Content-Based Retrieval for 3D Medical Models: A study case using Magnetic Resonance Imaging [1]

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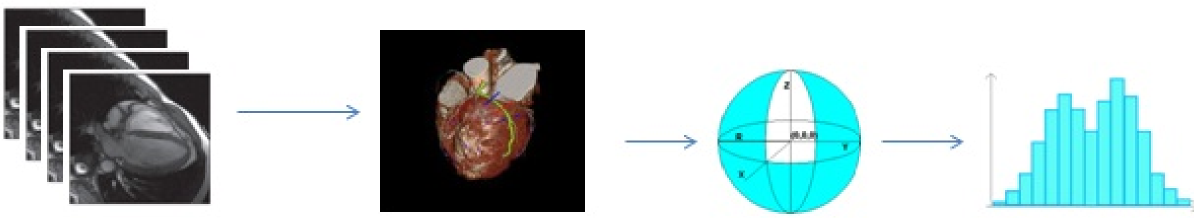

Figure 1. One technique that could be used [1], from a set of slices (1) the volume is extracted and reconstructed (2), histograms are created (4) based on the distance between model centroid and surface at random points(3)

***Abstract*—With hardware and software advances three-dimensional models are being used more extensively in the medical area in order to improve clinical examinations . Resonance Magnetic Imaging (MRI) is a non-invasive technique for detect anomaly from internal images of human body. This project aims to use Content-Based Image Retrieval method for search similar diagnostics given a specific exam and to present for expert frames that have a potential problem. It is expected that this technique assists the physicians make the diagnosis more accurate.**

***Keywords*-3D Cardiac Image; Volume Extraction; Resonance Magnetic; Content-Based Image Retrieval; CBIR**

I. Introduction

Three-dimensional (3D) models have been used more frequently in many sectors of our society, such as engineering, multimedia and health. One of the factors responsible for this increase is the advance of technology that provides mechanisms for reducing costs and improves performance on hardware and software. Additionally, 3D models can give more information than a two-dimensional image, offering images with different variations of color, contrast and resolution [2].

Due to these characteristics, many complex medical examinations use this technology on Medicine, like Magnetic Resonance Imaging (MRI) which allows experts identify anomalies from internal images of body without invasive methods. This examination is very accurate and the patient who is subjected to it almost did not suffer any side effects, the exam's duration varies between 15 minutes and 2 hours and generate hundreds of frames for each patient. Thus is necessary to develop techniques for help physicians in the access and retrieval of information accurately and quickly.

Content-based Image Retrieval (CBIR) uses information about the content of a given image as the query to provide the user with the most similar images contained in a database. In the medicine context, CBIR can help medical specialists by providing clinical history similar to that one presented for consultation [3].

The use of CBIR in 3D models and on medical area is innovative, mainly CBIR works are focused on 2D imagens and generic models. This is the scenario which this research is included. Based on shape characteritcs of 3D models, like volume, is expected apply a set of descriptors for retrieve cardiac models.

Contributions: This paper proposes the creation of a prototype for search and retrieval clinical history based on 3D medical model content from the examination of MRI images, more specifically models of heart in order to evaluate their volume alteration, that is a sympton of many heart problems like infarction, coronary disease, and arteries blocked.

A. Related work

It is noted that doesn't have many works dealing about CBIR for 3D medical model. A Systematic Review performed at December 2011 about CBIR 3D shows that about 50% of works recovered used a generic image database for testing their CBIR systems and anoter 35% do not mentioned their data sources[4] .

[1] Master's Thesis - Ongoing work

The Systematic Review conducted showed that the application of CBIR in 3D medical image context is still in its beginning. Currently, some challenges are being explored. Researchers are using descriptors, similarity functions and evaluation methods from generic models and applying them to the medical scenario. Efforts are necessary to make these skills more specific and hence to provide more accurate and useful results for society. However, there are still some many topics for research.

Studies proposed by Li el al. [5] and Saavedra et al. [6] stand out because they are based on 2D projections and on which silhouette features are extracted. In Leng et al. [7] the Tchebichev descriptor, which extracts features that are invariant with respect to image plane transformation, is applied on projections of the 3D models.

Gong et al. [8] worked with Fourier descriptor and Supervised Machine Learning to retrieve similar human faces. Yachun et al. [9] and Khe et al. [1] developed descriptors which used distance histogram. Song and Golshani [10], , Wang and Cui são utilizados métodos para rotular os modelos a fim de auxiliar na busca e no mapeamento and Gao et al. [11] labeled models to support search and geometric mapping.

Wei et al. [12] research was the only one founded in this review that just works with model color for retrieval.

Besides the topics cited before, it would be interesting to provide more public medical databases in order to allow tests and to facilitate researches in this area. This is not a simple issue, since patient identification must be preserved, but it is reasonable to think about simulations of different medical scenarios. Another point to highlight is related to both generic models and medical ones; there is no descriptors taxonomy, causing problems to evaluate new extractors and to find descriptors to be used as reference. One of the challenges for using 3D medical models concerns to 3D CBIR system performance which presents a worsening due to the complexity of geometric models in relation to two- dimensional images. In a scenario where real time is extremely important, this can be considered a huge gap, and efforts are necessary to create and to refine methods for this context. The review also showed that only a few of the retrieved works stood out owing to the innovative character of their research in applying particular techniques to medical models. It is important to highlight that none of these studies used public medical database.

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Glatard *et al.*[13] applied texture and local descriptors to retrieve left ventricle models during its systole. They used neighborhood concept to analyze how similar or different the texture in voxels neighbors is, the Figure 4 shows the image retrieval.

Wu *et al.* [14] combined different shape descriptors for analyzing cardiac models volume to identify the systole and diastole in a cardiac cycle, and used Euclidean distance to compare their similarity. This method was applied to multidimensional dynamic positron emission tomography (PET) images.

Aman, Yao and Summers [15] used a Scale-invariant feature transform (SIFT) descriptor and Bag of Words to retrieve Computed Tomography (CT) colonography. The authors applied Normalized discount gain to evaluate the result.

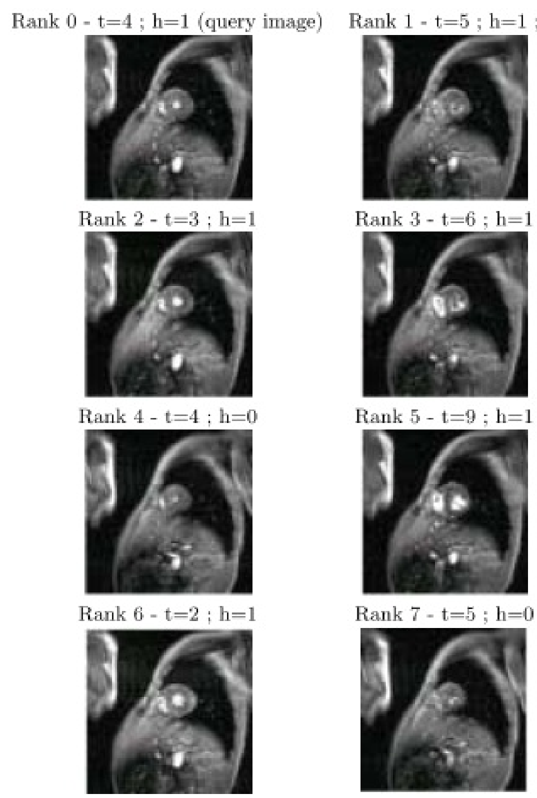

Figure 2. Heart image retrieval. The *t* represents the image instant and *h* the slice vertical position[13].

All these works presented satisfactory results, but was not specified how the models were obtained and [14] not cited how many models were tested, in [15] the SIFT descriptor was not detailed, as well [14] wich not specifies how the characteristic vector is formed. With this information and the points mencioned previously is possible conclude that this area needs more atention.

II. Technical background

In this section, some classical techniques that will be used on this project like CBIR and MRI are detailed.

A. Magnetic Ressonance Imaging

The MRI besides being very precise allow quantification of heart structures without invasive methods. In particular, MRI can be usefull for detecting coronary disease, througth evaluation of myocardial contractility, perfusion and viability [16]. Figure 3 shows a typical MRI exam.

- **Myocardial contractility:** the aim of this test is evaluate the left ventricle wall, in order to inform if it is growing enough during cardiac cicle.
- **Myocardial perfusion:** through a injection of a contrast (gadolinium) in the patient the expert analyze its distribution, regions with delayed arrival of the contrast that indicate a problem with cornary arteries.
- **Myocardial viability:** like myocardial profusion, the physician observes the distribution of contrast in a different heart tissues and clear regions indicating that this tissue could be infarcted.

Figure 3. Different slices extracted from MRI. Both of them show wall thinning [17].

B. CBIR

The CBIR look for return through a given image as template, the most similar images present in a database. It can be used in many areas like Engineering, Medicine and Geografy [18].

On **Pre processing** stage is made the implementation of the image data to a vector, where you can apply extraction algorithms to extract features and also prepare image to next step, the feature extraction. Through processing techniques, features relevant to the search are highlighted and noise which might cause discrepancy in the results are discarded [19].

On **Feature Extraction** the descriptors, which are essential in any CBIR system are developed. They describe low-level visual features such as color, texture and shape. Authors have studied extraction methods increasingly faster and more robust in order to improve the accuracy of the system[20]. Information resultant from extraction is stored and indexed on database. Indexing methods are techniques that improve the insertion and search of feature vectors, increasing system performance [21].

The **Similarity functions** seek calculate the content difference between two images based on their features. One of the images is given as search parameter and another is stored in the database and had their features previously extracted.

There are different ways to show results for users, the most common is use the ranking method and present images thumbnails according to the similarity degree in relation to a query [18]. Currently are being made avaiable tree-dimensional visualization methods which allow identify, for example, the descriptor that helped or not a particular image considered relevant.

The **Relevance Feedback** method is optional to CBIR systems. It consists in techniques that decrease semantic gap existing between user and computer. Through a user evaluation about results presented is possible to refine the search and improve the tool precision [22].

Figure 4 demonstrates a simple CBIR usage, in two-dimensional images.

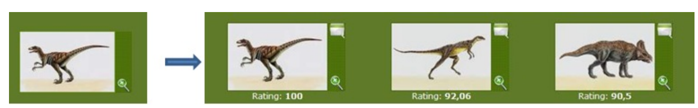

Figure 4. A CBIR system for dinosaurs, the first image was given for search parameter.

III. Proposal Technique

The research proposed consists of use CBIR and 3D medical model provided by MRI exam to aid diagnosis. The principal aim is provide to expert an indication that the exam has an anomaly and retrieve some clinical cases with similar symptoms. Another secondary activity is retrieval the frames that shows a deviation of the normal range.

The MRI cardiac will be provided by Medical School of University of São Paulo. also will be used MR cardiac from a database avaiable on Internet, that provides 45 cine-MRI images from a mixed of patients and pathologies: healthy, hypertrophy, heart failure with infarction and heart failure without infarction. The data contributor is the Imaging Research, Sunnybrook Health Sciences Centre, Toronto, Canada [23] Figure 5 shows a example of acquired image.

For CBIR method, some descriptors were chosen based in a Systematic Review preaviously conducted and may be used in this project . All they extract data volume. Table I presents a brief description of them.

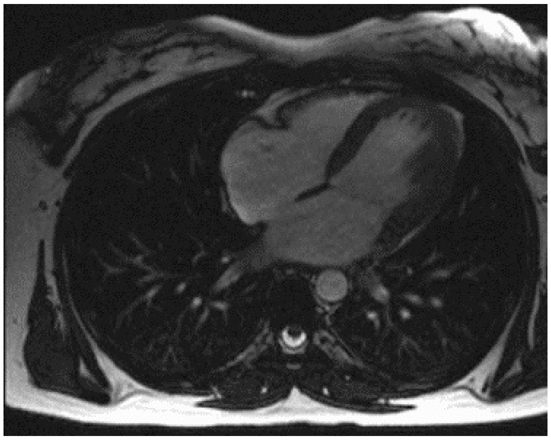

Figure 5. A short axis view from heart.

Descriptor	Authors	Description
VSIFT – *Volumetric Scale Invariant Feature Transform*	[24]	From Gaussian difference a feature vector is formed considering scale and direction of change of different gray levels of the voxels model.
Distance Histogram	[1]	The distance is computed between center of the model and the surface in random points. The distance is normalized in relation to maximum distance founded and is divided into ranges that form the histogram bins.
Surface Distribution	[14]	Analyzes the ratio of surface contained in a given volume.
3D Volume shape descriptor	[25]	The model is divided into four quadrants and extracts the values of gradient of each quadrant, eight histograms are formed representing the magnitude of the gradient and in the end they are concatenated.

Table I
BRIEF DESCRIPTION OF DESCRIPTORS THAT WILL BE DEVELOPED

Next steps of this project include :

- The development of descriptors and its application on 3D models to compose the feature vector;
- Applying different similarity functions based on Gonçalves *et al* [26], to analyze results considering different scenarios.
- Implementing a prototype for expert upload a new set of MRI to be compared with another cases on database, and verify if the computer processing identify any anomalies on exam.
- Precision *versus* Recall is a metric widely used in research in the two-dimensional context. Equations 1 and 2 shows Precision and Recall. Figure 6 presents the graphic originated by them.

$$\frac{RelevantImages \bigcap RecoveredImages}{RecoveredImages} \quad (1)$$

$$\frac{RelevantImages \bigcap RecoveredImages}{RelevantImages} \quad (2)$$

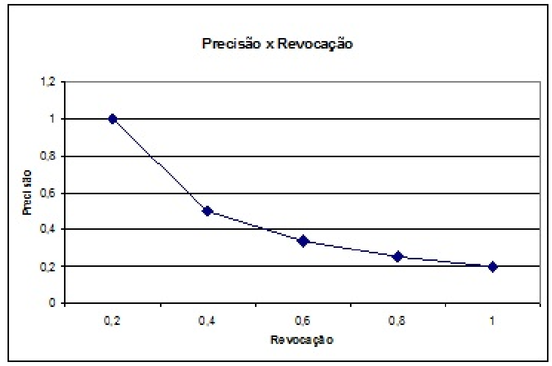

Figure 6. Precision *versus* Recall graphic.

IV. Initial Results

A Systematic Review was performed about CBIR for 3D models [4] and was noted that many descriptors are being tested for generic models (chair, tables, birds, spoons). Also we realize that the performance for retrieval is an obstacle to the widespread use of 3D CBIR. Because there is a greater volume of data to be analyzed the performance tends to be worse and therefore it is necessary to implement optimization techniques.

Some of the algorithms chosen require a three-dimensional reconstruction from the frames, eg. [1] and [14], thus, two steps were added to the project:

1) **Reconstruction**: through open source softwares, will be reconstruct three-dimensional volume from MRI slices and it will be exported for a object file (a 3D format which load the polygonal mesh information).
2) **Loader:** the object file needs be read and interpreted by a programming language to make possible its manipulation. In this project it is being used Java 3D. Figure 7 shows the interface implemented with a generic woman bust.

An example of descriptor applied is demonstred on Figure 8.

The technique proposed was applied at 3D synthetic hearts models, and was noted that distace histograms, presented on Figure 9 are differents for two cases indicating that models are not similar. With those histograms is possible extract information like area, standart deviation and average and compare this data with another models and its respective histograms.

V. Conclusion

This research project aims to develop techniques for retrieval three-dimensional medical models based on its contents, focusing cardiac objects specifically MRI scans. It is known that medical examination is common to be submitted several “slices”of an organ for specialis’s analysis them, it is desired

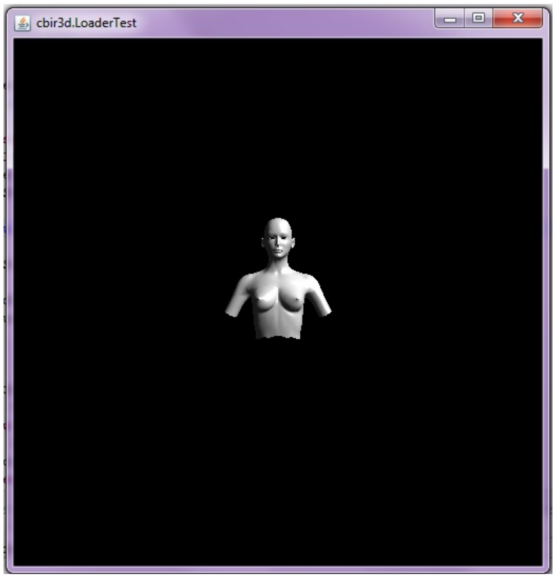

Figure 7. A generic woman bust.

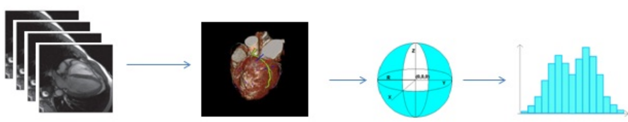

Figure 8. One technique that could be used [1], from a set of slices the volume is extracted and reconstructed histograms are created based on the distance between model centroid and surface at random points.

that this project can extract data regarding the volume and so apply toward extracting three-dimensional models.

At the end of this project it is expected that the results of the search are relevant to assist diagnosis in addition to contributing to the prior art regarding the definition and development of techniques in the context of 3D CBIR and medical. Through submission of papers to conferences and / or periodicals,we intend to assess responsiveness to the project and study the feasibility of transferring technology to the productive sector, since the demand for using 3D models is growing in recent years and such a tool can be very useful in this scenario.

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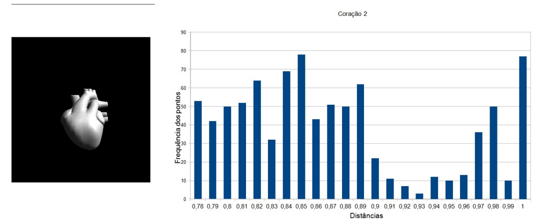
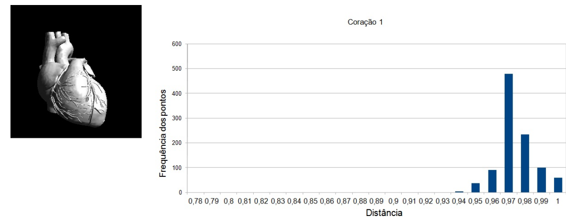


(a) A simple model of heart and its distance histogram.



(b) A complex model of heart and its distance histogram. Althought the model be more complex is noted that it is more uniform, with the same distance in many points of the model.

Figure 9. Histogram Distance Technique

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