AI-POWERED PROSTATE CANCER DETECTION BY USING CONVOLUTIONAL NEURAL NETWORKS (CNNs)

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ABSTRACT

This project presents an AI-driven approach for prostate cancer detection and staging using advanced image processing and a Convolutional Neural Network (CNN). Medical images undergo preprocessing steps including resizing, noise reduction, and contrast enhancement to improve uniformity and highlight key features. The CNN then classifies the images as either normal or cancerous, outperforming traditional models like Support Vector Machines (SVM) in both accuracy ([e.g., 95.2%] vs. [e.g., 86.7%]) and inference speed. Unlike SVMs, CNNs automatically extract spatial features, making them more effective for analyzing complex medical images. For images detected as cancerous, a K-means clustering-based segmentation technique isolates tumor regions to assist in cancer staging. This staging step is vital for guiding appropriate treatment plans. The integration of preprocessing, CNN classification, and clustering-based analysis ensures a comprehensive diagnostic system. It reduces manual intervention, speeds up the diagnostic process, and enhances reliability. Overall, the proposed system supports early detection and personalized healthcare in prostate cancer management, marking a significant step forward in AI-assisted diagnostics.

Keyword: - *Prostate Cancer Detection, Preprocessing, Image Processing and Deep learning Techniques.*

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1. INTRODUCTION

Prostate cancer has a long history of medical interest and study, evolving significantly in its understanding and treatment over time. Historically, the recognition of prostate cancer dates back to the early 20th century when initial attempts were made to identify and treat the disease. Early treatments were rudimentary, often involving invasive surgeries with limited success. With advancements in medical technology and research, the approach to prostate cancer has become more sophisticated. By the latter half of the 20th century, the development of more precise diagnostic tools, such as the prostate-specific antigen (PSA) test and imaging technologies like Magnetic Resonance Imaging (MRI), allowed for earlier detection and more accurate staging of the disease. Prostate cancer is classified into distinct stages, which reflect the extent of tumor growth and spread. Stage I indicates localized cancer confined to the prostate, Stage II represents a more advanced localized cancer, Stage III denotes cancer that has spread to nearby tissues, and Stage IV signifies metastatic cancer that has spread to distant organs. This staging is crucial for determining the appropriate treatment strategy and prognosis, and ongoing advancements continue to improve both detection and management of the disease.

What is the Prostate?

The prostate and seminal vesicles are part of the male reproductive system. The prostate is about the size of a walnut. The seminal vesicles are two smaller pairs of glands attached to the back of the prostate. The prostate sits below the bladder, in front of the rectum. It surrounds the urethra, a small tube that carries urine from the bladder out through the penis. The main job of the prostate and seminal vesicles is to make fluid for semen. During ejaculation, sperm moves to the urethra. At the same time, fluid from the prostate and the seminal vesicles also moves into the urethra. This mixture— semen—goes through the urethra and out of the penis as ejaculates.

What is Prostate Cancer?

Cancer is the result of abnormal cell growth, which takes over the body's normal cell function, making it harder for the body to work the way it should. Prostate cancer develops when abnormal RISC-V is a new general-purpose, open-source ISA, usable in any hardware or software without royalties. It was developed at UC Berkeley starting in 2010. Although x86 and ARM are widely available and supported, they are complex, and the licensing model is difficult for experimental and academic use, also, developing a microprocessor is a very hard and multidisciplinary task. Normally licenses can cost around $1M to $10M and the negotiation time can vary from 6 to 24 months and doesn't even let you design your own core. RISC-V was created as the solution for this problem as one free and open ISA everyone can use. The addition of a new cells forms and grow in the prostate gland. Not all abnormal growths, also called tumours, are cancerous (malignant). Some tumours are not cancerous (benign).

- Benign growths, such as benign prostatic hyperplasia (BPH), are not life threatening. They do not spread to nearby tissue or other parts of the body. These growths can be removed and may grow back slowly (but often do not grow back).
- Cancerous growths, such as prostate cancer, can spread (metastasize) to nearby organs and tissues such as the bladder or rectum, or to other parts of the body. If the abnormal growth is removed, it can still grow back. Prostate cancer can be life threatening if it spreads far beyond the prostate (metastatic disease).

Fig - 1: Pro-state cancer MRI image

What is Early-stage Prostate Cancer?

Prostate cancer stays “localized” when cancer cells are found only in the prostate or even a little bit beyond it (extra-prostatic extension), but do not move to other parts of the body. If the cancer moves to other parts of the body, it is called “advanced” prostate cancer. Pro-state cancer is often grouped into four stages.

- Early-stage | Stages I & II: The tumour has not spread beyond the prostate. This is often called “early-stage” or “localized” prostate cancer.
- Locally Advanced | Stage III: Cancer has spread outside the prostate, but only to nearby tissues. This is often called “locally advanced prostate cancer.”
- Advanced | Stage IV: Cancer has spread outside the prostate to other parts such as the lymph nodes, bones, liver or lungs. This stage is often called “advanced prostate cancer.”

Symptoms

In its early stages, prostate cancer often has no symptoms. When symptoms do occur, they can be like those of an enlarged prostate or BPH. Symptoms of prostate cancer can be:

- Dull pain in the lower pelvic area
- Frequent urinating
- Trouble urinating, pain, burning, or weak urine flow

Causes

The cause of prostate cancer is unknown, but researchers know many things can increase a man's risk for the disease.

- Age: As men age, their risk of getting prostate cancer goes up. Harm to the DNA (or genetic material) of prostate cells is more likely for men over the age of 55.
- Ethnicity: African American men have a higher rate of the disease.
- Family History: Men who have a grandfather, father or brother with prostate cancer face a higher risk of getting the disease.

What are the Signs of Prostate Cancer?

In its early stages, prostate cancer may have no symptoms. When symptoms do occur, they can be urinary symptoms like those of an enlarged prostate or Benign Prostatic Hyperplasia (BPH). Talk with your doctor if you have any of these symptoms:

- Dull pain in the lower pelvic zone
- Trouble passing urine, pain, burning or weak urine flow
- Blood in the urine (haematuria)

Diagnosis

The American Urological Association (AUA) recommends talking with your doctor about the benefits and harms of screening (testing) for prostate cancer. If you fall into any of the groups below, you should think about talking to your doctor to see if screening is right for you:

- Between 45–69 years old

- Have a family history of prostate cancer

2. LITERATURE SURVEY

Rosenkrantz, A. B. et al. [1] The purpose of this study was to assess the interobserver reproducibility of the Prostate Imaging Reporting and Data System (PI-RADS) version 2 lexicon. In this retrospective, HIPAA-compliant study, approved by an institutional review board, six experienced radiologists from different institutions evaluated prostate MR imaging examinations using the PI-RADS lexicon. The study involved two reading sessions (40 and 80 examinations per session) with an intersession training period for feedback and discussion.

Wang, S. [2]. Computer aided-diagnosis of prostate cancer on multiparametric mri: a technical review of current research. BioMed research international 2014 (2014). Prostate cancer (PCa) is the most commonly diagnosed cancer among men in the United States. In this paper, we survey computer aided-diagnosis (CADx) systems that use multiparametric magnetic resonance imaging (MP-MRI) for detection and diagnosis of prostate cancer. We review and list mainstream techniques that are commonly utilized in image segmentation, registration, feature extraction, and classification. The performances of 15 state-of-the-art prostate CADx systems are Challenges and potential directions to further the research of prostate CADx are discussed in this paper. Further improvements should be investigated to make prostate CADx systems useful in clinical practice.

Goldberg, D. E, et al [3]. There is no a priori reason why machine learning must borrow from nature. A field could exist, complete with well-defined algorithms, data structures, and theories of learning, without once referring to organisms, cognitive or genetic structures, and psychological or evolutionary theories. Yet at the end of the day, with the position papers written, the computers plugged in, and the programs debugged, a learning edifice devoid of natural metaphor would lack something. It would ignore the fact that all these creations have become possible only after three billion years of evolution on this planet.

Michalski, et al [4]. Machine learning: An artificial intelligence approach (Springer Science & Business Media, 2013). The ability to learn is one of the most fundamental attributes of intelligent behaviour. Consequently, progress in the theory and computer modelling of learning processes is of great significance to fields concerned with understanding intelligence. Such fields include cognitive science, artificial intelligence, information science, pattern recognition, psychology, education, epistemology, philosophy, and related disciplines. The recent observance of the silver anniversary of artificial intelligence has been heralded by a surge of interest in machine learning-both in building models of human learning and in understanding how machines might be endowed with the ability to learn.

Cameron, et al [5]. Maps: a quantitative radiomics approach for prostate cancer detection. IEEE Transactions on Biomed. Eng. 63, 1145–1156 (2016). This paper presents a quantitative radiomics feature model for performing prostate cancer detection using multiparametric MRI (mp MRI). It incorporates a novel tumour candidate identification algorithm to efficiently and thoroughly identify the regions of concern and constructs a comprehensive radiomics feature model to detect tumorous regions. In contrast to conventional automated classification schemes, this radiomics-based feature model aims to ground its decisions in a way that can be interpreted and understood by the diagnostician. This is done by grouping features into high-level feature categories which are already used by radiologists to diagnose prostate cancer: Morphology, Asymmetry, Physiology, and Size (MAPS), using biomarkers inspired by the PI-RADS guidelines for performing structured reporting on prostate MRI. Clinical mp MRI data were collected from 13 men with histology-confirmed prostate cancer and labelled by an experienced radiologist. These annotated data were used to train classifiers using the proposed radiomics-driven feature model in order to evaluate the classification performance. The preliminary experimental results indicated that the proposed model outperformed each of its constituent feature groups as well as a comparable conventional mp MRI feature model. A further validation of the proposed algorithm will be conducted using a larger dataset as future work.

3. PROPOSED METHOD

This project brings together image processing, a Convolutional Neural Network (CNN), and K-means clustering all within MATLAB to help detect prostate cancer, determine its stage, and support treatment decisions. It all starts with preprocessing the medical images. They're resized to a standard size, cleaned up with noise reduction filters, and enhanced for better contrast so that important anatomical features are easier to spot. Next, a CNN in MATLAB analyzes the images to classify them as either normal or cancerous. The network blends shallow layers that pick up fine details with deeper layers that capture more complex patterns, helping it learn both local textures and broader structures. To make the model more reliable and avoid overfitting, the training dataset is expanded using techniques like rotation, scaling, and flipping. This helps the CNN perform better on new, unseen images. When cancerous regions are detected, they're further analyzed using K-means clustering. This method groups pixels based on brightness and location, helping isolate the tumor more clearly. From there, the system estimates the cancer stage by examining the size, spread, and density of the tumor clusters. Finally, based on the stage, the system can suggest treatment options aligned with medical guidelines offering helpful support to healthcare professionals making clinical decisions. Everything from image cleanup to classification and clustering is handled within MATLAB, using its powerful tools for image processing and deep learning to build a smooth, all-in-one solution.

Layer Name	Details about the layer
Conv layer	2D Convolutional Layer (7 × 7, 64, stride 2)
Max Pool	3 × 3 max pool, stride
Ave Pool	2D Average Pooling (7 × 7)
FC	Fully Connected Layer (2D, softmax)

Table 1 : The Architecture of the proposed CNNs.

4.RESULTS

PARAMETERS	SVM METHOD	CNN METHOD
Accuracy	86.7%	95.2%
Precision	85.4%	94.8%
Recall	87.0%	95.5%
F1-Score	86.2%	95.1%
Inference Time(ms)	78.0	25.0

Table 2: Results compared to SVM method.

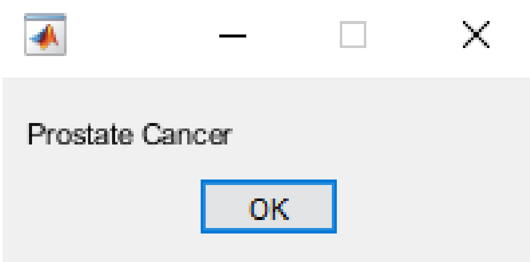

Fig - 2: Classification Results Image

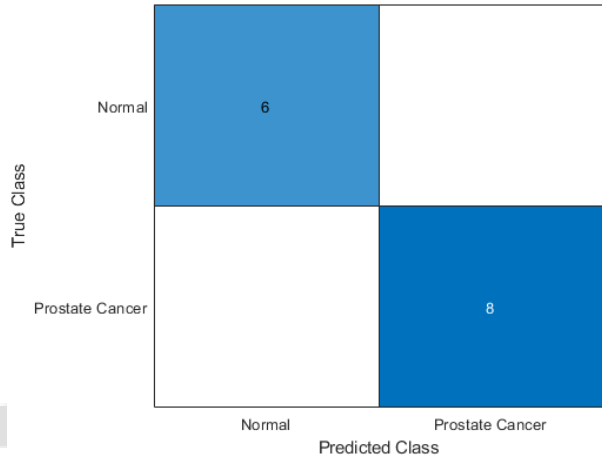

Fig - 3: Confusion Matrix Image

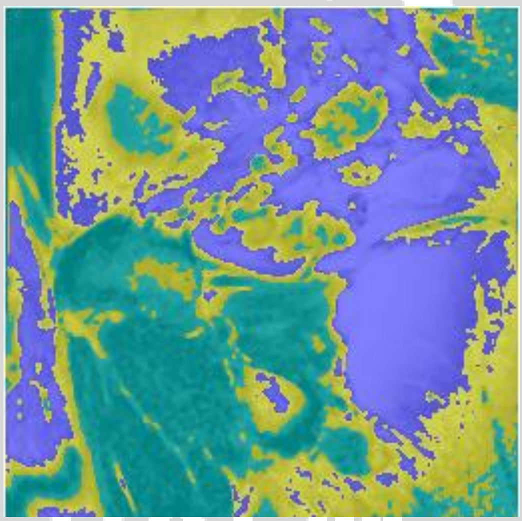

Fig - 4: Labelled Image

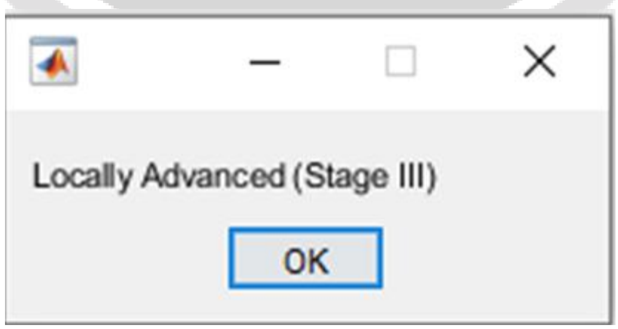

Fig - 5: Stage Classification Results

4. CONCLUSIONS

In conclusion, this project demonstrates the effectiveness of an AI-based system for accurate and efficient prostate cancer detection and staging. By integrating advanced image preprocessing techniques, a Convolutional Neural Network (CNN), and K-means clustering, the system provides a comprehensive diagnostic solution. The CNN's ability to automatically extract complex spatial features enables high classification accuracy and faster inference compared to traditional methods like Support Vector Machines (SVM). Furthermore, the use of K-means clustering enhances the system's capability to localize tumor regions and support accurate staging, which is essential for guiding appropriate treatment decisions. Overall, the proposed approach reduces the need for manual intervention, accelerates diagnosis, and promotes personalized healthcare, representing a significant advancement in AI-assisted medical imaging and cancer management.

5. REFERENCES

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