Automated Kidney Stone Detection Using Image Processing Techniques

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***Abstract*—Kidney stones are now a serious issue that, if not treated right away, can lead to complications and occasionally even require surgery to remove. Image processing can greatly increase the likelihood of accurately detecting stones well in advance. It has the propensity to produce accurate results and is an automatic method of finding the stone. Because kidney stones have low contrast and speckle noise, finding them via ultrasound imaging is a very difficult task. By using appropriate Image processing-MatLab approaches, this problem is solved. The speckle noise in the ultrasound image is first pre-processed using the image restoration technique. Stone placement detection was then performed using the reconstructed image.**

I. INTRODUCTION

Image processing is a domain of study that involves the analysis, manipulation, and interpretation of digital images using various algorithms and mathematical techniques. It is a multidisciplinary field that combines aspects of computer science, mathematics, physics, and engineering. The goal of Image processing is to extract useful information from digital images, improve image quality, or perform various image-based tasks, such as object detection and recognition, segmentation, registration, and restoration.

Image processing can be broadly classified into two categories: analog Image processing and digital Image processing. Analog Image processing involves the manipulation of physical images using optical and electrical techniques, whereas digital Image processing involves the manipulation of digital images using computational algorithms. Image processing finds applications in a wide range of fields, including medical imaging, surveillance and security, remote sensing, robotics and automation, entertainment, and agriculture. In the medical field, Image processing is used to diagnose diseases, plan treatments, and monitor the progress of medical procedures. In the field of surveillance and security, Image processing is used to detect and track objects, recognize faces, and identify potential threats. Some common techniques used in Image processing include filtering, segmentation, feature extraction, and pattern recognition. Filtering techniques are used to remove noise or enhance certain features of an image, while segmentation techniques are used to partition an image into regions of interest. Feature extraction techniques are used to extract relevant information from an image, while pattern recognition techniques are used to recognize and classify objects in an image. In summary, Image processing is an interdisciplinary field that involves the use of mathematical algorithms and computational techniques to analyse, manipulate, and interpret digital images. It has numerous applications in various domains, and a wide range of techniques and tools are used in Image processing to extract useful information from images, improve their visual quality, and perform image-based tasks.

II. LITERATURE SURVEY

Birds Tsao, Chang and Lin, published a research paper named after “Ultrasonic Renal- Stone Detection and Identification for Extracorporeal Lithotripsy” analysed the exact position of palpable urinary calculus and demonstrated its problems which are crucial for extracorporeal shock wave lithotripsy. Because it constantly uses stun waves to detect kidney stones. But the miss-hit of shock waves may harm the tissue badly. Their investigation revealed that the spot clamour exists in all ultrasonic images that should be removed. [1]

Viswanath and Gunasundari, published a research paper named after "Design and analysis performance of kidney stone detection from ultrasound image by level set segmentation and ANN classification" by lowering specific vitality levels that confirm the presence of urinary calculus in a specific area, improved accuracy in 2014. To complete the procedure, the artificial neural network idea was effectively applied. But the system they proposed will not specify the size of the stones detected.[2]

Angshuman Khan, Rupayan Da and M C Parameshwara, published a research paper named after "Detection of kidney stone using digital Image processing: a holistic approach" finds whether the kidney scan image has stones in it or not but it doesn't detect and calculate the size of the stone. [3]

Sakshi Garg, Angadpreet Walia, Abhilasha Singh & Anju Mishra, published a research paper named after "A Study on Shape Detection: An Unexplored Parameter in the Gallstones Identification the system uses several Image processing methods to detect stones in Gall Bladder. [4]

A renal ultrasound is a very useful exam which allows doctors to quickly evaluate the condition of kidneys without exposing patients to radiation or using IV contract. The test can be repeated without any harm. Still, it cannot reveal every type of kidney stone, therefore patients usually require additional exams [5].

F. L. Coe, A. Evan, and E. Worcester, in article [6] "Kidney stone disease," the study developed a method for defining the boundary of regions of interest in a digital KUB CT scan but it doesn't detect the stone.

V. Romero, H. Akpinar, and D. G. Assimos, [7] developed a method for detecting the object of interest (kidney stones) including its size and location in a digital KUB CT scan image.

R. C. Gonzalez and R. E. Woods, [8] book on Image processing techniques applied in the program include Contrast Adjustment, Segmentation.

A. C. Kak and A.Rosenfeld [9] book in the area of Digital Picture Processing.

Despite numerous studies on kidney stone detection, some recent works which are done by Mehmet Baygin , Orhan Yaman, Prabal Datta Barua [10] and Tanya Borges, Akash Rai, Dharm Raj, Danish Ather, Keshav Gupta [11] still face certain limitations. Some of these include lack of focus on reducing unwanted signals from ultrasound images and improving image quality, weak segmentation in detecting stones, inaccurate detection and location of stones, and cumbersome execution time and memory usage.

III. METHODOLOGY

This The proposed system for kidney stone detection is implemented using image processing techniques in MATLAB. The methodology is divided into two main phases: Pre-processing and Stone Detection.

1. Image Acquisition

- Ultrasound (US) kidney scan images are taken as input.
- Images are selected through a GUI using MATLAB.

2. Pre-processing Phase

This phase improves image quality and removes noise for accurate detection.

- Grayscale Conversion
- Convert RGB image into grayscale using rgb2gray () to simplify processing.
- Initial Thresholding Apply threshold ($b > 20$) to segment image into binary form.
- Noise Removal (Median Filtering) Use medfilt2() to remove speckle noise while preserving edges.
- Second Thresholding Apply another threshold ($mo > 250$) to refine the image.

- Morphological Operations
  - Use imfill() to fill holes in objects
  - Use bwareaopen() to remove small unwanted regions

IV. REGION OF INTEREST (ROI) SELECTION

- Use roipoly() to select the kidney region where stones are expected.
- This focuses the detection process on relevant areas.

4. Stone Detection Phase
- Connected Component

Labeling Apply bwlabel() to identify individual stones.
- Feature Extraction

Extract properties like location and pixel area of each stone.

V. STONE SIZE CALCULATION

- Calculate size based on pixel area.
- Convert area into real-world measurement (mm).
- Formula used:
  - Size = √(Area)

VI. VISUALIZATION

- Draw bounding boxes around detected stones using rectangle ().
- Highlight stones clearly in the output image.

VII. OUTPUT DISPLAY

- Show:
  - Processed image with detected stones
  - Size of each detected stone
- Results are displayed through a MATLAB GUI.

VIII. FINAL RESULT

- If stones are present → Display location + size
- If no stones → Display “No Stone Detected”

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IX. RESULTS

The The proposed system for kidney stone detection using image processing techniques was successfully implemented and tested on multiple ultrasound images.
The system takes ultrasound kidney scan images as input and processes them through various stages such as preprocessing, segmentation, and detection. The results obtained demonstrate that the system can effectively detect the presence of kidney stones and highlight them clearly

- For images containing kidney stones, the system successfully:
  - Detected the stones accurately
  - Highlighted the detected stones using bounding boxes
  - Calculated and displayed the size of each stone in millimetres
- For images without kidney stones, the system correctly:
  - Identified the absence of stones
  - Displayed an appropriate message such as “No Stone Detected”

The preprocessing techniques significantly improved the quality of ultrasound images by reducing noise and enhancing important features, which contributed to better detection accuracy.
The results also show that the system is capable of detecting multiple stones in a single image and providing individual size measurements for each detected stone.

Overall, the system achieved:
- Accurate detection of kidney stones
- Clear visualization of detected regions
- Reliable size estimation of stones

These results confirm that the proposed approach is effective and can assist in early diagnosis using ultrasound imaging.

X. DISCUSSION

The proposed system for automated kidney stone detection using image processing techniques demonstrates an effective and low-cost approach for medical diagnosis using ultrasound images.
One of the major challenges in ultrasound imaging is the presence of speckle noise and low contrast, which makes it difficult to detect small kidney stones. In this project, the use of preprocessing techniques such as grayscale conversion, thresholding, and median filtering helped in improving image quality and reducing noise. This significantly enhanced the visibility of stones in the scan images.

The system successfully identifies kidney stones by applying connected component analysis, which allows accurate detection of stone regions. Additionally, the method calculates the size of each detected stone, which is an important factor for medical diagnosis and treatment planning. The use of bounding boxes around detected stones provides a clear visual representation, making the system user-friendly.

Compared to traditional methods like CT scans and MRI, the proposed system using ultrasound images is cost-effective, safer (non-ionizing), and easily accessible. This makes it highly beneficial, especially in rural or low-resource areas.

However, the system has some limitations. The accuracy of detection depends on the quality of the input ultrasound image. Extremely noisy or poor-quality images may lead to incorrect detection or missed stones. Also, the system may face difficulty in detecting very tiny stones or distinguishing them from similar intensity regions.

Overall, the project proves that image processing techniques can be effectively used for automatic kidney stone detection, reducing manual effort and assisting doctors in faster diagnosis. With further improvements such as integrating machine learning or deep learning models, the system can achieve even higher accuracy and robustness.

XI. CONCLUSION

This The project "Automated Kidney Stone Detection Using Image Processing Techniques" successfully demonstrates an efficient method for detecting kidney stones from ultrasound images. By applying various image processing techniques such as grayscale conversion, thresholding, median filtering, and connected component analysis, the system is able to accurately detect and localize kidney stones.

The proposed system not only identifies the presence of stones but also calculates their size and location, which is highly useful for medical diagnosis and treatment planning. The integration of a user-friendly GUI in MATLAB makes the system easy to use even for non-technical users.

Compared to traditional diagnostic methods like CT scans and MRI, this approach is cost-effective, safe, and accessible, as it utilizes ultrasound images that do not involve harmful radiation. This makes the system suitable for widespread use, especially in areas with limited medical resources.

Although the system performs well, its accuracy depends on the quality of the input images, and detecting very small stones remains a challenge. Future enhancements such as incorporating machine learning or deep learning techniques can further improve detection accuracy and automation.

In conclusion, this project provides a reliable, affordable, and efficient solution for early kidney stone detection and has the potential to assist healthcare professionals in improving patient care

REFERENCES

[1] Tsao, Chang, and Lin in Ultrasonic Renal-Stone Detection and Identification for Extracorporeal Lithotripsy | IEEE Conference Publication | IEEE Xplore

[2] Viswanath and Gunasundari Design and analysis performance of kidney stone detection from ultrasound image by level set segmentation and ANN classification | IEEE Conference Publication | IEEE Xplore

[3] Angshuman Khan, Rupayan Das and M C Parameshwara https://iopscience.iop.org/article/10.1088/2631-8695/ac8b65

[4] Sakshi Garg, Angadpreet Walia, Abhilasha Singh & Anju Mishra A Study on Shape Detection: An Unexplored Parameter in the Gallstones Identification | SpringerLink

[5] A renal ultrasound is a very useful exam which allows doctors to quickly evaluate the condition of kidneys without exposing patients to radiation or using IV contract. https://ic.steadyhealth.com/ultrasound-procedure-forkidney-stones

[6] F. L. Coe, A. Evan, and E. Worcester, "Kidney stone disease,"Journal of Clinical Investigation, vol. 115, no. 10, pp. 2598-2608,2019 https://www.jci.org/articles/view/26662/pdf.

[7] V. Romero, H. Akpinar, and D. G. Assimos, "Kidney stones: A global picture of prevalence, incidence, and associated risk factors," Reviews in Urology, vol. 12, no. 2-3, pp. 86-96, 2019 https://www.semanticscholar.org/paper/Digital-Image-Processing- Gonz%C3%A1lez-Woods/72ce0faa2d0be574f5cb88cfe6353a3ba40a08ae

[8] R. C. Gonzalez and R. E. Woods, Digital Image Processing, 2nd ed., 2019, ch. 2, pp. 47-51 and ch. 10, pp. 568-611 https://www.semanticscholar.org/paper/Digital-Image-Processing- Gonz%C3%A1lez-Woods/72ce0faa2d0be574f5cb88cfe6353a3ba40a08ae.

[9] A. Rosenfeld and A. C. Kak, Digital Picture Processing, 2nd ed., Academic Press,2018, ch.10https://www.sciencedirect.com/book/9780125973021/digital-pictureprocessing.

[10] Mehmet Baygin, Orhan Yaman, Prabal Datta Barua Exemplar Darknet19 feature generation technique for automated kidney stone detection with coronal CT images – ScienceDirect

[11] Kidney Stone Detection using Ultrasound Images by Tanya Borges, Akash Rai, Dharm Raj, Danish Ather, Keshav Gupta: SSRN.

[12] A Gallery of High-Resolution, Ultrasound, Color Doppler & 3D Images (ultrasoundimages.com)