A Prototype for Interactive Information Visualization as Support for Computer-Aided Diagnosis

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Abstract. *Computer-Aided Diagnosis (CAD) can offer a second opinion to help physicians compose a more precise diagnosis, and interactive Information Visualization (IV) tools can complement CAD systems by providing a more intuitive way to interpret data from patients and exams. In this study, we developed an interactive IV prototype to improve comprehension of a flexible database for a CAD system in the cardiomyopathies context. This prototype is integrated with a web application to retrieve Cardiac Magnetic Resonance exams, and a qualitative evaluation conducted with health professionals showed that IV provided valuable data analysis capability. The results have shown that the integration of advanced visualization tools in our developed prototype can enhance clinical decision-making, improving the effectiveness of CAD systems.*

1. Introduction

Computer-Aided Diagnosis (CAD) systems use pattern recognition techniques to provide relevant second opinions for health professionals [Rank et al. 2020]. 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]. 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 systems and as a comparison basis for medical professionals [Wang 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]. Building effective and intuitive IV resources that can adapt to the underlying data structure is relevant and helps to deal with the large data demand of CAD systems [Malik and Sulaiman 2013; Silva et al. 2020]. In previous study, we developed and validated a generic and flexible DB model for medical exams and data to support research on CAD in different application contexts Alvim et al. [2025]. This DB model was validated in a real case study considering a CAD system for cardiomyophathies based on Cardiac Magnetic Resonance Imaging (CMRI) exams, as well as focused on Dilated Cardiomyopathy (DCM) and Hypertrophic Cardiomyophathy (HCM).

The main objective of this study was to verify the relevance of interactive IV resources, based on a generic and flexible DB model, to support the analysis of medical image databases and the development of CAD systems. To this end, we: designed and developed IV resources integrated into the system validated in a previous study Alvim et al. [2025];

planned a qualitative evaluation protocol based on a semi-structured interview; and carried out the evaluation with medical experts, recording the results. As the main contributions of this study we highlight the development of a flexible, reusable, interactive, and customizable IV tool for the presentation of relevant information of a real medical DB, as well as the integration and the qualitative evaluation of the developed IV tool on a DB application of data storage and retrieval.

2. Related Work

Several researches 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] accessed the improvement of diagnostic reasoning produced by inexperienced medical students when using visual EHR interfaces.

These works, however, did not present flexible structures that are fully integrated into data retrieval applications, which is important given that different medical contexts may need specific data types and many clinical implementations may require constant DB maintenance and manual generation of visual elements to address new data types. We explored this limitation as the scope of the present work using the DB model that we developed and validated to propose and evaluate generic and flexible IV resources.3 We also collected and analyzed the initial impressions of medical professionals on the usefulness of the implemented IV functionalities.

3. Materials and Methods

We used data from 400 CMRI exams shared by the Heart Institute of the *Hospital das Clínicas* of the *Faculdade de Medicina da Universidade de São Paulo* (InCor-HCFMUSP) to populate the DB. Each exam includes DICOM images, demographic information (age, height, sex, and weight), morphological features extracted from the images in previous studies [Bergamasco et al. 2022; Costa et al. 2024], and a diagnosis provided by a physician: DCM, HCM, or No Anomaly (NAN). The use of these exams was approved and authorized by the Committees for Ethics of the institutions 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 IV resources were developed with the Microsoft Power BI Software, a BI visualization tool for data processing and analysis [Carlisle 2018]. Although Power Bi is a well-known commercial platform for data visualization, this work presents an innovative approach to the tool by integrating the tool to a dynamic GUI for the retrieval of complex medical, providing the dynamic generation of customized visualizations to support medical decision-making processes.

3.1. Development of Information Visualization Functionalities

Figure 1 illustrates the overall structure of the web application developed that includes: the CMRI DB, a RESTful web services layer, a Graphical User Interface (GUI) validated in a previous study [Alvim et al. 2025], and the Power BI-based IV resources developed and evaluated into the scope presented in this paper.

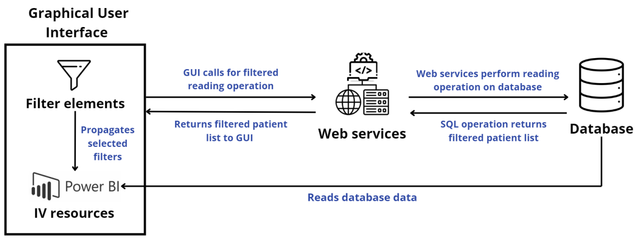


Figure 1. Web application structure. The IV resources developed on Power BI read the DB data and present them through intuitive visualizations. The reading operation is triggered by the GUI's filtering and fetching functions, and the web services perform the filtered SQL reading operation on the DB. 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.

A dashboard with different types of 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 DB was used as a data source for the dashboard, thus, when a new attribute is inserted or removed in the DB, Power BI captures the live state of the DB tables without requiring manual insertions or reconfiguration of the connection.

The dashboard contains graphs for demographic data, exam execution data, and patient data during the exam execution. The standard Power BI filtering function involves selecting any region with data in the visualization, or passing parameters through the dashboard URL, specifying the table, attribute, and value to filter.

To fully integrate the dashboard with the web application GUI, the filtering components' behavior (Figure 2a) was 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 a Power BI filter string is triggered (Figure 2b). Then, this string is sent through a web request that updates the dashboard. reflecting the newly selected filters on the dashboard views. This approach helps the user customize the dashboard and visualize the data of patients who correspond to the selected filters, improving the data analysis value of the 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 composed in order to filter a Power BI dashboard.

Figure 2. 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 URL.

3.2. Qualitative Evaluation

A qualitative evaluation procedure was performed with a physician and a biomedical scientist, both experts in Cardiology and CMRI, having over 30 and five years of experience, respectfully. Both participants are familiar with the medical data storage and analysis tools currently employed at their workplace.

The evaluation was conducted in a videoconference session during 45 minutes, with the participation of four members from the technical (computer science) team and the two health professionals. A semi-structured interview was conducted during this meeting. A protocol was defined (Figure 3) to guarantee the covering of all topics and the comprehension of the topics by the participants. Questions, answers and related discussions are presented in section 4.

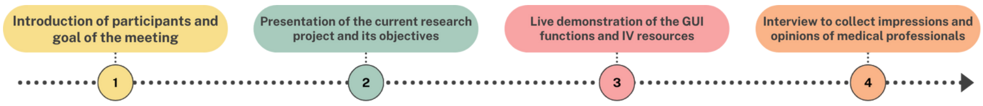
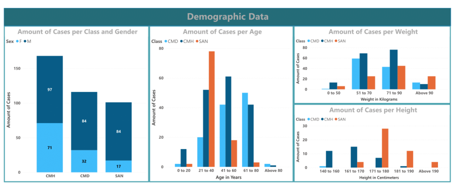


Figure 3. Protocol of the qualitative evaluation with health professionals.

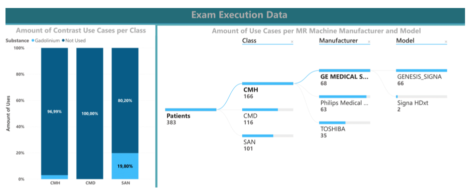
4. Results and Discussion

Figure 4 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. 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 CAD systems [Silva et al. 2020].

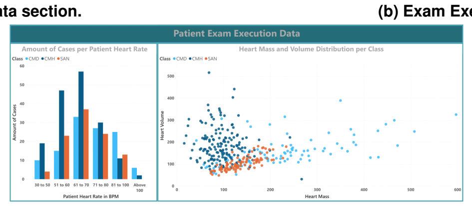
The first set of graphs is titled "Demographic Data" (Figure 4a), and presents bar graphs that show the number of patients in terms of gender, age, weight, and height. The second set is "Exam Execution Data" (Figure 4b), which presents the use cases for each contrast substance used in the CMRI exams, and a hierarchical tree that associates the MRI machine manufacturer and model. The third set is "Patient Exam Execution Data" (Figure 4c), which provides the number of cases per patient heart rate range during the exam, and the correlation between the heart mass and volume, calculated in previous works [Silva et al. 2020]. In addition to the visualizations developed for system 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 PowerBI.



(a) Demographic data section.



(b) Exam Execution Data section.



(c) Patients Exam Execution Data section.

Figure 4. Dashboard created on Power BI for data visualization integrated with the DB and its filtering and retrieval application.

Following the interview script summarized in Section 3.2, the impressions of the participating experts regarding the data dashboard and the web application were collected. Table 1 presents the questions and the summarized answers of the medical professionals. The participants also asked questions after the presentation about how quickly the exam data and information from electronic medical records and CSV files could be included in the DB. 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).

Question	**Answer**
Q1: Is there any tool currently used at your workplace with similar functionalities? If so, which ones?	Both the physician and the biomedical scientist affirmed that they were not aware of any tool with this practicality.
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?	The participants answered positively, and the physician provided examples of how the tool would be helpful to keep track of their work, such as viewing the percentage of patients in each class of diagnosis in a time period.
Q3: Considering what was presented, would it be possible to evaluate the quality and usefulness of the presented graphical visualizations to medical professionals?	The physician stated that the dashboard graphs are classic and useful, and added that it is important that the data ranges are customizable with the filter tools presented on the GUI.
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?	Both participants said that new ideas will arise from using the system, and that they could suggest different visuals for specific questions that emerged from the clinical routines.
Q5: In a future more comprehensive evaluation, would your team be available to conduct a formal assessment of the application?	The physician responded positively, but said that the evaluation would probably be internal due to the Brazilian General Law on Personal Data Protection (LGPD) [Federative Republic Brazil 2018].

Table 1. Summary of questions and answers for interview with medical professionals

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. Conclusion

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 while using a well-known commercial platform for the development of IV resources. 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.

A limitation of this study was the qualitative and simultaneous evaluation with only two health professionals, which may have lead to biased results. Given the availability of more health professionals, in future work, a formal performance and security evaluation of the final system will be carried out with the users, in order to provide quantitative measures of the system's usability. Future work also involves the expansion of the current CMRI exams 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, extracted from exams or electronic health records as well.

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