Augment: Enhancing Education Through Augmented Reality

SDSMT Mobile Computing 2017

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Duration: 24 months

Budget: $39,856

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Abstract

The Augment project will develop augmented reality content and tools for university curricula. This project brings together faculty in Computer Science, Industrial Engineering, Mechanical Engineering and Humanities to develop the required data standards and academic interfaces for multi-curricular content creation. The Augment project will employ computer science senior design teams to develop sample target applications in the represented disciplines which can then be applied to content creation in several existing courses. This content will be integrated into the curriculum and deployed using phones, tablets and Hololens's to display content as a proof of concept. Comparison to non-Augmented courses will be used to determine the efficacy of the Augment approach.

1 Project Background

1.1 Introduction

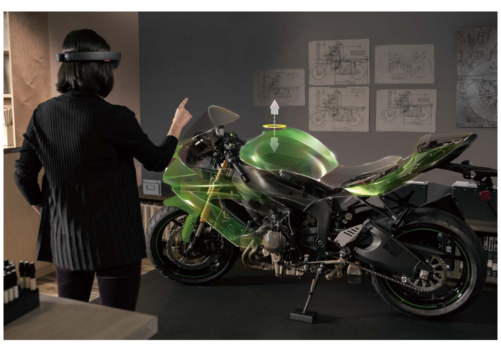
The use of technology in STEM education is an essential component to the various STEM disciplines. Not only is the subject under study technological, but the methods by which we teach are technological. Such tools allow us to better leverage our intelligence, giving more “bang for the buck”. Over the last 30 years [1, 3], educators have commented on a decrease in the ability to visualize 3D objects. Some authors have proposed that we spend less time working with our hands. Some have pointed out that our expectations for visualization have increased, meaning greater demand and a feeling of decreased ability. In some cases it may be due to some of the very tools we use.

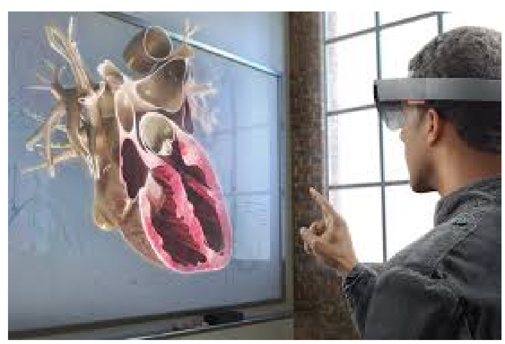
1.2 The Dream

Imagine in your Calculus III course being able to see the intersection of the two bounding surfaces in a volume integral problem. Imagine having the ability to walk through a machine design or slice through a complicated structure visually for 3D Printing. Imagine the instructor tossing up more active blackboards in the room or pulling up lab examples. Imagine guided labs where you see the objects labeled and instructions available at each step. Also think about the overlays for lab safety or enhancements for museums.

We are at a point where it is possible to have high quality 3D visualization available at all levels in education. Using modern augmented reality or virtual reality equipment, it is possible to visualize complicated mathematical objects, machines, or industrial processes. This is not a new concept. Virtual reality systems have for decades promised to add a dimension to education (pun intended). The difference now is that the hardware is finally cheap enough and small enough to be practical.

Think about the actual use of virtual reality at SDSM&T. Like universities across the nation, it is nearly non-existent. Why? This proposal aims to address that question. Before we state the project specifics, we need to address some terms and technology.





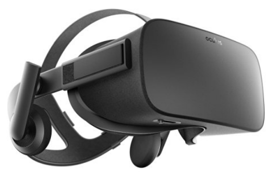
1.3 The difference between virtual and augmented reality

Because the industry is young, it is important to clearly define the terms.

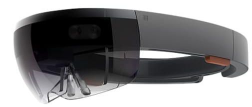
Virtual Reality, VR, is the term used to describe computer generated environments and the objects within. The goal is a simulation of an alternate reality, separate from the current environment. Virtual Reality systems such as the Oculus Rift cover the eyes with a stereo display providing the user with a very realistic 3D experience.

Augmented Reality, AR, is used to describe computer augmentation to the current environment. Devices such as phones or the new Microsoft Hololens add to virtual objects to the current user's surrounding environment. AR's goal is to provide an enhanced experience in the current surroundings.

Because of this, VR is well suited to gaming, simulation training, virtual tourism and telepresence. AR is fundamentally tied to the current environment. It is well suited for environmental overlays, in situ training, object identification and prompting.



Occulus Rift



HoloLens

1.4 Augmented is actually better than virtual

There are a number of reasons emerging that show augmented reality is a much better approach than virtual reality for traditional classroom courses. One very important reason has to do with student interaction and motion sickness. VR technology separates individuals from the environment and often from each other. It currently separates the student from the class and the instructor. [1] Augmented Reality tends to bring people together over virtual objects allowing team or class participation. VR systems suffer from motion sickness effects which limit many individuals to 20 minutes per session. Due to the environmental context, AR systems allow for a much longer session before presentation of motion sickness or eye fatigue. AR systems can be used even without content and context switching between traditional and augmented is much smoother.

Even if the motion sickness and eye fatigue are addressed in VR, K12 has adopted AR. There are apps available for Android and iOS to enhance the educational experience in science, art and languages [2, 4, 6].

1.5 The lack of content problem

The old adage you might recall is "give a professor a powerpoint slide deck and they can lecture for a day, teach them how to create powerpoint slide decks and they can lecture for decades nonstop." While that might have not been completely accurate, it gets to the core of the problem. It is currently possible through 3D modeling tools and specialized software to produce 3D objects which can be rendered in specific AR apps. Using the Mobile Computing Funds we can generate content for a specific course using a specific device.

The impediment to curricular scaling is there is no standardization. So what can be rendered in vendor A's app does not render in vendor B. This presents problems for having Android and iOS devices or crossing over to the Microsoft Hololens. There needs to be a standard XML data representation that all the networked rendering devices understand. There also needs to be a standard tagging system. A tag is a physical visual clue (image, QR code, etc) that prompts and roots the 3D structure to augment the region. A system is in place to do tagging and not surprisingly these are known as AR tags. The PI has experience in tagging, tag identification, tag localization and dynamic content generation based on the tags [5].

Beyond lack of standardization in AR, there is no common science and engineering tool for producing 3D content for AR. The Math classes use Maple, and Mechanical courses use tools such as Solidworks

[1]Since current computing power does not allow for dynamic surrounding environment to be easily integrated in.

and Matlab. Industrial Engineering uses a different tool chain. It is very much like where we were on Arpanet prior to HTML. Having a common format makes it so that different browsers can all access web materials. Although browsers can resolve different sets of files, they all resolve HTML.

The human visual processing system has a great ability to reconstruct three dimensional structure from two dimensional images and motion. Meaning if you move around, your eye picks up details and you are able to embed the object in three dimensions. Experiments show that it just pops up. The ability of the person viewing to select the viewing angle can be important at times. Differences in experiences will give some an advantage in the 3D reconstruction. We therefore assert that end user control is important.

2 Project

A good starting point for the concept would be a student studying Calc III. A typical problem is to figure out the volume of an object. If the book has a QR/AR tag next to the problem, then the student could use an app on their phone, point the phone at the tag, and, by looking through the phone, the 3D image (graph) is seen floating above the book. As the student moves the phone around, the view of the solid changes. By slicing the volume, the student can see how to solve the problem.

Project Augment will begin with a survey of content from the subjects listed below such as the Calc III example. Faculty will bring forward specific instances of 3D augmentation that will place demands on the data channels, the user interface, or the hardware requirements. Two Senior Design teams will be created to work out the processes and create the software. The PI working with the senior design teams (CSC and IENG) will draft the software requirements and begin Agile-based software development. The requirements will be described in usage terms as User Stories. We will run in a series of development cycles of fixed lengths, known as sprints. Each sprint will focus on some of the requirements and deliver working prototypes in an incremental fashion.

There are several detailed components to this project. First, we need to select the file format for the 3D object, the localization tags, and the various metadata required. A localization tag would be a variation of a QR code intended to link to the intended object and to place the object in the visual field. Second, we need to determine how best to get commercial packages such as Solidworks to export the data in the format we develop. For brevity, we skip the technical details on the algorithms and software.

Following this the Senior Design teams will be employed to create iOS, Android, and Hololens apps using the common datatypes as well as work on the commercial application export problem. Faculty will be used as the customer base and early on will create content to incrementally test the apps. The senior design team will present their finished products at the design fair and display the faculty-generated content as proof of concept. Faculty can then generate printed materials such as lab books and lecture notes with embedded tags. These will link to the objects bringing the materials to life. Same thing can be done with presentations and the objects come alive in the room.

2.1 The content goal

We intend to produce AR content for the following subjects:

Arts and Humanities Three-dimensional textual enhancements could provide students with greater facility for entering and exploring texts both as readers and writers. One such tool, for example, might allow students to visualize the parts of their own essays as three-dimensional blocks in order to think about those essays' shape. Another might utilize three-dimensional overlays to annotate literary texts, providing new virtual spaces where students could respond to those texts. Both would be especially beneficial for engineering students engaged in courses for writing and reading.

Calculus III One of the significant challenges that face Calculus III instructors is the difficulty in getting the students to understand the three-dimensional objects that arise in the course. This affects the sections on coordinate systems, optimization, and integration.

Civil Engineering With the increasing complexity of building systems, AR could be used to illustrate the interaction of the structural, electrical, plumbing, communications, and HVAC systems within a structure. Load paths and deformations could also be illustrated for the structural system.

Machine Design and Mechanics The ability to show the dynamics of 3D objects in 3D can greatly enhance the understanding of not just the design, but why the design is effective. Discussions of the mechanical behavior of materials could be enhanced by AR manipulatives that illustrate such concepts as axial, bending, and torsional stresses.

Methods Engineering A major effort in industrial engineering is in designing the best method for accomplishing a task, training those who need to perform it, and then verifying that it is in fact the best method. AR has the ability to improve the accuracy of assembly methods and to ensure quality and safety are maximized by assisting the performer in knowing the next step and following it precisely.

Robotics Robots are expensive and simulation can save significant funds. We can skip aspects of the robot that we are not interested in and simulate the parts we are interested in. For example, test the navigation algorithm without a complete robot.

2.2 Student Benefits

Augmented reality really can improve (either by speed or by depth) the educational experience. It should increase understanding and reduce frustration. Having the base technology on the phone or tablet means no additional investment in technology is required. Less time spent on the mechanics of visualization means more time on problem analysis–and for some students, they will keep all of their fingers.

3 Results

3.1 Validation of results

The identified courses are either multi-section courses or courses offered often enough to allow for comparison of traditional lecture approaches to augmented lectures. Surveys and test question comparison will be done to test for better attitudes, higher student engagement and increased subject comprehension. Table 1. shows the timeline for data collection.

Table 1. Assessment and evaluation timeline

Measurement	Evaluation Type	Fall 2018 – Spring 2019			
		Mon 1	Mon 2	Mon 3	Mon 4
Science/Engineering Motivation Questionnaire II	Summative	Pre			Post
Spatial visualization test (freshmen)	Summative	Pre			Post
Student Assessment of Learning Gains (SALG)	Formative				
Student/instructor focus group	Formative & Summative				
Course grades and retention rates	Summative				

Note: Mon1, Mon2, ... Mon4 refers to Month 1, Month 2, .. Month 4 for Fall 2018 and Spring 2019 semesters (evaluation will occur both semesters).

3.2 Dissemination of results

Development of the product will be done on Bitbucket (similar to GitHub, but better educational support, and the PI has this already setup for Senior Design). Bitbucket has available Wiki's, Git based repo and a full tool chain for Agile development. We also plan publication of the results in ASEE. A web portal can be created linked to this to disseminate the results. This system will also allow open source style code or curricular development. The project will continue as a community supported open source project.

3.3 Future work

AR has the potential to enhance learning environments. In many rural areas and reservations, resources are very limited. Labs may be limited or non-existent and instructors in short supply. Augmentation of material through remote instructors, remote lab experiences and remote curricular materials can make up for significant shortages found in the under-served populations. Thus a good math instructor can be in several remote schools at one time. These ideas will be explored in a Broadening Participation NSF proposal.

4 Products and Timeline

4.1 Deliverables

- Android AR Mobile App
- iOS AR Mobile App
- Hololens AR Mobile App
- Application export software
- Curriculum repository and Web portal
- Specific Curriculum for focus areas
- Documentation for future use
- Publications and NSF Proposal

4.2 Timeline

Summer 2017

- Hardware purchased and Senior Design teams members identified

Fall 2017

- Content Survey, User Stories, Requirements and Test cases
- Data container development and data flow estimation
- App Initial Architecture and Design, Networking and 3D Graphics Engine work
- Android and Hololens initial code development

Spring 2018

- Android/Hololens graphics and GUI prototype
- Faculty prototype
- Android/Hololens GUI refinement and feature development

Summer 2018

- iOS Port and development
- Testing and deployment: Android, Hololens.

Fall 2018

- iOS testing and deployment, issue tracking and bug fixes
- Curriculum development and validation, NSF Proposal

Spring 2019

- Curriculum development, Validation studies
- Distribution of software and presentation of results (conferences and papers)

References

[1] Holly Ault and Samuel John. Assessing and enhancing visualization skills of engineering students in africa: A comparative study. *Engineering Design Graphics Journal*, 74(2):12–20, June 2010.

[2] Matt Dunleavy, Chris Dede, and Rebecca Mitchell. Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology*, 18(1):7–22, 2009.

[3] I. E. Esparragoza. Enhancing visualization skills in freshman engineering students. Preprint.

[4] Kangdon Lee. Augmented reality in education and training. *TechTrends*, 56(2):13–21, 2012.

[5] J. Lillo, L. Woody, and D. Nix. Navigation assistance for the blind. Senior Design Team Report, 2015.

[6] M. E. C. Santos, A. Chen, T. Taketomi, G. Yamamoto, J. Miyazaki, and H. Kato. Augmented reality learning experiences: Survey of prototype design and evaluation. *IEEE Transactions on Learning Technologies*, 7(1):38–56, Jan 2014.

Budget

We are asking for $39,856.

Team

- Jeff McGough, MCS
- King Adkins, HUM
- Adam Piper, IENG
- Christer Karlsson, MCS
- Shaobo Huang M.E.
- Brent Deschamp, MCS

Student Senior Design team to be determined.

Cost Breakdown

Item	Unit cost	Number	Total
Summer student salary	$2132[1]	8[2]	$17056
Hololens[3]	$3000	6[4]	$18000
Graphics cards[5]	$700	4	$2800
Conference[6]	$2000	1	$2000
Total			$39856

Budget Justification:

1. The $2132 figure comes from 40 hours per week for 4 weeks at $12 / hour and 11% overhead. $40 * 4 * 12 * 1.11 = 2131.2$
2. We are looking for five students in year one and three in year two. The plan is for one month support each. So we figure eight student months which will probably be allocated as 5 students for one month each in summer one and 3 students one month each in summer two.
3. The Hololens is the current “hot” AR device. This world changes very quickly and by the time the funds are available, other options will certainly be on the market. Two student teams (CS and IENG Senior Design) and six faculty using the Hololens will need at least 8 units.
4. Selected so the entire student team or faculty team can use at the same time.
5. Complicated graphics can require a larger video cards to process the files. The estimate is based on the current cost of the nVidia GTX 1080 and four of the faculty will be needing the cards.
6. Only one person is required to attend to present.