Using Machine Learning to Diagnose Misaligned CT Scans

Sheridan C. Perry[1], Mathew Folkman[2], Takara O'Brien[1], Lauren A. Wilson[1], Eric Coyle[1], Raymond W. Liu[2], Charles T. Price[3], Victor Huayamave[1]

[1] *Embry-Riddle Aeronautical University – Daytona Beach, FL, 32114*

[2] *Rainbow Babies and Children's Hospital – Cleveland, OH, 44106*

[3] *International Hip Dysplasia Institute – Orlando, FL, 32806*

Contact Author Email: *huayamav@erau.edu*

ABSTRACT

The usage of machine learning has grown exponentially in recent years; however, its applicable uses for medical diagnosis are still in an early stage. Conditions such as Developmental Dysplasia of the Hip (DDH), Cerebral Palsy (CP), and Femoroacetabular Impingement (FAI) rely heavily on imaging techniques such as Ultrasound and Computed Tomography (CT) scans. Radiologists use multiple manually computed metrics using these images to diagnose conditions. This is time-intensive and requires an aligned image to get accurate diagnoses. The proposed application uses a deep learning detection algorithm to assist in the metric computation process. The algorithm is implemented using MATLAB R2023A and is trained on CT data gathered from 60 healthy participants. The algorithm performed well on images aligned according to the standard anteroposterior alignment used for radiological measurement. However, the variance of the metrics computation significantly increases when faced with severe misalignment in the craniocaudal or mediolateral axes. Additional algorithm improvements must be made to overcome this increased variance.

Background

Machine learning has opened the path of exploration for many new disciplines and fields. The medical field is at the forefront as one of the fields that can benefit the most from utilizing this new tool. Many conditions are diagnosed using medical imaging such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and Ultrasonography (US) scans. These scans are performed by skilled operators, but still suffer from the same errors and biases that plague any system with a human variable. Whether it be the operator making a mistake while scanning, or the patient moving at the wrong moment getting an aligned scan of a requisite section is difficult. This misalignment can delay diagnoses being made and can heavily deter research if existing datasets contain a considerable number of misaligned images. Many diagnoses rely on metrics that are drawn on an aligned scan to facilitate diagnoses.

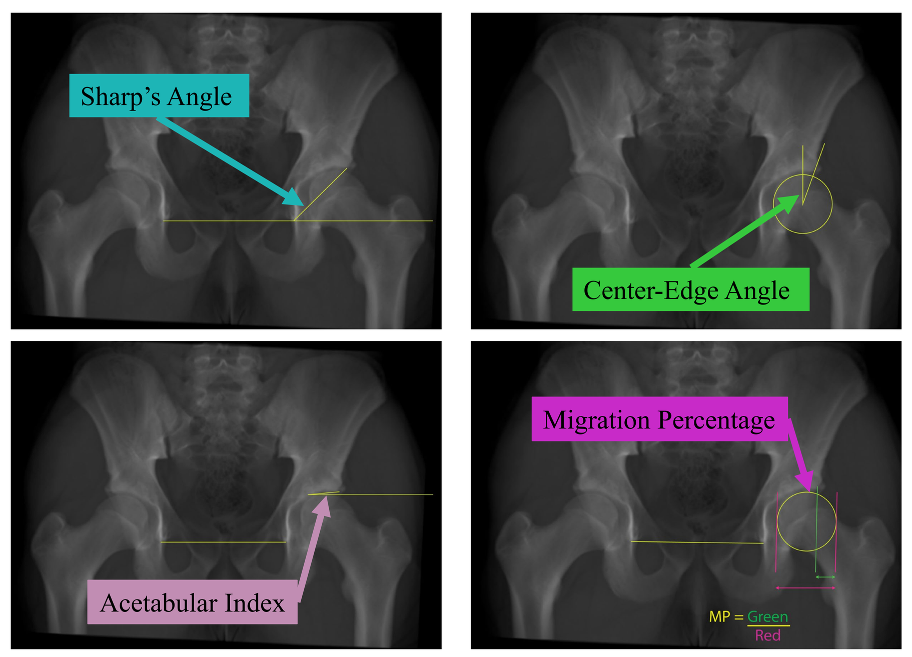

Figure 1: Showcasing standard pelvic metrics used in radiology to diagnose conditions such as DDH, CP, and FAI [1-5]

This project proposed to use machine learning to automate misaligned CT scans to compensate for human biases. Specifically, this project utilizes a Convolutional-Neural Network (CNN) known as You Only Look Once (YOLOv4) to predict the requisite locations for the computation of the metrics.

Methodology

Machine learning requires a dataset to train the algorithm or network. In this case a dataset of 60 patients (evenly split between male and female) was obtained and subsequently misaligned along craniocaudal and mediolateral axes in set increments [3-5].

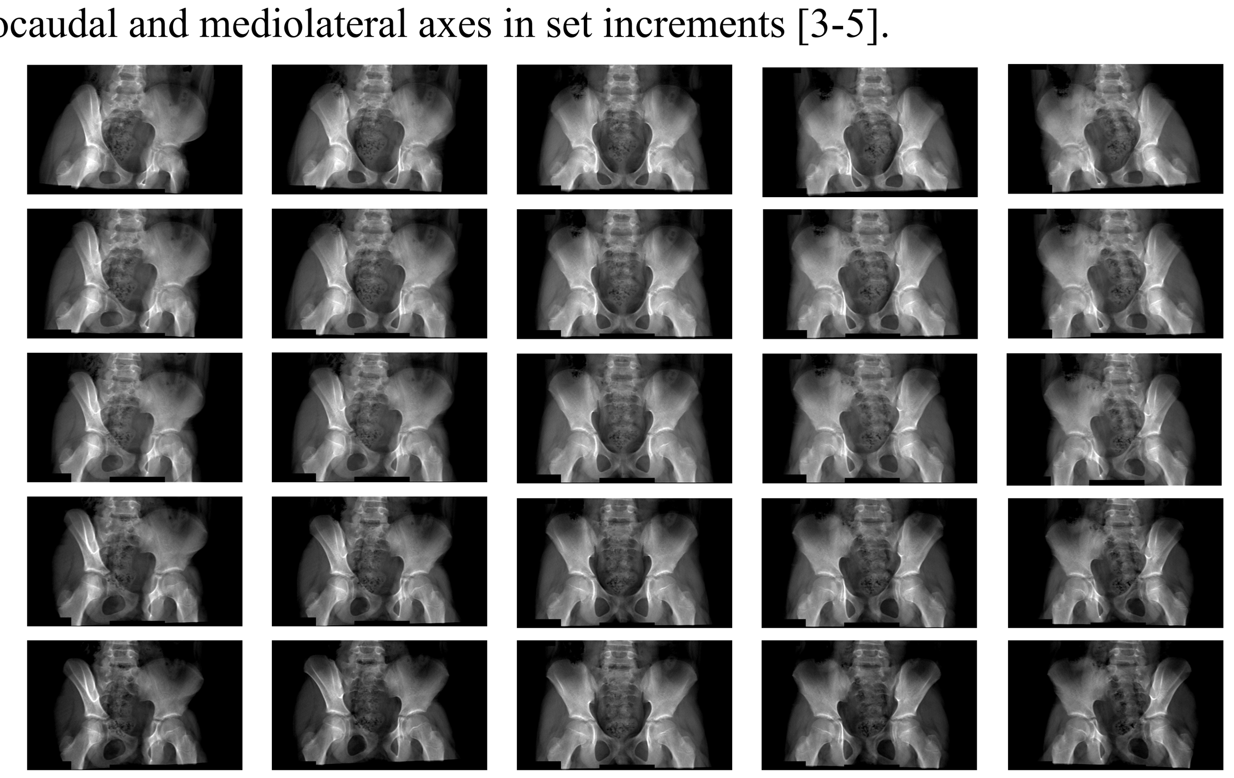

Figure 2: Collage of misaligned images rotated around craniocaudal and mediolateral axes [2,4-5]

The computation of the metrics relies on key reference points that were manually labeled.

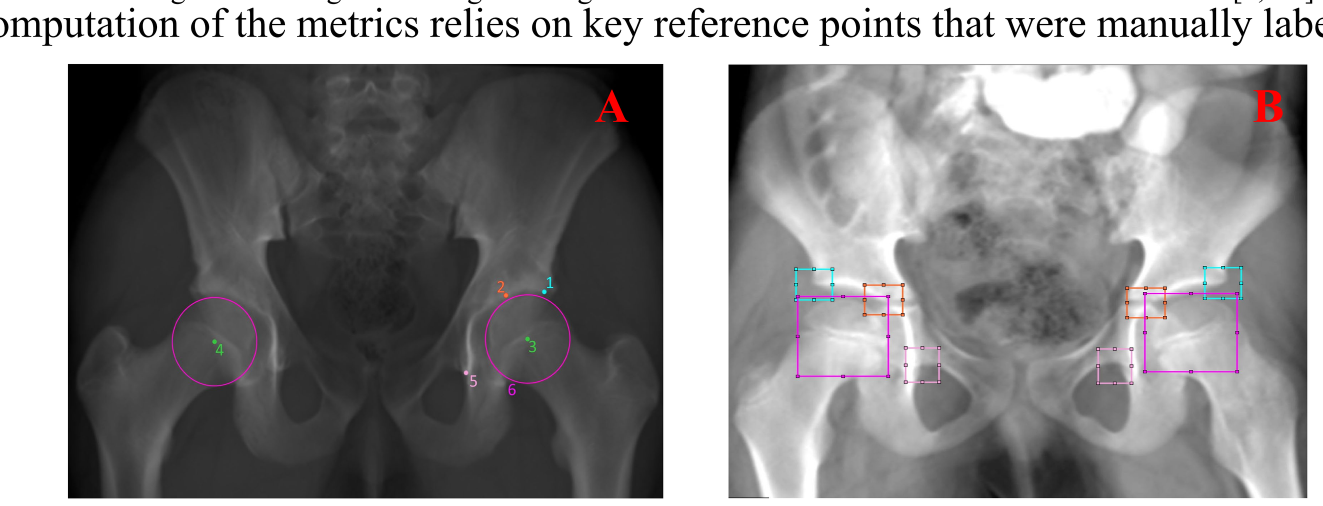

Figure 3: Labeling process and associated bounding boxes (3A is the reference and 3B the bounding boxes centered on 3A points) [4-5]

Machine Learning Flowchart

A summary is provided of the general process; however, the intricacies of the machine learning process are explored in greater detail in both publications [4,5]

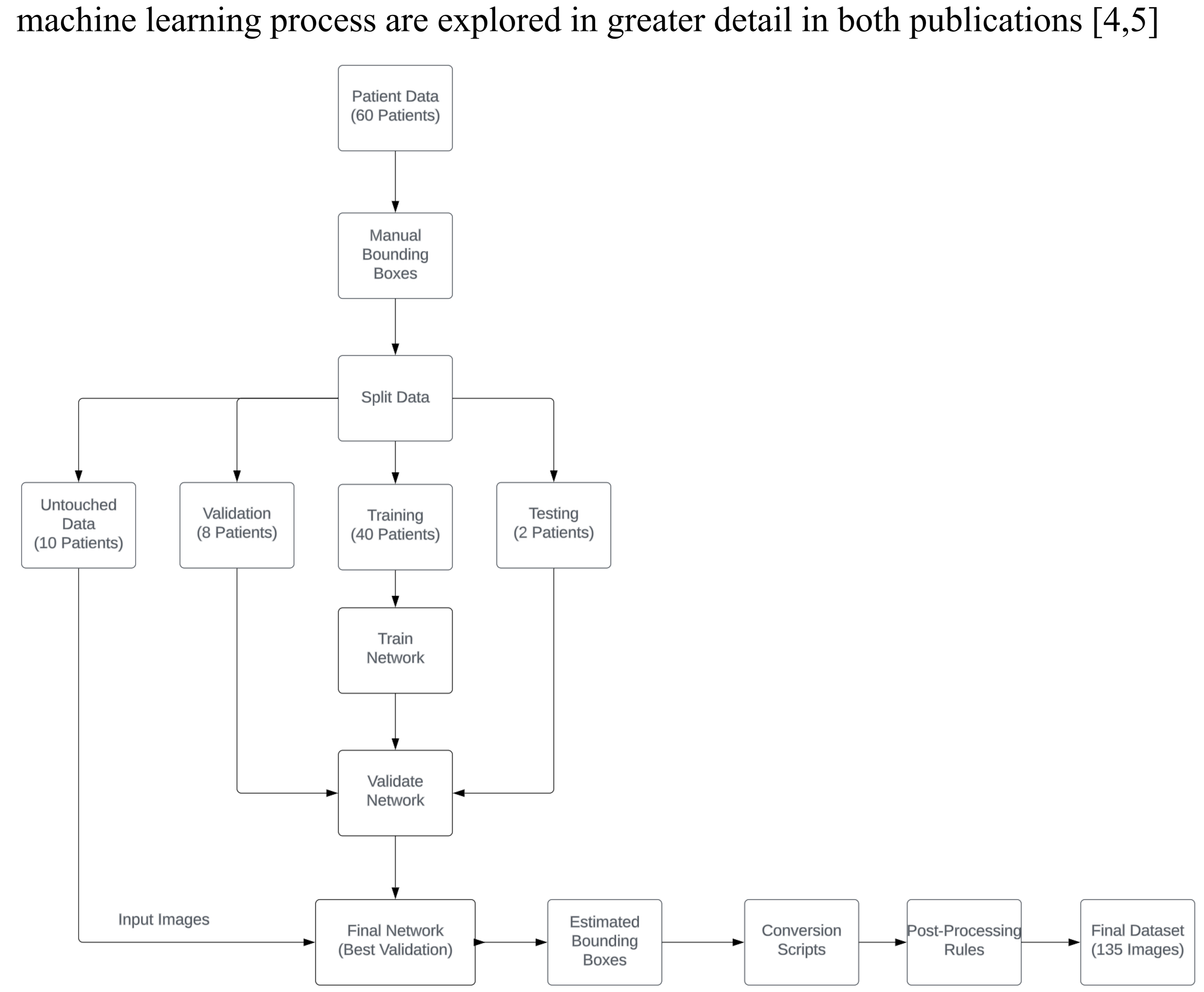

Figure 4: Network training summary [4,5]

Results

The computed metrics show promising results in terms of the precision of the results.

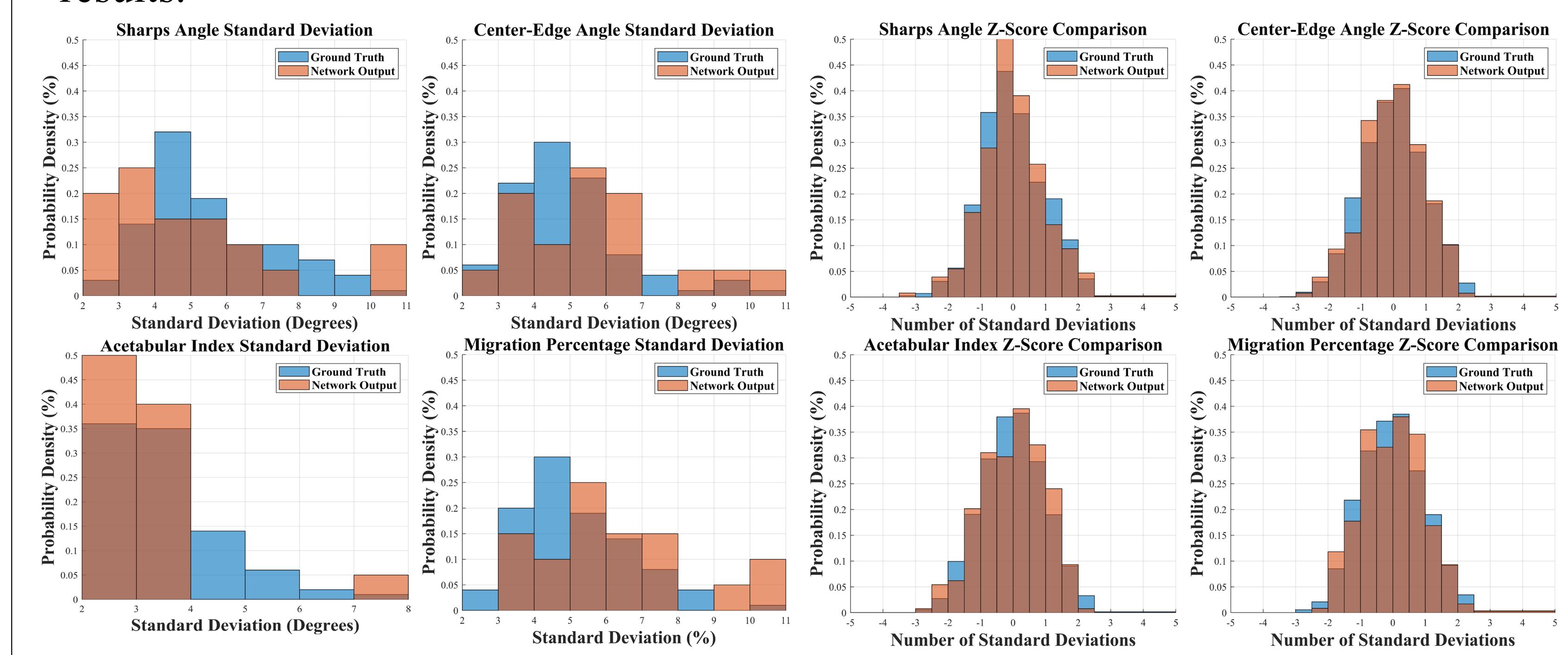

Figure 5: Standard deviation and Z-score comparison between manually labeled and estimated angles [4,5]

The standard deviation remains consistently low and the Z-score generally remains within 3 standard deviations of the arithmetic mean of the associated patient. This level of consistency shows high precision and consistent variance throughout the manual labeling and estimations.

Future Work

The applications of this study are enormous. While optimizations are necessary to implement this type of algorithm it holds large potential. In theory provided that a set of misaligned training data is manually labeled, and the network retrained it could be possible to accurately compute the metrics without the need for human input. This would allow radiologists to only oversee the results and ensure that they are reasonable, which would greatly increase the efficiency and reduce the workload on radiologists to diagnose conditions.

Publications

Perry, S, Folkman, M, O'Brien, T, Wilson, L, Coyle, E, Liu, RW, Price, CT, & Huayamave, V. "Utilizing Neural Networks to Assist in the Assessment and Predictive Measurement of Developmental Hip Dysplasia Radiographs." Proceedings of the ASME 2023 International Mechanical Engineering Congress and Exposition. Volume 5: Biomedical and Biotechnology. New Orleans, Louisiana, USA. October 29–November 2, 2023. V005T06A008. ASME. https://doi.org/10.1115/IMECE2023-113658

Perry, S., Folkman, M., O'Brien, T., Wilson, L., Coyle, E., Liu, R., Price, C., and Huayamave, V. (March 1, 2024). "Unaligned Hip Radiograph Assessment Utilizing Convolutional Neural Networks for the Assessment of Developmental Dysplasia of the Hip." ASME. ASME J of Medical Diagnostics. doi: https://doi.org/10.1115/1.4064988

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