

Developing an Interactive Mechanism Design and Simulation Tool using VR

BACKGROUND

Robotics is an increasingly popular tool in engineering education. Robots in K-12 experiences are often off-the-shelf products which feature modular parts and a build experience which guides students predictably towards a working robot, potentially restricting creativity. Thus, it is difficult for amateurs to gain an intuitive, let alone analytical understanding of how the many factors in a design experience may affect a robot's motion and performance. The design process is an exploration of failure: students must build failed mechanisms to understand what will work. A comprehensive and intuitive design and simulation software package could be used to bridge this gap between the desired movements and the optimal design to achieve them.

Game engines are gaining popularity as a modeling tool due to their easy-to-use integrated graphics and physics capabilities. The Unity game engine has been used in academic research to model complex, dynamic systems in fields ranging from molecular biology to urban planning [1, 2]. Unity has also been used within the field of robotics to model and optimize control algorithms [3, 4]. Meanwhile, previous works have explored virtual reality's capabilities of 3D modeling with the conclusion that it resulted in greater creativity and faster feature creation rate than traditional CAD programs [5]. Industry has also adopted virtual reality as a tool for testing how users interact with engineering designs, because it can quickly provide an immersive experience for the user without the costs of fabrication [6]. For example, the Ford Motor Company uses virtual reality to allow users to interact with their vehicles' interior layouts to gain feedback on the ergonomics during the development process [6].

INTELLECTUAL MERIT

I propose leveraging the simulation capabilities of game engines along with the interactive experiences provided by virtual reality to investigate whether a virtual design tool for robots can make the process more accessible and engaging for novices. Existing research has developed virtual reality tools for engineering education; however, these tools have focused on visualizing and interacting with static problems [7, 8]. This work will focus on simulating dynamic mechanisms, with a focus on allowing the user to interact with and control the mechanisms' movements. My goal is to make the design of mechanisms more intuitive by allowing the user to quickly draw or assemble a mechanism in a virtual space and then interact with it to see how their design will move. This provides more intuition when designing than drawing a static sketch on paper or in a traditional CAD environment. Thanks to the simulation capabilities of game engines, however, this concept can go beyond merely visualizing the kinematics of a device. Once the user is satisfied their robot is capable of the movements they desire, the user will be able to place the robot in a dynamic simulation to see if the robot will perform as desired. This will be the first general-purpose dynamic simulation environment in VR. This will allow the user to have a more realistic visualization of the device, but also to design, test, and optimize the robot's control algorithms all within the virtual space.

Methods

I will use the game engine Unity because I have explored its usefulness as a simulation and optimization tool for robotic systems in my undergraduate research. Whereas prior mechanisms had to be manually coded into the system, this work will build a general-purpose, interactive design tool for constructing robots in the virtual space. This will involve developing intuitive interface for a user to draw and connect primitive shapes to form a mechanism using a VR headset, position-tracking cameras, and controllers (such as an HTC Vive).

The next phase will be to develop a system whereby the user can quickly set up and run automated tests in the dynamic simulation environment to see how their mechanism performs. In these tests the user should be able to interact with the robot in the virtual space by manipulating parts of the mechanism to manually create motion and then write control algorithms to recreate the same motion. My prior work has indicated that this can be done by extracting information about the state of a mechanism, which can then be fed into a feedback loop in Unity.

Evaluation

The completed virtual environment shall be compared against a traditional design approach through user trials. Following the example of existing research, these trials will take the form of a class, perhaps through a collaboration with a colleague in engineering education, in which students are presented with different robotic mechanism design challenges and are allowed to use either traditional design tools such as CAD software or this virtual environment [9]. Then the speed and effectiveness with which the students complete the challenges can be measured and compared to determine if the virtual environment is a more effective tool for facilitating the design of mechanisms. Moreover, the student's understanding between the mechanical design of a mechanism and its motion should be assessed before and after these trials to determine which tool led to a more intuitive understanding of these relations.

BROADER IMPACTS

This work will explore whether virtual reality can be leveraged as a tool to enhance users' design capabilities. This should prove particularly useful for novices by providing an intuitive interface for designing mechanisms. Students will be able to grasp the mathematical relations that dictate a design's performance more readily when they have a tool for investigating those relationships themselves. If the evaluation results are promising, then a working version of the virtual environment can be made available online so that other instructors and students can explore its usefulness. The performance of the virtual environment compared with traditional design tools will indicate what improvements in VR technology or modeling/simulation software are necessary.

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