Display Content Adaptation Using a Force Sensitive Office Chair

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ABSTRACT

In this paper, the author introduces a novel method for non-invasive, implicit human-computer interaction based on dynamically evaluated sitting postures. The research question addressed is whether or not the proposed system is able to allow for non-obtrusive screen content adaptation in a reading situation. To this end, the author has integrated force sensor array mats into a traditional office chair, providing sitting postures/gestures of the person seated in real time. In detail, variations in the center of pressure were used for application control, starting more generally with usability assessment of cursor control, breaking them down to simple(r) pan and zoom of screen content. Preliminary studies have indicated that such a system cannot get close to the performance/accuracy of keyboard or mouse, however its general usability, e.g., for handicapped persons or for less dynamic screen content adaptation, has been demonstrated and some future potential has been recognized.

Keywords: *Ambient Intelligence, Dynamic Screen Content Adaptation, Force Sensor Arrays, HCI, Sitting Postures/Gestures*

1. AMI TECHNOLOGY IN AN OFFICE ENVIRONMENT

Traditionally, office work is concerned with (1) using the keyboard for input operations and (2) precise point, click, and drag&drop operations using the computer mouse. However, as more and more people spending their working day in front of the screen, beside the "processing-centered tasks" a new class of interaction gains more and more importance: The computer (screen) as "reading device" for scientific papers, e-books, newspapers, and other information-rich information. While conventional computer work requires frequent user inputs, the usage as an electronic reading device often comes along with a "relaxed", reclined sitting posture, with hands – most the time – away from both keyboard and mouse. In this "mode of operation", however, scarce interaction with the computer, e.g., for moving invisible screen areas into focus, for turning pages, for magnifying interesting data, and so on, has to be necessarily enabled.

To address this problem, i.e., leaving the reader in a comfortable sitting posture but at the same time allowing him/her for convenient (limited) application control, the utilization of ambient

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intelligence (AmI) technology is expected to serve as a feasible solution. According to (Crutzen, 2006), one of the characteristics of AmI technology is that smart objects will make our whole lives relaxed and enjoyable – AmI will be capable of (1) meeting needs, (2) anticipating and responding intelligently to spoken or gestured wishes, and (3) desires without conscious mediation. To pick up on this vision, we propose a non-invasive, natural behaving sitting posture controlled input/feedback system integrated into a common office chair, and providing the computer user with implicit functionalities for controlling the screen content on display. The operating principle is thereby based upon the proven fact that people naturally lean towards items and adjusts their position in order to better inspect them (Harrison & Dey, 2008).

The **research question** addressed in this work is:

RQ: whether or not it is possible to (conveniently) use a non-invasive, implicit sitting posture acquisition system integrated into a common office seat for unobtrusive, non-disruptive screen content adaptation (e.g., zoom, pan) in a relaxed, probably reclined, reading situation.

1.1. Related Approaches

Since Doug Engelbart's, "Mother of All Demos" (Engelbart, 1968), where he demonstrated the computer mouse (Engelbart, 1970) to the public for the first time, many research groups all over the world have investigated alternative approaches for interacting with the computer employing different levels of accuracy and workload. Harrison and Dey (2008) were, to our best knowledge, the first who recognized the need for inconspicuous, implicit assistance in the considered tasks. Their system "Lean and Zoom" follows a camera-based approach for magnifying screen content based on the measured face-screen distance. Even though this system shows good performance and demonstrates ease of use, the usability is to some extent restrictive as the user has – on desired magnification – to move the whole body towards the screen and furthermore, the utilization of cameras is in general somehow problematic. For example, cameras have to be calibrated before usage in order to estimate correct camera parameters like metric information (Sauer et al., 2006), both angle and distance to the camera are limited (Sippl et al., 2010) (this is particularly true for Webcams integrated into computer screens), they are susceptible to varying lighting conditions, reliable distance/position detection is often compromised already by small motions of the head (Sippl et al., 2010), computer vision algorithms to be applied are, in relation to the finally used control commands, too complex, etc.

Other feasible approaches for unobtrusive detection of body movement, gestures/postures, or any other expressive body language to be used for implicit interaction with the computer are, admittedly all with their specific drawbacks, eye movement (Jacob, 1990) or gaze gestures (Drewes et al., 2007; Drewes & Schmidt, 2007; Sippl et al., 2010; Luca et al., 2007). Common to all technologies using movements of the eye are a number of limitations, such as contact lenses or spectacles, lighting conditions (brightness, shadows), or posture and movement of the head. The "Midas-touch problem" (Jacob, 1990) indicates that reducing the dwell time when inspecting the displays leads to unstable system behavior, however, increasing the dwell time too much prevents undisturbing, "relaxed" usage. In addition, the eye is normally used for triggering output – using it as "input sensor" is unnatural and may result in further conflicts or even user distraction.

Recently, increasing effort has been put into research focused on electrooculography (EOG) (Bulling et al., 2008, 2011), and electroencephalography (EEG) (Choi & Lee2006; Knezik & Drahansky2007; Felzer & Nordmann, 2008). The approach is to use the changing electrical potential of brain waves generated by the eye movements or detected during EEG measurements. However, also here are a number of limitations preventing the universal application of these techniques such as that the eye can rapidly get tired incapacitating further usage, blinking/winking of the eyes has to be incorporated, a (test) person's head has to be equipped with physical electrodes, sweating on the scalp may gives rise to low amplitude tracings (short circuit caused by saline), and others. A complete different approach in form of a balance disk (type "IKEA Virrig") with a set of embedded sensors (e.g., ball switches for tilt sensing or a compass for measuring rotational movements) was used by Holleis et al. (2006) and Schmidt et al. (2004) for hands-free control of the mouse cursor. Application in edutainment/gaming indicated some problems and restrictions caused by missing precision and latency – which, in the end, disallows also this system to be used for solving the here addressed problem.

Summary

All of the related technologies/systems for implicit and "relaxed" screen content adaptation discussed previously have shown some drawbacks or limitations, prohibiting its universal, particularly non-distractive, application, and calling for a new, less susceptible solution. In the following, we present with the "force sensitive office chair" one potential solutions considering the aforementioned issues.

Outline

The rest of the paper is structured as follows. The next Section 2 presents a general system overview to allow for non-invasive, posture controlled, screen content adaptation, Section 3 presents two case studies conducted to assess the quality and usability of such a device. The final Section 4 concludes the paper, draws some conclusions for practical application, and discusses potentials for future improvements.

2. A FORCE SENSITIVE SITTING POSTURE RECOGNITION SYSTEM

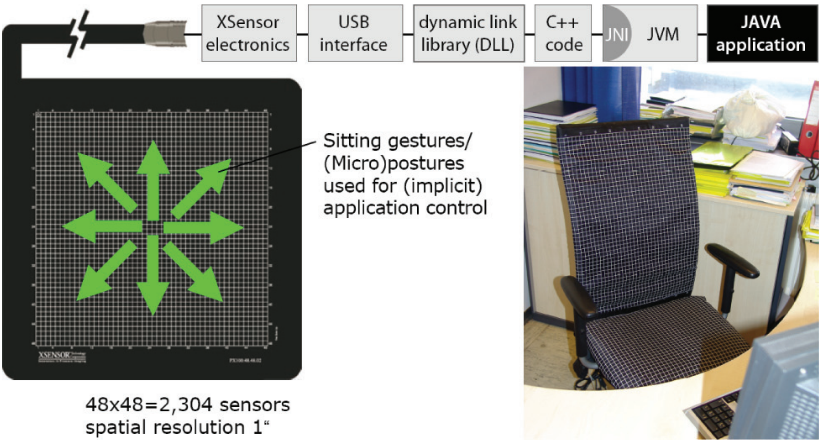
In this work we present our initial findings on a non-invasive, implicit, sitting posture based screen content adaptation system. The underlying functional principle are force sensitive array (FSA) mats, integrated into both seating and backrest of a standard office chair (Figure 1). The arrays allows for dynamic tracking of sitting posture variation, i.e., person movements in the seat.

In more detail, the underlying technological assembly and principle of sitting posture sensing/processing is as follows. For real time recognition of postures, XSensor pressure sensor technology (http://www.xsensor.com/pressure-imaging/), built up from pressure sensing matrices with specialized electronics connected to a computer, was employed. Each "sensor mat" consists of a matrix of capacitive sensors (in our case, using two mats of type "PX100:48.48.02", 48 by 48 sensors each, covering a sensing area of about $61 \times 61 cm^2$) formed into a continuous film. This film is connected to an electronics module that translates the physical compression of each cell of the matrix into a capacitance value that is correlated to pressure. After preprocessing, 16 bit pressure values are forwarded to the application (Java) via USB-Interface, dynamic link library (DLL), and JNI-Wrapper at a maximum of $100Hz$. With such a system even slight variations in the pressure distribution between the two surfaces can be detected.

For processing of sensor data a 3-staged approach is followed in the software application.

1. **Sitting posture acquisition:** As soon as a person is seated (determinable by a weight threshold exceeded on the seat map), the 48 by 48 array of force sensitive sensors (sensor size/spatial resolution 1 by 1) for both seating and backrest is read out once and buffered for later reuse (zero pressure filtering).
2. **Zero pressure filter:** After the "single image snapshot", data from the two pressure sensitive mats is continuously recorded at an update rate of about $10Hz$. In order to keep data quantity to be processed as low as possible, with – at the same time – not loosing information accuracy, the initial

Figure 1. Technically, the underlying functional principle of the sitting posture-aware seat prototype is based on force sensitive mats integrated into seating and backrest, and allowing for dynamic tracking of sitting postures



gathered pressure image was deducted from all further images. The result is a zero matrix with sparse entries indicating changed sensor values only (for clarification see Figure 5). Dynamic center of pressure values are then derived from these sparse matrices.

3. **Center of pressure (COP):** The center of pressure (COP) (Ferencz et al., 1993) is calculated for each frame and for both seating and backrest. COP is used as it can be calculated much more efficient than processing the whole matrix several times a second, with same quality of results when used for cursor control or content adaptation (zoom/pan). Separately for the two force sensor array mats, deviations in (x,y) from the initial position of COP (x_0, y_0) are determined in real time, and used for application control. In the given cases (see Section 3), the sensor sheet attached to the seating alone is used for cursor control (in the form indicated in Listing 1), seat mat and y-coordinate (for controlling the zoom level; $y < y_0$ zoom out, $y > y_0$ zoom in) of the backrest mat are used for screen content adaptation.

3. PRELIMINARY STUDIES

In order to assess the quality and usability of this, generally spoken, "sitting posture based input device", user studies were conducted whose findings will be presented in the following.

3.1. Case 1: Sitting Postures for Mouse Cursor Control

For the reasons substantiated in the introduction, but also to discover the general capabilities of such a system, the initial (and, of course, ultimate) goal – supported by the high update rate of the force sensitive arrays – was to implement a input device for controlling the cursor on the screen in real time and with similar behavior as the computer mouse. If this goal can be achieved, any other control task (such as the suggested screen content adaptation) can be easily implemented as a specialization from the underlying general system.

3.1.1. Cursor Movement

While the direction of movement of the cursor on the screen was related to the (x, y)-position

Listing 1. Mapping between center of pressure (seat) and screen cursor position

```
// seat map
// x,y represents COP coordinates
if (xi > xj)
  xcursor += (xi-xj)*corrfactX;
if (yi > yj)
   ycursor += (yi-yj)*corrfactY;
...
xj = xi;
yj = yi;
```

of the center of pressure, the distance to the origin (derived from first pressure image) was used to control the moving speed of the cursor towards the indicated direction. The performed experiment was a classical movement task described first by Fitts' in the corresponding law.

Fitts' index of performance (IP) (Fitts, 1954; Fitts & Peterson, 1964) was found to be a valuable predictor of the movement time in any cursor positioning task and has become the standard method to identify performance differences between input devices like mouse, keyboard, joystick, etc. (Slocum, 2005) and thus, should also be applied as metric for assessing the usability of the current setting. Chin and Barreto (2006a, 2006b) found that the bigger part of interaction between a human and a computer is covered by "point and click" actions. Nevertheless, in the first study we evaluated point actions only – once the cursor hits the destination/circle (by moving over), the next target is generated and displayed. MacKenzie et al. (2001) evaluated the accuracy of different types of computer pointing devices and found that the mouse was the fastest device and the joystick the slowest; the mouse also had the flattest learning curve. Another important result of the study was that the accuracy measures with an independent contribution to pointing device throughput were able to discriminate among devices. This work (MacKenzie et al., 2001) can be extended by adding, for the first time, a measure for a sitting posture based input device.

3.1.2. Evaluation

During software implementation and first user tests we experienced that mouse input (point/movement only, click omitted) would be always immeasurable faster compared to the pressure sensitive seat interface, at least for untrained users and most likely due to the fact of slow movement contingency in the seat. (Higher responsiveness of posture changes would allow for increased cursor movement speed, but, at the same time, would make it even more difficult to accurately point to a small target). To qualitatively assess the usability of a sitting posture controlled cursor control system, a Fitts' law test was implemented and conducted, comparing a point operation using a keyboard's numeric keys 1 to 9 (except 5) as "keyboard mouse" and the seat posture interface (Figure 2). The times for reaching the circular objects with either the keyboard or the "seat-steered" cursor were recorded into files for later evaluations. One test series encompassed 30 measuring points with each input technology. Also, in this – compared to mouse input considerably slower – case, the keyboard input is much faster compared to the posture control (Figure 3). As already the movement time alone (for 10 test runs) clearly shows a high deviation between the two interface types (more than double the time, much higher variance: $\overline{x_{keyboard}} = 4.57 \pm 2.66 sec.$,

Figure 2. User view (without labeling) for the Fitt's law test comparing keyboard and posture interface

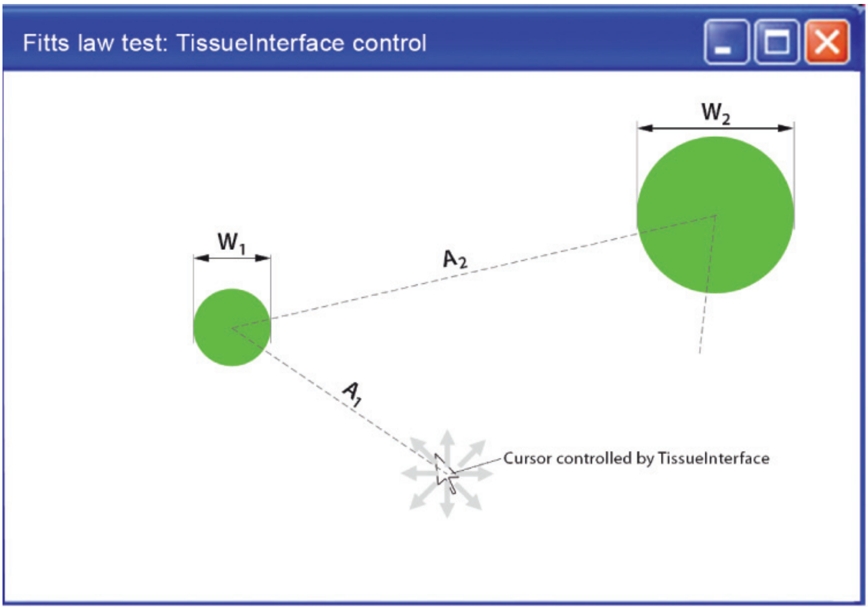
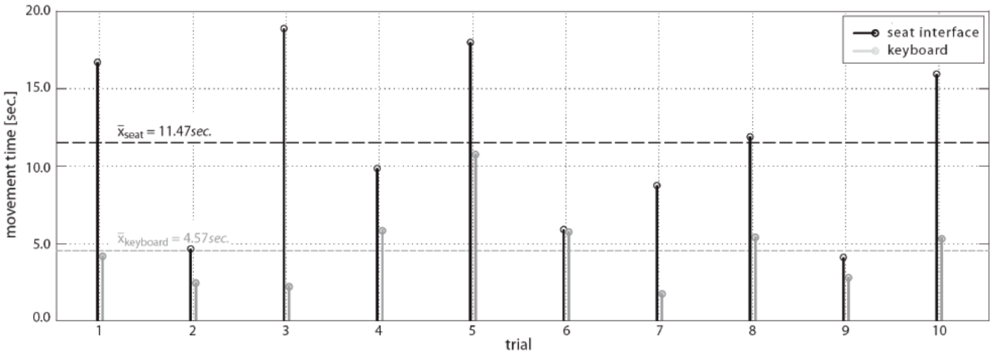


Figure 3. Case study employing "Fitts' law" for testing the usability of the pressure sensitive seat interface in relation to keyboard control (using "arrow keys")

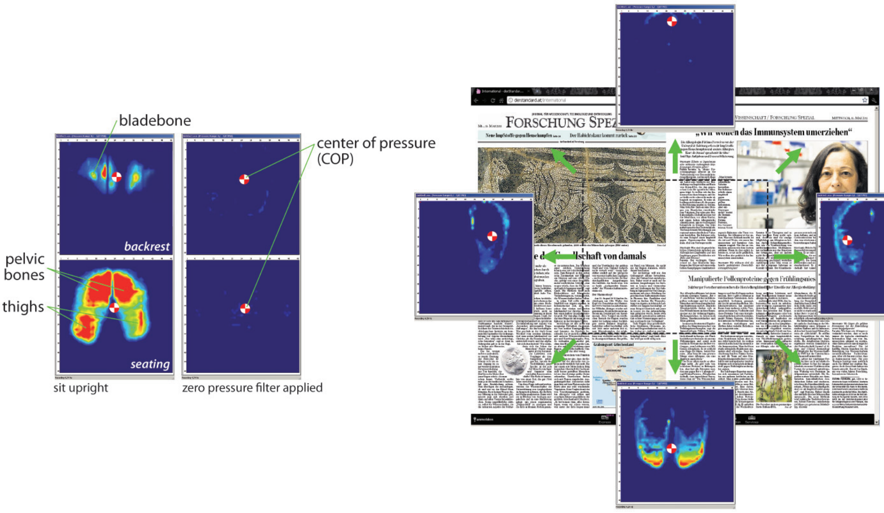


$\overline{x}_{seat} = 11.47 \pm 5.65 sec.$), the "index of performance" (IP) was no more calculated.

In this preliminary test study it became evident that the utilization of a force sensitive seat interface cannot replace the classical mouse input, at least not for high dynamic, precise mouse cursor control as generally required by (healthy) computer users. It has to be noted, however, that this input device still can get a chance to be used by handicapped people as its general usability has been proven. It is a matter of fact, for example, those physical disabilities, like spinal cord injuries or spinal dysfunctions, incapacitates a population of people to use classical input devices like mouse, keyboard or joystick (Chin & Barreto, 2006a). Given the

Figure 4. The mat attached to the backrest (y-axis only) is used for controlling the "zoom level" of the screen content. When sitting upright (left-hand side), the content is shown in original size (100%), the more leaning forward (right-hand side), the higher the magnification of the screen content.

Figure 5. In case of magnification (by leaning forward), weight stabilizing on the seating can be used to scroll (pan) continuously through the screen content by dynamically evaluating changes in the center of pressure. The right image shows typical pressure images (with applied zero pressure filter) together with the corresponding COP points.



increasing penetration with, and usage of computers in working life, for daily activities, and in social communication over the Internet it is of essential importance to make computers and the Internet also available to these individuals with disabilities.

3.2. Case 2: Non-Invasive, Implicit Screen Content Adaptation

From the results of the first study we were brought back down to earth, investigating in a second study the potential of such an interface for limited control tasks, such as dynamic screen content adaptation as claimed in the research question (Figure 4). Such a application is not aimed to replace traditional controls like keyboard or mouse, but to provide the computer user with limited possibility for implicitly control applications in “relaxed” situations as when reading electronic news, ebooks, or even scientific papers. Much potential is seen in such tasks, where optimization with respect to interaction performance (movement time) and positioning accuracy is not the central matter. Quite the contrary -- the focus is not on qualitative measures, but on usability assessment for implicit, convenient, non-distracting, potentially emotionally influenced application control.

Basically, the same setting as in the previous study was used for the tests, however, only relative movements were evaluated and no precise positioning on pixel granularity was requested. First tests with applied zero pressure filter and more complex COP calculation algorithms, as described by Siebenthal (1998) (Sections 3.6.3 through 3.6.6) (neighboring method, i.e., sum of squared distances), showed good user experience and control behavior (Figure 5). Nevertheless, detailed user studies and qualitative assessment of the interface characteristics, are ongoing and will be published elsewhere.

The parametrization of this interface would be, by all means, application specific, allowing, for instance, when reading newspapers, to bring the previous/next page on display when exceeding a certain threshold in left/right movement, or to define the manner of how to browse through an archive of images, control a media player, or studying extensive data tables – with specific functions each.

4. CONCLUSION

In this work we have shown that a non-invasive, dynamic sitting posture acquisition system integrated into a common office chair can be used for implicitly and intuitively control standard computer applications, however, with both limited point/movement performance and accuracy. Nevertheless, such a input system can gain excess value for a special group of handicapped people, such as those with spinal cord injuries. A second, even more promising field of application, is its use as assistive technology, e.g., to employ computers as reading devices for newspaper or scientific papers. Future experiments have to be conducted to improve on the behavior of the interface (linkage sitting posture – application control) and to verify the supposed lower cognitive workload (or distraction) when using this interface instead of keyboard or mouse.

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