VDI Center for Visual & Decision Informatics

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Executive Summary			
Title: Monitoring and Early Detection of PCG Anomalies			**Project ID:** 6a.002.TUT
Today's Date: 03/16/2017	**Estimated Start Date: 08/01/2017**		**Type: [x] New [ ] Continuing**
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Project Description: Heart auscultation is one of the cursory and cost-effective diagnostic tests. It can provide primary evaluation of hemodynamic status and detect cardiovascular diseases. Therefore, personalized cardiac health monitoring systems based on phonocardiogram (PCG), have the potential to advise or reassure the individual about the heart status. These systems require a prior training and tuning using both normal and abnormal PCG samples of a patient in addition to an accurate segmentation process. In the absence of abnormal samples, no classifier can be trained properly and thus be applied to early detection of abnormal beats –if and when- they occur in an otherwise healthy person with no past history of cardiac problems, even if accurate beat segmentation can be achieved. To address this drawback efficiently and propose a reliable personalized solution for early detection of heart anomalies, we propose a novel abnormal beat (i.e. PCG cycle) synthesis approach, which can create potential abnormal beats for an individual by degrading his/her regular normal beats. We aim to model the common cause of heart degradation in the dataset as a "degrading system" that turns regular normal beats to abnormal ones. Our main assumption is that if it is the same physical cause that occurs in the person being monitored, then the same degrading system will be able to synthesize similar abnormal future beats. Once potential abnormal beats are generated, then a classifier can be trained to detect early abnormal beats as soon as they appear.

Experimental Plan: During the project period the focus will be particularly drawn to the following key research topics:

- Address the shortcomings of the conventional PCG segmentation caused by the nonlinearity and contamination of noise and artifacts.
- Tackle the aforementioned problems by developing novel machine learning approaches for segmentation.
- Create potential abnormal PCG beats for an individual by using the library of filters over his/her regular normal PCG cycle.
- Perform learning by 1D CNNs to negate the necessity of extracting handcrafted features and to detect abnormal beats in real time.
- Explore and test optimal CNN topologies and synthesizer kernels on the largest public heart sound database.

Related Work: The lack of structured methods for probing heart sounds, limitation of human audible frequency range, and environmental noise are the major shortcomings of using heart sound. Therefore, recently proposed automatic decision support systems using PCG are increasingly using signal processing and machine learning approaches. The existing methods in anomaly detection using PCG signal mainly consists of three steps: (1) PCG segmentation, (2) Feature Extraction, and (3) Classification. Several studies use time domain (e.g., histogram approaches, local amplitude changes, signal energy, etc.), frequency domain (e.g., Fourier transform magnitude and phase, approximate entropy, etc.), time-frequency domain (e.g., wavelet domain, short time Fourier transform), and nonlinear analysis (e.g., phase space approaches, Lyapunov exponent, correlation dimension, etc.) in order to learn the patterns of the abnormal beats. The proposed methods show promising results in detecting abnormal heart activity. However, they require examples of abnormal heartbeats and, thus, cannot be used as an advance warning system for a patient without prior heart problems and abnormal beats.

How this project is different: To the best of our knowledge, this will be the first study of personalized cardiac health monitoring and early detection of PCG anomalies. In this project, "the common causes of degradation" are modelled from other patients' PCG training data and are then applied to synthesize "potential" abnormal PCG data for a new person. Thus, the proposed approach only needs to be trained using the regular normal and synthesized abnormal beats. In addition, using CNN negates the necessity to extract handcrafted manual features, trained for an individual. Therefore, such a solution can conveniently be used for real-time PCG monitoring and early alert system on a light-weight wearable device.

Milestones for Year 1:

3 months: PCG segmentation: literature review

6 months: Design and development of new segmentation algorithm for localizing the occurrence of the first abnormal beat, i.e. the first S1, marking the beginning of the systole, and the second S2, marking the end of the systole.

9 months: Developing and optimizing the synthesizer kernels, and CNN topology.

12 months: System deployment and testing in order to maximize the early detection accuracy in the sense of sensitivity and specificity.

Deliverables for Year 1:

1. A novel PCG segmentation method.
2. Realization of the capabilities of the PCG signals in early detection of heart anomalies.
3. A deep learning approach for PCG feature extraction and classification.
4. A report on the potential of using such a system in ambulatory and home health monitoring.

Proposed Budget for Year 1:

Researcher Salary	€34,400
Indirect salary costs	€18,232
Overhead	€50,527
Travel	€8,000
Material and supplies	€1,841
Other cost	€15,000
Total	**€115,000**

How this Project may be transformative? Unlike existing systems, the proposed system enables automatic early heart anomaly detection for healthy people with no history of heart problems. It can also suggest additional diagnostic tests for further medical assessments. Moreover, the project emphasizes the classification of PCG signals (normal vs. abnormal) with state of the art classification performance.

Potential Member Company Benefits: CVDI companies can benefit from the proposed technique in both feature extraction and classification. We believe that our research is likely to stir a wide interest in medical environments such as acute ambulatory care, and home health care units. In addition, the proposed framework provides the possibility of health monitoring in daily life for a wide range of people (e.g., elderly, athletes, casual exerciser).

Progress to Date: Studying the necessary background knowledge on both dataset and theoretical aspects of the problem was a priority and led to a research review. So far, we have developed a novel classification framework with application to automatic anomaly detection where the results demonstrate the effectiveness of the proposed technique. Our proposal ranked second in the Physionet challenge 2016 (CinC2016 held in Vancouver, Canada).

Estimated Knowledge Transfer Date: 07/31/2018