Plantar pressure-based gestures for medical image manipulation

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Abstract

In this work, we present an interaction concept for manipulating an image viewer only using a pressure-sensitive shoe insole. A simple foot gesture set has been created and applied to a prototypical user interface, which enables the changing of slices of medical image data in an image viewer. In a pilot study the gestures were tested according to the NASA Task Load Index (NASA-TLX). The Purpose of this project was to estimate how suitable and user-friendly different foot gestures are in practice. We found plantar pressure-based gestures are quite intuitive and users get quickly accustomed to using them. However, gestures based on overlapping pressure-sensitive areas might lead to unintended results.

1 Introduction & Related Work

During image-guided surgical procedures, surgeons need to interact with preoperative or intraopreative data presented by medical systems. However, due to the need of maintaining sterility, computer interaction is heavily constrained. Often both hands of the leading surgeon are occupied and therefore interaction tasks are allocated to surgical assistants. This demands clear instructions from the leading surgeon and requires more time (O'Hara et al., 2014). Several publications propose touch-less interaction using foot gestures, an survey of the most common gestures in literature is presented in Velloso et al. 2015. Plantar pressure has been used to perform foot gestures in a subtle way and to identify different users and undergrounds while walking (Fukahori et al. 2015, Matthies et al. 2017). In Hatscher et al. 2017 a prototype shoe with a mounted distance sensor and a gyroscope has been built. An image viewer is manipulated using solely heel rotation and ball lifting/tapping. In Fitzke et al. 2015 a Force Sensing Sesistor Mouse was developed. This pointing device consists of 5 pressure sensitive sensors attached to an insole. Similar to a joystick each of the sensors represents one of the basic directions with the exception of the down direction which is implemented

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using 2 sensors in the heel. Based on a similar approach, we use a pressure-sensitive insole to manipulate an image viewer. The interaction is focused on scrolling up and down.

2 Material & Methods

2.1 Material

For the prototype and the following pilot study the shoe insole "PlantaPress", which is manufactured by Thorsis Technologies GmbH, Germany is used. The insole has 50 pressure sensors integrated, which dynamically measure the foot load. It is attached to a sensor electronic and can transmit data to a Bluetooth dongle in a range of 10 meters. It is majorly used by orthopedists to identify inappropriate mechanical stress on the foot and to possibly initiate appropriate treatment. As soon as the sensor electronic is activated, the measurement starts.

2.2 Interaction

The user can manipulate four functions inside the image viewer with the help of four gestures:

- **Activating** the viewer : pressure on the big toe, while lifting the heel completely
- **Deactivating** the viewer: pressure on the heel, while lifting the ball of the foot completely
- **Increasing** slice number: shifting weight to the ball of the foot
- **Decreasing** slice number: shifting weight to the back of the foot

In order to recognize the gestures as such, the insole sensors are grouped into areas shown in figure 1.

Figure 1: Pressure areas and mapping of the four gestures
From left to right: defined four sensor areas, activation, deactivation, increase, decrease

To ensure a precise as possible interaction, it is important to take into account the physiology of the user. Depending on the size, weight and personal variety of putting on pressure, different output data has to be interpreted and integrated into the system. In order to achieve this, a calibration step has been integrated. During calibration the user is instructed to perform each foot gesture for three seconds. For each gesture a threshold is computed according to:

$P_{threshold} = \frac{1}{t} * \sum_{i=0}^{t} p_{gesture}(i) * constant$ the constant varies between 0.8 and 1.0 depending on the gesture.

2.3 Interface

The graphic interface of the prototype is split into the main image viewer and a visualization of the acquired pressure data, which shows the pressure points after exceeding a certain threshold. As shown in figure 2 on the right side a 5x10 matrix was created, each cell represents a sensor, the matrix itself covers the whole insole (right or left). The state of the system is shown with a colored border (green for active and red for inactive).

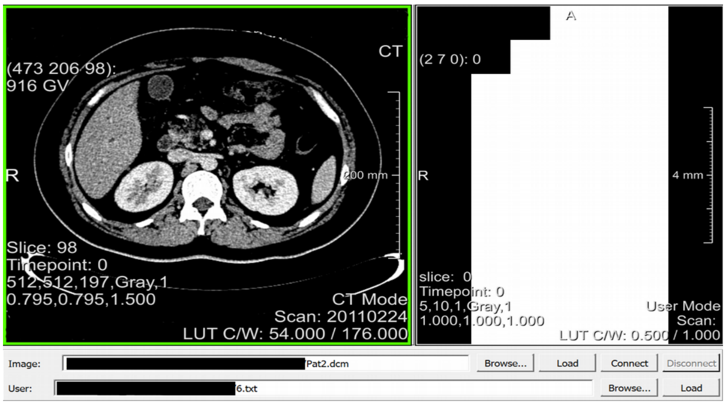

Figure 2: Activated Prototype (green border), on the right side pressure area of the big toe is shown

3 User Test and Results

3.1 Pilot study

In a pilot study we gathered 14 students in the range of 20 to 28 years to test the user-friendliness of the foot gestures. At the beginning each participant created a user profile consisting out of various thresholds computed by the calibration module. After the calibration and explanation of the gesture set, the participants had to perform the following eight tasks:

1. Activate System
2. Scroll Up
3. Scroll Down
4. Deactivate System
5. Activate System
6. Scroll to slice 151
7. Scroll to slice 68
8. Deactivate System

Finally, the participants had to fill out a NASA-TLX questionnaire.

3.2 Results

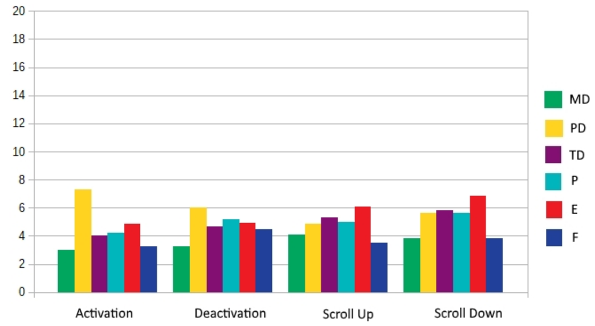

Figure 3: Mean results of the NASA-TLX questionnaire for the dimensions Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Performance (P), Effort (E) and Frustration (F). (0 = low/good, 20=high/poor)

The bar chart shows all averages of physical, mental and temporal demand to be under 10. This indicates the participants did not find the gestures too demanding. None of the gestures seem to overwhelm the participants in their execution. In several cases the calibration was slightly off and needed to be fixed manually. During the experiment the system was unintentionally deactivated 4 times. When trying to disable the system, participants involuntary changed the slice number instead 7 times. Asking to scroll to slice 151 problems ended in overall 6 failed attempts. Some participants needed 3 tries to pass the given task.

4 Discussion

We presented a new interaction concept that expands our previous work in the field of foot-based interaction with medical images. (Hatscher et al. 2016, Hatscher et al. 2017). Overall the usage of plantar pressure-based gestures have potential for manipulating medical images in a surgical set up. The physical demand is relatively low and intuitive for scrolling up and down. The effort for scrolling up and down can be lowered with a better accuracy during performance, which could be achieved if the pressure thresholds for the different speeds are adjusted. The experiment has also shown the need for a better calibration. While the activation gesture was rated as most physically demanding, it was rated with the best performance and was not involuntarily triggered compared to the deactivation gesture. The deactivation gesture and the scroll down gesture share some of the same sensor activity which lead to multiple unintentional slice number changes right before the deactivation. Because the system delivers satisfying performance for scrolling up and down a solution could be to trigger the activation and deactivation with other sensors like a gyroscope, a voice command or the by simply using the left foot for activation/deactivation and the right foot for scrolling. Nevertheless, although the used shoe insole was not designed for this task, it managed to perform well and users got quickly accustomed to its usage for medical image manipultion.

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