HREmo: A measurement system of students' studying state in online group class based on rPPG technology

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Abstract. The CONVID-19 Pandemic has broken the traditional teaching method, but ignorance of students’ feedback made many teachers feel the teaching quality was degraded. Although some researchers have proposed that whether students are attentive or dozing off by analysing student expressions, head corners, and eye postures, but it is difficult to adapt to the situation where students frequently lower their heads to take notes in actual situation. Therefore, this paper proposes a heart rate acquisition and analysis system HREmo based on remote photoplethysmography technology (rPPG). The time and frequency domain characteristics of the heart rate variability signal are further analysed through the heartbeat interval obtained by the pulse waveform. It has multiple advantages such as bases on objective indicators, calculates in fast speed and low cost. The recognition error of heart rate is within 1%, and it has accurate trend prediction for students’ concentration and mental workload. Furthermore, this article takes a group class as an example to describe in detail how to put HREmo in the teacher panel to help teachers provide students with more personalized status reminders.

Keywords: online education, studying state monitoring, remote heart rate measurement, affective computing.

1. Introduction

Today's online education emphasizes subdivided teaching scenarios to provide a more comfortable online learning experience for children of different grades and different learning goals. The combination of junior grades and K12 education has produced a 1V6 group class teaching mode, where students can start audio and video throughout the entire process to communicate with teachers. This paper proposes a listening state measurement system based on rPPG technology: HREmo, which extracts heart rate from student videos and further analyses the heart rate variability to determine the concentration and psychological stress level of students when listening. This system has three major functions: it increases the analysis dimension of the students' listening status, improves the lecturer's ability to supervise the lecture, and improves the fit between the classroom content and the students' acceptance ability.
2. Scenario analysis

China's online education market is currently in a period of rapid development. Under the influence of the epidemic, the growth rate of online education users will reach a new high in 2020, and the growth rate will be significantly ahead of other Internet applications. A lecturer can teach up to tens of thousands of students in one class. However, in the face of small and low grades, parents pay more attention to the teacher's careful care and guidance. Under the traditional large class mode, the connection between students and teachers is very weak, so 1V6 group classes The form came into being, and its logic is "large class teaching, small class experience". Under the circumstance that the main lecturer can teach a large number of students at the same time, a small class with six people is created, and a tutor is equipped to follow the class. In a classroom environment with a small number of people, students are prone to form a sense of companionship learning, the entire learning process is more immersed, and students are more able to perceive their own existence.

2.1. How does the teacher know the student's learning situation

In the scene of 1V6 group class, students can see the videos of themselves and the other five members at the same time, and the teacher can also open the students' video monitoring screen to observe the students' class status in groups. The key to ensure the quality of 1V6 group class is to make students think that the teacher only gives lectures to six people, and the teacher needs to pay more attention to each student, so the observation pressure of the lecturer is greatly increased. In the research for the lecturer, it is found that it is very difficult for teachers to obtain the necessary information from the students' videos in the process of class. When they think about the content of the lecture, they can only use the "glance" way to view the students' videos. Because the number of students is far larger than the offline physical classroom, and they are not familiar with the students, it is difficult for online education teachers to make timely eye contact with students like offline teachers Communicate with each other and get feedback from students. We need to further analyse the students' videos, extract the students' current listening situation, and let the teacher do multiple-choice questions instead of filling in the blanks, that is, the teacher only needs to make the choice of "whether to remind the distracted students" and send the automatic voice with one button.

2.2. Interface and data flow design

Originally, the lecturer's monitoring of students' listening status will be classified according to whether the questions are correct or not in class. The indicators that the teacher focuses on are: correct rate, the number of pairs, the number of pairs interrupted, and the number of wrong pairs. With these student classifications on the panel, the teacher will respond with praise or encouragement. Answer rate is the most easily observed indicator, but we can not ignore the reasons behind the right and wrong answers. As mentioned above, the heart rate can be extracted based on the video, so as to analyse the students' high mood in class.

Based on the "right and wrong" coordinate axis and the "anxiety" dimension, students can be divided into four categories. For each category of students, teachers can send out more suitable reminders.

![Figure 1. The old classification of students' learning quality.](image)
Figure 2. New classification quadrant of students' learning quality.

- **High accuracy and high concentration:** the students who are most concerned about have obvious outstanding performance in the accuracy of answering questions and interactive participation, and often get praise.
- **Low accuracy but high concentration:** the students who need to be encouraged most often work hard but can't see the meeting report for the time being. If the lecturer doesn't encourage them in time, it may cause the students' enthusiasm to weaken and develop to the third quadrant.
- **Low accuracy and low concentration:** for the students who need to solve the problems most, the lecturer needs to take more effective ways to communicate with the students and even their parents, and analyze the reasons for the students' low class status.
- **High accuracy but low concentration:** for students who need to give praise and reminders at the same time, the level of students is significantly higher than the average level of the class, and the system can not give them effective feedback. If they continue not to listen carefully, they also have the risk of developing to the third quadrant with the progress of teaching.

2.3. **HREmo**

When the lecturer and students initiate single or multiple interactions, it is recorded as an interaction logarithm. The interacted person needs to perceive the existence of the initiator. We can divide the degree of interaction into three levels: strong, medium and weak.

- **Strong degree of interaction:** personalized point-to-point interaction through audio or video (including AI dialogue), both sides make personalized answers according to each other's situation, such as teacher-student microphone connection, call to answer questions.
- **Medium degree of interaction:** personalized point-to-point text interaction, pay attention to the sense of atmosphere, only one side may make personalized response, but the other side does not make explicit response, such as the teacher refreshing the chat area, students sending bullet-screen comments.
- **Weak degree of interaction:** in the form of one against many interaction, both sides did not form explicit response, such as the system generating class praise list.

**HREmo** belongs to the medium degree of interaction. The teacher obtains the students' status in the silent observation way and gives personalized reminders. The students will adjust the class status in real time to form a closed loop. In this closed-loop, there are teachers' expectations for students' performance (i.e. all students are expected to approach the first quadrant), students' feedback adjustment after being reminded, and then teachers will adjust guidance strategies according to students' dynamic development to help students approach the first quadrant.
In the heart rate panel, in video The student learning quality quadrant in the data area can display the overall situation of students in a group, a class or all the listening students, and the macro data can reflect whether the teacher's lecture rhythm is appropriate; at the same time, the students in different quadrants will display the classification label under their avatars (take the second and fourth quadrants in the figure as an example), and the teacher can click the phase Remind students of their faces.

3. Method

1V6 group class naturally has a video interaction mode. Through the early analysis of students' videos in class, it is found that the face videos we can collect have the following characteristics:
- The face is well illuminated
- Each video has similar varying illumination noise
- The video source has high face integrity
- The range of facial movement is small

But at the same time, our scene has many videos and a large amount of computation per unit time, so we put the core of rPPG algorithm improvement on reducing the size of the algorithm and improving the operation speed as far as possible without affecting the accuracy.

3.1. rPPG technology framework

In 2008, Verkruysse et al. first studied and proved that the photoplethysmography signal related to the heart rate can be analyzed from the facial video collected by the camera to realize the remote measurement of the heart rate [1]. The related principle is called rPPG. On this basis, a large number of follow-up studies have been devoted to improving the accuracy and robustness of this remote measurement technology, and many new methods and new frameworks have been proposed. Subsequently, Poh et al. proposed the application of blind source separation algorithm (BSS) to measure heart rate in the RGB three-channel [2]; Sun et al. proposed a basic framework for remote measurement of heart rate using joint time-frequency analysis under ambient light conditions [3].
Figure 5. The SOP flow of rPPG technology [4].

- Face video selection: select the color cluster with the most pixels in the center of the face as the skin pixel (including the pixel selection within the range of skin tone and saturation). The range is set to the first frame and then used for subsequent frames of each video.
- Sub-channel processing and trajectory normalization: the ROI is divided into three channels, and all pixels in the ROI are spatially averaged to get the R, G, B observation points of each frame.
- Independent component analysis based on approximate diagonalization of joint eigenmatrix: the normalized original orbit is decomposed into three independent ground source signals by JADE-ICA. The green channel is often selected as the required source signal.
- Fast Fourier transform and filtering: the power spectrum is obtained by fast Fourier transform, and the operation range is set between [0.75, 2.5] Hz, corresponding to [45, 150] bpm.
- Illumination noise elimination: multi video heart rate spectrum superposition to remove the strongest noise.

Ten participants, aged between 15 and 25, were recruited for the experiment. They were all students. Apple watch series 6 was used as the heart rate acquisition device (PPG technology was used to calculate the heart rate). At the beginning of the experiment, the subjects were asked to watch the online class which was consistent with their educational level, and the facial video was recorded at the same time. One minute later, the heart rate extracted from the facial video was compared with that of Apple watch, and the results showed that our average error was less than 1%.

Figure 6. Heart rate calculation interface and heart rate calculation results.

Figure 7. The discrepancy between our results and Apple Watch measurement results.
3.2. Extracting HRV Signal

3.2.1. Data collection. The ECG of the participants can be recorded at the same time using Apple Watch. When participant is emotionally awakened, place the index finger of the other hand on the crown of the watch, thus forming a current path in the body to measure the ECG signal. The formal collection time is a 30 seconds period, the preparation process and the end of the collection will be excluded from the 30s of the formal collection.

3.2.2. Export the R-R interval and analyse HRV. The ECG manuscript in PDF format can be obtained. Import the PDF file into MATLAB, and restore the vector signal through operations such as background removal, noise removal, and boundary extraction. Use the Findpeaks() function the location of the peaks, and set the peak spacing within the heart rate frequency range. After obtaining the peak coordinates, convert the digitized ECG drawing to the original drawing scale to obtain the time difference sequence between the peaks. Calculate the pulse wave period.

After obtaining the R-R interval, time domain analysis, frequency domain analysis and nonlinear methods can be used to analyze HRV. We focus on HR, SDNN, LF, HF and nonlinear features.

3.3. Monitoring fatigue and pressure from HRV signals

3.3.1. Attention detection based on heart rate variability (HRV). In previous medical research, time domain and frequency domain analysis are often used in clinical treatment of heart disease diagnosis and anxiety diagnosis [5]. When people feel anxious, sympathetic nerve activity will increase, parasympathetic nerve activity will decrease, and heartbeat variability will therefore decrease. Non-linear analysis can get the correlation with individual’s attention [6]. The most commonly used non-linear analysis method is Poincaré plot. Each point on the graph represents the distance between a pair of adjacent heartbeats. Some studies claim that SD1 will rise to a very high value when a person maintains attention for a long time [7], so it can be used to judge whether the subject is in long-term attention.

3.3.2. Brain workload detection based on heart rate variability (HRV). In healthy people, mental stress, standing, 90-degree tilt and light exercise can increase LF (low frequency) in the HRV spectrum, and deep breathing can increase HF (high frequency). Regarding mental workload, predecessors have found in some studies [8][9]. When the mental workload increases, the heart rate and heart rate variability will change significantly, which is embodied in the increase of the heart rate and the decrease of the heart rate variability. At the same time, under different mental workload levels, the sensitivity of heart rate variability will be higher than that of heart rate [10].

3.4. NPS of HREmo

We distributed the 1V6 group teacher panel equipped with HREmo system to 28 online education teachers for trial, and asked them to fill in the questionnaire (in Chinese). The teacher said HREmo well analysed the students' concentration index, which is the most important factor they focus in the class, and the NPS reached 14.29%.
4. Conclusions
This paper introduces a kind of heart rate measurement and emotion analysis system HREmo based on RPPG technology. The system can be used in online education video class to help teachers have a more detailed grasp of students’ learning status in class, and make more personalized prompts according to the subdivided student types, so as to improve the learning efficiency of online education students and reduce the emotional resistance caused by not being able to face-to-face The purpose of separation. In the technical part, we improve the RPPG algorithm, and use JADE-ICA algorithm in the blind source separation part to reduce the computational load of large-scale video processing. After the teacher’s trial, HREmo gets a higher NPS value, which greatly reduces the occurrence of online education teachers not knowing the status of students.

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