Lockheed Martin Internship report

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TERMA

LOCKHEED MARTIN

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Acknowledgements

A great thanks to the following people for all their help during the internship:

Alexander Tramm: Thank you for being a great intern leader. You always knew how to motivate us and were fun to work with and hang out with.

Jon Olson: You were a great manager. You were always positive and kind and we could always count on your help. Thank you Jon.

Jean-Pierre Njock II: I learned a lot from JP. Thank you for always being ready to give a helping hand. A true Guttermand.

Andrew Rebeck: You could always count on Andy to tell his honest opinions. Thank you for always being honest and telling great stories.

Lockheed Martin and F-35 II Lightning

Lockheed Martin is one of the biggest actors within the defense industry. Besides the F-35 II lightning they are currently developing, they have produced the F-16 fighting falcon, C-130J Super Hercules and are also currently developing the supersonic plane Lockheed Martin X-59 Quesst with NASA.

The corporation was formed by the merger of Lockheed Corporation with Martin Marietta in March 1995 and as January 2022, the number of employees are approximately 115,000 worldwide. Lockheed Martin has 4 different operation areas: Aeronautics, Missiles and Fire Control, Rotary and Mission Systems and Space.

The F-35 II Lightning is a stealth multirole combat aircraft manufactured for air superiority and strike missions. It descends from Lockheed Martin X-35 which beat Boeing X-32 in 2001 and won the Joint Strike Fighter (JSF) program. The first F-35 flew in 2006 and the plane entered service in 2015.

The F-35 is produced as 3 different variants: The A, B and C model. The A model is also known as the CTOL variant (conventional takeoff and landing) and operates from traditional runways. It’s the smallest and lightest among all of the variants, and it can

operate at up to 9G. The B model is known as the STOVL variant (short takeoff and vertical landing) and is the first aircraft in aviation history which accomplished both supersonic flight and STOVL. It is designed to operate from various short bases and ships. The C model is known as the CV variant (carrier takeoff and landing) and is built for United States Navy (USN) carrier operations. The wingspan is larger than the other models and it has foldable wings, allowing for more space in tighter aircraft carrier operations. All the models can fly at Mach 1.6.

Denmark is one of the international partner nations in the F-35 program together with United Kingdom, Italy, the Netherlands, Canada, Australia and Norway. The Air Force Plant 4 in Fort Worth is where the overall system integration and final assemble happens and is where I have worked during my internship.

Work during the internship

My work has focused on improving a computer vision segmentation solution consisting of a neural network called FOD AI. It helps the F-35 mechanics to find FOD (foreign object debris) when performing inspections on different areas on the aircrafts. FOD refers to anything that unintentionally ends up inside the plane and it can lead to severe damage of the plane if not removed. Lockheed Martin already has many measures to prevent FOD, but it's still a major problem. The FOD AI is an additional attempt to combat this issue.

Synthetic training data generation

When working with neural networks, the quality and quantity of the training data is crucial. Data augmentation is therefore often a good way to increase the size of the training data and thus training a better model. The first project I worked on was using a GAN to create synthetic data of F-35 bays with FOD which could be used for training the FOD AI model. The GAN which was used is a conditional GAN or cGAN where the model is trained on an input image and a labeled mask image. The trained model can

generate fake images of F-35 bays with FOD that looks like the real images using a mask image as an input.

Figure. 1: Image and mask of a mock-up bay to illustrate how the cGAN is used. Left: Labeled mask image. The white area is FOD and the black area is background. Middle: “Real” image of the mock-up F-35 bay. Right: cGAN generated image using the mask to the left.

By tuning the model and aligning it with our current FOD AI model it was possible to arrive at a cGAN model that was able to achieve a quality of the generated images so it was difficult to classify them as real or fake. An example using a mock-up bay can be seen in figure 1.

The cGAN was one way to generate more synthetic data for training the FOD AI. Another approach we used was to superimpose FOD onto clear F-35 bays. This was done by randomly choosing a fixed number of FOD images and randomly transforming both the FOD and the background, resulting in some of the images looking realistic. Not all the different FOD types are expected to be found everywhere in the F-35 building process, some FOD types are more dominant in the early process and others later in the process. In order to control the FOD type distribution in the images to more closely mimic the real scenarios I implemented the ability for the user to create a configuration file with a FOD type distribution. The number of FOD superimposed was also made random from 0 to a user-chosen max number of FOD on each image in an attempt to increase the diversity of the synthetic data and thus making the FOD AI more robust. Afterwards a log file was generated, where the actual FOD type distribution, number of FOD in each image and other characteristics were saved.

Quantization of FOD AI model

A smaller model runs faster than a larger one, and therefore I looked into the possibilities of making the FOD AI smaller with quantization, while still maintaining much of the accuracy of the original-sized model. Neural networks are over-parameterized models meaning many different choices of weights and biases can obtain or nearly obtain the same loss. Therefore you can reduce the bit precision without impacting the accuracy much. The parameters in PyTorch models usually have a bit precision of FP32 and it was possible to reduce the bit precision to INT8 in many of the layers while still obtaining an accurate model. With this type of quantization the inference unfortunately only worked on the CPU while the original model could be run on GPU resulting in the inference time of the original model still was faster. Thus the quantization efforts did not end here. Future interns or other of my coworkers may continue the efforts in the future.

Tracking FOD when labeling

The last improvement for the FOD AI I worked on and is still working on while I'm writing this report, was to use AI to track the FOD masks in each frame of the videos we used to train and test the model. An image segmentation AI was already used to label the videos, but the person labeling need to label every frame - even if the FOD only have moved a bit. The tracking would eliminate the need to label every frame and therefore potentially make the labeling faster. The labeler should then have the opportunity to manually add or remove masks if the AI tracking was not sufficient.

Trips and fun outside of work

Mardi Gras in New Orleans

The other interns and I went to New Orleans for Mardi Gras, a huge festival celebrated every year before the beginning of Lent. It was an amazing experience I recommend to everyone who loves Jazz, beers and good times. We listened a lot to live Jazz, but we also found bars with live Rock and Soul. We stayed in a hostel in central New Orleans

and met a bunch of nice people from all over the world, especially Harry from UK was great to hang out with.

Figure. 2: Left: Aksel, William, Jacob and me enjoying a beer while listening to Jazz. Right: One of the many parades we saw during Mardi Gras.

Washington DC

We saw a lot of monuments and museums in Washington DC. It was a very cultural experience, and I especially enjoyed the national air and space museum. All kinds of aircrafts were exhibited, all from a huge space shuttle and the Lockheed SR-71 Blackbird to the Wright brothers' first aircraft prototypes and small single-seat aerobatic aircrafts. We also went to many different art museums and a natural history museum.

Figure. 3: Left: Lockheed SR-71 Blackbird inside the National Air and Space Museum. Right: Me in a failed attempt to be a classic tourist (my finger should have pointing at the Washington monument top).

Solar eclipse

April 8th 2024 was the day we were lucky enough to experience a total solar eclipse. Fort Worth was right on the path. We chose to take a day off to experience it and we gathered all of our cameras, sunglasses and solar eclipse glasses and drove towards a state park. The morning started out great with only a few clouds in the sky, but as we drove towards the state park, the cloud layer grew thicker and our hope to be able to see the eclipse grew slimmer. By tracking the weather and cloud layer we made a plan B and drove to a parking lot in little city south of Dallas. The plan turned out great. All of the clouds were gone when the eclipse began. It was an incredible experience. We could feel the change is the atmosphere as we approached the total eclipse and in the 5 minutes duration of the total eclipse, the birds stopped chirping and the street lights turned on. The humidity in the air rose drastically due to the cooler temperature and we saw crescent shadows from the trees before and after the total eclipse.

Figure. 4: Left: Crescent shadows from a tree emerging during the eclipse. Right: Photo of the total eclipse. The red dots are solar prominences - massive loops of the sun's plasma that hangs attached to the visible surface of the sun.

Conclusion

This internship has offered a lot of great times but we have also had our fair share of bad luck. We have had difficult situations with our cars to say the least, and we have had problems with getting our badges resulting in needing escorting from our coworkers. But we have tried to stay positive. I'm thankful for all of my coworkers for lending a hand during the hardships.

It has been great to experience the US and I'm grateful for every trip and activity we have been on. Living in the US has also been a lot different than I expected. People are a lot more religious and outgoing than I'm used to in Denmark and we have had some great experiences due to the hospitality of the people we have met.

I have also learned a lot during my work with the FOD AI. I have been able to work on many different aspects regarding improving the FOD AI and my coworkers have been great to collaborate with.

Overall I have learned a lot – both from work but also from our personal experiences.