Mixed-Reality Barriers: Person-Tracking in K-12 Schools

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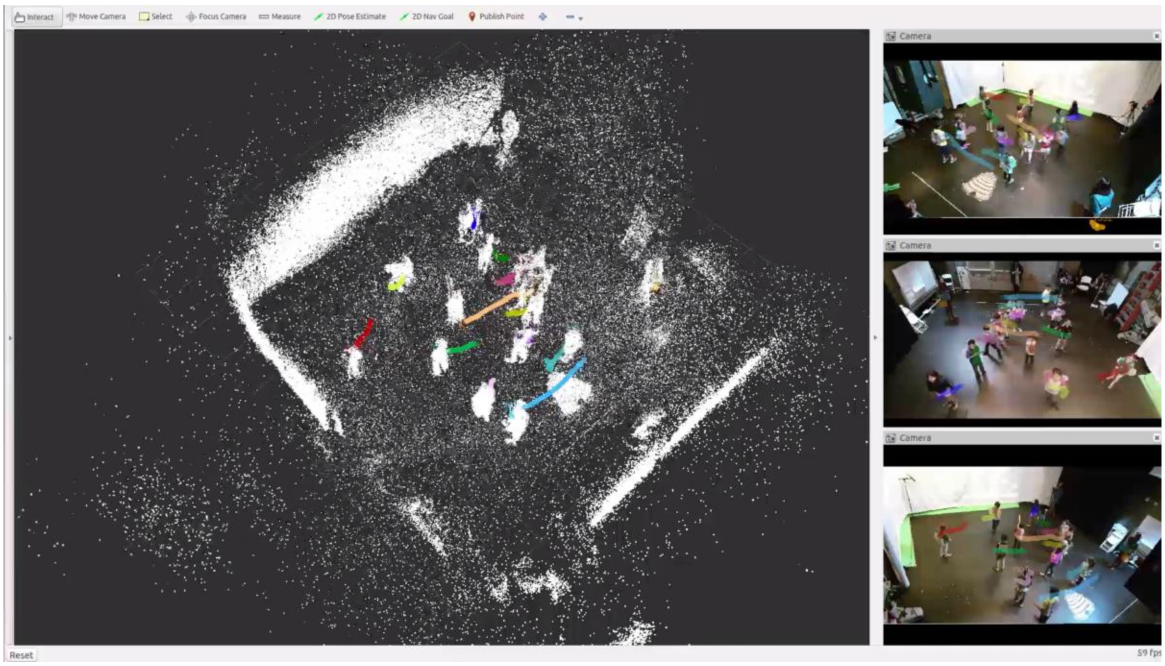

Figure 1: A visualization of OpenPTrack's interface. On the left is a point cloud showing the person-tracking, and on the right classroom of students in the mixed-reality science learning environment.

ABSTRACT

As new and emerging technologies are introduced into schools, internet technology (IT) infrastructure, hardware, and support needs continue to grow. Coupled with these demands is the unknown nature of precisely how new and emerging technologies affect learning and collaboration in the classroom. This paper will investigate the use of OpenPTrack (OPT), an open-source person-tracking system, in classrooms at two different school sites: University Lab School and Esperanza Prep. Through these two cases we discuss the barriers presented by the use of emerging technologies in K-12 schools including IT needs, staff support, and pre-existing institutional structures.

Keywords: Technology barriers, mixed-reality, person-tracking, open-source, public schools.

Index Terms: N.1.7: Learning Environments- Virtual and Augmented Reality

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1 INTRODUCTION

With the reduction in cost and complexity of many computational sensors, the push to implement and adopt emerging, interactive technologies in the classroom has become overwhelming. Products such as Google Cardboard and the Oculus Rift appear to present low barriers to entry within the realm of virtual reality (VR). However, the appearance of easy implementation obfuscates many issues inherent in the use of these devices in traditional educational settings. These issues include factors such as the cost of smartphones for each student to pair with a Google Cardboard, computers that must be connected to each of the Rift headsets, the additional teachers and staff required to configure devices for students, and the IT staff needed to keep devices up-to-date and functional long-term.

Many person-tracking technologies — both marker and markerless — that support mixed-reality (MR) environments also appear to be decreasing in complexity and cost. Much like VR, MR's barriers to implementation are due to high start-up and IT infrastructure costs, the additional IT staff needed to install and operate these systems, and the large space required for permanent installation of person-tracking systems. Each of these issues illustrates a significant obstacle for all schools to overcome, while the list as a whole highlights the impracticality of implementing emerging technological systems, specifically in public schools, which are often short-staffed and under-resourced.

In this paper we first discuss related work, then describe an open-source person-tracking effort, OpenPTrack (OPT). The overarching goal of OPT is to further reduce the cost and complexity of person-tracking and subsequently MR. This aim was accomplished through providing free software and the ability to network low-cost depth sensors (the Microsoft Kinect) to track groups of people in large spaces. We then present two distinct case studies of OPT implementation: (1) in a research elementary school (University Lab School)[1] and (2) in a public charter school (Esperanza Prep). These two case studies will be used to highlight issues that arise in an ideal setting (University Lab School) and in a more realistic scenario (Esperanza Prep). We conclude by reflecting on key considerations for implementing person-tracking in traditional educational settings.

2 Related Work

Previous work on first- and second-order barriers on general technology implementation and adoption in K – 12 classrooms [1]–[3] illustrates many of the barriers to implementing any technology in the classroom. Moreover, literature covering issues such as how teacher beliefs affect technology use in the classroom [4], [5], the need for teacher professional development [6], [7], and the need for institutional support at both the first- and second-order for new technologies to be fully adopted in the classroom [8]–[10] further support the difficulties in classroom technology use.

However, research specifically on augmented reality (AR), MR, and VR implementation barriers in the classroom is still scarce, as these technologies are just now becoming mainstream. Literature available on AR supports the argument that there are multiple usability factors associated with AR in the classroom [11], that available AR applications have a high rate of unreliability [12], and AR implementation is again dependent on a teacher's technical abilities in addition to the other factors enumerated [13].

Although there is a lack of literature on AR barriers, there are many examples of person-tracking and other sensing technologies that have been implemented and researched in formal and informal learning environments. This further scaffolds the use of MR in educational settings even with the issues and barriers presented. A few such examples are using wearable accelerometers for body-based interactivity and embodiment [14], [15], using a system of tag-based tracking (RFID) in conjunction with Microsoft Kinect for museum visitor engagement [16], and using marker-based tracking to teach young learners about physics in an augmented reality environment [17]. Each of the barriers and successes enumerated above are transferable as there are many stakeholders, significant physical infrastructure requirements, and continuing education needed to adequately deploy MR, in turn, creating novel learning environments.

3 Creating OpenPTrack for Science Through Technology Enhanced Play (STEP)

With issues above in mind, our research centered on creating an MR learning environment through markerless tracking technologies – a system where many students would have the opportunity to interact and collaborate within a large body-based interactive environment concurrently. Within the scope of markerless tracking our additional requirements were a 30 Hz refresh rate, the ability to track ten or more people at once, modular in where sensors can be positioned, and easy to calibrate. Our team found that there was no commercial product that met our requirements, yet we were determined to find a solution that could support the type of collaborative learning we are interested in studying. Technologies that support MR environments afford opportunities for embodied, collaborative learning in student-teacher interactions, a learning design and structure we consider valuable. In the specific cases detailed in this paper, student-teacher collaboration was organized around embodiment of the content within the tracked area.

With a decade of experience using and deploying sensing technologies at the Center for Research, Media and Performance (REMAP), our team pivoted and started the OpenPTrack [18] project — an open-source, distributed, person-tracking system. OPT uses multiple networked depth cameras to track groups of people in large spaces. As OPT's inception was in response to a need in educational research and classroom learning, the system was designed with educators in mind. We strove to incorporate low-cost hardware, such as basic consumer level computers and the Xbox Kinect. Even so, as this is an open-source project, there were (and continue to be) many barriers to adoption and implementation entwined with the system including a lack of user interface (UI), somewhat complex IT requirements, large space needs, the detailed nature of the start-up procedure, and the cost to build and maintain the system (even given low-cost hardware).

Despite these barriers, we successfully developed OPT into a reliable system, and installed the system at University Lab School to teach young learners about complex science phenomena such as how bees communicate through the Science Through Technology Play project (STEP). Through this specific implementation, there were many lessons learned about using computer vision technologies in the classroom, which are transferable to addressing barriers in the adoption and deployment of VR, MR, AR at the classroom level. In the following section we describe our OPT implementation at University Lab School, focusing on the issues we faced during the process.

4 Barriers to implementation

In the case of STEP at University Lab School, the first issue that highlights the barriers to adopting any large-scale technology was the struggle for physical space. In the case of the STEP project, we discovered that one of the barriers to adopting large-scale technology was the struggle for shared, physical space. OPT was originally installed in the Lab School's auditorium. However, at the start of the school year, we were notified that the school auditorium was no longer available due to remodeling plans. After much negotiation, we finally secured a large empty classroom in a nearby University building to install OPT. The struggle of finding space is representative of the fact that many resources are shared across classrooms in schools. One of the most essential resources

[1] Both school names provided are pseudonyms.

and necessary components of this project — space — is often limited. Furthermore, if a technology is installed in a shared space, scheduling enough time for setup, testing, and conducting lessons can be a serious barrier to using the purchased technology. In addition, once the OPT system is installed, the task of running OPT becomes an additional barrier. Who in the team has the knowledge and time to run and test the system? As was mentioned previously, due to the lack of a UI, OPT's start up process requires the operator to use command lines to start and run the system.

Due to many of the researches on the STEP project being unfamiliar with Linux (Ubuntu) and command line operations many hours were spent training those who would be running the STEP simulation at University Lab School. In the case of STEP, we had the luxury of having staff who helped develop OPT and had the institutional knowledge and relationships with the STEP team to properly train them to their required needs. An expert on running the system (Illum) was on call if any issues did arise. In a non-research setting, a teacher or educator would not likely have direct access to the technology expert or developer. Furthermore, school IT staff members are often responsible for many different categories of technology issues that can be distributed across many sites, further complicating ad hoc support.

In the end, the STEP project was implemented at University Lab School successfully in multiple classrooms without any serious technology failures. However, a minimum of three research staff members needed to be present for each classroom to run the technology, assist with the lesson, and provide general support for the teacher. This meant there were up to five adults (three researchers, a teacher, and a classroom aide) to run the STEP simulation for a class of about twelve students. This volume of adult support is unheard of in public school settings. In the next section, we shift our focus to using OPT in a more realistic educational setting without university or research affiliations.

5 Translating OPT for Public Schools

We present our work at the University Lab School as an ideal environment in which to implement educational interventions with the OPT system. Our hope is to understand how to best translate practices that were effective at the University Lab School to a public school environment with fewer resources and built-in forms of support. Because University Lab School is affiliated with a research institution, the school community is already committed to partnering with researchers to explore a wide range of interests. In particular, the school staff is invested in working to understand how to integrate new technologies into an array of academic content areas. In addition to the school's commitment to pursuing research on the cutting edge of educational technology, factors that make University Lab School a "best-case scenario" environment for these types of interventions are its low student-to-teacher ratio, presence of multiple researchers to support project development and infrastructure, less accountability for standardized test results and therefore time to explore learning with emerging technologies, and a permanent space where hardware can be installed for current and future iterations.

These concrete advantages must be noted if we are to consider how MR environments might translate to public schools with fewer resources. Over the past few years members of our team have used OPT in educational environments that present new and different challenges than University Lab School. One of these cases took place in a charter elementary school in Southeast Los Angeles. In the following paragraphs we detail a few of the barriers we encountered at this elementary school, Esperanza Prep, and reflect on how they might be addressed in future iterations in increasingly realistic circumstances in public schools.

At Esperanza Prep a single graduate student researcher (Dahn) worked with the school's visual arts teacher to create a digital mask-making unit of study. Over the course of 10 weeks, Dahn and Esperanza's visual arts teacher co-planned lessons. These lessons included a component in which students worked with an online authoring system that was then used to develop a final performance. The digital mask-making unit allowed students to showcase their creative work to an audience through body-based interactions, enabled by OPT, in an MR environment. The needs of the project included teacher and student support throughout the digital art-making process, and technical support in the temporary installation and configuration of the OPT system in the school's gymnasium for the final performance. For the purpose of traveling with the system to different sites, Illum had previously created a mobile OPT installation kit, complete with the hardware and setup instructions in order to streamline the mobile installation process.

In the end, the two-hours of performance and student/audience interaction with the OPT system required a great deal of time and resources on the part of the involved researchers. Illum assisted Dahn in the transportation of equipment to the school while providing technical support for the OPT system operation and configuration in the gymnasium. An additional graduate student researcher was also present to install the audio and visual equipment necessary for research data collection.

While the collaborating visual arts teacher enjoyed working on the project and was invested in its success, she did not have the capacity to learn the details of the system herself. During her daily "prep time" she usually had meetings or needed to prepare for her upcoming classes. The OPT system setup takes several hours and is not an undertaking that a teacher would be able to prioritize given a presumably tight schedule and requisite responsibilities. The temporary nature of the installation at Esperanza Prep added an additional layer of complexity to the project. While at University Lab School we were able to secure a more permanent space for the OPT system, Esperanza did not have a space that could permanently house the system even if we had the resources to install it.

It is important to note that due to the project's quick turnaround, as well as the fact that students were using the OPT system for a culminating performance rather than for the lessons themselves, it is difficult to assess the impact the experience had on student learning. These variables make it difficult to conclude if our efforts were "worth it" as the outside time, energy, and commitment cannot be directly linked to tangible outcome measures. Although the hardware required for OPT is relatively inexpensive, there is a high probability that it would be difficult for public schools to rationalize spending limited funds on technologies that may or may not produce results directly correlated with their overall goals or standardized accountability measures. Despite these uncertainties, we believe that the collaborative, embodied learning afforded by MR environments ought to be pursued. In the following section, we discuss the barriers to OPT implementation that need to be addressed in future work with MR in schools.

6 Discussion

Throughout this paper we have endeavored to highlight the many issues and barriers that are enmeshed within the implementation of emerging technologies in the classroom, specifically MR in the two cases presented. Nonetheless, we are in favor of using these types of technologies in the classroom. We feel that challenging the prevailing narrative of ease of implementation currently encompassing VR, AR, and MR conversations will help to strengthen future technology development for educational classroom use. In challenging this narrative, four prevailing issues come to the surface for critical discussion — *the cost and complexity of necessary hardware and infrastructure*, *requisite knowledge and skill to run the OPT system*, *space resource constraints*, and *the need for stakeholder buy-in*.

The first issue is one of hardware and infrastructure complexity and cost despite OPT's aim of affordability. Even the most basic technologies can be difficult for schools to justify purchasing, and OPT is not an inherently user-friendly technology due to the issues discussed. The STEP project was funded by the National Science Foundation, which gave our team flexibility and adequate funding for acquiring equipment and developing our own person-tracking software. Additionally, our team has the resources and IT knowledge to install these systems without outside assistance. University Lab School, again, presents an ideal scenario that is not illustrative of how public schools and institutions would likely choose to allocate time and money.

In contrast, the OPT deployment at Esperanza Prep showed clearly that the staff, time, and knowledge to run complex technology systems is not realistic or sustainable. For this two-hour temporary installation three people had to travel to the school and work together to install, set up, and test the system, which amounted to an eight-hour commitment for each researcher. The knowledge and time required to temporarily install an OPT system for one lesson would be beyond the expertise of a single classroom teacher. Additionally, as educators already have many obligations in regards to managing their classrooms, these technologies have the potential to become just another distraction from time spent teaching and learning.

To reiterate points from the cases above, space and infrastructure constraints present challenges on a case-by-case basis. While some schools have spaces where a permanent installation is feasible, others even struggle to find space for subjects such as art, science, or physical education. Space is a highly prized resource in many schools and is usually scarce rather than abundant. Additionally, even if OPT were installed in a permanent space, often these spaces are shared, and scheduling conflicts present challenges that could restrict teacher and student access to the system.

A final point of discussion is the necessity for stakeholder buy-in for successful deployment of MR technologies, meaning that first teachers and administrators have to actually want and be willing to use them for learning. Creating these types of collaborative learning experiences, and making them more commonplace will be a result of collective beliefs and collaborative efforts between researchers, administrators, teachers, and students. At University Lab School, researchers and teachers had a shared history and previous experiences working together, and at Esperanza Prep Dahn had a strong relationship with the visual arts teacher, administrators, and students, having been an instructional coach at the school previously. Therefore, although Esperanza Prep was a more realistic scenario than University Lab School, it did not present all of the challenges we might expect at traditional public schools. A shared belief and willingness to try new pedagogies and practices is a necessary first step for technologies such as OPT to be successful.

7 Conclusion

We fully support efforts that strive to thoughtfully implement emerging technologies in traditional educational environments even given the barriers addressed throughout this paper. Exposing and highlighting these barriers will strengthen the dialogue among educational researchers and educators, leading to stronger advocacy, research, and development of future educational technologies.

The authors acknowledge that this descriptive analysis is only a first step in finding solutions to the existing obstacles presented by introducing emerging technologies in the classroom. Future research in educational technology development, specifically in UI design and general deployment of these technologies in educational settings, is required. Furthermore, in conjunction with technology research, educational policy advocacy is needed to support technology and IT development efforts. Our experiences at University Lab School and Esperanza Prep lead us to conclude that if schools do not have the requisite resources, monetary and otherwise, insurmountable challenges and barriers will still be present in the implementation of even the most seemingly efficient and accessible educational technologies.

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