Applied Research Center
FLORIDA INTERNATIONAL UNIVERSITY

U.S. DEPARTMENT OF ENERGY

INFORMATION TECHNOLOGY/ARTIFICIAL INTELLIGENCE

PROJECT: Artificial Intelligence for EM Problem Set (D&D) – Structural Health Monitoring of D&D Facility to Identify Cracks and Structural Defects for Surveillance and Maintenance

CLIENT: U.S. Department of Energy
SITE: SRNL
PRINCIPAL INVESTIGATOR: Dr. Leonel Lagos

Description:

Structural health monitoring is imperative to the ongoing surveillance and maintenance (S&M) across the DOE complex. As these facilities await decommissioning, there is a need to understand the structural health of these structures. Many of these facilities were built over 50 years ago and, in some cases, these facilities have gone beyond operational life expectancy. In any of these scenarios, the structural integrity of these facilities may be compromised, so it is imperative that adequate inspections are performed with the minimal intervention of the human need to be performed on a continuous and ongoing basis.

Machine Learning and Deep Learning are state-of-start technologies capable of facilitating the assessment of structural integrity in aging nuclear facilities by detecting cracks using a Convolutional Neural Network (CNN) deep learning approach.

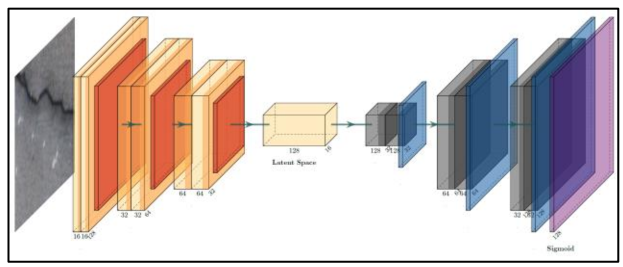
The overall objective of this task is to investigate specific applications to solve the DOE-EM problem sets in challenging areas, including potential applications of existing state-of-the-art technologies such as imaging, robotics, sensors, big data, and machine learning/deep learning, to assess the structural integrity of aging facilities in support of ongoing surveillance and maintenance (S&M) across the DOE complex.

Benefits:

- Identifying the structural defects with the help of the AI systems will minimize the manual inspection of the nuclear facilities.
- Early detection of structural defects will avoid the health risk to the project personnel working in the site.
- Developed models can detect the cracks with high accuracy and can run inference in Real-Time from remote sensors.
- AI models can be deployed for the various surveillance maintenance activities at multiple facilities.

Accomplishments:

- Implemented CNN deep learning approach for the surveillance & maintenance of the nuclear infrastructure.
- Implemented a Convolutional Auto Encoder (CAE) for anomaly detection which can visually highlight the cracks in imagery data.



Convolutional AutoEncoder (CAE) architecture

- Implemented a One Class Classifier (OCC), which is a hybrid approach with a combination of Auto Encoder (AE) and CNN.
- Ability to generate 3D point clouds from mesh files that are similar to LiDAR scans.
- Designed an AE to reconstruct 3D point clouds from synthetic and LiDAR data capable of detecting cracks.
- YOLOv3 (You Only Look Once V3) neural network architecture has been implemented, which is a real-time object detection mechanism suitable for streaming videos, static videos, and static images.

ABOUT

Since 1995, the Applied Research Center at Florida International University has provided critical support to the Department of Energy's Office of Environmental Management mission of accelerated risk reduction and cleanup of the environmental legacy of the nation's nuclear weapons program. ARC's research performed under the DOE-FIU Cooperative Agreement (Contract#DE-EM0005213) can be classified as fundamental/basic, proof of principle, prototyping and laboratory experimentation.

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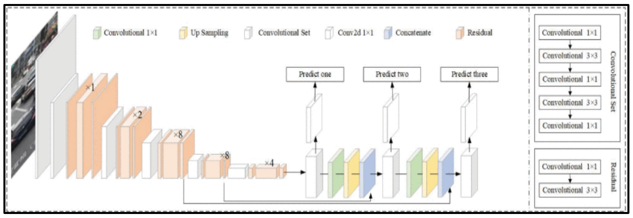

Structure detail of YOLOv3

```
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         [(None, 224, 224, 3)]     0
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 224, 224, 64)      1792
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 224, 224, 64)      36928
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 112, 112, 64)      0
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 112, 112, 128)     73856
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 112, 112, 128)     147584
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 56, 56, 128)       0
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 56, 56, 256)       295168
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 28, 28, 256)       0
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 28, 28, 512)       1180160
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 14, 14, 512)       0
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 7, 7, 512)         0
_________________________________________________________________
flatten (Flatten)            (None, 25088)             0
_________________________________________________________________
fc1 (Dense)                  (None, 4096)              102764544
_________________________________________________________________
fc2 (Dense)                  (None, 4096)              16781312
_________________________________________________________________
predictions (Dense)          (None, 1000)              4097000
=================================================================
Total params: 138,357,544
Trainable params: 138,357,544
Non-trainable params: 0
```

Summary of VGG16 model