Personalized Multimodal Geo-visualization through Inclusive User Modelling

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Abstract. This paper presents a geo-visualization system that can be personalized based on range of abilities of users and contexts of use. The personalization features uses the Inclusive User Model which simulates interaction and uses those to adapt interfaces based on perceptual, cognitive and motor abilities of users. For example, the proposed visualization system will automatically adjust font size and colour contrast based on perceptual capability of users. It also adjusts spacing between interactive screen elements based on motor abilities of users and context of use. A preliminary user study confirmed that the personalization feature can enhance the usability experience of users.

Keyword: Personalization.

1 Introduction

This paper presents a geo-visualization system that can be personalized based on range of abilities of users and contexts of use. The personalization features uses the Inclusive User Model [4] which simulates interaction and uses those to adapt interfaces based on perceptual, cognitive and motor abilities of users.

Interface personalization is well explored in the domain of content personalization and developing intelligent information filtering or recommendation systems based on user profiles. In most of those systems content (or information) is represented in a graph like structure (e.g. ontology or semantic network) and filtering or recommendation is generated by storing and analyzing users' interaction patterns. Little research work has been done beyond content personalization. A few representative and significant projects on interface personalization are the SUPPLE project at University of Washington [6, 11], and AVANTI project [9] for people with disabilities. The SUPPLE project [11] personalizes interfaces mainly by changing layout and font size for people with visual and motor impairment and also for ubiquitous devices. However, the user models do not consider visual and motor impairment in detail and thus work for only loss of visual acuity and a few types of motor impairment. The AVANTI project [9] provides a multimedia web browser for people with light, or severe motor disabilities, and blind people. It distinguishes personalization into two

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classes - static adaptation which is personalization based on user profile and dynamic adaptation that is personalization following the interaction pattern (e.g. calculating error rate, user idle time etc. from usage log) with the system.

The lack of a generalized framework for personalization of users with a wide range of abilities affects the scalability of products as the existing systems work only for a small segment of the user population. For example, there are numerous guidelines [12] and systems for developing accessible websites but they are not always adequate to provide accessibility. Moreover designers often do not conform to the guidelines while developing new systems and design non-inclusive applications. It is also difficult to change existing systems to meet the guidelines. There are a few systems (e.g.: IBM Web Adaptation Technology, AVANTI Web browser [9] which offer features to make web sites accessible but either they serve a very special type of user (motor-impaired for AVANTI) or there is no way to relate the inclusive features with the particular need of users. The Global Public Inclusive Infrastructure (http://gpii.net/) and the EU Cloud4All projects [5] work mainly based on users' explicitly stated preferences though it is still not clear how exhaustive this set of preferences are and how these preferences were collected from users at the first place.

We have identified a set of human factors that can affect human computer interaction and formulated models [4] to relate those factors to interface parameters. We have developed the inclusive user model, which can adjust font size, font colour, inter-element spacing (like line spacing, button spacing and so on) based on age, gender, visual acuity, type of colour blindness, presence of hand tremor and spasm of users. The model is more detailed than GOMS model [7], easier to use than Cognitive Architecture based models [1, 8], and covers a wider range of users than existing user models for disabled users. The user profile is created using a web form and the profile is stored in cloud. Once created, this profile is accessible to the user irrespective of application and device. We have conducted a series of user trials [2-4] involving people with different range of abilities to validate the user modelling system. We have already integrated this user modelling system with a digital TV framework (EU GUIDE system [10]) and an electronic agriculture system [3]. The present paper exploited this model for a Wisekar [13] based geo-visualization system for sensor networks.

2 Configuring Wisekar for the Geo-visualization System

Wisekar (**Wi**reless **Se**nsor **K**nowledge **Ar**chive) [13] is an Internet of Things (IoT) based repository developed at IIT Delhi for archival of sensor-derived information. While allowing both manual and automated contribution of information, Wisekar offers a flexible structure to represent this information in a variety of standards, for example in the OGC-defined SensorML. Furthermore, information based on multiple XML-derived standards can co-exist in Wisekar which facilitates the integration of this information with the Semantic Web. Geo-visualization of sensor node- and event-related information in Wisekar is convenient due to its hierarchical structure. Also, a RESTful API for event-contribution makes it possible for all kinds of sensor-enabled devices, from sensor nodes to mobile phones, to transfer their data to Wisekar over the HTTP protocol which is not restricted by firewalls.

Initially, web-based repositories developed to archive research data used a form-based interface for data-contribution. For example, the UCI machine learning repository (developed in 1998) [14] contains datasets for evaluation of machine learning algorithms. CRAWDAD (2005) [15] captures network data in datasets. In 2006, Sensorbase.org [16] was developed at UCLA to allow events to be streamed from sensor networks over HTTP in Environment Markup Language (EML), where EML is a standard defined on XML. SenseWeb [17] from Microsoft Research is a peer produced sensor network that offers a SOAP-based Web Service API for contribution of sensor events. A visualisation tool Sensormap is used to create mashups from SenseWeb data. A SOAP web-service requires a SOAP library at the client-end to consume the service. This led to the increasing popularity of REST-based web-services where the HTTP url along with methods GET, POST, PUT and DELETE could be used to invoke and use the services. Cosm [18], now Xively, is an IoT repository that offers a RESTful API for contribution of data formatted in Extended Environments Markup Language (EEML). However, other XML-based standards to describe sensor-based data also exist, such as the Open Geospatial Consortium (OGC) defined SensorML. To accommodate data described in multiple standards, IoT repository Wisekar has been developed which offers a RESTful web-service interface for data contribution. Wisekar allows multiple XML-defined standards to co-exist and also permits contributors to describe the structure of their data in XML.

A subdomain of Wisekar – Wisekar/home (http://wisekar.iitd.ac.in/home) – is used to archive research datasets on pervasive sensor environments. We develop a web-application for geo-visualization of Weather data, which uses one of the Wisekar/home datasets called *WorldWeather* as the data-source. The objective of this application is to use the world map as the visualization platform to present all weather information logged in *WorldWeather*. This information consists of temperature and humidity levels reported regularly for various places around the world.

Each node in the *WorldWeather* dataset corresponds to a place for which the temperature and humidity levels are monitored. Every node contains a sequence of events with the temperature and humidity values for the place over a period of time. After creating the *WorldWeather* dataset through a form-based interface, each node in *WorldWeather* is created using the Wisekar/home *POST node* API method:

POST node:
http://wisekar.iitd.ernet.in/api/home/resource.php/resource/node?key=<key>&datasetId=<datasetId>&localId=<localId>&nodeName=<name>&nodeDesc=<desc>&lat=<lat>&long=<long>

In the *WorldWeather* dataset, we create four nodes - New Delhi, Cambridge, Sao Paulo, and San Fransisco - by assigning appropriate values to the various fields, notably to <name>, <lat> and <long>. Wisekar/home generates a *node Id* for every node successfully added to it. To add events to the node, the *POST event* API method shown below is used.

POST event:
http://wisekar.iitd.ernet.in/api/home/resource.php/resource/event?key=<key>&nodeId=<nodeId>&typeId=<typeId>&status=<temp>,<hum>

In the *POST event* method, <nodeId> is the unique *node Id* generated by Wisekar/home for this node as discussed earlier, <typeId> is the *Wisekar Glossary type* which indicates that the status fields contain temperature and humidity.

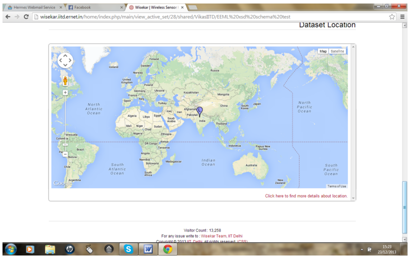
3 Wisekar Based Geo-visualization System

The geo-visualization web-application presents the dataset information on the map by adding a marker for each place (node). The information obtained from the latest five events logged in the dataset for each node is available in a chart that shows up when the marker is clicked. Three fields are presented for each event - *Reporting Time, Temperature and Humidity*. *Node name* and *Node Id* are presented on the top of the chart. The node and event details are visible on clicking the appropriate links on the chart.

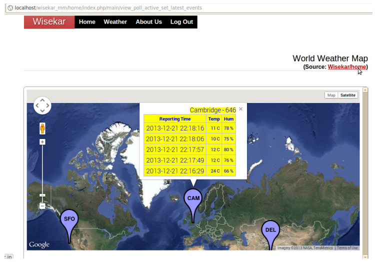
Figure 1 below shows four different renderings of the web-application for people with different range of visual and motor impairment. All these figures are reporting temperature and humidity data of different cities with possible extension to show pollution data as well. The system changes the foreground colour to blue and background colour to yellow for users having red green colour blindness (Figure 1b). It uses bigger font size and turns on high-contrast for people having blurred or distorted vision due to myopia, macular degeneration or diabetic retinopathy (Figure 1c). Finally the system also adjusts the default zooming level if the user has tremor or spasm in hand. A higher zooming level separates screen elements to reduce chances of wrong selection (Figure 1d).

4 User Trial

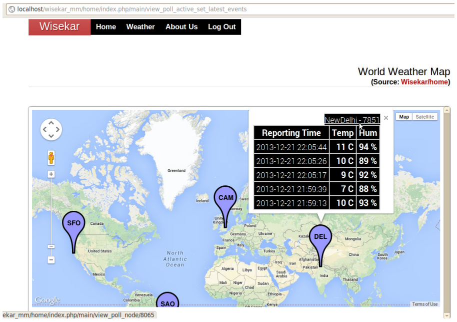
The following user trial reports a controlled experiment on the web-based Wisekar application. It compared users' objective performance and subjective preference for an adaptive and a non-adaptive version of the weather monitoring system. We purposefully used two different devices for signing up and using the application to highlight the notion of transporting user profile across multiple devices.



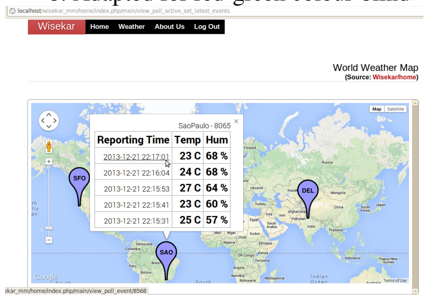
a. Non Adapted



b. Adapted for red-green colour-blind



c. Adapted for blurred vision



d. Adapted for blurred vision and hand tremor

Fig. 1. Personalized Wisekar System

4.1 Participants

We collected data from users with age-related visual or motor impairment. Table 1 below furnishes details of participants.

Table 1. List of Participants

Participants	Age	Gender	Impairment
P1	60	Male	Plus 2.5 Dioptre power
P2	57	Male	Minus 2.5Dioptre power
P3	59	Male	Plus 2.5Dioptre power
P4	42	Male	5/6 vision
P5	50	Female	Plus 1Dioptre power
P6	57	Male	Recently operated cataract, blurred vision
P7	59	Male	Plus 1.5Dioptre power

4.2 Material

We have used a Windows 7 HP computer with 54 cm × 33 cm monitor having 1920 x 1080 pixels resolution to record users' performance with the weather monitoring system. We used a standard Logitech mouse for pointing. Users signed up using a HP Tx2 laptop with 30 cm × 20 cm screen and 1280 × 800 pixels resolution.

4.3 Procedure

The participants were initially registered with the user modelling system using the Laptop. The sign-up page can be accessed at www-edc.eng.cam.ac.uk/~pb400/CambUM/UMSignUp.htm

After that participants were briefed about the weather monitoring system. The task was to report temperature and humidity of cities on a specific date (Figure 2). Each participant was instructed to report temperature and humidity six times for each of adapted and non-adapted conditions. The order of adapted and non-adapted conditions was altered randomly to eliminate order effect.

4.4 Results

During the sign up stage we found that different users preferred different font sizes ranging from 14 points to 18 points. We also noticed that one user was Protanomalous colour blind and he read 45 instead of 42 in the plate 16 of Ishihara colour blindness test.

During use of the weather monitoring system, we measured the time interval between pressing the left mouse button on the bubble with the city name (green transparent round shape in Figure 3a) and reporting of the required temperature and humidity data (Figure 3b).

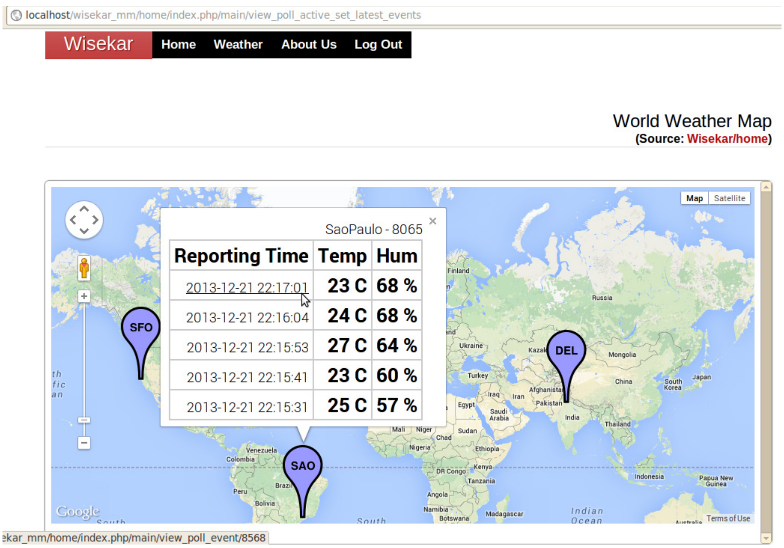
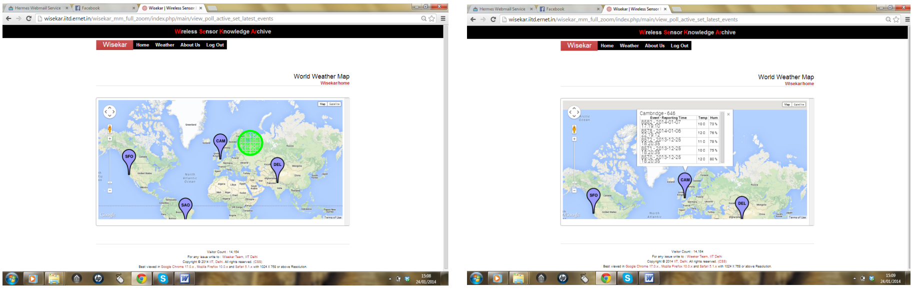


Fig. 2. Screenshots of Wisekar Weather monitoring system



a. The screenshot shown to user for selecting city

b. The weather reporting screen

Fig. 3. The experimental task

In total we analysed 84 tasks from seven participants (42 for adapted and 42 for non-adapted).. We found that users took less time in adapted condition (average 8.25 secs, std dev 3.1 secs) than non-adapted condition (average 9.75 secs, std dev 3.63 secs). All participants were already familiar with mouse and also practiced the system before the actual trial. So we assumed that each pointing task is independent to each other. Under this assumption, the difference is significant in a two-tailed paired *t*-test with $p < 0.05$ and with an effect size (Cohen's *d*) of 0.44 (Figure 4).

Without this assumption, the difference to significant in Wilcoxon signed-rank test ($Z = -2.89$, $p<0.05$).

We conducted a subjective questionnaire to understand users' subjective preference. All users noticed bigger font and preferred it. One user was colour-blind and he preferred the change in colour contrast too.

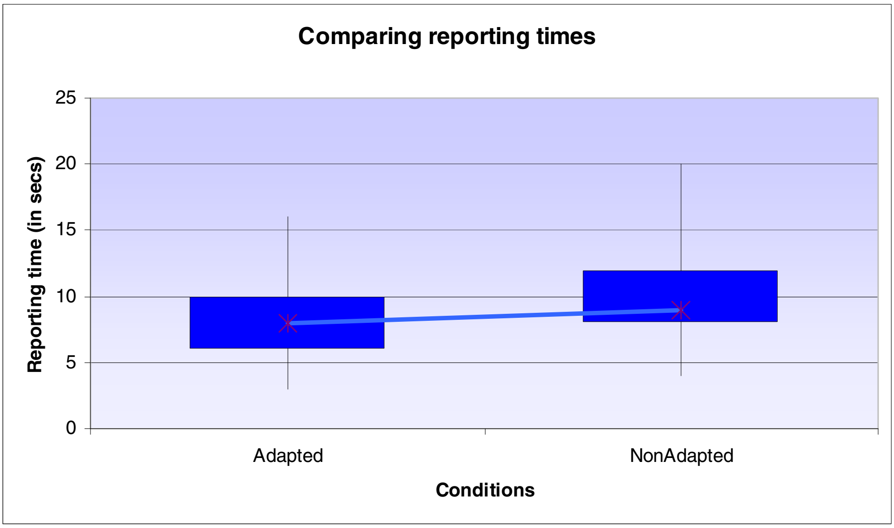


Fig. 4. Comparing weather reporting times

4.5 Discussion

The user study shows that users prefer different font sizes and colour contrast even for a simple system. The study also confirms that even for a simple text searching task, users performed and preferred an adaptive system that can automatically adjust font size, line spacing and colour contrast. The user modeling system successfully converted users' preference across two different devices having different screen resolutions. Future studies will collect data from more users and will use more complicated tasks than the present study.

5 Conclusion

This paper presents a personalized geo-visualization system based on a sensor network. A preliminary user study confirmed that the personalization feature can enhance the usability experience of users. The Sensor network already provides pollution data in the form of amount of Carbon-Dioxide in air and in future can be integrated to more versatile type of sensors. The whole system will have a plethora of applications like in Ambient Assistive Living (AAL) system, Weather monitoring and reporting system and even for visualizing sensor data in automobile and aircrafts. Future research will investigate these new applications of the system.

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