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SENSORIAL EXPERIENCE EXTENSIONS IN LEARNING ENVIRONMENTS

Fernando Luís-Ferreira
CTS, UNINOVA, Dep.º de Eng.ª Electrotécnica,
Faculdade de Ciências e Tecnologia, FCT,
Universidade Nova de Lisboa
2829-516 Caparica, Portugal

João Sarraipa
CTS, UNINOVA, Dep.º de Eng.ª Electrotécnica,
Faculdade de Ciências e Tecnologia, FCT,
Universidade Nova de Lisboa
2829-516 Caparica, Portugal

Gary McManus
Telecommunications Software & Systems Group,
Waterford Institute of Technology,
Waterford, Ireland

ABSTRACT
Emerging technologies are providing a wide range of benefits for people in their different activities. That fact ranges from daily life activities, to business, teaching or simply for recreation. In what concerns to people with special needs there is a wide range of devices and applications that can be of use in addressing those needs and the will to progress in life. Observing in perspective, the support provided by technology can be seen as augmenting our sensorial experience by providing additional information as in the case of virtual reality and augmented reality. The devices provide additional information for what people sense, adding information and enlarging the sensorial experience while mounting additional information. This paper describes a strategy to extend, thru common use technology, the awareness of people with limited sensorial experience, aligning with other emergent technologies widely applicable to different situations while keeping a focus on teaching environments. That includes sensory devices like the Leap Motion device and 3D printed materials, which combined provide new opportunities for blind people to sense and retrieve new information

KEYWORDS
Sensorial Experience, Learning.

INTRODUCTION
The existing technological innovations are widespread in diverse types of devices including the ubiquitous smartphone or any other wearable or portable devices. Computation is everywhere, supported by a wide range of sensors that provide contextual information (e.g. location, acceleration, lighting). All those devices and associated functionalities can be used to address multiple needs in daily life and provide support for work and amusement. Considering the sensors and its associated applications, by retrieving information from the surrounding world they become useful to extend the sensorial experience of people. The combined usage of those sensors with other emergent technological sensing and printing devices, as is the case of eye-trackers and 3D printers, provide additional information that can be useful to those sensorial extensions. Thus, the strategy of the present framework is to encapsulate diverse functionalities that, once adopted, can provide a setup for the improvement of the learning environment. Such strategy will be explained in the next sections in which the authors are proposing a methodology to improve teaching experience and promoting inclusion among students with limited sensorial experience. The first section presents the sensorial experience providing the importance of each sense to the learning process and how it can be improved by using technology that is currently available. Next it is presented a Framework that aims to support different dimensions of sensorial extensions. This Framework is designed with a particular focus on students with diverse disabilities. The section after this conceptual Framework makes an instantiation to a real demonstrator with a Leap Motion Sensor (MLS) and a 3D printed mockup. Finally, some conclusions are drawn along with the presentation of paths to future work.

SENSORIAL EXPERIENCE AND EXTENSIONS

Vision

The importance of vision in the learning process assumes a particular relevance, as humans use eyes as a primary sense to acquire information about the surrounding world usually aligned with motor functions [1]. Most of the artifacts and devices depend on our visual acuity to be handled and the perception of the environment thru the eyes conditions our activities, from reading to driving and walking all depends greatly on the effectiveness of the sense of vision. It is possible to execute some of those tasks without using the capabilities of the eyes but that becomes a very difficult operation. In what concerns to the process of acquiring information, about remote or fictional objects persons or situations, vision is used as sensorial input thru the usage of local devices (e.g. computer, TV, projector). In most of the cases vision is used to acquire codified information, in text or other high-level messages that will be interpreted by the brain. In what regards to the importance of vision to the learning environment, it is know that most of the input in classes, either local or remote, is based on seeing objects pictures and text. The usage of different materials, different shapes and colors can become a valuable asset to promote motivation and the engagement of students in the on-going teaching activities. These days most of business and scholar presentation are made of slides and demonstrations that assume particular importance to demonstrate the subjects being taught in a faster and sometimes schematic way. It is also of relevance to know that vision allows fast mobility either indoors or outdoors allowing more rapid and efficient mobility thus allowing more time for learning activities. In the case of those with partial or total blindness and those with amblyopia that can have access to geometrical experience by using 3D printing. The widest spread usage for 3D printing is the design and printing of shapes for amusement, for parts replacement or for creating new devices and shapes. This paper departs from the study of new learning technics to the adoption of 3D printing to give students the access to 3D shapes that otherwise could only be orally described and for that would depend mostly on imagination. The inclusion of 3D parts definition in otherwise textual documents can be of use in diverse situations to support the information transmission to students and people in general that have limited or inexistent visual experience.

Eye-tracking is a process that consists in measuring either the point of gaze ("where we are looking") or the motion of an eye relative to the head. An eye tracker is a setup or an integrated device that measures eye positions and eye movement. A wide variety of disciplines use eye-tracking techniques, including cognitive science, psychology, human-computer interaction, marketing research, and medical research [2]. Specific applications include tracking eye movement in language reading, music reading, human activity recognition, the impact of advertising, and assisting people with disabilities [3]. Eye-tracking systems are useful in helping researchers analyze usability designs or human psychology from gaze information as presented [4].

Hearing

Audition is fundamental for students as the teaching process usually assumes the form of a teacher talking to a class. The message provides information about the subjects to be taught but also promotes the social interaction between the teacher and the student. In the learning process, audition gives contents and form. It means that a student listens, not only the message, but also the way it is pronounced. This is particularly important in highlighting the importance of the contents and will be of more importance in learning language instead of mathematics or geometry where the contents are not subjective. Pronunciation will be an added content but also the emphatic expression of the teacher can change the relevance of the matters being explained. In this case we can consider the rhythm of the speech or the emotional aspects in the tone of the speaker and the pauses and advances. Another relevant aspect of audition is the access to the contents of other learning materials. Students can ear songs of other languages to help understanding the contents and have other opportunities to memorize words. Videos and computer-generated presentations can benefit from sound and music to enhance the contents and to increase the information being transmitted. Beyond that supportive role, music is also a way of knowing [5]. Music has a fundamental importance as for Harvard psychologist Howard Gardner, music intelligence is equal in importance to logical-mathematical intelligence, linguistic intelligence, spatial intelligence, bodily kinesthetic intelligence, interpersonal intelligence, and intrapersonal intelligence [6].

Lately there is another function that can be adopted in the audio interaction between human and computers and that is the input of instructions from voice commands or text dictation. In that case mouse and typing can become overridden by the voice transmission of text to computer and the alteration of computational devices (e.g. laptops, smartphones, car computers) by audible commands.

In overall advances in technology, in particular in voice recognition and natural language processing as raised audio to become a bidirectional form of interaction between humans and computational systems, which can be exploited for effectiveness, comfort and to overcome physical limitations.

Speech can be used as an input for human computer interfacing, as there are diverse software and operating systems able to recognize and convert speech to text. Those provide means of transducing a human feature, the voice, into computer signals that can be used as text or commands. In using such features, it is possible to use voice commands, either in work or learning environment, and to activate menus and commands that are usually typed on a keyboard and mouse. Automatic speech recognition provides the potential to make teaching accessible to all [7]. Speech recognizing programs provide configurable means to improve the conditions in which a voice of a user is perceived and converted to text or commands. Even if the tendency today is for natural language processing (NLP), that performance is not so relevant when the goal is to enter

commands or select options. In that case the need is for the instructions to be correctly translated for the computer and that can be improved by training the above-mentioned programs. In previous tests, standard speech recognition features that come with operating systems has proven to be sufficient efficient for the proposed goals.

Eye tracking is a technology that has been used for applications like the evaluation of websites, measurements of fatigue and emotional states, among other applications.

In general there are 4 classes of measurement to be made in eye-tracking evaluation [8]:

Movement measures – which are concerned with a whole variety of eye-movements through space, and the properties of these movements.

Position measures – which deal only with where a participant has or has not been looking, and the properties of the eye-movements at spatial locations.

Latency measures – which pertain to the number, proportion, or rate of any countable eye-movement event.

Numerosity measures – express the duration from the onset of one event to the onset of a second event. Measures of this type also appear in the form of spatial distances.

In the case that eye-tracker aims at moving the cursor to go to a point either for selecting or drafting, it is necessary to determine Position. Case it is aimed to select a point or an object, then Latency will be the most important measurement as, in accordance to typical use of the right key, will confirm an object or a set of objects, an option or a command to be executed. The objective to enable the movement of the eye to a certain point that will establish a start point to draw (e.g. of an arc or a like) and stopping the eyes for a limited time (e.g. 1~2 seconds) to confirm with such latency that this is the selected point to start the drawing. Then moving to another position, one can establish another parameter (e.g. the final point) or another input needed, just by stopping the gaze over such point. To notice also that some snap points function as attractors that will help on the design process and are already features of the AutoCAD software that will be a helpful contribution.

Pupil Dilation

The eyes function as a sensor with optical organic components with the aim of capturing information from the surrounding environment. The visual range is limited and thus directed to the objects that mostly capture our attention. The eyes direct our visual campus to what we want to see and our pupil adjusts to better focus what captures the attention of our brain and it movement depends on what is supposed to be observed in a given moment in that actual scene. The pupil is the opening through which light enters the eye and begins the process of visual perception. The diameter of that opening is determined by the relative [9] reaction of two opposing sets of muscles within the iris, the sphincter and dilator pupillae, and is determined primarily by the light and accommodation reflexes [10]. But in addition to reflexive control of the pupillary size there are also tiny, cognitively related, visually insignificant fluctuations in pupillary diameter that appear to serve no functional purpose whatsoever. These miniature pupillary movements, usually less than 0.5 mm in extent, appear to be attenuated reflections of changes in brain activation systems that underlie human cognition. These small but ubiquitous pupillary fluctuations form the basis of cognitive pupillometry, providing a unique psychophysiological index of dynamic brain activity in human cognition [11].

Touch

The importance of touch is such that it becomes present in almost every activity a person executes in a day. From the basic needs of eating and drinking most of the tasks executed need the sense of touch. Typing in any kind of machine or tapping a screen or even grabbing a pen or a pencil all request touch abilities.

Touch has a relevance that varies from the skills to be taught assuming a special relevance, in particular while teaching for arts, manufacture, handcrafts or other handwork skills. Children get a different experience when they touch the objects rather than only speak about or watch images of such items. When touching and modeling, as in the case of plasticine or other moulding material, the connections with the subjects get stronger and the matters are less likely to be forgotten. Activities involving movement and touch benefit creativity and promote diverse types of skills that activate different parts of the brain.

The interaction with computers comprises diverse types of input and output devices. Even with new technologies, input is done mostly with mouse and keyboard type devices. Those transmit our thoughts and ideas to the electronic format that will be handled electronically from the click of the keys or the mouse wheel and light sensors. In fact, touch is not being used as a resource because when a person touches a keyboard he doesn't receive input from that other than the confirmation of stroking a key or the handling of a mouse not really getting roughness or geometry. But on the other side, touch as an output only recently has gained some importance with 3D printers. Considering that information is mostly transmitted using vision and sometimes hearing, there is a new range of opportunities by using the sense of touch in printing diverse geometries that become accessible to visually impaired students and workers.

The Proposed Framework

Using all the presented technology it is possible to build a learning environment that will promote the usage of those technologies for the benefit of the teaching environment. The key to this goal is to make a system that learns with teacher's choices and previous recorded sections in order to generate the most appropriate contents for the identified teaching situation.

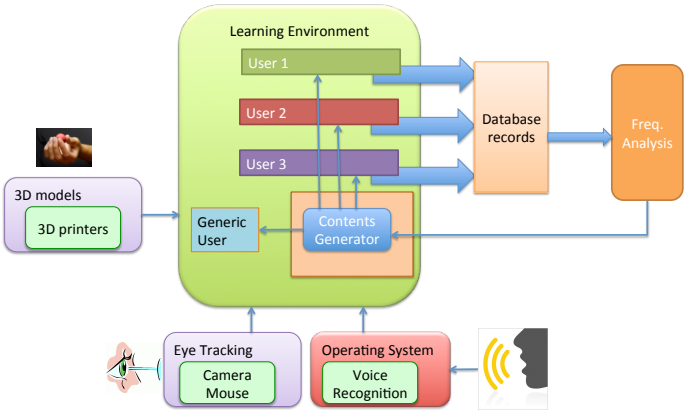

Figure 1 – Proposed Architecture for sensorial extension

The proposed architecture (Figure 1) established individual profiles for each user based on that user needs and the information to be transmitted. Database records will have the information accumulated from previous sessions and will be permanently growing in the teaching environment. That repository will suggest to the teacher (and to the learner in eLearning or self-guided learning) the best solutions in terms of contents that in fact benefit from previous choices and presented solutions. The system is adaptable to the current teaching situation and will promote the best usage of the existing technology to the current environment. With this in mind, the sensorial experience will benefit all students with a special benefit for those with any kind of sensorial disability.

The proposed approach has multiple applications like those mentioned in the next sections. But some application examples will highlight its usage and benefit in multiple ways. For instance, if a student is using a program and the sequence of instructions is recorded, the frequency analysis of such usage instructions will generate a personalized menu with the instructions most likely be used after another instruction. Thus, the system will provide that such instructions will become more accessible to another student that engages the same sequence of procedures. Example of this is, for instance, the case of drafting operations with a CAD software. 2D drafting commands tend to be followed by other 2D instructions while 3D operations will, most likely, be followed by 3D instructions. Such example is the simplest execution of a feedback loop that can be highly improved with proper algorithms that would manage more complex examples. The analysis of all cases will feed a generic user that would be provided with the most generic sequence of commands. Other users that match one of the identified profiles would be provided with an adjusted screen menu with a narrowed selection of the commands that most likely will be needed. This will be of great support for people with limited mobility that, this way, would have most benefit in accessing the commands that will most likely be needed next. Finally, the 3D printing will be suggested for support of the most adequate cases. The profile analysis will permit the utilization of different models for the needs of specific users. A database of 3D models can be used for different users according to their needs. Frequency analysis benefit both the manager of the system, usually the teacher or the training manager, and will benefit the student with the most suitable models for a given task or a learning process that fits a User profile.

In the case of people with accurate vision, the eye-tracking setup will be able to provide the right contents by monitoring the sequence of gaze movement for a given profile. Such analysis from the framework engine would anticipate and prepare the most needed contents

Inclusion of 3D models in documents

Documents have textual and graphic contents and are meant to be visualized and printed at two dimensions. Within the scope of the present work, in the framework of ACACIA project, it is aimed to help disabled people to have improved accessibility to documents according to their limitations. A first approach to such objectives would be to include 3D models that could be printed and thus illustrate the contents with palpable objects. Those models constitute an additional information to text and graphics, not a replacement of any existing information. That way, didactic materials continue to have value to students without vision problems and also to those students with special needs. Nevertheless, the additional models provide helpful additional information to both mentioned groups. At this point it is considered the inclusion of STL files at common PDF files. STL files stand for Standard Tessellation Language and is the most used language for 3D modelling. Computer Aided Design (CAD) programs export 3D models to STL without much problem and are used widely. Other 3D modelling formats have different characteristics, to name the most important; OBJ from Wavefront Technologies (now part of Autodesk), PLY (Polygon File Format) from Stanford University, mostly used for 3D scan files and 3MF from the 3MF[1] Consortium. Those instructions are the translated to G-code which is the language that adapts the 3D model to the specificities of the current 3D printer.

Online libraries can be found for different types of objects and some present architectural well-known objects or even art objects including famous sculptures as in the Digital Michelangelo Project [9]. The process of attaching an STL file (or other) to a pdf in quite simple and is worth for the expected results. The operation consists in selecting the TOOLS button in Acrobat Reader and then ATTACH FILE. The STL file can then be selected to be annexed to the PDF. On the other hand, it is also possible to record sound that describes the scene, becoming that record also attached to the file.

Viewing 3D models, and also zooming and rotating, becomes a direct operation on Mac environments as they can be visualized with Preview, as in Figure 2. As for the Windows systems, free STL viewers are available to download and install [2].

[1] http://3mf.io/
[2] http://www.open3mod.com/stl_viewer.htm

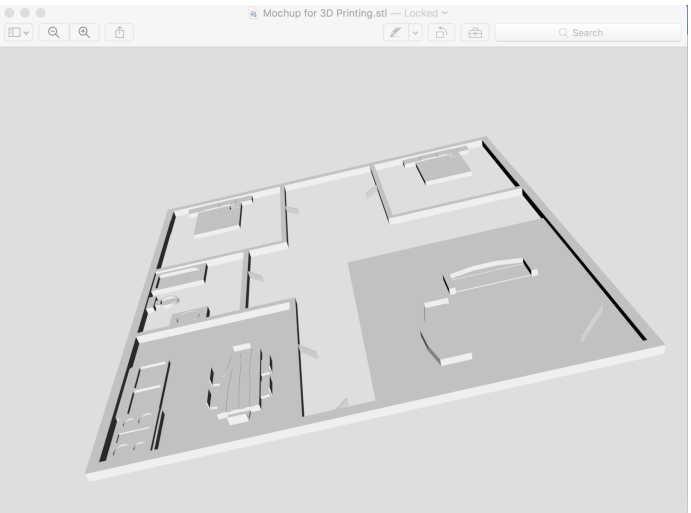

Figure 2 - STL model of a 3D mockup visualized with Preview

Models can be visualized by students with clear vision and can be 3D printed, for them to perceive the geometry, or it can be used for touch exploration tin the case of those without an option to visually explore the geometry.

Instantiation of the Framework using LMS and 3D printing

The goal of the pilot experience is to instantiate the proposed framework so that a blind person becomes able to analyse a 3D model with hands, while the system provides audible information about the part being pointed at such object. The identification of the movements is made with a Leap Motion Sensor (LMS), as in Figure 3. The main reason is that, the device goes beyond a camera that captures image, it has two cameras and infrared lights which are components of a hardware setup oriented for hand movement identification.

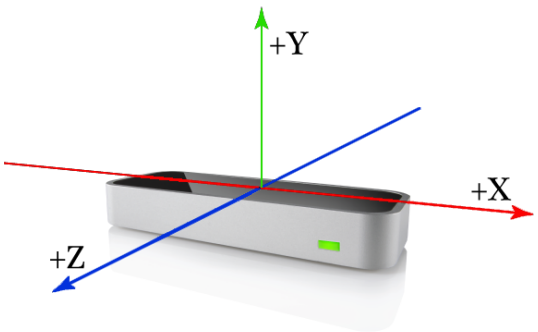

Figure 3 - Positioning system for the LMS

The presented axial system has an origin at the device's centre, with the measurements being made in millimetres from that origin, taking the user as in front of the device. In the proposed setup, the plan was inverted and the camera operates top-bottom so that user hands can wander over a 3D printed item while the LMS keeps track of hand and fingers. The result is that retrieving the position, which can be achieved with about 7,8% error rate (against 2,8% of a standard mouse) [12] it is possible to determine the coordinates of a selected finger. As can be seen next in Figure 4, a suspended LMC facing down over a 3D printed layout of a house can be used to determine which division is currently being pointed by that finger. The framework will then provide audio information about the selected division describing its contents. The description is gathered from the pdf file, which can have a script about each division's characteristics and contents or such contents can be provided in an annexed file that would also be attached to the PDF file, in the same manner as the STL file.

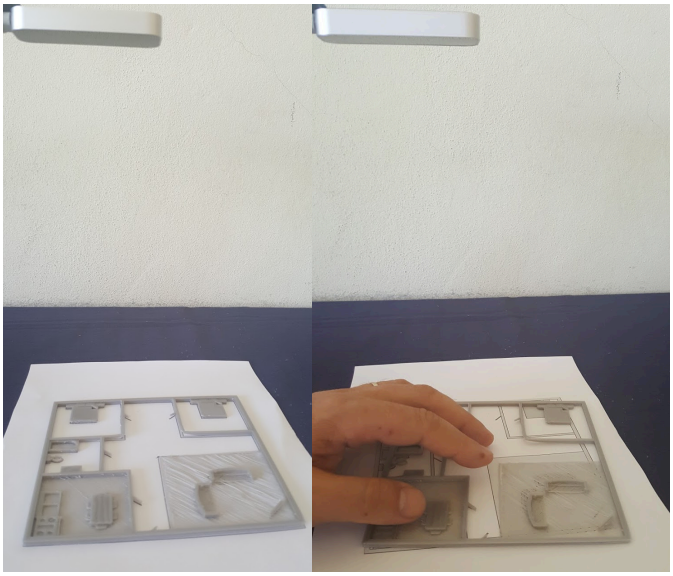

Figure 4 - Setup with LMC on top and 3D printed geometry

The movements are tracked with a reasonable precision, quantified in the fact that in the mock-up the divisions are clearly distinguishable by the system while for the furniture is not possible to determine adjacent items with precision. The audible description then explains what are the objects in each division that can be reached by touch and the relevant information to be provided.

The present work highlights the usability of the LMS, with a proper geometrical setup, to determine the position of the hand and fingers over a printed geometry. That can be, per se, useful to activate the correspondent description. In the case of blind people that solution will be much more interesting with a 3D printed geometry as it can be palpable.

Those geometric presentations should be aligned with the leap positioning system in order to ensure the precision and accuracy in determining the position of the hands.

It is important to highlight that with the readiness to transfer documents or even STL models, those successful experiences can be uploaded and promptly available to other teachers and their teaching environments. A community can build a repository of models and documents, even with narratives, uploaded in the cloud

CONCLUSIONS

The current research work aims at supporting students with special needs but also any other student can have access to the presented framework and benefit from its usage. Along with the generic framework, two main features are presented that improve the quality and information towards inclusion in the Learning environment; one is the inclusion of 3D models in documents and the other is a setup that provides information while touching a 3D printed model.

This document starts by presenting an analysis to the sensorial experience and its relation to the classroom providing ground to an innovation process that can be adopted to improve with students learning environment with current technology. After understanding the role of sensorial experience in the learning process, it is developed a framework that gathers technological devices and functionalities that extend the sensorial experience of the human body. This kind of exercise is particularly relevant for those lacking abilities in sensorial organs or with limited capabilities.

The results show that it is possible to improve the learning environment with technology currently available and that 3D printing can improve the possibilities for the students with vision problems to get knowledge by touching and listening to audio descriptions.

This is a technological advancement with special impact on those with limited sensorial capabilities. In future works it is aimed to extend the usage of machine learning capabilities to make evolutionary solutions that adapt to the student and to the teaching environment guidelines for an inclusive classroom of the future.

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