Integration Proposal for Thermal Imaging Modality into Health Information Systems

Ricardo Vardasca[1,2](✉), Marco Tereso[1], Antonio Pratas[1], Braulio Alturas[3], Domingos Martinho[1], and Fernando Bento[1,3]

[1] ISLA Santarem, Rua Teixeira Guedes 31, 2000-029 Santarem, Portugal
ricardo.vardasca@islasantarem.pt
[2] INEGI, Universidade do Porto, Rua Dr. Roberto Frias 400, 4200-465 Porto, Portugal
[3] ISTAR, ISCTE-IUL, Av. Prof. Aníbal Bettencourt 9, 1600-189 Lisboa, Portugal

Abstract. Thermal imaging allows to map and record surface temperature in a form of images, which in medicine can document pathological states and be an important complimentary diagnostic and treatment monitoring method. It is available for six decades, but some factors contributed to its low adoption, being the main the lack of integration with the existing health information systems at the healthcare institutions. It is aim of this research to address the lack of integration with existing technological infrastructure, through documenting and proposing a procedure to integrate thermal imaging as an imaging modality in health information systems. Requirements will be outlined, supported by UML modulation for simple use cases and class diagram along with the steps to adopt the DICOM standard. Following the proposed methodology, it will be possible to integrate thermal images with the existing health information systems, contributing to better performance of the exam, increase interoperability, ensure data security and availability, and improved patient care and satisfaction.

Keywords: Health information systems · integration · thermal imaging

1 Introduction

Infrared thermal imaging allows recording and mapping temperature surface of objects remotely. It has been used in medical research since 1956 providing important physiological data related to peripheral blood flow and autonomous nervous system, being an important complimentary mean of diagnostic and treatment [1–9].

The method is a non-invasive and radiation-free imaging modality, which makes it particularly valuable in cases where repeated imaging is required or when minimizing patient exposure to radiation is essential. It is a safe and comfortable imaging technique that can be used across different patient populations, including infants, pregnant women, and individuals with contraindications for other imaging modalities [1].

It allows a comprehensive assessment of the body by capturing thermal patterns over a larger area, providing a holistic view of heat distribution and temperature variations,

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enabling clinicians to identify abnormalities in specific regions or even systemic conditions that may manifest as thermal changes. This whole-body assessment can assist in identifying underlying conditions and guiding appropriate treatment strategies [1, 8, 9].

This imaging modality provides objective and quantifiable data by measuring temperature variations. This objectivity reduces subjectivity and enhances diagnostic accuracy. It can be used to monitor the progress of treatment, assess response to therapy, and objectively evaluate the efficacy of interventions over time. Thermal imaging enables real-time monitoring of physiological changes and responses. It can be used to track the dynamic thermal patterns of various conditions, such as inflammation, circulation disorders, or wound healing, allowing healthcare professionals to make timely decisions and adjustments to treatment plans [1–4, 7].

It is a patient-friendly imaging modality that does not require direct contact with the body. It is non-invasive and painless, making it well-tolerated by patients. This ease of use promotes patient compliance, reduces anxiety, and improves the overall patient experience during diagnostic procedures [1–3].

Thermal imaging enables the early detection of physiological abnormalities by visualizing heat patterns and temperature variations in the body. This can assist in the early diagnosis of conditions such as inflammatory diseases, vascular disorders, and certain types of cancer. Early detection allows for timely intervention and improved treatment outcomes [1–3].

This imaging method has the potential for diverse applications across multiple medical specialties. It can be used in areas such as dermatology, rheumatology, neurology, sports medicine, vascular medicine, and oncology, among others. That versatility allows for a broad range of diagnostic and monitoring possibilities [1–4].

Overall, the importance of using a thermal imaging modality in clinical practice lies in its ability to provide early detection, non-invasive assessment, objective data, real-time monitoring, patient-friendly experience, and potential for multidisciplinary applications. By leveraging thermal imaging, healthcare professionals can enhance diagnostic accuracy, improve patient outcomes, and provide more personalized and effective care.

Despite these advantages, this imaging modality is not widely available in clinical setting and health institutions. That happens due to some factors such as: lack of training and expertise of specialists, demands on standardization and validation of specific exams, absence of reimbursement and insurance coverage and mostly lack of integration with existing technological infrastructure [10–15].

It is important to mention that due to the particularity of the infrared thermal imaging modality data acquisition and dataset requirements an existing modality implementation cannot be adapted, being this one of the major barriers to its adoption widely and at point of care.

It is aim of this research to address the lack of integration with existing technological infrastructure, through documenting and proposing a procedure to integrate thermal imaging as an imaging modality in health information systems like other medical imaging modalities.

2 Thermal Imaging Workflow

The ideal workflow of a thermal imaging modality exam involves a patient consultation, prescription of a thermal imaging examination, image acquisition, image review and analysis, report generation and report distribution and access (see Fig. 1), typically follows these steps within a health information system integrated with a Picture Archiving and Communication System (PACS), Radiology Information System (RIS), and Digital Imaging and Communications in Medicine (DICOM).

The workflow starts with a patient being consulted with a physician or healthcare professional who determines the need for a thermal imaging examination based on the patient's symptoms, medical history, and clinical assessment. If a thermal imaging examination is deemed necessary, the physician prescribes the examination and enters the order into the RIS. The RIS generates an order, which includes patient information, examination details, and any specific instructions. The RIS schedules the thermal imaging appointment based on availability and resources. The patient is notified of the scheduled appointment time and any preparation instructions.

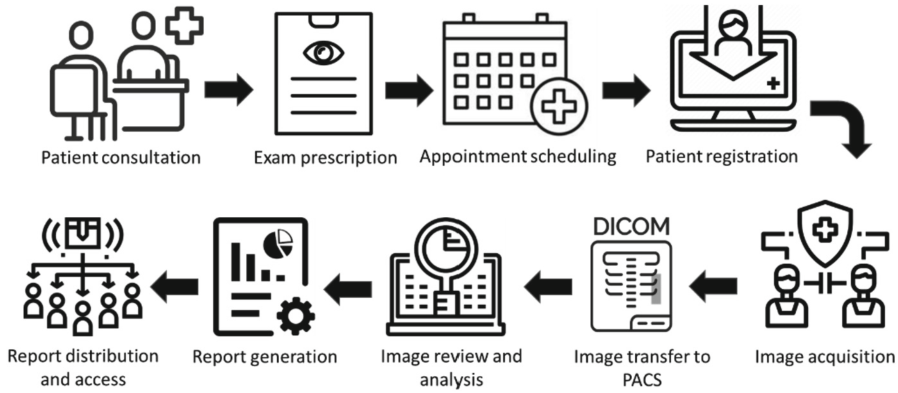

Fig. 1. Desired thermal imaging examination integrated workflow.

On the day of the examination, the patient arrives at the facility and goes through the registration process. The registration staff enters or verifies the patient's demographic information in the RIS, ensuring accurate patient identification and linking the examination to the correct patient record. The patient undergoes the thermal imaging examination. The healthcare professional operating the thermal imaging modality captures the thermal images and associates them with the patient's examination information. The modality generates DICOM-compliant thermal images and metadata.

The thermal images, along with associated metadata, are transferred from the thermal imaging modality to the PACS. This transfer can occur via DICOM network communication protocols. The PACS receives and stores the images in a secure and organized manner, associating them with the patient's unique identifier, examination details, and any other relevant information. The interpreting physician or radiologist accesses the PACS through a workstation or a dedicated image viewer. They retrieve the patient's thermal images from the PACS and review them to analyze the thermal patterns, identify abnormalities, and make a diagnosis or recommendation. After analyzing the thermal images, the interpreting physician generates a report summarizing their findings, conclusions, and recommendations. The physician uses a reporting tool integrated with the RIS to create the report, ensuring that it includes the patient's identification, examination details, relevant images, and any necessary annotations or measurements.

The finalized report is saved in the RIS, associating it with the patient's examination record. The report is typically made available in the health information system, allowing authorized healthcare professionals to access it for consultation, treatment planning, or further decision-making.

Throughout this workflow, the health information system, PACS, RIS, and DICOM facilitate seamless communication and integration of patient data, thermal images, examination orders, reports, and relevant clinical information. This integration ensures efficient and centralized management of the thermal imaging workflow within the healthcare facility, streamlining patient care and enabling accurate and timely diagnosis and treatment.

3 Integration Proposal

Integrating thermal imaging into a health information system involves connecting the thermal imaging modality with the Picture Archiving and Communication System (PACS) and Radiology Information System (RIS). This can be achieved through nine steps: requirements identification, choosing compatible systems, deployment of a thermal imaging modality, establishing communication, data mapping and translation, Integration testing, training and user support, compliance and security, and ongoing maintenance and support.

When fully integrating a thermal imaging modality into a health information system using a PACS, DICOM, and RIS, there are several functional and non-functional requirements that must be considered.

Functional Requirements:

- Patient Registration and Demographics, it should allow for accurate patient registration, including capturing and storing patient demographics such as name, age, gender, and unique identifiers.
- Order Management, it should support the creation, management, and tracking of thermal imaging examination orders, including prescription details, scheduling, and order status updates.
- DICOM Integration, it should be capable of sending and receiving DICOM-compliant data, including thermal images, from the thermal imaging modality to the PACS and RIS. It should ensure proper mapping, transmission, and storage of DICOM objects.
- Image Acquisition and Storage, it should facilitate the acquisition, transfer, and storage of thermal images in a secure and organized manner within the PACS, ensuring proper association with patient information and relevant examination metadata.
- Image Viewing and Analysis, it should provide tools for authorized healthcare professionals to access, view, and analyze the thermal images within the PACS, allowing

for proper zooming, panning, windowing, and image manipulation. It should support relevant measurement tools and overlays for image analysis.

- Reporting and Documentation, it should enable the creation, storage, and retrieval of thermal imaging examination reports, including relevant images, annotations, conclusions, recommendations, and patient identification. It should support report generation templates and customizable formats.
- Workflow and Task Management, it should support the management of the thermal imaging workflow, including task assignment, tracking, and status updates, ensuring smooth communication and collaboration among healthcare professionals involved in the process.

Non-functional Requirements:

- Security and Privacy, it should comply with relevant security standards and regulations to ensure the confidentiality, integrity, and availability of patient data and thermal images. It should include access controls, encryption, audit trails, and measures to prevent unauthorized access or data breaches.
- Performance and Scalability, it should be able to handle the data volume and processing requirements associated with thermal imaging, supporting efficient image transmission, storage, retrieval, and display. It should be scalable to accommodate future growth and increasing data demands.
- Interoperability, it should adhere to DICOM standards to ensure interoperability with other DICOM-compliant systems. It should support standard protocols for data exchange, such as DICOM and HL7, enabling seamless integration with other healthcare systems and interoperability across different facilities.
- Usability and User Experience, it should be designed with a user-friendly interface, intuitive navigation, and efficient workflows to enhance usability and user experience for healthcare professionals interacting with the system. Training and support resources should be provided to ensure proper system utilization.
- Reliability and Availability, it should have a high level of reliability, minimizing downtime and ensuring availability for accessing patient data and thermal images. It should include backup and disaster recovery mechanisms to protect against data loss or system failures.
- Compliance, it should comply with relevant regulatory requirements, such as Health Insurance Portability and Accountability Act (HIPAA) or other data protection regulations, as well as industry best practices for medical imaging systems. It should support auditing and logging functionalities for compliance monitoring.

These requirements provide a general guideline for integrating thermal imaging into a health information system using a PACS, DICOM, and RIS. Specific requirements may be required depending on the organization's needs, local regulations, and the capabilities of the chosen systems.

From the proposed requirements, UML modulation for use cases can be drawn considering the Thermal Imaging management system and the Thermal Imaging capture system (Fig. 2).

The Thermal Imaging management system, will have a physician who will prescribe a thermal imaging examination and enters the order into the RIS, access the PACS to view and analyze the thermal images, and generates a report summarizing the findings and recommendations based on the analysis of the thermal images. A registration staff can enter or verify the patient's demographic information in the RIS during the patient registration process, optionally can access the patient's information stored in the health information system (Patient Information Record System) for consultation, examination, or report generation purposes. The same actor in the RIS schedules the thermal imaging examination based on availability and resources.

At the Thermal Imaging capture system, the healthcare professional captures thermal images using the thermal imaging modality and associates them with the patient's examination details.

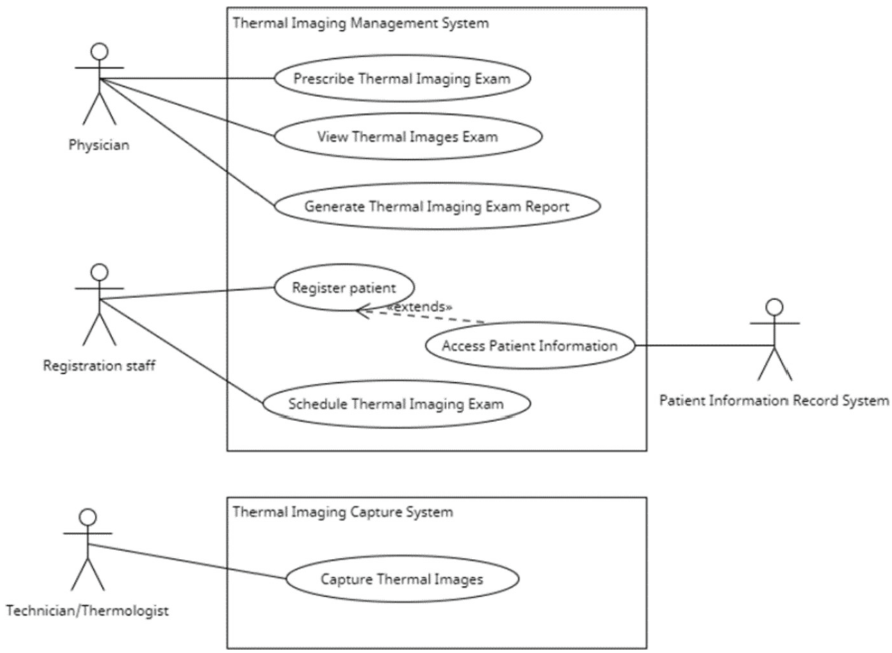

Fig. 2. The UML use cases diagram for the thermal imaging exam integration with the health information systems.

It is important to note that additional actors, use cases, and relationships based on the specific requirements and functionality of the integration may be required, this refers just to a simplest proposal of integration.

A UML class diagram for modulation of the integration of a thermal imaging modality into a health information system using a PACS, DICOM, and RIS was also defined. The "DICOMIntegration" interface represents the DICOM integration functionality (linking with the existing health information system at the facility), providing methods for sending and receiving DICOM data. The "RIS" class represents the RIS component, which handles order creation and scheduling. The "PACS" class represents the PACS component, responsible for storing and retrieving images. The "ThermalImage" class represents the thermal image entity, which encapsulates the image data, thermal values, and temperature unit. The "ExaminationOrder" class represents the examination order entity, which includes details such as the order ID, patient ID, date, and modality.

The class diagram, at Fig. 3, demonstrates the relationships and interactions between the components involved in the integration, including the DICOM integration, RIS, PACS, and the entities for thermal images and examination orders. It showcases the flow of data and functionality between these components within the health information system. Depending on the rearrangement of the integration systems requirements, new classes and associations may be required to be added.

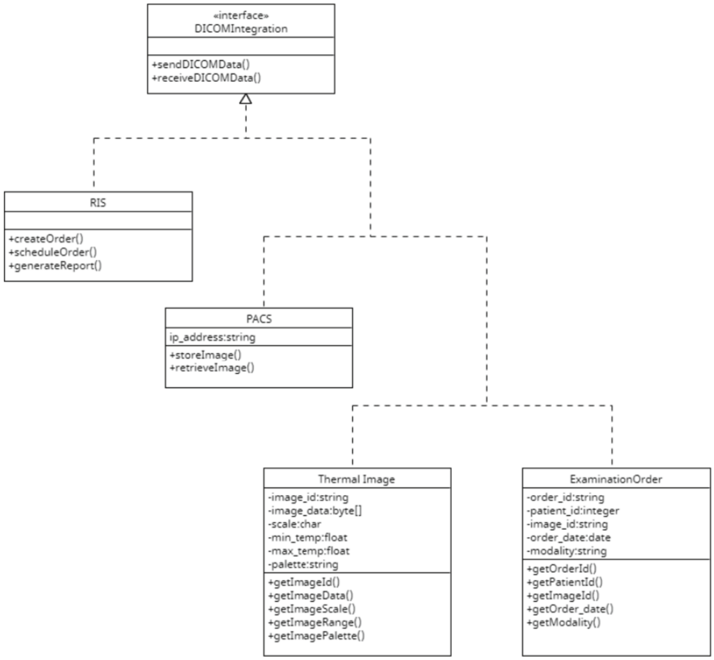

Fig. 3. The UML class diagram for the thermal imaging exam integration with the health information systems.

The DICOM standard provides a flexible framework for defining various medical imaging datasets, including thermal imaging, which has only defined the modality code. To define a medical thermal imaging dataset within the DICOM standard, apart from the data proposed by this research authors in a previous publication [16], some steps must be followed, such as: identifying relevant DICOM classes, defining necessary attributes, determining data types and formats, creating a data dictionary, assigning attribute tags, implementing DICOM conformance, testing and verifying, and documenting the whole process.

The DICOM classes and modules that are most appropriate for representing thermal imaging data need to be identified. DICOM includes a wide range of classes and modules that can be used to describe various aspects of medical images. For thermal imaging, some relevant classes and modules might include Patient, Study, Series, Equipment, Frame of Reference, Image, and Overlay Plane [17, 18].

The specific attributes are required to describe the thermal imaging data adequately. Attributes are elements that provide information about the image and its acquisition, such as patient demographics, acquisition parameters, thermal values, and image characteristics. For thermal imaging, some common attributes might include Patient Name, Patient ID, Study Date, Study Description, Body Part Examined, Thermal Scale, Thermal Map Data, and Temperature Units [17–19].

Using appropriate DICOM data types and formats to represent the thermal imaging data accurately will facilitate. DICOM supports various data types, including strings, numbers, dates, times, and binary data. For thermal imaging, you would typically use appropriate data types to represent temperature values, spatial coordinates, and other relevant information [17, 18].

A data dictionary is necessary to define all the attributes and their corresponding data types and formats. It will serve as a reference for implementing the DICOM dataset and provides a standardized description of the attributes and their associated values, ensuring interoperability across different systems. The data dictionary can be created using DICOM Structured Reporting (DICOM-SR) templates or other DICOM metadata management tools [17, 18].

Each DICOM attribute is identified by a unique tag that consists of a group number and an element number. Assign appropriate tags to each attribute in your data dictionary. Tag values must be unique within the dataset and adhere to the DICOM standard [17, 18].

It must be ensured that the thermal imaging dataset adheres to the DICOM conformance requirements. This includes complying with specific rules and guidelines defined by the DICOM standard. Validate your dataset against the appropriate DICOM conformance statements and ensure interoperability with other DICOM-compliant systems [16, 19].

Validate the thermal imaging dataset by testing it with DICOM-compliant software or tools. Verify that the dataset can be correctly read, displayed, and interpreted by different DICOM viewers and systems. Address any issues or inconsistencies that arise during testing.

The structure and content of your thermal imaging dataset, including the attribute definitions, data types, formats, and any specific implementation considerations must be documented. This documentation will be helpful for others who need to work with or integrate your dataset into their systems.

It's important to note that while the DICOM standard can accommodate thermal imaging data, there is no specific module or class dedicated solely to thermal imaging. Therefore, you may need to leverage existing DICOM modules that align closely with thermal imaging or use private tags to capture additional specific thermal imaging information not covered by the standard.

4 Discussion

There are some advantages about Integrating a thermal imaging modality system into a health information system using a PACS, DICOM, and RIS. Examples include centralized data management, enhanced workflow efficiency, improved data availability and accessibility, comprehensive patient records, data consolidation and interoperability, simplified reporting and documentation, regulatory compliance, data security, and contribute to a wider adoption of the modality improving patients care [10–15, 19].

By integrating the thermal imaging modality with the health information system, all patient data, including thermal images, examination orders, and reports, are stored centrally in a structured and organized manner. This centralization allows for easy access, retrieval, and management of patient information by authorized healthcare professionals.

Integration streamlines the workflow by automating various processes. It eliminates the need for manual data entry, reduces paperwork, and minimizes the chances of data duplication or errors. Healthcare professionals can quickly access patient records, schedule examinations, capture and store thermal images, and generate reports seamlessly, leading to improved operational efficiency.

With integration, thermal images and related patient data become readily available to authorized users within the health information system. This accessibility enables efficient collaboration, consultation, and decision-making among healthcare professionals involved in patient care. It facilitates timely access to critical information, ultimately improving patient outcomes.

Integrating thermal imaging data into the health information system enriches patient records by incorporating thermal images alongside other diagnostic images, laboratory results, and clinical documentation. This comprehensive view enables healthcare professionals to have a holistic understanding of the patient's condition, aiding in accurate diagnosis, treatment planning, and monitoring.

The integration with DICOM and other standard protocols ensures interoperability between different systems and healthcare facilities. It allows for seamless exchange of thermal images and associated data with other DICOM-compliant systems, facilitating continuity of care, referrals, and remote consultations. The consolidation of data also supports research, analysis, and population health management initiatives [17–19].

It enables efficient generation and storage of thermal imaging reports within the health information system. Physicians and radiologists can use reporting tools integrated with the RIS to create standardized reports with relevant findings, conclusions, and recommendations. This simplifies the documentation process, ensures consistency, and provides a comprehensive record of thermal imaging examinations.

Integration can help ensure compliance with regulatory requirements, such as data privacy and security regulations (e.g., HIPAA). By leveraging secure communication protocols and implementing access controls, encryption, and audit trails, the integration helps protect patient data, maintain privacy, and meet regulatory obligations.

Overall, integrating a thermal imaging modality system with a health information system using a PACS, DICOM, and RIS enhances data management, workflow efficiency, collaboration, and patient care. It promotes a more comprehensive and accessible healthcare environment, leading to improved diagnosis, treatment, and outcomes, leading to better patient care and satisfaction [15, 19].

5 Conclusion

In this research the main goal of address the lack of integration with existing technological infrastructure, through documenting and proposing a procedure to integrate thermal imaging as an imaging modality in health information systems was fulfilled. Minimal requirements, UML case studies, UML class diagram modulation and steps towards the definition of a DICOM dataset to perform a full integration.

It is important to mention that this is just a simple proposal, the implementation may differ with health institutions, since they face different scenarios and have different types of organization, which may lead to different actors, use cases, classes and relationships based on the specific requirements and functionality.

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