Integration of LIDAR Hardware onto Current Camera Systems for Shade Robotics

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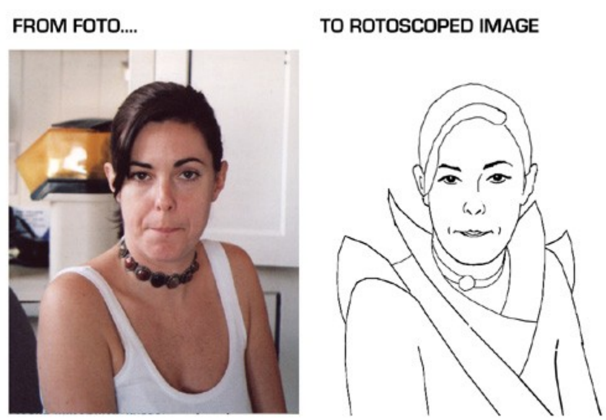
Introduction

In the current entertainment industry, visual effects (VFX) is a very commonplace addition. Marvel, Harry Potter, Avatar… so many franchises are known for their high quality special effects that allow the viewer to be immersed in fictional worlds. However, the process of adding visual effects is extremely complicated. There are numerous steps involved, with plenty of people working together to create an (hopefully) impressive final product. Almost everyone has seen a TV show or film with poor VFX, and oftentimes it becomes a point of criticism as it breaks the suspension of disbelief. Arguably the most important aspect of the VFX process is the creation of a digital mask. This is when objects in the video are isolated from the background, which allows VFX to be overlaid on top of the scene. In the current industry, there are two primary methods for creating this mask: chroma key and rotoscoping. Chroma key is the more commonplace method, due to it being cheaper and easier. This is when the scene is filmed over a solid color background (such as a green-screen). This makes it very easy to input the video into software, isolate the actors and props, and then overlay the background in post production.

Examples of chroma key
Sources (Left): https://expm1arts2301.wordpress.com/chroma-key-green-blue-screens/
(Right):https://www.premiumbeat.com/blog/chroma-key-green-screen-guide/

The other main method is rotoscoping. This is when the scene is shot as is, with an actual background instead of a green-screen. Then, an artist has to manually trace out each individual person/object that VFX will be applied onto… for each frame that the person/object appears in. This is how the first animated films were created, live footage was shot and then artists traced over the actors to allow for more realistic movement. Films run at 24 frames per second, meaning there is a lot of manual tracing involved if rotoscoping is used. This uses up a lot of time and money, but results in a cleaner and better looking application of VFX compared to chroma key in certain situations. For example, Gollum from the *Lord of the Rings* movies was made by rotoscoping over a live actor and adding the model in post-production, which helped portray realistic motion in the final product. Rotoscoping is still very big in the animation industry, and many large 3-D animated films use rotoscoping to capture more realistic motion for their characters.



Rotoscoping example:
Source: https://www.computerhope.com/jargon/r/rotoscoping.htm

The time and money spent on rotoscoping can be a very significant portion of a film's budget if it's very dependent on special effects. Currently, there are methods to try and make it easier and more time efficient. Some VFX software (the most common being Adobe After Effects), can automatically rotoscope objects in a video by the use of various algorithms. However, the object must greatly contrast its surroundings for the automated rotoscope to be accurate, and it has trouble properly rotoscoping multiple objects that overlap. An emerging method has been integrating Light Detection and Ranging (LIDAR) sensors into the process. LIDARs are 3-D sensors that can detect the distance of various objects in front of it. Recent developments in LIDAR technology have made them more powerful and accurate. Shade Robotics is a student startup in Ann Arbor that is attempting to create a VFX software package to overhaul the industry. There are many proposed features to their software, such as easier asset and texture management, but a big part of their package is being able to integrate LIDAR data to help expedite the rotoscoping process. By using algorithms similar to those in current automated rotoscoping software, in addition to utilizing LIDAR data to better isolate where objects are in a scene, the end result could be an automated rotoscoping process with accuracy unseen by current software. I was brought onto the team as a Product Engineer in order to integrate the LIDAR system they had developed onto current cameras, so the LIDAR can collect data as footage is shot. The team had already configured a LIDAR and developed code to process its output.

Methods

When I joined the team, I was the only person with a background in mechanical engineering. Most of the team had electrical engineering and/or computer science backgrounds. The rest were marketing or business students to help support the financial side of the company. Thus, I became the "resident expert" when it came to questions involving physical integration. I had to comment on the feasibility of certain ideas that other team members proposed, and explain why it would be good or bad. Oftentimes when I reasoned with mechanical engineering concepts, I had to explain it in a way they could understand, which is different from past experiences.

In order to integrate the LIDAR system the team built onto a camera, there were two components needed. The first was a driver box to house all the supporting electronic equipment for the LIDAR, such as the battery, microprocessor, physical data storage, etc. Prior to me joining, the team did not have a designated container. They would duct tape everything together, which is less than ideal to present to investors. However, it was enough for the testing they were doing in the field to configure the LIDAR. The second component was a mount for the LIDAR so that it could properly attach to the camera. Again, prior to me joining the team duct taped the LIDAR onto the camera. It got the job done, but one key factor in the success of the LIDAR system would be its positioning. Since it would be physically impossible to have the LIDAR sensor and video camera lens originate from the same position, an offset needed to be integrated into their software that processed the LIDAR data. Ideally, once an offset is inputted it will work for the camera it's attached to. The LIDAR would not be used indefinitely, as not every scene would be using VFX and require rotoscoping, so it would be taken off and on the camera. Thus, a proper mount needed to be developed to keep the LIDAR in an unchanging position relative to the camera to keep the software offset accurate.

Prior to doing any design work, I asked the team what vital features they wanted out of the two components. For the driver box, they wanted a small form factor, which would allow it to be portable. Additionally, they wanted all the components to be secured somehow to reduce the risk of damaging the electronics while in use. For the mount, the primary desire is what was stated above: keeping the position of the LIDAR consistent. They also wanted the LIDAR to be easily attached and detached from the camera for a better user experience. Another feature would be to utilize the hot shoe on the camera. A hot shoe is the part on most modern cameras where the flash or other attachments slide into. The reason they wanted this is an end goal of full integration. During their testing, the team would have to start filming video and collecting LIDAR data separately. However, by modifying the LIDAR and using the hot shoe, additional functionality could be added by having the LIDAR start and stop via the camera. This would allow film and data to be collected simultaneously and with the same button.

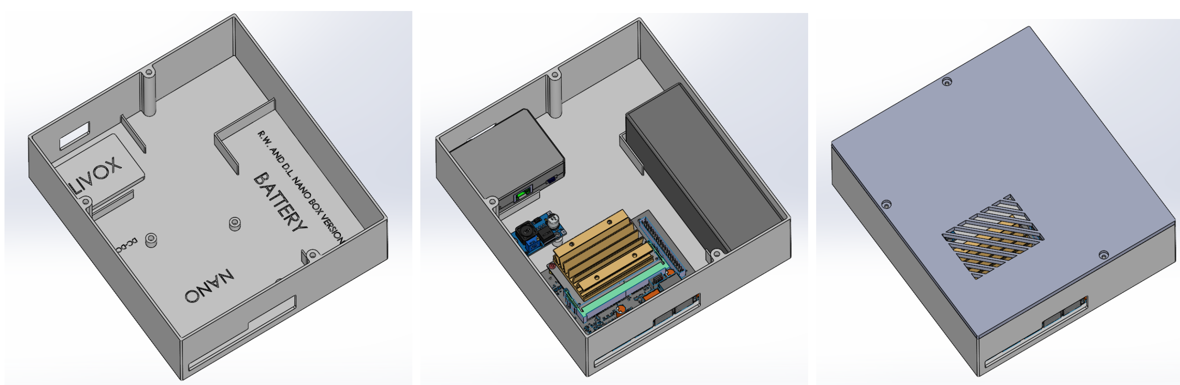
Hot shoe on a camera
Source: https://portraitsrefined.com/hot-shoe/

To help with the design process, I also proposed some questions that the team could ask current industry workers (such as directors, camera technicians, etc.) during interviews. The topics covered by the questions were primarily related to the user experience. Examples include asking about the average time length for a filming session, where equipment rests on the camera technician, etc. More product related questions would be asking about the maximum weight the driver box should weigh, whether the hot shoe was vacant in some scenes, etc. Throughout my engineering curriculum, it's been drilled into my head to strive for improvement and near perfection. However, often it's been improvement for the sake of improvement, and judged in the eyes of the engineer. But as explained to me by the CEO of Shade, Brandon Fan, as well as in the entrepreneurship courses I took after joining the team, the customer should dictate the improvement. The world of entrepreneurship is different, a paying customer is what keeps the company standing, so improvement should be for the sake of attracting more users. This was drastically different from my work experiences, which have been in large corporations, where improvements are a push for efficiency to cut costs. Thus, I had to tailor the questions to support this center statement: "What can we do to create a valid proof of concept and have you invest into our product?" Something that stuck with me during conversations with the team was that VFX was a multi-step process with people overseeing each step. Even if one person in the process (director, camera operator, post-production artist, etc.) is not convinced by the product, the investment is a no-go, so making a tailored proof of concept is extremely important.

Results

Throughout the design process, many ideas and concepts were proposed. I'd receive feedback on them by the team, and iterate on the design. In addition, FDM 3-D printing was utilized to enable rapid prototyping and testing. This allowed for the team to physically evaluate the design, which helped with the feedback and iteration loop. Though, the team overestimated the potential for 3-D printing, as many fine features (such as fastener threads) are near impossible to properly print. With my previous experiences in 3-D printing, I had to explain its limitations, while also finding workarounds. For example, to allow screws to be used, I used brass threaded inserts instead of printing threads.

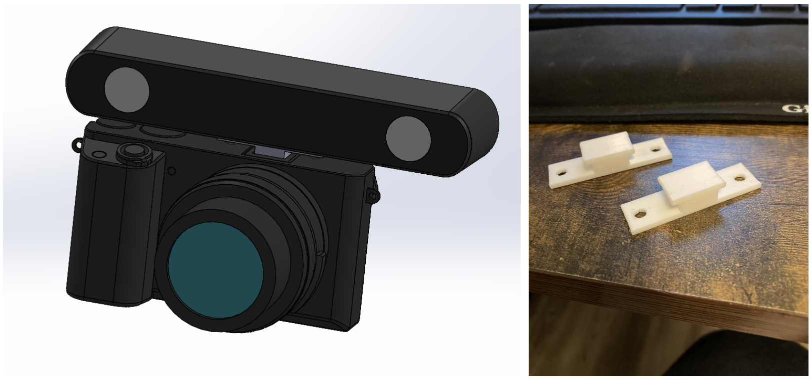
Here is the CAD model for the final prototype of driver box:



(Left): Driver box base, (Center): Driver box base with electronics inside, (Right): Driver box with attached lid

M.4 brass threaded insert used in the driver box
Source: https://www.amazon.com/LUOQIUFA-knurled-Diameter-Internal-Threaded/dp/B08G9NL291

Here is CAD and an image of the hot shoe mount:

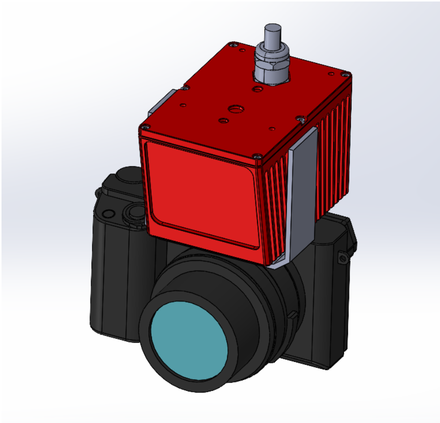


(Left): CAD model of the LIDAR attached to the hot shoe, (Right): 3-D printed mounts

Discussion

In the end, these solutions were adequate in the team's, and my, eyes. However, a lot of work still needs to be done before the final product is idealized. First, the problems with the driver box. It is too big for realistic usage. The dimensions of the box are 19x17x6 cm, which can be very inconvenient to carry around. The weight of the box was not an issue, just the size. As seen in the CAD model, there is a lot of empty space, and yes, the design could be condensed quite considerably. The electronics could stack on top of each other to save room, which is the end goal for the product. The reason why it was not implemented now is due to the team still being in a testing phase for the LIDAR system. While out doing field tests, there are frequent adjustments if something malfunctions. The level of maintenance is quite considerable, so I wanted to have a temporary design to help. It's not shown, but there is a lot of wiring, whether it be power or data cables, that run through the various components. Although I could have made a much smaller design, it would have been a nightmare to adjust something in the field. Thus, the team agreed that a more open driver box would be a good idea, and a more consolidated design will be adapted once everything is near perfect and requires no tampering during a filming session. This also coincides with the fact that the hardware will change in the future to optimize the system, and also the team wants to move from having an external battery in the box to having the entire LIDAR setup powered by the camera. This allows for extended use of the LIDAR, but is something that needs to be developed later down the line. Additionally, the box is not optimized for manufacturing, as that was not something I had in mind. Since this was a couple-time solution, creating a design optimized for mass production was not a priority. The usage of 3-D printing allows for much higher flexibility in physical features, at a cost of glacial production speeds. But this product should be relatively low quality, so it should not be too much of an issue. Further work would only need to be done if demand is much higher than anticipated and production needs to match. Regardless of these issues, this driver box was a huge step for the team from a duct taped group of electronics.

The mount prototype is much better. It allows the LIDAR to slide in and out of the hot shoe very easily, while also keeping it secure when in use. The only caveat is that the small size will make it pretty hard to integrate the electronic wiring to have the simultaneous filming and data capture. There may be a potential workaround by not having the wiring directly inside the mount, but it's a low priority project for the company right now. Duct tape is no longer needed, and the team is pretty happy about it. A point of discussion comes from the team changing the LIDAR during the project. When I joined, a different LIDAR was used (seen below) and I had designed a mount for it. The team changed to the LIDAR seen above for a multitude of reasons. Although the first LIDAR worked, it tended to overheat which would stop it from collecting data—unideal for an actual filming session. Also, it generated a decent amount of noise which could be heard audibly for up to 10 meters away. This led to an ambient buzzing in the background of captured video, which is unacceptable. The new LIDAR did not have the same capabilities, as it had a limited range of use, but all the problems with the previous LIDAR were not present, so the team went forward with it.



CAD model of the first LIDAR and the designed mount

All in all, the two solutions have made the idea much more presentable to customers. The group has presented the solutions while pitching to companies and the feedback has been positive, for the most part. The main criticisms are what was stated previously, with the biggest being the size of the driver box. But, it has been satisfactory as a proof of concept for a lot of the people the company has spoken to.

Conclusions

This was my first experience working in an entrepreneurship environment, which has been quite different from my past projects. It was much faster-paced than what I have been used to, and a part of that comes from a push to be the first innovation on the market. The need to incorporate feedback from different customer groups leads to a lot of design changes in the product, and I needed to adapt accordingly. Nevertheless, the end result of this project was two solutions that the team deemed sufficient and have helped the company progress. Additionally, being the resident expert for mechanical engineering topics was something new. During my internships, generally I am surrounded by people with mechanical engineering backgrounds. Usually I ask the more seasoned engineers for advice, so having the roles reversed was a unique experience. Though, I will eventually be a seasoned engineer, so being able to explain topics and provide advice to others has been a valuable practice.

I know in the final iteration of Shade's product before hitting the market, there will be little to nothing left of my design. Despite this, I have enjoyed this project and felt that I am a part of something bigger. Currently, there is a large amount of traction in the company, and some employees at big name VFX studios have shown interest in Shade's product. I am glad to have contributed to that interest, even if it was minor compared to the vast amount of work put into developing the actual software package.

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