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Method Article

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Acquisition and synchronisation of cardiography signals from a clinical patient monitor with facial video recordings

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Abstract— A far too frequent practical challenge in clinical informatics research and method development for acquiring vital signs is the extraction and synchronisation of signals from proprietary devices for the clinical monitoring of patients. In an ongoing study evaluating methods for video-based remote photoplethysmography (rPPG), we needed to extract ground truth values of electrocardiogram (ECG) and pulse oximetry (SpO2) signals from the Philips vitals monitor while recording the facial video of the subject, simultaneously. This ground truth data will be used to train the model that will perform rPPG. Various software can extract data from the Philips vitals monitor with features like data acquisition, parsing, and visualisation, but they lack synchronisation with the facial video. Therefore, we developed the Patient Monitor Data Extractor (PMDE), which collects data from the Philips IntelliVue monitors following the Data export interface programming guide provided by Philips. We set up a DHCP server on a Windows 7 computer with a webcam and interfaced with the monitor through LAN with UDP/IP. We used C++ and Windows Sockets API to develop our software and communicate over UDP. For synchronisation with the video cameras, we turned off the light in the room and used this sudden brightness drop as a trigger. The timestamp of the monitor was recorded when the webcam detected the trigger. The PMDE software records ECG at 500 Hz and SpO2 at 125 Hz with a synchronisation error of less than two sampling periods, which is about 40 ms for a 50 fps video. We conclude that PMDE is uniquely suited for recording data for rPPG evaluation because of its synchronisation feature. We have used PMDE to collect a dataset of facial videos with ground truth ECG and SpO2 signals. We intend to make PMDE available as open source to save other researchers time.

Keywords— Clinical informatics, remote photoplethysmography (rPPG), vital signs, data extraction, software, patient monitor

I. INTRODUCTION

The heart rate and oxygen saturation in the blood are two primary signals reflecting a person's health. Multiple vendors

provide commercial devices to measure these vitals accurately. A lot of data is generated in hospitals and clinics. However, this data is usually not stored or analysed. Storing this data can help develop non-contact methods to measure heart rate, such as remote photoplethysmograph (rPPG). rPPG is a non-contact method to extract the heart rate information of a person by recording the face using an RGB camera. In an attempt to develop a tool that can accurately perform rPPG measurements, we noted and validated a lack of data to train models. Thus, we set out to build our dataset, which contains the real-time ECG and SpO2 data while the facial video of the person is being recorded simultaneously. The accuracy of the model depends on the quality of the data. To collect the data, we needed software to collect it while synchronising it with each frame of the facial video being recorded. We conducted a thorough literature search but found no software catering to our needs. Thus we decided to develop our software, the Philips Monitoring Data Extractor.

This software is the medium to collect the ECG and SpO2 signals from the Philips Patient monitor that measures the heartbeat and an RGB camera that records the video. The ECG and the SpO2 signals act as the ground truth for model training and evaluation. We use this software as the moderator providing synchronization to compare the rPPG measurement of Blood Volume Pulse (BVP) with the ECG and PPG. Our software can export the data from the Philips monitor to a computer. Also, synchronisation is an essential aspect of the software, without which it would not be easy to map the ground truth ECG and SpO2 signals with the video recording. This paper presents our iterative survey and discusses the PMDE software in detail.

II. PREVIOUS WORK

Our literature search found eight software that can acquire vital signs from different patient health monitoring device brands. INSMA is a multimodal data acquisition, parsing, and visualisation tool designed to work with Philips IntelliVue monitors [1]. It was being tested in the University Hospitals Cleveland Medical Centre ICU. WaveformECG is open-

Table 1: Comparison of software that can acquire vital signals from patient monitors. The ability to sync with facial videos is mentioned in the last column.

Name	Language	OS	Signals/Frequency	Protocols	License	Supported devices	Sync
INSMA [1]	C++	Windows	ECG - 500 Hz, SpO2 -125 Hz	UDP/IP-LAN, RS-232-MIB	Elsevier user license	Philips	
VitalRecorder [2]	C++	Windows	ECG - 500 Hz, SpO2 -100 Hz	serial, HTTP	CC	Philips, CardioQ-ODM	
WaveformECG [3]					Apache 2.0	Philips, GE, Schiller, Norav	
VSCapture [4]	C#.NET	Windows, Mac, Linux		UDP/IP-LAN, RS-232-MIB	Apache 2.0	GE Datex S/5	
AIMS [5]			ECG, SpO2, BP				
UoQ dataset [6]			ECG, SpO2, BP			Philips Intellivue MP30 & MP70, Datex Ohmed	
ixTrend [7]							
ECG android app [8]							
PMDE	C++	Windows	ECG - 500 Hz, SpO2 - 125 Hz	UDP	CC	Philips Intellivue	✓

source and web-based tool for managing and analysing ECG data [3]. It is designed for clinical research and provides a means to test data-processing algorithms. It stores ECG data in time series and has analysis features using various algorithms. Users can also upload ECG data from various vendors and perform analysis. Anesthesia Information Management System (AIMS) is a commercial software for anesthesia research [5]. It monitors the patient’s vitals, like ECG, SpO2, and Blood Pressure (BP), under a dose of anesthesia. It was developed in the 1980s and has seen significant improvement. The VitalRecorder was designed to overcome the drawbacks of AIMS, like limited capability for acquiring vital signs data [2]. It is free-to-use software under a Creative Commons Attribution 4.0 International License (CC 4.0) that allows easy data acquisition and editing, automatic recording, filters, file utilities, and a data bank. Another open-source software that may be used by anesthesiologists involved in research is VSCapture [4]. This software can acquire vitals data from the GE Datex S/5 series monitor with minimal initial expense and hardware requirements.

A German commercial product, ixTrend Professional developed by Ixculture, provides features like recording, storing, visualising, and exporting data from the patient monitors [7]. It stores data in CSV or Dataplore format. Its features include simultaneous recording from 8 monitors, real-time visualisation, GUI, and batch function. However, it is expensive for research. A researcher attempted to use a smart-

phone to remotely acquire the data from a patient monitor and store it in the cloud [8]. They developed a mobile application, ‘ECG android app’ to provide the end user visualisation and data logging functionality. However, it was limited to mobile phones and could be used only when the phone was connected to the IOIO boards.

All these software can acquire data from some patient vitals monitors. However, none can be used to sync the ECG and oximeter readings with the frame of the facial video. Thus, we design PMDE to add the synchronisation functionality to advance our research on rPPG.

III. PMDE

We designed an experimental setup to collect data for rPPG. The dataset consists of facial video recordings of a person along with the instantaneous ECG and SpO2 readings recorded by the Philips IntelliVue MX400 patient monitor. The vitals monitor ground truth reading for every frame of the video is essential so that the model learns how to predict heart rate accurately. We need to extract the readings from the vitals monitor to sync the data with the video frames. Doing the synchronisation manually could result in errors. Thus, we needed software to automatically extract the data from the vital signs monitor and sync the data with the video frames. The PMDE has been designed to sync the extracted data with the facial video frames using the Data export interface program-

ming guide for IntelliVue X2, MP Series & MX Series, and Avalon FM Series. It is a guide provided by Philips describing the capability of the Data Export Interface and mentioning that it is the user's responsibility to design the program. This section will discuss how PMDE works and how to use it.

A. Vital Signs Monitor

The Philips IntelliVue MX400 patient monitor is a portable and compact state-of-the-art for clinical use. It provides comprehensive patient information at a glance and can extract vital signs like ECG, photoplethysmograph wave, real-time SpO2 number, pulse, and respiration rate. For our application, we need real-time ECG and SpO2 readings. We used a LAN interface with UDP protocol to transfer data from the vitals monitor to the computer. We set up a DHCP server on the computer and configured the LAN. The operating system of the computer used was Windows 7.

B. Implementation

The PMDE has been written in C++ programming language. We used the Windows Socket API (or Winsock) to develop the functionality of communication over UDP. Winsock defines how windows software can access a network service like UDP or TCP/IP. The PMDE uses Winsock to communicate with the vitals monitor over UDP. Figure 1 explains the step-by-step procedure of how the Winsock works to establish a connection and how data is transferred. First, a connection is established between the vitals monitor and the computer by sending an association request and creating an MDS event report.

After the connection is established, the lights of the experiment room are turned off. The sudden brightness drop acts as a trigger that indicates the initiation of the experiment. The timestamp of the initiation of the experiment is noted and based on this, the video frames synchronise with the heart rate. Once the trigger is detected, poll data is requested for a period. Pressing any key on the keyboard begins the data collection. One data packet is sent every 1024 ms. Each packet has four responses with a recording time of 256 ms. The recording is performed for the time selected by the user, and it stops automatically. An association release request is sent, indicating the end of one experiment.

The user must manually enter experiment details before beginning the recording for each experiment, like the test name, the time in seconds that the recording has to be conducted, and if all the cameras are running. The test name can be alpha-numeric to protect the subject's identity and indicate

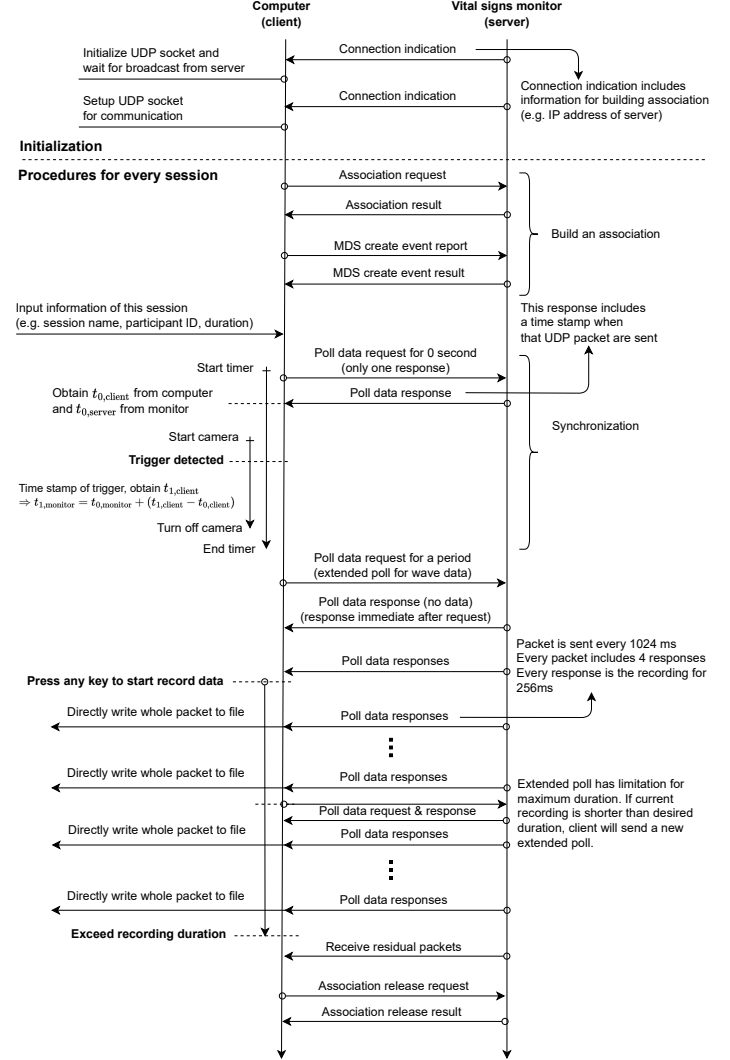


Fig. 1: Procedure of synchronisation of the vitals with the facial video

the type of test being conducted. Figure 2 contains a flowchart that demonstrates the step-by-step usage of the software.

C. Result

The PMDE can extract real-time data from the Philips IntelliVue MX400 and store it in the computer in the BIN format, which can also be converted to the CSV format. It acquires the ECG data at a frequency of 500 Hz and the SpO2 data at 125 Hz. The measured ECG and SpO2 data are synchronised with the frames of the facial video being recorded. The synchronisation error is less than two sampling periods, which is about 40ms for the 50 fps video.

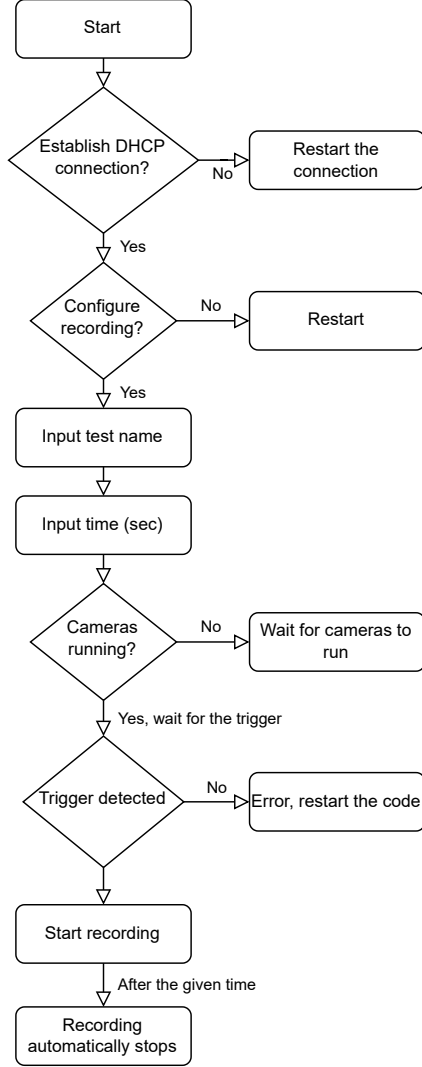


Fig. 2: Flowchart of the usage of the software

IV. DISCUSSION

We designed the PMDE software for rPPG applications. Its primary function is to sync facial video with the heart rate data, which no other software can do. The PMDE can be used to develop comprehensive datasets with synced ground truth heart rates. These datasets could be used to train the rPPG models, which will predict the heart rate based on real-time facial videos. The performance of PMDE in extracting the ECG and SpO2 signals data is comparable to the software mentioned in the review section. It is robust and easy to use, as all the instructions on usage are mentioned

A time delay occurs because of data transmission from the

monitor. To reduce this delay, we directly connect the monitor and host with an internet jumper line to transmit UDP packets through LAN. The host grabbing frames cause another delay from the webcam. We use a webcam with lower image quality (or lower byte rate) to reduce this delay. This delay is less than 33 ms based on the frame rate of the webcam.

V. COMPLIANCE WITH ETHICAL REQUIREMENTS

A. Statement of Informed Consent

For all the experiments conducted, written consent is taken from every participant. They can choose whether they want their facial video to be public.

B. Statement of human and animal rights

We follow the guidelines of the Human Research Ethics Committee (HREC) of the National Cheng Kung University (NCKU) for the clinical evaluation and video filming of participants (NCKU HREC-F-107-008-2 and NCKU HREC-F-108-244-2).

VI. CONCLUSION

The PMDE is a unique tool for extracting and synchronising the data from the vital signs monitor with the video frames for rPPG applications. It serves the purpose of building a dataset to train or evaluate an rPPG model that can extract the heart rate data of a patient just by recording the facial video using an RGB camera. We plan to update the PMDE software to work on all the active Windows versions supported by Microsoft and different models of Philips vitals monitors. We plan to quantify the time delay to minimise the delay error further. Once we add the GUI feature, we will make the PMDE public.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the manuscript's contents, and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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