Deep Learning Based Event Identification for Reliable Monitoring of Nuclear Facilities

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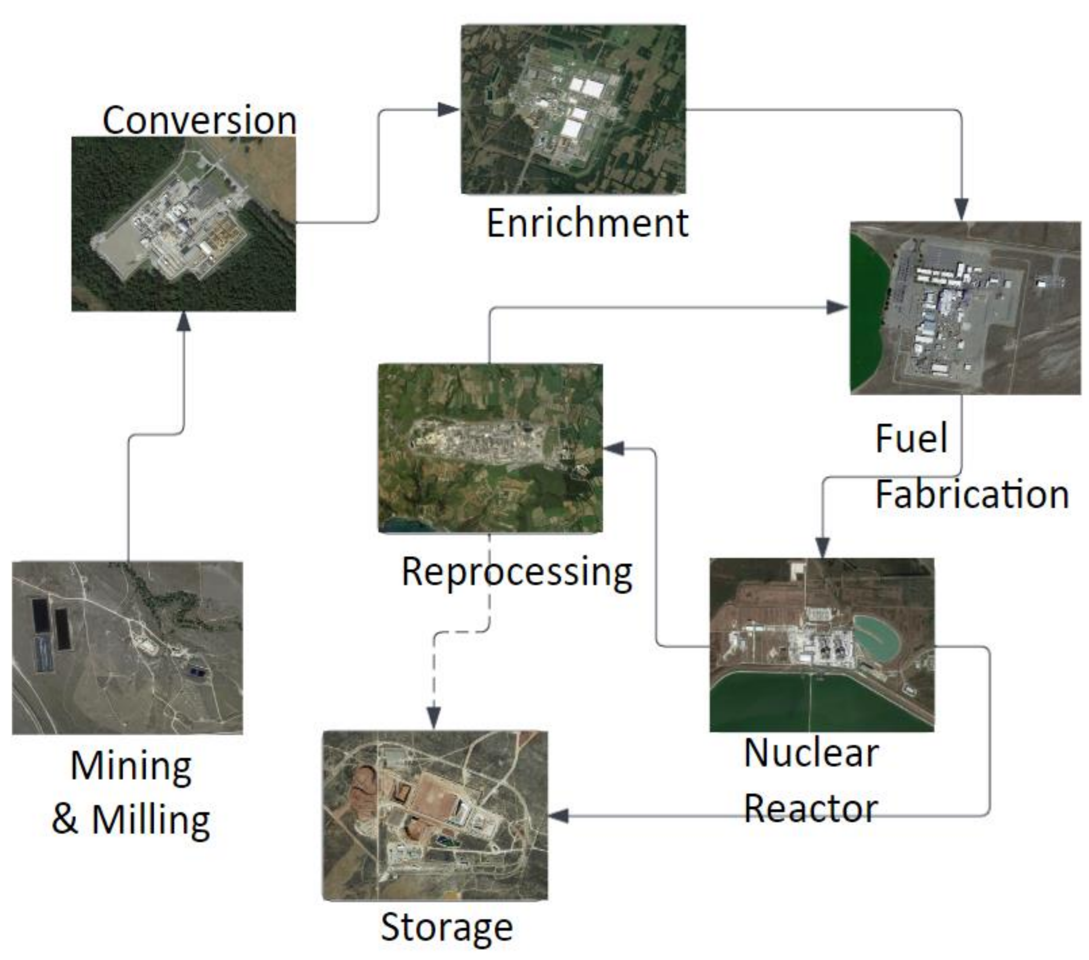
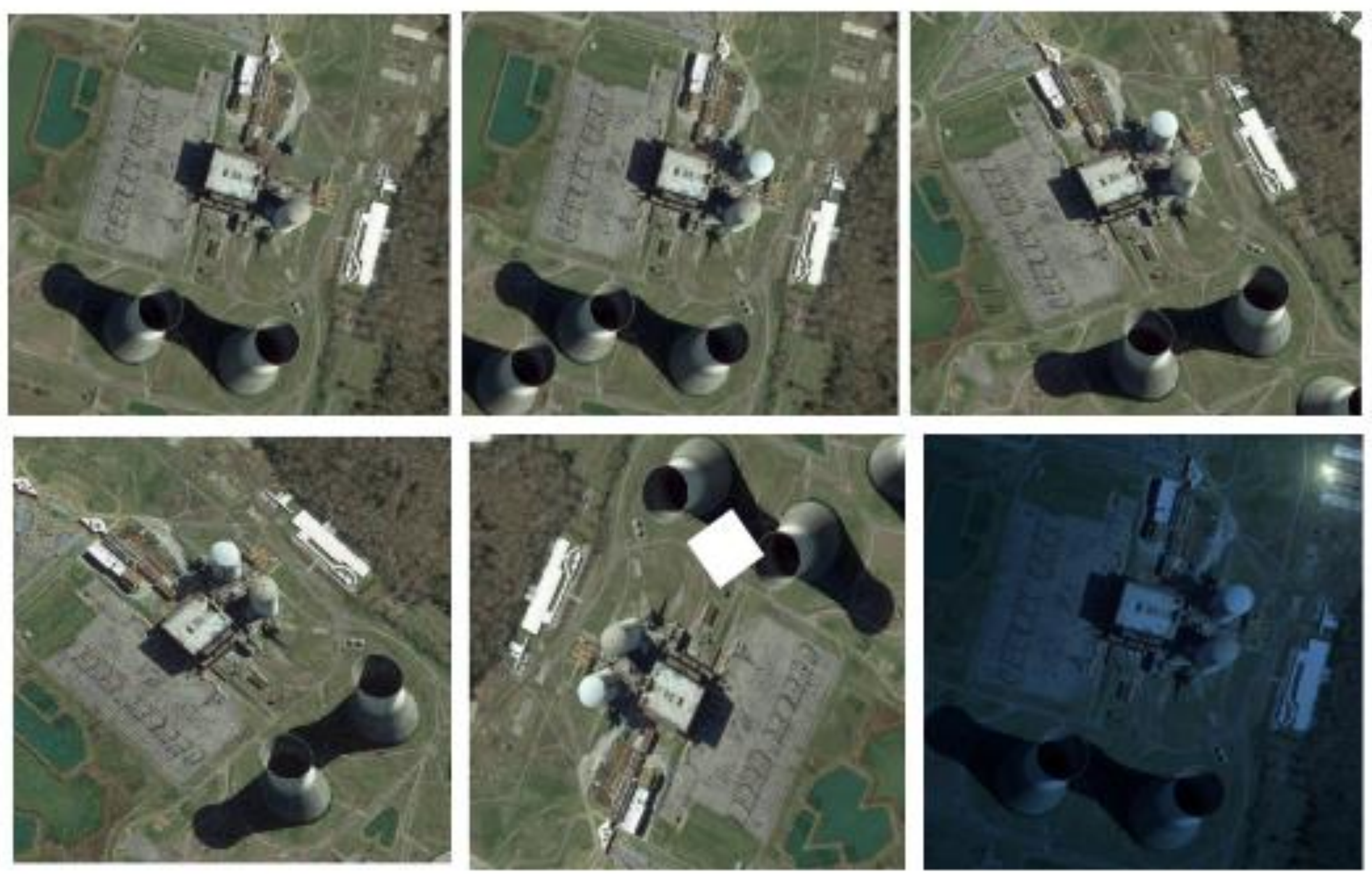
Introduction

Fuel cycle facilities are the facilities that use or alter nuclear material with the goal of energy production. Where significant nuclear material will be handled and stored will directly relate to the nuclear reactors in operation around the world. From mining and extracting, to use and storage, the state, as well as other safeguard programs, will want to keep track of all this material and where it's going. Cube Satellites (CubeSats) are expected to be used for their much more manageable size and cost for this project as most of the technology can be fit onto one of these satellites to accomplish this task.There is good reason to believe that using a CubeSat sensor for observing Earth is promising when including the capabilities of machine learning algorithms such as deep learning. Since this proposal has to do with image processing to determine states of a nuclear facility, deep learning is a great method to use, as it's been praised for its breakthroughs in this aspect and built especially for image classification.By being able to utilize Commercial Off The Shelf (COTS) components, often without modification, makes the use of CubeSats much more accessible to research and other space projects.

Fuel Cycle



Dataset



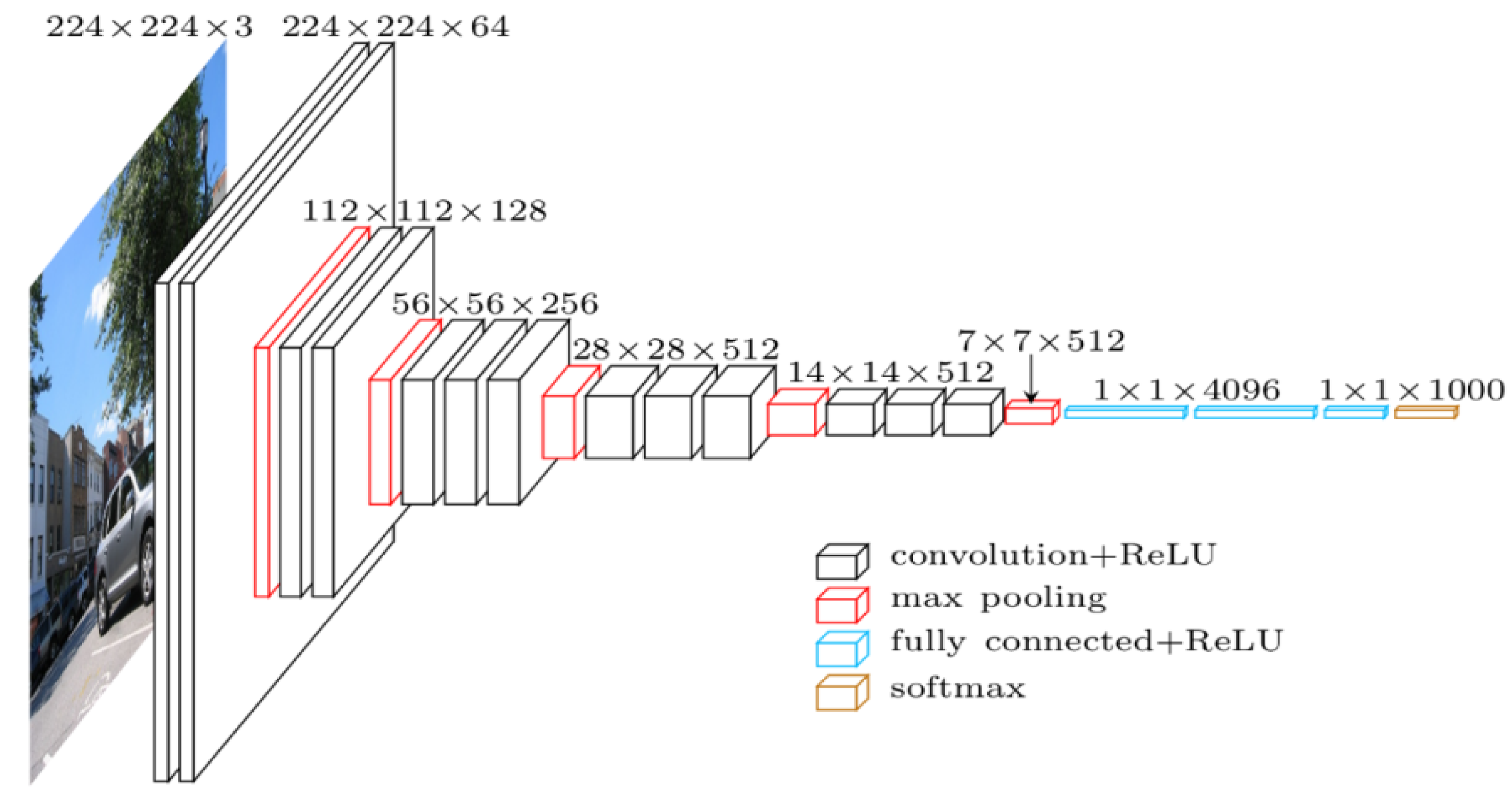
Conclusion

This project, which serves to find out the capabilities to monitor nuclear facilities through satellites and deep learning algorithms, has several tasks to complete. Like initially creating the excess of image data through data augmentation and manufacturing, and understanding how deep learning architectures work in order to have it focus on the features that will define each nuclear facility. With the level of accuracy and detail that deep learning machines have been able to accomplish, it seems reasonable to test its ability to handle this task as to use for verification. If it can be done without becoming too expensive with the amount of satellite hardware and machine processing, it could prove to be an excellent tool for nuclear non-proliferation efforts.

Deep Learning

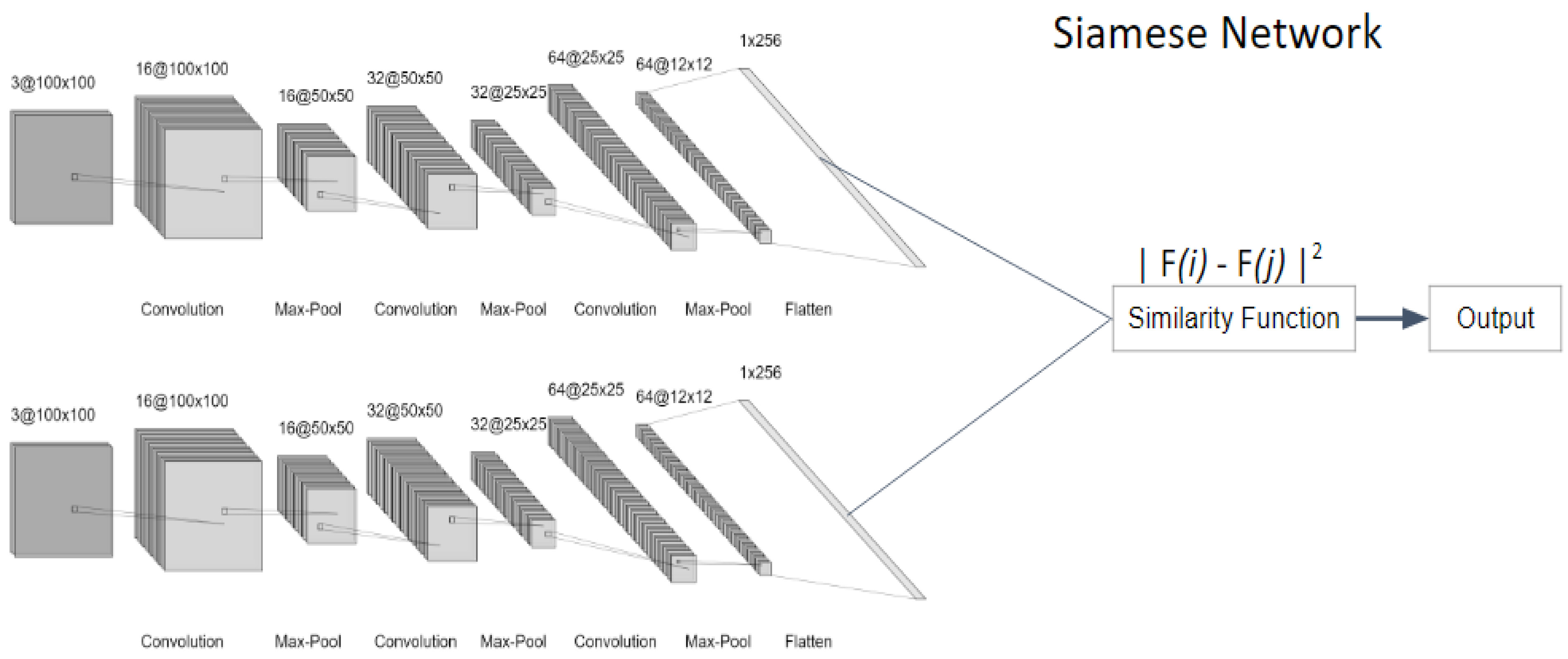
By utilizing this technique, the difficult task of defining multiple nuclear facilities by hand becomes manageable for this project, by understanding how to create a deep learning architecture that will perform this task instead. It is understood that there are certain features in facilities that may define them, such as cooling towers, reactor containment vessels, a source of water, transformers and switchyards for a nuclear reactor. These can help identify what components can be used to identify a nuclear reactor, but it is a much more difficult task to say in what orientation, style, or environment these will all be placed in for every single reactor. This is where machine learning can help in finding optimal features to look for through remote sensing.

Ideally the method of deep learning is to have several thousands of images to train a machine to recognize through seeing as many as possible to optimize its feature detection for classification, but with nuclear facilities, the amount of available images is small. This leads to an issue of how well can a machine classify with a small amount without overfitting. The best option for this is to start creating more data. This is done through data augmentation and manufacturing, which is to change something about the image so that the object is still there, but the way the machine sees it is different from the original image. This allows it to learn more efficiently with the smaller dataset. Many methods are used to raise accuracy in these smaller datasets, and they happen to work well, especially when using more complicated architectures and systems to focus the machine on certain objects.



Few Shot

There are multiple methods of deep learning image classification, and for this project, the challenge is to find the difference between two extremely similar images where there may only be a small change in comparison to the entire picture. While normal deep learning may be able to accomplish this, with a lack of data, it makes it difficult to get an admirable accuracy. Few Shot learning requires a small amount of data as it instead utilized a similarity function after transforming these images into a feature space. The idea is that instead of training a machine to discover multiple types of features for classification, we simply train the algorithm to notice a significant change that would be considered an anomaly in declared processes by the facility. This would aid in safeguarding the facility by bringing attention to a human when a certain facility may likely be operating differently from expected.



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