Design and Implementation of an Orthanc Plugin for Semi-Automatic Interpretation of Medical Images

by

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Declaration

I, Andrew Shawa, do hereby declare that the work in this dissertation has not been previously submitted in candidature for any degree. This dissertation is the result of my own work and investigations, except where otherwise stated. Other sources are acknowledged by given explicit references. A complete list of references is given.

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Certificate of Approval

This dissertation of Chimuka Moonde has been approved as fulfilling the requirements or partial fulfilment of the requirements for the award of Master of Science in Computer Science by the University of Zambia;

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Abstract

In the domain of medical imaging, the role of automated image interpretation tools is becoming increasingly critical in facilitating the diagnosis and treatment of diverse diseases. The escalating volume and intricacy of medical images necessitate the development of advanced tools that can support automatic image analysis. This paper outlines work associated with the design and implementation of a plugin for semi-automated interpretation of medical images for the free and open source DICOM viewers, specifically DICOM viewers embedded inside the Orthanc server. The primary objective is to augment the functionality of these viewers, empowering them to assist radiologists and healthcare professionals in the comprehensive interpretation and analysis of medical images. This abstract outlines how DICOM viewer plugins can be integrated with machine learning models to enhance the efficiency and accuracy of medical image interpretation, ultimately leading to improved patient care and outcomes.

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List of Abbreviations

Abbreviation	Description
AI	Artificial Intelligence
DICOM	Digital Imaging and Communications in Medicine
EI	Enterprise Imaging
TAM	Technology Acceptance Model
UNZA	The University of Zambia
UTHs	University Teaching Hospitals

CHAPTER ONE

INTRODUCTION

1.1 Introduction

This chapter explains why this study is being conducted. It begins by outlining the study's context. The chapter also includes a statement of the problem, as well as the aim, objectives and questions.

1.2 Background of the Study

The Republic of Zambia grapples with a severe shortage of radiologists, having only five serving a population of 17 million in 2019 [1]. This scarcity emphasizes the challenges in radiological diagnosis, forming the basis for a compelling case study. Positioned as a pilot project, this study investigates the impact of the radiologist shortage while exploring the feasibility of implementing efficient medical imaging workflows using enterprise imaging techniques. The overarching objective is to showcase the potential of enterprise imaging in addressing the grand challenges associated with medical imaging in Zambia. This comprehensive background aligns with the global trend of leveraging technology to overcome healthcare disparities, forming a cohesive narrative that underscores the urgency and significance of the proposed research.

In the domain of medical imaging, where high-resolution images are vital for precise diagnosis and effective treatment planning, challenges persist in manual image interpretation. The global demand for tools automating image interpretation processes has surged, leading to the exploration, design, and development of extensions or plugins tailored for DICOM viewers. This study hones in on free and open source viewers used within Orthanc, seeking to augment their functionality for automated support in medical image interpretation. The primary goal is to empower these viewers with innovative plugins integrating advanced methodologies like deep learning, computer vision, and pattern recognition. These methodologies aim to streamline image interpretation, automatically analyze medical images, and extract relevant information, offering valuable insights for clinical decision-making. The potential impact includes reduced interpretation time, heightened accuracy, and enhanced workflow efficiency, ultimately contributing to superior patient care and treatment outcomes. This concerted effort seamlessly integrates technological advancements with the real-world challenges faced by healthcare systems, forming a cohesive narrative that underscores the urgency and significance of the proposed research.

1.3 Problem Statement

In the context of the rapidly evolving field of medical imaging, where high-resolution images play a pivotal role in diagnosis and treatment planning, the challenge persists in the manual interpretation of these images, relying heavily on the expertise of radiologists. Despite technological advancements, there is a recognized need to alleviate the workload of healthcare professionals and enhance the efficiency of image interpretation processes. This study addresses the research problem of improving the interpretation of medical images by exploring, designing, and developing specialized extensions or plugins for DICOM viewers, specifically targeting Orthanc. The primary objective is to enhance the DICOM viewer's functionality, enabling semi-automated interpretation of medical images. Framed within the broader goal of streamlining image interpretation, reducing the workload on radiologists, and ultimately improving patient care and treatment outcomes, the study seeks to determine the usefulness and feasibility of these extensions. The research also explores the integration of web services to facilitate communication between the developed plugins and a pre-trained AI model, contributing to the overarching aim of advancing the semi-automated interpretation of medical images.

1.4 Research Aim

This research aims to investigate the feasibility of designing, implementing and evaluating an Orthanc plugin for semi-automated interpretation of medical images. This includes implementation of plugins for DICOM image viewers dundled within Orthanc as well as Web Services to provide communication between the plugins and a pre-trained AI model for medical image interpretation.

1.5 Research Objectives

1.5.1 Broad Objective

- The main objective of this study is to investigate the feasibility of designing, implementing and evaluating an Orthanc plugin for semi-automated interpretation of medical images.

1.5.2 Specific Objectives

1. To determine how medical images are currently being interpreted at the UTHs

2. To design and implement an Orthanc plugin for semi-automated interpretation of medical images.

3. To evaluate the usefulness

and effectiveness of the Orthanc plugin for semi-automated interpretation of medical images.

1.5.3 Research Questions

1. How are radiological medical images currently being interpreted at the UTHs

2. How are plugins/systems for semi-automated interpretation of medical images designed and implemented?

3. How are plugins/systems for semi-automated interpretation of medical images tested for efficiency,usefulness and effectiveness?

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section delves into pertinent literature to enhance the understanding of software tools for semi-automated medical image analysis. The review explores existing research and insights relevant to the design and implementation of innovative software tools in medical image interpretation.

2.2 Software Tools for Semi-Automated Medical Image Analysis

2.2.1 Syngo

The paper "Clinical Validation of Siemens' Syngo.via Automatic Contouring System" by Pera et al, provides valuable insights into the benefits of using artificial intelligence to assist in the manual delineation of organs at risk in radiation therapy. The paper discusses the time-consuming process of manual delineation and the potential benefits of using validated software tools assisted by artificial intelligence to significantly improve the radiation therapy workflow, reduce the time required for segmentation, and standardize the critical organs delineated in different clinical pathologies[2].

The Syngo.via Automatic Contouring System is a dedicated multimodality imaging software solution for radiation therapy offered by Siemens Healthineers. The automatic contouring algorithm is based on deep learning and has been trained and validated with patient images from multiple institutions across the world[2]. The system uses a server-client architecture and can automatically contour organs required for radiation therapy planning.

This paper involved the clinical validation of Siemens' Syngo.via Automatic Contouring System. The study evaluated the manual adjustments made to the automatic contours to establish the applicability of the system and used the Jaccard index, the Dice coefficient, and the Hausdorff distance to compare the results of the tested delineation to a ground-truth delineation[3]. The study also used the Radiation Oncology Therapy Group (RTOG) RANK classification system to evaluate the autocontouring solution.

The RANK system is a specific qualitative classification system that evaluates the quality of automatically delineated organs at risk. The RANK system assigns a score from 1 to 4 to each organ at risk based on the quality of the automatically generated contours. A score of 1 indicates that the contours are unacceptable and require manual correction, while a score of 4 indicates that the contours are acceptable and require no further manual correction. In this study, the RANK system was used to evaluate more than 600 contours corresponding to 18 different automatically delineated organs at risk. The results showed that 64% of the evaluated structures received the maximum score of 4, indicating that the contours were acceptable and required no further manual correction. Only 1% of the structures were classified with the lowest score of 1, indicating that the contours were unacceptable and required manual correction.

The results of the study showed that the Syngo.via Automatic Contouring System offers good auto contouring results and significant time savings. The system was able to automatically contour organs required for radiation therapy planning, and the contours generated by the system were comparable to the ground-truth delineation. The study also found that the system was able to reduce the time required for segmentation, which can be a time-consuming process in radiation therapy planning[2].

Overall, this paper provides valuable insights into the potential benefits of using artificial intelligence to assist in image interpretation and the importance of validating the contours generated by computer tools. It provides valuable insights into the potential benefits of using AI-assisted image interpretation and the importance of validating the contours generated by computer tools.

2.2.2 AMIDE: A Free Software Tool for Multimodality Medical Image Analysis

One paper that could be useful for our literature review is "Amide's a Medical Image Data Examiner (AMIDE): A Free Software Tool for Multimodality Medical Image Analysis" by Loening et al [4]. This research describes the development of AMIDE, a free and open-source software tool for analyzing volumetric medical images, including PET, CT, and MRI. The authors highlight the unique features of AMIDE, such as its ability to handle non-orthogonal reslicing and its support for an unlimited number of data sets and regions of interest. They also discuss the validation of AMIDE through comparisons with other existing software packages.

The development of AMIDE involved the implementation of a variety of algorithms and techniques for medical image analysis. These included algorithms for data reslicing, interpolation, and visualization, as well as techniques for handling multiple data sets and regions of interest. The authors also conducted a validation study to compare the performance of AMIDE with other existing software packages for medical image analysis. The validation study involved the acquisition of a PET and CT scan data set from a nude mouse, which was then analyzed using AMIDE and other software packages. The results of the validation study showed that AMIDE performed comparably to other software packages in terms of accuracy and precision[4].

The development of AMIDE was motivated by the need for a free and open-source software tool for medical image analysis that could be used across multiple platforms. The authors note that existing software packages for medical image analysis can be expensive and may not be accessible to researchers and clinicians in low-resource settings. By providing a free and open-source alternative, AMIDE has the potential to make medical image analysis more accessible and available to a wider range of people, regardless of their socioeconomic status or geographic location and improve access to healthcare.

Overall, the results of the study demonstrated the feasibility and effectiveness of developing a free and open-source software tool for medical image analysis. The authors noted that AMIDE has the potential to improve access to healthcare by providing a low-cost alternative to existing software packages. Additionally, the validation study showed that AMIDE can perform comparably to other software packages in terms of accuracy and precision, indicating that it is a viable option for medical image analysis

While this research does not directly address the use of plugins and web services for semi-automated image interpretation, it provides a useful example of a free and open-source software tool for medical image analysis. The methodologies used in the development and validation of AMIDE could serve as a reference for the development and testing of our own plugin and web service. Additionally, the strengths of AMIDE, such as its open-source nature and support for multiple platforms, could be relevant to our own solution.

2.2.3 SlideRunner

"SlideRunner: An Open Source Software Tool for Massive Cell Annotations in Whole Slide Images" by Aubreville et al is a paper that introduces SlideRunner, an open source annotation and visualization tool for digital histopathology [5]. The paper addresses the challenges of annotating large-scale image data and the need for tools that can handle this task efficiently. The authors discuss the importance of multi-label expert data sets for improving the generalization of machine learning approaches. The main idea of the paper is to present SlideRunner as a solution for massive cell annotations in whole slide images and to highlight its features and capabilities.

The tool is capable of setting annotations like object centers (for e.g. cells) as well as object boundaries (e.g. for tumor outlines). It provides single-click annotations as well as a blind mode for multi-annotations, where the expert is directly shown the microscopy image containing the cells that he has not yet rated. The paper provides examples of SlideRunner's use in cell annotation and mitosis detection. The results show that SlideRunner is an efficient and effective tool for massive cell annotations in whole slide images [5].

While SlideRunner offers a promising solution for massive cell annotations in whole slide images, it is designed for manual annotations by experts, while our solution aims to implement automated annotations using plugins and web services to connect AI models to DICOM web viewers. However, the methodology used to develop SlideRunner and the challenges it addresses still provide valuable insights for the development of our solution.

2.2.4 AnnotatorJ

In the paper "AnnotatorJ: An ImageJ Plugin for Semi-Automated Image Annotation of Biological Samples," the authors present a software tool that can accelerate the manual labor of annotating cells and create high-quality datasets that can improve the accuracy of state-of-the-art solutions[6]. The tool, AnnotatorJ, is an ImageJ plugin that combines single-cell identification with deep learning and manual annotation. The authors tested the efficiency of their plugin with three experts on two test sets comprising nucleus and cytoplasm images. They found that their plugin accelerates the hand-annotation process on average and offers up to four orders of magnitude faster export.

The authors of the paper used the DL4J Java framework for U-Net contour suggestion in Contour assist mode to annotate objects easily[6]. They also provided multiple export options in the plugin. The authors compared their tool with other available software tools created for image annotation tasks and compared their feature scope in a table. They also discussed other tools such as ilastik and Suite2p in the Supplemental Material.

While the paper presents a promising tool for semi-automated image annotation, it is important to note that it is primarily intended for biological samples and may not be directly applicable to radiology images. Additionally, the paper does not discuss the integration of their tool with DICOM web viewers, which is a key aspect of the solution we are trying to create. However, the paper provides a detailed methodology and results that can be useful in the development of our own solution.

2.2.5 QuPAth

QuPath, an open-source software for digital pathology image analysis, presented by Bankhead et al. [7], addresses the critical need for accessible tools in pathological assessment. While the focus of the paper centers on digital pathology, a notable component aligns with the proposed solution for radiology image interpretation. QuPath's versatile features, including automated annotation functionality, provide valuable insights for enhancing the proposed system's annotation capabilities.

Bankhead et al. meticulously detail the methodology behind QuPath's development, emphasizing its user-friendly platform for tumor identification and biomarker evaluation. The integration of JavaFX for the graphical user interface and OpenCV for image processing, coupled with features like handling large whole slide images and machine learning tools, contributes to QuPath's success in diverse research applications.

In the context of annotation, QuPath stands out with its automated annotation functionality, enabling researchers to identify regions of interest within digital pathology images. The process involves selecting a set of training data representing the features to annotate, such as known tumor regions. QuPath then extracts features from this training data, encompassing texture, color, and shape, to train a machine learning algorithm. The trained algorithm subsequently automatically annotates regions of interest in new images, and researchers can fine-tune these annotations using QuPath's tools, ensuring accuracy and relevance. This nuanced approach balances efficiency with the researcher's expertise, a crucial consideration for ensuring the reliability and reproducibility of annotations.

The authors provide a comprehensive overview of QuPath's development and capabilities, offering in-depth insights into its features and showcasing successful applications in various research scenarios. This thoroughness enhances the paper's credibility. However, a potential limitation arises when aligning this paper with the proposed solution. QuPath predominantly focuses on digital pathology image analysis, distinct from radiology image interpretation.

In summary, the QuPath paper excels in providing a detailed account of its subject matter. However, the inherent focus on pathology images poses a challenge when extending its applications to radiology image interpretation. Despite this disparity, there is an opportunity to leverage QuPath's strengths and methodologies to guide the development of tools tailored to the specific requirements of radiology. This strategic approach involves a comprehensive understanding of both the strengths and limitations of QuPath, allowing for the nuanced refinement of solutions that align with the unique demands of radiology. While QuPath's primary emphasis is on digital pathology, its foundational principles, encompassing automated annotation, feature extraction, and user-friendly interfaces, offer pertinent insights for the proposed system in radiology image interpretation.

2.2.6 The 3D Slicer RVXLiverSegmentation plug-in

The paper "3D Slicer RVXLiverSegmentation plug-in for interactive liver anatomy reconstruction from medical Images" presents the RVXLiverSegmentation plug-in, a software tool for interactive liver anatomy reconstruction from medical images [8]. The plug-in is designed to provide automatic reconstructions that can be edited by the user with other tools proposed in the plug-in and in 3D Slicer. The authors created their own dataset to develop the plug-in, as annotated datasets are still missing for many clinical applications. The plug-in has numerous clinical applications, such as hepatic volumetry, which is becoming increasingly important in view of the growing number of chronic hepatopathies requiring transplants or hepatectomies.

The RVXLiverSegmentation plug-in provides interactive tools for manual annotation and segmentation of liver anatomy from medical images. Once the medical image data is loaded into the 3D Slicer interface, the liver can be segmented with the associated tab, either by using interactive tools or by an automatic deep learning-based algorithm for CT scans only. The reconstructions of hepatic vessels (portal vein and inferior vena cava) are based on tree structures interactively built by the user, who places the nodes of important branches and bifurcations (with specific anatomical nomenclature) into the scene of the medical image to be processed[8]. The plug-in also has tabs for annotation and segmentation of portal veins and inferior vena cava, as well as editing of their segmentations. These interactive tools allow the user to manually annotate and segment the liver anatomy, which is important for creating reference datasets and evaluating medical image processing algorithms .

One strength of this paper is the development of a plug-in specifically dedicated to liver anatomy reconstruction, which can be used publicly by any user for the construction of new datasets related to liver pathologies. However, it should be noted that the RVXLiverSegmentation plug-in only provides manual annotation and segmentation tools, which may be time-consuming and subject to inter-observer variability. Another potential weakness of the plug-in is that it is designed for use with 3D Slicer, which may not be accessible or preferred by all users.

2.3.7 PROCEEDINGS OF SPIE: Semantic Annotation of Medical Images

The Proceedings of SPIE on Semantic Annotation of Medical Images provides valuable insights into the annotation capabilities of medical imaging software tools. The paper describes an automated and context-sensitive workflow for semantic image annotation using an image parsing system complemented by an ontology-based context-sensitive annotation tool. This system automatically detects anatomical structures in CT volumes and maps them to concept labels coming from the Medico Ontology and is based on Marginal Space Learning (MSL) and uses a sequence of learned classifiers to estimate the position, orientation, and shape of organs[9]. The authors suggest that their framework brings together the diverse paradigms of machine learning-based image analysis and ontology-based modeling for accurate and scalable semantic image annotation. However, the authors also note that manual image annotation remains an important complement to automated image analysis, as the image parsing system is not yet able to fully capture the content of arbitrary medical images .

In relation to our research, the strengths of this paper lie in its focus on semantic annotation and its proposed workflow for automated and context-sensitive annotation. The paper's emphasis on ontology-based modeling and machine learning-based image analysis could inform the development of our own software tools for semi-automated image interpretation. However, the paper's limitations in relation to our research lie in its focus on manual annotation and its lack of discussion on the integration of AI models with free and open-source DICOM web viewers.

2.2.8 Automated Image Annotation for Semantic Indexing

In the paper "Automated Image Annotation for Semantic Indexing and Retrieval of Medical Images" by Krishna A N and B G Prasad, the authors discuss a content-based image retrieval (CBIR) system designed for medical images[10]. Utilizing the statistical co-occurrence matrix method, the system extracts texture information within the images and addresses the semantic gap between low-level visual features and high-level semantic concepts through automated image annotations. The study introduces a classification-based multi-class multi-label semantic model and a corresponding learning procedure using the J48 decision tree classifier to tackle automatic image annotation.

The methodology details the use of texture information obtained through the statistical co-occurrence matrix method, emphasizing the improvement achieved by bridging the semantic gap with automated image annotations[10]. The study's results demonstrate the effectiveness of the proposed CBIR system in retrieving visually similar medical images. Notably, the classification-based multi-class multi-label semantic model, along with the learning procedure using the J48 decision tree classifier, proves successful in addressing the challenge of automatic image annotation.

The paper's strengths lie in its innovative use of automated image annotations to bridge the semantic gap, enhancing CBIR system accuracy. The proposed classification-based model with the J48 decision tree classifier shows promise for automatic image annotation. However, weaknesses include the absence of discussion on the system's scalability, practicality in real-world settings, and integration with existing DICOM web viewers.

Compared to the proposed solution of using plugins and web services to connect an AI model for image interpretation to free and open-source DICOM web viewers like Orthanc, Krishna A N and B G Prasad's paper provides valuable insights into automated image annotations and classification-based semantic models for CBIR system accuracy. Nevertheless, the paper lacks detailed discussion on scalability, practical implementation, and integration with DICOM web viewers, crucial aspects of a semi-automated image interpretation system.

2.3 Summary

Collectively, the reviewed systems present notable strengths in various aspects of medical image analysis. However, a comprehensive analysis reveals several shared gaps. Primarily, none of these systems addresses the specific needs of DICOM images in radiology, lacking functionalities tailored for seamless integration with DICOM web viewers like Orthanc. This critical gap compromises the overall effectiveness of these tools in the context of radiological image interpretation. Additionally, scalability concerns, practical implementation aspects, and the absence of detailed discussions on integration with DICOM web viewers are common limitations across the surveyed literature. The proposed solution of implementing plugins and web services emerges as a strategic response to these collective gaps, promising a more specialized and efficient approach to semi-automated interpretation of radiological images.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter includes the study design, study settings, population, sampling procedure, research instruments, data processing, analysis and interpretation in order to come up with sufficient quality information that will be useful for decision-making. For this reason, any kind of research should be governed by a well-defined methodology based on scientific principles.

3.2 Current medical Image Interpretation Process

3.2.1 Research Design and Approach

Research design is a basic plan that guides data collection and analysis in a study and it has to have a plan with a set of rules that enable the researcher to conceptualise and observe the problem understudy.

In this study the researchers applied the qualitative research method that involved collecting and analysing non-numerical data to understand concepts, opinions or experiences of the stakeholders involved as well as gather in-depth insights into the research problem. The qualitative approach helped to study attitudes, opinions, behaviours, and other defined variables of the population.

3.2.2 Sample Population

A sample population can be defined as a group or subset of the total populations selected for observation and analysis. The target population was made up of radiologists from the University Teaching Hospitals.

3.2.3 Study Setting

The study was conducted at the University Teaching Hospitals (UTHs), and the participant selection process exclusively utilized conducive sampling. This approach focused on choosing radiologists who were readily accessible and willing to participate in the research.

3.2.3 Sampling Procedure

The study distinctively employed the conducive sampling strategy, specifically targeting radiologists who exhibited accessibility and a sincere readiness to actively contribute to the research objectives. This method placed emphasis on selecting participants according to their availability and enthusiasm for engagement, embodying a pragmatic and convenient recruitment approach.

3.2.4 Data collection instruments

The research used interviews to collect required data from the study population. This study employed structured interviews which are a systematic approach to interviewing where all candidates were asked the same predetermined questions in the same order. Structured interviews can be conducted face to face, online or over the telephone, sometimes with the aid of lap-top computers. But in this study, the interviews were conducted face to face with a standard duration of less than 20 minutes on each session. Other instruments included audio recorders on smartphones and notepads that were used to collect data and notes from the interview sessions.

3.2.5 Validity and reliability of the study instrument

The instruments were presented to the supervisor for further comments and improvement hence all necessary adjustments were made for items which were found unsuitable were removed. To ensure reliability of the collected information, some of the items during the interviews were asked more than one time to the respondents to see if there is consistency in responses from the respondents.

3.2.6 Data analysis procedures

Data analysis is a process of editing, coding, classification and tabulation of collected data. The process involves operations which are performed with the purpose of summarising and organising the collected data from the field. Since the study was qualitative, the data obtained using interviews was analysed by considering major themes to extract relevant information. This helped the researcher to make a description of the data collected from the field based on research objectives and derived conclusions on what to take regarding its usefulness.

3.2.7 Ethical Considerations

The ethical handling of medical images and their associated data is of utmost importance. Ensuring privacy and confidentiality is a priority, with a commitment to obtaining informed consent. Aligned with these ethical principles, the current study seeks to develop and implement a software tool for semi-automated medical image interpretation. Adhering to ethical mandates, ethical clearance was obtained from The University of Zambia Biomedical Research Ethics Committee (Reference Number: 2731-2022) and The National Health Research Authority (Reference Number: NRHA000024/10/05/2022), to conduct this study at the University Teaching Hospitals (UTHs).

3.3 Design and Implementation of the Orthanc Plugin for Semi-Automated Medical Image Interpretation

This section defines the design structure and implementation of the project software. It specifies the architectural design of the software, taking into accounts its structure, components and the relationship and interaction between its components.

3.3.1 Design

Automatic image interpretation systems are software programs that can be used to analyze medical images and to identify potential problems. DICOM viewers like those embedded within Orthanc can be integrated with automatic image interpretation systems to provide radiologists with real-time feedback on their diagnoses. This could help radiologists to make more accurate diagnoses and to identify potential problems sooner.

There are several approaches available for integrating these platforms with automatic image interpretation systems to enhance their capabilities. One such approach under active development involves the utilization of a plugin that enables seamless communication between the DICOM viewer and the automatic image interpretation system. Through this plugin, the DICOM viewer can effortlessly transmit medical images to the automatic image interpretation system for analysis and subsequently receive the results of the analysis. This integration facilitates a streamlined workflow, allowing for efficient collaboration between the viewer and the interpretation system.

Another method for integrating DICOM viewers with automatic image interpretation systems entails leveraging a web service. In this scenario, the automatic image interpretation system exposes a web service interface, enabling the DICOM viewer to transmit medical images to the interpretation system for analysis. Through this web service, the viewer can securely send images to the system and retrieve the corresponding analysis results. This approach provides flexibility and compatibility, as the DICOM viewer can interact with the interpretation system via standard web protocols, facilitating seamless data exchange and fostering interoperability.

Both the plugin-based integration and the utilization of web services offer distinct advantages in integrating DICOM viewers with automatic image interpretation systems. The choice of approach depends on factors such as system architecture, compatibility requirements, and the specific capabilities of the viewers and interpretation systems. Regardless of the chosen integration method, the ultimate goal is to create a cohesive environment where medical images can be effortlessly transmitted, analyzed, and interpreted, thereby enhancing the efficiency and effectiveness of image interpretation in the medical field.

3.3.2 Implementation

The aim is to implement a plugin for annotation of medical images in the Orthanc viewer. The plugin is meant to work hand in hand with an AI model that will be aiding in automatic interpretation of Dicom images. This section provides a detailed explanation of the implementation process and the interactions between the plugin, the AI model, and the Orthanc viewer.

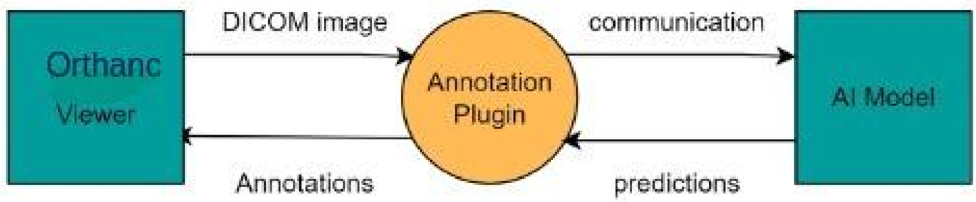

Fig. 3.1. Context diagram highlighting the interactions between the Dicom viewer, AI Model and Plugin.

The first step in the implementation process is the development of the plugin specifically designed for the Orthanc viewer. The plugin acts as an intermediary between the viewer and the AI model, facilitating the automatic interpretation and annotation of medical images. The plugin is designed to capture the event of image loading within the viewer, enabling it to trigger the AI model for analysis and subsequent annotation. The development of the plugin for the was inspired by the work of Rubin et al [11], who proposed the use of an electronic Physician Annotation Device for annotation and quantitative analysis of radiological images.

In the forthcoming context of Annotation Generation, the plugin will effectively utilize the annotation capabilities of the Orthanc viewer to enhance the interpretation of medical images. By leveraging the output generated by the AI model, the plugin will dynamically generate annotations in real-time, allowing for the precise localization and characterization of identified pathologies. These annotations will serve as visual indicators, highlighting the affected areas within the loaded medical image.

By providing visual cues and relevant information about the nature and location of pathologies, the generated annotations will greatly assist radiologists and healthcare professionals in their interpretation and analysis of the medical image. This visual representation will enable a more comprehensive understanding of the image content, aiding in accurate diagnosis and treatment planning.

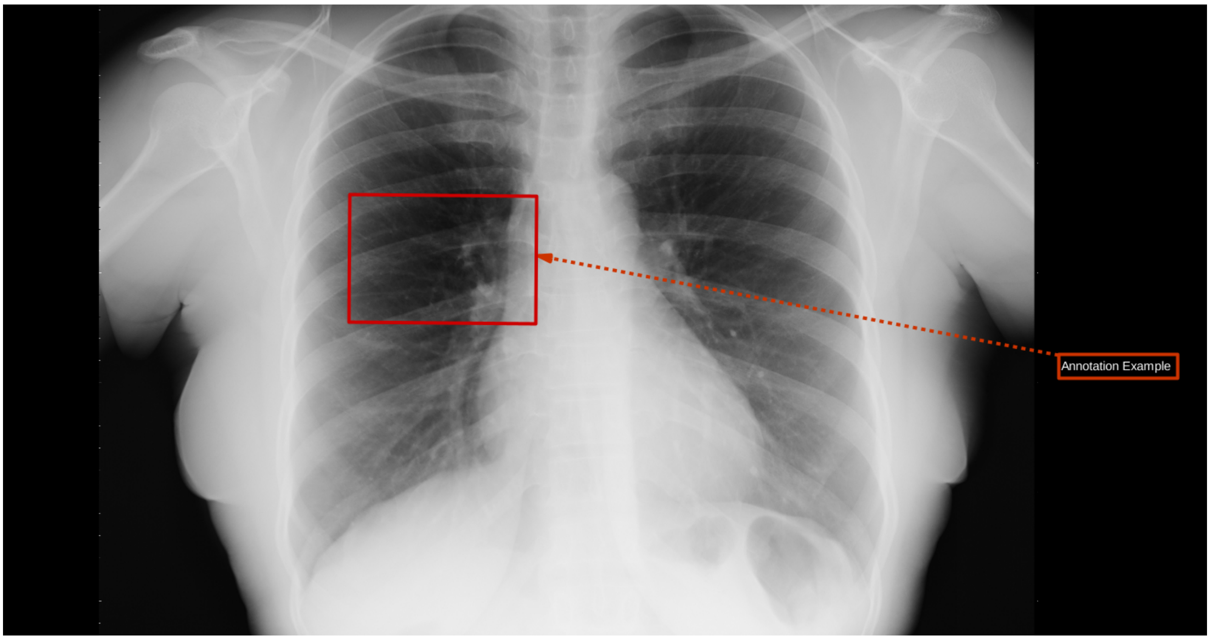

Fig. 3.2. Shows an exemplary instance of how an image would ideally be annotated in Orthanc.

The dynamic and real-time nature of the annotation generation process will ensure that the annotations are always synchronized with the AI model's output, providing up-to-date and relevant information. This seamless integration of AI-driven annotation generation within the plugin and the Orthanc viewer will enhance the overall efficiency and effectiveness of medical image interpretation, ultimately benefiting both the medical professionals and the patients.

3.3.3 AI Model Integration

The AI model emerges as a pivotal component in the realm of automatic DICOM image interpretation, exerting a profound influence on the overall process [12]. Leveraging the power of deep learning techniques, this AI model undergoes rigorous training on an extensive dataset comprising meticulously annotated medical images. This comprehensive training empowers the model to adeptly recognize and classify an array of pathologies with remarkable accuracy [13].

To seamlessly integrate the AI model into the plugin, a robust interface is established. This interface acts as a vital link, enabling smooth communication and efficient information exchange between the AI model and the plugin. Through this collaboration, the plugin gains access to the AI model's analytical capabilities, empowering it to automatically interpret and analyze images.

The integration of the AI model within the plugin architecture creates a mutually beneficial relationship. The plugin utilizes the AI model's advanced capabilities, while the AI model benefits from the plugin's interface to interact with the DICOM viewer and medical image data. This collaboration enables a comprehensive and automated approach to DICOM image interpretation, improving accuracy, speed, and efficiency.

By harnessing the AI model's deep learning capabilities, the plugin can effectively process and analyze DICOM images, extracting important information, detecting abnormalities, and generating valuable insights. This integration represents a significant advancement in medical image interpretation, with the potential to enhance diagnostic accuracy, streamline clinical workflows, and ultimately improve patient outcomes.

3.4 Evaluating the Usefulness and Effectiveness of the Orthanc Plugin for Semi-Automated Medical Image Interpretation

3.4.1 Sample population

The target population for the evaluation of the Orthanc plugin consisted exclusively of expert participants, specifically three radiologists in training at the University Teaching Hospital. The small sample size was deliberate, focusing on the expertise and in-depth insights provided by these professionals in the field.

3.4.2 Study Setting

The study was carried out at the University Teaching Hospital (UTH) in Lusaka.

3.4.3 Sampling procedures

The study exclusively employed conducive sampling, selecting radiologists who were readily accessible and willing to participate in the research. This method focused on choosing participants based on their availability and willingness to engage, ensuring a practical and convenient approach to participant recruitment.

3.4.4 Data collection instruments

The evaluation process used a questionnaire to collect required data from the study population. This study employed a TAM questionnaire which was provided online for users to fill in after interacting with the plugin. Other instruments included smartphones and computers for the purpose of performing the tasks.

3.4.5 Validity and reliability of the study instruments

To establish validity of the instruments applied, the researchers conducted a pilot study prior to the actual data collection. The instruments were presented to a radiologist, the team supervisor, for testing, further comments and improvement hence all necessary adjustments were made for items which were found unsuitable were removed.

3.4.6 Data analysis procedures

The data analysis procedures encompassed operations designed to summarize and organize the information gathered from the field. The analysis involved a thorough review, comparison, and interpretation of the data collected through questionnaires. This process aimed to distil meaningful insights and patterns from the responses, providing a comprehensive understanding of the gathered information.

3.4.7 Ethical consideration

As it was with the initial study carried out to understand the current processes of medical image interpretation, the evaluation process utilised the already sought ethical clearance from the University of Zambia Biomedical Research Ethics Committee (UNZABREC), National Health Research Authority (NHRA) and approval was granted by the University Teaching Hospital to conduct a study at the institution. Lastly, participants were required to consent to the study before the test was conducted and their confidentiality was guaranteed.

CHAPTER FOUR

RESULTS AND EVALUATION

4.1 Evaluation

The evaluation process for the Orthanc plugin utilized the TAM2 questionnaire, recognized for its advancements over the original TAM questionnaire [14]. TAM comprehensively measures user acceptance of technology by evaluating key factors, including perceived usefulness, ease of use, job relevance, and output quality. Notably, the assessment of perceived usefulness delves into an individual's belief in the system's capacity to enhance task performance. Consequently, the TAM questionnaire was specifically chosen to evaluate the utility and overall effectiveness of the Orthanc plugin.

4.1.1 Study design

During the testing phase, participants were involved in a session designed to assess the usefulness and effectiveness of the Orthanc plugin. Before the session began, they were informed about the study and asked to sign a consent form. The session commenced with an introduction to the experiment's objective and a detailed explanation of the procedures involved. Participants were provided with a comprehensive instruction manual outlining specific tasks they were required to complete.

Throughout the session, the participants' progress was closely monitored and assistance was offered when needed. All participants were asked to perform a set of predefined tasks, as listed in Table 4.1.

Table 4.1: study tasks

INPUTS	• Website URL: http://localhost:8044
ASSUMPTIONS	• User has access to the locally installed version of the Orthanc server

STEPS	1. Open questionnaire using link provided: https://forms.gle/HgVpidTqZGWR8gSL6 *Note: Do not fill in section 4 going up before interacting with the Orthanc Plugin 2. Visit website by clicking the provided URL: http://localhost:8044 3. On the landing page, access images by: a. Clicking "all studies" b. Select a study c. Select a specific series d. Open series with "Orthanc Web Viewer" 4. . Fill in the rest of the questionnaire:
EXPECTED DURATION	10 minutes
INSTRUCTIONS FOR USER	● Please follow all outlined steps above
NOTES	

After the completion of all tasks, the users were required to fill in the questionnaire based on their interaction with the Orthanc plugin.

4.2 Results

4.2.1 Current method of interpreting medical images at the UTHs

4.2.1.1 Introduction

This section presents the findings of the interviews that were carried out at the University Teaching Hospitals where registered and practising Radiologists were interviewed. Two participants were interviewed and provided the needed information. Furthermore, the participants also gave their comments on various issues affecting the radiological workflows , how they can be improved and recommended some functionalities that would be helpful to the image interpretation process in order to make their work easier and better. The table below shows the demographic details of the expert radiologists that were interviewed.

Table 4.2:Shows interviewees demographics

NAME	EXPERIENCE	HOSPITAL(S)
Radiologist 1	Over 5 years	UTHs, LMUTHs, MAINA SOKO
Radiologist 2	Less than 5 years	UTHs
Radiologist 3	Over 5 years	UTHs

4.2.1.2 Medical Image Interpretation Procedure

In the course of interviews with registered and practicing Radiologists at the University Teaching Hospitals, valuable insights were gathered regarding the current method of interpreting medical images. The procedure involves receiving images stored on compact disks along with corresponding request forms. Both Radiologist 1 and Radiologist 3, for instance, highlighted the importance of meticulously reading through the clinical information provided on these forms before loading the images onto a DICOM viewer. Radiologist 1 emphasized the significance of making careful note of both positive and significant negative findings. Leveraging their expertise in radiology and background health information, the radiologists synthesize conclusions, which may manifest as clear and definite diagnoses, differential diagnoses indicating multiple possibilities, or general comments outlining the identified findings without a specific commitment to a diagnosis. Following the interpretation, Radiologist 1 noted the importance of sampling images and logging the information into a final report. Radiologists predominantly employ RadiAnt DICOM and Weasis DICOM Viewer software for image viewing, reflecting the current practices observed during the interaction.

4.2.1.3 Measures for Ensuring Accuracy and Quality of Image Interpretation

In the context of medical image interpretation, Radiologist 1 emphasized crucial measures to ensure accuracy and quality at the University Teaching Hospitals. Highlighting the pivotal role of reliable and versatile DICOM viewers, Radiologist 1 specifically noted the importance of a reasonably large screen size. Additionally, Radiologist 1 underscored the critical factor of appropriate lighting conditions in the interpretation room. Radiologist 2 recommended the effective use of windowing techniques to further enhance image quality [15]. Additionally, Radiologist 3 stated that a systematic approach in the evaluation process is followed, outlining specific steps to qualify or disqualify a given pathology..

To facilitate dynamic viewing of dimensions, Radiologist 2 suggested the practice of splitting a series of images, particularly relevant for CT scans. Radiologist 2 stressed the significance of increasing contrast for improved visualization. Moreover, all interviewed radiologists unanimously acknowledged the value of peer review as a vital practice for obtaining a second opinion on diagnoses. These measures collectively contribute to enhancing the accuracy and quality of medical image interpretation.

4.2.1.4 Challenges Associated with Medical Image Interpretation

Addressing the challenges associated with medical image interpretation, insights from the interviewed Radiologists at the University Teaching Hospitals shed light on key obstacles in the process. Notably, Radiologists, particularly Radiologist 1, highlighted the time-consuming nature of typing reports without templates. Another challenge identified by Radiologist 1 was the difficulty in making diagnoses when faced with a lack of or unclear medical background information.

Radiologist 1 also emphasized the challenge posed by information that is hard to read due to poor handwriting, contributing to potential misinterpretations. Furthermore, the ambiguity of interpretation results, often caused by a lack of proper health information, was noted as a significant hurdle. Both Radiologist 2 and Radiologist 3, in alignment with these challenges, underscored the time taken to arrive at a final diagnosis as a notable concern. Collectively, these insights provide a comprehensive understanding of the challenges faced by Radiologists in the intricate task of medical image interpretation.

4.2.1.5 User recommended features

In response to user feedback, particularly from Radiologist 1 and Radiologist 2, several recommended features emerged to enhance the medical image interpretation process at the University Teaching Hospitals. Radiologist 1 specifically suggested the implementation of software capable of pointing out abnormalities on the images, providing valuable assistance in the identification of critical areas. Additionally, Radiologist 1 highlighted the importance of interfaces equipped with the capability to flag out areas of interest, termed as review areas, streamlining the attention to specific regions during interpretation.

Furthermore, Radiologist 2 recommended the integration of automated searching of patient information, emphasizing the potential for increased efficiency in accessing and retrieving pertinent patient data. These user-recommended features, stemming from the practical experiences and insights of the radiologists, offer valuable considerations for the improvement and optimization of medical image interpretation workflows.

4.2.1.6 Summary

In summary, the interviews with Radiologists at the University Teaching Hospitals provided insightful perspectives on medical image interpretation. The procedures, challenges, and user-recommended features were explored, revealing current practices and areas for improvement. Notable outcomes include measures to ensure accuracy, identified challenges like time-consuming reporting, and valuable user suggestions for enhanced software functionality. These findings form a solid foundation for refining medical image interpretation workflows, leveraging technology to address challenges, and ultimately improving patient care outcomes.

4.2.2 Design and Implementing the Orthanc Plugin for Semi-Automated Medical Image Interpretation

4.2.2.1 Orthanc Plugin Annotation

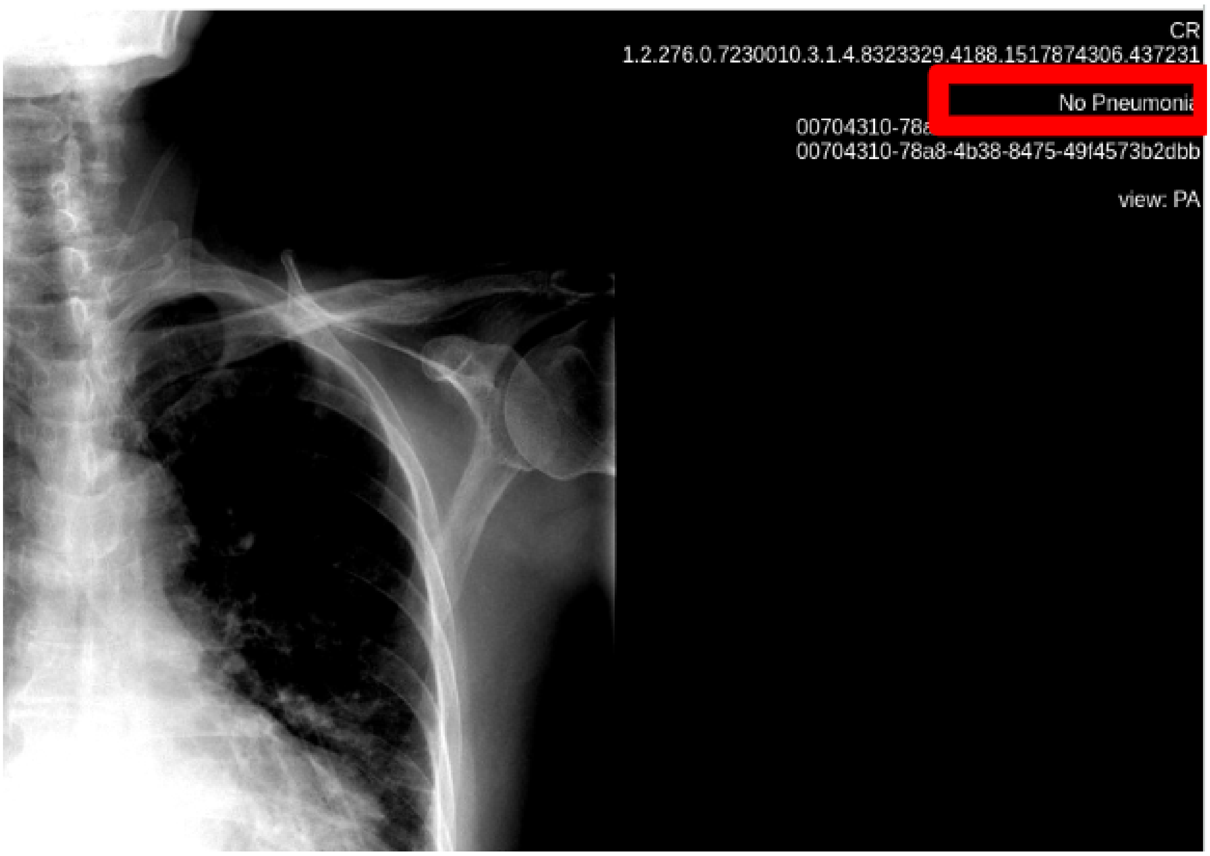

Figure 4.1: Orthanc plugin annotation

Figure 4.1 Shows an annotation of the absence or presence of a particular pathology or for which an AI Model was trained to predict. In this case, the plugin is displaying the “No Pneumonia” annotation which indicates that the image being examined currently has no pneumonia. The users of the Orthanc plugin are able to see these annotations once an image is opened inside the Orthanc Web Viewer embedded within the Orthanc server [16].

4.2.2.1 DICOM Image Metadata

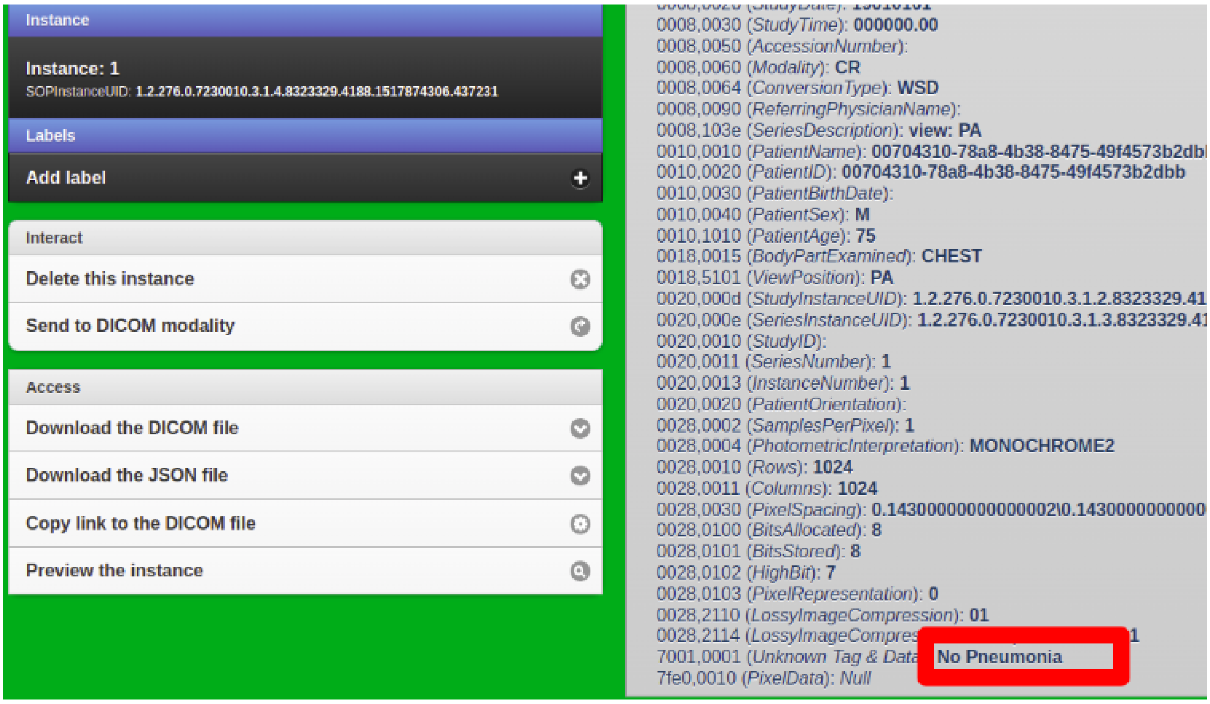

Figure 4.2: DICOM metadata

Figure 4.2 Shows the DICOM image's metadata panel when viewed inside the Orthanc server. The annotations are passed as custom metadata tags using the results returned from the AI Model and this metadata element is displayed inside the DICOM viewer once opened.

4.3.3 Evaluating the Usefulness and Effectiveness of Orthanc plugin for Semi-Automated Medical Image Analysis

The evaluation of the Orthanc pluginform's usefulness and Effectiveness was done by presenting the system to radiologists in training at the UTH and giving them clearly outlined tasks that they were required to perform before filling in a questionnaire to indicate their level of satisfaction based on the interaction with the system. This section contains a summary of selected elements from the questionnaire which are directly linked with aspects of the plugin that were being measured.

4.3.3.1 Demographic Details

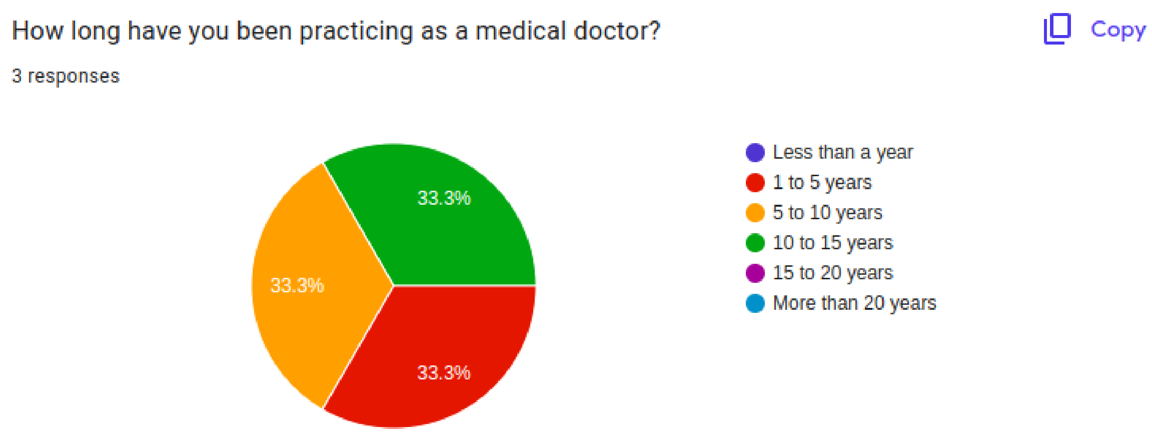

Figure 4.3: Work experience in the field

Figure 4.3 shows the range in the time period the respondents have been practising in their professional field.

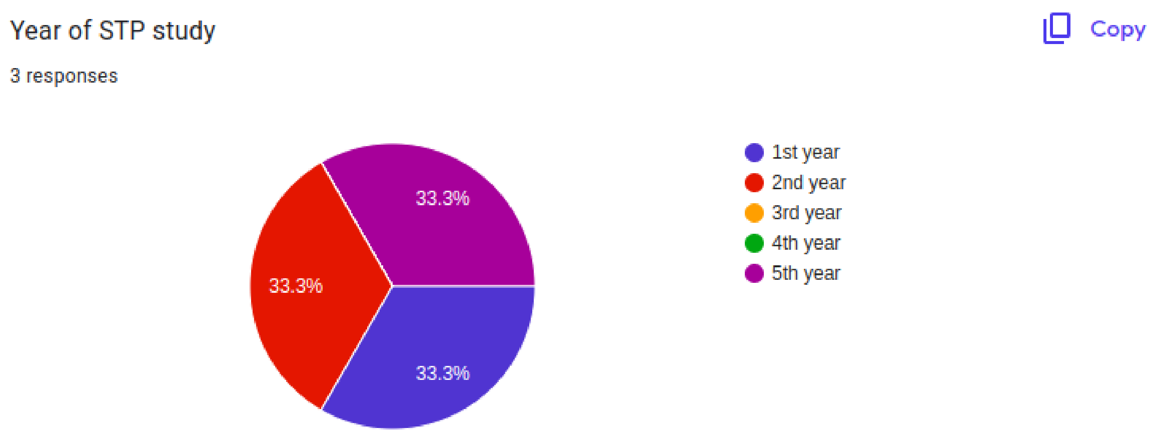

Figure 4.4: Year of STP study

Figure 4.4 shows the current year of STP (specialty training programme) study of the participants.

4.3.3.2 Perceived Usefulness

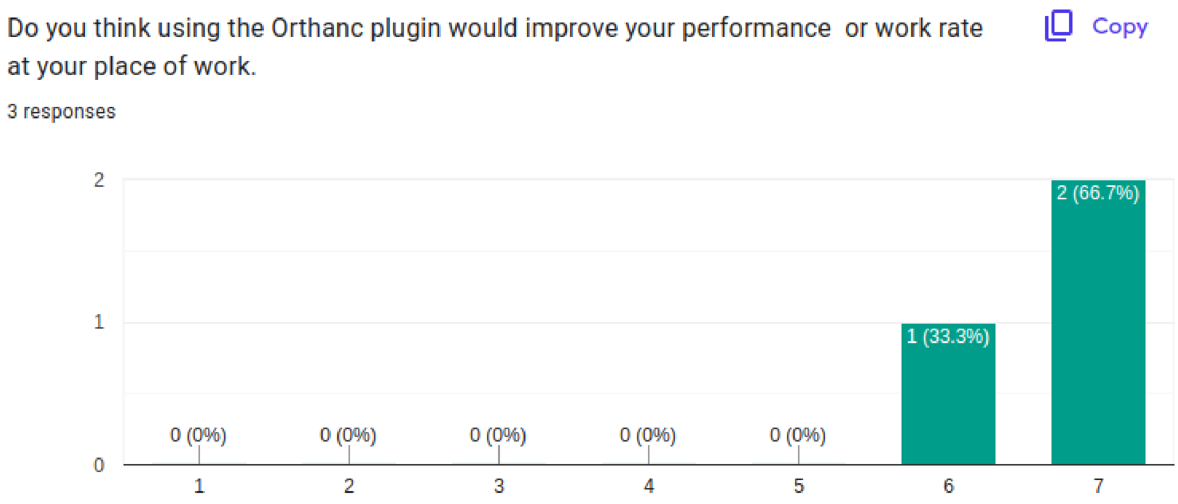

Figure 4.5: Improvement of performance or workrate

Figure 4.5 shows the perceived usefulness of the Orthanc plugin in terms of how the platform would affect the user's work rate.

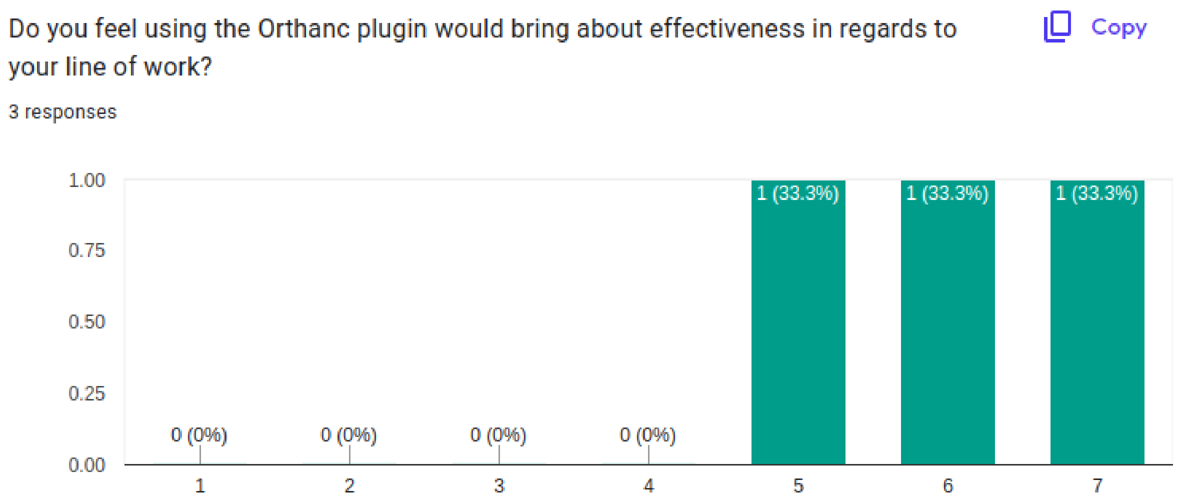

Figure 4.6: Orthanc plugin effectiveness

Figure 4.6 shows the perceived usefulness of the Orthanc plugin in terms of how the platform would bring about effectiveness in regards to the user's line of work.

4.3.3.3 Perceived Ease of Use

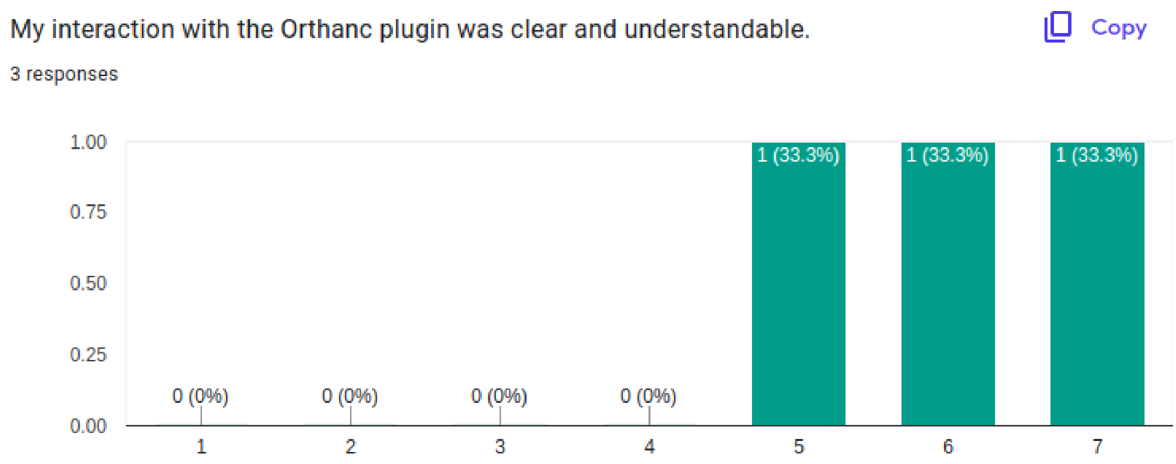

Figure 4.7: Clear and understandable Orthanc plugin

Figure 4.7 shows the perceived ease of use of the Orthanc plugin with regards to how clear and understandable the system is perceived to be.

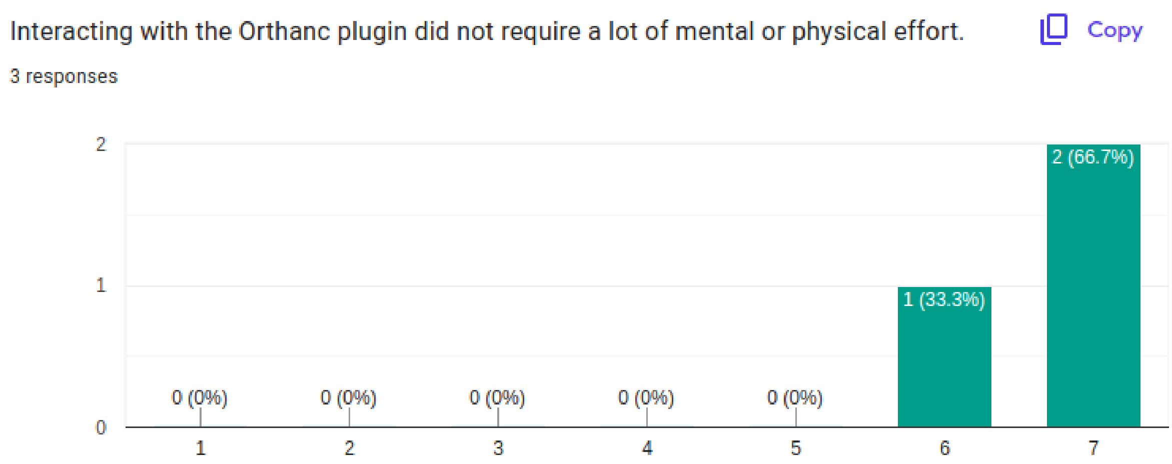

Figure 4.8 Mental and physical effort required to use the plugin

Figure 4.8 shows the perceived ease of use of the Orthanc plugin when it comes to effort required to use the system.

4.3.3.4 Job Relevance

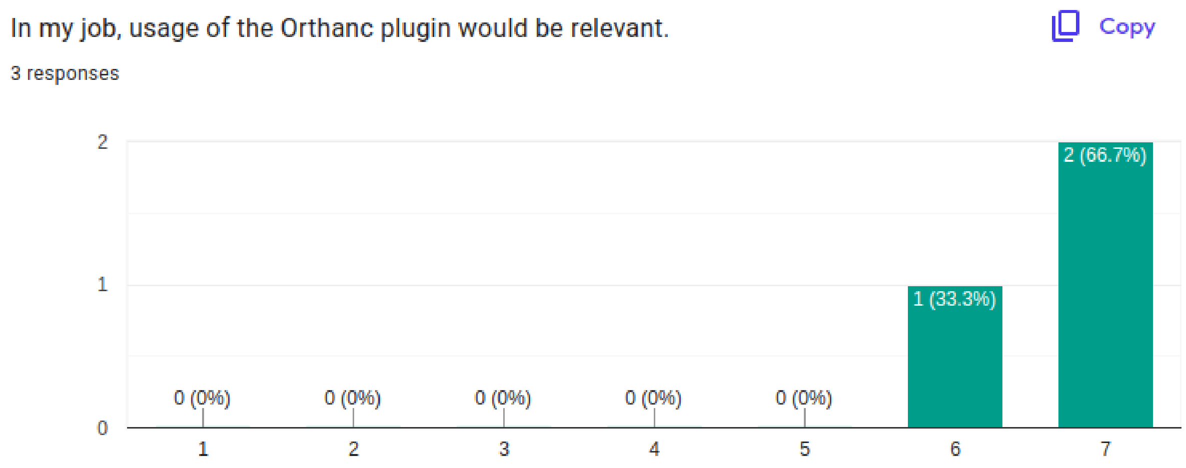

Figure 4.9 Orthanc plugin relevance

Figure 4.9 shows how much the users feel the system would be relevant to their job.

4.3.3.5 Output Quality

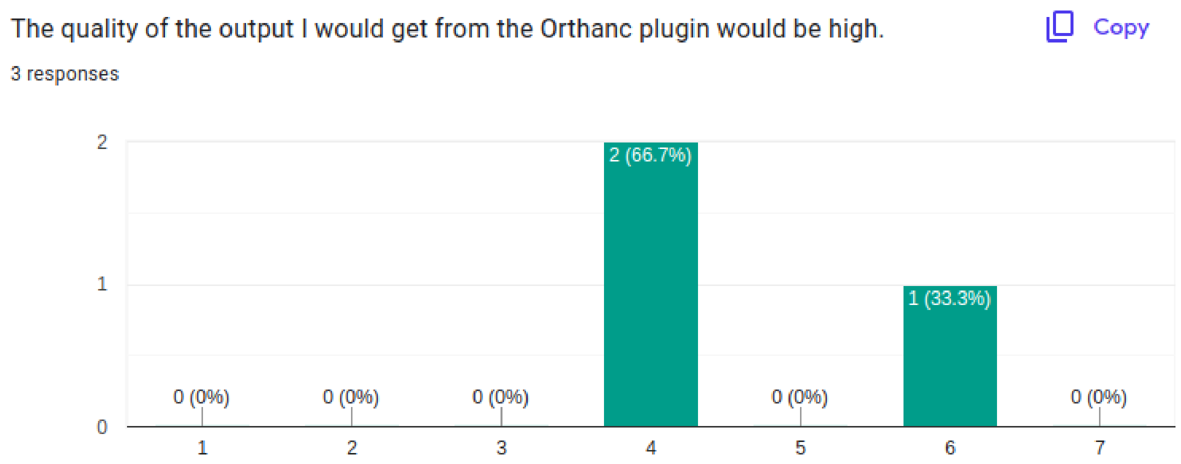

Figure 4.10 High output quality

Figure 4.10 shows how many of the participants feel the level of output quality for the Orthanc plugin would be high after having interacted with the system. the users have when it comes to the output of the Orthanc plugin.

CHAPTER FIVE

DISCUSSION

In this chapter, the discussion centers on the findings obtained from the questionnaire administered to radiologists to assess the usefulness and effectiveness of the Orthanc plugin. The Likert scale, ranging from 1 (highest level of disagreement) to 7 (highest level of agreement), was utilized to gauge participants' responses.

5.1 Demographics

The participants in the Orthanc plugin evaluation had diverse levels of work experience. Two of the three participants had over 5 years of experience, bringing a seasoned perspective. The other had less than 5 years of work experience.

5.2 Perceived Usefulness

Participants' views on the usefulness of the Orthanc plugin varied. One participant expressed a moderately high level of agreement (6), indicating confidence that the system would improve day-to-day tasks and enhance the overall radiological workflow. The other two participants demonstrated a more affirmative stance with a level of agreement at 7. When it comes to the system's potential to enhance effectiveness, the three participants indicated 5, 6 and 7 as their levels of agreement .

5.3 Perceived Ease of Use

In terms of the perceived ease of use, participants displayed positive attitudes. One participant indicated 5, 6 and 7 as their levels of agreement regarding the clarity and understandability of the plugin. Additionally, One participant indicated a moderately high level of agreement (6) while the two other participants strongly agreed (7) that the system would not demand a significant amount of physical or mental effort to operate.

5.4 Job Relevance

The evidence from the results again demonstrated positive perceptions. One participant expressed a moderately high level of agreement (6) regarding the system's relevance and importance to their work. The other participants, however, exhibited a more affirmative stance with a level of agreement at 7, emphasizing the perceived significance of the system in their professional context.

5.5 Output Quality

Participants' perspectives on the output quality of the Orthanc plugin varied. Two participants indicated a somewhat lower level of agreement (4) regarding the anticipated high output quality. In contrast, the other participant exhibited a moderately high level of agreement (6), suggesting a more optimistic outlook. These contrasting opinions highlight the diverse expectations regarding the system's output quality.

5.6 User Comments

Respondents shared valuable insights, emphasizing the importance of isolating feedback on pneumonia diagnosis from demographic details annotations. The suggestion to present it separately and possibly highlight it by color was made to enhance visibility and ensure a user-friendly interface.

Additionally, one user expressed a significant concern about the accuracy of the results. This underscores the critical aspect of result accuracy, highlighting a key consideration for users in their evaluation of the Orthanc plugin.

CHAPTER SIX

CONCLUSION

In conclusion, this study has delved into the critical area of medical image interpretation, particularly focusing on the design and implementation of innovative software tools for semi-automated analysis within the context of the University Teaching Hospitals in Zambia. The research design and approach, which employed qualitative methods, allowed for a comprehensive understanding of the attitudes, opinions, and behaviors of the radiologists involved. The study highlighted the challenges posed by the shortage of radiologists in Zambia and emphasized the potential of enterprise imaging techniques to address these challenges. Furthermore, the investigation into the Orthanc plugin for automated support in medical image interpretation showcased the potential impact of integrating advanced methodologies such as deep learning, computer vision, and pattern recognition. The primary goal of empowering these viewers with innovative plugins is to streamline image interpretation, automate the analysis of medical images, and extract valuable information for clinical decision-making. The potential benefits include reduced interpretation time, heightened accuracy, and enhanced workflow efficiency, ultimately contributing to superior patient care and treatment outcomes.

Moving forward, the findings of this study underscore the urgency and significance of leveraging technology to overcome healthcare disparities, particularly in the domain of medical imaging. The insights gained from this research contribute to the body of knowledge aimed at improving medical image interpretation processes, ultimately benefiting healthcare systems and patient outcomes. As technology continues to advance, the integration of innovative software tools holds promise for revolutionizing the field of medical image interpretation, and this study serves as a stepping stone towards that transformative future.

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7. Appendix A: Interview Questions, Responses and Tam Questionnaire

Table A.1: Interview Questions

RESEARCH QUESTION	INTERVIEW GUIDE QUESTIONS	PROBING /FOLLOW UP
Demographic Details	1. How long have you been working here? 2. Where else have you worked before or are currently working for any other institution apart from this institution?	Do you have software tools that help with interpretation of images? Did you have software tools that help with interpretation of images at the other facility/facilities you have previously worked for?

To determine how medical images are currently being interpreted	1. Can you describe the typical workflow for interpreting medical images at the University Teaching Hospitals? 2. Are there specific tools or software applications that have become integral to the image interpretation process? 3. In your role, do you collaborate with other healthcare professionals, such as referring physicians or specialists, during the interpretation of medical images? 4. What measures are in place to ensure the accuracy and quality of your image interpretations? 5. Can you discuss any challenges or complexities you encounter in the interpretation of certain types of medical images?	How do you approach the analysis of a set of images, from initial review to final reporting? Are there quality assurance protocols or ongoing training programs for radiologists? How do you address ambiguous cases or situations where additional information is needed?

Table A.2 Interview Responses

NAME	DEMOGRAPHIC DETAILS	ENSURING ACCURACY AND QUALITY	COMMENTS
Radiologist 1	5 years experience and counting as a radiologist in training at the University Teaching Hospitals (UTHs). Occasionally Works from Levy Mwanawasa and Maina Soko Military hospitals.	● Having a reliable DICOM viewer ● Having a reasonably large enough screen for viewing images ● Having appropriate lighting in the room	It would be nice to have software that points to abnormalities on the image
Radiologist 2	Less than 5 years of work experience as a radiologist in training at the University Teaching Hospitals. Worked at Solwezi General Hospital and Mary Begg Health Services	● Windowing ● Contrast enhancement	It would be nice if time taken to complete the interpretation process could be reduced

Radiologist 3	Less than 5 years of work experience as a radiologist in training at the University Teaching Hospitals. Worked at Arakan and Gonda Camp Hospitals	• Following systematic pathology identification steps	

Demographic Details

- Participant gender
- How long have you been practicing as a medical doctor?
- Year of STP study

Intention to Use

- Assuming you had access to the Orthanc plugin, would you use it?
- Would you recommend other Doctors to use the Orthanc plugin?

Perceived Usefulness

- Do you think using the Orthanc plugin would improve your performance or work rate at your place of work?
- Do you feel using the Orthanc plugin would bring about effectiveness in regards to your line of work?
- Would you find the Orthanc plugin to be a useful tool in your line of work?

Perceived Ease of Use

- My interaction with the Orthanc plugin was clear and understandable.
- Interacting with the Orthanc plugin did not require a lot of mental or physical effort.
- I would find the Orthanc plugin to be easy to use.
- I would find it easy to get the Orthanc plugin to do what I want it to do.

Subjective Norm

- My supervisors would allow me to use the Orthanc plugin.
- My patients would benefit from my use of the Orthanc plugin.

Voluntariness

- My use of the Orthanc plugin would be voluntary.
- My supervisor would not require me to use the Orthanc plugin.

Job Relevance

- In my job, usage of the Orthanc plugin would be important.
- In my job, usage of the Orthanc plugin would be relevant.

Output Quality

- I had no problem with the quality of the Orthanc plugin's output.
- The quality of the output I would get from the Orthanc plugin would be high.

Result Demonstrability

- The results of using the Orthanc plugin would be positive to me.
- I believe I could communicate to others the benefits of using the Orthanc plugin.
- I would have no difficulty telling others about the results of using the Orthanc plugin.
- Do you have any comments and/or suggestions on the Orthanc plugin for future improvements?

Figure A.1 TAM Questionnaire

8. Appendix B: Ethical Clearance Approval

NATIONAL HEALTH RESEARCH AUTHORITY
Paediatric Centre of Excellence, University Teaching Hospital, P.O. Box 30075, LUSAKA
Chalala Office Lot No. 18961/M, Off Kasama Road, P.O. Box 30075, LUSAKA
Tell: +260211 250309 | Email: znhrasec@nhra.org.zm | www.nhra.org.zm

Ref No: NHRA000024/10/05/2022 **Date: 10th May, 2022**

The Principal Investigator,
Ernest Obbie Zulu,
University of Zambia
Lusaka, Zambia.

Dear Ernest Obbie Zulu,

Re: Request for Authority to Conduct Research
The National Health Research Authority is in receipt of your request for authority to conduct research titled **"Enterprise Medical Imaging for Streamlined Radiological Diagnosis in Zambian Public Health Facilities."**

I wish to inform you that following submission of your request to the Authority, our review of the same and in view of the ethical clearance, this study has been **approved** on condition that:

1. The relevant Provincial and District Medical Officers where the study is being conducted are fully appraised;
2. Progress updates are provided to NHRA quarterly from the date of commencement of the study;
3. The final study report is cleared by the NHRA before any publication or dissemination within or outside the country;
4. After clearance for publication or dissemination by the NHRA, the final study report is shared with all relevant Provincial and District Directors of Health where the study was being conducted, University leadership, and all key respondents.

Yours sincerely,

Prof. Godfrey Biemba
Director/CEO
National Health Research Authority

Figure B.1 NRHA Ethical Clearance Approval

UNIVERSITY OF ZAMBIA
BIOMEDICAL RESEARCH ETHICS COMMITTEE

Telephone: +260 977925304 | Ridgeway Campus
Telegrams: UNZA, LUSAKA | P.O. Box 50110
Telex: UNZALU ZA 44370 | Lusaka, Zambia
Fax: + 260-1-250753 | E-mail: unzarec@unza.zm
Federal Assurance No. FWA00000338 | **IRB00001131 of IORG0000774**

5th May, 2022

Your REF. No. 2731-2022

Dr. Ernest Obbie Zulu,
University of Zambia,
Department of Library and Information Science,
Lusaka.

Dear Dr. Zulu,

RE: ENTERPRISE MEDICAL IMAGING FOR STREAMLINED RADIOLOGICAL DIAGNOSIS IN ZAMBIAN PUBLIC HEALTH FACILITIES (REF. NO. 2731-2022)

The above-mentioned research proposal was presented to the Biomedical Research Ethics Committee on 5th May, 2022. The proposal is **approved**. The approval is based on the following documents that were submitted for review:

a) Study proposal
b) Questionnaires
c) Participant Consent Form

APPROVAL NUMBER : REF. 2731-2022

This number should be used on all correspondence, consent forms and documents as appropriate.

- **APPROVAL DATE : 5th May 2022**
- **TYPE OF APPROVAL : Fast Track**
- **EXPIRATION DATE OF APPROVAL : 4th May 2023**
  After this date, this project may only continue upon renewal. For purposes of renewal, a progress report on a standard form obtainable from the UNZABREC Offices should be submitted one month before the expiration date for continuing review.
- **SERIOUS ADVERSE EVENT REPORTING**: All SAEs and any other serious challenges/problems having to do with participant welfare, participant safety and study integrity must be reported to UNZABREC within 3 working days using standard forms obtainable from UNZABREC.
- **MODIFICATIONS**: Prior UNZABREC approval using standard forms obtainable from the UNZABREC Offices is required before implementing any changes in the Protocol (including changes in the consent documents).
- **TERMINATION OF STUDY**: On termination of a study, a report has to be submitted to the UNZABREC using standard forms obtainable from the UNZABREC Offices.

Figure B.2 UNZABREC Ethical Clearance

All Correspondence should be addressed to the
Permanent Secretary
Telephone: +260 211 253040/5
Fax: +260 211 253344

In reply please quote:
MOH/
No............................

REPUBLIC OF ZAMBIA

MINISTRY OF HEALTH

NDEKE HOUSE
P. O. BOX 30205
LUSAKA

16th May, 2022

Obbie Zulu
LUSAKA

RE: REQUEST FOR AUTHORITY TO CONDUCT RESEARCH

Reference is made to your letter dated 25th April, 2022 in which you requested the Ministry, for permission to conduct a research titled "***Enterprise Medical Imaging for Streamlined Radiological Diagnosis in Zambia Public Health Facilities***". I wish to inform you that my office has no objection to this request provided that;

1. The relevant Institution Director where the study is being conducted are fully appraised;
2. The final study report is cleared by NHRA before any publication or dissemination within or outside the country; and
3. After clearance for publication or dissemination by NHZRA, the final study report is shared with the Ministry.

Kindly ensure minimum interruption in health service delivery to the selected health you will undertake your research.

By copy of this letter, the Provincial, District Health Offices and facilities are advised to allow you undertake the above mentioned research and provide you with the relevant support.

Yours faithfully

Prof. Lackson Kasonka
Permanent Secretary- Technical Services
MINISTRY OF HEALTH

Figure B.3 MINISTRY OF HEALTH Ethical Clearance Form

REPUBLIC OF ZAMBIA
MINISTRY OF HEALTH
University Teaching Hospitals -Adult

Fax: +260 211 250305
e-mail: mduth@yahoo.com

P/Bag Rw 1X
Lusaka - Zambia
Tel: +260 211 253947 (Switch Board)
+260 211 251451

OFFICE OF THE SENIOR MEDICAL SUPERINTENDENT

Our Ref:

Your Ref:

5th September, 2022

Dr. Ernest Obbie Zulu
University of Zambia
Department of Library & Information Science
P O Box 50110
LUSAKA

Dear Dr. Zulu,

RE: REQUEST FOR AUTHORITY TO CONDUCT RESEARCH

The University Teaching Hospital – Adult is in receipt of your letter dated 5th September, 2022 in which you had requested to conduct a research titled ***"Enterprise Medical Imaging for Streamlined Radiological Diagnosis in Zambia Public Health Facilities" at the University Teaching Hospital."***

I wish to inform you that permission has been granted and you are advised to liaise with the Head of Department.

Yours faithfully,

Dr. Mwila Lupasha
Head Clinical Care
for/**Senior Medical Superintendent**
UNIVERSITY TEACHING HOSPITALS - ADULT

Figure B.4 UTH Ethical Clearance Form