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Building Augmented and Virtual Reality Experiences for Children with Visual Diversity

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Abstract

Currently, a binational network of universities carries out a collaborative project which seeks to promote inclusion and education in environmental issues for children. The so-called "Colombia-Québec collaborative project" seeks to develop interactive narratives about four Colombian animals to help develop language, cognitive and motricity skills in children while they gain awareness of endangered animals. Chosen animals include the cotton top tamarin, the jaguar, the spectacled bear, and the condor. We are building several interactive systems which take advantage of augmented and virtual reality technologies to expand narratives developed by speech and language therapists. Our goal is to use these systems to study the effects of the virtuality continuum in visually diverse children's development. We present our advances towards achieving it.

CCS Concepts

• ***Computing methodologies*** → ***Virtual reality; Mixed / augmented reality;***

1. Introduction

The Institute for Blind and Deaf Children of Valle del Cauca in Cali, Colombia works on the rehabilitation of children with conditions of low visual capacity that belong to the following functional groups: central visual field alteration, peripheral visual field reduction, hemianopsias and blurry vision without visual field reduction (Figure 1). Among the methods the Institute use to support rehabilitation is narration, which is acquired parallelly with language development during the early years of life. Narration, both written and oral, favours language learning [PACR21]. It requires children to acquire the ability to structure and combine simple phrases to produce a discourse that leads to the use of more complex syntactic structures. This ability is an early indicator of the presence of language disorders and language learning difficulties [NB03].

The virtuality continuum (VC) is a line that takes a user from the real world to the virtual immersive world [MTUK95]. In the middle of this line are mixed realities (MR) and their technologies, which include augmented reality (AR) and virtual reality (VR). There are tools that have been developed to create a more inclusive world.

Figure 1: *Visual diversity from normal vision to the left to blurred vision to the right. Field alterations are in the middle.*

Some of these tools are based on VC technologies, such as the emoji placement system for the visually impaired [Par20]; or systems to help people with autism to identify the emotions that third parties feel and to react with different gestures [SHZB19, CLL15]. Additionally, the use of VC technologies has the potential to increase the ability to enhance learning [TKBS18, KPL*21]. Indeed, AR and VR use interactive technology to take advantage of multiple senses, as sensations are not only perceived by sight, but by senses such as hearing, touch or kinaesthetics allowing a more au-

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thentic imitation of external reality [PORCC17]. However, a lot of work still needs to be done regarding the development of AR and VR applications aimed at supporting visually diverse children.

Our goal is to explore the effects of AR and VR in language development for visually diverse children while stimulating multiple senses. Nevertheless, creating inclusive narratives for the greatest number of children requires gaining better understanding about the visually impaired [WBW*19]; exploring alternatives such as animation to enrich storytelling [Kar19]; and, a way to validate how AR and VR will influence sensorially diverse children [CAM*19]. The "Colombia-Québec collaborative project" seeks to develop interactive narratives about four Colombian animals to help develop language, cognitive and motricity skills in children while they gain awareness of endangered animals.

Our approach proposes four stages: (1) a local artist provided us with several pieces of art from the cotton top tamarin, the jaguar, the spectacled bear, and the condor. At this point, we are at the reality end of the VC. Children can interact with the pieces with their touch and feel the shapes and textures of the chosen animals. (2) Writing of children stories. Stories about the cotton top tamarin and the spectacled bear are aimed at children from zero to two years. Stories about the Jaguar and the Condor are aimed at children from two to five years. Stories of all four animals are aimed at children older than five years. (3) Creating AR and VR environments which will be used to expand the stories. At this point we will move along the VC line. (4) Validation of expanded stories. In the next section we explain some of the AR and VR applications which we are developing and how we plan to validate them.

2. Interactive systems along the VC Line

2.1. VR flight simulation of the condor

For this system we wanted to take advantage of motion sensors, to favour knowledge about the condor, but also develop motricity (Figure 2). First, we present all four animals falling on the background. Every time the children capture one animal, they are able to hear the sound of the animal. Additionally, if they capture a condor, the game goes to a flying level were the children have to fly like a condor over its habitat. In this scenario children have to extend their arms emulating a pair of wings. To get the direction of flight, we get the distance between the two hands. The sensor provides the position of both hands and their direction of movement. We obtain the angle of flight from the inclination formed by these two joints (hands) using the Arc Tangent function taking the X and Y component of the distance between the two joints. The speed of animals falling can be customised as children with different visual conditions will be able to capture animals which are falling more slowly or faster. We are using the Kinect V2 sensor and Unity 3D. At the moment we have sorted out the technical aspects, while the 3D models for the environment are being drawn by an artist. In the future it should be possible to migrate the system to the Azure Kinect platform.

2.2. AR augmented skin of the jaguar

The artist provided us with a tapestry that the children will touch to feel the patterns on the jaguar's skin (Figure 3). At first, the way

Figure 2: *Flight of the condor. The animals are falling and when the condor is selected the children will fight over its habitat.*

Figure 3: *Jaguar's skin tapestry.*

we proposed to augment this piece of art was to integrate a couple of Raspberry Pi computers with a touch sensor and a display. That way we could identify when the children touched one half or the other of the tapestry. However, after having analysed the tapestry, we found that this solution could ruin it. Instead, we propose to use machine learning in an Android tablet to identify on which half of the tapestry the children are putting their hands. We are still deciding which technique to use. However, we plan to take the geometry of the square of the Jaguar's skin frame and divide it in two halves. Then, we will detect the hand in each half.

2.3. AR puzzles and masks for the cotton top tamarin and the spectacled bear

We are developing two systems for the cotton top tamarin. The first one is an AR system that allows the superposition of tamarin masks for children with low visual ability. This system displays interactive elements and is adjustable for the types of conditions of low visual capacity shown in Figure 1. Figure 4A shows how the masks can be placed in one of five possible places, for instance, children with visual field diversity can see the masks in the region that is visible for them, while the application detects the children face. The second one is an AR system which superimposes augmented information about the tamarin while the children are sorting a puzzle (Figure 4B). For the spectacled bear we are developing two systems. The first one is an AR system which superimposes augmented information about the bear and at the end displays a maze to take the bear back to its habitat (Figure 4C). The second one uses a 3D printed version of the bear's head to display information and sound (Figure 4D). To develop the first system, we created an AR filter with the SparkAR tool. For the others we used Vuforia for marker training, the Unity game engine, a game tree search algorithm for the puzzle and a maze generation algorithm. The game tree is a classical game tree representing all possible states in the puzzle. The tree branches all 120 combined possibilities of solution when the child has placed from zero to a total of five pieces in several different orders (five possibilities in the first level, four in the second, three in the third, two in the fourth, and one in the fifth). Within the tree we are able to detect if the next piece has been placed correctly (verifying if one of the deterministic paths has been followed). The maze generation is achived using a recursive backtracker algorithm.

2.4. Towards the metaverse

Extended Reality (XR) interactively integrates VC technologies and forms the basis of what is known as the metaverse. The metaverse allows the interaction and collaboration of several users in a XR world through an avatar-style representation of each of the users [Swe19]. Thus, for those narratives which will involve all four animals, we are planning to use immersive VR with the Oculus Quest and MR with the Hololens 2 device. Here the idea is to design two minigames the children can interact with. Initially these systems will be implemented as single user system. However, we will explore a way to develop the XR environments so they can be extended to multiple users in the metaverse. We already had our first experience in the metaverse. Here we integrated a VR environment with the four animals using Mozilla Hubs which allows walkthroughs of several users (Figure 5). We tested with one child from the Institute. As Mozilla Hubs allows the creation of web-based worlds, we found it was difficult to make the child enter the Oculus' web browser application and then to enter the environment's URL. We will study better ways to do this at a later stage. For the MR experience we are planning to use the 3D printed heads of the animals (Figure 6) mixed with virtual animal environments. What we plan to do is to make children take each animal head to its corresponding natural habitat within a MR environment. For these environments we will seek to stimulate multiple senses which, of course, include vision, hearing, kinaesthetics, but could include, in the future, smell (with the Cilia development kit) and haptics (with vests and gloves from bHaptics).

3. Discussion

We are developing several AR and VR systems that we expect are useful to aid visually diverse children development. Particularly we expect the systems will aid children's language and cognitive development, but it is possible we find the systems are useful to develop children's senses. As we are still in a developing phase, we cannot provide all the details. For example, we need to find a way to use these systems in younger children (but probably for the youngest we will limit the experiments to AR, leaving VR for the oldest ones).

4. Conclusion and further work

We have presented several AR and VR systems that will be used to aid language development. We are at an intermediate implementation phase. We have advanced more on those systems described in Sections 2.1 and 2.3 while the others are in planning phase. We need to measure the effectiveness of such systems in different manners. For this, we will use direct observation, questionnaires (applied to speech and language therapists) and following up a therapy experience. Also, we want to use the OpenBCI device to analyse neural responses of children. To understand this device and method to measure children's behaviours we are designing an experiment where users will be presented with images from the cotton top tamarin displaying the universal facial expressions (Figure 7). Then, we will study the neurological output with the different expressions. When the project is finished and tested, the systems will be located at the XR laboratory at the Institute, as far as we know, the firs laboratory in Latin America studying the effects of VC technologies in visually and auditory diverse children. Here, we presented how we want to use technology for children with low vision, but several of these systems also consider low auditive conditions.

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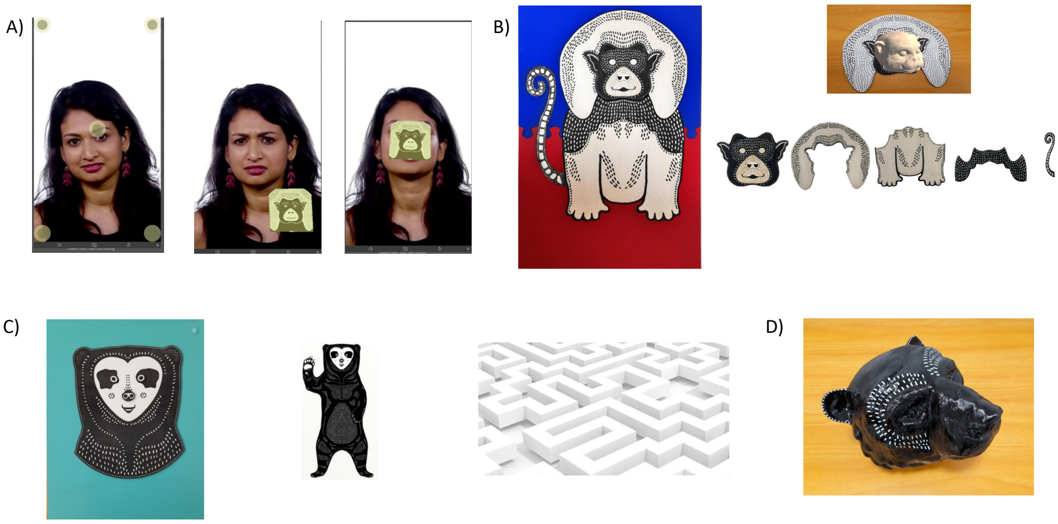

Figure 4: *Using AR. A) Facial filters that can be displayed in different places. B) Puzzle, pieces and one augmented piece. C) Spectacled bear displays information and then displays a puzzle to take the bear to its habitart. D) 3D bear art.*

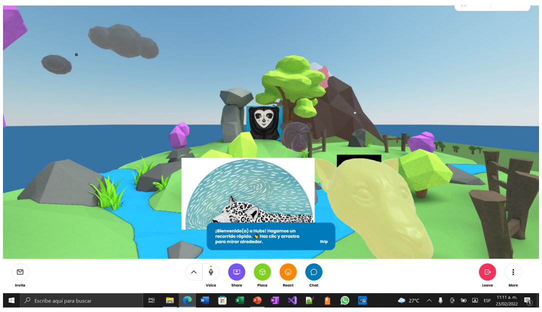

Figure 5: *An animal VR metaverse in Mozilla Hubs.*

Figure 6: *3D printed heads of animals to be used in a MR environment.*

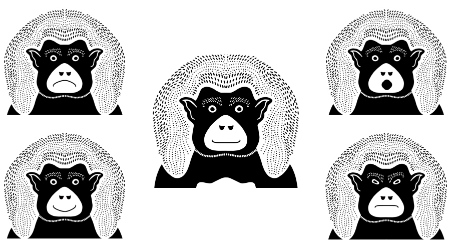

Figure 7: *Cotton top tamarin's facial expressions.*

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