

CLAIMS

1. A processor-implemented method comprising:

(a) receiving synchronized photoplethysmograph (PPG) signal and 3-axis acceleration
5 signal from sensors associated with the user of a wearable device;

(b) partitioning the received PPG signal and 3-axis acceleration signal into multiple
windows;

(c) determining whether motion is present in one of the multiple windows of the 3-axis
acceleration signal based on a threshold value of the 3-axis acceleration signal calculated using
10 standard deviation of raw time signal amplitude and applying a decision tree;

(d) pre-processing the 3-axis acceleration signal and PPG signal by performing zero-
phase digital filtering in the one of the multiple windows when there is motion in the one of the
multiple windows of the 3-axis acceleration signal, wherein the zero-phase digital filtering is
performed by processing input data in both the forward and reverse directions;

(e) performing Fourier transform on the pre-processed 3-axis acceleration signal and
PPG signal to obtain power spectra of the 3-axis acceleration signal and PPG signal in the one
of the multiple windows when there is motion in the one of the multiple windows of the 3-axis
acceleration signal, wherein the power spectra comprises fast Fourier transform (FFT) peaks of
the 3-axis acceleration signal and PPG signal in the one of the multiple windows;

(f) determining whether a peak of the 3-axis acceleration signal is present in a range
20 around a first highest peak of the PPG signal;

(g) determining whether the peak of the 3-axis acceleration signal affects heart rate of
the user by performing random forest learning on two peak features when the peak of the 3-axis
acceleration signal is in the range around the first highest peak of the PPG signal, wherein the
two peak features comprise i) a ratio of power of the first highest peak of the PPG signal to that
25 of the determined 3-axis acceleration signal peak present in the range around the first highest
peak of the PPG signal, and ii) a reciprocal of power of a second highest peak of the PPG
signal; and

(h) estimating the heart rate of the user in the one of the multiple windows using the
30 second highest peak of the PPG signal when the peak of the 3-axis acceleration signal affects

heart rate of the user; and

(i) obtaining a post-processed heart rate of the user in one of the multiple windows of a server and estimating a final heart rate based on a histogram, wherein a median value of a most frequently occurring wave is selected as the final heart rate.

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2. The method as claimed in claim 1, further comprising:

(j) estimating the heart rate of the user in the one of the multiple windows using the first highest peak of the PPG signal when at least one of the peak of the 3-axis acceleration signal is not present in a range around the first highest peak of the PPG signal and the peak of the 3-axis acceleration signal does not affect the heart rate of the user.

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3. The method as claimed in claim 1, further comprising:

(k) performing zero-phase digital filtering of the PPG signal in the one of the multiple windows when there is no motion in the one of the multiple windows of the 3-axis acceleration signal;

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(l) performing Fourier transform on the filtered PPG signal to obtain power spectra of the PPG signal in the one of the multiple windows, wherein the power spectra comprises FFT peaks of the PPG signal in the one of the multiple windows; and

(m) estimating the heart rate of the user in the one of the multiple windows using a highest peak of the PPG signal.

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4. The method as claimed in claim 3, further comprising:

estimating the heart rate of the user in remaining windows by repeating at least one of the steps of (c)-(m).

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5. The method as claimed in 4, further comprising:

forming the histogram with a predefined bin size for the heart rates of the user in the multiple windows;

selecting a bin with a highest number of occurrence in the histogram; and

considering a median value of the selected bin as a heart rate of the user.

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6. The method as claimed in claim 1, further comprising:

eliminating noise from each of the multiple windows of the PPG signal based on a threshold value for the PPG signal; and

removing direct current (DC) component from each of the multiple windows of the PPG signal upon eliminating the noise.

7. A system comprising:

a wearable device associated with user, wherein the wearable device comprises:

multiple sensors;

one or more memories; and

one or more hardware processors, the one or more memories coupled to the one or more hardware processors, wherein the one or more hardware processors are configured to execute programmed instructions stored in the one or more memories to:

(a) receive synchronized photoplethysmograph (PPG) signal and 3-axis acceleration signal from the multiple sensors;

(b) partition the received PPG signal and 3-axis acceleration signal into multiple windows;

(c) determine whether motion is present in one of the multiple windows of the 3-axis acceleration signal based on a threshold value of the 3-axis acceleration signal calculated using standard deviation of raw time signal amplitude and applying a decision tree;

(d) pre-process the 3-axis acceleration signal and PPG signal by performing zero-phase digital filtering in the one of the multiple windows when there is motion in the one of the multiple windows of the 3-axis acceleration signal, wherein the zero-phase digital filtering is performed by processing input data in both the forward and reverse directions;

(e) perform Fourier transform on the pre-processed 3-axis acceleration signal and PPG signal to obtain power spectra of the 3-axis acceleration signal and PPG signal in the one of the multiple windows when there is motion in the one of the multiple windows of the 3-axis acceleration signal, wherein the power spectra comprises fast Fourier transform (FFT) peaks of the 3-axis acceleration signal and PPG signal in the

one of the multiple windows;

(f) determine whether a peak of the 3-axis acceleration signal is present in a range around a first highest peak of the PPG signal;

(g) determine whether the peak of the 3-axis acceleration signal affects heart rate of the user by performing random forest learning on two peak features when the peak of the 3-axis acceleration signal is in the range around the first highest peak of the PPG signal, wherein the two peak features comprise i) a ratio of power of the first highest peak of the PPG signal to that of the determined 3-axis acceleration signal peak present in the range around the first highest peak of the PPG signal, and ii) a reciprocal of power of a second highest peak of the PPG signal; and

(h) estimate the heart rate of the user in the one of the multiple windows using the second highest peak of the PPG signal when the peak of the 3-axis acceleration signal affects heart rate of the user; and

(i) obtain a post-processed heart rate of the user in one of the multiple windows of a server and estimate a final heart rate based on a histogram, wherein a median value of a most frequently occurring wave is selected as the final heart rate.

8. The system as claimed in claim 7, wherein the one or more hardware processors are further configured to execute programmed instructions to:

j) estimate the heart rate of the user in the one of the multiple windows using the first highest peak of the PPG signal when at least one of the peak of the 3-axis acceleration signal is not present in a range around the first highest peak of the PPG signal and the peak of the 3-axis acceleration signal does not affect the heart rate of the user.

9. The system as claimed in claim 7, wherein the one or more hardware processors are further configured to execute programmed instructions to:

(k) perform zero-phase digital filtering of the PPG signal in the one of the multiple windows when there is no motion in the one of the multiple windows of the 3-axis acceleration signal;

(l) perform Fourier transform on the filtered PPG signal to obtain power spectra of the PPG signal in the one of the multiple windows, wherein the power spectra comprises FFT peaks

of the PPG signal in the one of the multiple windows; and

(m) estimate the heart rate of the user in the one of the multiple windows using a highest FFT peak of the PPG signal.

5 10. The system as claimed in claim 9, wherein the one or more hardware processors are further configured to execute programmed instructions to:

estimate the heart rate of the user in remaining windows by repeating at least one the steps of (c)-(m).

10 11. The system as claimed in claim 10, further configured to execute programmed instructions in the one or more memories to:

form the histogram with a predefined bin size for the heart rates of the user in the multiple windows;

select a bin with a highest number of occurrence in the histogram; and

15 consider a median value of the selected bin as a heart rate of the user.

12. The system as claimed in claim 7, wherein the one or more hardware processors are further configured to execute programmed instructions to:

20 eliminate noise from each of the multiple windows of the PPG signal based on a threshold value for the PPG signal; and

remove direct current (DC) component from each of the multiple windows of the PPG signal upon eliminating the noise.

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