EVALECHOCARD: A Database in Echocardiography for the Comparison of Methods Dedicated to the Estimation of Regional Wall Motion Abnormalities

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Abstract

An image database of echocardiograms, EVALECHOCARD, dedicated to regional wall motion scoring is presented. It is devoted to become a public reference database, in order to develop an objective comparison on the same data of different computer vision packages aiming at scoring the regional wall motion. The database construction is described, including the data acquisition, the experts' annotation and the database constitution. Results on the composition of the database are presented. The choice of data acquired on in-hospital patients, suspected of various cardiac diseases, has provided a high rate of pathological segments (39%). Moreover, difficult cases, such as low echogenic patients, were not discarded from the database. Therefore, this information which is available for each segment can be used pertinently to measure the performances of the different algorithms.

1. Introduction

Evaluation is a primordial task when developing computer vision software, but this step is too often bypassed. Indeed, it is not enough considered as necessary and prestigious by the research community in image processing.

For instance, concerning the topics of "Computers in Cardiology", several databases of physiological signals have been proposed since many years, and particularly databases of electrocardiograms (ECG) [1], which allow a quantitative and an objective comparison of different software packages, but there is no equivalent in the field of cardiac imaging.

More generally, considering the field of computer vision, including both medical and non medical imaging, the same statement can be generally done, with some notable exceptions, for instance databases of digital mammograms or databases of cerebral images. Moreover, most of these databases were developed for an educative purpose, which is a little different from algorithm testing.

In this context, EVALECHOCARD is a project of the French national program TECHNO-VISION of evaluation of computer vision technologies. This two-year program has two main objectives: 1) to constitute some reference databases; 2) to perform an objective evaluation of different computer vision packages on these databases, using adapted evaluation tools.

In this program, EVALECHOCARD is one of the two projects in medical imaging. It is focused on echocardiographic image sequences, with the aim of estimating regional wall motion (RWM) abnormalities.

In a clinical setting, the evaluation of RWM is based on the visual assessment of the cine loop. Reading performances strongly depend on reader's expertise and are subject to both intra-operator and inter-operator variability. Some quantitative methods, based on radiofrequency signal processing (color kinesis), on Doppler tissue imaging or on image processing, have been proposed, in order to reduce operator's variability. Despite the potential interest of these new methods, no one succeeded in taking the place of visual examination. One possible reason for this failure is the lack of quantitative and comparative evaluation. Thus the construction of a reference database including a high number of representative cases which can be shared by different research teams is a key point for the development of evaluation.

This paper presents the first part of the

EVALECHOCARD project, i.e. the construction of the reference database.

2. Methods

2.1. Data acquisition and pre processing

Data were acquired from 100 in-hospital patients, suspected of various cardiac diseases. Five different operators from the echocardiographic department at HEGP acquired apical 2-chamber and 4-chamber views in harmonic mode during standard clinical examinations. Two ultrasound devices from two different manufacturers were used. Cine echocardiographic data, including images and ECG, were recorded during at least one whole cardiac cycle. Numerical information was stored either in a specific export format or in the DICOM format.

For each view, an image series corresponding to one whole cardiac cycle was selected from the QRS complex. Dedicated software was developed to assist the choice of the cardiac cycle and to format images properly, for instance by removing text annotations, inherent to some DICOM data in ultrasound. It is now a plug-in of the Pixies package (http://.imagerie.apteryx.fr/pixies).

2.2. Data annotation

Two experts in echocardiography annotated image data. Only the image series corresponding to the previously selected cardiac cycle was given to the experts, so that both experts and computer vision technologies worked with identical information. This point was crucial for evaluating fairly the performances of the evaluated algorithms.

The experts defined three points on an intermediate image of the cardiac cycle (25% of the cycle), between the end-diastole and the end-systole: one point at the apex and one point at each extremity of the mitral valve. These points were used to define the segmentation into seven segments, in agreement with the standardized segmentation of the heart [2], according to the procedure given in [3]. The coordinates of these points are further referred to as the geometrical information.

Moreover the grid derived from the segmentation was superimposed on the images of the series, in order to be sure that the definition and the location of the segments were the same for the experts and for the computer vision methods. Expertise relied on the visual assessment of the cine loop of these images.

Annotation and scoring of each segment resulted from a consensus between the two experts. It included the echogenicity of the segment, the wall contraction, and the homogeneity of the contraction. This last parameter indicated whether the whole segment had a similar behaviour, or not.

The echogenicity and the homogeneity were assessed using a binary variable. The RWM was classified into four basic states: normal, hypokinetic, akinetic, dyskinetic. Furthermore some non homogeneous segments were scored by a combination of two states, for instance normal/dyskinetic. Finally, a mention “not available” was recorded for very low echogenic segments, for which no reliable scoring could be found after consensus.

Using Matlab software, dedicated software with a user-friendly interface was developed for the annotation task. This enabled us to minimize human errors in reports.

2.3. Database construction

Image data were encoded in the INTERFILE format with minimal text information. For a fully anonymous data collection, all nominative data and dates were removed. Data issued from constructor including the image matrix dimensions, the temporal resolution, the number of images, the device, and the clinical centre were recorded, as well as the information resulting from the expertise, including the view type (2-chamber or 4-chamber), the geometrical information and the expert scoring of each segment of the view.

All the textual data were stored in a relational database (mySQL), with some additional information that was required for the administration and the management of path to image data.

An interface using XML was created which allows the administrator to define which field of the database can be accessible in reading/writing/deletion/selection for the different users. Using this structure, some new parameters, describing the patient or the exam can be easily introduced, which is prerequisite for an evolutive system.

A Web secure access was implemented to select and retrieve data. Every authorized user have had the possibility to select studies according to different criteria and to download an archive file containing all the selected data. The INTERFILE format allowed a cine display of image data, using standard software packages of medical imaging (for instance, the demonstration version of Pixies, which can be freely downloaded).

2.4. Methods of classification

Three computer vision programs are currently evaluated. Two of them: factor analysis of the left ventricle, further called FALVE [4, 5] and the parametric analysis of main motion further called PAMM [6], are parametric imaging techniques, which are based on the time signal intensity curve of each pixel. The third one is based on the estimation of a motion vector field inside the myocardium, followed by the computation of two mean time displacement curves inside each segment, one curve corresponding to the radial displacement and one to the tangential displacement [7]. Moreover a classification stage was added to each method, in order to provide a RWM score for each segment. Different approaches were tested. Firstly, the visual interpretation of parametric images, according to reading rules, provided these scores directly [3, 4, 5], but still depended on an expert. Secondly, a quantification of the parametric images, which imitated the reading rules was proposed, cf. [3, 8] for FALVE images and [9] for PAMM images. The objective was to resume the information contained in one segment into one single or two parameters, and to classify the RWM according to the value of this index, using adapted thresholds. Thirdly, an approach was based on the time displacement curves estimated for each segment, and relied on more sophisticated classification procedures, using support vector machines.

To compare the classification performance with the reference scoring or to compare the methods with each other, a whole set of indices was proposed. It included contingency tables built from the comparison of the contraction scores of the individual segments, and the comparison of global wall motion scores using Bland-Altman or linear correlation. A user-friendly dedicated interface was built, to identify mismatched segments or outlier patients.

3. Results

3.1. Database composition

Hundred patients were included in the database, 37 were acquired using the first ultrasound device, 63 using the second one. The expertise of the 200 views led to the following results: 61% of the segments have a normal wall motion, according to the repartition shown in the Figure 1.

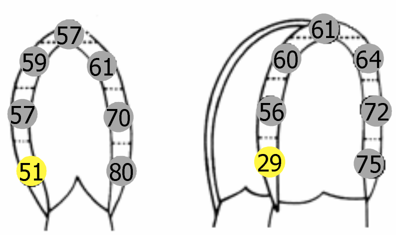

Figure 1: Regional repartition of the normal segments (each number indicates a percentage of segments)

The 39% remaining segments were scored as follows:

- 15% as hypokinetic;
- 4% as akinetic;
- 4% as dyskinetic (among these segments, 1/3 were located at the apex and 1/3 were located at the basal septum);
- 12% of the segments had a composite score;
- 4% were not scored, because of too low echogenicity.

Overall, 84% of the segments were annotated as echogenic and 84% of the segments as homogeneous in contraction, according to the repartitions shown in Figures 2 and 3.

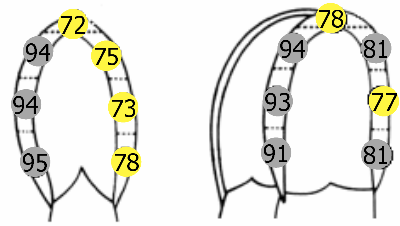

Figure 2: Regional repartition of the echogenic segments (each number indicates a percentage of segments)

Thus, Figure 2 indicates that the majority of the low echogenic segments are located in the anterior wall, at the apex, and finally in the lateral wall. This finding on the EVALECHOCARD database was in conformity with conventional observations.

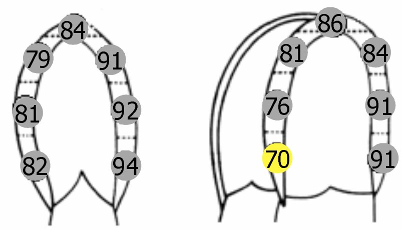

Figure 3: Regional repartition of the homogeneous segments (each number indicates a percentage of segments)

The higher number of basal septal segments having a composite wall motion contraction was not surprising, since this segment has a complex 3D wall motion.

3.2. Learning stage

The learning stage will come to an end in fall 2006. Some partial results have shown that this stage is primordial for improving the performances of each method. For instance, a partial use of the EVALECHOCARD database enabled to improve the settings of the PAMM method [9]. Furthermore, a preliminary step was undertaken when using acquisitions from the first ultrasound device, based on the quantification described in [3, 8]. When applying the same approach to the acquisitions from the second device, some difficulties arose due to variations of spatial sampling. The quantitative parameter was thus modified in order to take this specific point into account.

4. Discussion and conclusions

A first version of the EVALECHOCARD database was built, which is currently used by different research teams for a learning phase. The introduction of some new cases in the database is straightforward. Moreover, its structure can be upgraded easily, and it will be possible to include some additional information, such as patient's clinical status, or global ejection fraction, etc.

We hope that the high number of segments with regional wall motion abnormalities (almost 40%) will make the learning stages more efficient. To test the different software packages, fifty additional patients will be provided to the different laboratories without the expertise of the segments. All the results of the evaluation will be available in early 2007.

Not only the methods but also the learning strategies are different from one laboratory to another. Thus only the whole packages: image processing and classification methods could be compared in a first time.

The learning stage can be designed by taking into account the location of the segment, or not. The first approach is theoretically more appropriate, but it requires more learning cases; indeed some wall motion abnormalities like dyskinesia are rare on some particular locations. Therefore, the debate on the learning strategy is still open.

Difficulties in the creation of public image databases are due to multiple reasons. Firstly, rapid technological development and improvement of image quality make the data rapidly obsolete. Moreover, the choices concerning the acquisition parameters can always be criticized. Evolutive and simple systems are thus required to make upgrades faster and easier. For that reason, we have chosen a simplification of the data structure of the images. Moreover, this first experiment enables some new exchanges. The comparison of different methods on the same data will allow us to underline the limitations inherent to each method or to each class of methods and possibly to develop some cooperative approaches for the long term.

In conclusion, the EVALECHOCARD database is operational and makes possible the comparison of different computer vision packages dedicated to regional wall motion assessment. It will become available to other laboratories in 2007, upon the signature of an agreement.

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