A Wearable Hardware Platform for Capturing Expert's Experience

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ABSTRACT

In this article, we propose a mapping of methods (that facilitate the transfer of experience from expert to trainee) to low-level functions such as gaze, voice, video, body posture, hand gestures, bio-signals, fatigue levels, and location of the user in the environment. This mapping is used to decompose the low-level functions to their associated sensors. After reviewing the requirements, a set of sensors is proposed for the experience-capturing platform. Based on this, a first version of hardware platform is designed and implemented. Our proposed platform is modular and can be adapted to different sensors from different vendors as technology progresses. Furthermore, we discuss key challenges and future directions associated with the hardware platform. This work was done as part of an EU project called WEKIT.

Keywords: sensors, experience capturing, augmented reality, AR, WEKIT, WT

Index Terms: WT, AR, WEKIT

1 INTRODUCTION

For the daily smooth operations of an organization, experienced workers are vital at every level. By sharing their knowledge, experience, expertise of procedures, and best practices with colleagues, trainees, managers and bosses, they build, maintain, and support the different functions of an organization. Industries are fully aware of that and are trying new ways to capture, support, and preserve, the experience of an expert [1].

One of the key challenges faced by the industry is keeping the workers up to date in terms of their skill set. With this in mind, WEKIT is a European research and innovation project supported under Horizon 2020 to develop and test within three years a novel way of industrial training enabled by smart Wearable Technology (WT).

The WEKIT industrial learning methodology comprises of capturing experience of an expert, and re-enacting the experience for training novices [2], with the former being the focus of this article.

In a recent study by [3], using the principles of 4C/ID model [4] for hands on industrial training an extensive review was performed, and the authors proposed instructional methods in the form of components that facilitate the transfer of experience from an expert to a novice.

2 METHODOLOGY

In this section, first, we will discuss the mapping of transfer mechanisms; second, we outline sensor recommendations, and finally we discuss the proposed hardware platform prototype.

2.1 Mapping Transfer Mechanisms

The authors [3], define instructional methods as transfer mechanisms i.e., methods that facilitate the transfer of knowledge. The transfer mechanisms include: remote symmetrical tele-assistance, virtual/tangible manipulation, haptic hints, virtual post its, mobile control, in situ real time feedback, case identification, directed focus, self-awareness of physical state, contextualisation, object enrichment, think aloud protocol, zoom, and slow motion. In this section, we decompose the different transfer mechanisms to low-level functions and their associated state-of-the-art sensors [5].

1. Remote symmetrical tele-assistance

   Description: View and capture the activity of another person from their perspective transmit video & audio.

   Sensors: smart/AR glasses.

   Key products: Moverio BT-200/2000, Microsoft Hololens, Sony SmartEyeglass, Google Glass, Meta 2, Vuzix M-100, Optinvent Ora-1, ODG R7.

2. Virtual/ tangible manipulation

   Description: Hand movement tracker, accelerometer, gyroscope.

   Sensors: Depth camera, smart armband.

   Key products: Myo Gesture control armband, Leap Motion controller.

3. Haptic hints

   Description: Vibrations on arm or fingers.

   Sensors: Vibrotactile bracelets and rings.

Key products: Myo, magic ring.

4. Virtual post its, contextualisation, in situ real-time feedback,

   Description: Object tracking in environment.

   Sensors: Smart glasses, Tablet Computer or Mobile Phone.

   Key products: several.

5. Mobile control,

   Description: control dials and other user interface elements.

   Sensors: hand gesture, controller.

   Key products: Myo, Leap motion.

6. Case identification

   Description: Link with existing cases, link with error knowledge.

   Sensors: case based reasoning component.

   Key products: no specific sensor.

7. Directed focus

   Description: Direct focus of user.

   Sensors: Gaze direction / object recognition, EEG (attention/focus/mental effort),

   Key products: Smart Glasses (or gyroscope only), MyndPlay MyndBand, Interaxon Muse EEG, Neurosky Mindwave, Emotiv EEG.

8. Self-awareness of physical state

   Description: Fatigue level, vigilance level, Biodata (e.g., steps, sleep, heart rate,), body posture: ergonomics (e.g. lean back, forward).

   Sensors: EEG, smart watch, posture tracker.

   Key products: MyndPlay MyndBand, Neurosky Mindwave, Emotiv EEG, Fitbit, apple watch, LeapMotion, Myo, Lumo Lyft, Alex posture.

9. Think aloud protocol

   Description: Capture voice of the user.

   Sensors: Microphone.

   Key products: Cochlea Wireless Mini Microphone, built-in microphone of Camera/Smart Glasses, Wireless Microphones (e.g. from AKG).

10. Zoom

    Description: zoom in and get details.

    Sensors: Smart glasses / tablet with high-resolution camera.

    Key products: Several.

11. Slow motion

    Description: Allow replay at slower speed.

    Sensors: High frame rate camera (high frame rate often comes at price of resolution with smart glasses; and vice versa).

    Key products: Several.

The mapping from transfer mechanisms to sensors is not injective. For instance, a transfer functions such as remote symmetrical tele-assistance requires both audio and video information, for which we need more than one sensor. On the other hand, some smart glasses (such as Microsoft Hololens) are equipped with a number of integrated sensors, which enables it to capture various transfer mechanisms. Some transfer mechanisms (e.g., virtual post its, contextualisation, in situ real-time feedback) need highly processed information provided by subroutines or software libraries of an API. Some transfer mechanisms (such as zoom and slow motion) are computationally expensive and can be impractical based on the current state-of-the art of wearable devices.

2.2 Sensor recommendations

In this section, we will discuss recommendations on sensor choice that are used in the development of the first hardware platform and discuss the associated issues.

In order to design and develop the first version of the hardware prototype, we focus on the most important transfer mechanisms defined in the studies [2, 3].

Taking into consideration features such as built-in microphone array, environment capture, gesture tracking, mixed reality capture, Wi-Fi 802.11ac, and fully untethered holographic computing, Microsoft Hololens [6] was selected for the role of AR / Smart glasses. Furthermore, the built in components of Hololens enable us to capture several different attributes of the user and her environment. For EEG, the MyndBand [7] and Neurosky chipset were favoured due to the availability of the processed data and real time feedback. For detecting hand, arm movements and gestures: Leap Motion [8] and Myo armband [9] were chosen. To track the position and angle of the neck, Alex posture tracker [10] was suggested.

2.2.1 Data from sensors

In this section, we analyze the different types of data and interpreted signal available from the selected sensors. As shown in Table 1, by using the API associated with Microsoft Hololens, we get processed data in the form of spatial data, orientation, and gaze, and interpreted data in the form of gestures, but, raw data is not accessible. We can get raw data for Leap motion, Myo, and the Myndband, this was important in allowing us to manage the visualisations, record the data for post processing and help us discover potentially new interpreted markers or algorithms relating to experience capture. Also, different sensors require different bandwidths. It is particularly high for video signals (associated with AR glasses), moderate for Leap motion and audio signals (microphone of AR glasses) and low for Myo, Myndband, and Alex posture tracker.

Table 1: Sensors and their raw/processed/interpreted Data,

Sensor	**Data**		
	Raw	**Processed**	**Interpreted**
Microsoft HoloLens	Not accessible via official API	Spatial data, Orientation, Gaze	Gesture
Leap Motion	Raw sensor images	Hand model data	-
Myo	Raw EMG data available	Orientation and acceleration	Detected pose
MyndPlay MyndBand	512Hz Raw	Bandwidth spectrum 0.5Hz - 100Hz. Delta - Mid Gamme	Attention, meditation, zone, mental effort, familiarity
Alex posture tracker	Raw accelerometer and gyroscope	Unconfirmed from Vendor	Head, Neck and Shoulder posture

2.3 Proposed Hardware Platform

The proposed hardware platform (as shown in Figure 1) consists of three components: smart glasses, external sensors, and sensor processing unit, with the last two being housed in a WEKIT Vest. In addition to AR display, the smart glasses can comprise of other sensors or features such as microphone, gesture tracking, and voice command, gaze tracking. The external sensors comprise of components that are not part of the existing AR glasses, for instance, EEG, posture tracking, and hand tracking. As most AR glasses have limited computational power, the sensor-processing unit acts as a processor for collecting, syncing and streaming the data from all the different sensors. The number of sensors can be decreased or increased based on the requirements of the industrial training scenario. Hardware components can use different communication standards such as: WiFi and Bluetooth. The proposed architecture is quite flexible and allows for communication protocols such as Apache Thrift [11], TCP/IP, UDP.

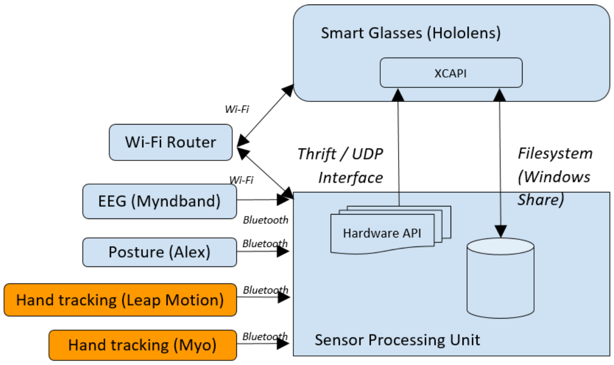

Figure 1: Proposed hardware architecture

Figure 2: Hardware platform first iteration

Based on the proposed hardware architecture, during the first iteration we arrived at a hardware platform design as shown in Figure 2. We can see that the sensors such as: EEG, Alex, SPU, and power bank are mounted on the smart/AR glasses (HoloLens). This hardware solution proved heavy and impractical and was replaced during the second iteration (as shown on Figure 3). In the second iteration, the wearable platform comprised of a vest that housed the external sensors, SPU, and power bank. This solution is adaptable to different sensors from different vendors and can include more sensors over time.

The WEKIT Vest was proposed in response to the aforementioned weight and support issues in the first prototype, but was also addressing another fitting issue uncovered in the early trials, which indicated the best placement for the Leap Motion was around the torso. The Vest allowed for adjustable placement of the Leap Motions and other sensors using Velcro attachments and was easily fitted and transferred between users.

A key benefit of the simple and modular design of the vest is that new sensors and technologies can be easily added or removed as new requirements arise.

Figure 3: Hardware platform second iteration

3 DISCUSSION

In this section, we elaborate on the different challenges faced during the development of the hardware platform.

It was observed that the Leap Motion hand sensor could not accurately capture hand movements at a distance; hence, for activities such as reaching out and moving something at a distance, the device would not work. It was concluded that detailed hand movements should be recorded separately, i.e., after an action is performed, by mimicking the movements near the sensor. The resultant “virtual hands” would then be placed in the required place over dials or levers in the video stream during subsequent session editing.

Adjustability of the sensor placement is important factor as some sensors and accessories are body worn, and dependent on the activity. It may not be appropriate to have them placed in certain positions, for example if having to lean over machinery, protruding items on the front of the body may get caught on something. To this end, a body vest was designed to have items clipped on all around, and came with movable pockets and panels of different sizes, such that, we were able to place an external battery pack on the back, and as necessary move the Leap Motion on the front of the body, or the side, and adjust it for different body shapes.

During testing of the hardware at an industrial evaluation site, it was observed that some wireless devices were more susceptible to electrical interference than others. This was narrowed down to older versions of Bluetooth that had more difficulty maintaining connections in noisy environments compared to modern versions. This has been a factor in subsequent sensor choices whether by preferring wired sensors, or by using Bluetooth 4 if available.

When integrating the software that would run on HoloLens and the Sensor Processing Unit, limitations on the available APIs and processing power were quickly reached. It was concluded that for providing data to the Hololens, a protocol should be chosen that is simple such that it does not put much computational load on the system, and can handle dropping packets without retry so can behave gracefully on a heavily loaded system. Initial designs used Apache Thrift, and then pure TCP, but UDP was settled on as it met all the above restrictions.

Secure and usable sensor placement was an important factor. Considerations that had to be made included ease of adjustment for various body shapes, ergonomics, health and safety, and robustness.

In future, first, we will perform evaluation of completed prototype for industrial case scenarios developed in the WEKIT project and analyse the data collected from the trials. Second, we will try to use the AR/smart glasses and external sensors from different vendors to make the platform open. Finally, on location trials will be performed to further classify and resolve potential environmental factors or interference, which can affect performance of the overall system and the user experience.

4 CONCLUSION

In this paper, we propose a mapping of high-level methods (that facilitate the transfer of experience from expert to trainee) to low-level functions such as gaze, voice, video, body posture, hand gestures, bio-signals, fatigue levels, and location of the user in the environment. This mapping serves as the basis for decomposing the low-level functions to their associated sensors. After reviewing the requirements, a set of sensors are proposed for the experience-capturing platform. Based on this, a first version of hardware platform is designed and implemented. Furthermore, we discuss key challenges and future directions associated with the hardware platform.

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