Whitepaper

Knowledge-based Automated Fetal Biometrics Using *syngo* Auto OB Measurements

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Knowledge-based Automated Fetal Biometrics

Gustavo Carneiro, Ph.D., Bogdan Georgescu, Ph.D., Sara Good, RDMS
Siemens Medical Solutions, USA, Inc., Ultrasound, Mountain View, CA USA

Introduction

Accurate ultrasound-based fetal biometric measurements are important for delivery of high quality obstetrical health care. Common measurements include: the bi-parietal diameter (BPD), head circumference (HC), abdominal circumference (AC), femur length (FL), humerus length (HL), and the crown rump length (CRL). The American Institute of Ultrasound in Medicine (AIUM) publishes guidelines for measuring these values. 1.) These values help diagnose fetal pathology including growth restriction, microcephaly, and macrosomia. In addition, they are utilized to estimate the gestational age (GA) of the fetus (i.e., length of pregnancy in weeks and days). Accurate estimation of GA is important to determine the expected delivery date, assess the fetal size and monitor fetal growth.

The most common current workflow requires expert users to perform biometric measurements manually. This paradigm yields several challenges: 1) the quality of the measurements are user dependent; **(Figure 1)** 2) manual measurements are time consuming with typical exam times greater than 30 minutes; and 3) users may develop repetitive stress injury (RSI) due to the multiple keystrokes needed to perform each measurement. In context of these challenges, workflow automation has the potential to: 1) improve accuracy; 2) decrease inter-user exam variability. 3) increase patient throughput; and 4) reduce the risk of RSI.

Figure 1. Examples of bi-parietal diameter measurements made by several users demonstrating inter-user variability.

In order to automate measurements, Siemens Healthcare, developed a novel knowledge-based workflow application, *syngo*® Auto OB measurements, based on advanced statistical pattern recognition technology. This application enables rapid automated measurement of fetal biometrics, and is designed to increase 1) workflow efficiency (the process requires approximately one second); 2) robustness to normal variations in the anatomy of interest; 3) robustness to speckle noise and signal drop-out typical in ultrasound images; and 4) segmentation accuracy.

To achieve these benefits, a database-guided segmentation paradigm[2,3] in the domain of fetal ultrasound images is utilized. This approach directly leverages expert annotation of fetal anatomical structures in large databases of ultrasound images to apply statistical pattern recognition methods.

Database Guided Segmentation

Statistical pattern recognition is a field of research that focuses on theories and algorithms that enable automatic learning of statistical patterns from data collections. Database guided segmentation is a new paradigm in the field of medical image analysis that applies statistical pattern recognition principles to guide the segmentation of anatomical structures from medical images. This approach exploits a large collection of data annotated by expert users in order to "train" a statistical model representing the anatomy of interest. This learning capability distinguishes this new approach from previous attempts of automated quantification of fetal biometrics which focused on anatomical grayscale border detection.

The database for this application includes over 3,000 annotated images of fetal biometric measurements (i.e., BPD, HC, AC, FL, HL, and CRL). Each image was meticulously annotated before inclusion in the learning engine. Depending on the specific biometric parameter visualized, different annotations, based either on an ellipse or a line, were carefully made.

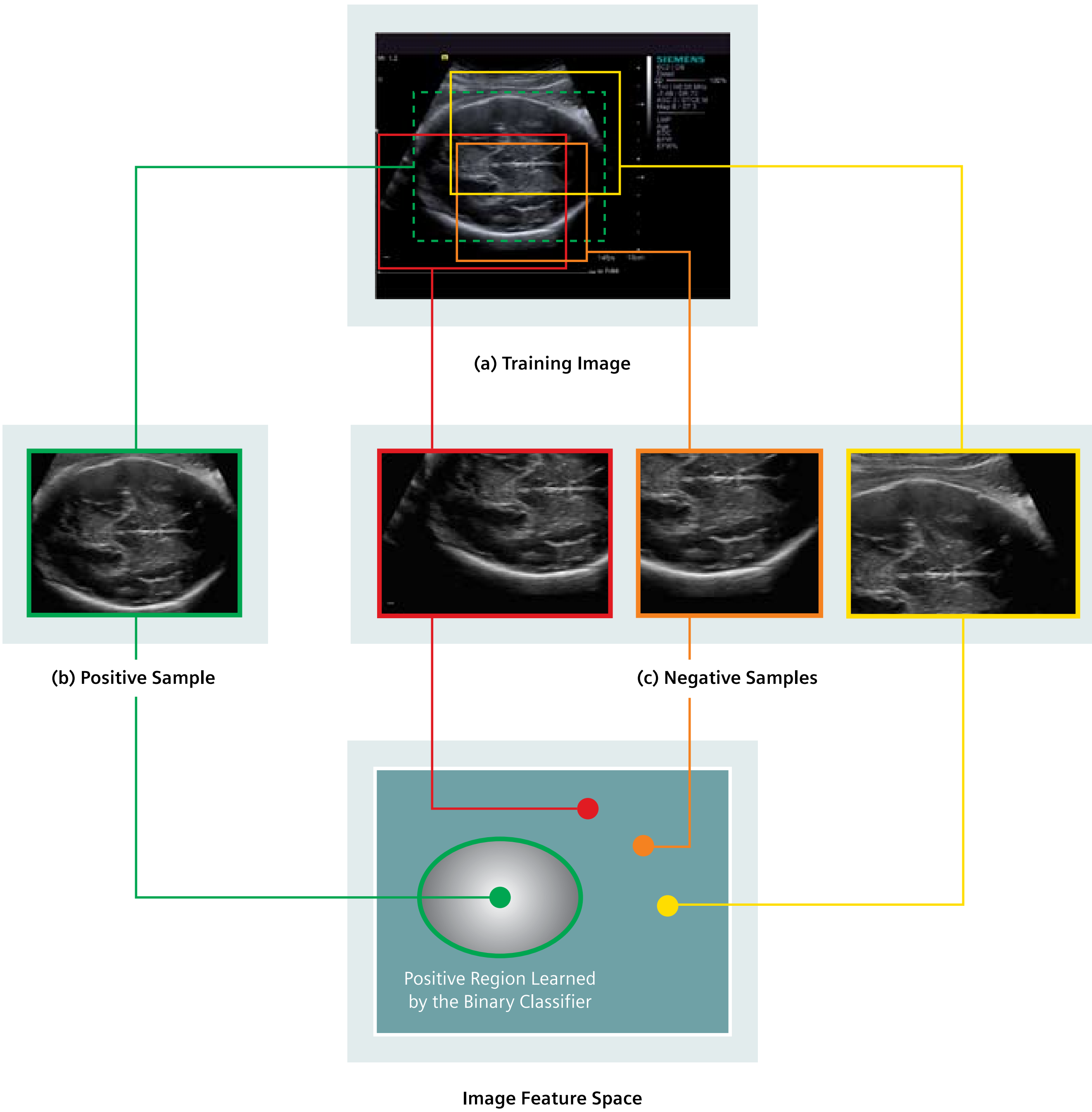

Figure 2. Training. **(a)** Annotated training image (ellipse contained within dashed green box), and rectangular regions representing positive (green rectangle) and negative (red rectangle) samples. **(b)** Positive sample extracted from the annotation. **(c)** Negative samples. **(d)** Image feature space with a positive region learned by the binary classifier. Notice that each sample from the image is represented by a point in the image feature space. The goal of the binary classifier is to find the region in this space that separates positive from negative samples.

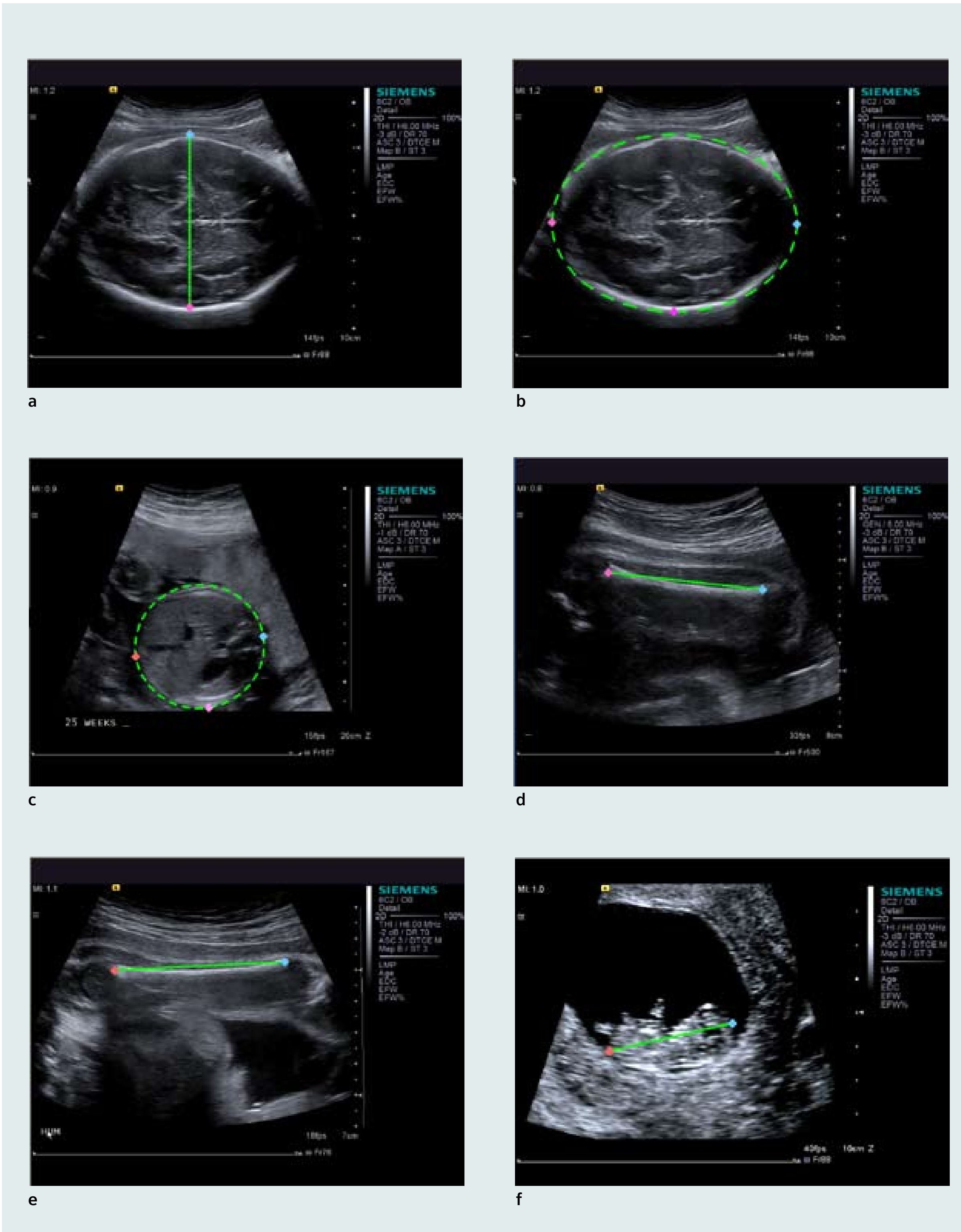

Figure 3. Examples of automatic fetal biometrics measurements. **(a)** BPD, **(b)** HC,**(c)** AC, **(d)** FL, **(e)** HL, **(f)** CRL.

Automatic Segmentation and Measurement of Fetal Anatomies

The automatic segmentation and biometric measurement of fetal anatomy is based on hierarchical and discriminative pattern recognition methods, exploiting sequential Monte Carlo sampling schemes. The basic detection principle is to train a discriminative binary classifier to separate the pattern of interest (the positive set) from the remaining (the negative set). Essentially, using user-expert annotation, it is possible to provide a positive sample, and several negative samples, as depicted in **Figure 2**. The binary classifier is then used to detect positive regions in new image data. However, the training of such binary classifiers always involves a trade off between robustness and accuracy. In order to alleviate this problem, a hierarchy of classifiers is trained, where simple statistical models are learned first. These simple models are extremely robust, in the sense that they always find the positive sample in an unseen test image, but they also detect a relatively high number of false positives. The complex models are then responsible for eliminating the remaining false positives. The sequential Monte Carlo sampling is an important implementation to speed up the detection process. The interested reader is referred to more detailed descriptions of the process [2,3].

Automated Quantification

Once the structures are detected as depicted in **Figure 3**, quantification parameters are calculated using the length of the ellipse (for HC and AC), or the line (for BPD, FL, HL, and CRL). The gestational age of the fetus is computed using previously published models [4].

Conclusions

Siemens Healthcare addresses the consistency and reproducibility challenges of fetal biometry through *syngo* Auto OB measurements, a knowledge-based workflow application enabling automatic analysis of ultrasound images. This application utilizes statistical pattern recognition technology to build a hierarchy of target anatomical structure models learned from a database of over 3000 expert annotated exams. The framework is carefully designed to allow the detection of structures with simultaneous high precision and speed. Clinical evaluation demonstrates a seamless integration of the application into clinical workflow with a reduction of up to 75% in number of keystrokes compared to conventional manual measurements.

References

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Local Contact Information
Siemens Medical Solutions USA, Inc.
51 Valley Stream Parkway
Malvern, PA 19355-1406 USA
Telephone: +1-888-826-9702
www.usa.siemens.com/healthcare

Europe: + 49 9131 84-0
Asia Pacific: + 65 6490 6000
Latin America: + 1-786-845-0697

Global Business Unit Address/
Siemens Medical Solutions USA, Inc.
Ultrasound
1230 Shorebird Way
Mountain View, CA 94043 USA
Telephone: +1-888-826-9702
www.siemens.com/healthcare

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Global Siemens Headquarters
Siemens AG
Wittelsbacherplatz 2
80333 Munich
Germany

Global Siemens Healthcare Headquarters
Global Siemens AG
Healthcare Sector
Henkestrasse 127
91052 Erlangen
Germany
Telephone: + 49 9131 84-0
www.siemens.com/healthcare

Legal Manufacturer
Siemens Medical Solutions USA, Inc.
Ultrasound
1230 Shorebird Way
Mountain View, CA 94043 USA
Telephone: +1-888-826-9702
www.siemens.com/healthcare

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