CASE WESTERN RESERVE UNIVERSITY
COLLEGE OF ARTS AND SCIENCES

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Dec 8, 2019

Proposal for Nord Grant

Purpose: We propose to use Nord Grant funding to help advance our long-term goal of using augmented reality to develop a "Physics Playground" as a novel educational platform. Briefly, in the Physics Playground students wearing an augmented reality (AR) headset could play with real-world objects, (such as toy rollercoasters, magnets, or pendulums, for instance), while the AR is used to holographical add "physics information" to the objects in real-time. As a simple example, students could play with a toy roller coaster while the AR set holographically adds information helping to explain the physics. In this setting, the students could experience the behavior of roller coaster as they choose to launch it from different heights (providing a real-world experience), while the AR superimposes velocity and acceleration vectors (thus providing a visualization of the abstract physics concepts.) The Physics Playground idea and its impact on learning are described in more detail below.

Funding from a Nord Grant would enable our group to begin implementing portions of the Physics Playground, observe students using the playground, and make preliminary evaluations of its effectiveness as a teaching modality. The technology and methods developed from this work would provide our group with experience in the area of cyberlearning. This, along with establishing a track record would improve our chances for success in future requests for funding from the NSF for instance. (Our group has already submitted one proposal on the Physics Playground to the NSF. The idea was well received, but one criticism was our lack of experience in this area.) Although the request for a Nord Grant is inspired by our vision of a Physics Playground, the technology developed would be freely shared with any other CWRU teachers, faculty, or researchers interested in these same concepts.

The work on this project is in collaboration with the Interactive Commons, and thus the choice of AR is the Microsoft HoloLens. The Microsoft HoloLens is a pioneering, augmented-reality headset device that projects holograms. Unlike other virtual-reality devices, this lightweight, wireless headset with a transparent visor allows wearers to see and hear the people and objects in the real world – providing an augmented reality or "mixed-reality" experience that blends the real world with the virtual world. With HoloLens, one can make holograms appear on a desk or transform a classroom into what feels like the surface of Mars. Students and teachers can wear the devices and interact together as they view the same hologram as if it was an object in the room, or students can wear the device for study or distance learning.

Scope of the Nord Grant Project: In particular, our proposal consists of three parts:

Part 1) Implement real-time position tracking of moving objects using tools freely available from OpenCV (Open Source Computer Vision Library, https://opencv.org/). OpenCV is an open source computer vision and machine learning software library, and was built to provide a common infrastructure for computer vision applications. Several groups have already used this software to track the position of objects in two dimensions, provided demonstrations on YouTube, and have made their code available for use [1-4].

Part 2) (Teaching Innovations) Develop HoloLens application of toy roller coaster which will use input from the real-time tracking to determine the position of the cart on the tracks. As the cart is traveling on the roller coaster, the application will superimpose arrows on the cart to indicate the velocity and acceleration of the cart. Students can then explore the relationships such as: 1) The speed at the bottom of the ramp as a function of the initial height, 2) the velocity of the cart as both a function of time and as a function of location on the down-ramp, 3) the direction and magnitude of the acceleration as the cart takes a turn on the tracks or when the cart does a loop. In addition to exploring, students can be given task such as measuring and plotting the velocity of the cart at the bottom of the ramp as a function of height, and be asked to explain the results in terms of physics principles.

Part 3) (Metrics and Data Collections) Evaluate the effectiveness of this mode of teachings. The idea would be to recruit students from campus to use the applications, and then test their knowledge gained with pre and post quizzes. The results would be compared to a control group which received a more standard lecture. IRB approval for this evaluation would be used in order to allow for the publication of the results.

Professional Development: As the leader of this Nord Grant project, I have experience developing applications for the Microsoft HoloLens, and then using them as teaching tools in several of my course. With funding from the Active Learning+ fellowship, a student and I developed HoloLens applications for use in PHYS 324 – Electricity and Magnetism I. This work was in collaboration with the Interactive Commons which provided access to the HoloLenses, implemented the synchronization of the HoloLens, and supported the teaching of three class sessions at the IC. The physics concepts and application software for the HoloLens were written by me and my student. Figure 1 shows a snapshot of a class at the IC demonstrating the concepts to electrostatics.

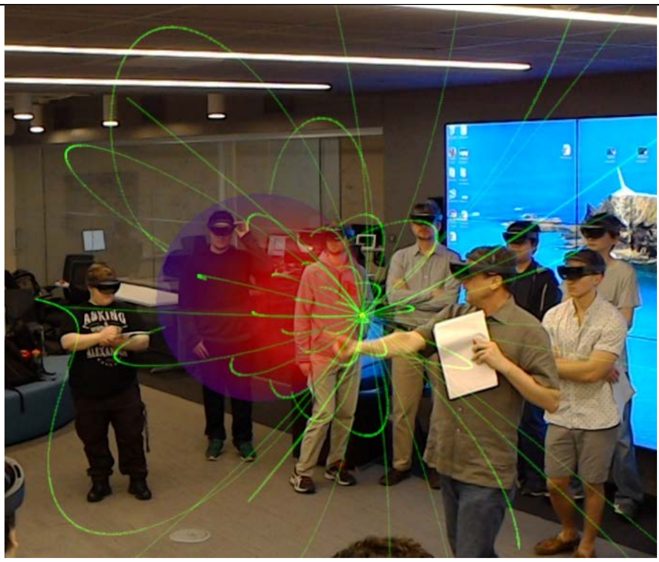

Figure 1: Snapshot of a class at the Interactive Commons using the HoloLens to teach the concepts of electrostatics. This is a representative view of what the students can see while participating in the class. The colored sphere represents a conducting sphere and the green lines represent an electric field. With this HoloLens applications, the students are able to visualize in 3D the shape of the electric field lines as a point charge is moved around the room.

Professional Impact: Rapid technological and societal changes require an educated, flexible citizenry ready for careers that have yet to be invented. Accordingly, workers must be skilled in both domain specific knowledge and the 4 Cs of 21st century thinking: creativity, critical thinking, communication, and collaboration. These skills are essential for a workforce that can keep pace with and contribute to technological innovation and scientific advancement. Consequently the implementation of education must expand to promote the 4Cs and include effective techniques for assessing the cognitive and intellectual development of the students. To achieve this, transformative advances in learning approaches are needed to educate a new generation of students, teachers, and workers in highly technological and collaborative environments.

The Physics Playground addresses this challenge with the creation of a novel collaborative learning environment called the Augmented Reality Physics Playground and Laboratory (ARPPL). In this lab multiple participants are equipped with augmented reality headsets that superimpose holographic images upon physical objects in real-time to provide experiences that are simultaneously familiar and novel, thus bridging the known with new learning. The ARPPL concept provides an opportunity to test the possibilities of augmented reality as a flexible, adaptive, personalized and collaborative learning environment. The particular implementation of ARPPL for this project uses roller coasters as a platform for connecting student experiences with the fundamental concepts kinematics such as linear and centripetal acceleration, kinetic and potential energy, and the conservation of energy. Importantly, participants are able to build and play with real model-sized roller coasters while an augmented reality system automatically synchronizes the holographic images to the real world hardware.

[1] youtube.com/watch?v=EDT0vHsMy34

[2] pysource.com/2018/04/05/object-tracking-with-mean-shift-opencv-3-4-with-python-3-tutorial-29/,

[3] youtube.com/watch?v=CigGvt3DXIw

[4] lirtex.com/robotics/fast-object-tracking-robot-computer-vision/

[5] 2018 NSF Proposal, RFP NSF 17-598. Title: “An Augmented Reality Physics Playground and Laboratory as a Collaborative Learning Environment”, PI: Michael Martens, Amount: $750k.

If you have any further questions, please feel free to contact me.

Sincerely,

Michael A Martens

Michael A. Martens

NORD GRANT APPLICATION

BUDGET

EXPENSES

Camera: SVPRO 1080P Full HD Industrial Webcam CS Mount Lens 60fps/120fps	$ 56.00	2	$ 112.00
Roller Coaster: The Dragon, Coasterdynamix Kit	$ 500.00	1	$ 500.00
Miscelaneous supplies			$ 150.00
Student hourly pay			
Spring Semester			
10 hours/week * 16 weeks	$ 11.00	160	$ 1,760.00
Fall Semester			
10 hours/week * 16 weeks	$ 11.00	160	$ 1,760.00
Overhead on Salary	58%		$ 2,041.60
Cost Sharing			
Professor Martens time will be considered the cost share			
Total Project Cost			$ 6,323.60

Physics Department Administrator
Kathy Kjaglien
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Dec 8, 2019

Dear Nord Grant Committee,

We have reviewed Prof. Martens Nord Grant proposal, “A Physics Playground”, and support his efforts in this area. This proposal is in alignment with the physics departments culture and strategic plan of providing our undergraduate students with quality instruction, and for exploring innovative methods of teaching. In his time here at CWRU, Prof. Martens has been a UCITE Learning Fellow, an Active Learning Fellow, and has been nominated for both the Wittke and the Deikhoff awards for teaching excellence.

In the past several years, Prof. Martens has invested time and effort working with the Interactive Commons (IC) on the development of applications for the Microsoft HoloLens. Subsequently he has used the HoloLens in his PHYS 324 course in Electricity and Magnetism. And this semester he offered a 2 credit hour course PHYS 147 – Augmented Reality for Teaching Science. This course was not considered part of Prof. Martens official teaching load, but was an important contribution of his time to the physics department, and to our undergraduate students (including physics, computer science, material science, and mechanical engineering majors.)

The funding from the Nord Grant would provide Prof. Martens with an opportunity to continue his research with the HoloLens and in cyberlearning more generally. The primary function of the Nord Grant is to provide support for undergraduate students to implement the technology supporting the “Physics Playground”, and for developing applications for the HoloLens. In itself, this work would provide valuable experience for the students involved. In the longer term, the technology, applications, and lessons learned from this project would be shared with other interested parties at CWRU.

Importantly, the funding from the Nord Grant would add to Prof. Martens repertoire in this area and improve his chances of getting further funding. Prof. Martens has already submitted one proposal to the NSF with the idea of funding a “Physics Playground” with positive feedback, but this was not accepted in part to the groups lack of experience. The department would support Prof. Martens future attempts to seek funding this area.

We have also reviewed the scope, budget, and timeline for the proposal and agree that the goals are consistent with the request for resources. Prof. Martens previous work with the HoloLens and his active collaboration with the Interactive Commons have given him the experience to make reasonable and informed judgments regarding the resources needed to accomplish the task of building some of the support infrastructure needed for the long-term goal of realizing “A Physics Playground.” With respect to contribution of resources to this project from the Physics department, we consider the considerable time that Prof. Martens has invested in this area as a significant amount of support, and would not be able to contribute any further financial support.

Sincerely,
Corbin Covault
Glenn Starkmann
Co-chairs of the Physics Department

MICHAEL A. MARTENS

Education

Ph.D. in Physics 1991. Case Western Reserve University, Cleveland, Ohio.
Thesis Title: **Gradient and RF Coil Issues in Magnetic Resonance Imaging**.

B.S. in Physics 1987**.** Case Western Reserve University, Cleveland, Ohio.
Graduated with Highest Honors. Best Senior Thesis in Physics.

Scientific Appointments

2015 – pres **Professor**, Case Western Reserve University**,** Cleveland, OH
2011 – 2015 **Associate Professor**, Case Western Reserve University**,** Cleveland, OH
2006 – 2011, **Scientist II,** Fermi National Accelerator Laboratory, Batavia, IL
2000 – 2006, **Scientist I,** Fermi National Accelerator Laboratory, Batavia, IL
1994 – 2000, **Associate Scientist,** Fermi National Accelerator Laboratory, Batavia, IL
1991 – 1994, **Research Associate,** Fermi National Accelerator Laboratory, Batavia, IL

Sample of Research Funding

2013 – 2018, **Ohio Third Frontier (OTF) Innovation Platform Program**
PI on $3M grant to design and build a liquid helium free MRI main magnet using the high temperature MgB_2 superconductor and to design a RF coil for MRI guided breast biopsy systems.

2013-2015, **National Science Foundation, Partnerships for Innovation: Building Innovation Capacity**
PI on $580K grant to design novel MRI systems utilizing MgB_2 superconducting wire and cryogenically cooled RF coils.

Teaching Experience and Awards

2017 Nominated for the Carl F. Wittke Award for Excellence in Undergraduate Teaching.
2016 CWRU ITS Active Learning+ Fellow. Introduce 3D augmented reality (HoloLens) into the PHYS 324 (Electricity and Magnetism) classroom.
2016 Nominated for J. Bruce Jackson, MD, Award for Excellence in Undergraduate Mentoring.
2016 Nominated for the Carl F. Wittke Award for Excellence in Undergraduate Teaching.
2015 Active Learning Fellowship program in the ITS department at CWRU.
2014 Nominated for the Diekhoff Award for Mentoring
2012 UCITE Learning Fellow, CWRU