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Sensor Technology, Gamification, Haptic Interfaces in an Assistive Wearable

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Abstract

In this paper, we introduce the solution proposed by the SUITCEYES project in the form of a haptic intelligent personalized interface (HIPI) that integrates elements from the areas of smart textiles, sensors, semantic technologies, image processing, face and object recognition, machine learning, affective computing, and gamification. We report on recent developments in the project, which include experiments with sensors for detection of obstacles, psychophysical experiments with temperatures and vibrations, development of a number of high performing algorithms for object recognition, and also the design, development, and experimentation with a smart-textile based garment that allows flexible positioning of sensors and actuators.

Keywords

Deafblindness, haptic interfaces, assistive wearable, sensor technologies, gamification, machine learning

Introduction

With the convergence of technologies such as sensors and signal processing; machine learning; data and image processing; smart and haptic interfaces; as well as the escalating implementation of Internet Protocol version 6 (IPv6), and the expansion of the Internet of Things (IoT), new modes of connectivity and communication have emerged and practical applications of IoT technologies have become increasingly feasible. These rapidly emerging modes of communication and information sharing have the potential to solve long standing challenges for those who typically have faced barriers to free communications whether due to circumstance (e.g. a firefighter in heavily smoke filled enclosures), or sensory, or functional impairments (e.g. a person with diminished sight and hearing senses). Adequate communication solutions remain minimal and new intelligent, multimodal, personalized communication interfaces are needed to meet their needs.

Useful information and communication technologies (ICT) are continuously developed improving the quality of life for many people. Among those whose communication abilities are severely restricted are people with deafblindness. While there are many ICT solutions developed to facilitate communication for persons with deafness or blindness, there are very limited tools and facilities developed for persons with deafblindness. While many people with deafblindness retain a small degree of their hearing and/or visual capacity, deafblindness is a unique condition where the impairments in the combined vision and hearing is of “such severity that it is hard for the impaired senses to compensate for each other.” Limited communication is a major problem for this group. Accordingly, the solutions developed for either blindness or deafness are not adequate to meet the needs of this group. Although congenital deafblindness is relatively rare, deafblindness can be acquired due to causes such as illness, accident or age. The current number of people with deafblindness in the EU countries is likely to rise considerably in the coming years due to the aging population.

In the three-year long (2018-2020) EU funded project SUITCEYES (Smart, User-friendly, Interactive, Tactual, Cognition-Enhancer that Yields Extended Sensosphere), we propose a new, intelligent, flexible and expandable mode of haptic communication via soft interfaces (Olson et al.). The ambition is to combine and develop cutting-edge technologies that would improve the communicative lives of those with deafblindness, enabling them to become active members of the society. Based on user needs and informed by disability studies, our proposed solution brings together smart textiles, psychophysics, sensors, semantic technologies, image processing, face and object recognition, machine learning, and gamification. It addresses three challenges: perception of the environment; communication and exchange of semantic content; learning and joyful life experiences. SUITCEYES extracts and maps the inner structure of high-dimensional, environmental and linguistic clues to low-dimensional spaces, which then translate into haptic signals. It also utilizes image processing, mapping environmental data to be used for enriched semantic reasoning. SUITCEYES' intelligent haptic interface will help the users to learn activation patterns by a new medium. With this interface, users will be able to take more active part in society, improving possibilities for inclusion in social life and employment.

The solution is being developed in a user-centred iterative design process, with frequent evaluations and optimizations. The proposed solution takes into account and will adapt to potential differences in levels of impairments and user capabilities.

Currently the most common mode of communication for people with deafblindness is the use of sign language conveyed with hand gestures, requiring close physical contact and commonly touch of hands with human interpreters. In SUITCEYES sensors, signal and image processing, as well as object and face recognition are used to capture environmental clues that can then be conveyed to the person with deafblindness via haptic signals through soft smart-textile-based interfaces. Machine learning, semantics and ontologies extend the linguistic capabilities and the user's haptic vocabulary, while at the same time facilitating communication that would no longer rely on close physical contact with an interpreter or care-provider. Here, haptic signals are triggered on appropriate parts of the body customised to the sensitivities of individual users. For improved training in the use of this technology, pedagogical gamification-based learning will engage and facilitate the learning process in a fun and user-centred fashion.

The proposed solution will free the hands of the user for other tasks, it will enable communication from a distance, and it will allow detection and conveyance of important information by other means (e.g. through signal and image processing) than the need for a constantly present human interpreter. The proposed solution, however, is not meant as a replacement for interpreters or human contact; it is rather envisioned as a complement to other modes of communication.

The components of the project include a user situated in an environment that is enhanced by sensors and other IoT components which could allow numerous forms of interactions such as:

i. Simple proximity trigger: components can communicate their location ID to the prototype. This allows recognition of objects and people when they come into close vicinity to the user.

ii. Automatic proximity trigger: various services can be triggered automatically when two things come into proximity with each other. For instance, when the user approaches home, the prototype can act as a key communicating with door-lock and open the door.

iii. Simple and direct user feedback: components can also supply feedback in order to reassure the user that a certain trigger has been activated.

iv. Automatic sensor triggering: the various smart components surrounding the user can communicate with each other and thereby elicit and aggregate information concerning physical structures, visual elements, surrounding signs and sounds.

v. Personalised user feedback: the feedback can be personalised in order to retrieve specific kinds of information that matches the needs of the individual user.

A range of potential feedback modalities are explored including vibration, pressure and temperature, as well as various ways in which these can be combined or positioned to provide different signals. Likewise, a variety of sensors are explored to provide information about the environment: distance sensors to detect proximity of obstacles, a camera feed to allow recognition of objects or people, indoor positioning systems to help locate objects, or radio frequency identification to identify when the objects come near. A processing unit is being used to interpret sensor input against a knowledge base and determine appropriate feedback. Smart textiles are used to accommodate sensors, feedback units and the processing unit on different parts of the body, either mounted on the textiles, or built into them, as appropriate. Moreover, gamification is the integration of video game elements into non-game services and applications, to improve the user experience, engagement and performance (Deterding et al. 2426).

Discussion

User-Studies

Deafblindness which can be congenital or acquired, and complete or partial, presents research with an enormously broad spectrum of possible user needs, whose common denominator must be selected carefully. Extensive user studies are, therefore, an integral part of the project where currently more than 70 interviews have been conducted with just a few more in coming days. Most of the transcriptions have been done, and ongoing analysis indicates the importance of solutions that help the users to get out and about, taking an active part in life and work and contributing to the society. Furthermore, there is an expressed need for potential solutions that will facilitate engaging in reciprocal and equal social relationships with friends, family and acquaintances. Study participants have indicated a need for affordable devices that are robust and cannot easily be broken, stolen or misplaced. They have also indicate the need for a neutral appearance that is not strange looking and which would attract unwelcomed attention. Based on these and continued user studies, the project will shortly define "Personas, environments and use scenarios" that will inform design and development decisions in other subsections of the project.

Capturing, translating and semantically representing environmental cues

After initial discussions with the Project’s Advisory Board, and a number of potential users, it was decided to address three specific but related research tracks: situational awareness, navigation, and communication.

Selecting and ontologically interpreting specific visual cues (for the sake of navigation) can be treated in the same way as picking significant concepts from a vocabulary to transmit between any two users for communication. Here, the single major difference between navigation and communication is that for the latter, sequences of such cues must be encoded for and decoded after transmission. Therefore, we envisage both research areas as addressable by the same entwined strategy, identifying visual vs. verbal signs, and relating their content to a knowledge graph to secure a standard semantics for both tracks. This part of the project consists of three tasks, the interplay of which is illustrated in Figure 1.

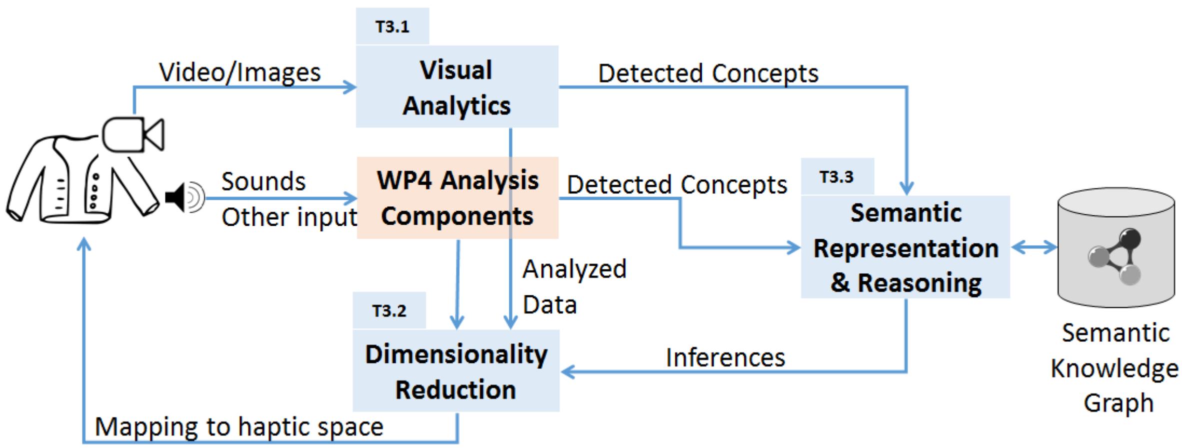

Fig. 1. Schematic overview of the interrelationships between tasks.

Visual input from the camera mounted on the smart garment, called the HIPI (Haptic Intelligent Personal Interface), is fed to the visual analytics component which extracts the detected concepts (objects, faces, activities etc.). The latter are fed to the semantic representation and reasoning component, which is coupled with a semantic knowledge graph (also called an "ontology"), semantically aggregating the multimodal information from the analyses and inferring higher-level derivations. Various outputs and signals are submitted to the dimensionality reduction component, which will map the respective information to the haptic space.

With dimensionality reduction playing a key role both for visual analytics, and semantic knowledge representation and reasoning, we have postulated that concept embeddings, constituting geometric or topological vocabularies to encode visual vs. verbal percepts, are a suitable approach in globally ongoing current research in several fields to be tested for

SUITCEYES' purposes. This implies that in parallel with collected user needs, we can depart from visually recognized concepts represented as embeddings, and use them as a test vocabulary for simple interaction between two users with deafblindness (i.e. communication). Such a vocabulary will be scalable and can be tailored to individual needs while offering a robust overlap between perceived and communicated semantic content by haptic means.

What is presented above is a very short outline of the current research which is conducted within the SUITCEYE project. In addition to the above, much work has been conducted on development of distant sensors array and algorithms, psychophysics experiments, and creation of a garment that allows flexible attachment of various components as and where needed. Many interesting results are emerging in all of the subsections of the project. These will be reported on in more details shortly.

Conclusions

In this paper we have just touched upon a few of the elements included in the SUITCEYES project. Although too early to write detailed accounts of all the findings so far in this paper, we have taken the opportunity to provide an introduction to the work conducted in the project. With almost two years remaining, we expect significant results to emerge in the continuation of our work.

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