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Automatic classification of resuscitation activities on birth-asphyxiated newborns using acceleration and ECG signals

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ABSTRACT

Objectives: Newborn deaths are reported to be caused mainly by birth asphyxia. Information learned from ventilation and other treatment could help increase survival rate of newborns in need of resuscitation. Characteristics of manual bag-mask ventilation have been studied in our previous works. However, other resuscitation activities could have important impacts as well. This paper illustrates the classification of several predefined resuscitation activities using information from acceleration and ECG signal.
Methods: Time and frequency domain features were extracted from the acceleration and ECG signals. A 2-stage classifier was trained on data of manually annotated activities by observing videos of 30 resuscitation babies. Leave-one-out cross validation was used: for each fold, the classifier was trained on activities of 29 patients and tested on activities of 1 patient.
Results: The average accuracy of the classification of activities is 79%.
Conclusions: The performance of the classification algorithms indicates that it is possible to use ECG and acceleration signals to automatically derive useful information regarding resuscitation activities.

1. Introduction

Complication at birth and/or birth asphyxia lead to the deaths of nearly a quarter of the estimated 3 million newborn deaths according to a recent report from the Save the Children organization[1] [1,2]. Birth asphyxia is usually referred to as a failure to initiate spontaneous breathing and/or to have a 5-min Apgar score <7. Initiation of positive pressure ventilation within the first minute of life – “The Golden Minute”, is recommended as a treatment to increase survival chance. The delay in executing basic resuscitation might result in a progressive decrease in heart rate, blood pressure, brain injury or even death [3]. Guidelines for neonatal resuscitation are currently applied in practical use [4,5]. However, the key factors of effective treatment remain unrevealed.

Safer Births[2] is a research collaboration between Haydom Lutheran Hospital in Tanzania and Stavanger University Hospital, University of Stavanger, and Laerdal Global Health in Norway. The mission of Safer Births is to establish new knowledge and develop innovative products in order to provide better equipment and improve competence of health workers. The project has collected resuscitation data of more than 500 newborns, using sensors measuring various signals: flow, pressure, CO_2, ECG, and acceleration signals.

The detection and parameterization of events characterizing manual bag-mask ventilation have been described in our previous works [6]. We have also investigated the possible correlation between ventilation parameters and different patient groups by developing an exploratory analysis framework [7–9]. The results demonstrate that the interaction between clinical treatment and human physiological conditions are highly complicated. Ventilation is important yet not the only factor. During ventilation, there

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[1] www.savethechildren.org.

[2] www.saferbirths.com.

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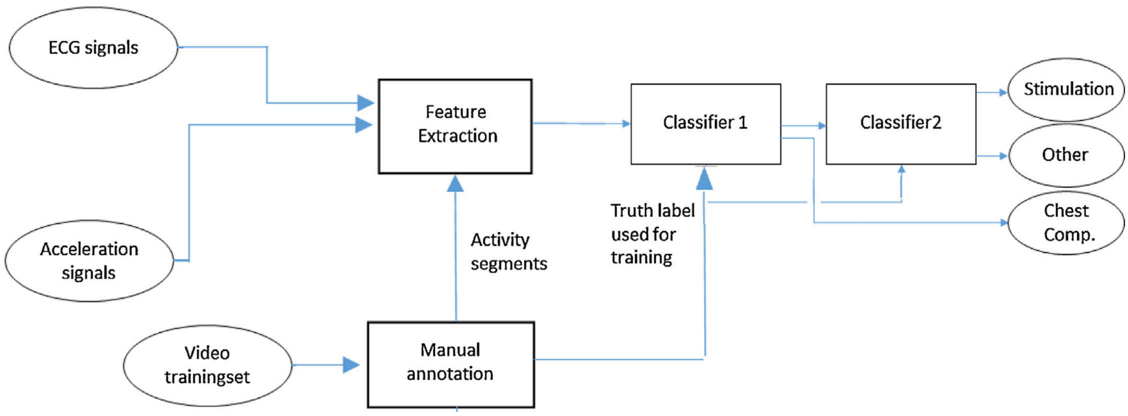

Fig. 1. Segmentation information (start time and end time) and true labels of annotated activities are retrieved from annotated videos. Features from ECG and acceleration signals are used for the training of resuscitation activity classification. There are 2 stages of classification (classifier 1 and classifier 2). The activity segments and true labels are used as training data. The results are 3 classes of activities: chest compression, stimulation and other.

could be other resuscitation activities applied simultaneously, such as drying thoroughly, stimulation, suction, chest compression, etc., and those activities could have important impacts on the responses of the babies.

Activity recognition based on accelerometer measurements has been increasingly investigated during the past decades [10–16]. An accelerometer is a device measuring acceleration forces in three orthogonal directions (X, Y and Z axes). Wearable devices (e.g., smart phones, health status monitors, etc.) have made use of integrated accelerometer sensors in detecting and classifying daily human activities efficiently. Various features, e.g., features in time domain [10–13] or frequency domain [15] or both [16,14], were extracted from acceleration signals measured by the devices worn tightly on the body and the activities typically categorized were running, walking, standing, sitting, and jumping.

To identify activities having significant impacts on the improvement of asphyxiated newborns during resuscitation, it is necessary to study videos recorded in the delivery room [17,18]. However, in practical situations, video recordings are not likely to be available, and video reviewing is very time consuming. This paper illustrates the classification of several predefined resuscitation activities using information extracted from acceleration and ECG signals. The objective of this paper is to investigate the possibility of studying the activities automatically. The ultimate aim is to develop an automatic system to support clinicians in retrieving information about activities not only more quickly, but also when videos are not available. Fig. 1 shows an overview of the activity classification system.

2. Dataset

Laerdal Global Health[3] in Stavanger, Norway has developed the Laerdal Newborn Resuscitation Monitor (LNRM) for research in a limited resource setting. There are various types of information measured by LNRM: the ventilation (airway pressure, flow, CO_2), ECG and acceleration signals. In this paper, we used information from the ECG and accelerometer sensors. Fig. 2 shows the ECG sensor placed gently over the baby's abdomen. The acceleration signal is measured by an accelerometer attached to the ECG-sensor. The ECG and acceleration signals are sampled at 500 Hz and 100 Hz, respectively. All sensor signals are synchronized. The signal data is saved in a memory unit integrated in LNRM and can be transmitted to a computer via a USB port.

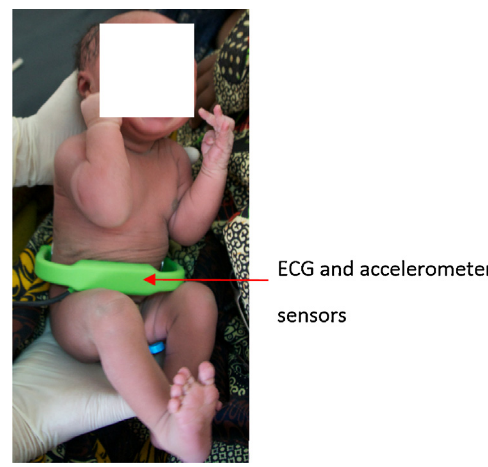

Fig. 2. The ECG-sensor placed on the newborn measuring ECG signal. An accelerometer sensor attached to the ECG-sensor measuring acceleration signal.

In this paper, the data includes physiological signals and videos of 30 patients recorded at the Haydom Lutheran Hospital from October 2013 to January 2014. The videos were manually annotated using the ELAN tool[4] to provide ground truth labels used for training and testing the automatic classification of activities. A medical doctor defined the resuscitation activity labels, and instructed how to distinguish the activities when studying the resuscitation videos. The annotations in this feasibility study were performed by the main author after receiving such instructions.

Defined by clinicians, the manual annotations include seven different types of resuscitation activities: *chest compression* (the birth attendant places fingers on the chest of newborns to perform heart compression), *back stimulation* (the birth attendant is moving a hand up and down the back to stimulate the column and spinal cord), *tactile stimulation* (usually a more gentle stimulation on chest or feet), *drying thoroughly* (the birth attendant uses a cloth to wipe the baby), *moving baby*, *moving ECG-sensor*, and *uncategorized movements* (which also affect the ECG and acceleration signal). The manual annotations may contain overlapped activities. Due to the similarity and therefore difficulty in distinguishing, we exclude sequences of activities happening simultaneously. In addition, we merge some classes into one group. Specifically, *back stimulation*, *tactile stimulation* and *drying thoroughly* are grouped

[3] http://www.laerdalglobalhealth.com/.

[4] https://tla.mpi.nl/tools/tla-tools/elan/.