Claims

1. A computerized method for measuring oxygen saturation in a user's blood, the method comprising:

measuring a set of photoplethysmography (PPG) signals from one or more different wavelengths of light, each PPG signal measured from a respective wavelength and comprising pulsatile and non-pulsatile components;

calculating, for each PPG signal, a gradient of the non-pulsatile components of the PPG signal with respect to light intensity of the respective wavelength;

determining the user's skin tone from one or more gradients of the set of PPG signals and a first data model;

calculating a modulation ratio from the pulsatile and non-pulsatile components of a pair of PPG signals measured from a pair of different wavelengths of light;

selecting one from a plurality of second data models based on the user's skin tone; and

determining the oxygen saturation in the user's blood from the modulation ratio and the second data model selected for the user's skin tone.

2. The method according to claim 1, wherein the set of PPG signals comprises a plurality of PPG signals, the method comprising:

measuring the plurality of PPG signals from a plurality of different wavelengths of light; and

determining the user's skin tone from the one or more gradients of the plurality of PPG signals and the first data model.

3. The method according to claim 1 or 2, wherein the one or more different wavelengths of light define at least two wavelengths in the range of 495 nm to 1000 nm.

4. The method according to claim 3, wherein the at least two wavelengths at least 50 nm apart from each other.

5. The method according to any one of claims 1 to 4, wherein the one or more different wavelengths of light define at least two of green, orange, red, and infrared light.

6. The method according to any one of claims 1 to 5, wherein the first and second data models are constructed using one or more machine learning algorithms.

7. The method according to any one of claims 1 to 6, wherein the second data models comprise a model for dark skin tone and a model for non-dark skin tone.

8. The method according to any one of claims 1 to 7, further comprising performing a pulse verification process on the pair of PPG signals for calculating the modulation ratio, the pulse verification process for rejecting pulses in the PPG signals that do not satisfy conditions defined in a third data model.

9. The method according to claim 8, wherein the conditions in the third data model comprise a matching difference threshold between the PPG signals within a time period, such that the PPG signals are rejected if they do not meet the matching difference threshold.

10. The method according to claim 8 or 9, wherein the conditions in the third data model comprise a motion strength threshold, such that pulses with motion strength above the motion strength threshold are rejected.

11. The method according to any one of claims 8 to 10, wherein the conditions in the third data model comprise a heart rate boundary, such that pulses are rejected if the corresponding heart rates are outside of the heart rate boundary.

12. The method according to claim 11, further comprising optimizing the heart rate boundary in an iterative process.

13. A computerized method for determining a user’s skin tone, the method comprising:

controlling a lighting element to emit one or more different wavelengths of light by incrementing an electric current supplied to the lighting element over a plurality of increment steps;

measuring a set of photoplethysmography (PPG) signals from the one or more different wavelengths of light, each PPG signal measured from a respective wavelength and comprising pulsatile and non-pulsatile components for each increment step of the plurality of increment steps;

calculating, for each PPG signal, a gradient over the plurality of increment steps of the non-pulsatile components of the PPG signal with respect to light intensity of the respective wavelength, the light intensity for each increment step being defined by the electric current supplied to the lighting element in the respective increment step; and

determining the user's skin tone from one or more gradients of the set of PPG signals and a first data model.

14. The method according to claim 13, wherein the set of PPG signals comprises a plurality of PPG signals, the method comprising:

measuring the plurality of PPG signals from a plurality of different wavelengths of light; and

determining the user's skin tone from the one or more gradients of the plurality of PPG signals and the first data model.

15. The method according to claim 13 or 14, wherein the one or more different wavelengths of light define at least one wavelength in the range of 495 nm to 1000 nm.

16. The method according to claim 15, wherein the one or more different wavelengths of light define at least two wavelengths in the range of 495 nm to 1000 nm.

17. The method according to claim 16, wherein the at least two wavelengths are at least 50 nm apart from each other.

18. The method according to any one of claims 13 to 17, wherein the one or more different wavelengths of light define at least one of green, orange, red, and infrared light.

19. A measurement device for measuring oxygen saturation in a user's blood, the measurement device comprising:

one or more lighting elements for emitting one or more different wavelengths of light;

one or more photodetectors for detecting the one or more different wavelengths of light; and

a processor configured for performing the computerized method according to claim 1.

20. A non-transitory computer-readable storage medium storing computer-readable instructions that, when executed, cause a processor to perform the computerized method for measuring oxygen saturation in a user's blood according to any one of claims 1 to 12.