Whitepaper

Automated Image Biometrics Speeds Ultrasound Workflow

ACUSON SC2000 Volume Imaging Ultrasound System

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The following text reviews measurement consistency and reproducibility challenges within echocardiography. Past techniques used in automated measurements methods are discussed. An innovative, new method based on learned pattern recognition is proposed with workflow benefits.

Introduction

Cardiac biometrics are routinely measured from echocardiograms to provide quantitative analysis of the human heart. For example, M-mode measurements of left and right ventricular dimensions and wall thicknesses are extracted at diastole and systole. Measurements are also made of the aortic valve, aortic root, and the left atrial dimension. From the 2D parasternal long axis or short axis view, measurements such as wall thickness and ventricle dimension are extracted. From Doppler data, pressure gradients and measurements of valve stenosis and regurgitation are extracted. **Figure 1** shows several examples of cardiac biometrics that are measured in a standard echocardiogram.

Varying skill levels among echocardiographers and sonographers plus the wide range of image quality across patient exams add complexity and measurement variability. This individualized reading of an ultrasound image can unavoidably lead to significant inter-user and intra-user variation in the final measurements. Consistent and reproducible measurements performed with speed and fidelity are key challenges to advancing the practice of echocardiography. Siemens Corporate Research (SCR) has developed a fundamentally novel innovation based on a learned pattern recognition technology to deliver measurement reproducibility and to accelerate workflow. This methodology, which is theoretically designed to be probabilistic, hierarchical, and discriminant (PHD), enables automatic, consistent, rapid and accurate measurements of cardiac biometrics. The PHD detection technology will be elaborated later in this discussion.

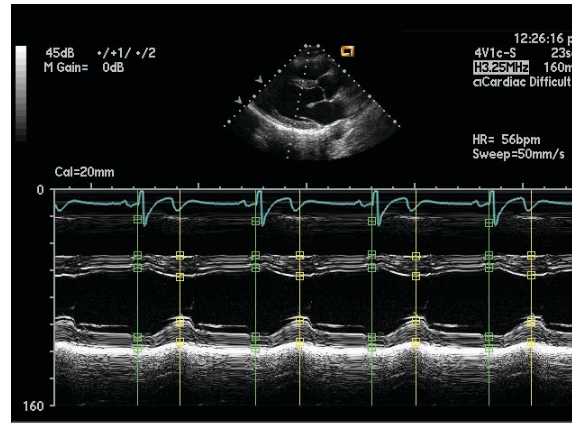


Figure 1a. *M-mode echocardiogram*

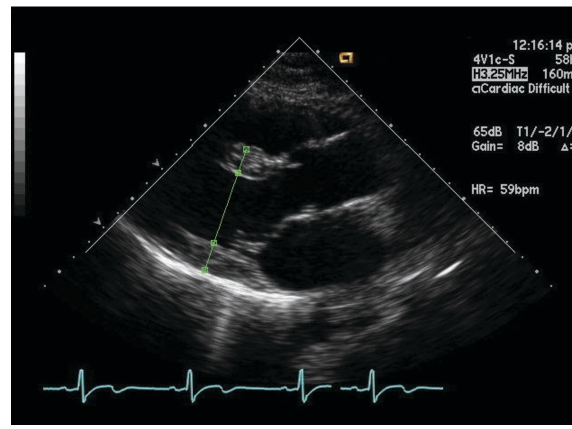


Figure 1b. *B-mode echocardiogram*

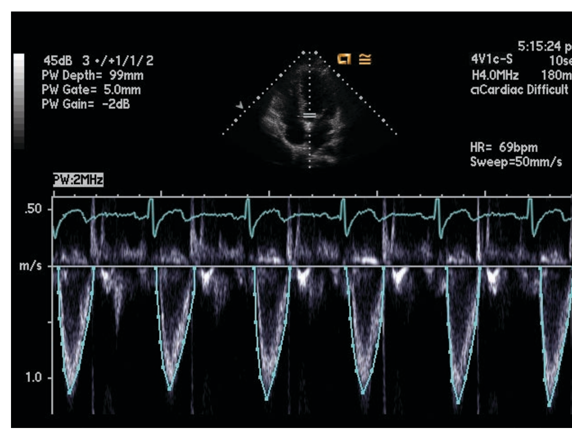


Figure 1c. *Doppler echocardiogram; LVOT*

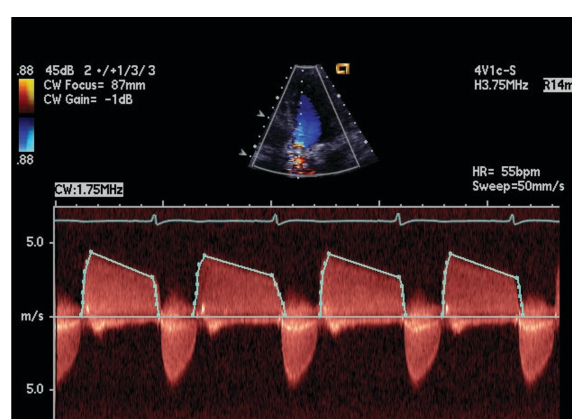


Figure 1d. *Doppler echocardiogram; aortic regurgitation*

Annotated Database

Learned pattern recognition technology is based on a broad subfield of artificial intelligence called machine learning. Learned pattern recognition methods revolve around designing and developing algorithms and techniques that enable computers to "learn", e.g., to extract information from data automatically via computational and statistical methods. Learning is derived from a large series of manually identified measurements. This learning capability distinguishes Siemens' approach from previous attempts in automated quantification of cardiac biometrics.

Alternate techniques for automated measurements outside learned pattern recognition have leveraged image processing techniques such as edge detection and nonlinear image filtering. These techniques work well for images of good quality, but are prone to failures when dealing with noisy images. In general, these techniques are generic and hence applicable to other applications while learned pattern recognition is customized for the specific measurements within cardiac ultrasound.

SCR collected a large database of over 1000 full exams, from which M-mode, 2D, and Doppler images were used for learning purposes. The selected images represent patients with pathologies commonly seen in clinical cardiology practices. Each of the images has been meticulously measured by placing identifying landmarks by one or more clinical experts before being fed into the learning engine. Different annotations based on landmarks and deformable parametric contours have been progressively designed. A deformable parametric contour can be defined by connecting a cohort of landmarks or using other parametric representations. **Figure 2** illustrates how an annotated dataset of an M-mode echo is formed.

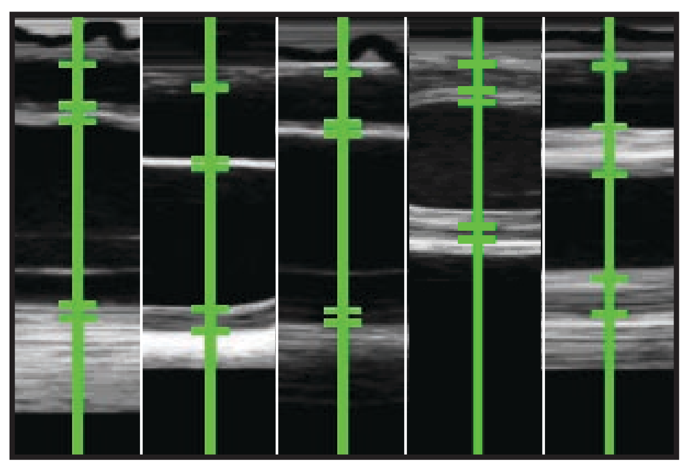


Figure 2a.

Figure 2. Representative database of M-mode echocardiograms in normal and abnormal studies. (a) Image samples extracted from the original raw M-mode echocardiograms measuring M-mode LV dimensions at diastole. Five individual landmarks are identified. (b) The image samples are then normalized based on their identifiers.

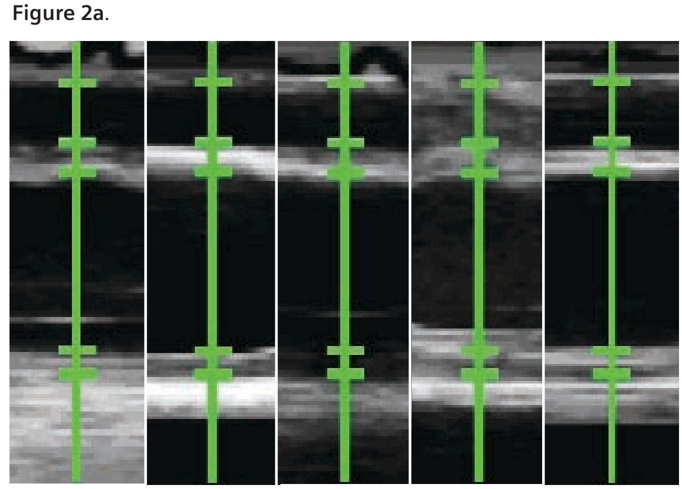
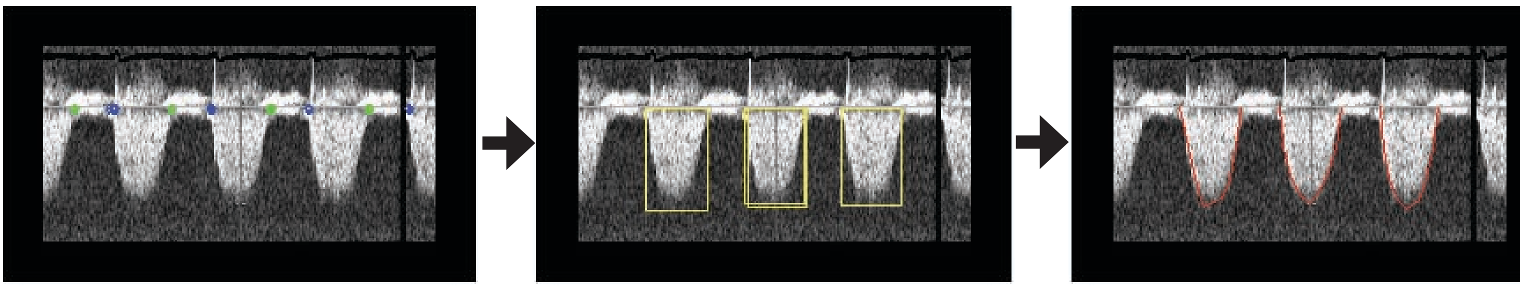


Figure 2b.



Root detector with mode selection **Box detector with mode selection** **Warping detector with post processing**

Figure 3. *A pictorial illustration of applying the PHD framework for detecting curves in a tricuspid regurgitation image example.*

The PHD Framework for Deformable Structure Detection

Automatic detection of deformable structures (i.e. cardiac tissues) is a precursor to deriving the cardiac biometrics, accomplished using a framework that is probabilistic, hierarchical, and discriminant (PHD). The basic detection principle is to learn a discriminant binary classifier which separates the deformable pattern of interest (the positive) from the remaining (the negative). Since deformable structure lies in a high-dimensional parameter space, an exhaustive search in this space for the optimal parameter is computationally prohibitive.

Instead of attempting to learn one super classifier, a series of binary classifiers are identified then arranged into a progressive hierarchy. To build a detector hierarchy that supports fast evaluation, simple models are progressively built into more complex computational models. The overall detection probability is then propagated throughout the hierarchy. Further details of the PHD framework can be found from other sources.[1, 2]

Figure 3 illustrates how the PHD detection framework is used for detecting curves in a tricuspid regurgitation image example. First, the left and right root detectors are applied to detect the left and right roots. Second, the box detector is applied to detect the rigid box that bounds the structure. Finally, a warping detector that is trained based on perfectly warped examples is applied to detect the deformable structure.

Measurement	User, Manual (one cardiac cycle)	Computer, Auto
M-mode – LV	20 – 25 sec	Less than 1 sec
B-mode – LV (ES/ED)	24 – 30 sec	Less than 3 sec
PW Doppler LVOT VTI	14 – 20 sec	Less than 1 sec
CW Doppler AoR Deceleration Time	4 – 8 sec	Less than 1 sec

Table 1. *Speed comparison between manual and automatic annotation.*

Automated Quantification and Speed Improvement

Once the structures are detected, e.g. cohorts of landmarks are detected from M-mode and 2D echocardiograms and the deformable parameterized curves from Doppler echocardiograms, quantification parameters can be calculated. If multiple heart rates are present and fused together, robust measurements of cardiac biometrics can be derived.

The automatic algorithm frees the need for manual measurements previously required for extracting biometrics. Automation running speed is fast. **Table 1** compares the time needed for an average user and the computer to perform typical biometric measurements.

Conclusions

Siemens has addressed the measurement consistency and reproducibility challenges in routine echocardiographic studies by leveraging clinical insights from experienced experts to design an innovative solution that enables automatic measuring of cardiac biometrics. This solution is based on learned pattern recognition technology which builds a model of the target deformable structure by extracting knowledge from an annotated database of over 1000 exams, covering a wide spectrum of patients and pathological cases. The PHD detection framework is carefully designed to allow the detection of deformable structures with high precision and speed. Automated biometrics show time savings over manual measurements and can improve exam efficiencies.

References

1. *Zhou SK, Guo F, Park JH, Carneiro G, Jackson J, Brendel M, Simopoulos C, Otsuki J, Comaniciu D. A probabilistic, hierarchical, and discriminant (PHD) framework for rapid and accurate detection of deformable anatomic structure. IEEE International Conference on Computer Vision. Rio de Janeiro, October 2007.*

2. *Zhang J, Zhou S, McMillan L, Comaniciu D. Joint real-time object detection and pose estimation using probabilistic boosting network. IEEE Computer Society Conference on Computer Vision and Pattern Recognition. Minneapolis, Minnesota. June 2007.*

Standalone clinical images may have been cropped to better visualize pathology.

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