This Senior Project examines world of cutting-edge surveying technology which will be implemented into Cal Poly’s Construction Management 239 Construction Surveying course. It creates a field exercise for student learning that mimics the application of Global Navigation Satellite Systems (GNSS) and how they are used in the construction industry. The new exercise includes the use of GNSS receivers, base hubs, field computers, and a Topcon MAGNET Field application. From the research phase to the training/learning phase to the implementation of the assignment into the course this project embodied the “Learn-By-Doing” philosophy. This project was successful in demonstrating how GNSS base and rover receivers communicate between each other, satellites, and a field computer to survey an area in preparation for or during a construction project. Students were able to set up, collect points, and perform distance and area calculations using the Topcon receivers and Topcon MAGNET Field application for field computers. This project was completed in 6 weeks and was able to be rolled out for CM 239 Construction Surveying course’s Week 10 lab assignment.

**Key Words:** Surveying, GNSS, Receiver, Topcon, Field Computers, Assignment

**Introduction & Background**

Prior to this project there was a lack of information, assignments, and courses pertaining to the use of Global Navigation Satellite Systems (GNSS) being used for construction surveying. Through conversation with Construction Management faculty member, Dr. Bryan Knakiewicz, an idea to create a new lab activity for the Construction Management 239 Construction Surveying course surfaced in attempts to provide students with a more well-rounded education. The main objective for this new lab activity was to mimic the use of cutting-edge construction surveying technology. This lab will take students from setting up the receivers, to configuring them to communicate to each other as well as the proper satellites, to the collection points and using those points to identify locations, calculate elevation differences, area and distances. Before being able to produce such a lab activity it was essential to become well-versed on the subject of Global Navigation Satellite Systems (GNSS).

*What is GNSS?*

Global Navigation Satellite Systems or GNSS are like the Global Positioning Systems or GPS patented by the United States Government; in which both systems work through the communication between receivers and satellites. These systems use a satellite navigation otherwise known as SATNAV as a way to pinpoint exact locations across the globe. GNSS allows for an increased speed of surveying, not only within construction but in other industries as well. Some of the satellites that are communicated with include the Galileo constellation, the GPS constellation, the BDS constellation and the GLONASS constellation. The surveying equipment requires a minimum of two receivers and an application to control them. The GNSS receivers and antennas are used to locate “the form, boundary, position of objects or points in space relative to other forms, boundaries, or points” (Novatel). In terms of accuracy, the GNSS Systems can achieve up to centimeter precision.
and are especially good in open areas. Some of the best uses include localizing points, identifying building corners and setting up start/reference points.

**Equipment**

When it comes to using GNSS in the field, there are two types: RTN and RTK. RTN stands for Real-Time Network, which utilizes a network of fixed receivers that provide differential corrections in real-time to the rover through radio frequencies. The equipment required to operate and RTN systems include: a rover, a tripod, a rover rod, a RTN Subscription, a cell phone/Tablet or SIM card that accompanies handheld data collectors and a data collector. On the other hand, RTK stands for Real-Time Kinematic, which requires two receivers, a tripod for the base station, a rover rod with a tripod, cables, communication equipment, a data collector, power device as well as a handheld data collector. The base receiver will communicate with different satellites to achieve a real time position for the rover receiver. The lab created here uses the RTK style of surveying, with Topcon receivers and their MAGNET Field application.

**GNSS in Construction**

In construction there are three overarching types of surveying techniques that are typically associated with GNSS. The first is considered a static survey, which is where the receivers remain in a fixed location for the duration of the surveying observation. This period of time is often referred to as occupation time and is usually calculated by how long the rover receiver is kept in a static position in order to achieve the desired accuracy level. The longer the occupation time the more accurate the results will be. In the static survey a typical occupation time can range from ten minutes to six hours. The second type of surveying technique is referred to as a dynamic survey. With a dynamic survey the rover will be moved around the site to different locations while it continuously communicates with the same satellites as the base station. The added mobility of the dynamic survey provides an increased rate of coordinate point collection in comparison to a static survey. The tradeoff between the large number of points and added mobility means that the points are considered to be less accurate than those captured with a static survey. The algorithms that are used rely on the concept that while the rover receiver is in motion, it will stay locked onto the satellites no matter where it navigates to on the site. The third overarching surveying technique stems from the dynamic surveying technique. Real-time dynamic surveying utilizes similar algorithms and techniques explored by the dynamic survey. The key differences are that the rovers used in real-time dynamic surveying run and collect points in real time. Instead of having to apply different techniques and algorithms in post-processing, the coordinates will be provided in real time. With this type of surveying, it is essential that there is a permanent link or frequency communication link between the rover and the base station.

**GNSS vs. Total Station**

Often there are discussions and discrepancies about which type of surveying, GNSS or Total Station, are better. In short, they both have their own benefits, but there are five main categories that are used to compare the two. These categories include ruggedness, range, accuracy, setup, and line of sight. As noted in Figure 1, SITECH depicts a great comparison that shows the advantages of each. When it comes to ruggedness, the GPS or GNSS side of survey is more beneficial. The Total Stations have lots of glass, fragile pieces and moving parts that can easily break or become damaged if not taken
care of. The GPS on the other hand, has a hard rugged outer shell that protects the interior instruments from water and dust. The lack of moving parts also makes the GNSS systems more resistant to damage than Total Stations. With range, GPS once again is the better of the two options. When it comes to GPS and GNSS the range capability is significantly farther than a Total Station. This is due to the fact that a Total Station works with line of sight between the two pieces of equipment whereas GPS/GNSS communicate through radio frequencies. This means GNSS/GPS can be up to three miles apart and still communicate. When it comes to accuracy, the Total Station is about ten percent more accurate than a GPS. With this being said, GNSS and GPS systems are working to become more accurate. An example of this is the static survey discussed earlier. These devices can take up to 6 hours to achieve a similar type of accuracy as the Total Station. Setup is very comparable between the two. Both systems require daily setup and take down and the time for each depends on the level of comfort the user has with the device. Lastly, both systems require a level of line of sight. Total Stations require a line of sight to the other instrument whereas GPS and GNSS on the other hand, require a minimal line of sight to the sky. In this category, GPS and GNSS systems are significantly more beneficial. The need for only minimal line of sight allows a GNSS rover to navigate up to three miles away from the base station and still be able to communicate. With a Total Station, to be able to sight in and collect points you would need to move the equipment numerous times in order to get the same points as a GNSS system.

<table>
<thead>
<tr>
<th>Ruggedness</th>
<th>Total Station</th>
<th>GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Less Rugged (moving parts &amp; user maintenance)</td>
<td>Rugged (no moving parts)</td>
</tr>
<tr>
<td></td>
<td>Water and dust resistant</td>
<td>Water &amp; Dust proof</td>
</tr>
<tr>
<td>Range</td>
<td>700m Robotic 350m Grade Control</td>
<td>Typical 1-3miles / 2-8km</td>
</tr>
<tr>
<td>Accuracy</td>
<td>0.01ft / 3mm</td>
<td>0.1ft / 30mm</td>
</tr>
<tr>
<td>Setup</td>
<td>Quick daily setup and use</td>
<td>Initial infrastructure requirement</td>
</tr>
<tr>
<td>Line of Sight</td>
<td>Line of sight to Instrument</td>
<td>Line of sight to sky</td>
</tr>
</tbody>
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*Figure 1: Total Station vs GPS (Blair [https://slideplayer.com/slide/6058806/])*

**Methodology**

The main objectives associated with this project was to develop a new lab activity for the Construction Management 239 Construction Surveying course and for the students to learn how to successfully use the GNSS equipment. It was critical for the lab to portray the different uses of the GNSS equipment and to mimic how professionals use similar equipment in the field. The first step
was to understand the equipment through background research and once there was a thorough grasp of the concepts, it was time to begin working with the equipment. The equipment in question consisted of two Topcon GNSS receivers and a field computer with the Topcon’s MAGNET Field application. Once there was a base of knowledge built off research, it was time to work with the equipment. The steps followed throughout the project included setting up the equipment, working through the software, brainstorming the lab assignment, creating a PowerPoint and the lab assignment, testing the assignment, and finally rolling the assignment and PowerPoint into the CM 239 Construction Surveying course.

Setting up and learning how to use the equipment was a time-consuming segment. The first steps with the setup included turning on the receivers and attaching them to their stands. The base is to be screwed onto the tripod and the rover onto a bipod and adjustable rod. The base station needed to be set away from tall buildings that would obstruct the communication with the satellites as well as set to a height that was above eye level. The rover on the other hand, was always set to a height of two meters. Once the receivers were powered on and set to the proper height it was time to dive into the field computer and the MAGNET Field software. The set up in the MAGNET Field application was not very intuitive and each step needed to be followed exactly or the results would not be calculated or be incorrect. In order to ensure the setup of the field computer was correct there were multiple meetings with Jeff Waggamon, a Topcon representative. After a few meetings I had developed a better understanding of the software and began to collect points and ponder different ideas for a lab activity.

The next step was to begin brainstorming ideas for the lab activity. Adjacent to the Construction Management building (Building 186) is a large area of grass and trees that provided the perfect location to host a lab, see figure two for more information. After spending numerous weeks working with the equipment, multiple ideas for a lab started to present themselves. With the overarching goal for the senior project being to mimic the uses of Global Navigation Satellite Systems (GNSS) and how they are used in the construction industry; it was essential that the lab encapsulated multiple different activities and be written in such a way that the students would experience in the field. With the vast capabilities of the MAGNET Field application, it was key that a significant portion of the lab would be conducted within the application. The first lab activity that came to mind was using the GNSS rover to locate different telecom and water utility boxes scattered within the lab area. This would give the students an opportunity to get used to collecting points. Given the applications ability to calculate elevation, the next question would be for the students to calculate the difference in elevation as if they were to have to perform a cut or fill calculation. Another major application of surveying is being able to calculate the distance between two points. With that being said the next lab question would include a distance calculation. Within the MAGNET Field application there is an “Inverse between two points” function that allows you to find the distance between those two points. Therefore, the next question was written as if the electrical subcontractor needed to know how much conduit was required to run from one light pole to another. The third major function within MAGNET Field is the ability to calculate area based off points collected, in which students would be required to collect points around the perimeter of the “job site area” and find the area of said location. In order to make the area question more applicable, a fifth question was added. Students were required to calculate the area of the gravel path, depicted in yellow in Figure 2, and then were given a section cut of a concrete sidewalk, portraying a five-inch slab and four inches of gravel fill. With this information they were to calculate the area of the path, the volume of concrete needed, the volume of gravel fill needed and as a bonus they were asked how many concrete trucks were needed to complete
said job. Once the lab was brainstormed, it was time to test it and put together a PowerPoint teaching the students how to setup and complete the lab. The PowerPoint referenced in Appendix B, shows the fifty-four different steps that need to be followed in order to complete the lab noted in Appendix A.

The next step included doing a complete run through of the lab, before rolling it into the course for their week ten lab activity and ensuring every single receiver was ready to be used. It is important that each receiver collects enough data before being used for surveying, as without this collection time students would be forced to wait up to ten minutes for each point to be recorded. Consequently, each receiver was turned on and allowed to collect data for approximately an hour while the lab was being tested with receivers that have already gone through this process. Once the first run through was completed, it was decided that in order to error on the side of precaution a second run through should be completed with two separate receivers that had only just gone through the data collection phase. This occurred one day before it was time for the students to complete the lab on their own. With the completion of the second run through, it was time for the lab to be presented to the students.
Application

The end goal for this project was to include the assignment and PowerPoint in the week ten slot for the CM 239 Construction Surveying course. This goal was met successfully and was applied to both sections of the Winter CM 239 course. The first section completed the lab from 9:00 to 11:00 a.m. on Wednesday March 3rd, 2022, and the second section completed the lab during the same time period on Friday March 11th, 2022. During the first section there were four different groups that followed the PowerPoint attached in Appendix B in order to set up their own rovers and configure the MAGENT Field application. The students followed the steps with a few minor questions. Configuring the different settings within the application took them approximately forty-five minutes to an hour before they were able to begin with the collection of points and answering of different questions within the assignment. The second section followed the same PowerPoint and were also able to setup the equipment with only a few minor obstacles that were quickly fixed. They also followed a similar timeline of about forty-five minutes to an hour of setup and thirty minutes to collect the points and calcite their answers.

Speaking with the students after the completion of the lab was very beneficial in that they were asked for as much feedback as possible, in hopes to grow and perfect the assignment for the future. Group number three from the Wednesday’s session felt this lab was one of the most applicable that they have had throughout the quarter. They specifically liked how the questions were worded within the assignment, saying, “The questions were written as if a superintendents or foremen were asking us to complete a task that we will experience in the future.” Group number one from the Friday session felt that the setup was challenging, as they had never seen a software such as Topcon’s MAGNET Field before. When they were asked if they felt they would be able to complete the setup faster if they had to do it again, they were confident that the second time around would be easier and smoother.

Lessons Learned

Throughout the project there were multiple challenges and challenges that were overcome and used to learn, grow, and improve. The first challenge encountered was that within the setup of the coordinate system there was an issue with a geoid file on a few of the field computers. Without this geoid file the receivers weren’t able to locate and orientate themselves properly. To overcome this, with the help of the Construction Management 239 Construction Surveying course’s Instructional Support Assistant, Kyle Passey, the proper geoid files were uploaded to each of the field computers. The second challenge that required overcoming was that all but one of the field computers ran in ‘Demo Mode’ due to an issue with the licensing. In this mode the field computers could only collect a maximum of seven points and in order to complete the entire lab, a minimum of forty points was required. Unfortunately, we were unsuccessful in updating the licensing of all the field computers prior to conducting the lab activities. To overcome this issue, the lab was shortened to only require the use of seven point and the base station. Even with the shortened lab, the students were still required to identify different utility boxes, calculate the difference in elevation, calculate the distance between two points as well as find the area of a smaller location. Another issue with the field computers was that when they connected to the internet, they downloaded a corrupt file. This file inverted the screen as well as where the user would click which made it extremely challenging to perform the simplest of tasks such as increasing the volume. This ended up happening to two of the field computers rendering them unusable until a patch was downloaded. This left us with four
working field computers. During the first lab activity there was only four different groups which allowed us to complete the lab smoothly. Unfortunately, during the second lab activity another one of the computers downloaded the corrupt file and forced us to combine groups in order to complete the lab. The last issue that was encountered was with the field computers connection with the rover receiver. On a couple of occasions, the field computer would automatically upload an offset for the rover. This meant that no matter where the rover was located, the field computer would depict the point to be up to one hundred yards away. The best fix for this issue that was found, was to turn off both the rover and base receivers and restart them. Each of these issues presented a different challenge that required different types of problem solving in order to achieve success in the lab.

Conclusion

This project sought to create a field exercise for student learning that mimics the uses the of Global Navigation Satellite Systems (GNSS) surveying and how they are used in the construction industry today. The lab activity and presentation that was produced as a result of six weeks of research, self-taught skills, advice, learning, and practice takes the students enrolled in Construction Management 239 Construction Surveying through different activities that will prepare them for different scenarios they will face in industry. This lab comes at the end of the surveying course which allows them to compare the use of different surveying techniques to how the GNSS works. Each lab question has a goal of preparing students for different tasks they could be faced with as they begin to work in the field.
References


Waggamon, Jeff. Topcon