. The Raspberry Pi operates at 5V of electric charge connected to it through a MicroUSB power slot.

The external unit is connected to the processing unit by a twisted-pair cable on the processing unit's GPIO pins. Figure 5 depicts the schema of the processing unit's GPIO pins, clearly showing the pin numbering. Pins 10 and 16 were used to connect the twisted-pair cable. The "physical" connection is shown in Figure 6 in subsection 3.4.

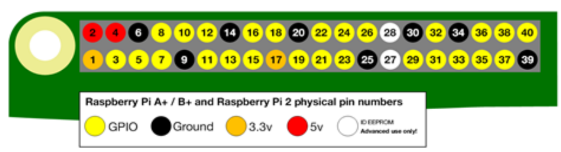

Figure 5. Raspberry Pi's GPIO schema with pin numbering (source [5]).

The task of the processing unit is to transform the electric pulses from the external unit to the actual speed of the wheel and send it to the control unit.

3.2.3 Control unit

Since the main goal of this unit is to receive the speed of the wheel from the processing unit and adjust accordingly the playback speed of the video clip to be displayed on the display unit, this unit should be efficient and stable enough to process Full HD 1080p video.

A laptop with a 2.2 GHz Intel Core 2 Duo CPU, 4 GB of RAM, and an ATI Radeon HD 4500 graphic card with 2.2 GB memory was used in our project.

3.2.4 Display unit

This unit is used to display the video clip to the user of the exercise bike. In our original idea this unit should be a computer monitor connected to the control unit by an HDMI cable, but for simplification reasons, the display of the control unit was used in the end.

3.3 Software

The external and display units, both being passive units with no processing capabilities, needed no software to run/process data. The following two subsubsections are thus dedicated to describe the software used to process data by the processing and control units, respectively.

Everything has been developed in the Java programming language due to its wide portability and sufficient efficiency [6]. The Eclipse programming environment has been chosen, because its ease of use and familiarity [4]. The additional libraries, specific to each unit, are presented in the following subsubsections.

3.3.1 Software used in the processing unit

Raspberry Pi, being the main processing unit of the system, needs an efficient operating system. For the purposes of the project we have chosen the Linux distribution Raspbian, which is a special flavor of the Debian operating system, optimized for operation on the Raspberry Pi platform [1].

To process and preparing the data from this unit for the control unit the Pi4J library of Java functions was used. Pi4J is an open source project, which aims to prepare a user-friendly environment to control the input and output of the Raspberry Pi [7]. This library provides functions for Java developers that abstracts the operation of the lower level Raspberry Pi platform specifics, and thus allowing them to focus on application development rather than to worry about underlying hardware performance [13].

The TCP/IP protocol was used to transfer the data from this unit to the control unit. Since the TCP/IP protocol implementation is part of the operating system and the knowledge about its operation is part of every computer networks course, we omit all its operational detail here – these can be found in [8].

3.3.2 *Software used in the control unit*

This unit is responsible for decoding the video clip to be sent to the display unit. For this purpose, VideoLAN's VLC player was used. Since video playback speed has to be dynamically adjusted to match with the data received from the processing unit, a library of functions, which offer these capabilities is needed.

Here we used the VLCj library. VLCj is an open source project by VideoLAN aimed at creating a bond between their video player VLC, and the programming language Java [12]. VLCj creates Java bindings to almost all the functionality provided by the VLC player. It greatly simplifies the development of Java applications for playing different types of multimedia, streaming video content over the Internet connection, playback mode within server applications and the implementation of video on demand. All software used for our prototype is open-source and available on https://github.com/branax/XBike.

3.4 Putting it all together

The final product of our project is a prototype system, which allows us to control the playback speed of a video clip with the aid of an exercise bike simulator.

The bike simulator represents the real exercise bike. Its speed sensor (in the form of a magnetic switch) is connected to a Raspberry Pi computer by a twisted-pair cable (a resistor is added to this connection for voltage adjustment purposes). Electric pulses are sent to the Raspberry Pi when the simulator's wheel rotates. The Raspberry Pi is charged by a mobile phone charger, powerful enough to provide enough electricity for its smooth functioning. The speed of the wheel is calculated by the Raspberry Pi using the received electric pulses frequency and knowing the circumference of the wheel (at sensor radius). This speed is then sent to the control unit (the laptop described in subsubsection 3.2.3) through the Ethernet using the TCP/IP protocol. On the laptop an instance of the VLC player is running that displays the video clip. When the player receives the speed data from the Raspberry Pi, it adjusts its playing speed accordingly. The video clip is displayed directly on the laptop's screen.

The TCP/IP connection between the processing unit (Raspberry Pi) and the control unit (laptop) is implemented in a client-server fashion, the processing unit being the server and the control unit being the client. Figure 6 shows how the finished prototype looks like.

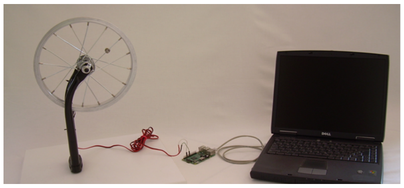

Figure 6. The prototype system.

4. CONCLUSIONS AND FURTHER WORK

Despite the fact that there are already similar products on the market, the main advantage of the presented prototype is its simple architecture and the ability to add additional modules and sensors to the processing unit. Moreover, due to its simplicity and reasonable price, our system could be accessible to different groups of users from young to old, from amateur to professional.

The modularity and the fact that our system is open source gives plenty of options for modification and/or extensions, thus offering vast possibilities for further work. The first step forward will be to implement our system on an actual exercise bike and test/evaluate its operation on real end users.

The expected increasing demand for such systems makes obvious the need for standardization of protocols, connections, modules that these systems use.

5. ACKNOWLEDGMENTS

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