

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ZEPP HEALTH CORPORATION

Petitioner

v.

UNIVERSITY OF CONNECTICUT

Patent Owner

Case No. IPR2025-00523
U.S. Patent No. 10,278,647

**PETITION FOR *INTER PARTES* REVIEW
OF U.S. PATENT NO. 10,278,647**

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LIST OF EXHIBITS¹

Ex-1001	U.S. Pat. No. 10,278,647 (“the ‘647 Patent” or “the Patent”)
Ex-1002	Declaration of Dr. George E. Yanulis
Ex-1003	Curriculum Vitae of Dr. George E. Yanulis
Ex-1004	Prosecution History of the ‘647 Patent
Ex-1005	Po-Hsiang Lai et al., <i>Lightweight Wrist Photoplethysmography for Heavy Exercise: Motion Robust Heart Rate Monitoring Algorithm</i> , Healthcare Technology Letters, Volume 2, Issue 1, pp. 6-11 (February 24, 2015) (“Lai”)
Ex-1006	Zhilin Zhang et al., <i>TROIKA: A General Framework for Heart Rate Monitoring Using Wrist-Type Photoplethysmographic Signals During Intensive Physical Exercise</i> , IEEE Transactions on Biomedical Engineering, Volume 62, Issue 2, pp. 522-531 (September 19, 2014) (“TROIKA”)
Ex-1007	Declaration of Sylvia D. Hall-Ellis, Ph.D.
Ex-1008	Zepp Health Corporation’s Stipulation Regarding Invalidity Challenges
Ex-1009	Docket Control Order (Dkt. 58) in <i>Research Foundation for The State University of New York v. Xiaomi Corporation et al.</i> , No. 2:23-cv-00353-RWS-RSP (E.D. Tex.)
Ex-1010	Judge Robert W. Schroeder, III (E.D. Tex.) – Calendar Events Set for 2/17/2026
Ex-1011	Judge Robert W. Schroeder, III (E.D. Tex.) – Case Statistics
Ex-1012	Docket entries in <i>Research Foundation for The State University of New York v. Xiaomi Corporation et al.</i> , No. 2:23-cv-00353-RWS-RSP (E.D. Tex.)

¹ In this Petition, 4-digit pin citations that begin with “0” refer to the branded numbers added by Petitioner in the bottom right corner of the exhibits. All other pin citations in this Petition refer to original page, column, paragraph, or line numbers.

I. INTRODUCTION

Zepp Health Corporation (“Petitioner”) requests inter partes review (“IPR”) of Claims 1-75 of U.S. Patent No. 10,278,647 (“the ‘647 Patent”) (Ex-1001), currently owned by University of Connecticut.

II. MANDATORY NOTICES UNDER 37 C.F.R. §42.8

Real Parties-in-Interest:

Petitioner identifies the following real party-in-interest: Zepp Health Corporation.

Related Matters:

- *Research Foundation for The State University of New York, University of Connecticut, and Worcester Polytechnic Institute v. Xiaomi Corporation, Xiaomi Communications Co., Ltd., Xiaomi H.K., Ltd., Xiaomi, Inc., and Zepp Health Corporation*, No. 2:23-cv-00353-RWS-RSP (E.D. Tex.) (the “Related Litigation”)
- *Research Foundation for The State University of New York, University of Connecticut, and Worcester Polytechnic Institute v. Samsung Electronics Co., Ltd., Samsung Electronics America, Inc., Samsung Austin Semiconductor, LLC, and Samsung Semiconductor, Inc.*, No. 2:23-cv-00141-RWS-RSP (E.D. Tex.)

- *Research Foundation for The State University of New York, University of Connecticut, and Worcester Polytechnic Institute v. Huawei Device Co., Ltd.*, No. 2:23-cv-00553-RWS-RSP (E.D. Tex.)

Lead and Back-Up Counsel, and Service Information

Pursuant to 37 C.F.R. §§ 42.8(b)(3)-(4), Petitioner identifies its counsel as follows. Petitioner consents to electronic service at the counsel's email addresses below.

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III. FEE AUTHORIZATION

The Office is authorized to charge all fees due for this proceeding to Deposit Account No. 502075.

IV. GROUNDS FOR STANDING

Pursuant to 37 C.F.R. § 42.104(a), Petitioner certifies that the ‘647 Patent is available for *inter partes* review, and that Petitioner is not barred or estopped from requesting an *inter partes* review of the challenged claims on the grounds identified in the petition.

V. IDENTIFICATION OF CHALLENGE

Pursuant to 37 C.F.R. § 42.104(b), Petitioner requests review and cancellation of Claims 1-75 of the ‘647 Patent pursuant to the following statement of precise relief requested.

- Ground: Claims 1-75 are obvious in view of Lai (Ex-1005) under 35 U.S.C. § 103.

VI. THE CHALLENGED PATENT

The ‘647 Patent describes a method and apparatus for heart rate monitoring and oxygen saturation estimation during intensive physical activity. Ex-0001, 6:34-38. The time-varying spectra of a heart-related signal (e.g., photoplethysmography [PPG] signal) is compared to a motion signal. *Id.*, fig 9. The spectra are computed from pre-processed signals to reduce noise and improve accuracy. *Id.*, 14:36-38.

The system also identifies motion artifacts, classifies them into categories such as pseudo-periodic, periodic, or random motion, and suppresses them. *Id.*, 4:5-8.

Also, based on the classification, the system discards spectral peaks or uses prior estimates to reconstruct the heart-related signal. *Id.*, 3:5-8.

VII. PROSECUTION HISTORY OF THE ‘647 PATENT

The ‘647 Patent, filed as Application No. 15/178,089 and claiming priority to U.S. Provisional applications No. 62/299,944, filed on Feb. 25, 2016, and No. 62/172,862, filed on Jun. 9, 2015, was allowed as none of the references discloses “[t]he method of Claim 6, wherein the time-varying spectral analysis further includes **pre-processing** the heart-related signal and the motion signal for the computing of the first TFS and the second TFS.” Ex-1004 (0938-0939), 2018-04-18 Office Action, at 8-9 (emphasis added).

However, the Examiner had already found that the subject matter of pre-processing, which the Patent Owner ultimately incorporated into claims 1, 35, and 69, was already included in the cited prior art. *Id.*, at 4 (“before conducting the spectral analysis, the signals are pre-processed by removing powerline noise and resampling”).

Further, none of the references relied upon in the Petition in combination with Lai (Ex-1005) were before the Examiner during prosecution of the ‘647

Patent. Nor were any similar teachings of other references discussed by the Examiner. Ex-1002, ¶35.

VIII. LEVEL OF ORDINARY SKILL IN THE ART

A person of ordinary skill in the art (“POSITA”) at the time of the purported invention of the ‘647 Patent would have had a working knowledge of physiological monitoring technologies and/or signal processing as used in physiological monitoring technologies. The POSITA would have had a bachelor’s degree in an academic discipline related to electrical, computer, software, optical, or biomedical technologies, in combination with two years of work experience related to the capture and processing of data or information signals, or designing and using biomedical sensors or systems, including but not limited to physiological monitoring technologies. Alternatively, a POSITA would have had a master’s degree in one of the above academic disciplines with one year of work experience as described above. Additional education can substitute work experience, and vice versa. The proposed level of skill for the POSITA would not change if a different priority of the invention date is found. (Ex-1002 ¶13)

IX. PRIORITY DATE

The ‘647 Patent claims priority to provisional application No. 62/172,862 filed on June 9, 2015. While the earliest possible priority date that the patent

owner may claim for the ‘647 Patent is based on provisional application No. 62/172,862’s filing date of June 9, 2015, Petitioner does not concede that any claim of the Patent is entitled to that priority date. Regardless, the prior art asserted in this petition was published before that earliest possible priority date, and thus qualifies as prior art under AIA 35 U.S.C. §§ 102(a)(1) and 103.

X. CLAIM CONSTRUCTION

Petitioner interprets the claim terms of the Patent according to the *Phillips* claim construction standard. 37 C.F.R. §42.100(b). Petitioner applies the plain and ordinary meaning to each claim term of the Patent as it would have been understood by a POSITA.

Further, the parties have not yet submitted claim construction contentions in the district court litigation. Petitioner respectfully reserves all rights to raise claim construction and other arguments in the district court litigation.

XI. BRIEF DESCRIPTION OF THE APPLIED PRIOR ART

As explained below, the claims of the ‘647 Patent do not identify anything new or significantly different from what was already known to those skilled in the art prior to the filing of the ‘647 Patent.

Lai (Ex-1005) was published on February 24, 2015, is thus prior art to the ‘647 Patent under AIA 35 U.S.C. §§ 102(a)(1) and 103. *See* Ex-1007, 29 (showing that Lai was published on February 24, 2015).

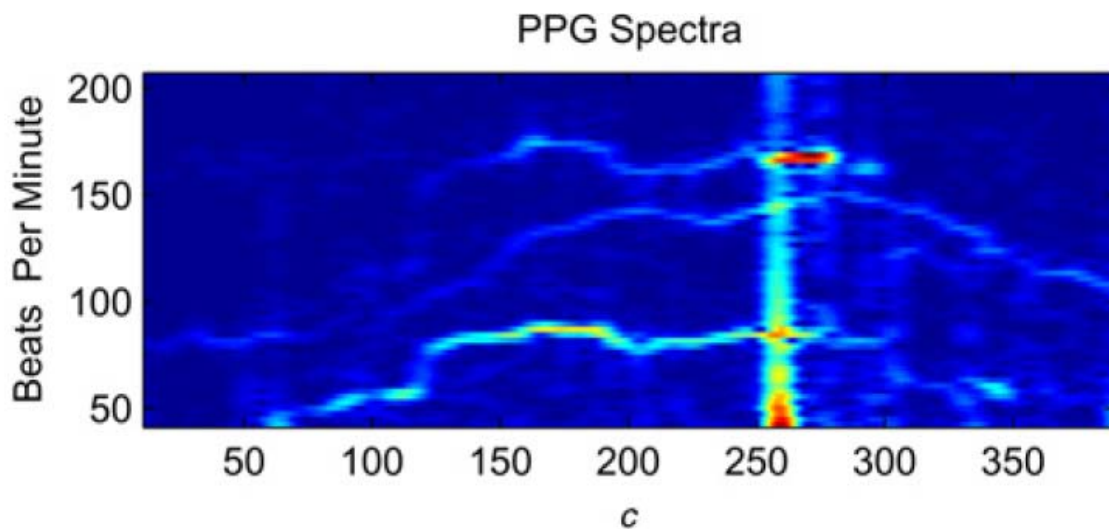
Lai notes that mitigating motion artifacts is a known challenge and a major research topic in PPG-based heart rate monitoring and highlights the challenges of motion artifacts in wearable devices like smartwatches, where high arm mobility increases the susceptibility of PPG signals to motion distortion. Ex-1005, 6 (“PPG is susceptible to motion artefacts, which have to be mitigated for accurate heart rate estimation. Motion artefacts are particularly apparent for wrist devices ... because of the high mobility of the arms”).

Lai’s discloses a method for mitigating motion artifacts in physiological signals, such as PPG signals, which employs Short-Time Fourier Transform (STFT). STFT is only one example of various well-known time-frequency spectrum analysis techniques in the field that the ‘647 Patent itself acknowledges, including Power Spectral Density (PSD), Variable Frequency Complex Demodulation (VFCDM), wavelet analysis, and smoothed pseudo Wigner-Ville methods. Ex-1001, 14:60-15:4, 19:57-64.

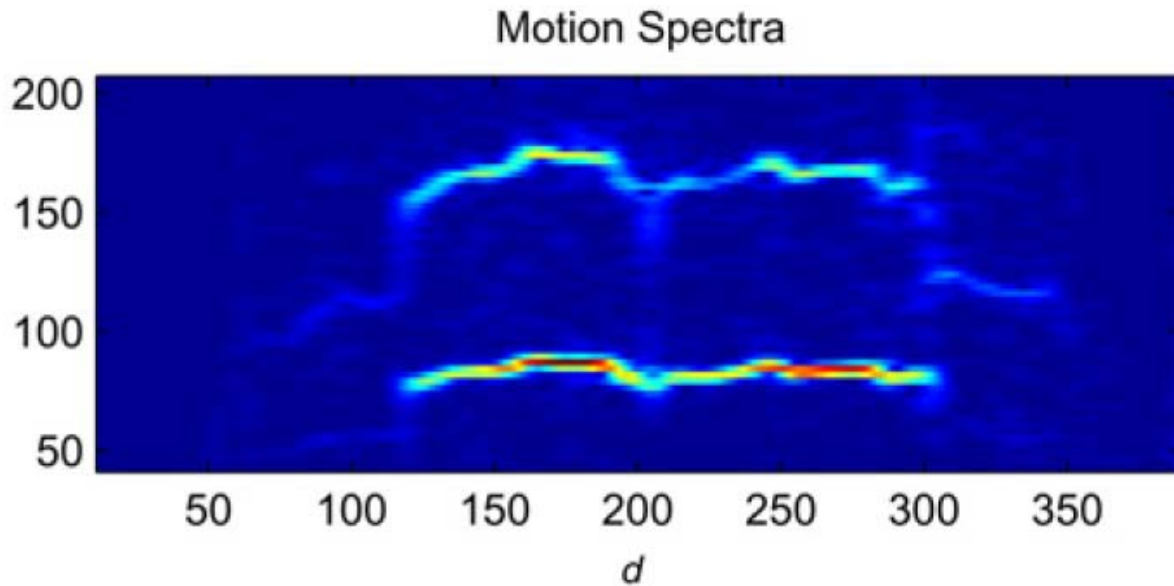
This demonstrates that combining accelerometers with time-frequency spectrum techniques to mitigate unwanted artifacts caused by movement was well-established and widely known in the field prior to the earliest possible priority date (June 9, 2015) of the ‘647 Patent. Ex-1002 ¶57.

Lai describes a method for processing streaming PPG and accelerometer signals to mitigate motion artifacts and extract heart rate estimates. Ex-1005, 6.

Using STFT for perform time-frequency spectral analysis, Lai analyzes PPG signals and motion signals segment by segment to detect significant peaks, including motion peaks that correspond to repetitive activities such as footsteps or arm movements. Ex-1005, 6. Motion artifacts are suppressed by separating cardiac components from unwanted motion-induced noise. For example, Figure 2c shows a PPG spectrum, where cardiac components are contaminated by motion artifacts, while Figure 2d shows the motion spectrum derived from accelerometer data. These spectra are used to identify and suppress motion peaks. *Id.*; Figs. 2c and 2d.

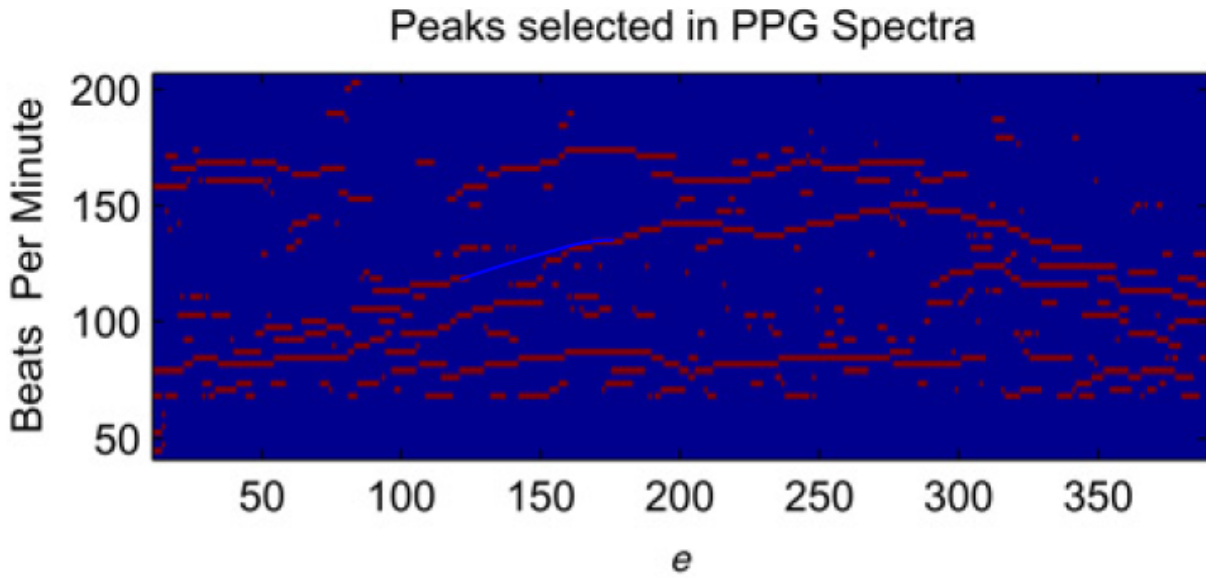


(Ex-1005, Fig. 2c)

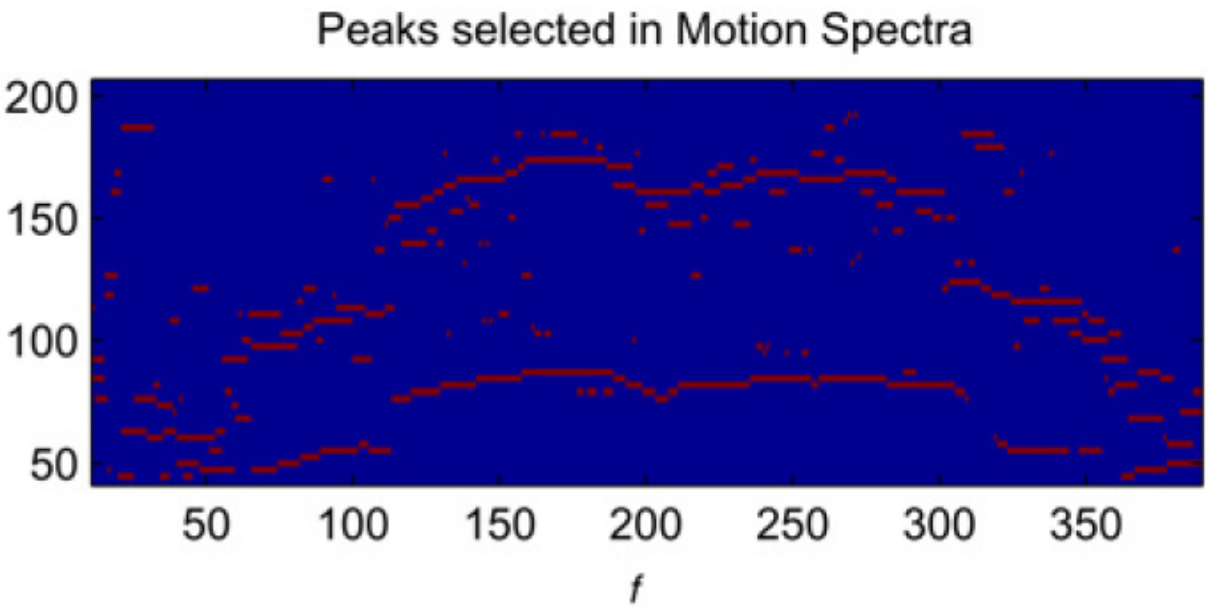


(Ex-1005, Fig. 2d)

Lai describes how motion artifacts, such as those caused by periodic movements, can be identified and mitigated by comparing the PPG spectrum with the motion spectrum. Ex-1005, 6-7. For example, the PPG and motion spectra in respective figure 2e and 2f show the detection of five peaks with the highest energy in their spectrum. These peaks are then ranked based on a scoring mechanism that considers their energy and proximity to motion frequencies. The ranking mechanism uses a scoring system, where peaks consistent with prior heart rate estimates are favored. This ranking ensures that the cardiac frequency is selected from the PPG peaks while suppressing motion-induced artifacts. Ex-1005, 6-7; Figs. 2e-2f.



(Ex-1005, Fig. 2e)



(Ex-1005, Fig. 2f)

The steps disclosed in Lai transform a noisy, raw signal into a clean and usable representation of the heart-related physiological parameter—heart rate—free from motion-induced distortions. Ex-1005, 7.

XII. DETAILED EXPLANATION OF THE UNPATENTABILITY GROUND

Claims 1-75 of the '647 Patent are obvious in view of Lai (Ex-1005) under 35 U.S.C. § 103 (AIA), as supported by the declaration of Dr. George E. Yanulis. Ex-1002. As discussed below, Lai either discloses the elements of claims 1-75 of the Patent or renders them obvious in light of the common knowledge in the art.

A. Independent Claims 1, 35, 69, and 70-75 are obvious in view of Lai (Ex-1005)

1. Preamble

[1pre], [70pre], [71pre], [72pre] A method / [35pre], [73pre], [74pre], [75pre] An apparatus for / [69pre] A non-transitory computer-readable medium having encoded thereon a sequence of instructions which, when loaded and executed by a processor, causes the processor to reconstruct a heart-related signal output by a biomedical sensor, the processor reconstructing the heart-related signal by: reconstructing a heart-related signal output by a biomedical sensor, the method comprising:

To the extent that each preamble is limiting, Lai discloses each preamble. Ex-1002 ¶¶64-69. Lai describes devices and methods for heart-related signal reconstruction, including wrist-based devices having PPG sensors and integrated accelerometers. Ex-1005, 6. Lai further describes these devices as incorporating biomedical PPG sensors and accelerometers to process and reconstruct heart-related signals. Ex-1005, Fig. 5b.



b

Figure 5 *Wrist devices used*

a Watch type form factor devices used in the experiment, see the main text for specifications

b LED sources and sensor of the devices

(Ex-1005, Fig. 5b)

A POSITA would recognize that such apparatuses facilitate the reconstruction of heart-related signals by integrating the biomedical sensor outputs (PPG and motion data) into a signal processing pipeline for noise removal and physiological signal reconstruction. Ex-1002 ¶65.

The reconstruction functionality of this apparatus is further detailed in Lai's description of its processing methodology. Lai describes pre-processing the raw biomedical sensor data (PPG and motion signals) through bandpass filtering and applying spectral analysis to isolate cardiac components and produce a robust reconstructed signal suitable for physiological monitoring. Ex-1002 ¶66; Ex-1005, 6; Figs. 1, 2c.

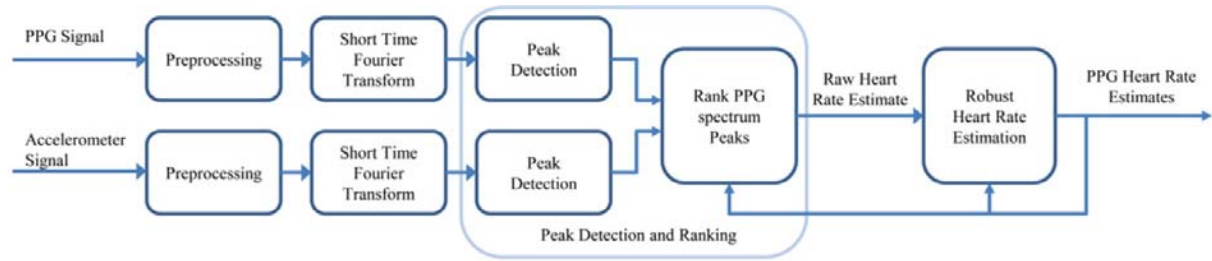
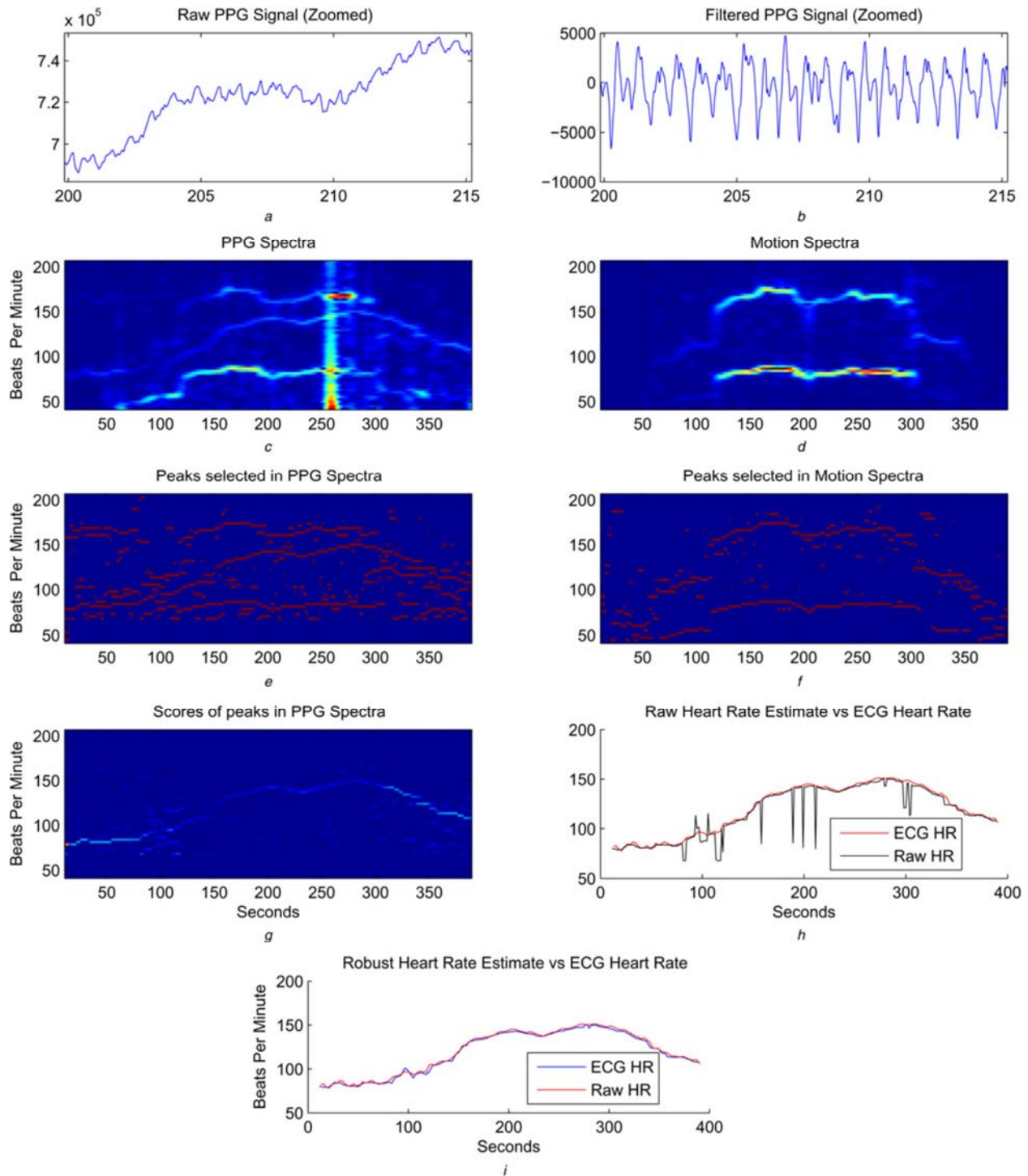


Figure 1 *System diagram of proposed method*

The proposed method contains four components: preprocessing, signal representation using short-time Fourier transform, detection of PPG and motion peak and rank PPG peaks as potential cardiac signal which outputs a raw heart rate estimate, and the Robust heart rate estimation

(Ex-1005, Fig. 1)



(Ex-1005, Fig. 2)

The '647 Patent confirms that such apparatuses, which include biomedical sensors and reconstruction units, were well known in the field. Ex-1001, 6:54-60

(acknowledging that a “pulse oximeter signal contains not only the blood oxygen saturation and heart rate (HR) data, but also other vital physiological information”); Ex-1002 ¶68.

The ‘647 Patent also describes integrated wearable devices capable of reconstructing heart-related signals for HR and rhythm monitoring. Ex-1001, 7:7-10 (“Utilizing a pulse oximeter as a multi-purpose vital sign monitor has clinical appeal, since it is familiar to the clinician and comfortable for the patient”) (citing Ex- internal citations omitted). Ex-1002 ¶69.

2. “Reconstructing” / “Reconstruction unit”

[1A], [69A], [70A], [71A], [72A] reconstructing / [35A], [73A], [74A], [75A] a reconstruction unit configured to reconstruct a representation of the heart-related signal to produce a reconstructed representation of the heart-related signal

Lai describes a process for reconstructing a representation of a PPG signal by combining and processing both raw PPG and accelerometer data to output a robust heart rate estimate. Ex-1005, 7. By mitigating motion artifacts through preprocessing and spectral analysis, Lai reconstructs a usable representation of the heart-related signal, which is then used for robust physiological monitoring. Ex-1002 ¶70; Ex-1005, Fig. 1.

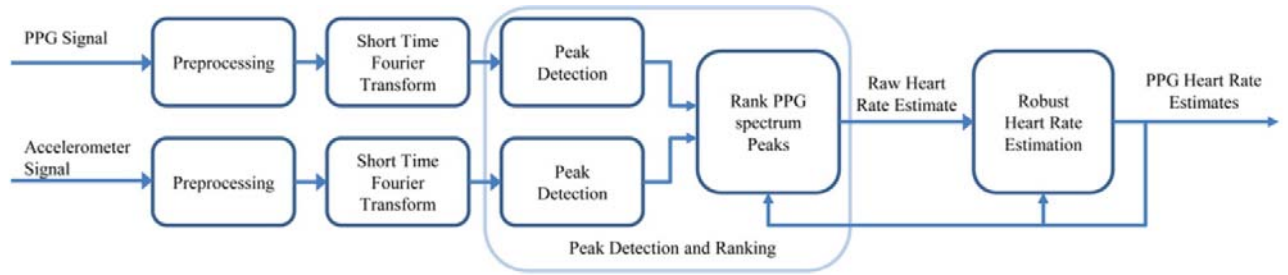
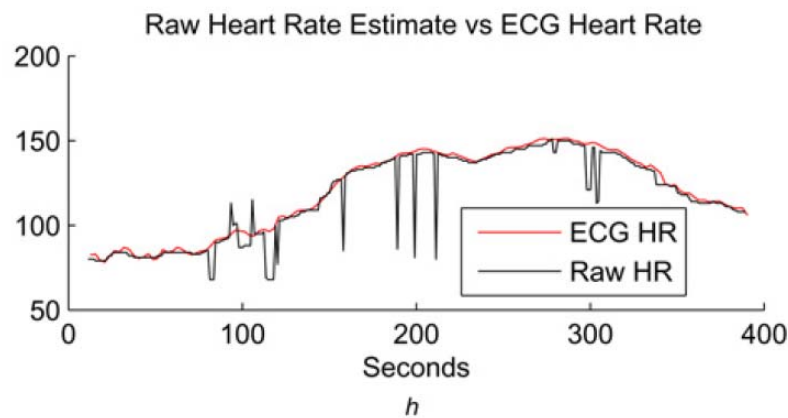


Figure 1 System diagram of proposed method

The proposed method contains four components: preprocessing, signal representation using short-time Fourier transform, detection of PPG and motion peak and rank PPG peaks as potential cardiac signal which outputs a raw heart rate estimate, and the Robust heart rate estimation

(Ex-1005, Fig. 1)



(Ex-1005, Fig. 2h)

Thus, Lai discloses these elements. Further, while Lai does not label any particular component as a “reconstruction unit,” a POSITA would recognize that Lai’s algorithm performs the functionality of such a unit. Specifically, Lai discloses receiving raw input signals from both PPG and accelerometer sensors, applying preprocessing steps such as removing baseline drift and DC components, and performing spectral analysis using STFT to isolate cardiac components from motion artifacts. This iterative combination of preprocessing and spectral analysis

reconstructs a representation of the heart-related signal suitable for further analysis.

Ex-1002 ¶72.

A POSITA would understand that these reconstruction steps directly corresponds to the claimed functionality of “reconstruction unit.” The reconstruction process not only filters and analyzes signals but also produces a refined representation that serves as the basis for calculating heart rate and other physiological parameters. This functionality could be implemented through software, hardware, or a combination of the two, as is typical for such systems. As a result, Lai’s algorithm inherently performs the functions needed to process raw signals and generate a reconstructed representation of the heart-related signal, which serves as a basis for calculating a heart rate. Ex-1002 ¶73. Therefore, Lai also renders these elements obvious in light of the common knowledge in the art.

3. “Based On Time-Varying Spectral Analysis”

[1B], [35B], [69B], [70B], [71B], [72B], [73B], [74B], [75B] the reconstructing based on (i) a time-varying spectral analysis of the heart-related signal and a motion signal

Lai discloses that reconstruction of the heart-related signal and motion signal is based on time-varying spectral analysis through the use of STFT. Ex-1005, 6-7 (“[s]ignal representation using short-time Fourier transform: The filtered signal is

then processed segment by segment. For each segment, the Fourier spectrum is computed”). Ex-1002 ¶74.

Lai applies STFT to both the heart-related signal (PPG) and the motion signal (accelerometer) to generate time-varying spectra for these signals. Figures 2c, and 2d illustrate how Lai compares the motion spectrum with the PPG spectrum to identify motion artifacts and isolate cardiac components, thereby mitigating motion-induced distortions. Ex-1005, 6-7, Fig. 2c, 2d. This reconstruction process is explicitly based on the time-varying spectral analysis of both signals. *Id.*; Ex-1002 ¶75.

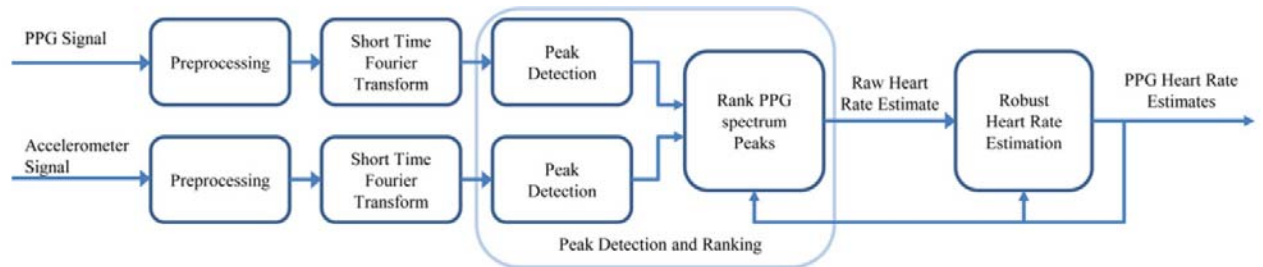
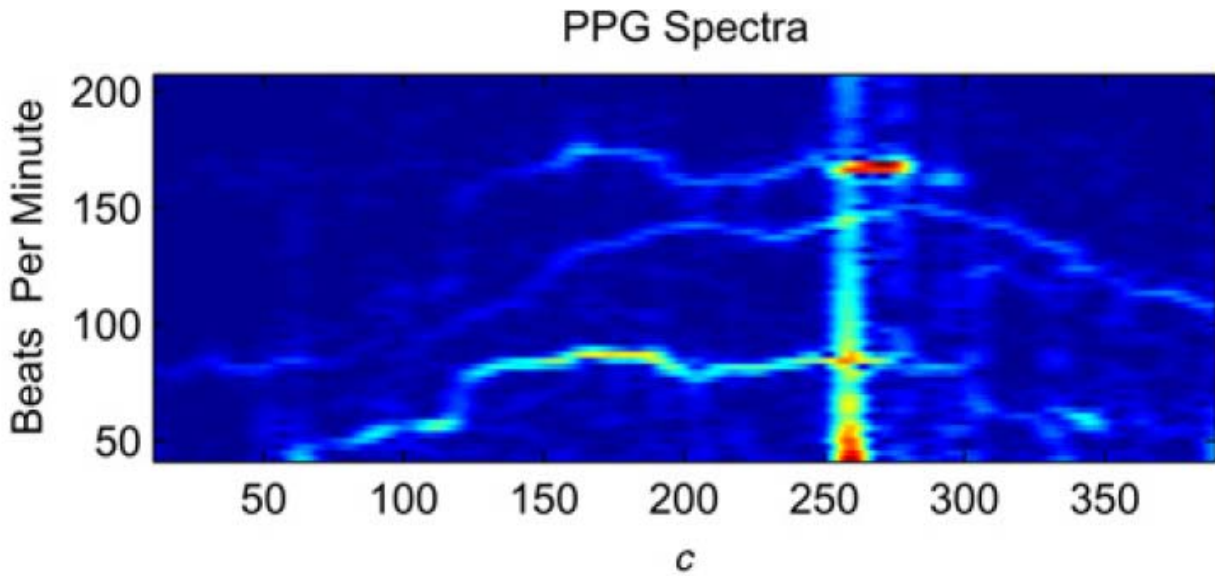


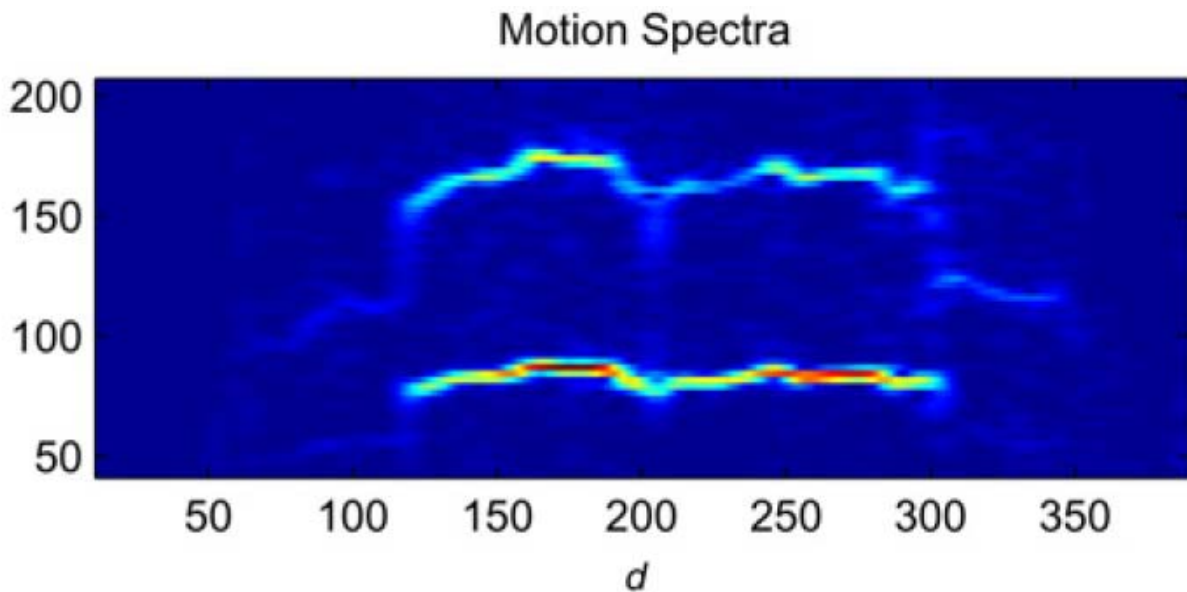
Figure 1 System diagram of proposed method

The proposed method contains four components: preprocessing, signal representation using short-time Fourier transform, detection of PPG and motion peak and rank PPG peaks as potential cardiac signal which outputs a raw heart rate estimate, and the Robust heart rate estimation

(Ex-1005, Fig. 1)



(Ex-1005, Fig. 2c)



(Ex-1005, Fig. 2d)

Thus, Lai discloses this element.

A POSITA further recognize that STFT is a widely known and established method for performing time-varying spectral analysis in signal processing, which captures dynamic changes in frequency content over time. Ex-1002 ¶77.

While Lai primarily describes STFT, the ‘647 Patent itself acknowledges that various time-frequency techniques, including VFCDM, smoothed pseudo Wigner-Ville, and wavelet-based methods, were standard approaches in the field for mitigating motion artifacts and reconstructing PPG signals. Ex-1001, 14:62-15:4. Ex-1002 ¶78.

4. “motion sensor”

[1C], [35C], [69C], [70C], [71C], [72C], [73C], [74C], [75C], the motion signal output by a motion sensor and representative of motion artifacts in the heart-related signal

Lai describes the use of an accelerometer as a motion sensor to detect motion signals that contribute to motion artifacts in PPG-based heart-related signals. Specifically, Lai describes an algorithm that processes streaming PPG and accelerometer data, enabling the detection and mitigation of motion artifacts caused by user movements. Ex-1002 ¶79; Ex-1005, 6; Figs. 1-2.

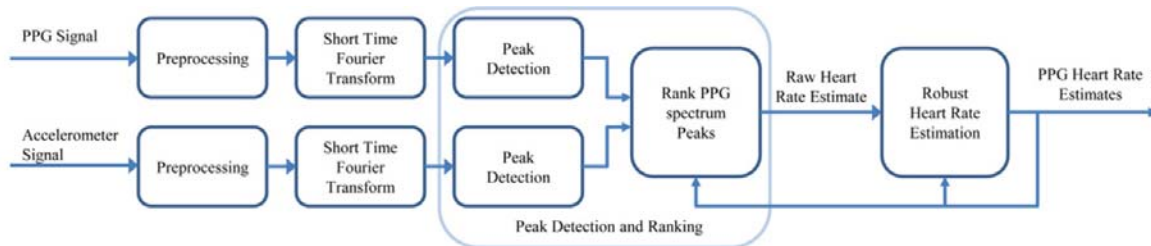
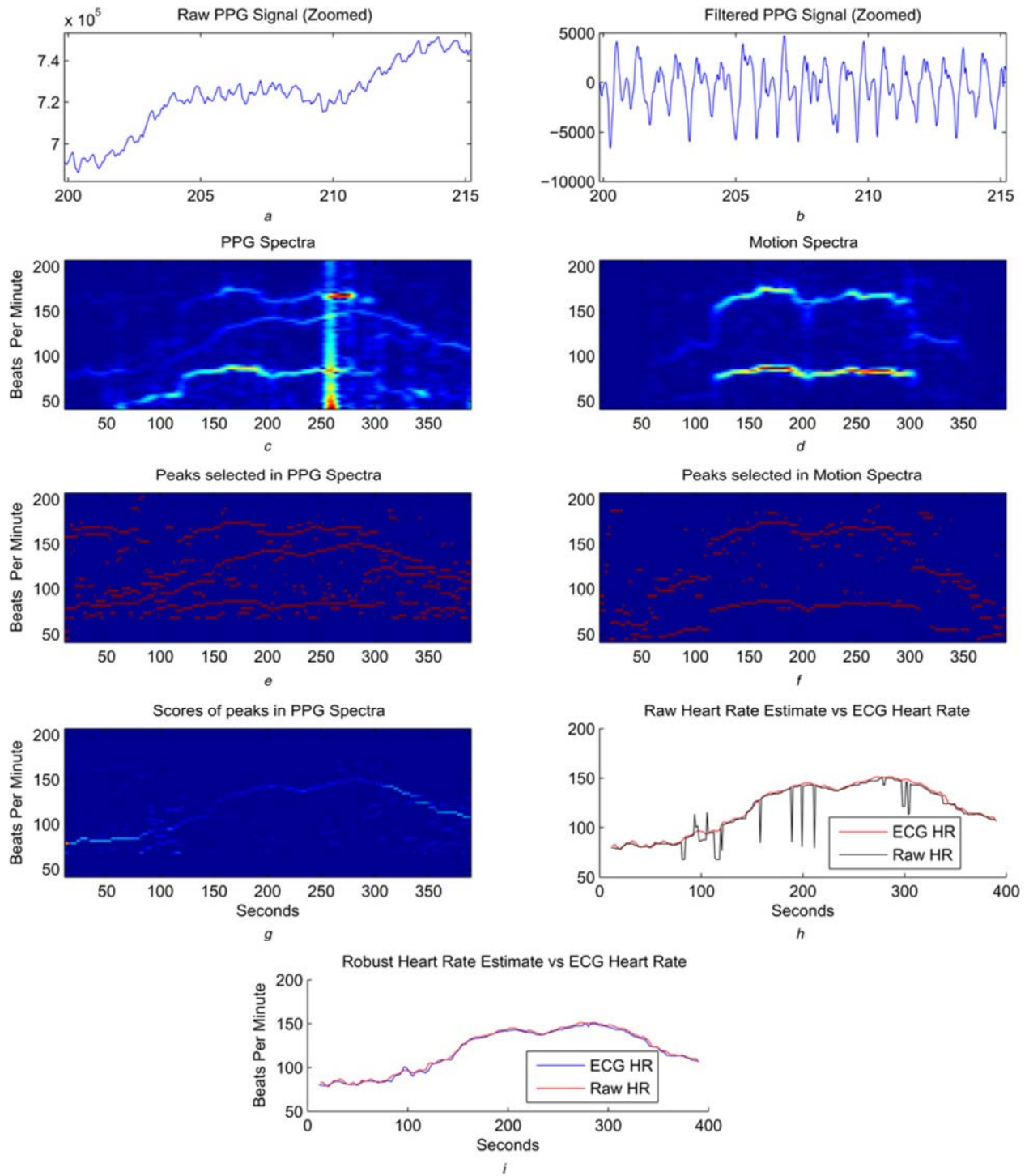


Figure 1 *System diagram of proposed method*

The proposed method contains four components: preprocessing, signal representation using short-time Fourier transform, detection of PPG and motion peak and rank PPG peaks as potential cardiac signal which outputs a raw heart rate estimate, and the Robust heart rate estimation

(Ex-1005, Fig. 1)



(Ex-1005, Fig. 2)

Lai's hardware configuration includes "[t]hree accelerometers," which are used to generate motion signals that characterize motion-induced distortions in PPG signals for removal. Ex-1002 ¶80; Ex-1005, 10.

The '647 Patent acknowledges that accelerometer-based motion signals are widely used to detect and mitigate motion artifacts in PPG signals. It states: "[a]cceleration data are also shown to be helpful to remove MA [motion artifacts]" and describes prior art techniques, which use accelerometer data to filter motion artifacts from PPG signals. Ex-1001, 9:10-22. Ex-1002 ¶81.

A POSITA would recognize an accelerometer as a motion sensor that outputs motion signals is "representative of motion artifacts in the heart-related signal." Ex-1002 ¶82.

Thus, Lai discloses this element.

5. "artifacts produced by movement"

[1D], [35D], [69D], [70D], [71D], [72D], [73D], [74D], [75D] the motion artifacts being signal artifacts produced by movement of the biomedical sensor relative to a sensing location

Lai discusses the susceptibility of PPG signals to motion artifacts caused by the movement of a wrist-worn biomedical sensor relative to the sensing location on the user's skin, explaining that such movement introduces significant distortions in

heart rate estimation due to the high mobility of the user’s arm. Ex-1005, 6. This identifies that the motion artifacts arise from the relative motion of the biomedical sensor (e.g., a smart watch) against the skin’s surface, leading to interference in the recorded PPG signal. Ex-1002 ¶84.

A POSITA would know that Lai’s reference to motion artifacts caused by the mobility of wrist-worn devices describes motion artifacts as signal distortions resulting from the movement of the sensor relative to its sensing location, i.e., the point of contact between the sensor and the user’s skin. Such relative motion is a well-recognised source of noise in PPG signals, requiring methods to mitigate its effects for accurate heart rate estimation. Ex-1002 ¶85.

Thus, Lai discloses this element.

6. “classification”

[1E], [35E], [69E], [70E], [71E], [72E], [73E], [74E], [75E] (ii) a classification of the movement
--

Lai discloses this element. For instance, Lai discloses processes for detecting, analyzing, and ranking components in both the PPG signal and the motion signal, which can reasonably be interpreted “classification of the movement.” Ex-1005, 6. While Lai does not explicitly state that the classification concerns the movement of the biomedical sensor relative to a sensing location,

such motion is inherently described in Lai’s discussion of motion artifacts caused by the movement of a wrist-worn device relative to the user’s skin. Lai states, “PPG is susceptible to motion artefacts, which have to be mitigated for accurate heart rate estimation. Motion artefacts are particularly apparent for wrist devices, for example, a smart watch, because of the high mobility of the arms.” Ex-1005, 6. These motion artifacts arise from the relative motion of the sensor against the sensing location (i.e., the point of contact between the sensor and the user’s skin), and Lai’s algorithm is designed to detect and mitigate such artifacts, thereby implicitly addressing the relative motion of the biomedical sensor. Ex-1002 ¶87.

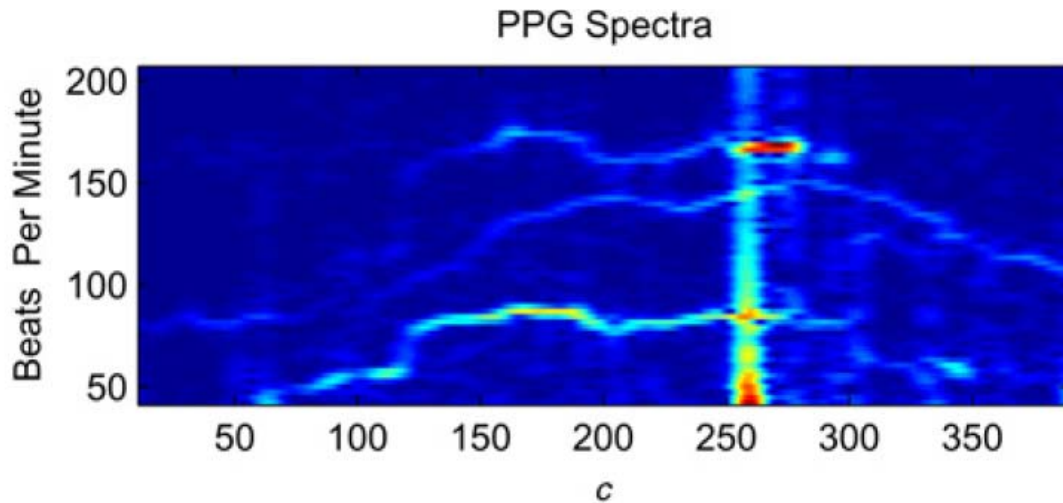
Beyond addressing relative motion, Lai describes a broader process for detecting and classifying the movement that causes motion artifacts. Specifically, Lai discloses “[d]etection and ranking of potential cardiac and motion components,” which involves distinguishing cardiac signals from motion artifacts by analyzing spectral characteristics of both the PPG signal and accelerometer data. Ex-1005, 6-7. Motion artifacts are identified by comparing the motion spectrum (derived from the accelerometer) with the PPG spectrum. Overlapping frequencies, particularly those exhibiting periodic harmonic patterns, are treated as motion-induced artifacts. For example, Lai states, “Motion artefacts corresponding to periodic footsteps and arm movements with harmonics can be recognised by comparing the resulting PPG spectrum and the motion spectrum.” Ex-1005, 6-7.

This artifact detection step establishes whether motion is interfering with the heart-related signal and forms the first part of the classification process. Ex-1002 ¶88.

In addition to detecting artifacts, Lai evaluates the spectral characteristics of the motion signal to infer the nature of the movement causing the artifacts.

Periodic motion, such as rhythmic arm swings or footsteps, is recognized by the presence of harmonics or recurring patterns in the motion spectrum. Ex-1005, 6-7; Fig. 2d and 2f. While Lai does not explicitly describe pseudo-periodic or random motion, a POSITA would understand that the absence of harmonics (broadband noise) corresponds to random motion, while non-perfect harmonics exhibiting variability in their patterns indicate pseudo-periodic motion. Ex-1002 ¶89.

Thus, a POSITA would understand Lai's detection and ranking process as a classification process that fulfills two key objectives: (1) determining whether motion artifacts are present (artifact detection) and (2) evaluating the characteristics of the movement (periodic, pseudo-periodic, or random). These steps allow the algorithm to adapt its artifact mitigation strategies based on the nature of the movement, such as focusing on suppressing harmonics for periodic motion or applying fallback methods (discussed below in Section B.9) for random motion. Ex-1002 ¶90; Ex-1005, Fig. 2c.



(Ex-1005, Fig. 2c)

7. “Pre-Processing”

[1F], [35F], [69F] wherein the time-varying spectral analysis includes pre-processing the heart-related signal to produce a pre-processed heart-related signal, pre-processing the motion signal to produce a preprocessed motion signal

Pre-processing steps in Lai’s algorithm include filtering both raw PPG signals (heart-related signals) and accelerometer signals (motion signals) to produce preprocessed heart-related and motion signals prior to spectral analysis by STFT. Ex-1005, 6; Fig. 1, 2a-2d; Ex-1002 ¶92.

Pre-processing steps, including bandpass filtering of PPG and accelerometer signals, are routine and well-known in the field. A POSITA would recognize that

Lai's algorithm follows these well-established techniques to produce preprocessed heart-related and motion signals for spectral analysis. Ex-1002 ¶93.

Thus, Lai discloses this element.

8. "Computing TFS"

[70F], [71F], [72F], [73F], [74F], [75F] wherein the time-varying spectral analysis includes / [1G], [35G], [69G] computing a first time-frequency spectrum (TFS) of the heart-related signal using the preprocessed heart-related signal and a second TFS of the motion signal using the pre-processed motion signal

Lai discloses that the application of STFT to preprocessed PPG and accelerometer signals, shown in Figure 1, produces time-dependent frequency representations of the signals yield a first TFS of the heart-related signal (PPG) and a second TFS of the motion signal (accelerometer). The first TFS isolates cardiac frequency components, while the second characterizes motion-induced frequency components. Ex-1005 6-7; Figs. 1, 2c, 2d. A POSITA would recognize these time-frequency representations as TFS because STFT inherently computes time-varying frequency content. Ex-1002 ¶95.

As detailed in Section A.7 above, Lai's pre-processing steps filter raw PPG and accelerometer signals to produce refined inputs for spectral analysis. By applying STFT to these preprocessed signals, Lai computes the time-varying

frequency content of each signal. A POSITA would recognize that the resulting time-frequency representations constitute the claimed TFSs, as these were standard outputs of time-varying spectral analysis techniques like STFT. Ex-1002 ¶96.

The ‘647 Patent acknowledges that time-varying spectral analysis inherently involves computing TFSs for heart-related and motion signals. Ex-1001, 39:54-62. This confirms that standard time-frequency techniques, such as VFCDM, smoothed pseudo Wigner-Ville, and wavelet analysis, are routinely applied to compute TFSs for both PPG and accelerometer signals. Ex-1002 ¶97.

A POSITA would recognize that the resulting time-frequency representations constitute the claimed TFSs, as these were standard outputs of time-varying spectral analysis techniques like STFT. *See* Ex-1004 (0938), 2018-04-18 Office Action, pg. 8. (“Chon et al. ‘employ computation of time-frequency spectrum analysis of the signals’ and ‘demonstrates that this is a suitable technique for removing artifacts from a heart related signal. Modification is considered to comprise application of a known technique to a known process to yield a predictable result.’”); Ex-1002 ¶98.

Thus, Lai discloses these elements.

9. “Outputting” / “Output Unit”

[1H], [69H], [70F], [71G], [72F] outputting / [35H], [73G], [74G], [75H] an output unit configured to output the reconstructed representation of the heart-related signal.

Lai outputs “raw heart rate” and “PPG heart rate estimates,” derived from processed PPG data, which constitute representations of reconstructed heart-related signals obtained after Lai’s algorithm processes the PPG and motion signals. For example, Figure 1 depicts these outputs as the result of an algorithm that takes streaming PPG and accelerometer signals as inputs. Ex-1005, 7-8; Fig. 1. Lai further discloses the ability to transmit data to external devices, such as mobile devices or laptops. These external devices function as output units by displaying, storing, or processing the reconstructed heart-related signals. Ex-1005, 10. A POSITA would recognize such common established hardware components in physical monitoring systems as functional equivalents to an “output unit.” Ex-1002 ¶100-101.

Thus, Lai discloses these elements.

B. Dependent Claims 2-34 and 36-68 are Obvious in View of Lai (Ex-1005)

1. “Artifacts are Suppressed”

[2] The method of claim 1, / [36] The apparatus of claim 35, wherein the motion artifacts are suppressed in the reconstructed representation of the heart-related signal.

Lai discusses suppression of motion artifacts during signal reconstruction through preprocessing steps and time-varying spectral analysis. As detailed in Section A.2 above, Lai’s algorithm filters raw PPG signals to remove baseline drift and DC components and uses STFT to separate cardiac frequencies from motion-induced components. Ex-1005, Fig. 2a-2i (illustrating the reconstruction process); Ex-1002 ¶103.

Figures 2c and 2d demonstrate the identification of motion artifacts in the spectral domain by comparing PPG and accelerometer data and suppressing these artifacts through frequency-domain separation. This process ensures that the cardiac frequency components remain dominant in the final representation of the heart-related signal. Ex-1005, 6; Ex-1002 ¶104.

A POSITA would understand the final output of Lai’s algorithm, described as a “robust heart rate estimate,” as being derived from raw PPG signals that have been processed to suppress motion artifacts and isolate physiologically relevant

cardiac components, thus reflecting the claimed reconstructed representation of the heart-related signal. Ex-1002 ¶105.

Thus, Lai discloses these elements.

2. “Average of Peak-to-Peak Intervals”

[3] The method of claim 1, / [37] The apparatus of claim 35, wherein: in an event the classification indicates that the movement does not rise to a level causing the motion artifacts, the reconstructed representation is based on an average value of peak-to-peak intervals in the pre-processed heart-related signal.

As explained in Section A.6, Lai’s algorithm involves classifying the movement by detecting motion artifacts and assessing the nature of the motion. For movements that do not rise to a level causing motion artifacts, Lai describes scenarios where the PPG spectra show no “apparent motion artefacts” Ex-1005, 6. In such instances, a POSITA would recognize that the periodicity of the cardiac waveform, where each peak in the PPG signal corresponds to a heartbeat, is intact. This periodicity enables the use of peak-to-peak interval averaging as a computationally efficient and well-known time-domain method for reconstructing the heart-related signal and calculating heart rate. Ex-1002 ¶107.

The ‘647 Patent acknowledges various other fallback strategies such as averaging techniques. Ex-1001, 26:50-51 (“simply us[ing] a moving average of

several past HR beats or some other variant”). This confirms that averaging techniques, including peak-to-peak interval averaging, were well-understood and widely used in signal reconstruction. Ex-1002 ¶108.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

3. “Filtering”

[4], [38] wherein the pre-processing includes filtering the heart-related signal and the motion signal to produce a filtered heart-related signal / [17] [51] and a filtered motion signal, respectively, / the filtered heart-related signal being the pre-processed heart-related signal and the filtered motion signal being the pre-processed motion signal

As detailed in Section A.7 above, Lai’s routine pre-processing steps include filtering both the PPG and the motion signal resulting in filtered signals. Ex-1005, 6. Ex-1002 ¶111. Thus, Lai discloses these elements.

4. “Down-Sampling”

[5], [18], [39], [52] wherein the pre-processing further includes down-sampling the filtered heart-related signal, the down-sampling being at a sampling rate less than an original sampling rate

Lai describes down-sampling in a preprocessing pipeline that, as detailed in Section A.7, applies a bandpass filter to raw PPG signals to remove baseline drift and noise. Following this, the sampling rate of the filtered signal is reduced by factors of 5 or 10 to optimize computational efficiency. Ex-1005, 6; Ex-1002 ¶114.

A POSITA would recognize down-sampling the heart-related signal at a rate less than the original sampling rate is a routine step in digital signal processing and commonly used for efficiency and signal integrity purposes (e.g., anti-aliasing). *See also* Ex-1004 (0935-0936), 2018-04-18 Office Action, 5-6 (“to downsample the sampling rate is considered obvious”); Ex-1002 ¶115.

Thus, Lai discloses this element.

5. “3-Dimensional Spectra”

[6], [40] wherein the first TFS computed and the second TFS computed are 3-dimensional spectra, the first TFS computed and the second TFS computed each including a respective time-varying amplitude or power distribution with respect to time and frequency
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As detailed in Section A.8 above, Lai’s TFS analysis involves using STFT to compute first and second time-frequency representations of respective filtered PPG and accelerometer signals. Ex-1005, 6. Figure 2c in Lai shows the TFS of the PPG signal, while Figure 2d depicts the TFS of the motion signal. Both spectra are

plotted with respect to time and frequency, with varying intensities (visualized as colors) that represent amplitude (or power) at specific time-frequency coordinates. *Id.*; Fig. 2c, 2d; Ex-1002 ¶117.

A POSITA would recognize these plots as 3-dimensional spectra, where the three axes (time, frequency, and amplitude or power) are simultaneously represented; *see also* Ex-1004 (0938), 2018-04-18 Office Action, at 8 (“[t]hree-dimensional spectra is also considered to be within routine skill in the art”). Ex-1002 ¶118.

Thus, Lai discloses this element.

6. “TFS is PSD”

[7] The method of claim 1, / [41] The apparatus of claim 35, wherein the first TFS computed is a first time-varying power spectral density (PSD) and the second TFS computed is a second time-varying PSD.

In Lai, PPG and motion spectra, plotted with respect to time and frequency, use color intensity to represent amplitude or energy at specific time-frequency coordinates. Ex-1005, Fig. 2c, 2d. A POSITA would recognize that while Lai refers to these visualizations as “energy” distributions, energy and power are directly related in signal processing. Accordingly, a POSITA would recognize them as 3-dimensional spectra where the axes represent time, frequency, and

power and, thus, displays of time-varying power distributions that directly correspond to the claimed first and second TFSs as time-varying PSDs. Ex-1002 ¶120.

The ‘647 Patent itself confirms that TFSs are computed using well-known time-frequency techniques, such as VFCDM, smoothed pseudo Wigner-Ville, or wavelet-based methods. Ex-1001, 15:1-4. The same techniques were also standard in producing PSDs. *Id.*, 19:57-64 (“computing a window-segmented power spectral density of both PPG and accelerometer signals in real-time) (internal citations omitted). This further reinforces that time-varying power distributions, such as those demonstrated in Lai’s Figures 2c and 2d, are expected outputs of these techniques. Ex-1002 ¶121.

Thus, Lai discloses these elements.

7. “Pseudo-Periodic, Periodic, Random Movement”

[8A], [70H], [42A], [73H] wherein the reconstructed representation is a current reconstructed representation and wherein, based on the classification indicating that the movement does rise to a level causing the motion artifacts and is a pseudo-	[21], [55] wherein, in an event the result indicates that the movement does rise to the level causing the motion artifacts, classifying the classification of the movement further includes determining whether the movement is either a pseudo-periodic
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periodic movement or a periodic movement	movement or a periodic movement, versus a random movement.
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Lai explains that “motion artefacts corresponding to periodic footsteps and arm movements with harmonics can be recognised by comparing the resulting PPG spectrum and the motion spectrum” and describes a process for separating cardiac components from motion artifacts based on signal characteristics derived from the spectral analysis of PPG and accelerometer data. Ex-1005, 6-7; Figs. 2c, 2d; Ex-1002 ¶123.

As discussed in Section A.6 above, Lai’s detection and ranking process serves as a classification of the movement. A POSITA would recognize that the structured harmonic patterns in the accelerometer spectrum, such as those caused by rhythmic steps or swings, correspond to periodic motion. Similarly, motion with approximately structured but irregular harmonic patterns would be understood as pseudo-periodic motion, while the absence of harmonics or structured patterns would suggest random motion, which the ‘647 Patent defines as “non-periodic movements.” Ex-1001, 17:24-26. Thus, the classification distinguishes periodic or pseudo-periodic movements that cause significant motion artifacts from random movements, which are less likely to interfere with the heart-related signal. Ex-1002 ¶124.

Lai further describes reconstructing the heart-related signal based on this classification. For movements classified as periodic or pseudo-periodic, the algorithm mitigates motion artifacts by isolating cardiac components in the PPG spectrum while suppressing motion-correlated peaks identified in the accelerometer spectrum. Ex-1005, 6-7; Fig. 1, 2i. This reconstruction process dynamically updates the current representation of the heart-related signal, producing what Lai refers to as a “robust heart rate estimate,” free from motion-induced distortions. Ex-1002 ¶125.

A POSITA would understand that Lai’s algorithm applies this classification of motion patterns during the reconstruction process by analyzing TFS derived from the PPG and accelerometer signals. A comparison of spectral characteristics allows the system to identify and categorize motion-induced components, suppressing those corresponding to periodic or pseudo-periodic movements to produce a “current reconstructed representation” of the heart-related signal, consistent with the claim language. Ex-1002 ¶126.

Thus, Lai discloses these elements.

8. “Peak’s Corresponding Frequency in TFS”

[8B], [70I] the reconstructing includes: / [42B], [73I] to reconstruct the representation includes: determining whether at least one spectral peak is present having a corresponding frequency within a given frequency range at a
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point in time in the first TFS computed, the current reconstructed representation being reconstructed for the point in time

Figure 2c in Lai illustrates the TFS of the PPG signal, showing spectral peaks at specific points in time and frequency that correspond to a heart rate frequency range chosen based on human heart rates (e.g., 0.5-3 Hz). This TFS directly corresponds to the claimed “first TFS computed” and the claim’s requirement to determine whether a “spectral peak is present.” A POSITA would understand that Lai’s analysis inherently determines whether at least one spectral peak is present within this frequency range for each time segment of the TFS. Ex-1002 ¶128.

While Lai’s use of spectral peaks is a segment-wise analysis, a POSITA would understand that each identified peak corresponds to a specific time point within the TFS. For instance, when a spectral peak is identified as corresponding to a heart rate frequency, Lai’s algorithm reconstructs the signal for that point in time, yielding its robust heart rate estimate. Thus, Thus, Lai discloses the claimed elements of determining spectral peaks in the first TFS computed and reconstructing a representation for the corresponding point in time. Ex-1002 ¶129.

Thus, Lai discloses these elements.

9. “Prior Reconstructed Representation”

[8C], [70J] / [42C] [73J] wherein, based on a determination that the at least one spectral peak is not present, the reconstructed current representation is based on a prior reconstructed representation, the prior reconstructed representation associated with a previous point in time in the first TFS computed

As the ‘647 Patent states, “where HR is not detectable in the window ... embodiments disclosed herein may take a previous window’s HR value as the current HR (or simply use a moving average of several past HR beats or some other variant).” Ex-1001, 26:44-51. This acknowledgment of interchangeable fallback methods, including referencing prior HR values or applying moving averages to ensure signal continuity and accuracy, especially in cases where no valid spectral peaks are detected for a current time window, reflects a widely accepted practice in the field of physiological signal reconstruction. Ex-1002 ¶130 (stating that fallback mechanisms are routine and well-known in the field).

A POSITA would recognize that basing a current reconstructed representation on a prior reconstructed representation associated with an earlier time point—or applying other fallback strategies, such as, e.g., mathematical interpolation—are logical and routine for ensuring the signal’s continuity. Ex-1002 ¶132.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

10. “0.5-3 Hz”

[9], [11], [43], [45] wherein the given frequency range is 0.5 Hz to 3 Hz.
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As detailed in Section A.8, Lai discloses detecting spectral peaks within a known physiological heart rate frequency range, focusing on “the frequency range within which human heart rate falls.” Ex-1005, 6. A POSITA would interpret this range to correspond to the cardiac frequency range of 0.5-3 Hz, as it encompasses the physiological limits of heart rates, from bradycardia (slow heart rates, ~30 bpm or 0.5 Hz) to tachycardia during intense exercise (fast heart rates, ~180 bpm or 3Hz). Ex-1002 ¶134.

In fact, the ‘647 Patent acknowledges that “defined HR range (30-180 bpm)” of “0.5 Hz to 3 Hz ... is typically the HR frequency range accounting for both normal and elevated heart rates.” Ex-1001, 25:61-62; 36:25-28. It explicitly states that this frequency range “takes into account both at rest and high HR due to either tachycardia or exercise scenarios” and confirms that “for HR estimation, the strategy is to eliminate frequencies that are outside of this HR frequency range as they are most likely due to motion artifacts or harmonics of the FIR [sic HR] frequency.” Ex-1001, 36:25-33. Ex-1002 ¶¶135-136.

A POSITA would recognize that narrowing the frequency range represents a well-known design choice aimed at optimizing computational efficiency, as this approach filters out irrelevant frequencies, while retaining only those spectral peaks most relevant to heart rate detection and estimation. This also aligns with Lai’s disclosure of isolating cardiac spectral peaks for robust heart rate estimation, which focuses on physiologically relevant HR frequencies. Ex-1005, 6; Ex-1002 ¶137.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

11. “Retaining, Discarding”

[10], [44], [71H], [74H] wherein the reconstructing includes: retaining up to a pre-determined number of candidate spectral peaks located at a first point in time in the first TFS computed, the candidate spectral peaks retained based on having corresponding frequencies within a given frequency range and highest amplitude or power values relative to other spectral peaks located at the first point in time, the other spectral peaks having respective frequencies within the given frequency range; and discarding each of the candidate spectral peaks retained that is associated with a same frequency as a dominant spectral peak located at a second point in time in the second TFS computed, the first point in time and the second point in time having same time values.

Lai discloses comparing peaks retained in the PPG spectrum (first TFS) with peaks in the motion spectrum (second TFS) to identify and suppress motion artifacts. Ex-1005, 6-7; Fig. 2. For each time point, Lai's process involves identifying spectral peaks in the PPG spectrum with the highest amplitude or power values relative to other peaks within the cardiac frequency range. A POSITA would understand that these retained peaks are most likely to represent cardiac components. The retention ensures that only the most relevant spectral peaks are preserved for further analysis. Ex-1002 ¶139.

The comparison involves identifying dominant motion-induced peaks in the accelerometer spectrum (second TFS), which are defined by their largest amplitude or power values in the motion spectrum. Peaks in the PPG spectrum that coincide in frequency with these dominant motion-induced peaks are discarded as motion artifacts. Ex-1005, 6-7. Figure 2 shows “three motion peaks with highest peak” in the motion spectrum, illustrating how these dominant peaks, caused by periodic movements, are compared to the PPG spectrum to identify and remove motion artifacts. This comparison enables time-matched evaluation, facilitating the removal of motion artifacts by discarding PPG peaks that align with dominant motion-induced peaks at the same time point. *Id.*, Fig. 2f; Ex-1002 ¶¶140-141 (stating that identifying and removing spectral peaks corresponding to motion

artifacts by aligning them with acceleration spectra, is routine and well-known in the field).

A POSITA would recognize that this process equally applies to methods for discarding motion-induced peaks to isolate cardiac components and, thus, corresponds to the claim requirement of retaining spectral peaks in the PPG spectrum based on their amplitude or power and, subsequently, discarding peaks that match dominant motion-induced peaks in the motion spectrum. Motion-induced dominant peaks, which have the largest amplitude or power values, are prioritized for suppression because they represent the most significant contributors to motion artifacts. Ex-1002 ¶141.

Thus, Lai renders this element obvious in light of the common knowledge in the art.

12. “Prior Reconstructed Representation”

[12] The method of claim 10, / [46] The apparatus of claim 44, wherein the representation is a current representation, wherein the reconstructed representation is a current reconstructed representation, and wherein, in an event the discarding discards each of the candidate spectral peaks retained, reconstructing the current representation is based on a prior reconstructed representation, the prior reconstructed representation associated with a previous point in time in the first TFS computed, the previous point in time being an earlier point in time with respect to the first point in time.

As previously analyzed, Lai’s PPG spectrum corresponds to the claimed “first TFS computed” and Lai discloses both “wherein the reconstructed representation is a current reconstructed representation” and basing a current reconstructed representation on a prior reconstructed representation associated with an earlier time point. See Sections A.7-A.9, B.7-B.9 above.

In instances where all candidate spectral peaks in the PPG spectrum are discarded due to noise or motion artifacts, a POSITA would reasonably interpret Lai’s reconstruction to fall back on prior reconstructed representations associated with earlier time windows in the first TFS computed (i.e., the PPG spectrum) to ensure signal continuity when generating its robust heart rate estimation. This fallback involves reverting to the most recent prior reconstructed representation (i.e., a signal derived from a previous point in time relative to the current point being processed in the first TFS), as supported by the ‘647 Patent and well-established practices recognised by a POSITA. See Sections B.2 and B.9 above (‘647 Patent suggesting “simply us[ing]” available fallback strategies as alternatives); Ex-1002 ¶145.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

13. “Second Discarding”

[13] The method of claim 10, / [47] The apparatus of claim 44, wherein the discarding is a first discarding and wherein the representation is a current representation and, wherein, in an event the first discarding results in at least one remaining candidate spectral peak retained, reconstructing the current representation further includes: second discarding, wherein the second discarding discards remaining candidate spectral peaks, of the at least one remaining candidate spectral peak retained, based on whether a corresponding frequency of the at least one remaining candidate spectral peak retained is distanced by at least a frequency difference threshold from a prior reconstructed representation’s frequency, the prior reconstructed representation associated with a previous point in time in the first TFS computed, the previous point in time being an earlier point in time with respect to the first point in time.

A POSITA would recognize that Lai’s “first discarding” corresponds to the discarding detailed in Sections B.11 and B.12 above, where motion-induced artifacts are removed from cardiac-relevant spectral peaks by comparing candidate peaks in the PPG spectrum (first TFS) against dominant peaks in the accelerometer spectrum (second TFS). As discussed, this comparison ensures that motion-correlated peaks, such as those caused by periodic footsteps or arm movements, are identified and discarded by isolating cardiac-relevant components in the PPG spectrum, thus, achieving a refined set of candidate peaks for further analysis. Ex-

1005, 6-7. This process directly corresponds to the claim’s description of first discarding. Ex-1002 ¶148.

A POSITA would recognize that this comparison step directly corresponds to the claim’s description of first discarding by eliminating peaks associated with motion-induced frequencies and refining the retained set. Ex-1002 ¶142.

Regarding the “second discarding” mechanism, Lai further supports a refinement process that ensures temporal consistency across reconstructed representations. A POSITA would understand that abrupt changes in heart rate are physiologically implausible under normal conditions and likely indicate noise or artifacts. Thus, discarding candidate peaks that deviate beyond a defined threshold from prior reconstructed HR values ensures that outlier peaks caused by noise or artifacts are excluded. Ex-1002 ¶150.

The ‘647 Patent acknowledges the use of prior reconstructed representations or averages as fallback methods. Ex-1001, 26:47-51; 61-67; 27:1-3 (even in cases where a HR spectral peak is detectable, but “the difference between its value and that of the previous HR is more than 10 bpm” that HR may be replaced “by the most recent HR value from a previous window segment (or a moving average of several past HR beats or some other variant”). Ex-1002 ¶151.

By equating these methods—relying on the most recent HR data or a calculating moving average—the ‘647 Patent confirms that such interchangeable

options represent routine and well-known fallback strategies in the field for ensuring robust HR reconstruction. Ex-1002 ¶152.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

14. “Discarded by Second Discarding”

[14A] The method of claim 13, / [48A] The apparatus of claim 47, wherein: based on each of the at least one remaining candidate spectral peak retained having been discarded by the second discarding, reconstructing the current representation is based on the prior reconstructed representation

The fallback mechanisms detailed in Sections B.12 and B.13 above, where the reconstructed representation uses a prior reconstructed representation when no valid spectral peaks remain, directly apply here. A POSITA would understand that a second discarding process, which removes peaks deviating beyond a threshold from prior reconstructed values, can result in all remaining candidate spectral peaks (i.e., each of the at least one remaining candidate spectral peak [sic]) being discarded. Ex-1002 ¶154 (stating that discarding processes that remove peaks deviating beyond a threshold from prior reconstructed values are routine and well-known in the field).

A POSITA would therefore understand that when no valid peaks remain after the second discarding—similar to after the first discarding—Lai’s reconstruction process can ensure continuity and robustness by referring to prior data, using the same fallback strategies described in Section B.12 above. Ex-1002 ¶156.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

15. “Closest Frequency”

[14B], [48B] based on at least one last candidate spectral peak remaining, the at least one last candidate spectral peak remaining not discarded by the second discarding, reconstructing the current representation is based on a selected candidate spectral peak selected from amongst the at least one last candidate spectral peak remaining having a closest corresponding frequency to the prior reconstructed representation’s frequency relative to respective frequencies of each of the at least one last candidate spectral peak remaining.

The ‘647 Patent confirms that “an accurate HR may be estimated by selecting the components that match closest to the actual HR frequency,” which demonstrates that estimating and selecting the appropriate candidate peak based on proximity to prior reconstructed values was a well-understood practice in the field. Ex-1001, 36:32-33. Ex-1002 ¶158.

Further, as detailed in Sections B.12 to B.14 above, Lai discloses fallback mechanisms that address situations where no valid spectral peaks remain after the second discarding process. These mechanisms rely on prior reconstructed representations to ensure signal continuity and maintain physiologically plausible outputs. Ex-1002 ¶159.

Selecting the peak closest to a prior reconstructed frequency is routine and well-known in the field. A POSITA would understand that, for any “remaining” candidate peaks—those non-distant peaks that fall within the threshold frequency range—selecting the peak closest to a prior reconstructed frequency is a logical and routine approach for ensuring signal continuity and robustness of the reconstructed representation. *Id.*

Thus, Lai renders this element obvious in light of the common knowledge in the art.

16. “Largest Power/Amplitude”

[15] The method of claim 10, / [49] The apparatus of claim 44, wherein the dominant spectral peak has a largest power or amplitude value relative to other peaks located at the second point in time in the second TFS.
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Lai explains that motion-induced components, such as those from periodic footsteps or arm movements, are identifiable in the motion spectrum, where

prominent peaks corresponding to these periodic movements are compared against the PPG spectrum for artifact suppression. Ex-1005, 6-7; Ex-1002 ¶159.

While Lai does not explicitly state that these peaks are the largest in amplitude or power, a POSITA would recognize that dominant peaks in the motion spectrum are typically the ones with the largest amplitude or power values in the spectrum, as they represent the primary periodic motion frequency. For example, Figure 2f illustrates “three motion peaks with highest peak,” showing how dominant motion-induced peaks in the accelerometer spectrum are identified and subsequently compared to peaks in the PPG spectrum for motion artifact suppression. Ex-1005, Fig. 2f; Ex-1002 ¶160 (stating that dominant peaks, identifiable by the largest amplitude or power values, are routinely used to align with PPG peaks during artifact suppression).

The ‘647 Patent confirms that “the largest frequency peak ... represents the fundamental frequency.” Ex-1001, Table 2. It further confirms the significance of identifying dominant motion-induced peaks for artifact removal, explaining that coherence between the spectral peaks of the PPG and motion signals indicates noise contamination, requiring those peaks to be discarded. *Id.*, 26:44-51; 20:33-36. This corresponds to Lai’s disclosure of comparing dominant peaks in the motion spectrum to PPG peaks for effective artifact removal. Ex-1002 ¶165.

A POSITA would understand that Lai’s method of leveraging dominant spectral peaks—i.e., motion spectrum peaks having the largest power or amplitude—directly corresponds to the claimed element, as targeting the most significant motion-induced frequencies is not only routine but logical, as it ensures robust suppression of motion artifacts. Ex-1002 ¶166.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

17. “Classification Indicating; Peak Present”

[16] The method of claim 10, / [50] The apparatus of claim 44, wherein the retaining and the discarding are based on: the classification indicating that the movement is a pseudo-periodic movement or a periodic movement; and determining that at least one spectral peak with a corresponding frequency in the given frequency range is present at the first point in time.

As detailed in Sections A.6-A.7 above, Lai discloses classifying motion types into periodic, pseudo-periodic, or random movements based on structured patterns in the accelerometer spectrum. The classification directly informs the retaining and discarding processes by identifying whether motion artifacts stem from periodic or pseudo-periodic movements, which necessitate targeted suppression. Ex-1002 ¶168.

Further, as detailed in Section B.8 above, Lai also discloses determining whether at least one spectral peak is present in the cardiac frequency range of the PPG spectrum at a given point in time. By focusing on peaks within the physiological heart rate range, Lai’s method identifies valid cardiac-related components. Ex-1005, 6-7; Fig. 2c.

These steps—classification of motion patterns and identification of spectral peaks—are inherently interconnected. The classification step distinguishes between motion patterns (e.g., periodic or pseudo-periodic), which informs the subsequent retention or discarding of spectral peaks. For instance, motion artifacts caused by periodic movements, such as rhythmic footsteps or arm swings, can be detected in the accelerometer spectrum and used to suppress corresponding peaks in the PPG spectrum. Ex-1005, 6-7; Ex-1002 ¶¶169-170.

Therefore, a POSITA would recognize that Lai discloses the classification of motion types and the retention or discarding of spectral peaks based on their relevance to cardiac signals. Ex-1002 ¶171.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

18. “Amplitude Modulation”

[19], 72[G] classifying the classification of / [53], [75G] a classification unit, the classification unit configured to: classify the movement by comparing an amount
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of amplitude modulation in the second TFS computed to an amplitude modulation threshold, wherein the classification indicates whether the movement rises to a level of causing the motion artifacts based on a result of the comparing.

Although Lai's classification utilizes a frequency closeness measure, which is compared to a predefined threshold (parameter C_m) to determine whether a PPG is influenced by motion artifacts, rather than explicitly computing amplitude modulation (AM), a POSITA would recognize that AM is a well-known method for analyzing signal variations and is inherently represented in time-frequency analysis through spectral energy changes over time. As stated in Section B.6 above, Lai already calculates spectral energy values, which correspond to amplitude-related variations in the second TFS. The thresholding mechanism Lai employs to remove irrelevant or fluctuating spectral components can logically be extended to include AM analysis. A POSITA, aware of standard practices in the field, would find it routine to apply AM analysis techniques to directly compare an amount of amplitude modulation in the second TFS to a predefined threshold. Such an analysis would classify whether the motion rises to a level causing motion artifacts, consistent with the claimed method. Ex-1002 ¶173.

Further, a POSITA would recognize this classification process as corresponding to the claimed "classification unit," functionally implemented to

perform the determination. Therefore, Lai’s method logically encompasses the claimed classification process based on AM analysis. Ex-1002 ¶174.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

19. “Sensor Type”

[25] The method of claim 21, / [54] The apparatus of claim 53, wherein the amplitude modulation threshold is dependent on a type of the motion detector sensor.

A POSITA would understand that the selection of the AM threshold inherently depends on the type of motion sensor used, including, for example, manufacturer-specific sensor sensitivities caused by inherent variances in design or design type (e.g., accelerometer vs. gyroscope), as such characteristics define the amount of signal AM and thus the sensitivity to motion artifacts. Ex-1002 ¶176.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

20. “Identifying 3 Frequencies”

[22A] The method of claim 21, / [56A] The apparatus of claim 55, wherein, in determining whether the movement is either the pseudo-periodic movement or the periodic movement, versus the random movement includes, the method further includes:
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identifying a first, second, and third frequency associated, respectively, with a first, second, and third spectral peak in the second TFS at a point in time in the second TFS, the first, second, and third peaks having largest power or amplitude values relative to other peaks in the second TFS at the point in time, the first spectral peak being a largest spectral peak amongst the first, second, and third spectral peaks

As detailed in Sections B.7 and B.16, Lai teaches “determining whether the movement is either a pseudo-periodic movement or a periodic movement” and that “the dominant spectral peak has a largest power or amplitude value relative to other peaks located at the second point in time in the second TFS.” A POSITA would understand that periodic motion is characterized by a dominant peak and harmonically related secondary peaks, while pseudo-periodic motion exhibits slightly irregular yet structured patterns. In contrast, random motion lacks coherence and displays irregular or broadband energy distributions. Ex-1002 ¶178.

Further, Lai ranks spectral peaks based on their amplitude or power. Figures 2e and 2f illustrate the detection of peaks with the highest energy, noting that “three motion peaks with the highest peak” represent how “motion leads to high energy in both channels.” Ex-1005, Fig. 2e, 2f. A POSITA would interpret this as corresponding to the claimed “first, second, and third peaks having largest power

or amplitude values relative to other peaks in the second TFS at the point in time,” with “the first spectral peak being a largest spectral peak” among them. Ex-1002 ¶179.

The identification and ranking of these peaks facilitate classification of movement types by analyzing the coherence and harmonic structure of the motion spectrum. This classification aligns with the ‘647 Patent’s confirmation that structured patterns in motion spectra indicate repetitive activities causing motion artifacts. Ex-1001, 17:24-26; Ex-1002 ¶180.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

21. “First, Second Ratio”

[22B], [56B] computing a first ratio of the second frequency identified to the first frequency identified and determining a first comparison result by comparing the first ratio computed to a first ratio value; and computing a second ratio of the third frequency identified to the first frequency identified and determining a second comparison result by comparing the second ratio computed to a second ratio value, wherein the classification further indicates that the movement is either the pseudo-periodic movement or the periodic movement, versus the random movement, based on the first comparison result and the second comparison result.

Lai identifies dominant spectral peaks in the motion spectrum based on amplitude (or power), explaining that repetitive activities, such as footsteps or arm

movements, produce structured patterns with harmonics. Ex-1005, 6-7 (“Motion artefacts corresponding to periodic footsteps and arm movements with harmonics can be recognisedrecognised by comparing the resulting PPG spectrum and the motion spectrum”). A POSITA would recognize that these harmonics manifest as consistent frequency relationships between dominant peaks, providing a clear basis for distinguishing periodic or pseudo-periodic motion from random motion, which lacks such structured coherence. Ex-1002 ¶183.

The ‘647 Patent acknowledges that repetitive movements “can result in predominately either one or two dominant peaks depending on the severity of repetitive motions,” while non-repetitive, i.e., random, motion artifacts appear as “a broadband spectrum without a dominant peak.” Ex-1001, 26:43-48. A POSITA would recognize that repetitive (periodic or pseudo-periodic) movements produce harmonics that manifest as integer frequency ratios between peaks (e.g., 2:1 or 3:1). Conversely, incoherent (random) motion patterns yield non-integer ratios. Ex-1002 ¶184.

Thus, a POSITA would recognize that applying standard signal processing techniques to verify integer-ratio relationships among the dominant spectral peaks identified by Lai is a logical and routine method for distinguishing harmonic patterns indicative of periodic or pseudo-periodic motion from random motion. A POSITA would further recognize cross-checking frequency ratios (e.g., second-to-

first and third-to-first peak ratios) as a useful tool in confirming harmonic relationships as it enhances reliability by minimizing the risk of misclassification (e.g., due to noise or transient artifacts). Additionally, the second ratio allows for precise differentiation of pseudo-periodic motion, which may slightly deviate from perfect integer ratios, from both periodic and random movements. Ex-1002 ¶185.

Thus, Lai renders this element obvious in light of the common knowledge in the art.

22. “Ratio Value”

[23] The method of claim 1, / [57] The apparatus of claim 56, the first ratio value is 2 and the second ratio value is 3.

As detailed in B.21, identifying integer-ratio relationships among dominant spectral peaks in Lai is a routine method for detecting periodic or pseudo-periodic motion. A POSITA would recognize that selecting specific ratio values to compare spectral peaks that represent the fundamental frequency and its higher order harmonics is a straightforward and logical choice; *see also* Ex-1001, Table 1 (confirming that 2:1 and 3:1 ratios are reasonable “assumption[s]”). Ex-1002 ¶¶187-189.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

23. “Average Value”

[24A] The method of claim 1, / [58A] The apparatus of claim 55, wherein, in an event the classification of the movement indicates random movement, the reconstructing includes:

computing an average value of a number of prior reconstructed representations outputted prior to the reconstructing, the number based on a duration of consecutive motion artifacts, detected prior to the reconstructing.

As detailed in Section B.9 above, Lai discloses that for random movements, i.e., “where HR is not detectable in the window,” fallback mechanisms rely on prior reconstructed representations, such as using the “previous window’s HR value.” Ex-1005, 6-7; Ex-1001, 36:25-34. Additionally, the ‘647 Patent confirms that averaging prior reconstructed values, e.g., through a “moving average of several past HR beats or some other variant,” is a routine and well-established practice in the field. A POSITA would recognize that applying a moving average, particularly for durations of consecutive motion artifacts, logically extends these fallback strategies to ensure robust and continuous signal reconstruction under random movement conditions. Ex-1002 ¶191.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

24. “Bandpass Filter, Pre-Processing, Average Value”

[24B], [58B] computing a bandpass filter cutoff frequency based on the average value computed; filtering the preprocessed heart-related signal by applying the band pass filter computed to produce a filtered, pre-processed heart-related signal; and wherein the reconstructed representation is based on an average peak-to-peak interval value of the filtered, pre-processed heart-related signal.

As detailed in Section B.9, fallback mechanisms relying on prior reconstructed values, such as applying a moving average, are well-documented. Similarly, bandpass filtering is a routine pre-processing step for PPG and accelerometer signals, widely used to isolate physiologically relevant components and remove noise or motion artifacts. See Section A.7 above. For example, bandpass filtering is applied to remove baseline drift and focus on the cardiac frequency range of 0.5 to 30 Hz (corresponding to heart rates of 30-180 bpm). See Section B.10 above; Ex-1002 ¶193.

The ‘647 Patent confirms that “[t]here are a number of general techniques used for artifact detection and removal. One of the methods used to remove motion artifacts is adaptive filtering” and acknowledges that “[a]n adaptive filter is easy to implement”). Ex-1001, 7:65-68 through 8:1; 8:12-13. A POSITA would recognize that using a moving average of prior HR values to compute the bandpass filter cutoff frequency enables the filter to dynamically adapt to the most likely heart rate

range, thereby minimizing the influence of noise and motion artifacts. Ex-1002 ¶194.

Integrating these approaches reflects standard practices in signal processing. As the reconstructed representation is based on the average peak-to-peak interval of the filtered, pre-processed heart-related signal, a POSITA would recognize that bandpass filtering improves signal fidelity by emphasizing cardiac components and suppressing artifacts. Ex-1002 ¶195.

Thus, Lai renders this element obvious in light of the common knowledge in the art.

25. “Concurrently”

[25] The method of claim 1, wherein the heart-related signal and the motion signal are produced, concurrently.
--

A POSITA would recognize that concurrent production and analysis of the heart-related and motion signals is routine and well-known in the field and necessary for motion artifact suppression in real-time applications. For example, Lai discloses that “[t]he algorithm takes streaming PPG and accelerometer data as inputs” Ex-1005, 6. This indicates that both signals are captured and analyzed in parallel to detect and mitigate motion artifacts in the PPG signal. Ex-1002 ¶197.

Thus, Lai discloses this element.

26. “Windowed Segments”

[26] The method of claim 1, / [60] The apparatus of claim 35, further comprising segmentation unit configured to: segment the heart-related signal into a plurality of windowed heart-related signal data segments and the motion signal into corresponding plurality of windowed motion signal data segments, wherein the reconstruction unit and the output unit reconstruct the representation and output the reconstructed representation, respectively, based on each windowed heart-related signal data segment and each corresponding motion signal data segment.

As detailed in Sections A.3, A.6 and A.8 above, Lai discloses segmenting the PPG and motion signals into windowed segments for analysis and reconstruction. Lai performs STFT on both signals in overlapping or non-overlapping time windows, enabling localized time-segmented spectral analysis. The ‘647 Patent confirms that “a window segment length T may be set to 8 seconds,” which is standard practice for segmenting signals in the field. Ex-1001, 23:50-51; Ex-1002 ¶199.

A POSITA would recognize that segmenting the signals into a plurality of time windows facilitates synchronized processing of the PPG and motion signals, allowing the reconstruction unit to reconstruct the representation for each segment. A POSITA would find it obvious to configure the reconstruction and output units to process windowed segments of the PPG and motion signals, which is a routine

and widely understood approach for time-segmented signal analysis and artifact removal. Ex-1002 ¶200.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

27. “Time Window”

[27] The method of claim 26, / [61] The apparatus of claim 60, wherein the time window is a value in a range from 2 to 32 seconds.

As analyzed above, Lai discloses segmenting signals into time windows for spectral analysis and reconstruction, applying STFT to the PPG and motion signals on a segment-by-segment basis. See Section B.27 above. The ‘647 Patent explains that “the assumption of 8 second data length largely stems from the fact that SpO₂ and heart rates do not change instantaneously” and acknowledges that “hence, an 8 second duration is a reasonable choice.” Ex-1001, 24:48-51.

A POSITA would recognize that selecting a time window length within the range of 2 to 32 seconds is a logical and well-supported extension of these teachings since shorter windows (2 sec.) provide higher temporal resolution to capture rapidly changing signals, while longer windows (32 sec.) optimize frequency resolution under more stable conditions. Ex-1002 ¶203.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

28. “Biomedical Sensor”

[28] The method of claim 1, / [62] The apparatus of claim 35, wherein the biomedical sensor is at least one of: a photoplethysmogram (PPG) sensor, piezoelectric sensor, Light Emitting Diode (LED) based sensor, camera sensor, and pulse oximeter sensor, and wherein the motion sensor is an accelerometer.

Lai discloses that its algorithm processes heart-related PPG signals and motion signals from an accelerometer for motion artifact suppression. Ex-1005, 6-7; Ex-1002 ¶205.

The ‘647 Patent acknowledges prior art use of “a spectral sensor and the skin surface subtraction technique to remove the spectrum of acceleration data from that of a PPG signal.” Ex-1001, 9:10-22; Ex-1002 ¶206.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

29. “Co-Located”

[29] The method of claim 1, wherein the biomedical sensor and the motion sensor are co-located.

As noted in Section B.25 above, heart-related signals and motion signals are concurrently produced and analyzed in Lai’s system. Lai describes the physical arrangement of the sensors, stating that the PPG sensor was “placed at the centre of the bottom case of the device ... to maintain direct contact with the user’s skin. Three accelerometers measuring orthogonal directions were built into the device to capture motions.” Ex-1005, 10; Ex-1002 ¶¶208-209.

As a POSITA would understand that the integration of the PPG sensor and accelerometers into the same device indicates their co-location, which facilitates synchronization for accurate signal collection. Thus, co-locating biomedical and motion sensors is a logical and common design choice for watch-type devices. Ex-1002 ¶210.

Thus, Lai discloses this element.

30. “Heart Rate Estimate”

[30] The method of claim 1, / [64] The apparatus of claim 35, further comprising a heart rate unit configured to employ the reconstructed representation to determine a heart rate estimate.

As detailed in Sections A.2 and A.7 above, Lai reconstructs a representation of the heart-related signal by combining and processing data from raw PPG and accelerometer inputs. A POSITA would understand that this reconstructed representation directly informs and serves as the foundation for determining a heart rate estimate. *See also* Ex-1004 (“[o]ne of ordinary skill in the art is considered to possess the knowledge to determine a representation of heart rate estimate from the heart rate sensor and/or ECG”). Ex-1002 ¶212.

Thus, Lai discloses these elements.

31. “SpO₂ Estimate”

[31] The method of claim 1, / [65] The apparatus of claim 35, further comprising an arterial oxygen saturation (SpO₂) unit configured to employ the reconstructed representation to determine a SpO₂ estimate.

While Lai primarily discusses HR estimation, a POSITA would recognize that the same reconstructed signal could be used to derive SpO₂ by using well-established pulse oximetry principles. Lai describes a pipeline where PPG signals,

reconstructed through spectral analysis produced by Lai's algorithm, provides the time-varying spectral components of the PPG signal, are used for physiological monitoring, including functions such as oxygen saturation estimation. Ex-1005, 6. Ex-1002 ¶214.

The '647 Patent confirms that SpO₂ estimation is an expected outcome when processing reconstructed PPG signals, as these systems are commonly used for multi-parameter physiological monitoring, including HR and SpO₂, and acknowledges that pulse oximeters are widely implemented in systems that reconstruct PPG signals to estimate both heart rate and oxygen saturation. Ex-1001, 6:54-60 (internal citations omitted). Moreover, the '647 Patent repeatedly emphasizes the utility of pulse oximeters as versatile vital sign monitors. *See, e.g.*, Ex-1001, 7:7-10. Ex-1002 ¶215.

These admissions establish that pulse oximeters, which inherently reconstruct PPG signals for SpO₂ estimation, were widely recognized and routinely implemented. *See* Ex-1004 (0937), 2018-04-18 Office Action, at 7 (“[m]easurement of oxygen saturation from the sensors employed by Venkatraman et al. is a well-known function”). Ex-1002 ¶216.

Additionally, the '647 Patent describes the OxiMA method, which combats motion artifacts in PPG signals for accurate SpO₂ and HR estimations,

demonstrating that SpO₂ estimation is a fundamental feature of reconstructed PPG signals. Ex-1001, 39:59-62; Ex-1002 ¶217.

The emphasis on reconstructing motion-contaminated PPG signals to estimate SpO₂ confirms that SpO₂ estimation is an expected and inherent outcome of such reconstruction pipelines. Ex-1002 ¶218.

Thus, Lai discloses these elements.

32. “Heart-Related Ailment”

[32] The method of claim 1, / [66] The apparatus of claim 35, further comprising an ailment unit configured to employ the reconstructed representation to detect or predict a heart-related ailment, the heart-related ailment including at least one of a heart rate variability (HRV) condition, an atrial fibrillation condition, a congestive heart failure condition, and a tachycardia condition.
--

As detailed in Section B.31 above, Lai describes a system for reconstructing PPG signals through spectral analysis for cardiovascular monitoring, including heart rate and oxygen saturation estimation. A POSITA would understand that Lai’s reconstructed signals, which provide time-varying spectral components, are suitable for detecting or predicting heart-related ailments, including HRV, atrial fibrillation (AF), congestive heart failure (CHF), and tachycardia. Specifically, Lai states: “[PPG] has been used in clinical settings for measuring cardiovascular functions such as heart rate and arterial blood oxygen saturation for decades.” Ex-

1005, 6. This demonstrates that Lai contemplated the clinical use of reconstructed PPG signals for a variety of cardiovascular functions. A POSITA would recognize that the time-varying spectral components disclosed in Lai inherently provide the data necessary to evaluate heart rate variability and detect conditions, such as AF and tachycardia, which are directly tied to irregularities in heart rate patterns. Ex-1002 ¶¶220-221.

The ‘647 patent confirms that reconstructed PPG signals are commonly used to detect or predict HRV, AF, CHF, and tachycardia. Ex-1001, 19:28-35. It further acknowledges the broad utility of pulse oximeters in monitoring multiple cardiovascular parameters. Ex-1001, 6:54-60. These admissions establish that the use of reconstructed PPG signals for detecting HRV, AF, CHF, and tachycardia was well-known and widely implemented prior to the ‘647 patent. Ex-1002 ¶¶222-224.

Additionally, the ‘647 Patent describes the OxiMA method, which enhances reconstructed PPG signals by mitigating motion artifacts, thereby improving their utility for HR and rhythm-related analyses. Ex-1001, 39:59-62. Ex-1002 ¶225.

A POSITA would understand that the improved reconstruction techniques disclosed in OxiMA inherently facilitate the detection of HRV, AF, CHF, and tachycardia, as these conditions rely on the analysis of reconstructed heart rate signals. Thus, a POSITA would find it obvious to apply Lai’s reconstructed PPG

signals to detect or predict HRV, AF, CHF, and tachycardia. The admissions in ‘647 and its references further confirm that detecting these ailments using reconstructed PPG signals reflects a routine and predictable application of well-established methods. Ex-1002 ¶¶226-227.

Thus, Lai discloses these elements.

33. “Real-Time”

[33] The method of claim 1, / [67] The apparatus of claim 35, wherein the reconstruction unit and the output unit are configured to reconstruct and to output, respectively, in real-time with respect to production of the heart-related signal and the motion signal.

Configuring the reconstruction and output units to operate in real time with respect to signal production are routine and well-known in the field. Ex-1002 ¶229.

As detailed in Section B.25, Lai’s algorithm concurrently processes streaming PPG and accelerometer signals. Ex-1005, 6 (“[t]he algorithm takes streaming PPG and accelerometer data as inputs”); *see also* Ex-1001, 8:12-13 (“[a]n adaptive filter is easy to implement and it also can be used in real-time applications”). Ex-1002 ¶230.

Thus, Lai discloses these elements.

34. “Non-Real-Time”

[34] The method of claim 1, / [68] The apparatus of claim 35, wherein the reconstruction unit and the output unit are configured to reconstruct and to output, respectively, in non-real-time with respect to production of the heart-related signal and the motion signal.

The ‘647 Patent states that “[t]he OxiMA method can be easily implemented in real-time.” Ex-1001, 41:17-18. This acknowledgment of real-time implementation implies flexibility, making non-real-time implementations an equally feasible and logical design choice in Lai’s system and method. Ex-1002 ¶232.

A POSITA would recognize that reconstruction and output can be configured to occur asynchronously relative to signal production to accommodate non-real-time applications, such as offline analysis or post-event diagnostics, where strict real-time processing is not required. This flexibility reflects well-established practices in the field for adapting signal processing methods to specific applications, and could have been readily implemented in Lai’s system and method.. Ex-1002 ¶233.

Thus, Lai renders these elements obvious in light of the common knowledge in the art.

XIII. DISCRETIONARY DENIAL WOULD BE INAPPROPRIATE

A. No Discretionary Denial Under *Fintiv*

The *Fintiv* factors strongly favor institution. In particular, Petitioner is offering a *Sotera* stipulation (see factor 4, below).

Factor 1: Potential Stay

No motion to stay has been filed in the Related Litigation, and the Board should not infer the outcome of such a motion even if filed. *See Sand Revolution II LLC v. Continental Intermodal Group - Trucking LLC*, IPR2019-01393, Paper 24 at 7 (PTAB June 16, 2020) (informative). Thus, this factor is neutral.

Factor 2: Proximity of Trial to FWD

The Related Litigation was filed in the Eastern District of Texas on July 31, 2023, and is currently set for trial before District Judge Robert W. Schroeder, III on February 17, 2026. Ex-1009. However, “a court’s general ability to set a fast paced schedule is not particularly relevant ... where, like here, the forum itself has not historically resolved cases so quickly.” *In re Apple Inc.*, 979 F.3d 1332, 1344 (Fed. Cir. 2020). Here, Judge Schroeder currently has seven other patent trials scheduled to begin on February 17, 2026. Ex-1010. Although the currently-scheduled trial date is about six months before a final written decision here (around August 2026), the Board has granted institution in similar circumstances. *See, e.g., NetNut Ltd. v. Bright Data Ltd.*, IPR2021-01492, Paper 12 (PTAB March 21,

2022) (granting institution when trial was scheduled six months before the final written decision deadline).

Further, Judge Schroeder currently has 135 active patent cases and a median time-to-trial of 50.6 months—pushing the realistic trial date here to likely a much later date than February 17, 2026. Ex-1011.

This factor favors institution or is, at worst, neutral.

Factor 3: Investment in Parallel Proceeding

The Related Litigation is in its early stages, with major activities including claim construction term exchanges not even having started as of the filing of this Petition. Ex-1009. The court has not issued any substantive orders, Ex-1012, and the parties have not yet invested substantial time in the litigation. Thus, this factor favors institution.

Factor 4: Overlapping Issues

There is no overlap of prior-art issues with the Related Litigation. Moreover, Petitioner offers the following stipulation: If the Board institutes review, Petitioner will not pursue in the Related Litigation the grounds raised or that reasonably could have been raised in this Petition with respect to the claims for which review is instituted. *See Sotera Wireless, Inc. v. Masimo Corp.*, IPR2020-01019, Paper 12 at 16-19 (Dec. 1, 2020) (precedential as to §II.A). Petitioner also filed a stipulation to that effect in the Related Litigation. Ex-1008.

The Director’s June 2022 memorandum states that, when a petitioner so stipulates, “the PTAB will not discretionarily deny institution” due to parallel litigation.

Memo, *supra* n.1, at 7.

Thus, this factor favors institution.

Factor 5: The Parties

Petitioner is a defendant in the Related Litigation. Accordingly, this factor favors institution.

Factor 6: Other Circumstances

The Petition’s merits are particularly strong as reflected above, which favors institution. Moreover, denying institution would negate Congress’s intent in providing a 1-year period to file petitions and would encourage forum shopping.

Accordingly, the *Fintiv* analysis favors institution.

B. No Discretionary Denial Under 35 U.S.C. § 325(d)

The prior art and arguments for the invalidity ground in this Petition were not presented during the prosecution of the ‘647 Patent. Ex-1002, ¶¶35-36. Thus, Petitioner is currently not aware of any indication that the Office was previously presented with “the same or substantially the same prior art or arguments.” 35 U.S.C. §325(d). The first prong of *Advanced Bionics* is therefore unmet, and the Board “need not address the second part.” *JUUL Labs, Inc. v. NJOY, LLC*, IPR2024-00160, Paper 10 at 13 (PTAB May 24, 2024).

Thus, the Board should not deny institution under section 325(d).

XIV. CONCLUSION

Accordingly, Petitioner respectfully requests that the Board institute IPR and cancel claims 1-75 of the '647 Patent.

Respectfully submitted,

/Jack Shaw/

Jack Shaw (Reg. No. 72,262)

CLAIM LISTING

Claim 1

[1pre] A method for reconstructing a heart-related signal output by a biomedical sensor, the method comprising:

[1A] reconstructing a representation of the heart-related signal to produce a reconstructed representation of the heart-related signal,

[1B] the reconstructing based on (i) a time-varying spectral analysis of the heart-related signal and a motion signal,

[1C] the motion signal output by a motion sensor and representative of motion artifacts in the heart-related signal,

[1D] the motion artifacts being signal artifacts produced by movement of the biomedical sensor relative to a sensing location, and

[1E] (ii) a classification of the movement,

[1F] wherein the time-varying spectral analysis includes pre-processing the heart-related signal to produce a pre-processed heart-related signal, pre-processing the motion signal to produce a preprocessed motion signal,

[1G] and computing a first time-frequency spectrum (TFS) of the heart-related signal using the preprocessed heart-related signal and a second TFS of the motion signal using the pre-processed motion signal; and

[1H] outputting the reconstructed representation of the heart-related signal.

Claim 2

[2] The method of claim 1, wherein the motion artifacts are suppressed in the reconstructed representation of the heart-related signal.

Claim 3

[3] The method of claim 1, wherein: in an event the classification indicates that the movement does not rise to a level causing the motion artifacts, the reconstructed representation is based on an average value of peak-to-peak intervals in the pre-processed heart-related signal.

Claim 4

[4] The method of claim 1, wherein the pre-processing includes filtering the heart-related signal to produce a filtered heart-related signal, the filtered heart-related signal being the preprocessed heart-related signal.

Claim 5

[5] The method of claim 4, wherein the pre-processing further includes down-sampling the filtered heart-related signal, the down-sampling being at a sampling rate less than an original sampling rate.

Claim 6

[6] The method of claim 1, wherein the first TFS computed and the second TFS computed are 3-dimensional spectra, the first TFS computed and the second TFS computed each including a respective time-varying amplitude or power distribution with respect to time and frequency.

Claim 7

[7] The method of claim 1, wherein the first TFS computed is a first time-varying power spectral density (PSD) and the second TFS computed is a second time-varying PSD.

Claim 8

[8A] The method of claim 1, wherein the reconstructed representation is a current reconstructed representation and wherein, based on the classification indicating that the movement does rise to a level causing the motion artifacts and is a pseudo-periodic movement or a periodic movement,

[8B] the reconstructing includes: determining whether at least one spectral peak is present having a corresponding frequency within a given frequency range at a point in time in the first TFS computed, the current reconstructed representation being reconstructed for the point in time; and

[8C] wherein, based on a determination that the at least one spectral peak is not present, the current reconstructed representation is based on a prior reconstructed representation, the prior reconstructed representation associated with a previous point in time in the first TFS computed.

Claim 9

[9] The method of claim 8, wherein the given frequency range is 0.5 Hz to 3 Hz.

Claim 10

[10] The method of claim 1, wherein the reconstructing includes: retaining up to a pre-determined number of candidate spectral peaks located at a first point in time in the first TFS computed, the candidate spectral peaks retained based on having corresponding frequencies within a given frequency range and highest amplitude or power values relative to other spectral peaks located at the first point in time, the other spectral peaks having respective frequencies within the given frequency

range; and discarding each of the candidate spectral peaks retained that is associated with a same frequency as a dominant spectral peak located at a second point in time in the second TFS computed, the first point in time and the second point in time having same time values.

Claim 11

[11] The method of claim 10, wherein the given frequency range is 0.5 Hz to 3 Hz.

Claim 12

[12] The method of claim 10, wherein the representation is a current representation, wherein the reconstructed representation is a current reconstructed representation, and wherein, in an event the discarding discards each of the candidate spectral peaks retained, reconstructing the current representation is based on a prior reconstructed representation, the prior reconstructed representation associated with a previous point in time in the first TFS computed, the previous point in time being an earlier point in time with respect to the first point in time.

Claim 13

[13] The method of claim 10, wherein the discarding is a first discarding and wherein the representation is a current representation and, wherein, in an event the first discarding results in at least one remaining candidate spectral peak retained, reconstructing the current representation further includes: second discarding, wherein the second discarding discards remaining candidate spectral peaks, of the at least one remaining candidate spectral peak retained, based on whether a corresponding frequency of the at least one remaining candidate spectral peak retained is distanced by at least a frequency difference threshold from a prior reconstructed representation's frequency, the prior reconstructed representation associated with a previous point in time in the first TFS computed, the previous point in time being an earlier point in time with respect to the first point in time.

Claim 14

[14A] The method of claim 13, wherein: based on each of the at least one remaining candidate spectral peak retained having been discarded by the second discarding, reconstructing the current representation is based on the prior reconstructed representation; and,

[14B] based on at least one last candidate spectral peak remaining, the at least one last candidate spectral peak remaining not discarded by the second discarding, reconstructing the current representation is based on a selected candidate spectral peak selected from amongst the at least one last candidate spectral peak remaining having a closest corresponding frequency to the prior reconstructed

representation's frequency relative to respective frequencies of each of the at least one last candidate spectral peak remaining.

Claim 15

[15] The method of claim 10, wherein the dominant spectral peak has a largest power or amplitude value relative to other peaks located at the second point in time in the second TFS.

Claim 16

[16] The method of claim 10, wherein the retaining and the discarding are based on: the classification indicating that the movement is a pseudo-periodic movement or a periodic movement; and determining that at least one spectral peak with a corresponding frequency in the given frequency range is present at the first point in time.

Claim 17

[17] The method of claim 1, wherein the pre-processing includes filtering the heart-related signal and the motion signal to produce a filtered heart-related signal and a filtered motion signal, respectively, the filtered heart-related signal being the pre-processed heart-related signal and the filtered motion signal being the pre-processed motion signal.

Claim 18

[18] The method of claim 17, wherein the pre-processing further includes down-sampling both the filtered heart-related signal and the filtered motion signal, the down-sampling being at a sampling rate less than an original sampling rate.

Claim 19

[19] The method of claim 1, further including: classifying the classification of the movement by comparing an amount of amplitude modulation in the second TFS computed to an amplitude modulation threshold, wherein the classification indicates whether the movement rises to a level of causing the motion artifacts based on a result of the comparing.

Claim 20

[20] The method of claim 19, wherein the amplitude modulation threshold is dependent on a type of the motion detector sensor.

Claim 21

[21] The method of claim 19, wherein, in an event the result indicates that the movement does rise to the level causing the motion artifacts, classifying the classification of the movement further includes determining whether the movement is either a pseudo-periodic movement or a periodic movement, versus a random movement.

Claim 22

[22A] The method of claim 21, wherein, in determining whether the movement is either the pseudo-periodic movement or the periodic movement, versus the random movement includes, the method further includes: identifying a first, second, and third frequency associated, respectively, with a first, second, and third spectral peak in the second TFS at a point in time in the second TFS, the first, second, and third peaks having largest power or amplitude values relative to other peaks in the second TFS at the point in time, the first spectral peak being a largest spectral peak amongst the first, second, and third spectral peaks;

[22B] computing a first ratio of the second frequency identified to the first frequency identified and determining a first comparison result by comparing the first ratio computed to a first ratio value; and computing a second ratio of the third frequency identified to the first frequency identified and determining a second comparison result by comparing the second ratio computed to a second ratio value, wherein the classification further indicates that the movement is either the pseudo-periodic movement or the periodic movement, versus the random movement, based on the first comparison result and the second comparison result.

Claim 23

[23] The method of claim 22, wherein the first ratio value is 2 and the second ratio value is 3.

Claim 24

[24A] The method of claim 1, wherein, in an event the classification of the movement indicates random movement, the reconstructing includes: computing an average value of a number of prior reconstructed representations outputted prior to the reconstructing, the number based on a duration of consecutive motion artifacts, detected prior to the reconstructing;

[24B] computing a bandpass filter cutoff frequency based on the average value computed; filtering the preprocessed heart-related signal by applying the band pass filter computed to produce a filtered, pre-processed heart-related signal; and wherein the reconstructed representation is based on an average peak-to-peak interval value of the filtered, pre-processed heart-related signal.

Claim 25

[25] The method of claim 1, wherein the heart-related signal and the motion signal are produced, concurrently.

Claim 26

[26] The method of claim 1, further comprising:
segmenting the heart-related signal into a plurality of windowed heart-related signal data segments and the motion signal into a corresponding plurality of windowed motion signal data segments; and
repeating the reconstructing and the outputting for each windowed heart-related signal data segment and each corresponding motion signal data segment.

Claim 27

[27] The method of claim 26, wherein the time window is a value in a range from 2 to 32 seconds.

Claim 28

[28] The method of claim 1, wherein the biomedical sensor is at least one of: a photoplethysmogram (PPG) sensor, piezoelectric sensor, Light Emitting Diode (LED) based sensor, camera sensor, and pulse oximeter sensor, and wherein the motion sensor is an accelerometer.

Claim 29

[29] The method of claim 1, wherein the biomedical sensor and the motion sensor are co-located.

Claim 30

[30] The method of claim 1, further comprising employing the reconstructed representation to determine a heart rate estimate.

Claim 31

[31] The method of claim 1, further comprising employing the reconstructed representation to determine an arterial oxygen saturation (SpO₂) estimate.

Claim 32

[32] The method of claim 1, further comprising employing the reconstructed representation to detect or predict a heart-related ailment, the heart-related ailment including at least one of a heart rate variability (HRV) condition, atrial fibrillation condition, congestive heart failure condition, and tachycardia condition.

Claim 33

[33] The method of claim 1, wherein the reconstructing and the outputting are performed in real-time with respect to production of the heart-related signal and the motion signal.

Claim 34

[34] The method of claim 1, wherein the reconstructing and the outputting are performed in non-real-time with respect to production of the heart-related signal and the motion signal.

Claim 35

[35Pre] An apparatus for reconstructing a heart-related signal output by a biomedical sensor, the apparatus comprising:

[35A] a reconstruction unit configured to reconstruct a representation of the heart-related signal to produce a reconstructed representation of the heart-related signal,

[35B] the reconstructing based on (i) a time-varying spectral analysis of the heart-related signal and a motion signal,

[35C] the motion signal output by a motion sensor and representative of motion artifacts in the heart-related signal,

[35D] the motion artifacts being signal artifacts produced by movement of the biomedical sensor relative to a sensing location, and

[35E] (ii) a classification of the movement,

[35F] wherein the time-varying spectral analysis includes pre-processing the heart-related signal to produce a pre-processed heart-related signal, pre-processing the motion signal to produce a preprocessed motion signal,

[35G] and computing a first time-frequency spectrum (TFS) of the heart-related signal using the pre-processed heart-related signal and a second TFS of the motion signal using the pre-processed motion signal; and

[35H] an output unit configured to output the reconstructed representation of the heart-related signal.

Claim 36

[36] The apparatus of claim 35, wherein the motion artifacts are suppressed in the reconstructed representation of the heart-related signal.

Claim 37

[37] The apparatus of claim 35, wherein: in an event the classification indicates that the movement does not rise to level causing the motion artifacts, the reconstructed representation is based on an average value of peak-to-peak intervals in the pre-processed heart-related signal.

Claim 38

[38] The apparatus of claim 35, wherein the pre-processing includes filtering the heart-related signal to produce a filtered heart-related signal, the filtered heart-related signal being the pre-processed heart-related signal.

Claim 39

[39] The apparatus of claim 38, wherein the pre-processing further includes down-sampling the filtered heart-related signal, the down-sampling being at a sampling rate less than an original sampling rate.

Claim 40

[40] The apparatus of claim 35, wherein the first TFS computed and the second TFS computed are 3-dimensional spectra, the first TFS computed and the second TFS computed each including a respective time-varying amplitude or power distribution with respect to time and frequency.

Claim 41

[41] The apparatus of claim 35, wherein the first TFS computed is a first time-varying power spectral density (PSD) and the second TFS computed is a second time-varying PSD.

Claim 42

[42A] The apparatus of claim 35, wherein the reconstructed representation is a current reconstructed representation and wherein, based on the classification indicating that the movement does rise to a level causing the motion artifacts and is a pseudo-periodic movement or a periodic movement,

[42B] to reconstruct the representation includes: determining whether at least one spectral peak is present having a corresponding frequency within a given frequency range at a point in time in the first TFS computed, the current reconstructed representation being reconstructed for the point in time; and

[42C] wherein, based on a determination that the at least one spectral peak is not present, the reconstructed current representation is based on a prior reconstructed representation, the prior reconstructed representation associated with a previous point in time in the first TFS computed.

Claim 43

[43] The apparatus of claim 42, wherein the given frequency range is 0.5 Hz to 3 Hz.

Claim 44

[44] The apparatus of claim 35, wherein to reconstruct the representation includes: retaining up to a pre-determined number of candidate spectral peaks located at a first point in time in the first TFS computed, the candidate spectral peaks retained based on having corresponding frequencies within a given frequency range and highest amplitude or power values relative to other spectral peaks located at the first point in time, the other spectral peaks having respective frequencies within the given frequency range; and discarding each of the candidate spectral peaks retained that is associated with a same frequency as a dominant spectral peak located at a second point in time in the second TFS computed, the first point in time and the second point in time having same time values.

Claim 45

[45] The apparatus of claim 44, wherein the given frequency range is 0.5 Hz to 3 Hz.

Claim 46

[46] The apparatus of claim 44, wherein the representation is a current representation, wherein the reconstructed representation is a current reconstructed representation, and wherein, in an event the discarding discards each of the candidate spectral peaks retained, reconstructing the current representation is based on a prior reconstructed representation, the prior reconstructed representation associated with a previous point in time in the first TFS computed, the previous point in time being an earlier point in time with respect to the first point in time.

Claim 47

[47] The apparatus of claim 44, wherein the discarding is a first discarding and wherein the representation is a current representation and, wherein, in an event the first discarding results in at least one remaining candidate spectral peak retained, reconstructing the current representation further includes: second discarding, wherein the second discarding discards remaining candidate spectral peaks, of the at least one remaining candidate spectral peak retained, based on whether a corresponding frequency of the at least one remaining candidate spectral peak retained is distanced by at least a frequency difference threshold from a prior reconstructed representation's frequency, the prior reconstructed representation associated with a previous point in time in the first TFS computed, the previous point in time being an earlier point in time with respect to the first point in time.

Claim 48

[48A] The apparatus of claim 47, wherein: based on each of the at least one remaining candidate spectral peak retained having been discarded by the second discarding, reconstructing the current representation is based on the prior reconstructed representation; and

[48B] based on at least one last candidate spectral peak remaining, the at least one last candidate spectral peak remaining not discarded by the second discarding, reconstructing the current representation is based on a selected candidate spectral peak selected from amongst the at least one last candidate spectral peak remaining having a closest corresponding frequency to the prior reconstructed representation's frequency relative to respective frequencies of each of the at least one last candidate spectral peak remaining.

Claim 49

[49] The apparatus of claim 44, wherein the dominant spectral peak has a largest power or amplitude value relative to other peaks located at the second point in time in the second TFS.

Claim 50

[50] The apparatus of claim 44, wherein the retaining and the discarding are based on: the classification of the movement indicating that the movement is a pseudo-periodic movement or a periodic movement; and determining that at least one spectral peak with a corresponding frequency in the given frequency range is present at the first point in time.

Claim 51

[51] The apparatus of claim 35, wherein the pre-processing includes filtering the heart-related signal and the motion signal to produce a filtered heart-related signal and a filtered motion signal, respectively, the filtered heart-related signal being the pre-processed heart-related signal and the filtered motion signal being the pre-processed motion signal.

Claim 52

[52] The apparatus of claim 51, wherein the pre-processing further includes down-sampling, at a sampling rate less than an original sampling rate, both the filtered heart-related signal and the filtered motion signal.

Claim 53

[53] The apparatus of claim 35, further including a classification unit, the classification unit configured to: classify the classification of the movement by

comparing an amount of amplitude modulation in the second TFS computed to an amplitude modulation threshold, wherein the classification indicates whether the movement rises to a level causing the motion artifacts based on a result of the comparing.

Claim 54

[54] The apparatus of claim 53, wherein the amplitude modulation threshold is dependent on a type of the motion detector sensor.

Claim 55

[55] The apparatus of claim 53, wherein, in an event the result indicates that the movement does rise to the level causing the motion artifacts, the classification unit is further configured to classify the classification of the movement by determining whether the movement is either a pseudo-periodic movement or a periodic movement, versus a random movement.

Claim 56

[56A] The apparatus of claim 55, wherein to determine whether the movement is either the pseudo-periodic movement or the periodic movement versus a random movement includes:

identifying a first, second, and third frequency associated, respectively, with a first, second, and third spectral peak in the second TFS at a point in time in the second TFS, the first, second, and third peaks having largest power or amplitude values relative to other peaks in the second TFS at the point in time, the first spectral peak being a largest spectral peak amongst the first, second, and third spectral peaks;

[56B] computing a first ratio of the second frequency identified to the first frequency identified and determining a first comparison result by comparing the first ratio computed to a first ratio value; and computing a second ratio of the third frequency identified to the first frequency identified and determining a second comparison result by comparing the second ratio computed to a second ratio value, wherein the classification further indicates that the movement is either the pseudo-periodic movement or the periodic movement, versus the random movement, based on the first comparison result and the second comparison result.

Claim 57

[57] The apparatus of claim 56, wherein the first ratio value is 2 and the second ratio value is 3.

Claim 58

[58A] The apparatus of claim 55, wherein, in an event the classification of the movement indicates random movement, the reconstructing includes: computing an average value of a number of prior reconstructed representations outputted prior to the reconstructing, the number based on a duration of consecutive motion artifacts, detected prior to the reconstructing;

[58B] computing a bandpass filter cutoff frequency based on the average value computed; filtering the pre-processed heart-related signal by applying the band pass filter computed to produce a filtered, pre-processed heart-related signal; and wherein the reconstructed representation is based on an average peak-to-peak interval value of the filtered, pre-processed heart-related signal.

Claim 59

[59] The apparatus of claim 35, wherein the heart-related signal and the motion signal are produced, concurrently.

Claim 60

[60] The apparatus of claim 35, further comprising segmentation unit configured to: segment the heart-related signal into a plurality of windowed heart-related signal data segments and the motion signal into corresponding plurality of windowed motion signal data segments, wherein the reconstruction unit and the output unit reconstruct the representation and output the reconstructed representation, respectively, based on each windowed heart-related signal data segment and each corresponding motion signal data segment.

Claim 61

[61] The apparatus of claim 60, wherein the time window is a value in a range from 2 to 32 seconds.

Claim 62

[62] The apparatus of claim 35, wherein the biomedical sensor is at least one of: a photoplethysmogram (PPG) sensor, piezoelectric sensor, Light Emitting Diode (LED) based sensor, camera sensor, and pulse oximeter sensor, and wherein the motion sensor is an accelerometer.

Claim 63

[63] The apparatus of claim 35, wherein the apparatus includes the biomedical sensor and the motion sensor.

Claim 64

[64] The apparatus of claim 35, further comprising a heart rate unit configured to employ the reconstructed representation to determine a heart rate estimate.

Claim 65

[65] The apparatus of claim 35, further comprising an arterial oxygen saturation (SpO2) unit configured to employ the reconstructed representation to determine a SpO2 estimate.

Claim 66

[66] The apparatus of claim 35, further comprising an ailment unit configured to employ the reconstructed representation to detect or predict a heart-related ailment, the heart-related ailment including at least one of a heart rate variability (HRV) condition, an atrial fibrillation condition, a congestive heart failure condition, and a tachycardia condition.

Claim 67

[67] The apparatus of claim 35, wherein the reconstruction unit and the output unit are configured to reconstruct and to output, respectively, in real-time with respect to production of the heart-related signal and the motion signal.

Claim 68

[68] The apparatus of claim 35, wherein the reconstruction unit and the output unit are configured to reconstruct and to output, respectively, in non-real-time with respect to production of the heart-related signal and the motion signal.

Claim 69

[69Pre] A non-transitory computer-readable medium having encoded thereon a sequence of instructions which, when loaded and executed by a processor, causes the processor to reconstruct a heart-related signal output by a biomedical sensor, the processor reconstructing the heart-related signal by:

[69A] reconstructing a representation of the heart-related signal to produce a reconstructed representation of the heart-related signal,

[69B] the reconstructing based on (i) a time-varying spectral analysis of the heart-related signal and a motion signal,

[69C] the motion signal output by a motion sensor and representative of motion artifacts in the heart-related signal,

[69D] the motion artifacts being signal artifacts produced by movement of the biomedical sensor relative to a sensing location, and

[69E] and (ii) a classification of the movement,

[69F] wherein the time-varying spectral analysis includes pre-processing the heart-related signal to produce a pre-processed heart-related signal, pre-processing the motion signal to produce a pre-processed motion signal, and
[69G] computing a first time-frequency spectrum (TFS) of the heart-related signal using the pre-processed heart-related signal and a second TFS of the motion signal using the pre-processed motion signal; and
[69H] outputting the reconstructed representation of the heart-related signal.

Claim 70

[70Pre] A method for reconstructing a heart-related signal output by a biomedical sensor, the method comprising:
[70A] reconstructing a representation of the heart-related signal to produce a reconstructed representation of the heart-related signal,
[70B] the reconstructing based on (i) a time-varying spectral analysis of the heart-related signal and a motion signal,
[70C] the motion signal output by a motion sensor and representative of motion artifacts in the heart-related signal,
[70D] the motion artifacts being signal artifacts produced by movement of the biomedical sensor relative to a sensing location, and
[70E] (ii) a classification of the movement,
[70F] wherein the time-varying spectral analysis includes computing a first time-frequency spectrum (TFS) of the heart-related signal and computing a second TFS of the motion signal; and
[70G] outputting the reconstructed representation of the heart-related signal,
[70H] wherein the reconstructed representation is a current reconstructed representation and wherein, based on the classification indicating that the movement does rise to a level causing the motion artifacts and is a pseudo-periodic movement or a periodic movement,
[70I] the reconstructing includes: determining whether at least one spectral peak is present having a corresponding frequency within a given frequency range at a point in time in the first TFS computed, the current reconstructed representation being reconstructed for the point in time; and
[70J] wherein, based on a determination that the at least one spectral peak is not present, the current reconstructed representation is based on a prior reconstructed representation, the prior reconstructed representation associated with a previous point in time in the first TFS computed.

Claim 71

[71Pre] A method for reconstructing a heart-related signal output by a biomedical sensor, the method comprising:

[71A] reconstructing a representation of the heart-related signal to produce a reconstructed representation of the heart-related signal,
[71B] the reconstructing based on (i) a time-varying spectral analysis of the heart-related signal and a motion signal,
[71C] the motion signal output by a motion sensor and representative of motion artifacts in the heart-related signal,
[71D] the motion artifacts being signal artifacts produced by movement of the biomedical sensor relative to a sensing location, and
[71E] (ii) a classification of the movement,
[71F] wherein the time-varying spectral analysis includes computing a first time-frequency spectrum (TFS) of the heart-related signal and computing a second TFS of the motion signal; and
[71G] outputting the reconstructed representation of the heart-related signal,
[71H] wherein the reconstructing includes: retaining up to a pre-determined number of candidate spectral peaks located at a first point in time in the first TFS computed, the candidate spectral peaks retained based on having corresponding frequencies within a given frequency range and highest amplitude or power values relative to other spectral peaks located at the first point in time, the other spectral peaks having respective frequencies within the given frequency range; and discarding each of the candidate spectral peaks retained that is associated with a same frequency as a dominant spectral peak located at a second point in time in the second TFS computed, the first point in time and the second point in time having same time values.

Claim 72

[72Pre] 72. A method for reconstructing a heart-related signal output by a biomedical sensor, the method comprising:
[72A] reconstructing a representation of the heart-related signal to produce a reconstructed representation of the heart-related signal,
[72B] the reconstructing based on (i) a time-varying spectral analysis of the heart-related signal and a motion signal,
[72C] the motion signal output by a motion sensor and representative of motion artifacts in the heart-related signal,
[72D] the motion artifacts being signal artifacts produced by movement of the biomedical sensor relative to a sensing location, and
[72E] (ii) a classification of the movement,
[72F] wherein the time-varying spectral analysis includes computing a first time-frequency spectrum (TFS) of the heart-related signal and computing a second TFS of the motion signal;

[72G] classifying the classification of the movement by comparing an amount of amplitude modulation in the second TFS computed to an amplitude modulation threshold, wherein the classification indicates whether the movement rises to a level of causing the motion artifacts based on a result of the comparing; and [72H] outputting the reconstructed representation of the heart-related signal.

Claim 73

[73Pre] An apparatus for reconstructing a heart-related signal output by a biomedical sensor, the apparatus comprising:

[73A] a reconstruction unit configured to reconstruct a representation of the heart-related signal to produce a reconstructed representation of the heart-related signal,

[73B] the reconstructing based on (i) a time-varying spectral analysis of the heart-related signal and a motion signal,

[73C] the motion signal output by a motion sensor and representative of motion artifacts in the heart-related signal,

[73D] the motion artifacts being signal artifacts produced by movement of the biomedical sensor relative to a sensing location, and

[73E] (ii) a classification of the movement,

[73F] wherein the time-varying spectral analysis includes computing a first time-frequency spectrum (TFS) of the heart-related signal and computing a second TFS of the motion signal; and

[73G] an output unit configured to output the reconstructed representation of the heart-related signal,

[73H] wherein the reconstructed representation is a current reconstructed representation and wherein, based on the classification indicating that the movement does rise to a level causing the motion artifacts and is a pseudo-periodic movement or a periodic movement,

[73I] to reconstruct the representation includes: determining whether at least one spectral peak is present having a corresponding frequency within a given frequency range at a point in time in the first TFS computed, the current reconstructed representation being reconstructed for the point in time; and

[73J] wherein, based on a determination that the at least one spectral peak is not present, the reconstructed current representation is based on a prior reconstructed representation, the prior reconstructed representation associated with a previous point in time in the first TFS computed.

Claim 74

[74Pre] An apparatus for reconstructing a heart-related signal output by a biomedical sensor, the apparatus comprising:

[74A] a reconstruction unit configured to reconstruct a representation of the heart-related signal to produce a reconstructed representation of the heart-related signal,
[74B] the reconstructing based on (i) a time-varying spectral analysis of the heart-related signal and a motion signal,
[74C] the motion signal output by a motion sensor and representative of motion artifacts in the heart-related signal,
[74D] the motion artifacts being signal artifacts produced by movement of the biomedical sensor relative to a sensing location, and
[74E] (ii) a classification of the movement,
[74F] wherein the time-varying spectral analysis includes computing a first time-frequency spectrum (TFS) of the heart-related signal and computing a second TFS of the motion signal; and
[74G] an output unit configured to output the reconstructed representation of the heart-related signal,
[74H] wherein to reconstruct the representation includes: retaining up to a predetermined number of candidate spectral peaks located at a first point in time in the first TFS computed, the candidate spectral peaks retained based on having corresponding frequencies within a given frequency range and highest amplitude or power values relative to other spectral peaks located at the first point in time, the other spectral peaks having respective frequencies within the given frequency range; and discarding each of the candidate spectral peaks retained that is associated with a same frequency as a dominant spectral peak located at a second point in time in the second TFS computed, the first point in time and the second point in time having same time values.

Claim 75

[75Pre] An apparatus for reconstructing a heart-related signal output by a biomedical sensor, the apparatus comprising:
[75A] a reconstruction unit configured to reconstruct a representation of the heart-related signal to produce a reconstructed representation of the heart-related signal,
[75B] the reconstructing based on (i) a time-varying spectral analysis of the heart-related signal and a motion signal,
[75C] the motion signal output by a motion sensor and representative of motion artifacts in the heart-related signal,
[75D] the motion artifacts being signal artifacts produced by movement of the biomedical sensor relative to a sensing location, and
[75E] (ii) a classification of the movement,
[75F] wherein the time-varying spectral analysis includes computing a first time-frequency spectrum (TFS) of the heart-related signal and computing a second TFS of the motion signal;

[75G] a classification unit configured to classify the classification of the movement by comparing an amount of amplitude modulation in the second TFS computed to an amplitude modulation threshold, wherein the classification indicates whether the movement rises to a level causing the motion artifacts based on a result of the comparing; and

[75H] an output unit configured to output the reconstructed representation of the heart-related signal.

**CERTIFICATE OF COMPLIANCE WITH TYPE-VOLUME
LIMITATION, TYPEFACE REQUIREMENTS, AND
TYPE-STYLE REQUIREMENTS**

Pursuant to 37 C.F.R. §42.24(d), I certify that the foregoing Petition complies with the type-volume limitation of 37 C.F.R. §42.24 and contains 12,192 words based on the word count indicated by the word-processing system used to prepare the paper, excluding the parts exempted by 37 C.F.R. §42.24(a). Further, the foregoing Petition complies with the general format requirements of 37 C.F.R. §42.6(a) and has been prepared using Microsoft Word in 14-point Times New Roman.

Dated: January 31, 2025

Respectfully submitted,

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CERTIFICATE OF SERVICE (37 C.F.R. §42.6(e)(1))

The undersigned hereby certifies that the above document was served on January 31, 2025, by filing this document through the Patent Trial and Appeal Board P-TACTS System, as well as delivering a copy via express mail upon the following attorneys of record for the Patent Owner.

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