Interactive Information Visualization as Support for Computer-Aided Diagnosis: Prototype and Qualitative Evaluation

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Abstract. ***Research Context:*** *Medical Information Systems (MIS) have evolved significantly to achieve efficiency and scalability in processing large amounts of multimodal data. Computer-Aided Diagnosis (CAD) models offer a second opinion to help physicians compose a more precise diagnosis. Effective CAD models need to be built on diverse, multicentric and, in specific cases, multimodal databases.* ***Scientific and/or Practical Problem:*** *The lack of standardization and complex interoperability among different MIS are major challenges that hinder the exploration of the maximum potential of digital data in healthcare applications, including the development of CAD models.* ***Proposed Solution and/or Analysis:*** *A generic, flexible and reusable relational data model was applied, developed specifically to support the training of CAD models from multimodal data. Through a case study using Cardiac Magnetic Resonance exams, a prototype with interactive Information Visualization (IV) functionalities was developed and qualitatively evaluated.* ***Related IS Theory:*** *The evaluation was inspired by the Fit-Viability Theory, as the prototype was evaluated primarily with regard to its potential for effective integration into real-world clinical workflows.* ***Research Method:*** *The research included: literature review; modeling; prototyping; development; qualitative evaluation through interviews with health professionals; and analysis and summarization of results.* ***Summary of Results:*** *Evaluated IV tools demonstrated strong potential to enhance clinical decision-making for the interviewed health professionals. From a Fit-Viability perspective, the system showed a promising fit with the users' analytical needs and clinical workflows, while also indicating viability in terms of technical feasibility and resource compatibility within the healthcare setting.* ***Contributions and Impact to IS area:*** *Results showed that the strategic combination of a flexible data model and customizable IV functionalities can provide valuable research tools and diagnostic aids to physicians. These insights offer practical guidance for enhancing MIS and CAD capabilities, particularly in supporting the effective analysis of medical databases.*

1. Introduction

Nowadays, the amount of digital data of different modalities that need to be stored, processed, and interpreted is growing rapidly [Acosta et al. 2022; Kaseb et al. 2019; Zhao et al. 2019]. The processing and analysis of these large digital databases have contributed significantly to the evolution and improvement of services provided to society, as well as to supporting decision-making in different applications and business areas [Acosta et al. 2022; Beerkens 2022; Wilkin et al. 2020; Zhao et al. 2019; Zhu 2019]. In this context, the development of effective and efficient Information Systems (IS) for processing and analyzing large volumes of digital data, as well as for extracting and adequately presenting information to users, becomes a major challenge in different areas of application.

In Healthcare, data are inherently multimodal, with a large amount and diversity of data routinely captured and stored, including clinical and demographic data, as well as signals, images, and videos from complex exams [Acosta et al. 2022; Horne et al. 2020; Huesch and Mosher 2017]. A single patient can generate, annually, around eighty megabytes of medical data related to digital medical records and imaging exams [Huesch and Mosher 2017]. This scenario favors the use of digital technologies, which can optimize data monitoring, collection, and storage processes in Healthcare [Viglio et al. 2025; Almeida et al. 2025]. Medical Information Systems (MIS) have evolved to handle large volumes of data, reaching satisfactory levels of efficiency and scalability [Bandeira and Fagundes 2025]. The lack of standardization and complex interoperability among different MIS is a major challenge that hinders the exploration of the maximum potential of digital data in Healthcare applications, especially in the context of Computer-Aided Diagnosis (CAD) [Marques et al. 2025; Torab-Miandoab et al. 2023].

CAD models use pattern recognition techniques to provide relevant second opinions for health professionals [Bandeira and Fagundes 2025; Rank et al. 2020; Zhou et al. 2021]. CAD has been successful in supporting medical decision-making processes by providing insights based on the analysis of medical records and images, such as Magnetic Resonance exams [Wang et al. 2024]. However, to ensure the generalization, robustness, and fairness of these models, it is essential to train and validate them using diverse datasets from multiple data centers, which enables CAD models to capture a broader spectrum of patient demographics and clinical practices [Almeida et al. 2023]. This process is critical for reducing bias and improving diagnostic accuracy across different populations: studies have shown that the lack of data diversity and interoperability between MIS can hinder the full potential of CAD in clinical settings [Salmi et al. 2024]. In addition, standardized storage of medical data in adequate databases is helpful to organize and facilitate the retrieval of information to be used as input for CAD models [Gómez-Flores et al. 2024].

Information Visualization (IV) resources can convert data into visual elements, such as graphs and visual maps, which provide an intuitive comprehension of the stored information [Silva et al. 2020; Muskan et al. 2022]. By combining medical databases (DB) with intuitive and interactive IV resources, we can create powerful tools for medical information retrieval and analysis to support the large data demand of MIS and CAD models [Doi 2007; Silva et al. 2020]. In this context, it is relevant to build effective and intuitive IV resources that can adapt to the underlying data structure [Malik and Sulaiman 2013]. The literature presents some works that propose IV tools for supporting medical data analysis, such as the studies of Lin et al. [2019] and Mandell et al. [2022]. However, they do not present flexible structures that are fully integrated into data retrieval applications, which is the scope of the research presented in this paper.

The use of flexible and generic data models can also contribute to reducing software development costs resulting from changes in requirements or modeling [Nascimento et al. 2025]. Combined with flexible IV tools, these data models can play a crucial role in standardizing data from different institutions and MIS [Poppe et al. 2019]. This approach enables the visual representation of complex data structures, facilitating understanding and alignment between technical and clinical teams, while promoting interoperability across heterogeneous systems. Data standardization is essential for collaborative Healthcare initiatives, where integrating clinical data from diverse sources is necessary for robust analysis and the development of CAD models [Almeida et al. 2023].

This study aimed to verify the relevance of interactive IV resources to support the analysis of medical image databases and the development of CAD models. The IV approach allows interactive search and analysis of medical data and exams from the point of view of medical professionals. The IV is built considering a flexible database structure that can dynamically adapt to the state of the stored medical data. In addition, the structure is reusable since its generic modeling can be applied to different types of exams and metadata in other medical contexts.

This study was inspired by the Fit-Viability Theory, which provides a framework for evaluating the alignment between technological solutions and organizational readiness [Wickramasinghe et al. 2018]. According to this theory, “fit” refers to the degree to which the system’s features match the tasks it is intended to support, while “viability” assesses the organization’s capacity to adopt and sustain the technology, considering factors such as infrastructure, resources, and strategic goals [Wickramasinghe et al. 2018].

By applying concepts from this framework, we justify the relevance of interactive IV tools in clinical data analysis. These tools not only align with the analytical needs of medical professionals (fit), but also demonstrate adaptability and reusability across different clinical contexts and data types (viability), supporting the development of robust and scalable CAD models [Poppe et al. 2019]. The developed tool was evaluated by means of an interview with experts, in order to address the adequacy and viability of the proposed artifact in a real scenario, following the common practice of gathering users’ opinions to evaluate IV tools [Veriscimo et al. 2020].

In the context of MIS, the results presented in this paper contribute by demonstrating, through a case study in Cardiology, that it is possible to develop and make available valuable, flexible, and customizable functionalities to specialist physicians for the analysis of diverse and multimodal medical databases. In this research, such contributions were made concrete through:

- application of a generic, adaptable, and reusable relational data model, developed specifically for the context of digital medical data and object persistence;
- development of a prototype of a flexible, reusable, interactive, and customizable prototype for presenting relevant information from a real medical database and conducting a qualitative evaluation with experts;
- integration of the developed prototype to a DB application of data storage and retrieval, presented in a previous study [Alvim et al. 2025];

- a protocol to execute a qualitative assessment with medical professionals and identify fit-viability criteria.

This study aligns with the Grand Challenges in IS across different themes. In the context of conception and elaboration of Systems of Information Systems (SoIS) [Graciano Neto et al. 2017], it explores how flexible and interactive IV tools can support the modeling and simulation of SoIS architectures in the medical domain. By proposing a generic and adaptable data model for medical databases, we addressed key aspects of SoIS design, including the specification of mission [Graciano Neto et al. 2017], such as CAD workflows. The proposed prototype enables spontaneous integration of new data sources from different MIS, reflecting the dynamic nature of SoIS where components can join on demand and contribute to the overall goal [Graciano Neto et al. 2017].

Furthermore, the research addressed concepts and solutions applicable in the context of IS complexity and Data Science challenges [Lopes et al. 2017; Maciel et al. 2017], since the proposed and evaluated data model and IV functionalities contribute as subsidies for the improvement of MIS interoperability, as well as for the organization, standardization and selection of data aiming at the training and test of computational models for Healthcare applications. These perspectives are consistent with the principles outlined by the Grand Challenges in IS, emphasizing the need for innovative theories and technologies to support the efficient development and application of IS.

This paper is organized into the following sections: Section 2 introduces the theoretical background and previous studies; Section 3 presents related works; Section 4 presents the materials, technological resources and the methodology applied in this study; Section 5 presents and discusses the results; lastly, Section 6 presents the conclusion.

2. Background

This study is part of a research project that aimed to develop and validate a generic and flexible database model for medical exams and data to support research on CAD in different application contexts. This DB model and its validation in a real case study were presented with further details by Alvim et al. [2025], in the context of a CAD tool for cardiomyopathy diagnosis based on Cardiac Magnetic Resonance Imaging (CMRI) exams, focused on Dilated Cardiomyopathy (DCM) and Hypertrophic Cardiomyophathy (HCM).

The DB model was validated by the implementation and evaluation of a web application composed of three layers: i) a relational DB to store data from a set of CMRI exams; ii) a RESTful web services Application Programming Interface (API) that enables operations of Creating, Retrieving, Updating, and Deleting (CRUD) DB instances; iii) a Graphical User Interface (GUI) with customizable filters to retrieve lists of patients and their demographic and morphological information persisted in the DB, as well as to download sets of CMRI exams in the Digital Imaging and Communications in Medicine (DICOM) format.

The generic and flexible DB, modeled and implemented, allows the dynamic registration of attributes and their data types, similar to how a column's metadata is stored in Database Management Systems (DBMS). With this approach, it is possible to insert new attributes for a patient or an exam in a relationship table without requiring changes in the DB schema to add new columns. The DB diagram and the data dictionary are available in Alvim et al. [2025].

The GUI communicates with the DB through the RESTful web services API. It is composed of dynamic filtering options for demographic and exam data, which are generated by retrieving all available attributes for patients registered in a specific DB table, together with their respective data types. This way, the GUI always reflects the current state of the database, decreasing the need for maintenance as the database grows or changes over time. Figure 1 shows an example of the dynamic behavior of the GUI when changes are made to the data. The GUI was evaluated in terms of usability and utility in a previous work [Alvim et al. 2025].

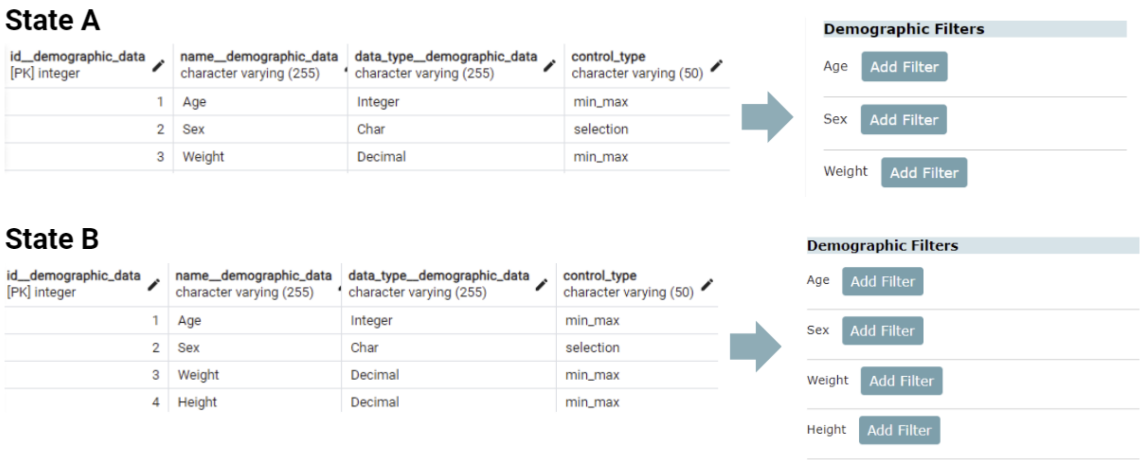


Figure 1. Different states of the Demographic Data table and the GUI filter elements generated based on the attributes' name and data type. State A does not include the attribute 'Height'; when this attribute is inserted, the interface shows its filter element automatically after reloading (State B), without requiring code maintenance.

The web application enables the retrieval of patients' demographic data that fit the selected filters. It also allows the user to download the DICOM files of these patients' exams and a Comma-Separated Values (CSV) file with morphological features, which were extracted from the exam images by image-processing algorithms developed in previous studies [Delmondes et al. 2015; Bergamasco et al. 2022; Costa et al. 2024]. The study described in this paper extended the web application's GUI by including flexible and dynamic IV functionalities that were qualitatively evaluated by medical professionals.

In this derived work, we conducted a case study to evaluate the fit and viability of the proposed data model in supporting Healthcare professionals with tasks such as standardization, search, organization, and analysis of medical data and exams from multimodal and heterogeneous databases. From the perspective of Fit-Viability Theory, we investigated whether the prototype meets clinical and operational needs and whether it can be sustainably implemented within existing technical and organizational constraints. The flexible IV functionalities are presented as solutions to address the challenges of data heterogeneity and complexity, offering support for clinical decision-making and efficient exploration of large volumes of medical information.

3. Related Work

Several studies have presented approaches and studies about IV applied to the visualization and analysis of medical data. Malik and Sulaiman [2013] presented an application that collects medical information from multiple sources and presents an overview of the patient's health records in a unified interface. Mandell et al. [2022] provided an interactive interface of visual representations of Electronic Health Records (EHR). Cheng and Senathirajah [2023] assessed the improvement in medical students' diagnostic reasoning when using visual EHR interfaces.

In terms of temporal visualization, Ruan et al. [2018] developed an interface that collects different clinical information about a patient and maps them in time and space to graphically present the body parts affected by diseases, besides a timeline of the patient's clinical history. Similarly, Lin et al. [2019] developed an IV tool for timeline visualization of a patient's records. Silva et al. [2020] presented a Virtual Reality approach to support interactive visualization of temporal data in health informatics.

Some studies present an overview of IV techniques. Younas et al. [2016] studied different IV techniques for EHRs, considering the readability and complexity of each technique. Polychronidou et al. [2019] presented a web-based platform for medical data visualization called *Health Vision*, which provides interactive visualization and analysis of heterogeneous medical information and propagates customizations through the different visual representations available. Yeshchenko and Mendling [2024] presented a comparison of different IV models for event sequence analysis, which is relevant in Healthcare timeline visualization. Both of these studies highlight the capability of standardizing different data types into intuitive and comprehensive visuals as necessary for an IV tool to be considered helpful and relevant.

The studies cited above inspired the development of the prototype evaluated in this research. However, the present work distinguishes itself by applying these tools within the context of a CMRI database, emphasizing interactivity and flexibility in both the data model and the visualization interface. Various types of visualizations were designed to explore the available data, and a dashboard was integrated into the GUI, allowing direct interaction with the database and reflecting the dynamic nature of the proposed model. Importantly, this study also collected and analyzed initial feedback from cardiology specialists regarding the usefulness of the implemented prototype.

Unlike related works, the evaluation strategy employed in this work was inspired by the Fit-Viability Theory, which enabled a more comprehensive assessment of the system's alignment with clinical needs and its feasibility for integration into real-world Healthcare environments. This theoretical lens differs from prior research, which overlooks expert-based evaluations of the system's adequacy and implementation potential in clinical practice.

4. Materials and Methods

This section presents the materials and methods applied to this study. Section 4.1 presents the data sources and technologies used to populate and implement the web application. Section 4.2 presents the methods applied to develop the IV resources. Section 4.3 presents the qualitative evaluation protocol.

The development of the proposed prototype was grounded in a DB application of CMRI exams, with integrated IV functionalities. These visualizations were embedded into the DB application GUI, enabling physicians to interact with patient data through intuitive dashboards tailored to their analytical needs.

The prototype was qualitatively evaluated based on a protocol designed to assess both the fit and viability of the system. The evaluation aimed to discuss whether the prototype aligns well with clinical tasks such as longitudinal exam analysis and case comparison (fit), and whether its integration with existing MIS would be feasible with minimal adaptation (viability). The development phases undergone in the current project are presented in Figure 2.

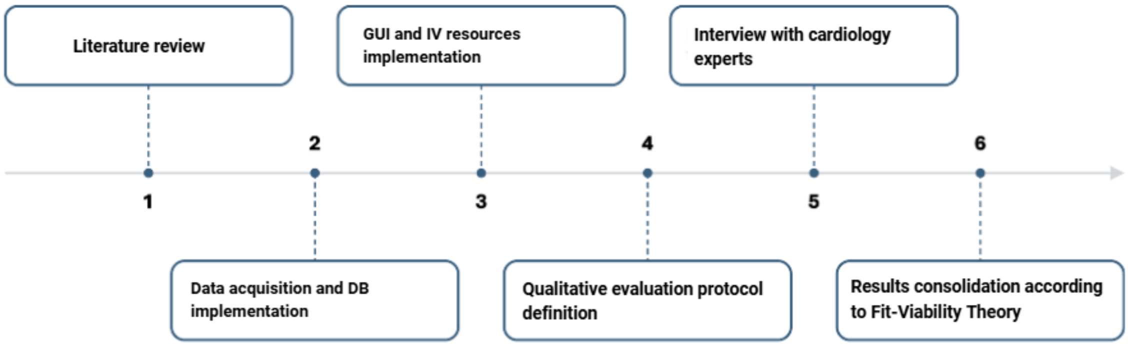


Figure 2. Phases to develop and evaluate the IV functionalities of the DB application for CMRI exams: from literature review to consolidation of results regarding fit and viability.

4.1. Materials

The data used in this project were acquired from 400 anonymized CMRI exams shared by the Heart Institute of the *Hospital das Clínicas* of the *Faculdade de Medicina da Universidade de São Paulo* (InCor-HCFMUSP). The exams include DICOM images, demographic information (age, height, sex, and weight), and morphological features extracted from the images in previous studies [Delmondes et al. 2015; Bergamasco et al. 2022; Costa et al. 2024]. Each exam also contains a report with the diagnosis provided by a physician: DCM, HCM, or No Anomaly (NAN). The sharing process, as well as the anonymization, security, and privacy of the shared data, were approved and authorized by the Committee for Ethics in Research on Human Beings of the School of Arts, Sciences and Humanities of the University of São Paulo (Aug. 9, 2021, No. 49049021.1.0000.5390), as well as the Committee for Ethics in Research of the HCFMUSP (Sep. 2, 2021, No. 49049021.1.3001.0068) [Gonçalves et al. 2024].

The DB was modeled with the DbSchema software [Wise Coders GmbH 2023] and codified in PostgreSQL DBMS [The PostgreSQL Global Development Group 2023]. The web services were implemented using a RESTful API with Python and the Flask framework [Pallets 2024]. The GUI was created and integrated with the web services by means the JavaScript, HTML, and CSS languages.

The IV resources were developed with the Microsoft Power BI Software, a BI visualization tool for data processing and analysis [Carlisle 2018]. This tool was chosen because it can be integrated with the DBMS, favoring real-time actualization, besides providing insights to support decision-making processes in various fields [Carlisle 2018]. This software provides customization and flexibility, allowing the integration of multiple data visualization resources with the DB, which was made using the JavaScript programming language.

4.2. Development of Information Visualization Functionalities

A dashboard with different types of data visualizations was built on Power BI and integrated into the web application GUI. This dashboard allows the creation of multiple graphic elements that correlate the attributes of different DB tables. The web application's DB was used as the data source for the dashboard; therefore, the DB tables were fully loaded into the software. When the DB is updated, Power BI captures the live state of the data without requiring manual insertions or reconfiguration of the connection. This is possible because of the flexible structure built in our approach, as presented in Section 2.

After loading the DB, a dashboard is created containing graphs representing demographic data, exam execution data, and patient data during the exam execution. The graphs built in each dashboard tab were determined by evaluating the available information in the DB structure, aiming to create visualizations that would provide valuable insights to physicians. Power BI allows for the private publication of the dashboard on a website and automatically generates an inline frame (iframe) element that can be incorporated into the GUI [Sharma et al. 2021]. Figure 3 illustrates how the IV feature integrates with the DB application.

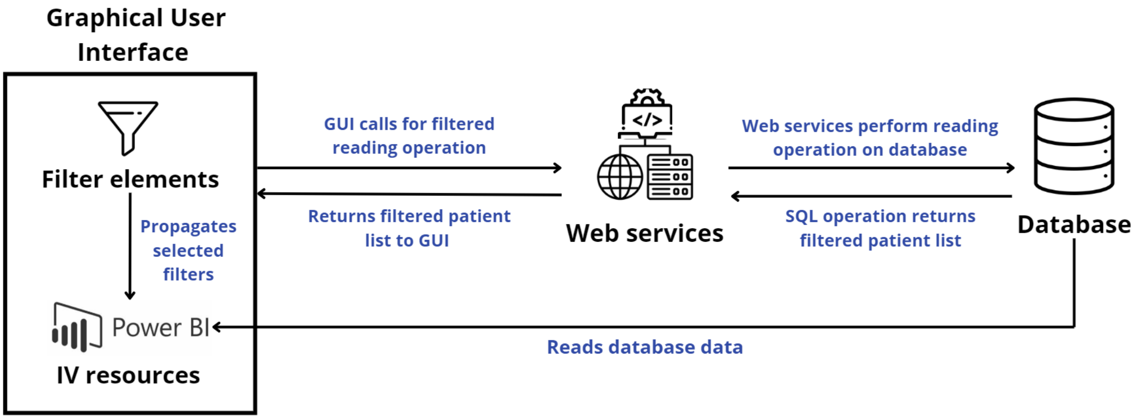


Figure 3. Web application structure. The IV resources developed on Power BI read the DB data and present them through intuitive visualizations. The reading operation is triggered by the GUI's filtering and fetching functions, and the web services perform the filtered SQL reading operation on the DB. The result is retrieved by the web services and passed on to the GUI, where it is visualized by the user. The selected filters on the GUI are automatically propagated to the Power BI dashboard.

The standard Power BI filtering function involves selecting any region with data in the visualization: the selected region is highlighted, and the corresponding data in other visuals are automatically highlighted as well. It is also possible to filter the dashboard by passing parameters through the web request, specifying the table, attribute, and value that must be filtered.

To fully integrate the dashboard with the web application GUI, the behaviors of the GUI filtering components (Figure 4a) were adapted to also control the state of the dashboard. Whenever a filter is added by the user on the "Fetch Patients" section of the GUI, a function to generate an equivalent filtering string is triggered. This is performed by a Python code that automatically builds a Power BI filter string while users define their filters (Figure 4b). Then, this string is sent through a web request that updates the dashboard iframe URL, reflecting the newly selected filters on the dashboard views. This approach helps the user customize the dashboard and visualize the data of the patients who correspond to the selected filters, improving the data analysis value of the implemented IV feature.

(a) GUI filtering elements with Class, Sex, and Machine Model filters selected by the user.

```
&filter=public_demographics/classe in ('CMD') and          powerbi.js:9
Sex/valor_dado_demografico in ('F') and
Machine_Model/valor_dado_da_execucao in ('GENESIS_SIGNA')
```

(b) Power BI filter string to be added to the iframe URL in order to filter a Power BI dashboard. CMD is the Portuguese label that corresponds to DCM.

Figure 4. GUI filtering components and automatically generated Power BI filtering string. The confirmation of a filter selection triggers the string generation, which is automatically added to the dashboard iframe URL to filter the IV resources.

4.3. Qualitative Evaluation

The qualitative evaluation procedure was performed with two people: a physician and a biomedical, both experts in Cardiology and CMRI. A protocol was defined (Figure 5) to guarantee the covering of all topics together with comprehension of the topics by the participants.

The evaluation was conducted in a 45-minute videoconference session, recorded with the participants' permission. Four members from the technical (computer science) team and the two health professionals have participated in this activity. A semi-structured interview was conducted during this meeting. The cardiologist (physician) has more than 30 years of experience, and the biomedical scientist working in Cardiology research has more than five years of experience. Both participants are familiar with the medical data storage and analysis tools currently available at their workplace.

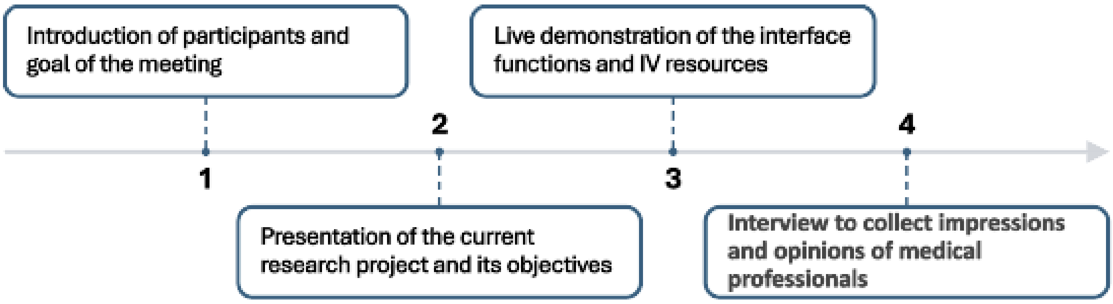


Figure 5. Protocol of the qualitative evaluation with health professionals.

In the first step of Figure 5, the coordinator of the team explained the goal of the meeting and the evaluation protocol. Next, a presentation of all the members was conducted. In the second step, it was explained that the proposed web application is a prototype to store, organize, and retrieve data and images from a medical DB to support research on CAD models by Computer Science professionals, as well as to provide IV capabilities for medical professionals. The live demonstration of the interface (step 3) involved patient retrieval using the various available filters, highlighting the integration of the filter elements with the IV functionalities. Lastly, the set of questions presented in Table 1 was asked to the participants; answers and related discussions are presented in Section 5.2.

Table 1. Questions asked in a semi-structured interview with medical professionals as a qualitative evaluation of the developed prototype.

Question	Description
Q1	Is there any tool currently used at your workplace with similar functionalities? If so, which one?
Q2	Could the presented tool add any value to the routine processes of professionals at your workplace? If so, how? Could you provide a practical example?
Q3	Considering what was presented, would it be possible to evaluate the quality and usefulness of the presented graphical visualizations to medical professionals?
Q4	Could you suggest graphical visualizations that were not presented in the prototype but could be useful for medical professionals in searches and analyses of the exam database?
Q5	In a future, more comprehensive evaluation, would your team be available to conduct a formal assessment of the application?

To assess the proposed prototype through the lens of Fit-Viability Theory, the described qualitative evaluation aimed to capture insights into the system's fit, defined as its alignment with clinical tasks, workflows, and user expectations, and its viability, referring to the feasibility of implementation within existing healthcare infrastructures.

The qualitative data collected during the interview were analyzed thematically and mapped into a Fit-Viability matrix [Mettler 2016]. The responses were reviewed in the recording and categorized from low to high according to two dimensions: Fit, which includes indicators such as relevance to clinical routines, support for data analysis, and adaptability to different hospital contexts; and Viability, which encompasses factors like ease of integration with existing MIS, learning curve, and resource requirements. Each response was coded and positioned within the matrix to identify strengths, gaps, and opportunities for improvement. This structured mapping enables a clear visualization of how the system aligns with real-world clinical needs and its potential for adoption, distinguishing this study from related works that often lack expert-based evaluations grounded in implementation feasibility.

5. Results and Discussion

This section presents and discusses the results of the study. Section 5.1 presents the IV dashboard developed and the considerations regarding this IV resource. Section 5.2 presents and discusses the qualitative evaluation of the final application. Lastly, Section 5.4 discusses the limitations and advantages of the proposed approach.

5.1. Interactive Information Visualization

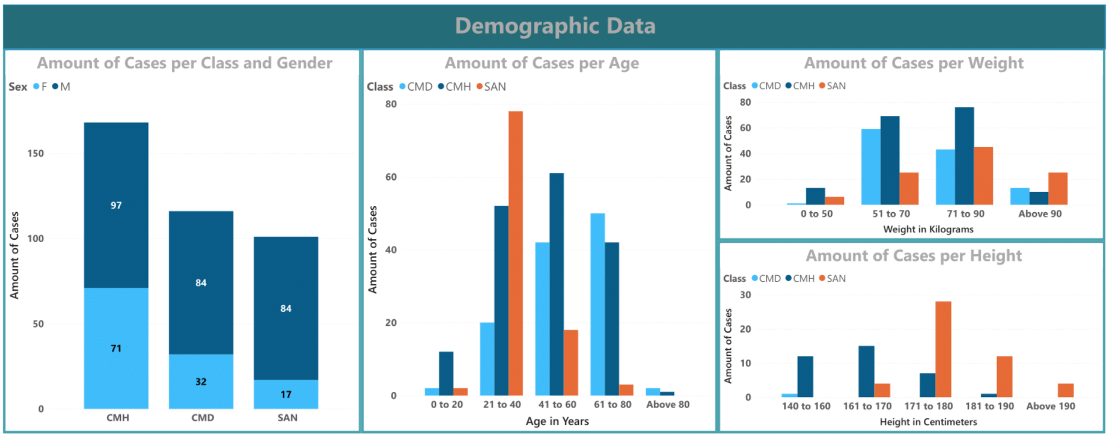
Figure 6 presents the developed dashboard. The dashboard is connected to the DB and automatically reflects the current state of the persisted data. Additionally, visual elements can be added or updated in the software, and the changes are automatically reflected in the GUI by the incorporated iframe element.

The dashboard is completely integrated with the GUI and automatically reflects the filters selected by the user, by using a string automatically built by a Python code from the filters selected by the user (Figure 4). This resource helps the process of information retrieval and analysis by providing friendly, intuitive, and customizable visualizations of the stored data, which are essential to reduce the complexity of the large amounts of medical information necessary to support the building of CAD models [Vieira and Correa 2011; Silva et al. 2020].

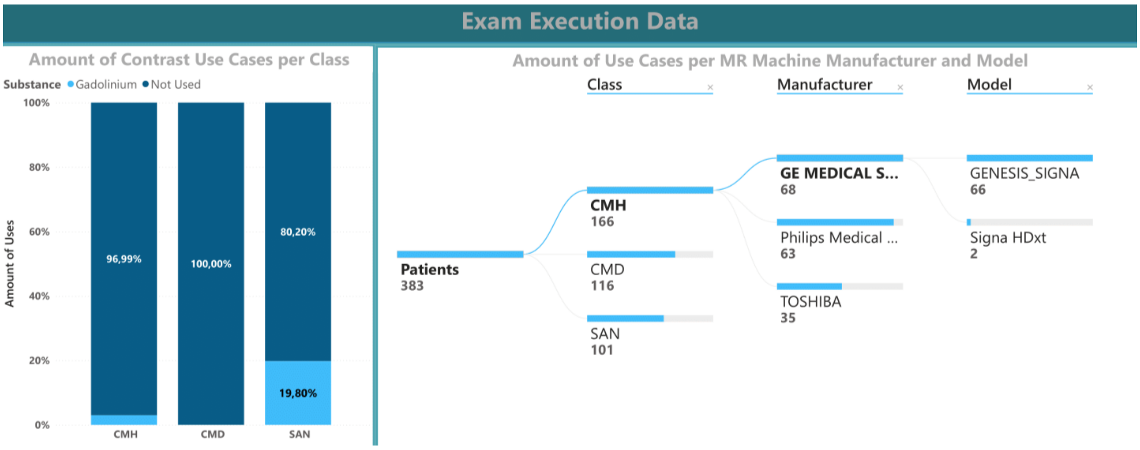
The first set of graphs is titled “Demographic Data” (Figure 6a), and presents bar graphs that show the number of patients in terms of sex, age, weight, and height. The bar graph for sex distribution presents the stacked counts of patients of each class of diagnosis segmented by sex. The remaining bar graphs present bars for each diagnosis in segmented age, weight, and height ranges.

The second set of graphs is “Exam Execution Data” (Figure 6b), and presents a bar graph with the stacked count of use cases for each contrast substance used in the CMRI exams, with one bar for each diagnosis. The second visual is a hierarchical tree that associates the machine manufacturer and model for the exams of each diagnosis.

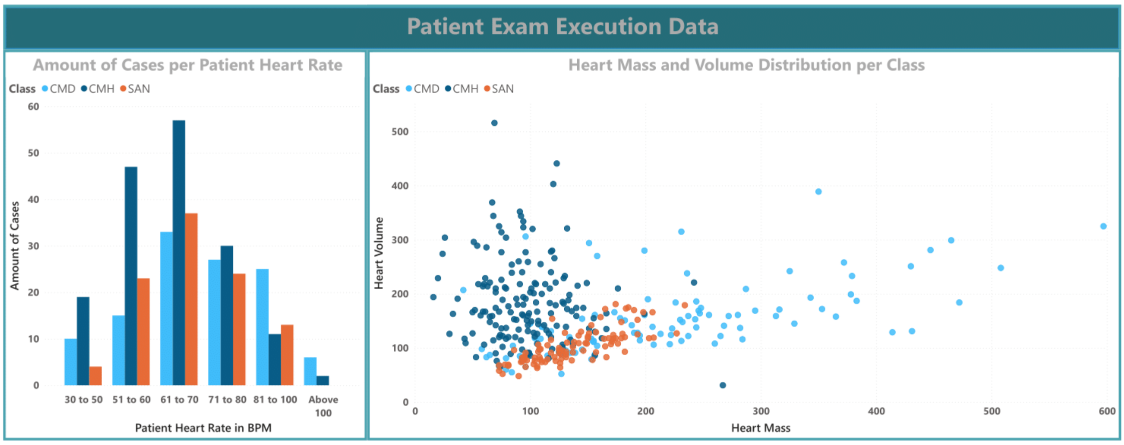
Lastly, the third set of graphs is “Patient Exam Execution Data” (Figure 6c), which provides a visualization of patients’ useful clinical metrics retrieved from an exam execution. The first graph is a bar graph similar to the visuals of the first set, showing the number of cases per heart rate range. The second graph is a distribution of points correlating the heart mass and volume calculated in previous works [Bergamasco et al. 2022] and registered in the DB as features. Filter elements for features and descriptors are one of the possible expansions of the prototype, which will increase its data retrieval and analysis value.



(a) Demographic Data section.



(b) Exam Execution Data section.



(c) Patient Exam Execution Data section.

Figure 6. Dashboard created on Power BI for data visualization integrated with the DB and its filtering and retrieval application. CMD, CMH, and SAN are the Portuguese labels that correspond to DCM, HCM, and NAN, respectively.

In addition to the visualizations developed for prototype evaluation, other visuals can be easily included in the dashboard, taking advantage of the flexibility of the database model and web application developed, as well as the different resources provided by Power BI.

5.2. Qualitative Evaluation

Following the interview script summarized in Section 4.3, it was possible to collect the impressions of the participating experts regarding the data dashboard and the web application. In addition, important directions for improvements and future developments related to the data model and the prototype as a whole were also identified.

Regarding Q1, both the physician and the biomedical scientist affirmed that they were not aware of any tool with this practicality. They mentioned that the access to the exams' database is currently done via queries by a specialized group, and the data is returned in Excel files, which are generally difficult to read. The physician added that *WebPAX* [Simmons 2013] (the exam storage tool used at their workplace) also does not present this amount of data, and that he was aware of new software that extracts information from DICOM files, but it does not have the same dashboard and statistics functionality.

The participants answered positively to Q2, and the physician provided examples of how the tool would be helpful to keep track of their work. For example, it would be possible to know the percentage of patients with DCM in the last 2 years, and then view the percentage of patients in each class of diagnosis, which would already be useful information. He added that biomedical professionals should be instructed to register the contrast substance used and its quantity, allowing them to control the economic aspect of spending on the substance. He also stated that the tool had very practical and useful uses, given that there would be adjustments to perform specific tasks.

Regarding Q3, the physician stated that basic graphs and percentages are classic and useful, but that there are certainly more professional visualizations that can be made, to which the biomedical scientist agreed. The physician added that it is important that the data ranges are customizable, which is already possible with the filter tools presented on the interface. For Q4, both participants said that new ideas will arise from using the prototype, and that they could suggest different visuals for specific questions that emerged from the clinical routines in the future.

The physician responded positively to Q5, but said that the evaluation would probably be internal due to the Brazilian General Law on Personal Data Protection (LGPD) [Federative Republic Brazil 2018]. He added that it would be possible to use the tool for a specific purpose in his workplace: if a colleague needs to collect data for a project or analysis and they can retrieve it through the system, it would be possible to convince them to present a formal evaluation.

The participants also asked questions after the presentation about how quickly the exam data could be included in the DB, and how easy it would be to include data that did not come from the DICOM file, since they would be interested in including relevant clinical information available in electronic medical records and CSV files. It was confirmed that data in DICOM or CSV files can be easily included in the DB using scripts, and that the automatic integration of the DB with the IV resources and interface would allow the retrieval and visualization of this information automatically, without needing any maintenance in the implementation. Given this positive response, participants said that it "exponentially" increases the value of the tool, and they expressed interest in integrating the tool with all exams available in their *WebPAX* storage (approximately 20 thousand exams).

Overall, the impressions of the experts interviewed were positive, as the usefulness and practicality of the tool were highlighted several times by the participants. The professionals stated that they were not aware of a similar system being used at their workplace, demonstrating that this research provided a useful and innovative contribution. The integration of the IV tool and the system's flexibility for the inclusion of new exams and attributes, as well as the low need for code maintenance, met the expectations of healthcare professionals of having a tool for data and exam analysis that was easy and intuitive to use for non-programmers.

Furthermore, professionals suggested that specific visualizations could be integrated into the interface to increase the analytical power provided by the system, and that their team could participate in a formal evaluation of a future version of the application. These impressions suggest that the contribution of this research can be improved and further extended to similar medical contexts to become a key tool for healthcare professionals.

5.3. Fit-Viability Considerations

The interviewed cardiology specialists emphasized that the prototype is well-aligned with clinical needs, particularly in supporting data analysis of cardiac MRI exams and facilitating case comparisons. This alignment reflects a strong fit between the system's features and the tasks performed by healthcare professionals, a core dimension of Fit-Viability Theory. The ability to adapt visualizations to different clinical scenarios reinforces the relevance of the system in real-world diagnostic workflows.

The participants highlighted the flexibility of the relational data model and the interactivity of the graphical interface as key strengths. These characteristics contribute to the system's adaptability across diverse hospital environments, further supporting its fit with varying institutional contexts. The customizable nature of the dashboard and visualizations allows clinicians to tailor the tool to their specific analytical needs, enhancing the perceived usefulness and relevance of the prototype. As long as Power BI could provide adequate access to the dashboard regarding privacy concerns, it could be integrated to existing MIS to provide insights into the patients' and exams' data.

From a viability standpoint, the interviewees noted that integration with existing systems would be feasible with minimal technical adjustments. Additionally, the low learning curve associated with the prototype was seen as a facilitator of adoption, indicating that the prototype could be realistically implemented without significant training or infrastructure changes. These factors demonstrate the system's operational feasibility, a key component of the viability dimension. These results are summarized in the Fit-Viability matrix presented in Figure 7.

5.4. Limitations and Strengths

The current research project faced limitations, and possible solutions are being discussed and applied. The first limitation to highlight is that the evaluations were carried out in a specific context of application: CMRI exams. However, since the DB and IV resources

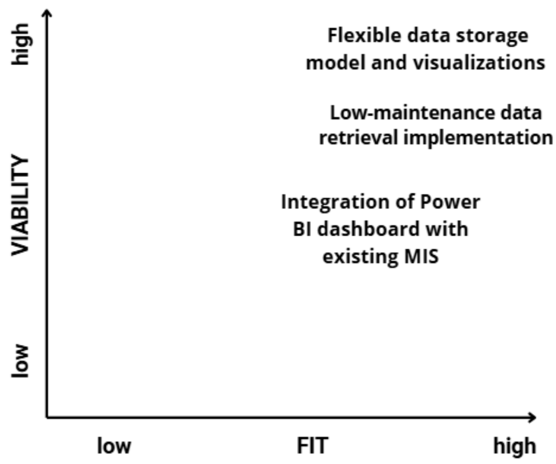


Figure 7. Fit-Viability matrix of the results from the qualitative evaluation of the developed prototype. The key points to highlight were the capability of integrating the developed functionalities with existing data and MIS. Regards related to the developed data model, data visualizations, and data retrieval functionalities were mapped according to the cardiology experts' observations on how they could be included in clinical routines and existing MIS used by their team.

were conceptualized and implemented with a flexible approach, it is possible to implement and evaluate them under other healthcare contexts once the data is available.

Another limitation is that a quantitative evaluation is necessary to complete the system's evaluation. The initial qualitative evaluation was focused on studying the viability of the prototype for a future formal evaluation with more participants and the use of quantitative metrics.

However, the qualitative evaluation conducted considered experts in the area, and their opinions helped validate and identify points of improvement, which already contributed to the further development of the IV tool. The interviewed healthcare professionals confirmed that their team could participate in an objective evaluation of a future version of the prototype, which will provide more objective insights regarding the value of the current research project's contributions.

The use of the Power BI software presents a limitation in terms of access to a third-party application. However, the use of this tool was a proof of concept regarding the use of commercial IV technologies for the proposed solution. The version used in this project is free and available to all those involved in the research and evaluation processes. Other IV technologies that guarantee security and privacy during access to the data will be considered to prevent dependency on a single proprietary third-party application.

Lastly, the LGPD prevents the application and IV resources from being available online without the implementation of clear data security features and rules, since the data persisted in the DB can only be accessed by authorized professionals. Currently, anonymization techniques appropriate to the Healthcare field are being discussed to avoid any sort of sensitive data being stored in the application, as well as implementation options to enable secure remote access through a private network by authenticated and authorized users. For example, the existence of the intermediate web services layer allows for the implementation of security protocols in the RESTful API, which can ensure that the operations performed on the DB are protected and authorized.

Overall, the current limitations can be assessed by the expansion and protection of the current prototype. The flexible approach that was prioritized in all of the developed artifacts will allow these improvements to be implemented with little need for maintenance in the current functionalities, optimizing the use of time and resources.

6. Conclusion

The development and evaluation of IV resources discussed in this paper were successful, and the utility and practicality of the prototype were highlighted by medical professionals. They confirmed that the developed tool provides valuable data retrieval and analysis functionalities that would be helpful in various tasks at their workplace, including the visualization and analysis of clinical and economical aspects of Healthcare.

The medical professionals who evaluated the tool showed interest in including all of their available exams in the DB to access the retrieval and visualization resources for them as well. It is also possible to expand the filtering options on the GUI to include other information persisted in the DB, such as features and descriptors, which can also be included in new dashboard visuals. The flexibility provided by the implementation of all the developed artifacts allows these improvements to be included in the system without requiring major code maintenance, which is a key contribution achieved.

Unlike many related studies, this research incorporates direct feedback from domain experts to assess both the fit and viability of the proposed solution. This expert-based evaluation provides a more grounded and practical understanding of the system's potential for clinical adoption. By applying Fit-Viability Theory, the study addresses a gap in the literature, where technical solutions are often proposed without sufficient consideration of their alignment with clinical workflows or their feasibility in real Healthcare settings.

The evaluation conducted in this study allowed the identification of key criteria related to both the fit and viability of the proposed solution. From the fit perspective, the prototype meets clinical demands by offering interactive and flexible IV functionalities that support data analysis and case comparison. From the viability standpoint, the feedback from cardiology specialists highlighted the ease of integration with existing systems and the low learning curve, which favors adoption in real-world settings. These findings, grounded in the Fit-Viability Theory, support the conclusion that the proposed solution is both appropriate for the problem and feasible from technical, organizational, and user perspectives.

Future works involve the expansion of the current CMRI DB, as well as the implementation of filter elements for features, descriptors, and other demographic or exam-related data that can be registered in the DB. The flexibility of the implemented prototype also allows it to be adapted for other Healthcare contexts. As the medical professionals mentioned, other visualizations can be added to the dashboard based on the needs that emerge from the clinical routine. A future final system can be launched for remote users, in compliance with the data protection legislation, and it can be evaluated in an objective assessment to ultimately validate its relevance and contribution.

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References

Acosta, J. N., Falcone, G. J., Rajpurkar, P., and Topol, E. J. (2022). Multimodal biomedical AI. *Nature Medicine*, 28(9):1773–1784.

Almeida, C., Bernardino, H., Souza, J., and Campos, L. (2025). Real-time heart failure prediction: An approach for ambient assisted living. In *Anais do XXI Simpósio Brasileiro de Sistemas de Informação*, pages 57–66, Porto Alegre, RS, Brasil. SBC.

Almeida, J. R., Pazos, A., and Oliveira, J. L. (2023). Clinical data integration strategies for multicenter studies. In *DoCEIS 2023: Technological Innovation for Digital Transformation*, pages 175–190. Springer.

Alvim, L. T., Gonçalves, V. M., and Nunes, F. L. S. (2025). Building flexible databases by using web services for computer-aided diagnosis of cardiomyopathies: from conceptual definition to evaluation. *Accepted for publication on the Journal of the Brazilian Computer Society*.

Bandeira, J. d. S. and Fagundes, R. A. d. A. (2025). Enhancing Alzheimer's disease diagnosis: Insights from MLP and 1D CNN models. In *Anais do XXI Simpósio Brasileiro de Sistemas de Informação (SBSI)*, pages 359–368, Porto Alegre. SBC.

Beerkens, M. (2022). An evolution of performance data in higher education governance: a path towards a 'big data' era? *Quality in Higher Education*, 28(1):29–49.

Bergamasco, L. C. C., Lima, K. R. P. S., Rochitte, C. E., and Nunes, F. L. S. (2022). A bipartite graph approach to retrieve similar 3D models with different resolution and types of cardiomyopathies. *Expert Systems with Applications*, 193(116422):1–18.

Carlisle, S. (2018). Software: Tableau and Microsoft Power BI. *Technology | Architecture + Design*, 2(2):256–259.

Cheng, L. and Senathirajah, Y. (2023). Using clinical data visualizations in electronic health record user interfaces to enhance medical student diagnostic reasoning: randomized experiment. *JMIR Human Factors*, 10(e38941):1–9.

Costa, S. S. H., Gonçalves, V. M., and Nunes, F. L. S. (2024). Applying ventricular wall shape and motion features from CMRI for aiding diagnosis of cardiomyopathies. In *Proceedings of the 24th Brazilian Symposium on Computing Applied to Health*, pages 142–153. SBC.

Delmondes, P. H. M., Bergamasco, L. C. C., and Nunes, F. L. S. (2015). Recuperação de modelos médicos por conteúdo usando extrator local de área e distância. *Revista de Informática Teórica e Aplicada*, 22(2):10–30.

Doi, K. (2007). Computer-aided diagnosis in medical imaging: historical review, current status and future potential. *Computerized Medical Imaging and Graphics*, 31(4):198–211.

Federative Republic Brazil (2018). Law no. 13,709 of August 14th, 2018. Available at: `https://www.planalto.gov.br/ccivil_03/_ato2015-2018/2018/lei/L13709compilado.htm`. Accessed: Feb. 2nd, 2025. General Law on Personal Data Protection (LGPD).

Gonçalves, V. M., Bergamasco, L. C. C., and Nunes, F. L. S. (2024). 3D Hough Transform-based left ventricle 3D object classification for cardiomyopathy diagnosis. In *2024 IEEE 34th International Workshop on Machine Learning for Signal Processing (MLSP)*, pages 1–6. IEEE.

Graciano Neto, V. V., Oquendo, F., and Nakagawa, E. Y. (2017). Smart systems-of-information systems: Foundations and an assessment model for research development. In *I GranDSI-BR: Grand Research Challenges in Information Systems in Brazil 2016 – 2026*, chapter 2. Sociedade Brasileira de Computação, Porto Alegre.

Gómez-Flores, W., Gregorio-Calas, M. J., and Coelho de Albuquerque Pereira, W. (2024). BUS-BRA: a breast ultrasound dataset for assessing computer-aided diagnosis systems. *Medical Physics*, 51(4):3110–3123.

Horne, E., Tibble, H., Sheikh, A., and Tsanas, A. (2020). Challenges of clustering multimodal clinical data: review of applications in asthma subtyping. *JMIR Medical Informatics*, 8(5):e16452:1–e16452:20.

Huesch, M. D. and Mosher, T. J. (2017). Using it or losing it? the case for data scientists inside health care. *Catalyst Carryover*, 3(3).

Kaseb, M. R., Khafagy, M. H., Ali, I. A., and Saad, E. M. (2019). An improved technique for increasing availability in big data replication. *Future Generation Computer Systems*, 91:493–505.

Lin, C., Sun, Q., and Wang, C. (2019). Web-based management and visualization of myocardial ischemia data. In *2019 Chinese Automation Congress (CAC)*, pages 5424–5428. IEEE.

Lopes, F. S., Silva, L. A. d., and Breternitz, V. J. (2017). Research and education in Data Science: Challenges for the area of Information Systems. In *I GranDSI-BR: Grand Research Challenges in Information Systems in Brazil 2016 – 2026*, chapter 14. Sociedade Brasileira de Computação, Porto Alegre.

Maciel, R. S. P., David, J. M. N., Claro, D. B., and Braga, R. (2017). Full interoperability: Challenges and opportunities for future information systems. In *I GranDSI-BR: Grand Research Challenges in Information Systems in Brazil 2016 – 2026*, chapter 9. Sociedade Brasileira de Computação, Porto Alegre.

Malik, M. S. A. and Sulaiman, S. (2013). Towards the development of an interface model for information visualization in multiple electronic health records. In *2013 International Conference on Computer Medical Applications (ICCMA)*, pages 1–5. IEEE.

Mandell, G. A., Keating, M. B., and Khayal, I. S. (2022). Development of a visualization tool for healthcare decision-making using electronic medical records: a systems approach to viewing a patient record. In *2022 IEEE International Systems Conference (SysCon)*, pages 1–8. IEEE.

Marques, B. T., Magalhães, R. P., Almada, L., do V. Madeiro, J. P., Mattos, C. L. C., and Macedo, J. (2025). Interpretability of machine learning models for cardiac arrhythmia classification. In *Anais do XXI Simpósio Brasileiro de Sistemas de Informação (SBSI)*, pages 489–496, Porto Alegre. SBC.

Mettler, T. (2016). Anticipating mismatches of hit investments: Developing a viability-fit model for e-health services. *International Journal of Medical Informatics*, 85(1):104–115.

Muskan, Singh, G., Singh, J., and Prabha, C. (2022). Data visualization and its key fundamentals: a comprehensive survey. In *2022 7th International Conference on Communication and Electronics Systems (ICCES)*, pages 1710–1714. IEEE.

Nascimento, D. C., Vanderlei, I. M., and Silva, D. d. (2025). Conceptual modeling of algorithm parameterization and results considering volatile data requirements: A case study in the context of primary healthcare. In *Anais do XXI Simpósio Brasileiro de Sistemas de Informação (SBSI)*, pages 399–408, Porto Alegre. SBC.

Pallets (2024). Welcome to Flask – Flask Documentation (3.1.x). Available at: `https://flask.palletsprojects.com/en/stable/`. Accessed: Feb. 23th, 2025.

Polychronidou, E., Kalamaras, I., Votis, K., and Tzovaras, D. (2019). Health Vision: an interactive web based platform for healthcare data analysis and visualisation. In *2019 IEEE Conference on Computational Intelligence in Bioinformatics and Computational Biology (CIBCB)*, pages 1–8. IEEE.

Poppe, O., Sæbø, J. I., and Braa, J. (2019). Strategies for standardizing health information analysis. In Nielsen, P. and Kimaro, H. C., editors, *Information and Communication Technologies for Development. Strengthening Southern-Driven Cooperation as a Catalyst for ICT4D*, pages 260–271, Cham. Springer International Publishing.

Rank, N., Pfahringer, B., Kempfert, J., Stamm, C., Kühne, T., Schoenrath, F., Falk, V., Eickhoff, C., and Meyer, A. (2020). Deep-learning-based real-time prediction of acute kidney injury outperforms human predictive performance. *npj Digital Medicine*, 3(139):1–12.

Ruan, W., Appasani, N., Kim, K., Vincelli, J., Kim, H., and Lee, W.-S. (2018). Pictorial visualization of EMR summary interface and medical information extraction of clinical notes. In *2018 IEEE International Conference on Computational Intelligence and Virtual Environments for Measurement Systems and Applications (CIVEMSA)*, pages 1–6. IEEE.

Salmi, M., Atif, D., Oliva, D., Abraham, A., and Ventura, S. (2024). Handling imbalanced medical datasets: review of a decade of research. *Artificial Intelligence Review*, 57(273).

Sharma, K., Shetty, A., Jain, A., and Dhanare, R. K. (2021). A comparative analysis on various business intelligence (BI), data science and data analytics tools. In *2021 International Conference on Computer Communication and Informatics (ICCCI)*, pages 1–11. IEEE.

Silva, L. S., Aranha, R. V., Ribeiro, M. A. O., Nakamura, R., and Nunes, F. L. S. (2020). Exploring visual attention and machine learning in 3D visualization of medical temporal data. In *2020 IEEE 33rd International Symposium on Computer-Based Medical Systems (CBMS)*, pages 146–151. IEEE.

Simmons, C. (2013). WebPAX PACS and Universal Viewer v8 Medical Imaging System announced by Heart IT. Available at: `https://enewschannels.com/business/`. Accessed: Feb. 9th, 2025.

The PostgreSQL Global Development Group (2023). PostgreSQL: the world's most advanced open source database. Available at: `https://www.postgresql.org/`. Accessed: Feb. 23th, 2025.

Torab-Miandoab, A., Samad-Soltani, T., Jodati, A., and Rezaei-Hachesu, P. (2023). Interoperability of heterogeneous health information systems: a systematic literature review. *BMC Medical Informatics and Decision Making*, 23(318).

Veriscimo, E. d. S., Bernardes Junior, J. L., and Digiampietri, L. A. (2020). Evaluating user experience in 3d interaction: a systematic review. In *Proceedings of the XVI Brazilian Symposium on Information Systems*, SBSI '20, New York, NY, USA. Association for Computing Machinery.

Vieira, J. M. L. and Correa, R. F. (2011). Visualização da informação na construção de interfaces amigáveis para sistemas de recuperação de informação. *Encontros Bibli: Revista Eletrônica de Biblioteconomia e Ciência da Informação*, 16(32):73–93.

Viglio, S., Rodrigues, P., Jawabri, O. A., Espindola, V., Figueredo, L., Bulcão-Neto, R., Ribeiro-Rotta, R., and Neto, V. G. (2025). A systematic mapping on software functionalities in information systems used by community health agents for mouth cancer prevention. In *Anais do XXI Simpósio Brasileiro de Sistemas de Informação*, pages 39–48, Porto Alegre, RS, Brasil. SBC.

Wang, S., Zhao, Z., Ouyang, X., Wang, Q., and Shen, D. (2024). Interactive computer-aided diagnosis on medical image using large language models. *Communications Engineering*, 3(133):1–9.

Wickramasinghe, N., Schaffer, J. L., Seitz, J., Muhammad, I., and Vogel, D. (2018). Fit-viability model examination of e-health solutions. In Wickramasinghe, N. and Schaffer, J. L., editors, *Theories to Inform Superior Health Informatics Research and Practice*, pages 251–269. Springer International Publishing.

Wilkin, C., Ferreira, A., Rotaru, K., and Gaerlan, L. R. (2020). Big data prioritization in scm decision-making: its role and performance implications. *International Journal of Accounting Information Systems*, 38:100470.

Wise Coders GmbH (2023). DbSchema – database design, management & collaboration tool. Available at: `https://dbschema.com/`. Accessed: Feb. 23th, 2025.

Yeshchenko, A. and Mendling, J. (2024). A survey of approaches for event sequence analysis and visualization. *Information Systems*, 120(102283):1–20.

Younas, A., Malik, M. S. A., ur Rehman, K., and Shahid, R. (2016). A detailed study on temporal data visualization techniques in electronic health records. In *2016 Sixth International Conference on Innovative Computing Technology (INTECH)*, pages 638–643. IEEE.

Zhao, Y., Yu, Y., Li, Y., Han, G., and Du, X. (2019). Machine learning based privacy-preserving fair data trading in big data market. *Information Sciences*, 478:449–460.

Zhou, W., Yang, Y., Yu, C., Liu, J., Duan, X., Weng, Z., Chen, D., Liang, Q., Fang, Q., Zhou, J., Ju, H., Luo, Z., Guo, W., Ma, X., Xie, X., Wang, R., and Zhou, L. (2021). Ensembled deep learning model outperforms human experts in diagnosing biliary atresia from sonographic gallbladder images. *Nature Communications*, 12(1259):1–14.

Zhu, C. (2019). Big data as a governance mechanism. *The Review of Financial Studies*, 32(5):2021–2061.