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Advancements in the Development of a Radiologist Assistant Robot (Advaya Bot) and its Integration into Healthcare Applications

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***Abstract*— In this paper, the Advaya Bot - Radiologist assistant robot development & its usage in healthcare applications is presented. The final year project under-taken by us consists of the designing & developing of a bot that can assist healthcare professionals, specifically in the Department of Radiology. It is a growing concern among the community of radiologists that radiation exposure, even under protocol scenarios, is causing harm to them in the form of cancers, tumors, cataracts, dry eye syndrome, etc. Also, in departments like that of Ultra Sonography imaging, the manual use of a transducer is something not looked forward to by the patients. We aim to build a bot that can reduce radiation exposure, workload, and uncomfortable interactions for the doctors in the department of radiology imaging. The use of such bots is strictly domain specific. For the purpose of our final project, we have chosen the domain to be that of Ultrasonography (USG). We aim at eliminating the manual use of the transducer and replacing it with a bot. The bot shall be capable of greeting the patient and adjusting the location of the end-effector with the help of a radiologist or specialist from a distance. The end edge of the bot will also be capable of placing the transducer with the required pressure on the required area of the patient's body. In developing countries like India, the ratio of doctors to the number of patients is very low. We aim to unburden healthcare professionals and free them from harmful working conditions. The project undertaken represents the main project of the seventh semester by Electronics & Communication Engineering students, conducted under the guidance and supervision of faculty advisors.**

***Index Terms*— Robotics, Medical Engineering, Radiology, Robot, Applications**

I. INTRODUCTION

We were motivated by a strong understanding of the difficulties present in this crucial area of healthcare. In their pursuit of precise diagnosis, radiologists and other healthcare professionals face several urgent issues. The foremost among them is the ongoing threat of radiation exposure, which carries long-term health hazards like cataracts and cancer. Due to physical equipment being handled during radiological treatments, patients also feel,

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uneasy and anxious. This robot not only helps radiologists by lowering their exposure to radiation, but it also exemplifies efficiency and compassion by calming patients, establishing a calm environment, and deftly placing the transducer device under the USG chamber and X-Ray chamber. Our Radiologist-Assist bot increases patient comfort while also easing the workload for our healthcare professionals, enabling them to concentrate on providing top-notch care. It leverages the power of AI, ML, and robotics to reduce radiation exposure, enhance efficiency, alleviate patient discomfort, and support healthcare professionals in delivering more accurate diagnoses [1]-[10].

II. OBJECTIVE

The project, the Radiologist-Assist Bot, seeks to lower radiation exposure for medical staff, improve diagnostic effectiveness, increase patient comfort, and assist radiologists in providing more precise diagnoses while adhering to safety standards and ensuring cost-effectiveness [11]-[20].

III. AIM OF THE RESEARCH

The main objectives of the research works is focused on the specific domain of Ultrasonography (USG), aims to develop, and implement an innovative Radiologist-Assist Bot that significantly reduces radiation exposure for radiologists while optimizing efficiency, patient comfort, and diagnostic accuracy in USG procedures [20][30].

IV. PROPOSED METHODOLOGY

The Fig. No. 1 gives the proposed block diagram for implementing the bio-medical robotic project. The bot will utilize the power of actuators to move. The movements will be controlled by the handler (healthcare professional). Generally, the USG setup consists of a transducer and a monitor. With the help of this bot the distance between the monitor and transducer can be further increased. The transducer should be placed on the body of the patient at a required angle and at a required pressure that can be managed by the healthcare professional in charge.

As the bot will also be the first point of contact between the patient and the facility, the bot will be able to interact with the patient for hospitality purposes or can even relay communication between the healthcare professional and the patient. This is to reduce workload on the professional and make the patient feel more comfortable. On an advanced approach the bot can also be implemented in X-Ray imaging to move the required body part (like arms and legs) for the purpose of proper imaging. X-Ray imaging creates more radioactive exposure for professionals thus putting their health at stake.

With more implementation of such bots, we can safeguard our doctors and other professionals from ionizing radiation and decrease their workload. Simultaneously, the patients can feel more comfortable during their medical imaging procedure [1]-[10]. The biomedical robotic project aims to enhance medical procedures, specifically ultrasound (USG) and X-ray imaging. The robotic system will rely on actuators for movement and will be controlled by a healthcare professional.

Ultrasound (USG) Setup Enhancement: Utilizes a transducer and monitor for USG imaging. The robotic system facilitates an extended distance between the monitor and transducer, enhancing flexibility in positioning. The transducer is placed on the patient's body at a specific angle and pressure, adjustable by the healthcare professional.

Patient Interaction and Comfort: Serves as the initial point of contact between the patient and the medical facility. The robotic system can interact with the patient, providing hospitality and relaying information.

Further the work will aim to reduce the workload on healthcare professionals and create a more comfortable environment for the patient.

The specific mathematical procedures for calculating the correlation between images and defining the contacts between the probes and the tissues are outlined as under …

$$Corr(I_k, I_{nc}) = \frac{\sum_{p=1}^{M}\sum_{q=1}^{N}[I_k(p,q)]}{Avg\ [I_k(p,q)]} \quad (1)$$

In this context, the contact feature (ck) represents the correlation between two images, where (px, py) denotes the pixel locations in the image frames, and M & N stand for the heights & widths of input image, respectively. Ik & Inc correspond to the averages intensities of pixel in the acquired images and the images without contact with the tissue. The parameter t_{corr} serves as the thresholds for determining the levels of contact. Assessing the degree of compression is crucial, as forces given by the robot to the tissue induces deformation. Greater force results in increased distortion. This deformation can lead to patient discomfort and potential inaccuracies in clinical diagnoses. The proposed compression feature is defined as the disparity between the maximum and minimum indices of pixels brighter than the threshold t_{comp}, relative to the image's vertical size. The mathematical expression for calculating this image compression feature is formulated as follows

$$U = max(p)\ \&\ p = avg(s) \quad (2)$$

$$L = max(q)\ \&\ q = avg(y) \quad (3)$$

$$f_c = \frac{U-L}{Mn} \quad (4)$$

In Equation (3), the variables U & L represent the maximum & minimum locations of pixel with intensities greater than the threshold t_{comp}. The compression feature, denoted as f_c, is defined in Equation (3), where M corresponds to the height of the image along the y direction. The procedure for adjusting the forces value dependent on the outputs of the image qualities assessment algorithms are outlined in Equations (4) and (5).

$$VV_{ss} = SVM(p,q) \quad (5)$$

$$F_{z+1} = F_z + F_q + F_D \quad (6)$$

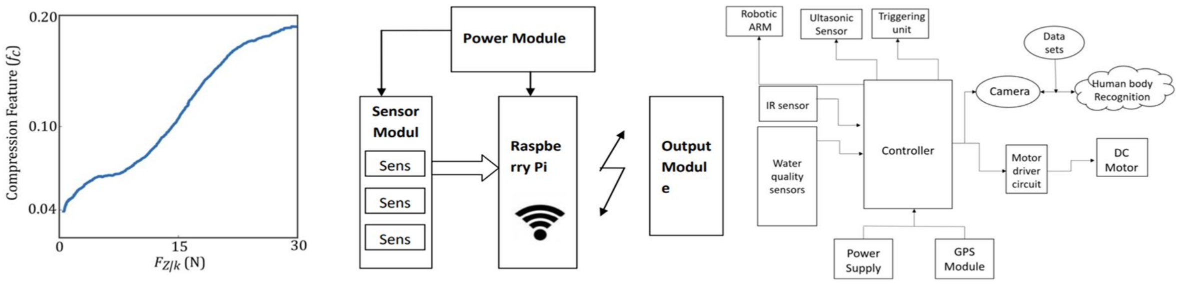

Fig. 1: Compression feature vs measured force / Overall block diagram used for the project work / Block-diagram of the proposed robotic system

In this topic, of the Advanced Application in X Ray Image Processing, the Explores advanced application in X Ray imaging's. The robotic system can move specific body parts (e.g., arms and legs) to optimize imaging. Addresses concerns related to ionizing radiation exposure for healthcare professionals during X-ray procedures. Radiation Safety and Workload Reduction: Implementation of the robotic system safeguards healthcare professionals from excessive ionizing radiation exposure. Aims to decrease the workload on professionals by automating certain tasks, ensuring precise movements during imaging. Improved Patient Experience: By integrating robotics, the medical imaging procedures become more efficient and less invasive. Patients experience enhanced comfort and reduced anxiety during procedures. Overall Impact: The proposed methodology contributes to the well-being of healthcare professionals by minimizing radiation exposure. Simultaneously, it improves the overall patient experience, making medical imaging procedures more accessible and less stressful.

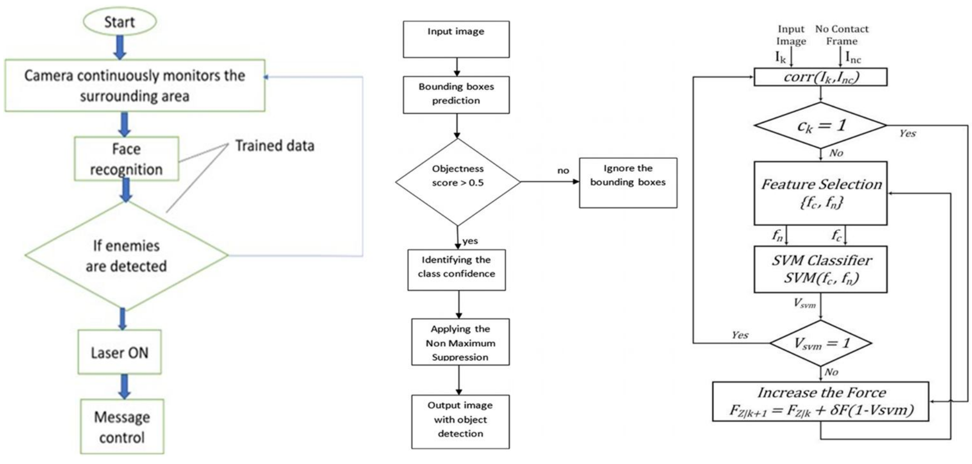

Fig. 2: Quality Assessment Algorithm / Obstacle avoiding algorithms utilized in the project's work / Obstacle avoiding algorithms utilizing in the project's work

V. HARDWARE & SOFTWARE

The main module will show movement about its various axes to go to the desired position and orientation. The sensors on the edge-effector will give the measurement for the pressure it applies [11- [20]. Raspberry Pi 3 Model B, Raspbian buster, Putty, VNC Viewer, Windows or IOS, Joints and Actuators, encoder for joint position's feedbacks, force-torque sensor to the detecting of the external forces, & utilizing some of the proximity type of sensing devices for the detecting the obstacles and objects, end-effector, power source Python IDLE, Flasher, SD Card Formatter, Adafruit IO [21]-[30].

VI. APPLICATIONS & ADVANTAGES

During an ultrasonography (USG) scans, the sonographers are in close contacting with the patients, that putting them at the risks of transmitting of many diseases from patient. The less involvement of humans will protect the privacy of the patient's personal information. An automated robotic system designed to scan tissue, promoting an extended distance between the sonographer and patient while reducing the duration of physical contact. Additionally, its adaptability allows for deployment in resource-constrained regions, addressing the global shortage of sonographers [1]-[10].

VII. RESULTS & DISCUSSIONS

Evaluations of robotic ultrasound have taken place in diverse settings, encompassing the operating room, remote clinics, and even space. Tailored systems have been created to facilitate abdominal, obstetric, vascular, and various other applications. The innovative design allows sonographers the flexibility to conduct ultrasound scanning without proximity to the patient, enabling efficient rescans of areas of interest. The system takes into account sonographers' preferences regarding ultrasound scanning techniques and facilitates rapid training for various applications. In our proposed system, tissue scanning is automated through the use of a dexterous robotic arm equipped with an ultrasound probe (transducer) [11]-[20].

Certainly, breaking down the expected outcomes in more detail: Evaluation in Various Environments: Robotics based ultrasounds have undergone evaluations in diverse environment, including the operating room, remote clinic & even spaces. This suggests that the technology is adaptable and can be employed in a wide range of settings, extending its potential applications beyond traditional healthcare facilities.

Design for Different Applications: The systems have been specifically designed to cater to various medical applications. This includes abdominal, obstetric, vascular, and potentially other diagnostic and interventional procedures. Tailoring the system for different applications indicates its versatility and ability to address a spectrum of healthcare needs.

Remote Scanning Capability: A significant outcome is the capability of the robotic ultrasound system to conduct scans without the physical presence of sonologists near the patient. This is particularly beneficial in scenarios where immediate access to specialized healthcare professionals is limited, such as in remote locations or emergency situations.

Consideration of Sonographer Preferences: The system takes into account the preference of sonographer in terms of how the ultrasound based scanning takes place is performed. This consideration is crucial for the successful integration of the technology into existing healthcare workflows, ensuring that it aligns with established practices and is user-friendly for medical professionals.

Quick Training for Different Applications: The robotic ultrasound system can be trained rapidly for various applications. This quick adaptability is advantageous as it allows the system to be easily configured for different types of ultrasound examinations. This feature is essential in a dynamic healthcare environment where diverse imaging needs may arise.

Automation of Tissue Scanning: The proposed system automates the process of tissue scanning using a dexterous robot arm equipped with the ultrasound probe (transducer). Automation offers several benefits, including standardized and precise scans, reduced potential for human error, and increased efficiency in the ultrasound procedure.

The developed robotic system demonstrates efficient selective harvesting of tomatoes through a combination of color detection and image processing algorithms. Equipped with a camera, the system captures images of tomatoes in its field of view. Utilizing advanced color detection techniques, the algorithm analyzes the images to identify tomato colors. Upon detecting a red tomato, the robot's arm replicates the necessary motion to gently pluck it from the plant, ensuring precise movements to avoid any harm to the plant or fruit. For yellow tomatoes, a similar plucking motion is employed, but with an additional controlled rotation to safely deposit the tomato into the designated basket. This rotation facilitates effective separation and collection of harvested tomatoes, enhancing overall system productivity. The integration of color detection and image processing significantly improves the robot's ability to distinguish between red and yellow tomatoes. By adapting its movements based on detected colors, the robot optimizes efficiency and accuracy, seamlessly merging technology with agricultural practices. This innovative approach streamlines tomato harvesting, contributing to increased productivity in the agricultural sector. In summary, the expected outcomes highlight the adaptability and versatility of robotic ultrasound technology. It addresses the need for accessibility in different environments, caters to various medical applications, enables remote scanning, considers user preferences, and offers quick training for different procedures. The automation of tissue scanning with a dexterous robot arm further enhances the efficiency and precision of ultrasound examinations.

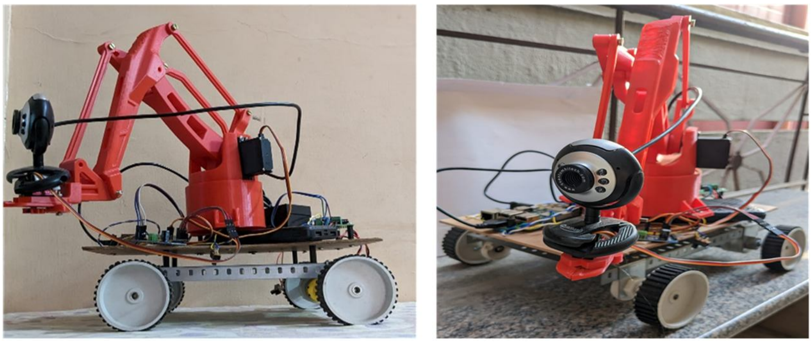

Fig. 3: Reference of Panda Robot Arm Developed by the team / Reference of Panda Robot Arm Developed by the team

VII. CONCLUSIONS

In conclusion, the Advaya Bot project marks a groundbreaking development in the field of healthcare and medical imaging. By creating a Radiologist assistant robot, this project has demonstrated its potential to revolutionize healthcare applications. Advaya Bot streamlines the radiologist's workflow, enhances diagnostic accuracy, and reduces the time required for image analysis. The robot's ability to efficiently process medical images, assist in diagnostics, and provide support in healthcare settings has far-reaching implications for the medical field. It not only improves the quality of patient care but also aids healthcare professionals in handling the ever-growing volume of medical imaging data. As this technology continues to advance, Advaya Bot stands as a significant advancement in the quest for more efficient, accurate, and accessible healthcare solutions.

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