Detection of Inferior Vena Cava Filters on CT scans using an Artificial Intelligence Algorithm

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INTRODUCTION

The IVC (inferior vena cava) is a large blood vessel that travels through the abdomen. An IVC filter is a spider-like flexible metal object which is compressed to sit inside of the IVC.

IVC filters catch blood clots traveling up the inferior vena cava and reaching the heart. The filters are designed to be removed after a certain amount of time, and without retrieval, there are potential complications. **Unfortunately, the retrieval rate for IVCF stays low.**

PROJECT GOALS

- **Automation of IVC filter detection** through a patient's abdominopelvic CT scan.
- **Artificial intelligence pipeline** for rapid identification of IVC filters and follow-up to advance patient healthcare and reduce complications.

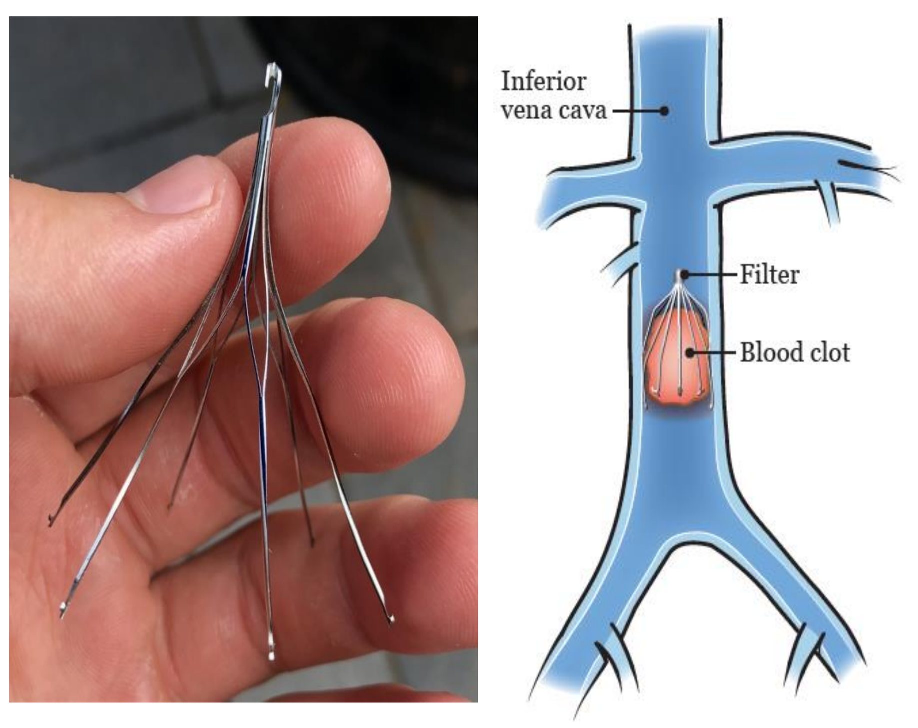

Figure 1: Image of an unused IVCF (left) and rendering of IVC filter in the vein catching a clot (right)+.

DATA OVERVIEW

DATASET INFORMATION

A CT scan dataset was collected for the purpose of this research from the Mayo Clinic Health System. Scans were collected from radiology report texts, deidentified, and manually verified.

The final dataset contains 90 scans with IVC filters and 90 normal scans.

DATA PREPROCESSING

Before being used in the model, the following steps were used to prepare CT images:

- 40cm were cropped from the base of the lung.
- Each scan was resized to a shape of 128 x 128 x 64 pixels. 128 is the width, height and 64 is the slices.
- The intensity was cropped to a range of 1 to 2500 Hounsfield units(HU).
- Normalization also occurs, shown in Figure 2. With hard normalization, more techniques are used to increase the size of the filter as well as select only denser materials in the image (including metals, bones, etc.)

DATA AUGMENTATION

Data augmentation techniques were utilized to reduce any bias brought by the position of IVC filters. The technique used was a rotation between -20 and 20 degrees, as seen below in Figure 3.

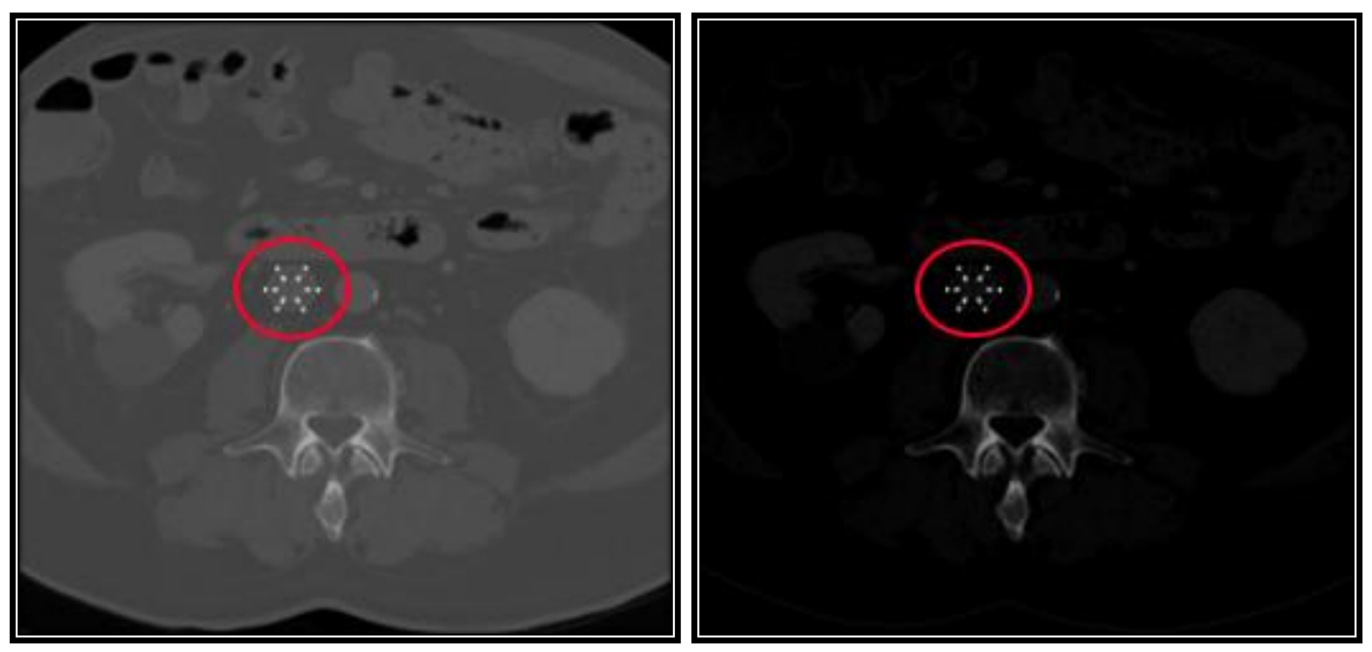

Figure 2: IVCF before normalization (left) and after normalization (right)

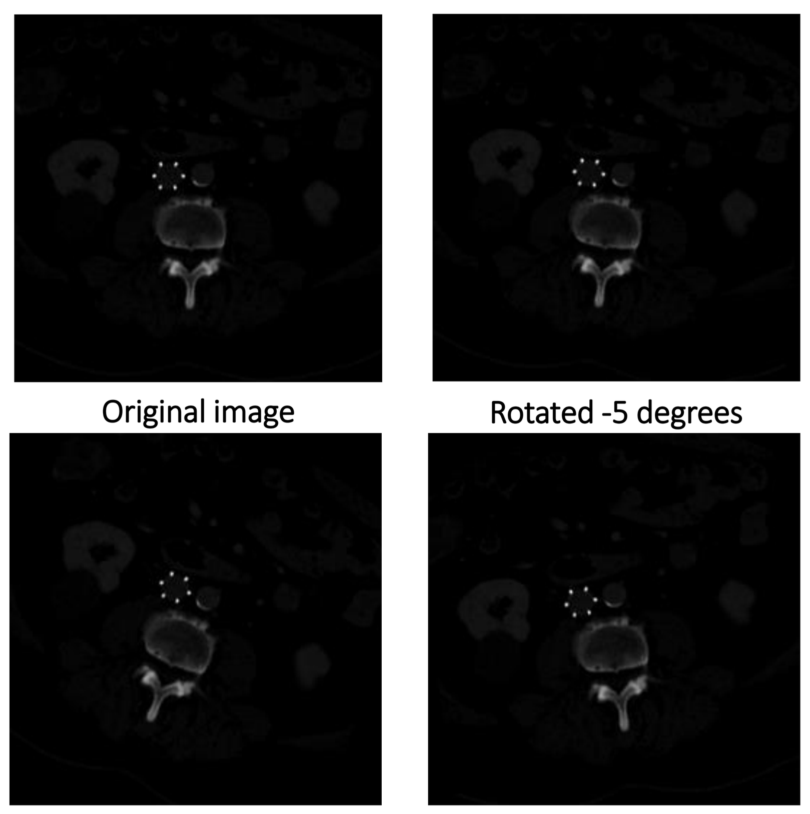

Figure 3: Image augmentation while model training

Software used for Analysis

TensorFlow Python Scikit-learn Pydicom

+ https://www.mskcc.org/cancer-care/patient-education/ivc-filter-placement

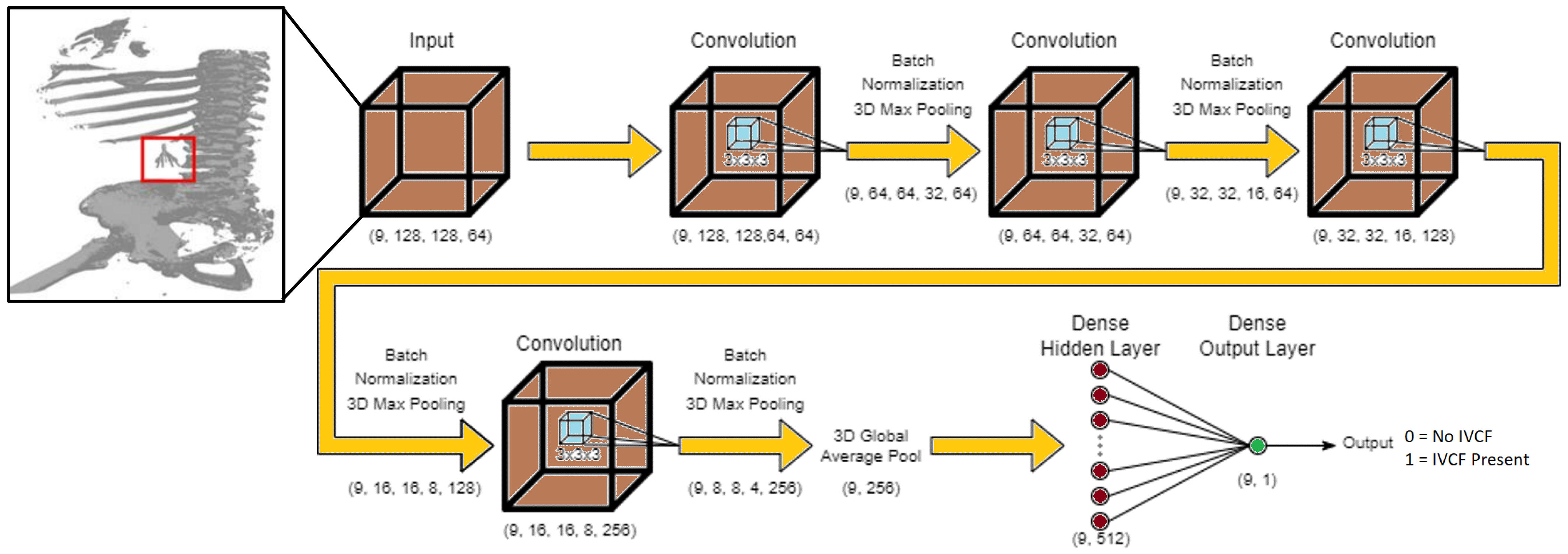

Figure 4: Architecture of the UNet model used for detection of IVCF

MODEL OVERVIEW

A deep learning Convolutional Neural Network (CNN) was determined to be best suited for this application.

A deep learning model offers a higher overall accuracy when compared to machine learning approaches. This is necessary for the medical field as patient safety is a top priority.

MODEL DESIGN

- The model uses **four convolutional layers** which have 64, 64, 128, and 256 filters, respectively.
- Each convolutional layer is followed by batch normalization and max-pooling layer.
- After the final max-pooling, a global average pool is performed followed by a dense hidden layer, and an output prediction layer.
- Each scan input to the model is a **3D image** in the mentioned shape (128, 128, 64).
- **The model outputs a 0 for a normal scan, and 1 if an IVCF is detected in a scan.**

MODEL TRAINING

A total of 144 CT images were used for **training** and 36 for **validation**. The training process is depicted in Figure 4. The model was trained for **300 epochs** with early stopping.

Deep learning models are computationally intensive, and all experiments were conducted using the computing resources available through the **Blugold Center for High-Performance Computing**.

RESULTS

Preliminary results are promising. The highest accuracy achieved was **97.3% on the training datasets and 94.44% on the validation dataset**. Figure 5 shows how the accuracy of the model increases with the number of epochs when the model is trained using 144 CT images.

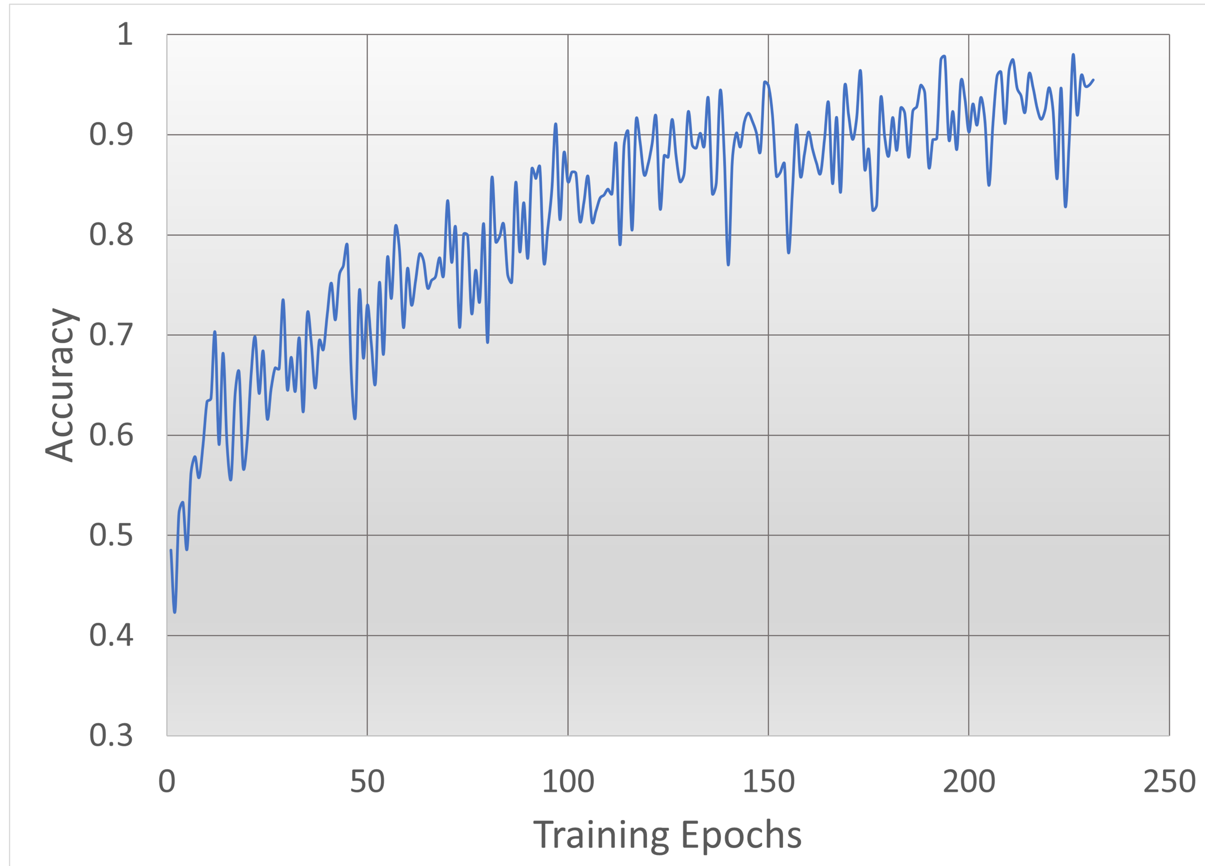

Figure 5: Training accuracy of deep learning model with epochs

FUTURE WORK

- The model will be tested for sensitivity and specificity to ensure its efficacy.
- The model will be tested with a 2D convolutional model to verify its applicability.
- The model will be deployed in the Mayo Clinic Health System to provide immediate results after a patient receives a CT scan.

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