Implementation of augmented reality in SAE Mini Baja

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IMPLEMENTATION OF AUGMENTED REALITY IN SAE MINI BAJA

by

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Submitted to Brigham Young University in partial fulfillment of graduation requirements for University Honors

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ABSTRACT

IMPLEMENTATION OF AUGMENTED REALITY
IN SAE MINI BAJA

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Engineers often encounter difficulties in connecting digital data with its physical counterpart. This applies to processing and interpreting data as well as effectively communicating design ideas and considerations. Augmented reality has the ability to solve these problems by overlaying digital data on a physical object. This allows engineers to further explore design considerations such as ergonomics as well as communicate data such as, Finite Element Analysis. This communication may be realized in discussing and collaborating with colleagues, as well as to judges in design reviews. Augmented reality is beneficial in these cases and is further explored in this thesis, utilizing the 2019 Brigham Young University Mini Baja vehicle as a case study.
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TABLE OF CONTENTS

ABSTRACT ....................................................................................................................... iii
ACKNOWLEDGEMENTS .................................................................................................... v
TABLE OF CONTENTS .................................................................................................. vii
LIST OF FIGURES .......................................................................................................... ix
1 Introduction ...................................................................................................................... 1
  1.1 Problem ..................................................................................................................... 1
  1.2 Solution ...................................................................................................................... 2
  1.3 Hypothesis .................................................................................................................. 4
2 Literature and Technology Review ............................................................................... 5
  2.1 Technology Review ..................................................................................................... 5
  2.2 Literature Review ....................................................................................................... 6
3 Methods .......................................................................................................................... 11
  3.1 Introduction to software ............................................................................................. 11
4 Results and Discussion ................................................................................................. 17
  4.1 Spatial Experiences .................................................................................................... 17
  4.2 ThingMark Experiences .......................................................................................... 20
  4.3 AR and Ergonomics .................................................................................................... 23
  4.4 Experience server technology .................................................................................. 25
5 Conclusions ................................................................................................................... 26
  5.1 Conclusion .................................................................................................................. 26
  5.2 Recommendations for Future Work ......................................................................... 26
6 References ..................................................................................................................... 29
Appendix A. PTC Software Explanation .......................................................................... 31
Appendix B. Viewing AR Experiences ............................................................................. 32
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>ThingMark</td>
<td>6</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Vuforia Studio</td>
<td>11</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Creo Simulate</td>
<td>13</td>
</tr>
<tr>
<td>Figure 4</td>
<td>FEA Analysis</td>
<td>14</td>
</tr>
<tr>
<td>Figure 5</td>
<td>FEA Experience</td>
<td>17</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Pedal Assembly</td>
<td>18</td>
</tr>
<tr>
<td>Figure 7</td>
<td>ThingMark Tracking</td>
<td>20</td>
</tr>
<tr>
<td>Figure 8</td>
<td>ThingMark Experience</td>
<td>21</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Ergonomics with AR</td>
<td>23</td>
</tr>
</tbody>
</table>
1 INTRODUCTION

1.1 Problem

In engineering, a large portion of time is dedicated to gathering and interpreting data. Although this applies to all areas of engineering, the automotive sector may be taken as a case study. In this case, it is often necessary for engineers to gather data such as: stress/strain, acceleration, linear speed, angular velocity, shock compression, fuel usage, etc. Traditionally, after these data have been gathered, it is collected in a two-dimensional (2-D) environment. Common environments include word documents, pdfs, pictures, and paper. This forces engineers to couple 2-D data with its appropriate three-dimensional (3-D) counterpart. Porter and Heppelmann (2017) describe the problem well:

There is a fundamental disconnect between the wealth of digital data available to us and the physical world in which we apply it. While reality is three-dimensional, the rich data we now have to inform our decisions and actions remains trapped on two-dimensional pages and screens. This gulf between the real and digital worlds limits our ability to take advantage of the torrent of information and insights produced by billions of smart, connected products worldwide (p.47).

It is vital to find new ways of viewing and connecting 2-D information with its 3-D counterpart. These new ways may not only relieve stress one may feel in analyzing data but may also provide a faster and more efficient way to interpret and use these data. This proposed type of technology may allow for a greater capacity to process information and
make critical design decisions for products in general. Connecting the 2-D and 3-D worlds is not only a problem when personally interpreting data, but also in the communication of that data to colleagues and even consumers and technicians in many cases. The aforementioned technological problems base themselves not only in how to interpret data but how to more effectively communicate that data as well.

1.2 Solution

The desired solution then is an easily accessible piece of technology that integrates the collected or theoretical data with its respective 3-D complement. An emerging technology that appears to have the capabilities to confront this issue is Augmented Reality (AR). Most have prior knowledge of or experience with Virtual Reality (VR); however, AR is different from VR in that it overlays digital information onto the 3-D world, rather than completely creating a digital world such as VR. This may allow engineers to process and interpret data more effectively and efficiently in certain cases, as the data may be superimposed over the proper part or sub-system. This will increase the engineer’s ability to connect data, since both the data and the physical object are integrated into one another. It will also be useful, as one may view how a particular object interacts with its real and immediate surrounding space.

It is important to note that AR technology may not only be beneficial to engineers but many others’ as well. An example career may be in the case of a maintenance technician, whose job is to fix and replace parts on a particular product. Products such as automobiles, contain sub-system components such as transmissions that are extremely intricate and complicated. Due to this type of complexity, AR has the potential to be
beneficial in assisting the technician in the steps required to fix such a product. As such, there are many studies currently investigating the viability of augmented reality as a type of training tool with interactive directions. This tool provides visual aid to technicians in order to be certain that each step is followed properly. This helps to eliminate human errors and the down-time associated with those respective errors. The augmented reality experience can also be of great benefit to individual consumers. Basic AR technology is already integrated into most smart phones and tablets, and companies such as Parametric Technology Corporation (PTC), provide a free application for download that enables AR experiences on one’s phone. These capabilities can help a consumer visualize data of the product, such as shock compression, or it may be extended to provide an experience that enables the consumer to fix certain problems with the respective product.

A great opportunity to show case this technology and how it can be beneficial is through the Society of Automotive Engineers (SAE) Mini Baja program sponsored by Brigham Young University (BYU). The SAE Mini Baja program is an intercollegiate competition where teams design, build, and test a single seat, off-road vehicle to compete in a variety of static and dynamic events. Integrating AR technology into the vehicle will serve as a test to validate how well this technology will solve the aforementioned problems. It will also be capable of identifying possible limitations in the software and experiences while also providing suggestions for future improvements. This technology may especially be useful in situations where one must conduct a design review, such as those encountered in the Mini Baja competition. AR will enable engineers to quickly and efficiently convey information and design decisions to other engineers in such situations,
by creating and using an AR experience. Such experiences may include Finite Element Analysis (FEA), real-time data collection, data documents, and sequenced steps.

Although there are many different companies that provide AR software, this paper will focus on the programs and applications provided by PTC. PTC provided BYU with educational versions of this software, which are extremely user-friendly for first time AR users and creators. They also provide a free application for anyone to download and view experiences free of charge. PTC’s products contain cutting-edge technology and are an industry standard. As such, this software contains the most appropriate products in allowing one to fully investigate the hypothesis by creating high quality AR experiences to integrate into the Mini Baja vehicle.

1.3 Hypothesis

I hypothesize that integrating augmented reality technology into the SAE Mini Baja car will improve the ability of engineers to interpret and process data more effectively than common two-dimensional methods, while also providing effective design communication between engineers.
2 LITERATURE AND TECHNOLOGY REVIEW

2.1 Technology Review

AR is an emerging technology which has seen an exponential increase in usage over the last few years. AR used to be accessible only to those with expensive units costing in the range of thousands of dollars. Although most people still do not own AR glasses, such as HoloLens, most people do own technology that is capable of providing basic types of AR experiences. This is primarily seen in common smart phones and tablets. A majority of these devices have the technology to run AR apps and provide the user with an augmented reality experience. Some phones and tablets, such as the iPhone 6S and iPad Pro and newer, have sophisticated AR device hardware purposefully built in to provide enhanced experiences with Apple’s AR developer software known as Apple ARKit. Google also has released developer similar software known as ARCore that allows for enhanced experiences on certain devices.

PTC’s software remains most popular among engineering and manufacturing companies as an industry standard. This software contains three different types of an AR tracking experience one may utilize. The first being the model tracking type. In this type of experience the app recognizes a certain object by its geometry and then overlays a picture or some sort of data on top of the actual object. The second type of tracking is that of spatial tracking. In this experience one points the camera at a horizontal surface and then clicks the respective surface. This action places the experience in the desired space and allows one to rotate (two fingers), pan (one finger), and zoom (pinch zoom) by touching your fingers to the object on the screen. The aforementioned Apple devices and
certain Android devices are capable to provide the user with these first two experiences. More information on acceptable devices and minimum hardware requirements regarding these experiences may be found on Vuforia’s website (Corporation, 2018). The third type of tracking is that of marker tracking. These experiences involve creating a marker and placing it in a specific location which will allow a general smart device to scan the marker and bring up the experience. The experience will remain only where the logo is located in space. In general, current smart devices are manufactured with the minimum hardware to provide for marker type tracking experiences. As AR is so readily accessible to the general public, it is imperative that its usage and benefits be further investigated in regard to the problem of disconnected data and physical objects.

2.2 Literature Review

To the best knowledge of the author, there appears to be very little to no literature existing on implementing AR experiences in cases of a Mini Baja program. As such, the literature review will contain information and articles representing a larger market sector,
being the automotive industry as well as general studies on AR. It appears that AR is in its infant stages regarding automotive applications in terms of the problems this paper seeks to address. Although there exists several articles detailing how AR may be used to increase the productivity of workers and manufacturing plants, there seems to be very little information on how AR may be beneficial in engineering applications. This paper will address the current literature regarding the use cases of AR in the automotive sector as well as acknowledge gaps to better provide direction for a course this study and future studies may follow to fill those respective gaps.

In a general sense, many companies are looking at how AR may be beneficial and are working to introduce new software and hardware to take advantage of AR experiences. Companies, such as Microsoft and Google, are working to produce viable AR glasses that may be used across all industries. An interesting example is produced in Microsoft’s most recent patent application publication. In this document the HoloLens is anticipated to be used not only in the private sector but the military sector as well. It is shown in the patent application that the newest version of HoloLens is anticipated to be a useful counter-terrorism tool. These new HoloLens will have the capability to conduct facial recognition and scan fingerprints and irides. This will allow HoloLens to build an in-field bioinformatics file which is then connected and shared with appropriate personnel in a field pursuit of wanted terrorists (Ralph F. Osterhout et al., 2019).

More specifically in the automotive sector, AR has been partially successful in being integrated into a consumer product that produces a heads-up windshield display that shows Global Positioning System (GPS) directions and information. It has also shown to be beneficial in automotive early warning systems. In such systems AR warning
information is projected on a heads-up windshield display. Schwartz and Fastenmeier (2017) show that augmented reality has the capability to further reduce traffic accidents by detecting potential problems and alerting the driver through various modal and specificity interfaces. This allows the driver to be alerted and react quicker than a case without an AR detection system.

The most popular use cases of AR involve experiences as an educational tool for students. In many schools across the world, AR is utilized to teach students about many different subjects. A study found that AR in the classroom is not only beneficial for students but teachers and professors as well. AR experiences provide tools for educators to apply in helping students visualize important concepts. It has been shown that in some situations, it may actually decrease the role an educator plays in the learning process because it enables learners to collaborate with other colleagues or friends depending on the situation (da Silva, Teixeira, Cavalcante, & Teichrieb, 2019). This shows that AR is very useful in collaboration dependent cases. It may be very useful in engineering as it will allow engineers to collaborate with one another using visual aids and thus being able to communicate design ideas more effectively.

In addition to AR as a consumer product, it is also clear that it is extremely beneficial as a training tool, especially in regard to automotive production line technicians. Mendoza et. al (2015) conducted a study in which factory workers utilized AR for torque auditing in automobile manufacturing plants. It was shown that AR not only significantly reduced training time but also increased statistical quality as there were fewer human errors with AR monitored torque auditing.
A study conducted by Jetter, Eimecke, & Rese (2018) show several key benefits for the use of augmented reality in industrial automotive applications. This study evaluated Key-Performance Indicators (KPI) that markets use to evaluate the effectiveness of AR experiences. Four major KPI’s represented in this study are reduction of time and errors, ease of use, spatial representation of contextual information, and cognitive workload. The conclusions of this study found that AR significantly decreased cognitive workload while both reduction of time and errors and spatial representation of contextual information significantly increased. This result agrees, in part, with a study conducted by Borsci, Lawson, Jha, Burges, and Salanitri (2016), in which it was found that immediately after training, a greater cognitive workload led to increased errors and time for an automotive technician to perform a given procedure. The technicians trained in a 3-D environment were able to not only decrease errors in the procedure but also perform it faster than the control group. This was due to a perceived decrease in cognitive workload among those trained in the 3-D environment. The results of this study may be extended to engineering as well, as AR experiences have the potential to decrease the cognitive workload of engineers and have similar benefits.

AR may also be integrated into smart, connected products. These products contain many sensors gathering data and transmitting it to the internet. Products can then communicate with one another or utilize artificial intelligence software to predict the performance of a device or even alert the user of a forecasted problem based on historical data. These types of products have the capability to further productivity and create better more customizable products for consumers (Porter & Heppelmann, 2014). These products may also transform companies as they utilize data analytics from the data
gathered among the various sensors. Certain companies employ a tool known as a “digital twin” in which a 3-D digital counterpart evolves to show how the physical product is changing in its respective environment. This allows a company to visualize the condition of a product even if not physically present (Porter & Heppelmann, 2015).

This thesis will address how AR may be used in design reviews and specifically for those held during the Mini Baja competition. Although using AR specifically in design reviews may be a somewhat novel idea, it is not new in relation to VR technology. Several studies (Freeman, Salmon, & Coburn, 2016; Coburn, Freeman, & Salmon, 2017; and Freeman, Salmon & Coburn 2018) have shown benefits for using VR technology in the design process. Although this thesis does not discuss VR specifically, it is important the reader is made aware of the key benefits of using VR in design reviews. This thesis explores ways in which AR may be of a similar benefit in improving the communication between engineers and in the design process.

The literature indicates that there are many uses for AR. In general, it serves as an effective learning tool which is seen more specifically in the automotive industry among technicians and line workers. Using AR in these cases will reduce errors and increase productivity. However, after conducting a literature review it appears there is a gap in the literature in how AR solutions can benefit engineers and more specifically mechanical engineers. This thesis will seek to address a few initial points that AR experiences may be able to assist with in these cases.
3 METHODS

3.1 Introduction to software

PTC’s software is relatively easy and straightforward to use. Vuforia studio is PTC’s main AR software. This software is available for anyone to download and comes with a 30-day free trial so anyone can get started for free. BYU owns a Vuforia enabled server to publish an unlimited amount of experiences. These experiences will remain available for viewing as long as the server is functioning correctly and has an up to date license key. However, in order to begin using the Vuforia software it is necessary to have a 3-D model at the very least. PTC produces a piece of Computer-Aided Design (CAD)

Figure 2 shows a screenshot of Vuforia Studio. This figure validates Solidworks models open directly in Vuforia. This figure is also given as a reference for the steps mentioned above regarding the creation of a basic AR experience.

software known as Creo Parametric (previously known as Pro-Engineer). This software integrates very well, not only with PTC’s products, but other CAD formats as well.
Vuforia studio allows one to upload CAD files from Creo, Solidworks, Inventor, and CATIA, as well as IGES, STEP, and STL files. This makes Vuforia extremely versatile with cross-platform formats and is very important for the use case mentioned above. The BYU Mini Baja team has CAD files in several different programs as well as several versions of said programs. The feature is very straightforward and is utilized by clicking upload (under resources), select files, click on the desired file, open, and then click add. After a file is uploaded to an experience, the user must drag and drop either a spatial target or ThingMark to the center pane (see Chapter 2.1) after which one does the same with the model item. From this point one navigates to the right most panel on the screen and under resources selects the desired CAD file. Then click save and publish which completes the steps for creating a basic AR experience (Fig. 2).
Although this basic experience is somewhat useful in order to solve the aforementioned problem it is important that we connect digital data so that engineers can better interpret and process the respective data. A very useful feature that can be incorporated into the experience is FEA. Although Vuforia does not conduct FEA by itself, it is possible to conduct a design study in Creo Simulate (Figs. 3-4) and then save the results as a 3-D model. This is a very useful feature which the Mini Baja team is focused on utilizing to be able to more effectively communicate design considerations and decisions with one another and in the design review for the 2019 Mini Baja design competition.

**Figure 3** shows Creo Simulate is very similar to other types of FEA packages. This is the model for the 2019 Mini Baja pedal assembly. The blue arrows indicate a displacement and the orange arrows indicate loading on the brake pedals.
To prepare the FEA results from Creo Simulate it is necessary to save the file as a .ol file type. This allows the results to be saved as a CAD file in which the FEA data is displayed over the top of the object. From here there are two choices one may make. The first is to upload it directly into Vuforia Studio and create an AR experience similar to the basic one with the addition of FEA data. The other choice is to import the file into Creo Illustrate which can then be utilized to create sequenced steps. The benefits of sequenced steps are briefly considered but creating a full experience with analysis is outside the scope of this project. Once in Creo Illustrate click on import, embed, and then the desired file. This allows an AR user to click through steps to assemble or disassemble components for a given assembly. This could be very useful for engineers in communicating their design work so to others so as to be able to understand how each

**Figure 4** shows the calculated von Mises stress plot for the conditions shown in Fig. 2.
component interacts with other components and how to conduct proper maintenance on any given part. It could also be used as a training tool for maintenance technicians which will not only speed up training but would also decrease human errors in fixing a given part or product.

Vuforia Studio is extremely versatile in the amount and types of experiences one may create. Another interesting experience worthy to note, is that Vuforia Studio also allows one to overlay real-time data on an augmented object. This technology is being implemented in manufacturing plants so that the status of machines may be monitored all at once just by simply holding a tablet or cell phone up to view the machines and their status. When used in conjunction with another PTC program called Thingworx, one may utilize the Artificial Intelligence (AI). The AI can look at historical trends of certain data and make predictions based on it. In the case of the Mini Baja vehicle it is possible to attach various sensors to the car which values are then sent over cellular network to Thingworx. Thingworx could then send notifications to the pit crew such as low fuel and clogged air filter warnings. This could increase the effectiveness and efficiency of a pit crew which is very important for endurance competitions. This type of AR experience requires quite a bit more knowledge of Information Technology and as such is also outside the scope of this project but is currently being investigated further by the Mini Baja team.

Vuforia Studio also allows one to attach documents to a given object and create hyperlinks to be able to switch back and forth between the documents and other models and experiences. This will likely be helpful in the design competition because it will allow us to switch between a normal model and an analysis model, such as that created
with FEA. It will also allow one to upload capstone artifacts that go into further detail about the design. This will not only make design reviews more efficient but will help each engineer communicate their design effectively to the judges. Not only will the judges be able to view the model, but they can switch to see 3-D analysis and can read artifacts of interest that detail the design and the changes made through each iteration. This will impact the team’s design review score and also help in communicating across each sub-team as to what is happening with the car and how each sub-team can better integrate the sub-systems with one another. Vuforia Studio makes this easy as one uploads the required artifacts into resources using the process mentioned above, then click on the 2-D box, drag and drop the hyperlink widget to the desired section of the screen, then use the right panel to link the document. Other widgets may be dragged and dropped that allow one to create an even more refined experienced. Such widgets could include 3-D gages or text, 3-D clickable buttons, and slider bars that allow for more degrees of freedom in how one slides and rotates an object in order to better view its data.
4 RESULTS AND DISCUSSION

4.1 Spatial Experiences

The results of Vuforia Studio provide high quality AR experiences rich in valuable information for engineers. Figure 5 shows a typical experience created for the Mini Baja team. This experience shows the FEA data for the 2019 pedal assembly. These types of experiences will now be very impactful, as anyone with a smart device may review the

Figure 5 shows a spatial experience arbitrarily located in space. This object may be placed on any horizontal surface that the user desires.
entirety of FEA data for this particular component without requiring sophisticated and expensive computer software. Such an experience is more beneficial in comparison to paper data, as a reviewer can now specifically explore the areas of interest of the component and view different locations where stress concentrations may be a concern. For example,

**Figure 6** shows the Pedal Assembly experience located in the car. This was done using spatial tracking and as such the user had to manually place these pedals in the car.
if a question is raised about how this data influenced the design, one may simply click on the hyperlink entitled “FEA Doc”. This brings a capstone justification artifact to the screen, which displays information on forces and displacements used, as well as safety factors. In this experience there is also a document detailing how this design meets SAE requirements and is rules compliant for a technical inspection which happens on-site at the competition. This helps engineers to quickly and efficiently display a given design and formal documentation to more effectively communicate design considerations to the judges. This experience also allows a user to switch between the analysis mode and a normal view mode (Fig. 6). As such, the user is given more control over which data they wish to view v. which to hide. This provides more customization options to allow a user to operate the experience to their maximum benefit in order to best understand and process the offered data.

These types of experiences will be very beneficial to the Mini Baja team. Sub-team leads will each be provided an iPad for the competition design review. Each sub-team will have a list of experiences they may utilize with appropriate hyperlinks to design artifacts. This will allow sub-team leads to conduct a well-organized presentation that proficiently communicates the team’s designs to the review judges. A disadvantage that should be noted is that, these types of experiences are not available on all devices as was discussed in further detail in Chapter 2.

Another disadvantage is that unfortunately, the locations of most Mini Baja competitions have spotty cell phone coverage at best. In such situations, it is important to be able to download and view experiences offline. Experiences that involve real-time data would also lose functionality in off-line environments and users will not be able to
update any experience without an internet connection. Vuforia View does provide the option to download an experience and save it to your personal library, provided the appropriate box is checked in Vuforia Studio when the experience was created. This option does allow one to download simpler experiences such as those seen in Figs. 5-9. This is a very important option because similar experiences will be used in the design review in communication and explanations with the judges.

4.2 ThingMark Experiences

Another experience type that the team will utilize is that which is tracked through a ThingMark. This allows any smart device to access a given experience. It may also be useful to utilize this type of experience specifically for design fairs and consumers.

Figure 7 shows a ThingMark placed in a specific location where the new pedal assembly is desired. This logo type tracking allows any smart device to view an experience.
ThingMarks may be strategically placed around the car so that as students and judges come to view the work and engineering of the car, they may download the Vuforia View app and view information about key points the team wishes to communicate about the car. Such places may include a marker for the Electronically Controlled Continuously Variable Transmission (ECVT), electronic control system, and the driver’s control.

Figure 8 shows an AR experience utilizing ThingMark tracking.
system, as these are the three main areas the 2019 Baja team is designing. This will help the team to be able to communicate the chosen designs in an interesting and engaging way. Vuforia also allows for attachments of videos and images. This is a useful tool for environments where the car cannot be physically turned on in order to convey such information. One such case would be videos of BYU’s newly developed ECVT. As this is a major engineering project conducted by this year’s team, it is important to emphasize this feature and communicate its design and advantages in an effective manner in the previously mentioned environments. An AR experience that includes a video of the working ECVT would be extremely useful in showing others how it worked and why it is a superior design over a mechanical CVT.

Another limitation in some cases is seen in Fig. 8. This limitation is that the AR experience is overlaid on top of everything else on screen. Even though the steering column should be seen in-front of the AR model, it is seen behind. This was also a limitation in Fig. 9 because we were not able to actually view a foot on top of the pedal assembly. This limitation should be investigated further to assess if it is possible to change certain parameters to allow for other objects to be in-front of the actual model. If this is not possible, then it would be a good feature for PTC to add in future revisions of Vuforia Studio.
4.3 AR and Ergonomics

Augmented Reality can also be useful in determining spatial orientation of objects in relation to real objects. This is seen in Fig. 9 where the pedal assembly is shown in relation to a driver’s foot. This is a quick and easy way to help engineers understand how the object interacts with its surroundings. In this case, a consideration of the resting angle of the pedals may be adjusted in order to create better ergonomics. This consideration is critical to competition performance so that the driver tires less and thus will have more stamina to perform well in the endurance race.

Figure 9 shows an Augmented Reality experience being utilized to look at foot position and which positions are comfortable to the user.
The AR experience shown in Fig. 9 included slider bars in order to make adjustments to the angle of the pedal assembly. An experiment was conducted utilizing three potential drivers for the 2019 Mini Baja competition. The driver sat in the car and a person standing to the left side of the vehicle used an iPad to access the pedal assembly experience. This person rotated the angle of the pedal assembly until the driver indicated it was comfortable. A third person placed a fist for the driver to rest their foot on to more accurately simulate a reaction force. The experience was then screenshotted after which a protractor was used to measure the angle of the assembly that was most comfortable for that particular driver. This was repeated three times. The angles measured were as follows: $35^\circ$, $32^\circ$, and $34^\circ$. This allowed the engineers to quickly gather data on the ergonomics of the pedal assembly with feedback that would not be possible with a CAD model of a person. This data can then be used to optimize the angle of the pedals for the driver who will be operating the vehicle for the majority of the endurance race.

This is a powerful tool that may be extended to nearly every part of the vehicle such as the frame. In past years, the Baja team has been concerned with the ergonomics of the frame. A parametric model of the frame could be produced that allows an engineer to quickly create a few frame experiences with different shapes and sizes. This could allow engineers to quickly gather ergonomic data such as that gathered with the pedals. This would decrease the amount of time involved in determining which frame geometry minimizes mass while providing good ergonomics. This will allow the Baja team to more efficiently create a comfortable frame for the driver and help the team meet its deadlines on time.
4.4 Experience server technology

As seen above, AR technology has demonstrated great capabilities to help engineers communicate their designs with others; however, in the experiences shown above it relies on the internet and having the capability to connect to the BYU experience server. It is important to recognize that currently one must be using BYU’s campus network in order to access an experience. A Virtual Private Network (VPN) may be set up on any number of devices of varying operating systems such as iOS, Android, Windows, and Linux, to access BYU’s experience server. This allows nearly every type of device to utilize the BYU VPN network. An iPad Air 2 was used to verify that the server is set up correctly and does indeed allow access to experiences through the BYU VPN. The instructions to set up the VPN were provided through BYU’s CAEDM website (University, 2019). BYU also provides similar instructions for many other devices. The VPN functions so long as one has a CAEDM account with BYU. It may also be possible to use a cell phone as a mobile hotspot that has a VPN with BYU and then several devices may be able to connect to the hotspot and access the server to view the AR experiences.
5 CONCLUSIONS

5.1 Conclusion

In the literature review it was shown that AR will decrease errors and increase productivity of line workers and technicians. In the case of the Mini Baja vehicle, it was also shown that AR may be utilized by engineers to explore FEA data; however, perhaps one of the greatest contributions of AR in this study was in the consideration of ergonomics. The ergonomics data one may gather from an AR experience has the potential to largely decrease time spent on ergonomic considerations, while providing the engineer with an interactive experience to further explore the type of set-ups that are comfortable and feasible. The ergonomics experiment shows that integrating AR technology into the SAE Mini Baja vehicle will improve the ability of engineers to interpret and process data more effectively than common 2-D methods, while also providing effective design communication between engineers.

5.2 Recommendations for Future Work

This paper briefly explored some features that could be useful and should be looked in to further. Sequence modeling through Creo Illustrate appears to be user-friendly and allows one to create an AR experience with sequenced steps. This would be very useful in training situations but could also help engineers better visualize how components interact with each other. It could also be a helpful feature for the ECVT sub-team when communicating their design. The ECVT packaging will include many components not seen on traditional Mini Baja vehicles that run mechanical Continuously Variable
Transmissions (CVT). It includes extra sensors, bearings, wiring, controllers, and actuators that will be packaged tightly on the vehicle and may be hard to see or will even be hidden underneath a CVT cover. As such a sequenced AR experience may be useful in showing off the overall sub-system. Creo Illustrate should be investigated further to determine the quality of experiences that may be created that will help the Mini Baja team’s augmented reality suite of experiences.

Another type of experience to be investigated for potential use is those utilizing real-time updates. This could potentially be beneficial to engineers working as a pit crew in the testing of the prototype vehicle. Each engineering sub-team may have a particular experience that relates to their subsystem. For Driver’s Controls this experience may contain information about shock travel, fuel consumption, and even real-time updates on forces in the tie-rod, steering column, and pedal assembly. For the ECVT team, this experience may include real-time data on engine rpm, gear ratio, throttle position, acceleration, and speed. This type of experience could benefit these engineers as they develop and test the prototype vehicle in allowing them to obtain and process data in real-time as well as helping them to connect the data with each 3-D counterpart.

It will also be important for the Mini Baja team to consider model tracking experiences. Currently the BYU server does not allow for model tracking experiences but will soon be upgraded with this capability. In model tracking a CAD model of an object to be recognized is placed in Vuforia Studio, similar to the steps outlined for the basic pedal assembly experienced. Then one may add widgets, 3-D images, gages, etc. The biggest difference with this type of experience is that the CAD model is used to recognize the shape of a real object which then has 3-D data laid over it. In the experiences shown
in the above figures, the pedal assembly is a digital CAD model instead of the actual object. Model tracking will be even more useful as it shows the real object with the data and may be utilized for various parts of the vehicle.
6 REFERENCES


APPENDIX A. PTC SOFTWARE EXPLANATION

Thingworx – AI software. Device data is uploaded through the internet into this software and predictive analytics may be performed.

Vuforia Studio – AR experience software, where one may create and publish an AR experience.

Vuforia View – Free app available for download from the Apple Store or Google Play.

Creo Parametric – CAD software

Creo Simulate – FEA analysis software

Creo Illustrate – Software used to create specific figures of a device, sequenced steps, and animations of an assembly
APPENDIX B. VIEWING AR EXPERIENCES

- Download Vuforia View app to phone or tablet
- Connect to BYU wi-fi or VPN as discussed in Chapter 4
- Find scan mode and scan the QR code to the left. This tells the app which server to connect to
- If you have a device capable of spatial experiences these will be populated in the library tab and it is as simple as clicking on
- For all devices you may scan the following ThingMark to view an experience(s).
- Your device should be able to scan these on the computer screen; however, if it proves difficult print this page out and try again.