Reality Capture Course Content: Exposing the Next Generation of Builders to Technology Moving the Industry Forward

This paper discusses the development and execution of lecture and laboratory educational content regarding reality capture technology and workflows. These educational modules were created to cover different use cases for reality capture technology that are currently being used in the construction industry. They also show how reality capture plays a role in the larger virtual design in construction (BIM) process. Importantly, these labs were designed to be completed with the LiDAR scanner on a typical iPhone, which has lowered the barrier to entry for reality capture education and use in industry. While the initial teaching of these courses was done in a synchronous in person format, content was also created to allow for these lessons to be completed asynchronously and remote, to provide students and faculty flexibility. This adds to the knowledge base of students in higher education by teaching elements of the BIM process not typically covered in a standard curriculum. The goal of this project was to provide a hands-on project for students, and faculty to understand how BIM can be used, and is currently being used on construction jobsites.

Keywords: Reality Capture, Education, BIM, Virtual Education, LiDAR

Introduction

The purpose of this project was to create course content on reality capture technology, with the goal of implementing it into the curriculum at California Polytechnic State University in San Luis Obispo (Cal Poly). While the department does a good job with BIM curriculum in the fundamentals course as well as the dedicated building information modeling (BIM) courses, there are several areas these courses can be updated, included adding additional tools and software, such as reality capture. The commercial construction course (CM 313) is the best class to implement this new content for a couple reasons. Firstly, reality capture is important to commercial construction. Whether you are doing a tenant improvement project and need to have a model of as-built conditions or are trying to implement quality assurance methods for work done on the project, reality capture is used on commercial projects very frequently. Secondly, students would be able to perform the reality capture labs over the length of the quarter on the commercial mockups that are currently being built. Pairing these lessons with an actual building activity will enhance student understanding of how reality capture integrates into the construction process and will allow for students to learn in a more personal way since it is attached to something they built themselves.

In addition, adding reality capture in the curriculum will be beneficial to broaden students' understanding of additional hands-on applications of BIM. Many students think of BIM just as Revit modeling, when in fact it is so much broader than that. Seeing this other element of the process could get students excited about BIM and show them that as a BIM engineer you aren't necessarily just sitting behind a computer screen all day.

One of the key points of interest with the project was dealing with the hardware limitations of reality capture. With many LiDAR scanners costing more than $50,000 it makes sense that this hasn't been a part of the curriculum. This problem has been solved by using the LiDAR scanners newly equipped on iPhone Pro models to stand in as our scanner. This lowers the main barrier to entry for reality capture and allows students to become familiar with use cases and workflows without being a financial burden.

Additionally, in keeping with modern standards in higher education, these educational modules were created with the intention of working in various modalities. In this way, the laboratory work has been accompanied by written lesson plans and video content to allow for students to perform this work in a remote and asynchronous manner as has been common throughout the ongoing COVID-19 pandemic.

Project Elements

The goal was to create a complete package of reality capture course content that could be added into a course without much adjustment. To do this, I created lecture content as well as multiple practical labs. With each deliverable, I first tested the content on either the BIM student club at Cal Poly, or the BIM student competition team. I started with a lecture at a BIM club meeting on reality capture and its uses in construction. Next, I ran lab 1 with the BIM student competition team on using reality capture for quality control (QC) of a poured concrete footing. Finally, I intend to run a final lab (Lab 2) with the BIM student competition team on scan-to-BIM workflows of the completed commercial mockups. For each of the labs, I taught them in person to a small group of students and have also created written lesson plans along with corresponding instructional videos.

The final list of deliverables includes:

Reality Capture Lecture	In person Lecture	Corresponding Lecture Presentation Slides	
Lab 1: QA/QC Lab	In person lab walkthrough	Written lesson plan	Video instruction
Lab 2: Scan to BIM Lab	In person lab walkthrough (planned)	Written lesson plan	Video Instruction

Reality Capture Lecture

I gave a lecture to the BIM club on reality capture technologies in construction. Considering that many students have never had exposure to reality capture, this was a broad summary level lecture covering what the technology was, how it was used, and how students can get started using it.

One of the key takeaways that I emphasized was the process-oriented nature of BIM. Often students just think of BIM as Revit, but it is a much broader series of interrelated steps with the ultimate goal of making construction better, and using tools and software to solve every day jobsite issues. Data collection through reality capture can be a major part of that BIM process and I wanted to put that into context for the students.

Next, I defined reality capture as it pertains to construction and discussed the forms that you will see it in on a jobsite, from tripod mounted scanners to backpack scanners, to scanners on robots and drones.

This was followed by a discussion of key reality capture use cases. The three broad categories of use cases we discussed were: model creation, QA/QC, and client communication. This was intentionally done to set the groundwork for the future labs. Understanding why companies use reality capture for model creation and QA/QC is important to getting buy-in from students in the labs on those topics in the future.

I ended with a call to action, encouraging students to explore this technology themselves, since all they need is an iPhone to start. From there, I opened the floor to questions and the attendees seemed to be very interested in the topic. Many people were asking thoughtful questions looking to go deeper on the use cases and the possibilities of the technology.

Lab 1: Surface Levelness QA/QC Lab

The first lab I created was intended to explore a specific QA/QC use case for reality capture technology. Specifically, the goal of the lab was to create a surface analysis of a concrete footing to check for levelness and see if the high points and low points in the concrete footing were within construction tolerance. The idea for this lab was inspired by larger scale QA/QC workflows I have seen in industry and have learned about through presentations. The premise is that you can use LiDAR to create a point cloud of a surface, and through analysis can identify high points and low points in that surface. This has a multitude of uses, from scanning a concrete slab to check for levelness, to identifying places with weakened structural integrity in a retaining wall.

My goal is to implement this lab into the commercial construction course (CM 313) to add a BIM component to the course which coincides with the construction of the commercial mockup students build in this class. To first test this lab, I conducted it with the BIM student competition team to get feedback on the lesson and to find improvements.

First, I had students take their LiDAR equipped iPhone and take a scan of the footings poured by the CM 313 classes. Each participant got a chance to work with the scanner and to create their own point cloud of a footing, to analyze later. While this works in a group of 5 like my test group, in a larger class setting, it would likely be more viable to have each construction group do the scan for their footing and then do the analysis individually.

Once everyone had completed their scans and had them on their computer, participants opened Autodesk ReCap to clean up the scan and get it ready for further processing as shown in Figure 1.
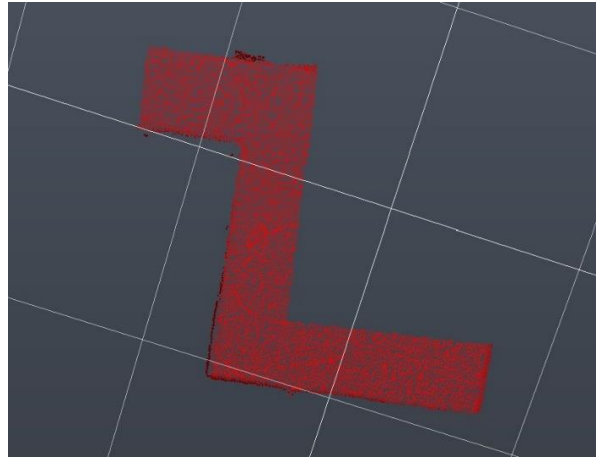
Figure 1: This is a cleaned point cloud of a footing from a CM 313 commercial mockup. Now with the noise removed, we are ready to take the point cloud into Autodesk Civil 3D.

Participants then brought these point clouds into Autodesk Civil 3D, where they created a surface from the point cloud. With this surface students could then create a heat map showing the high and low points in the footing as shown in figure 2. They can also gather numerical data regarding the high and low points (Figure 3). This information is extremely useful because it allows you to compare as-built conditions with quality standards set for that project. This can allow for both preventative and remedial action to be taken regarding quality.
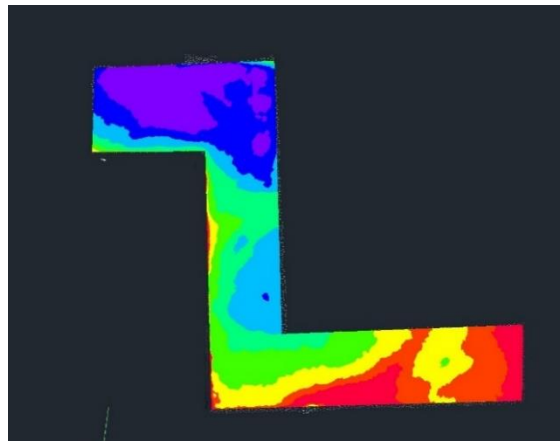

Figure 2: This is the final elevation heat map made from the point cloud shown in figure 1. The high points are indicated in purple, average points in green, and low points in red.

We discussed the data collected to see if it made sense, and looking at the elevation data collected, it indicated accuracy issues due to the hardware we were using. The scanner on an iPhone has inherent limitations compared to a construction grade scanner. One of the main issues is control. Since this scan couldn't be tied to control points, there was inevitably some tilt in the scan which can be seen visually in the heat map, as well as in the data. The data suggests about a 3" difference between the purple sections and the red sections, which is clearly not true. While I do think that this lab still has value despite hardware limitations, it would be good to iterate on this in the future and use better hardware so that the results are more accurate to as-built conditions.

~~Maximum Y coordinate~~	~~7996.99~~
Minimum elevation	-0.58'
Maximum elevation	-0.32'
Mean elevation	-0.41'

Figure 3: Elevation data from the surface shown in Figure 2. This data indicates a 3" difference between high and low points in the footing which is highly suspect. This is likely due to hardware limitations.

Once participants had completed the lab, we had a discussion on use cases and all the participants seemed to be excited about reality capture possibilities, especially those who had attended the previous lecture on the topic. I conducted a survey of the group regarding the lab and the feedback was largely positive, with the main caveats being the difficulty in downloading and learning multiple new software products in the same sitting. I think that in a classroom setting and with good planning, these difficulties can be mitigated. While this lab worked effectively in a synchronous setting like I tested it in, with the new hybrid model of education being further used, I also created a lesson plan document with step-by-step instructions combined with corresponding videos showing how to complete the lab. This was very much inspired by the content created for the Cal Poly BIM (CM 280) course which seems to be an effective learning method for BIM.

There seemed to be a difference in buy-in and overall comprehension between students who had attended the reality capture lecture and those who didn't. This would suggest that lecture content on reality capture prior to a lab would be helpful. I also think that in a classroom setting, you could help generate buy-in by making the lab a kind of contest; whichever group poured the footing with the smallest difference between the high and low points gets extra credit or a better grade on the lab assignment.

Lab 2: Scan to BIM Lab

The second lab I created was focused on participants creating a BIM model based on the completed commercial mockups, emulating a miniaturized scan-to-BIM workflow as used in industry. This use case for reality capture is particularly relevant to tenant improvement projects when creating a Revit model of as built conditions to further develop the construction model and set of plans. I also got inspiration to create this lab from experience and presentations related to BIM services. Companies may implement this service on interior buildouts when relying on drawings for dimensions alone isn't precise enough.

Again, the goal was to implement this lab into the CM 313 curriculum and act as a capstone to the build days by having a completed digital twin of the mockup that they completed throughout the 10-week quarter. As of this writing, I plan to run this lab with the BIM student competition team prior to their competition.

The lab begins with students using a LiDAR equipped iPhone to scan their mockup. This process is very similar to the process for reality capture used in the QA/QC lab, just on a slightly larger scale. In a full classroom setting, I would have each build group work together to create a scan of their mockup, for individual analysis later. Next, these students would again bring their point cloud into Autodesk ReCap and clean the point cloud to prepare for later modeling. Again, this is in line with the Recap steps from the prior lab, with the intention of reinforcing that learning. The initial scan students create looks like the raw point cloud shown in Figure 4. After cleaning said point cloud to the relevant data in Autodesk ReCap they will have a point cloud similar to that shown in Figure 5.
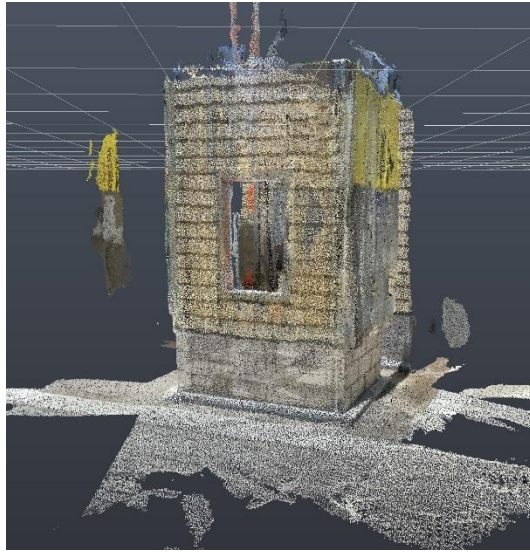
Figure 4: Screenshot of a raw point cloud of a CM 313 commercial mockup in Autodesk Recap

Figure 5: Screenshot of the point cloud from Figure 4 cleaned and ready for modeling in Revit.

After the scan is complete, and the data has been clean in Autodesk ReCap, students will then take their cleaned point cloud into Revit and model over it to create their final Revit model. There are many specific steps involved in creating the model, but this acts as a good reinforcement of Revit skills first learned in the courses prior to taking CM 313. It also allows them to apply those skills to a

real life example which will likely keep many more students engaged. After modeling they should end up with a model that looks something like that shown in Figure 6.
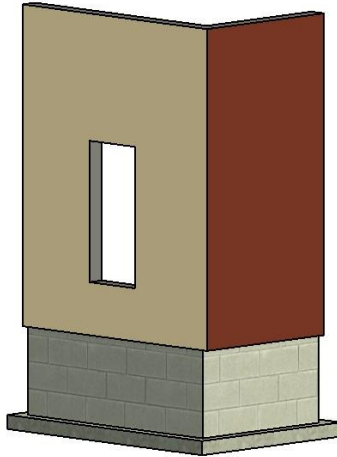

Figure 6: Screenshot of the final Revit model of the commercial mockup.

Course Content for Asynchronous Learning

While these laboratories are designed to be performed in an in-person synchronous format, with the current paradigm in education requiring flexibility, content to allow for asynchronous learning was also created.

Each lab was accompanied by written lesson plans walking through the lab purpose, goal, materials, procedure, and deliverables. The goal of the written lesson plans are so that students and other educators are able to recreate this lab in the future, and students who require asynchronous learning are able to do so.

In addition to the written lesson plans, there is video content included walking through the steps in the lab procedure. This allows for students to get more guidance and be better able to execute on the deliverables. This format for asynchronous learning was inspired by the format used by the CM 280 course during the COVID-19 pandemic which allowed for successful teaching of BIM processes.

Future Opportunities

While using iPhone LiDAR scanners to perform reality capture scanning was a convenient solution to the high costs of a scanner, the scale of work was limited as a result. Since the hardware has significant accuracy limitations, the work cannot be within the same tolerances required in industry, which are typically less than 1/8" over 10'. The inaccuracies increase with the size of the scan, so keeping the scope of these reality capture scans relatively small was important. If these scans were performed with higher level scanning equipment, students would have the opportunity to perform these tasks on larger scale projects. For instance, students with a proper scanner and proper control could possibly create a scan to BIM model of a larger mockup or even a small building given the

proper time and resources. This could a be monumental learning opportunity for students and a boon to the department as well.

Conclusion

This reality capture course content is a powerful opportunity to teach students an important part of the BIM process which is currently used in the construction industry. By lowering the barrier to entry with the use of iPhone scanners, students are able to learn about how reality capture works and the powerful use cases it has in construction management. These education modules would be beneficial to students and to the department as a whole if added to the curriculum, as well as any other university looking to expand and explore additional BIM workflows.