University of California, Irvine

SENIOR DESIGN MIDTERM: ABET REQUIREMENTS
TEAM 4DR

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4DR : 3D Reconstruction in Real Time

Note: Our project goal is to build upon 3d reconstruction in order to have full body tracking in relation to virtual reality. Therefore the project expands on the limitation of virtual reality and as a result, should have the same associated benefits that virtual reality achieves in meeting specific needs fitting a wide range of topics.

2.1) An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety and welfare.

Our project poses very little threat to public health, safety, or welfare. The only hardware components of the projects are the cameras, sensors, and computers. There is little to no risk that this equipment entails. In addition the devices will be operated in a closed environmental therefore it will not be in contact with the general public. Though we do understand that accidents and injury may occur no matter how low the risk is. With this in mind we strive to be as diligent as possible by adhering to strict safety procedures.

Our safety procedures for working with our Raspberry Pi's include the following. Not placing the device on conduction surface, which may lead to electrocution. Keeping the device away from any liquids, which may damage device or cause electrocution. Avoid handling the device while it is powered, be sure to properly power the device off before handling any hardware components. Lastly, be sure to keep the device away from excessive heat, the Pi's are designed to work at normal temperatures, excess heat may lead to damages and injuries (Jones).

In the case of emergencies, where an individual has been injured. Protocols has been set to ensure the safe recovery of the individual. Depending on the severity of the injury, emergency services may need to be called. Minor injuries will be treated on-site, with readily available first-aid kits.

The risk with conducting this project is very minimal. Despite this fact we intend on upholding the safety of the public and team members through strict safety protocols and rules.

2.2) An ability to apply engineering design to produce solutions that meet specified needs with consideration of global, cultural and social factors.

3D reconstruction could allow for full body motion tracking in virtual reality. Virtual reality (VR) has been used for a wide range of tasks across the world. Here in America, we have seen the use of virtual reality for entertainment in VR system such as the Playstation VR. In China, VR is a rapidly growing industry. The VR market in China is projected to be worth 7.9 billion USD by 2021 (Jing). Being able to track a body will completely change the world, as this will allow both VR and AR (Augmented reality) to grow. This is one of the main reasons that this project does not stop at 3D reconstruction, but trying to run it in real time.

Within a social and cultural context, the problem arises that 3D construction could be used with malicious intent. Deep fakes (see figure below) have become more prevalent because facial recognition technology has become more advanced through the coming years. These pictures, or videos that are completely false and can be used to worse degree with this project. For example with our project, Reconstructed 3D models of people may be used to create fake information and defame people. This puts a further emphasis on protection user data. There is an even greater risk for losing this information since this data may be sent across the internet to help the microcontroller with its processing. So to avoid possible leaks of private information, our project has a way of encrypting the message being sent across the internet. Also, users of the device should understand that they also have a responsibility of using the 3D reconstructed models in an appropriate way. Security, privacy, and encryption are all important design elements to remember when developing this project.

Another cultural impact that this can have within the world is the ability to give computer-generated-imagery artists and other computer-based artists a new accessible tool. The point of this project is to create a cheap alternative to the motion tracking suits and rigs within the cinema industry. The entire rig is designed with minimizing cost while maximizing quality of the 3d reconstructed models. Allowing artists to have more tools available, especially tools that were not readily available to them before, will give them an opportunity to contribute to different expertises. Many more people can get into cgi, video games, and other jobs that need video tracking.

2.3) An ability to apply engineering design to produce solutions that meet specified needs with consideration of environmental and economic factors.

The current world is coming to a global crisis of climate change because of many factors, one being the higher need for power by the average consumer. Power plants causes large emissions of greenhouse gasses in the atmosphere, leading to global warming, which eventually cause more people to use more energy for electronics like air conditioning and refrigerators. Our project will end up using a high amount of power, as to have it running in real time, it will need a graphics processing unit, gpu, to help us run such intensive code. So we need to also optimize our code, so that it does not require more processing power than required. Also, when scaling

this network of cameras up to larger numbers, we will look to need more components, which means more power needed.

Also, electronic waste can become a problem in the new future, so if we create a device made up of so many cameras, and microcontrollers, we need to remember that these electronic components will need to be recycled one day. Dependent on what materials our electronic components are made of, the creation and disposal process for those materials may be harmful for people. For example, polyvinyl chloride, or PVC, is a plastic that found in some power chords, which emitted deadly and harmful chemicals when being produced, and being burned for disposal (Cernansky). So when looking for components, it is important that we choose devices that are both long lasting, and are not created with hazardous materials. Additionally, these electronic components need to be used for a long time, so that there is no need to replace these components. So when choosing components, there was a choice between very cheap cameras with low resolution, and a bit more expensive cameras with higher resolution. The better choice was to get the cameras with higher resolution, because they would last longer within this world of ever-improving technology.

Finally, in the economic sense, the project is meant to be used by all types of people. This technology of 3D reconstruction should be open to the public, and this project looks to open up these topics by creating a more accessible 3D reconstruction device. Part of being accessible to the market, is to create it from cheap components, and keeping the barrier of entry from being low. This can go against the design choice of the environment, but there needs to be a balance between the two, to make sure this device is not too expensive for people to use. By allowing 3D reconstruction to be more readily available, it will also affect the market with the ability to 3D print those 3D reconstructions. Imagine a marble artist who is able to scan their sculpture and easily recreate that design, without needing the skills of a 3D modeler, and 3D printing their creation. This accessibility is important for the market, which is why the project will look into creating 3D objects as the end goal.

4.1) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments considering the impact of engineering solutions in a global and societal context.

The 4DR project requires use of optical sensors or cameras to collect data and therefore could raise a societal concern for data privacy if the product was used in a public area. The team's responsibilities would be to address these concerns and comply with any sort of regulation or law. Therefore, addressing these concerns, current efforts for testing the project are in private and in a closed environment. If the project were to expand out toward use in the public, there will be no efforts to publish any data collected but any data used will only be used with no ill intent to complete the sole action of the project which is 3D reconstruction. If the situation arises where our data collected was required to be public and our product was used in public, before publication, all data will be scrubbed for Personally Identifiable Data (PID) and removed.

The team has no intention of the last situation happening but will have efforts to ensure that we remove PID and are prepared if does happen.

The following will be a hypothetical of how our team would handle the worst possible situation regarding data privacy concerns. For example, we are testing our project outside to 3d reconstruct a car and plan to publicly share our data (we will most likely never have this plan realistically) and a person happens to be in the background when we decide to collect images and their face is shown in the images. The person raises the concerns that they do not want the pictures taken and we will address the issue by telling them that all image that can personally identify someone is completely deleted and provide them some documentation similar to the Chicago's Array of Things (initiative where nodes collect data) Privacy Policy. In the Array of Things Privacy Policy, they state that "Any such data (PID), such as could be found in images or sounds, will not be made public;" something along the lines of remove data or keeping it private would be our goal (Array of Things). If the situation occurred where we *have* to publish some sort of data, we would blur out the person's face, similar to what is seen in the figure to the right. The hypothetical is the worst situation that could occur and most likely would not happen but our team will be responsible and prepared to handle any such situation.

In terms of citation of contribution and work outside of the team, we acknowledge all references and team responsibilities in our work, code, documentation, and all other publications. For example, we have mentioned that OpenCV has been a huge resource in developing our project and therefore is cited in all places where it is used.

4.2) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in an economic and environmental context.

Our team, 4DR, recognizes the impact that electronic waste has on our environment and how our planet is finite in terms of spatial constraints. Although our project produces minimal waste, we understand that even buying any electronic component, such as a camera we may need, can eventually become waste. With that into consideration, we have bought only the necessary components that our project, 3D Reconstruction, needs in order to run. We are also utilizing hardware that we already own. By only buying components that are essential for our project to run and utilizing hardware our members already own, we are reducing the electronic waste, if any, our project may produce.

In terms of an economical context, our team bought most of the components needed for our project ourselves. The information about getting funded by UCI was relayed to our team after we already bought most of our necessary components. Our team only used the UCI funds to buy our last essential component because abusing and misusing UCI funds to buy unnecessary components would be unethical in an economic sense. In turn, this allows other groups to ethically use UCI funds for their necessary components. Our project was mostly funded by ourselves, therefore we took into consideration of how our budget would affect our product. Increasing it or decreasing our budget was based on how we thought a cheaper or pricier component would affect the real-time aspect of our project and we decided that we would buy the components that allow a somewhat seamless real-time 3D reconstruction of an object.

Overall, our team recognizes the impact that any engineering solution can have on our environment as well as how unethical the abuse of funds an engineering solution is given, without a set budget, can be, such as buying a component in bulk when only one is required. Therefore we took the necessary actions with these impacts in mind, such as creating a budget, buying only the essential components for our project to run, and utilizing hardware components we already own. By doing that we reduce the environmental impact and reduce the economical cost our project has.

7) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Our project, 3D Reconstruction, was beyond the scope of our knowledge (in terms of skills set and equipment) coming into the course. Therefore our members had to do extensive research on what equipment, programs, and skills were required in order to accomplish our goal. We needed to acquire new knowledge about 3D Reconstruction and the scope beyond (such as motion capture and VR) through extensive research and through our advisor, who has plenty of experience on machine vision.

When it comes to 3D reconstructing an object, we needed to learn the workflow of how to transform multiple 2D images to the third dimension. We researched and talked to our advisor on how can we take images from a stereo camera setup and then map them out in a way that allows us to get the depth of an object. For example, we found that in order to be able to map out the 2d images of the object and extract depth information, we needed to learn about epipolar geometry. In order to create the epilines that match a corresponding point in one image taken by 1 camera to epiline in the image taken by the other camera, which allows us to extract the depth of an object, we had to calculate the fundamental matrix. We then calculate this fundamental matrix by utilizing OpenCV to help us derive a set known of points in each image. In addition, our advisor told us about certain calibration techniques for the cameras. For example, one team member found through his research about using infrared projection to calibrate our cameras.

Epipolar geometry is only one of the strategies to reach our end goal and its application has been useful to our learning.

In addition to learning the process of creating our end goal product, the main caveat was project management. Our learning strategies could not be limited to the creation of the project but had to include the management of our projects in terms of meetings, presentations, reporting, and all other aspects. Additionally, we had to transition from individual work to working as a team. Our project management knowledge had a slow start in terms of being applicable but has streamlined to help us reach our end goal.

The members of 4DR are constantly researching and communicating with our advisor about more intelligent, more efficient, and practical ways to develop our project. Through our research we have found an assortment of techniques and resources to help aid our endeavor of 3D reconstructing an object, therefore illustrating our ability to acquire and apply new knowledge when needed. The ability to apply knowledge seamlessly moving forward has enabled us to progress in a timely matter and increase our proficiency in the topic of 3D reconstruction.

Work Cited

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