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(54) **Title**: DEVICE AND METHOD FOR EXTRACTING PHYSIOLOGICAL INFORMATION

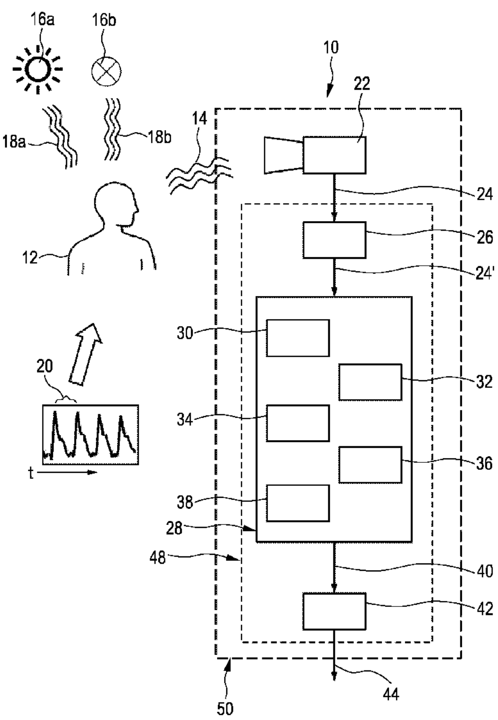

FIG. 1

(57) **Abstract**: The present invention relates to a device and a method for extracting physiological information from remotely detected electromagnetic radiation (15) emitted or reflected by a subject. A data stream (24) derived from detected electromagnetic radiation (14) is received, the data stream (24) comprising a sequence (102) of signal samples (104) representing a region of interest (58; 108) exhibiting a continuous or discrete characteristic signal (128) including physiological information indicative of at least one at least partially periodic vital signal (20; 138, 142). The sequence (102) of signal samples (104) is selectively partitioned into at least two distinct sub-sequences (116a, 116b, 116c, 116d) of defined signal subsets (66, 84) representing spatial sub-regions of the region of interest (58; 108). Each of a plurality of the at least two distinct sub-sequences (116a, 116b, 116c, 116d) is processed and thereby a plurality of distinct indicative characteristic sub-signals (74a, 74b, 74c, 74d; 122) is extracted, wherein each of the at least two distinct indicative characteristic sub-signals (74a, 74b, 74c, 74d; 122) is extracted from a respective distinct sub-sequence (116a, 116b, 116c, 116d). Consequently, an enhanced characteristic signal (72; 135) is generated by combining the extracted characteristic sub-signals (74a, 74b, 74c, 74d; 122).

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Device and method for extracting physiological information

FIELD OF THE INVENTION

The present invention relates to a device and method for extracting physiological information from remotely detected electromagnetic radiation emitted or reflected by a subject, wherein the physiological information is embedded in a data stream comprising a sequence of signal samples representing a region of interest exhibiting a continuous or discrete characteristic signal including physiological information indicative of at least one at least partially periodic vital signal.

BACKGROUND OF THE INVENTION

US 2011/0251493 A1 discloses a method for measuring physiological parameters comprising:

– capturing a sequence of images of a human face;

– identifying location of the face in a frame of the captured images and establishing a region of interest including the face;

– separating pixels in the region of interest in a frame into at least two channel values forming raw traces over time;

– decomposing the raw traces into at least two independent source signals; and

– processing at least one of the source signals to obtain a physiological parameter.

The document further discloses several refinements of the method. In particular, the use of remote photoplethysmographic (PPG) analyses is envisaged. Photoplethysmography is a commonly known optical measurement approach which can be used to detect blood volume changes in the microvascular bed of tissue of a monitored subject. Conventional PPG approaches include so-called contact PPG. Contact PPG requires measurement components (e.g., light sources and photodetectors) which basically have to be attached to a subject's skin. Consequently, standard photoplethysmography comprises obtrusive measurements, e.g. via a transceiver unit being fixed to the subject's earlobe or fingertip. Therefore, remote PPG measurement is often experienced as being unpleasant.

Typically, a standard (or: contact) PPG device includes artificial light sources to be directly attached to an indicative surface, e.g., a skin portion, of the subject to be observed. In this manner, avoidance or reduction of adverse effects is achieved. For instance, potentially disturbing incident radiation caused by other (or: ambient) light sources and undesired object motion with respect to the light source can be addressed. Correspondingly, also the receiver or detector, e.g. at least one photodiode, is closely fixed to the subject's skin patch of interest. In case the transceiver unit is too firmly fixed to the subject so as to avoid subject movement with respect to the equipment, signal quality can be deteriorated as well, e.g. due to undesired tissue compression.

Recently, remote PPG approaches applying unobtrusive measurements have been introduced. Basically, remote photoplethysmography utilizes light sources or, in general, radiation sources, disposed remote from the subject of interest. Preferably, for some applications, even readily available existing (ambient) light sources rather than defined special-purpose light sources are utilized. For instance, artificial light sources and/or natural light sources can be exploited. Consequently, in remote PPG environments, it has to be expected that due to widely changing illumination conditions, the detected signals generally provide a very small signal-to-noise ratio. Similarly, also a detector, e.g., a camera, can be disposed remote from the subject of interest for remote PPG measurements. Therefore, remote photoplethysmographic systems and devices are considered unobtrusive and can be adapted and well suited for everyday applications. The field of application may comprise unobtrusive inpatient and outpatient monitoring and even leisure and fitness applications. In this regard, it is considered beneficial that observed subjects can enjoy a certain degree of freedom of movement during remote PPG measurement.

Consequently, compared with standard (obtrusive) photoplethysmography, remote (unobtrusive) photoplethysmography is far more susceptible to distortion and noise. Undesired subject motion with respect to the detector and/or the radiation source can excessively influence signal detection. In particular, remote photoplethysmographic devices are frequently subjected to varying overall illumination conditions. Therefore, it has to be expected that the detected signals are almost always corrupted by noise and distortion.

In addition, remote photoplethysmography measurements may suffer from so-called specular reflections in the region of interest comprising at least a portion of the subject's skin tissue. Basically, specular reflection is considered a "mirror-like" reflection of incident radiation at a surface. Specular reflections may also occur at the skin surface of a living being. This applies in particular to greasy skin portions and, generally, to subjects having considerably dark skin (high content of melanin). Since skin portions which are subjected to specular reflections basically mirror incident radiation at the skin's surface, the radiation is prevented from penetrating the skin tissue and, consequently, from being reflected or absorbed by blood vessels and surrounding tissue portions. Therefore, specularly reflected radiation is considered non-indicative of the desired vital signals.

In summary, remote PPG is still considered to pose major challenges to signal detection and signal processing. Since the recorded data, such as captured reflected or emitted electromagnetic radiation (e.g., recorded image frames), always comprises, besides the desired signal to be extracted therefrom, further signal components deriving from overall disturbances, for instance noise due to changing luminance conditions (including specular reflections) and relative movement between the observed subject and the detection sensor, a detailed precise extraction of the desired signals is still considered to pose major problems for existing detection approaches and processing algorithms.

This applies in particular when the region of interest which has been selected for collecting indicative data to be processed during signal extraction is subjected to locally occurring disturbances. For instance, the subject's face can be selected to form the region of interest. To this end, for instance, a rectangular box more or less fitting the face can be chosen, while the remaining portion of the initial image frame can be disregarded during further processing. In other words, the region of interest can be cropped or clipped. The region of interest can be tracked over time over a sequence of image frames. Basically, tracking may comprise recurring pattern detection (e.g., face detection) or motion compensation based on algorithms directed to estimate positional shift of the region of interest over time in the sequence of frames. In this way, the region of interest can be kept "stable", at least to a certain extent. Tracking the region of interest via pattern detection, positional shift estimation or a suitable combined algorithm is considered to require huge processing power or, so to say, computational costs. However, varying disturbances within the region of interest cannot be addressed in this way.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a system and a method for extracting physiological information from remotely detected electromagnetic radiation emitted or reflected by a subject providing further refinements facilitating obtaining the desired signals with higher accuracy.

Furthermore, it would be advantageous to provide a device and a method even more adapted for enabling signal extraction under considerably poor ambient conditions such as varying luminance conditions and/or steady or even unsteady movements of the subject to be observed. It would be even further advantageous to provide a method and a device suitably configured for being less susceptible to internal local disturbances in the region of interest.

In a first aspect of the present invention, a device for extracting physiological information from remotely detected electromagnetic radiation emitted or reflected by a subject is presented, the device comprising:

– an interface for receiving a data stream derived from detected electromagnetic radiation, the data stream comprising a sequence of signal samples representing a region of interest exhibiting a continuous or discrete characteristic signal including physiological information indicative of at least one at least partially periodic vital signal,

– a partitioning unit configured for selectively partitioning the sequence of signal samples into at least two distinct sub-sequences of defined signal subsets representing spatial sub-regions of the region of interest,

– a signal extraction unit for processing each of a plurality of the at least two distinct sub-sequences and thereby extracting a plurality of distinct indicative characteristic sub-signals, wherein each of the at least two distinct indicative characteristic sub-signals is extracted from a respective distinct sub-sequence, and

– a data combining unit configured for generating an enhanced characteristic signal by combining the extracted characteristic sub-signals.

The present invention is based on the idea that spatially dividing or splitting the sequence representing the region of interest into at least two sub-sequences representing respective portions, portion-by-portion processing the portions, so as to extract sub-signals indicative of the desired vital signal and, eventually, combining the respective sub-signals into a resulting enhanced signal, can significantly improve the signal-to-noise ratio in the resulting extracted signals. This can even be the case under considerably adverse situations suffering from local or regional disturbances in the region of interest which even may drift or move within the region of interest over time.

It is worth noting that the signal subsets of which the sub-sequences are composed may be configured in an overlapping, disjoined or adjoined pattern. In other words, the at least two sub-sequences may represent partially overlapping, adjoined, or disjoined portions of the original signal samples. It should be understood that in some embodiments the at least two sub-sequences may comprise respective subsets which are different in size, shape or orientation. However, preferably the subsets within each of these sub-sequences are equal in size, shape or orientation.

When processing the whole region of interest, typically single entities (or: pixels) in the region of interest are agglomerated and combined per single region of interest, or, so to say, per image frame, so as to derive a single signal set, e.g., color information related values. In this way, locally occurring "spots" which undergo severe disturbances adversely influence the signal extraction processing for the whole region of interest. It would therefore be beneficial to account for these "spots" and to disregard or, at least, attenuate them during further processing. Practically, such kind of spot localization simply cannot be fully achieved due to restricted computational capacity and to the lack of suitably performing algorithms.

In other words, theoretically, it would be desirable to adjust or readjust the region of interest in terms of size (or: pixel size) in every single frame of a series of frames. Basically, this approach would be associated with a trade-off between choosing the size of the region of interest as small as possible, so as to (hopefully) obtain an ideal composition of the region exhibiting no major disturbances and choosing the region of interest as large as possible, so as to obtain a broad signal basis for the afore-mentioned pixel agglomeration.

The device of the invention provides for a beneficial solution for the above challenges, providing both manageable computational costs and considerable improvement of the signal-to-noise ratio. To this effect, the extracted characteristic sub-signals can be distinctly treated in the combining unit. In other words, the extracted characteristic sub-signals can be weighted or biased when generating the enhanced characteristic signal. In this way, greater prominence can be given to characteristic sub-signals which are considered to comprise a satisfying or even better signal-to-noise ratio ("plain" or relatively clean sub-signals). Conversely, characteristic sub-signals which are considered to show a poor signal-to-noise ratio (distorted sub-signals) can be attenuated or even disregarded. By partitioning the region of interest into a plurality of subsets, it becomes more likely that disturbance-affected portions of the region of interest are clearly present in one or more of the signal subsets (distorted subsets), while the remaining subsets are far less affected by these disturbances (relatively clean signal subsets). Consequently, during further processing, relatively clean signal subsets can be enhanced, while distorted signal subsets can be attenuated or even skipped.

It should be understood that in a given region of interest the at least two defined signal subsets the region of interest is partitioned into, may mutually cover an area which corresponds to the size of the region of interest. The signal subsets may be arranged in an adjoining order, a spaced order, or even in a partially overlapping order.

It should also be understood that determining the present state of each of the at least two defined signal subsets is not necessarily considered to be a rather black or white situation. There may be further increments or graduations related to a signal subset's quality or signal-to-noise ratio. Furthermore, it is worth noting that determining the actual state of the signal subsets does not necessarily require a distinct operation. By contrast, when combining the characteristic sub-signals, statistical algorithms may be applied, so as to allow for inline-weighting the sub-signals during combination.

For instance, the enhanced characteristic signal can be generated under consideration of a weighted average of the characteristic sub-signals, wherein the respective weighting factors are proportional to the quality or signal-to-noise ratio of each of the treated characteristic sub-signals.

In one embodiment, the variance of each of the characteristic sub-signals is calculated and the resulting enhanced characteristic signal can be generated on the basis of a weighted average of the characteristic sub-signals, wherein the weighting factors may correspond to the inverse variance of the respective sub-signal:

$$HBo(t) = \sum_i w(i) \cdot HBi(t), \quad (1)$$

wherein

$$w(i) = 1 / var(HBi(t) + \delta). \quad (2)$$

Argument t denotes time or may also represent a present frame number in a sequence of frames. HBo stands for the (overall) enhanced characteristic signal. HBi denotes a respective characteristic sub-signal. The actual weighting factor is denoted by w(i). The addition parameter δ (delta) may be considered a small bias which may be applied to even further attenuate distorted sub-signals by correcting extreme weights w(i) which are erroneously assigned to signal subsets which are heavily distorted and, therefore, not-indicative of the desired vital signals.

In another embodiment, sub-signal combination may be performed under consideration of a median of the characteristic sub-signals (at the same time instant or frame):

$$HBo(t) = median(HBi(t)) \, . \qquad (3)$$

Further statistical approaches can be envisaged which are applicable for the combination of the characteristic sub-signals. For instance, alpha-trimmed mean filtering can be applied to the characteristic sub-signals. Also in this way, extreme values (massively distorted sub-signals) can be eliminated or disregarded.

The data stream may comprise a sequence of frames or, more precisely, a series of image frames comprising spectral information. For instance, RGB-images comprising color information can be utilized. However, also frames representing infrared (IR) and red (R) information can form the sequence of frames. The image frames can represent the observed subject and further elements.

There exist several embodiments of the partitioning unit, the signal extraction unit and the data combining unit. In a first, fairly simple embodiment, the partitioning unit, the signal extraction unit and the data combining unit are commonly embodied by a processing unit which is driven (or: controlled) by respective logic commands. Such a processing unit may also comprise suitable input and output interfaces.

However, in the alternative, each of the partitioning unit, the signal extraction unit and the data combining unit can be embodied by separate processing units, controlled or controllable by respective commands. Hence, each respective processing unit can be adapted to its special purpose. Consequently, a distribution of tasks can be applied, wherein distinct tasks are processed (or: executed) on a single processor of a multi-processor processing unit, or wherein image processing related tasks are executed on an image processor while other operational tasks are executed on a central processing unit.

According to an advantageous embodiment, the partitioning unit is further configured for multiply partitioning the region of interest into at least two groups, each of which comprising at least two defined signal subsets represented by respective distinct sub-sequences, wherein the at least two groups comprise different partition patterns.

In this way, the region of interest may form a basis for different partition patterns which in turn allows for choosing a suitable group (or: pattern) for a given disturbance in the present region of interest. The higher the number of subsets in a group, the better a set of subsets may "match" a distortion-affected area or a highly indicative area. The smaller the number of subsets in the group, the broader is the basis for pixel agglomeration within the signal subsets which enables some spatial normalization which may basically result in more robust results, e.g. attributable to noise reduction through pixel averaging.

In one embodiment, a first group may have just one subset which basically corresponds to the whole size of the region of interest. In this way, also a conventionally derived "sub-signal" can be considered during further signal processing.

The at least two groups can be different in size, number, orientation, arrangement or even shape of their respective subsets. For instance, the region of interest can be multiply partitioned into four groups each of which having a size corresponding to the size of the region of interest. A first group may have just one subset. A second group may have two subsets each of which covering half the area of the subset of the first group. The third group may have four subsets each of which covering half the area of a subset of the second group. The fourth group may comprise eight subsets each of which covering half the area of a respective subset of the third group.

It is worth noting that for signal processing, a selection of subsets for processing and combining can be made within each of the groups. Still, however, also an embodiment can be envisaged wherein a selection can be made across some of the at least two groups. By way of example, a subset of a second group can be combined with four subsets of a fourth group. As mentioned above, the combination may involve generating an enhanced characteristic signal by "merging" respective characteristic sub-signals. Therefore, data combining may involve sub-signals of one group or a plurality of groups.

According to another aspect, each additional group of defined subsets exceeding a first group of defined signal subsets comprises a different number of defined signal subsets than a respective anterior group.

In this way, the device can be configured such that a further group can be added on demand, for instance, when data processing based on a given group or a given plurality of groups does not result in sufficient signal quality. In such cases, farther reaching segmentation or splitting of the region of interest can be an appropriate measure allowing for better "matching" distorted areas and high-indicative areas with a set of (considerably smaller) subsets. It should be noted that the term "anterior" does not necessarily relate to a temporal order.

In a further embodiment which can be combined with this embodiment, each additional group of subsets comprises a larger number of subsets, wherein each of the subsets covers a smaller portion than a respective subset of the anterior group. Conversely, each additional group of subsets exceeding a first group of subsets may comprise a smaller number of subsets, wherein each of the subsets covers a larger portion than a respective subset of the anterior group. It should be understood that within a group the signal subsets do not necessarily have the same size and shape. A group may comprise various different signal subsets.

According to yet another aspect, the signal extraction unit is further configured for group-wise processing each of a plurality of the at least two distinct sub-sequences of a respective group, thereby extracting a plurality of distinct indicative characteristic sub-signals per group.

In accordance with this embodiment, parallel processing (not necessarily temporally simultaneous processing, or concurrent processing) can be achieved. Furthermore, characteristic sub-signal combination can be performed "across" more than one group. Consequently, the region of interest of a single frame is more than once utilized for partitioning, sub-signal derivation and the enhanced characteristic signal generation. So, basically the same input data can be "multiplied" for data enrichment measures. Still, given the different subset patterns in each of the groups, the resulting signal quality can be improved under consideration of a weighting algorithm for combining the sub-signals.

In still another aspect, the data combining unit is further configured for group-wise generating an immediate characteristic signal by group-wise combining the extracted characteristic sub-signals for each group, and for generating the enhanced characteristic signal by combining the intermediate characteristic signals.

This embodiment is beneficial in that a two-stage combination of signals into the finally desired characteristic signal is achieved. In a first stage, group-wise, characteristic sub-signals for each of the subsets can be processed, as indicated above. Since more than one group is utilized, consequently several sets of sub-signals can be obtained. In the two-stage approach, sub-signal combination can be accomplished per group. In this way, for each group a respective intermediate characteristic signal can be derived. In the second stage, the intermediate characteristic signals can be combined into the resulting enhanced characteristic signal. In each combination stage, appropriate weighting and/or signal enhancing or diminishing algorithms can be utilized. Consequently, the signal-to-noise ratio in the resulting characteristic signal can be further improved.

According to another aspect, the signal extraction unit is further configured for processing an unpartitioned original signal set basically formed by the whole region of interest, thereby extracting another distinct indicative characteristic sub-signal. In other words, the unpartitioned original signal set can be regarded as a group comprising a single subset.

According to yet another aspect, the device further comprises a segmentation unit configured for determining an indicative frame section, in particular a skin portion of the subject, the indicative frame section comprising the region of interest. The segmentation unit can be further configured for motion compensation, face recognition and/or feature recognition. In the alternative or in addition, the device may further comprise a skin segmentation means for detecting the region of interest in the subject, preferably the skin segmentation means comprises a feature tracker for detecting at least one distinct skin portion, in particular a face pattern.

According to another aspect, the at least one at least partially periodic vital signal is selected from the group consisting of heart rate, heart beat, respiration rate, heart rate variability, Traube–Hering–Mayer waves, and oxygen saturation.

According to yet another aspect, the at least two distinct indicative characteristic sub-signals are associated with a signal space representative of characteristics of the electromagnetic radiation, wherein the signal space is preferably a color signal space comprising at least two complementary channels, wherein the at least two complementary channels are related to defined spectral portions, and wherein the at least two distinct indicative characteristic sub-signals are derived under consideration of at least two main components, each of which being related to a respective complementary channel.

Based on a ratio of the at least two complementary channels, the desired vital signal eventually can be calculated. For instance, the at least two complementary channels may correspond to a red channel, a green channel and a blue channel, each of which covering a distinct spectral portion of visible light. The desired vital signal extraction can make use of differences in radiation absorption (and, therefore, also in reflection) of the subject's blood vessels and the surrounding skin tissue. In the skin tissue, mainly melanin portions influence incident radiation. Making use of at least two, preferably three complementary channels can allow for disturbance compensation. This may involve defining suitable coefficients of a linear combination of the at least two, preferably three main components of the characteristic sub-signals. It goes without saying that the above composition may also apply to the characteristic signal generated through combining the characteristic sub-signals.

In an alternative embodiment, the at least two complementary channels may comprise infrared channels, or a combination of visible light and infrared light channels. Also in this way, the desired vital signals can be detected.

In still yet another embodiment, the device further comprises a sensor means, in particular a camera, configured for remotely sensing electromagnetic radiation and capable of capturing the data stream, preferably the sensor means comprises a spectral sensitivity adapted to spectral characteristics of complementary channels forming a signal space.

For instance, RGB cameras or cameras configured for sensing red and infrared portions of electromagnetic radiation can be applied. It is worth noting that beside RGB signal spaces, further additive or subtractive signal spaces (as well as their derivates, such as logRGB) can be envisaged. For instance, also a CMYK color space can be used. It should be understood that signal spaces can be converted into each other. Furthermore, also expanded signal spaces can be utilized, for instance a signal space comprising red, green, blue and infrared channels. However, in the alternative, also derivative signal spaces can be utilized, for instance a signal space making use of H, S, U and V signals (or their derivates), wherein the channels may represent hue, saturation, and the colour difference signals U and V.

According to another aspect, the signal extraction unit is further configured for enhancing a signal-to-noise ratio in each of the extracted characteristic sub-signals. Signal enhancing may involve illumination normalization, color normalization and motion compensation measures. Basically, these measures can be applied on the characteristic sub-signal level or on the characteristic signal level, but also on both levels.

In yet another embodiment, the partitioning unit is further configured for selectively partitioning the region of interest into an initial partition grid comprising a plurality of initial sub-samples, and for defining the at least two defined signal subsets based on a recombination of the initial sub-samples. In this way, partitioning the region of interest can be even more flexible. For instance, partitioning is not bound to portions having simple geometrical shapes (e.g., rectangle, triangle). By contrast, each of the at least two defined signal subsets may have a shape of any desired (polygonal) form. Also in this way, the signal subsets can be suitably adapted or matched to distortions or high-indicative areas in the region of interest.

In a further aspect of the present invention, a method for extracting physiological information from remotely detected electromagnetic radiation emitted or reflected by a subject is presented, the method comprising the steps of:

– receiving a data stream derived from detected electromagnetic radiation, the data stream comprising a sequence of signal samples representing a region of interest exhibiting a continuous or discrete characteristic signal including physiological information indicative of at least one at least partially periodic vital signal,

– selectively partitioning the sequence of signal samples into at least two distinct sub-sequences of defined signal subsets representing spatial sub-regions of the region of interest,

– processing each of a plurality of the at least two distinct sub-sequences and thereby extracting a plurality of distinct indicative characteristic sub-signals, wherein each of the at least two distinct indicative characteristic sub-signals is extracted from a respective distinct sub-sequence, and

– generating an enhanced characteristic signal by combining the extracted characteristic sub-signals.

Advantageously, the method can be carried out utilizing the device for extracting physiological information of the invention.

According to an embodiment, the method further comprises the step of:

– multiply partitioning the region of interest into at least two groups, each of which comprising at least two defined signal subsets represented by respective distinct sub-sequences, wherein the at least two groups comprise different partition patterns.

In yet another aspect of the present invention, there is provided a computer program which comprises program code means for causing a computer to perform the steps of the processing method when said computer program is carried out on a computer.

As used herein, the term "computer" stands for a large variety of processing devices. In other words, also mobile devices having a considerable computing capacity can be referred to as computing device, even though they provide less processing power resources than standard desktop computers. Furthermore, the term "computer" may also refer to a distributed computing device which may involve or make use of computing capacity provided in a cloud environment.

Preferred embodiments of the invention are defined in the dependent claims. It should be understood that the claimed methods and the claimed computer program can have similar preferred embodiments as the claimed device and as defined in the dependent device claims.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter. In the following drawings:

Fig. 1 shows a schematic illustration of a general layout of a device in which the present invention can be used;

Fig. 2a shows a simplified exemplary frame representing an observed subject;

Fig. 2b shows an enlarged partial view of the frame according to Fig. 2a, representing a region of interest;

Figs. 3a, 3b show segmentation patterns applicable to respective regions of interest;

Fig. 4 shows an illustrative representation of a region of interest which is partitioned into signal subsets;

Fig. 5 shows a representation of groups having different numbers of subsets which are processed and eventually combined;

Fig. 6 shows another representation of groups of signal subsets which are processed and combined in a two-stage approach;

Figs. 7a, 7b show a representation of a region of interest which is partitioned into an initial partition grid based on which two defined signal subsets are formed;

Fig. 8a, 8b, 8c depict diagrams, each of which showing a spectrogram comprising physiological information obtained from a subject of interest; and

Fig. 9 shows an illustrative block diagram representing several steps of an embodiment of a method according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

The following section describes exemplary approaches to remote photoplethysmography utilizing several aspects of the device and method of the invention. It should be understood that single steps and features of the shown approaches can be extracted from the context of the respective overall approach or embodiments. These steps and features can therefore be part of separate embodiments still covered by the scope of the invention.

Basic approaches to remote photoplethysmography are described in Verkruysse, W. at al. (2008), "Remote Plethysmographic Imaging Using Ambient Light" in Opctics Express, Optical Society of America, Washington, D.C., USA, Vol. 16, number 26, pp. 21434-21445.

Fig. 1 shows a schematic illustration of a device for extracting physiological information which is denoted by a reference numeral 10. For instance, the device can be utilized for recording image frames representing a remote subject 12 for remote PPG monitoring. The image frames can be derived from electromagnetic radiation 14 reflected by the subject 12. Possibly, under certain conditions, in particular specific luminance conditions, at least part of the electromagnetic radiation 14 could be emitted or transmitted by the subject

12. Radiation transmission may occur when the subject 12 is exposed to strong illumination sources shining through the subject 12. Radiation emission may occur when infrared radiation caused by body heat is addressed and captured. However, for remote PPG applications, a huge portion of the electromagnetic radiation 14 can be considered radiation reflected by the subject 12. The subject 12 can be a human being or an animal, or, in general, a living being. Furthermore, the subject 12 can be part of a human being highly indicative of a desired signal, e.g., a face portion or, in general, a skin portion.

A source of radiation, such as sunlight 16a or an artificial radiation source 16b, also a combination of several radiation sources can affect or impinge on the subject 12. The radiation source 16a, 16b basically emits incident radiation 18a, 18b striking the subject 12. For extracting physiological information from the recorded data, e.g., a sequence of image frames, a defined part or portion of the subject 12 can be detected by a sensor means 22. The sensor means 22 can be embodied, by way of example, by a camera adapted for capturing information belonging to at least one spectral component of the electromagnetic radiation 14. Needless to say, the device 10 also can be adapted to process input signals, namely an input data stream, already recorded in advance and, in the meantime, stored or buffered. As indicated above, the electromagnetic radiation 14 can contain a continuous or discrete characteristic signal which can be highly indicative of at least one at least partially periodic vital signal 20. The characteristic signal can be embedded in an (input) data stream 24.

According to an embodiment, for data capturing, a potentially highly indicative portion of the subject 12 can be selected (or: masked with a pixel pattern). When agglomerating respective single pixel values of the pixel pattern at an instant, a mean pixel value can be derived from the pixel pattern. In this way, the detected signals can be normalized and compensated for overall disturbances to some extent. Generally, the characteristic signal is considered to contain a constant (DC) portion and an alternating (AC) portion superimposing the DC portion. Applying signal processing measures, the AC portion can be extracted and, furthermore, compensated for disturbances. For instance, the AC portion of the characteristic signal can comprise a dominant frequency which can be highly indicative of the subject's 12 heart rate. The mean pixel value can be represented by a characteristic signal. The vital signal of interest 20 can be embedded in slight fluctuations (slight periodic property changes) of the characteristic signal. In the following, the captured data stream can be considered a representation of a certain area of interest in the subject 12 which may cover an agglomerated pixel area covering a plurality of pixels. In Fig. 1, the vital signal 20 may allow several conclusions concerning heart rate, heart beat, heart rate variability, respiratory rate, or even oxygen saturation.

The known methods for obtaining such vital signals may comprise tactile heart rate monitoring, electrocardiography, or pulse oximetry. To this end, however, obtrusive monitoring was required. As indicated above, an alternate approach is directed to unobtrusive remote measuring utilizing image processing methods.

The data stream 24 comprising the continuous or discrete characteristic signal can be delivered from the sensor means 22 to an interface 26. Needless to say, also a buffer means could be interposed between the sensor means 22 and the interface 26. Downstream of the interface 26, the input data stream 24' can be delivered to a processing module or processing unit 28. The partitioning unit 28 can be considered a computing device or, at least, part of a computing device driven by respective logic commands (program code), so as to provide for desired data processing. The partitioning unit 28 may comprise several components or units which are addressed in the following. It should be understood that each component or unit of the processing unit 28 can be implemented virtually or discretely. For instance, the partitioning unit 28 may comprise a number of processors, such as multi-core processors or single-core processors. At least one processor can be utilized by the partitioning unit 28. Each of the processors can be configured as a standard processor (e.g., central processing unit) or as a special purpose processor (e.g., graphics processor). Hence, the partitioning unit 28 can be suitably operated so as to distribute several tasks of data processing to adequate processors.

In accordance with an embodiment of the present invention, the processing unit 28 comprises a segmentation unit 30 configured for determining an indicative frame section, in particular a skin portion of the subject 12, such that the indicative frame section preferably comprises the region of interest. It should be mentioned that both the indicative frame section and the region of interest can match or correspond to each other. However, alternatively, the indicative frame section and the region of interest also may somehow deviate in size or position. The segmentation unit 30 can be adapted for skin segmentation and/or feature tracking measures. Both skin segmentation and feature tracking can be utilized for pattern detection, so as to initially detect the region of interest and to track the region of interest over time. Hence, the segmentation unit 30 can contribute in motion compensation.

In an alternative embodiment, however, pattern detection or skin segmentation can be performed manually by a user of the device 10. For instance, the user can mask a face portion or a skin portion of the subject 12 in a frame representing an initial frame for determining an initial frame section to be processed.

The partitioning unit 28 may further comprise a partitioning unit 32 configured for selectively partitioning the region of interest into at least two defined signal subsets. In this way, a sequence of frames embedded in the data stream can be split into at least two sub-sequences. As used herein, splitting or partitioning typically refers to dividing an area in a region of interest.

The partitioning unit 28 may further comprise a signal extraction unit 34 for processing each of a plurality of the at least two distinct sub-sequences generated by the partitioning unit 32. In this way, a plurality of distinct indicative characteristic sub-signals can be derived. So, instead of processing the region of interest as a whole, sub-portions thereof can be processed separately. In this way, locally occurring disturbances and distortions can be addressed. Signal processing, in particular signal extraction, can be performed by a signal extraction unit 34. The signal extraction unit 34 can be configured for processing each of a plurality of the at least two distinct sub-sequences. In other words, the signal extraction unit 34 does not necessarily have to process every sub-sequence generated by the partitioning unit 32.

Given that the portion of interest can be locally corrupted by distortions, it can be assumed that some of the at least two distinct sub-sequences (of respective subsets) exhibit heavily distorted signals while others may exhibit far less distorted signals. The higher the number of signal subsets the region of interest is partitioned into, the better a present distortion occurrence can be "matched" by some of the subsets.

As mentioned above, preferably, the partitioning unit 32 and the signal extraction unit 34 can be further configured for multiply partitioning and processing the region of interest such that at least two groups of signal subsets are formed and processed accordingly. In this way, each time instant (frame number) of the region of interest can be processed several times. The provision of at least two groups of defined signal subsets allows for far more flexibility when facing locally occurring distortions and disturbances in the region of interest.

In addition, the processing unit 28 can comprise a data combining unit 36 configured for generating an enhanced characteristic signal under consideration of the extracted characteristic sub-signals. For generating the enhanced characteristic signal, particularities of the characteristic sub-signals can be considered. For instance, statistical measures can be applied so as to attenuate outliers which are supposed to be mainly caused by locally occurring disturbances. Hence, the resulting enhanced characteristic signal can be further improved. It should be noted that on a basis of the characteristic sub-signals, local disturbance-related artefacts can be precisely realized and addressed. By contrast, when processing the region of interest as a whole, merely rather untargeted (in terms of local distortions) signal enhancement measures can be applied.

Still, however, the processing unit 28 can further comprise a signal enhancement unit 38 which is configured for further processing the characteristic signal generated by the signal combining unit 36. For instance, the signal enhancement unit 38 can be configured to seek for dominant frequencies in the characteristic signal. Alternatively, the signal enhancement unit 38 can be configured for filtering the characteristic signal such that frequency portions which are considered not to be indicative of the desired vital signal 20 can be disregarded or, at least, attenuated.

Eventually, a processed data stream 40 can be generated by the processing unit 28. Downstream of the processing unit 28, an (output) interface 42 can be provided to which the processed data 40 can be delivered. Both interfaces 26, 42 can be embodied by the same (hardware) connectors. Via the interface 42, output data 44 can be made available for further analyses and/or for display measures. The processing unit 28 as well as the interfaces 26, 42 can be embodied in a common processing apparatus or housing 48. Reference numeral 48 can also describe a virtual system boundary. Still, also the sensor means 22 can be integrated in the common processing housing 48. A potential overall system boundary of the device 10 is denoted by a reference numeral 50. It should be understood that the device 10 also can be implemented as a distributed device. For instance, at least the sensor means 22 can be partitioned separate or distant from the processing unit 28. Moreover, functional entities of the processing unit 28 can be implemented in distributed processing devices which can be connected via cable or wireless connections or networks.

Fig. 2a illustrates an (image) frame 54 comprising a representation of the subject 12. As mentioned above, a skin portion of the subject 12, in particular a face portion of the subject 12, is considered to be highly indicative of the desired vital signals. By way of example, in the frame 54 an indicative frame section 56 is chosen. To this end, pattern detection or recognition can be applied. For instance, the indicative frame section 56 can be determined upon face detection. Typically, the indicative frame section 56 comprises or corresponds to a region of interest 58. In Fig. 2a, exemplarily, the indicative frame section 56 and the region of interest 58 do not match.

As used herein, the term "region of interest" typically refers to a set or an array of pixels. Since motion-related disturbances have to be expected for remote photoplethysmography, it should be understood that the precise position of the region of interest 58 in each frame 54 of a series (sequence) of frames 54 can drift or move over time. Therefore, preferably, motion compensation measures are applied, so as to ensure that the region of interest 58 can be tracked over time.

Fig. 2b is an enlarged view of the region of interest 58 in the subject 12 chosen in Fig. 2a. As mentioned above, the region of interest 58 can be locally corrupted by distortions. For instance, distorted regions 60a, 60b can be present in the region of interest 58. In some subjects 12, depending on the observing environment, the forehead region can be susceptible to specular reflections. This applies in particular when the forehead region is sweaty or greasy. Therefore, the distorted region 60a can adversely influence the results of data processing focussing on the region of interest 58 as a whole. Basically, the same may apply to the distorted region 60b. For instance, the distorted region 60b can be formed by a portion of the subject's 12 skin which is barely illuminated. It goes without saying that the distorted regions 60a, 60b are merely exemplary representatives of various types of distorted regions that may occur in the region of interest 58. So, presumably, distortions may locally occur everywhere in the region of interest 58. It is therefore noted that a mere reduction of the size of the region of interest 58 does not provide a sufficient solution, since the smaller the size, the greater the influence of any distortion on the overall processing results. It would therefore be beneficial to maintain the size of the region of interest 58 while providing a data processing approach, allowing to somehow selectively addressing sub-regions of the region of interest 58.

A preferred approach to these demands may comprise partitioning the region of interest 58 into at least two defined signal subsets. In another preferred embodiment, partitioning the region of interest 58 comprises a multiple partition. Multiply partitioning may comprise deriving at least two groups of at least two defined signal subsets from the original region of interest 58.

In this connection, Figs. 3a and 3b are referred to. Fig. 3a shows an exemplary set of groups 64, 64', 64", 64"', while Fig. 3b shows an alternative exemplary set of groups 64a, 64a', 64a", 64a"'. Each of the groups 64, 64a may correspond to a defined region of interest 58. This may include a representation of the region of interest 58, 58a in each of the groups 64, 64a.

In Fig. 3a, the region of interest 58 is multiply partitioned. The first group 64 basically may comprise a single signal subset which may correspond to an original set 73 covering the whole area of the region of interest 58. The second group 64' may comprise two defined signal subsets which are denoted for illustrative purposes by reference numerals 66a, 66b. The third group 64" may comprise four defined subsets. By way of example, the fourth group 64"' may comprise sixteen signal subsets.

In Fig. 3b, the first group 64a also comprises a single signal subset which can correspond to an unpartitioned original signal subset 73 basically corresponding to the whole area of the region of interest 58. The second group 64a' may comprise two defined signal subsets. The third group 64a" may comprise four defined signal subsets. The fourth group 64a"' may comprise nine defined signal subsets. It goes without saying that a great variety of sets of groups 64, 64a comprising a great variety of signal subsets can be envisaged. The size, orientation and order of the subsets within the groups 64, 64a may vary as well.

Fig. 4 illustrates an exemplary approach to data processing which is based on a partitioned region of interest. Based on the region of interest, a group 64" is formed comprising four signal subsets 66a, 66b, 66c, 66d. Altogether, the signal subsets 66a, 66b, 66c, 66d may represent the region of interest 58. The defined signal subsets 66a, 66b, 66c, 66d may have the same shape and size, but may also comprise different shapes and sizes. Moreover, the defined signal subsets 66a, 66b, 66c, 66d may represent disjoined, adjoined or even overlapping portions of the region of interest. From some or each of the defined signal subsets 66a, 66b, 66c, 66d, a characteristic sub-signal 74a, 74b, 74c, 74d can be derived through sub-processing (indicated by the arrows 68a, 68b, 68c, 68d). Basically, the characteristic sub-signals 74 may be more or less affected by local disturbances occurring in some of the defined signal subsets 66a, 66b, 66c, 66d. As indicated by a curly bracket, the characteristic sub-signals 74a, 74b, 74c, 74d eventually can be combined, so as to generate an enhanced characteristic signal 72. Signal combining 70 may involve applying statistical algorithms, so as to attenuate or disregard characteristic sub-signals 74a, 74b, 74c, 74d which are considered to be massively corrupted.

Figs. 5 and 6 illustrate alternative exemplary partitioning, processing and combining approaches. In Fig. 5, exemplarily three groups 64, 64', 64" of signal subsets are shown. For each or at least some of the signal subsets in the groups 64, 64', 64", the respective characteristic sub-signal 74 can be processed. Signal combining 70 may involve combining some or each of the characteristic sub-signals 74. In accordance with the approach shown in Fig. 5, each of the characteristic sub-signals 74 is handled on the same level when combining. In other words, group-wise signal "pre-combining" is not applied.

In another signal combining approach which is illustrated in Fig. 6, two-stage combining is applied. Fig. 6 also shows three groups 64, 64', 64" of signal subsets. For at least some or all of the signal subsets, characteristic sub-signals 74 can be processed. An intermediate group-wise combining step 76, 76', 76" may follow. As indicated by a dashed curly bracket, signal combining 76 for the first group 64 is basically not necessary, since the characteristic sub-signal 74 is the single signal representative of group 64. In other words, provided that the group 64 merely comprises a single defined subset, the respective characteristic sub-signal 74 can be "looped through" in the signal combining step 76 since the characteristic sub-signal 74 basically corresponds to an intermediate characteristic signal 78.

For the second group 64' and the third group 64", intermediate group-wise signal combination 76', 76" involves a combination of the respective characteristic sub-signals 74a', 74b', and 74a", 74b", 74c", 74d", respectively. Consequently, intermediate characteristic signals 78', 78" can be generated. In a second combination stage, the intermediate characteristic signals 78, 78', 78" each of which is attributable to a group 64, 64', 64" can be combined (reference numeral 70), so as to generate a resulting enhanced characteristic signal 72. Both intermediate group-wise combining 76 and signal combining 70 may involve statistical data shape processing.

Figs. 7a and 7b describe an alternative approach to partitioning measures applicable to the region of interest 58. It should be understood that this approach can be combined with the signal combining approaches described in connection with Figs. 4, 5 and 6. In Fig. 7a, an initial region of interest 58 is partitioned or split into an initial partition grid 82 which is composed of a plurality of initial sub-samples 80a ... 80n. In addition, at least some of the initial sub-samples 80a ... 80n can be recombined, so as to define at least two signal subsets 84a, 84b. Consequently, each of the at least two defined signal subsets 84a, 84b can comprise a variety of different shapes. Signal subset determination is far more flexible and can address distortions and disturbances occurring in the region of interest 58 even more precisely.

Fig. 7b may basically correspond to Fig. 4. Fig. 7b illustrates that for each of the defined subsets 84a, 84b, a respective characteristic sub-signal 74a, 74b can be processed. Eventually, in a signal combining step 70, an enhanced characteristic signal 72 can be generated upon combining the respective characteristic sub-signals 74a, 74b.

Figs. 8a, 8b and 8c show exemplary spectrograms illustrating results of remote photoplethysmography analyses utilizing several approaches. In the respective diagrams, f denotes frequency, while t denotes time. The frequency axes can represent Hz (Hertz) values, while the time axes may also stand for the number of processed image frames. In this particular exemplary case, each of the respective time axes in Figs. 8a, 8b and 8c may cover a span of about 3200 frames which may basically correspond to a recording duration of about 160 s (seconds) at a sample rate (or: frame rate) of about 20 frames per second. The spectrograms shown in Fig. 8a, Fig. 8b and Fig. 8c, respectively, exemplify characteristic signals extracted at the same situation, namely signal detection results obtained from a subject initially stationary (standing still) and, later on, performing some workout on a fitness device. Under these circumstances, given that considerable periodic subject motion is involved, motion-related disturbances may render the detection and processing challenging.

The spectrogram of Fig. 8a illustrates a conventional signal extraction approach wherein the desired characteristic signal is derived (directly) from the whole portion of interest. Consequently, the signal-to-noise ratio is poor. The desired signal is almost completely hidden in noise.

The spectrogram of Fig. 8b represents a data processing approach wherein the region of interest is partitioned into basically equally sized subsets from which respective characteristic sub-signals were extracted. Then, the characteristic sub-signals are combined, so as to arrive at an enhanced characteristic signal. In Fig. 8b, signal combination is performed under consideration of a weighted average of the characteristic sub-signals. Consequently, a dominating vital signal 94 is emphasized. However, a disturbance-related signal 92 is still detectable in the spectrogram.

In the spectrogram of Fig. 8c, the extracted signal is processed under consideration of a plurality of groups each of which having a different number of signal subsets. In particular, four groups each of which representing the region of interest can be utilized, wherein the first group may comprise a (single) signal subset, wherein a second group may comprise two signal subsets, wherein a third group may comprise four signal subsets, and wherein a fourth group may comprise eight signal subsets. For each of the signal subsets (altogether fifteen subsets), a respective characteristic sub-signal is processed. Furthermore, in a signal combining step, the characteristic sub-signals are combined, so as to arrive at an improved enhanced characteristic signal. Signal combination can be performed under consideration of weighted averaging algorithms which may include variance calculation for each of the characteristic sub-signals. It can be clearly seen in Fig. 8c that the vital signal 94 obviously dominates the spectrogram.

Having demonstrated several alternative exemplary approaches covered by the invention, Fig. 9 is referred to, schematically illustrating a method for extracting physiological information from remotely detected electromagnetic radiation.

Initially, in a step 100, an input data stream or a sequence 102 comprising several frames 104a, 104b, 104c is received. A time axis is indicated by an arrow t. The data stream can be delivered from the sensor means 22 or a data buffer or storage means. The data stream can be embodied, by way of example, by a sequence of image frames varying over time. The image frames can comprise RGB-based pixel data. The data stream typically comprises a representation of a subject of interest.

In a subsequent step 106, a segmentation or pattern detection can be applied to at least one of the frames 104a, 104b, 104c. In this way, a region of interest 108 can be determined. For instance, face recognition and/or skin segmentation can be utilized. Another subsequent step 110 may follow, which may be directed to motion compensation, so as to allow to track the region of interest. For instance, a positional shift 112 of the region of interest 108 in consecutive frames 104a, 104b, 104c can be calculated, so as to determine a presumed position of the region of interest 108a, 108b over time.

A further step 114 may follow which may comprise partitioning the region of interest 108 into at least two defined signal subsets 66a, 66b, 66c, 66d. Furthermore, a sequence comprising the region of interest 108 can be multiply partitioned, so as to derive two or more groups of signal subsets 66a, 66b, 66c, 66d therefrom (not shown in Fig. 9). Over time, for each of the defined signal subsets 66a, 66b, 66c, 66d, a respective sub-sequence 116a, 116b, 116c, 116d may be formed based on a sequence 102' representing the region of interest 108. As indicated by a plurality of parallel connecting arrows, at least some of the following steps 118, 124, 134 may be applied in parallel to each of sub-sequences 116a, 116b, 116c, 116d.

In a step 118, a respective sequence of subsets undergoes an agglomerating procedure 120. Consequently, a characteristic sub-signal 122 per group can be detected. The characteristic sub-signal 122 may comprise a characteristic index element 128 per frame. The characteristic index element 128 can be attributed to a signal space 126. The signal space 126 may comprise at least two, preferably three, complementary channels 130a, 130b, 130c, each of which is indicative of a defined spectral portion. For instance, the at least two complementary channels 130a, 130b, 130c can be embodied by R-, G-, and B-channels. So, basically the characteristic index element 128 can comprise three respective components. Based on a linear combination of the at least two components of the characteristic index element 128, several signal enhancement measures can be achieved. For instance, compensation for motion and/or changing illumination conditions can be envisaged. Consequently, a processed characteristic sub-signal 132 can be obtained for each of the at least two sub-sequences 116a, 116b, 116c, 116d.

In a further step 134, the plurality of processed characteristic sub-signals 132 can be combined, so as to generate an enhanced characteristic signal 135. In this connection, statistical signal improvement algorithms can be applied. In yet another step 136, further analyzing measures can be applied to the enhanced characteristic signal 135. In addition, filtering, weighting and further signal enhancement operations ca be envisaged. For instance, a temporal representation 144 and/or a frequency-based representation 140 of desired vital signals of interest 138, 142 can be achieved.

By way of example, the present invention can be applied in the field of health care, e.g., unobtrusive remote patient monitoring, general surveillances, security monitoring and so-called life style environments, such as fitness equipment, or the like. Applications may include monitoring of oxygen saturation (pulse oximetry), heart rate, blood pressure, cardiac output, changes of blood perfusion, assessment of autonomic functions, and detection of peripheral vascular diseases. Needless to say, in an embodiment of the method in accordance with the invention, several of the steps described herein can be carried out in changed order, or even concurrently. Further, some of the steps could be skipped as well without departing from the scope of the invention. This applies in particular to several alternative signal processing steps.

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single element or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

A computer program may be stored/distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems.

Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. Device for extracting physiological information from remotely detected electromagnetic radiation emitted or reflected by a subject, comprising:

- an interface (26) for receiving a data stream (24) derived from detected electromagnetic radiation (14), the data stream (24) comprising a sequence (102) of signal samples (104) representing a region of interest (58; 108) exhibiting a continuous or discrete characteristic signal (128) including physiological information indicative of at least one at least partially periodic vital signal (20; 138, 142),

- a partitioning unit (32) configured for selectively partitioning the sequence (102) of signal samples (104) into at least two distinct sub-sequences (116a, 116b, 116c, 116d) of defined signal subsets (66, 84) representing spatial sub-regions of the region of interest (58; 108),

- a signal extraction unit (34) for processing each of a plurality of the at least two distinct sub-sequences (116a, 116b, 116c, 116d) and thereby extracting a plurality of distinct indicative characteristic sub-signals (74a, 74b, 74c, 74d; 122), wherein each of the at least two distinct indicative characteristic sub-signals (74a, 74b, 74c, 74d; 122) is extracted from a respective distinct sub-sequence (116a, 116b, 116c, 116d), and

- a data combining unit (36) configured for generating an enhanced characteristic signal (72; 135) by combining the extracted characteristic sub-signals (74a, 74b, 74c, 74d; 122).

2. Device as claimed in claim 1, wherein the partitioning unit (32) is further configured for multiply partitioning the region of interest (58; 108) into at least two groups (64, 64', 64", 64"'), each of which comprising at least two defined signal subsets (66; 84) represented by respective distinct sub-sequences (116a, 116b, 116c, 116d), wherein the at least two groups (64, 64', 64", 64"') comprise different partition patterns.

3. Device as claimed in claim 2, wherein each additional group (64', 64", 64"') of defined signal subsets (66; 84) exceeding a first group (64) of defined signal subsets (66; 84)

comprises a different number of defined signal subsets (66; 84) than a respective anterior group.

4. Device as claimed in claim 2, wherein the signal extraction unit (34) is further configured for group-wise processing each of a plurality of the at least two distinct sub-sequences (116a, 116b, 116c, 116d) of a respective group (64, 64', 64", 64'''), thereby extracting a plurality of distinct indicative characteristic sub-signals (74a, 74b, 74c, 74d; 122) per group (64, 64', 64", 64''').

5. Device as claimed in claim 2, wherein the data combining unit (36) is further configured for group-wise generating an intermediate characteristic signal (78, 78', 78", 78''') by group-wise combining the extracted characteristic sub-signals (74a, 74b, 74c, 74d; 122) for each group (64, 64', 64", 64'''), and for generating the enhanced characteristic signal (72; 132) by combining the intermediate characteristic signals (78, 78', 78", 78''').

6. Device as claimed in claim 4, wherein the signal extraction unit (34) is further configured for processing an unpartitioned original signal set (73) basically formed by the whole region of interest (58; 108), thereby extracting another distinct indicative characteristic sub-signal (74).

7. Device as claimed in claim 1, further comprising a segmentation unit (30) configured for determining an indicative frame section (56), in particular a skin portion of the subject, the indicative frame section (56) comprising the region of interest (58; 108).

8. Device as claimed in claim 1, wherein the at least one at least partially periodic vital signal (20; 138, 142) is selected from the group consisting of heart rate, heart beat, respiration rate, heart rate variability, Traube–Hering–Mayer waves, and oxygen saturation.

9. Device as claimed in claim 1, wherein the at least two distinct indicative characteristic sub-signals (74a, 74b, 74c, 74d; 122) are associated with a signal space (126) representative of characteristics of the electromagnetic radiation (14), wherein the signal space (126) is preferably a color signal space comprising at least two complementary channels (130a, 130b, 130c), wherein the at least two complementary channels (130a, 130b,

130c) are related to defined spectral portions, and wherein the at least two distinct indicative characteristic sub-signals (74a, 74b, 74c, 74d; 122) are derived under consideration of at least two main components (R, G, B; I, IR), each of which being related to a respective complementary channel (130a, 130b, 130c).

10. Device as claimed in claim 1, further comprising a sensor means (22), in particular a camera, configured for remotely sensing electromagnetic radiation (14) and capable of capturing the data stream (24), preferably the sensor means (22) comprises a spectral sensitivity adapted to spectral characteristics of complementary channels (130a, 130b, 130c) forming a signal space (126).

11. Device as claimed in claim 1, wherein the signal extraction unit (34) is further configured for enhancing a signal-to-noise ratio in each of the at least two distinct indicative characteristic sub-signals (74a, 74b, 74c, 74d; 122).

12. Device as claimed in claim 1, wherein the partitioning unit (32) is further configured for selectively partitioning the region of interest (58; 108) into an initial partition grid (82) comprising a plurality of initial sub-samples (80), and for defining the at least two defined signal subsets (66; 84) based on a recombination of the initial sub-samples (80).

13. Method for extracting physiological information from remotely detected electromagnetic radiation (15) emitted or reflected by a subject, comprising the steps of:

- receiving a data stream (24) derived from detected electromagnetic radiation (14), the data stream (24) comprising a sequence (102) of signal samples (104) representing a region of interest (58; 108) exhibiting a continuous or discrete characteristic signal (128) including physiological information indicative of at least one at least partially periodic vital signal (20; 138, 142),
- selectively partitioning the sequence (102) of signal samples (104) into at least two distinct sub-sequences (116a, 116b, 116c, 116d) of defined signal subsets (66, 84) representing spatial sub-regions of the region of interest (58; 108),
- processing each of a plurality of the at least two distinct sub-sequences (116a, 116b, 116c, 116d) and thereby extracting a plurality of distinct indicative characteristic sub-signals (74a, 74b, 74c, 74d; 122), wherein each of the at least two distinct indicative

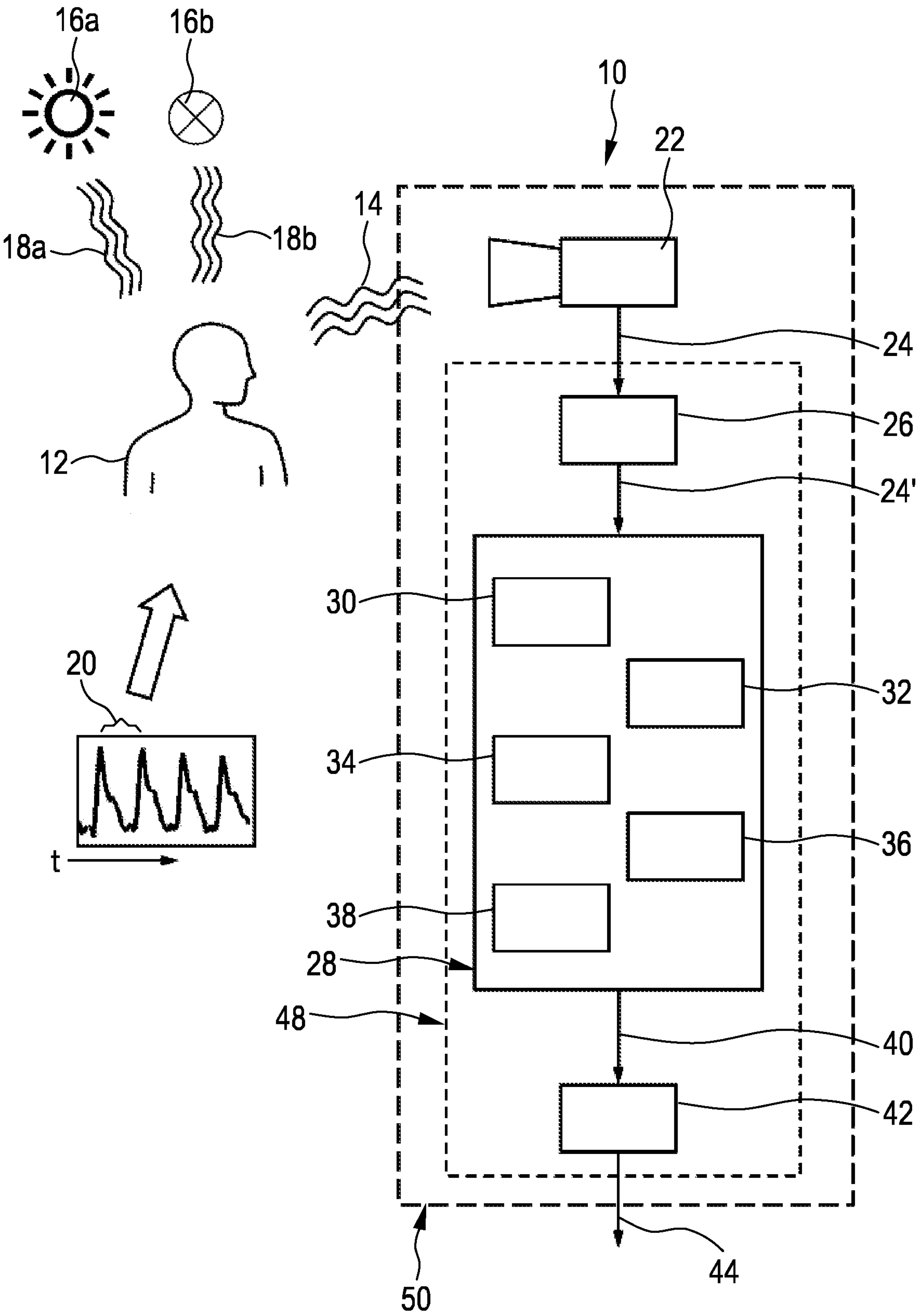
characteristic sub-signals (74a, 74b, 74c, 74d; 122) is extracted from a respective distinct sub-sequence (116a, 116b, 116c, 116d), and

- generating an enhanced characteristic signal (72; 135) by combining the extracted characteristic sub-signals (74a, 74b, 74c, 74d; 122).

14. The method of claim 13, further comprising the step of:

- multiply partitioning the region of interest (58; 108) into at least two groups (64, 64', 64", 64'"), each of which comprising at least two defined signal subsets (66; 84) represented by respective distinct sub-sequences (116a, 116b, 116c, 116d), wherein the at least two groups (64, 64', 64", 64'") comprise different partition patterns.

15. Computer program comprising program code means for causing a computer to carry out the steps of the method as claimed in claim 13 when said computer program is carried out on the computer.



16a
16b
10
22
14
18a
18b
24
26
12
24'
30
32
20
34
36
t
38
28
48
40
42
44
50

FIG. 1

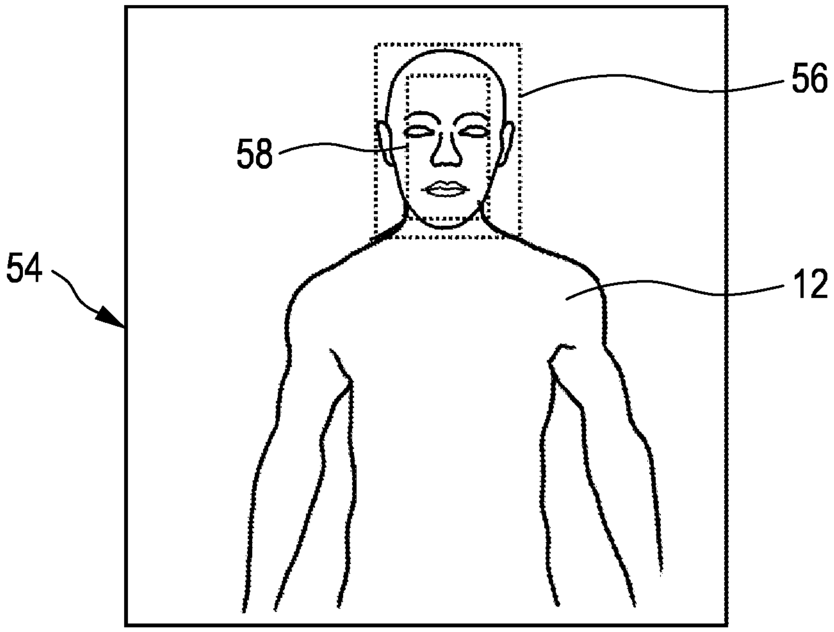


FIG. 2a

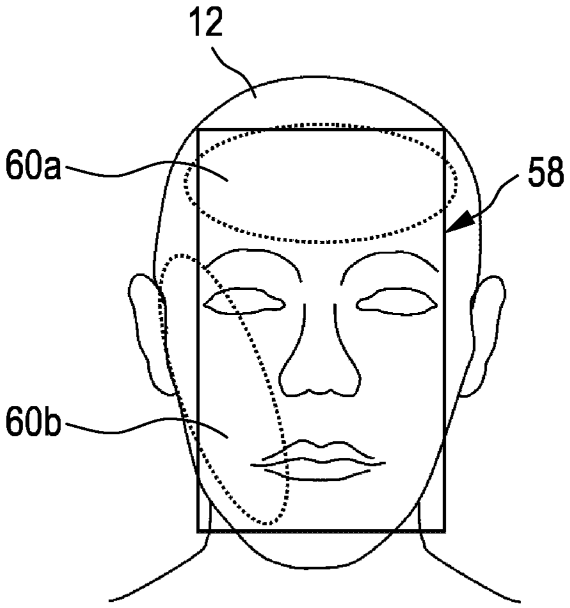


FIG. 2b

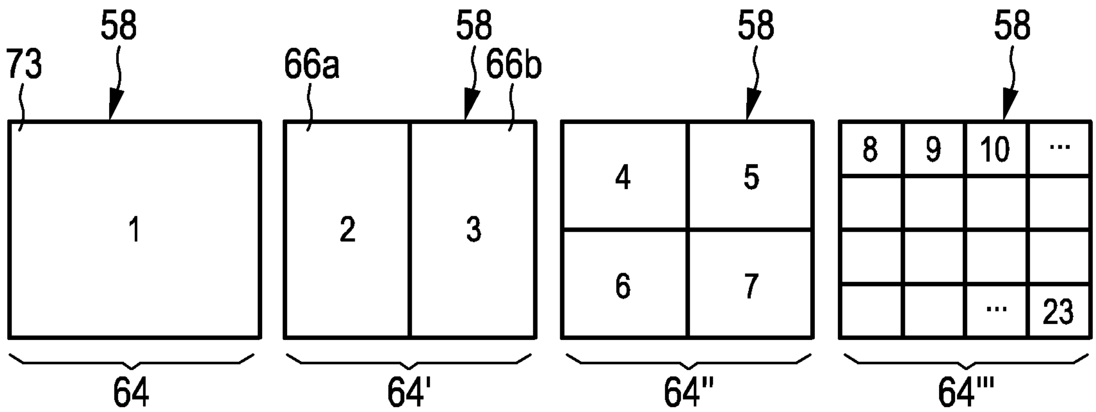
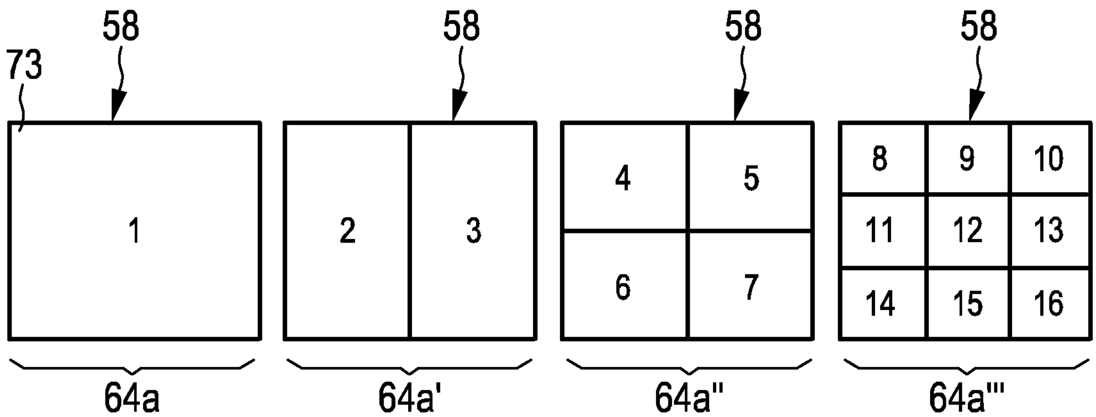

73
58
66a
58
66b
58
58
1
2
3
4
5
6
7
8
9
10
...
...
23
64
64'
64''
64'''

FIG. 3a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15
16
64a
64a'
64a''
64a'''

FIG. 3b

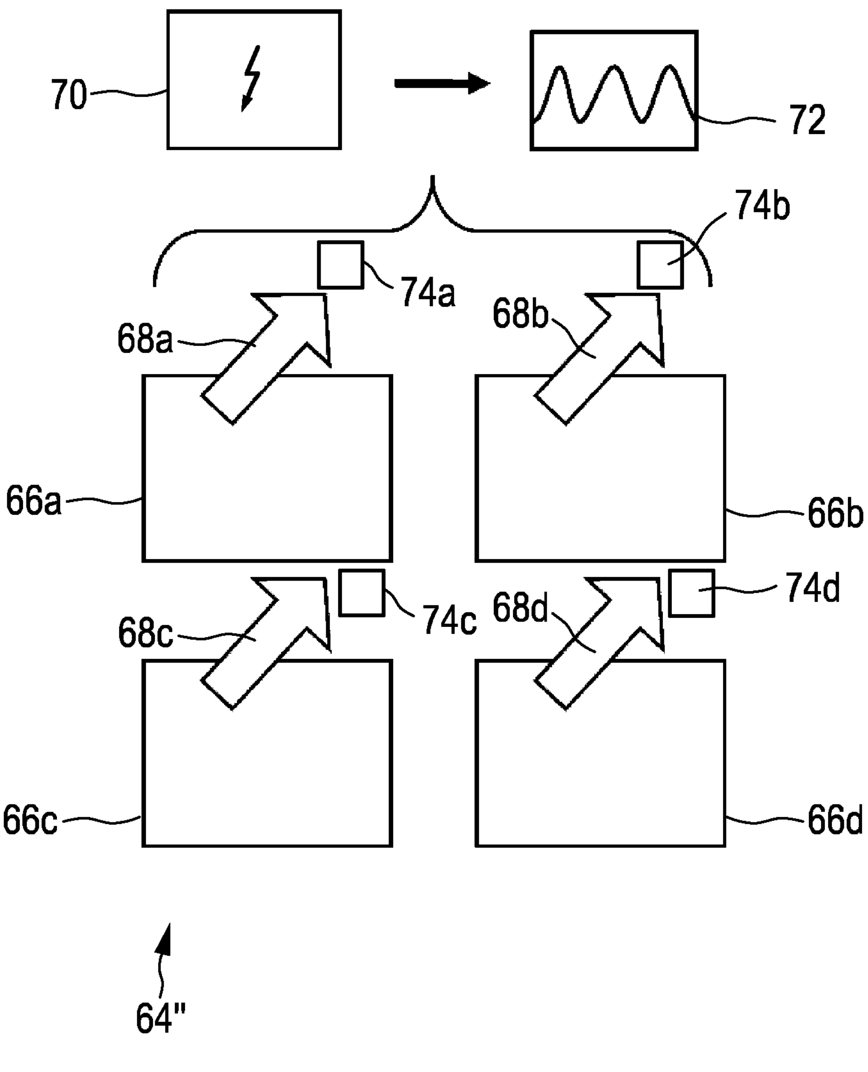


FIG. 4

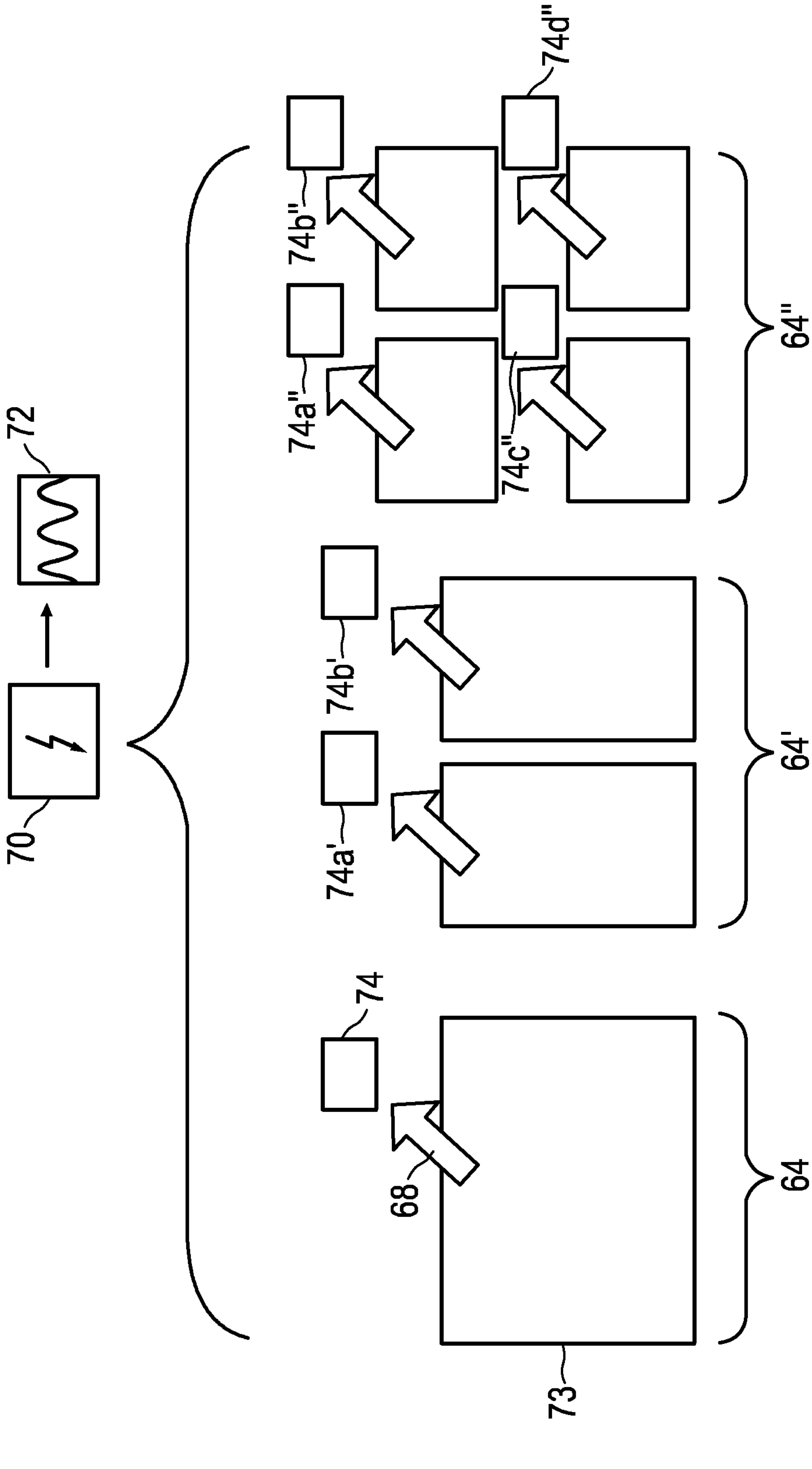


FIG. 5

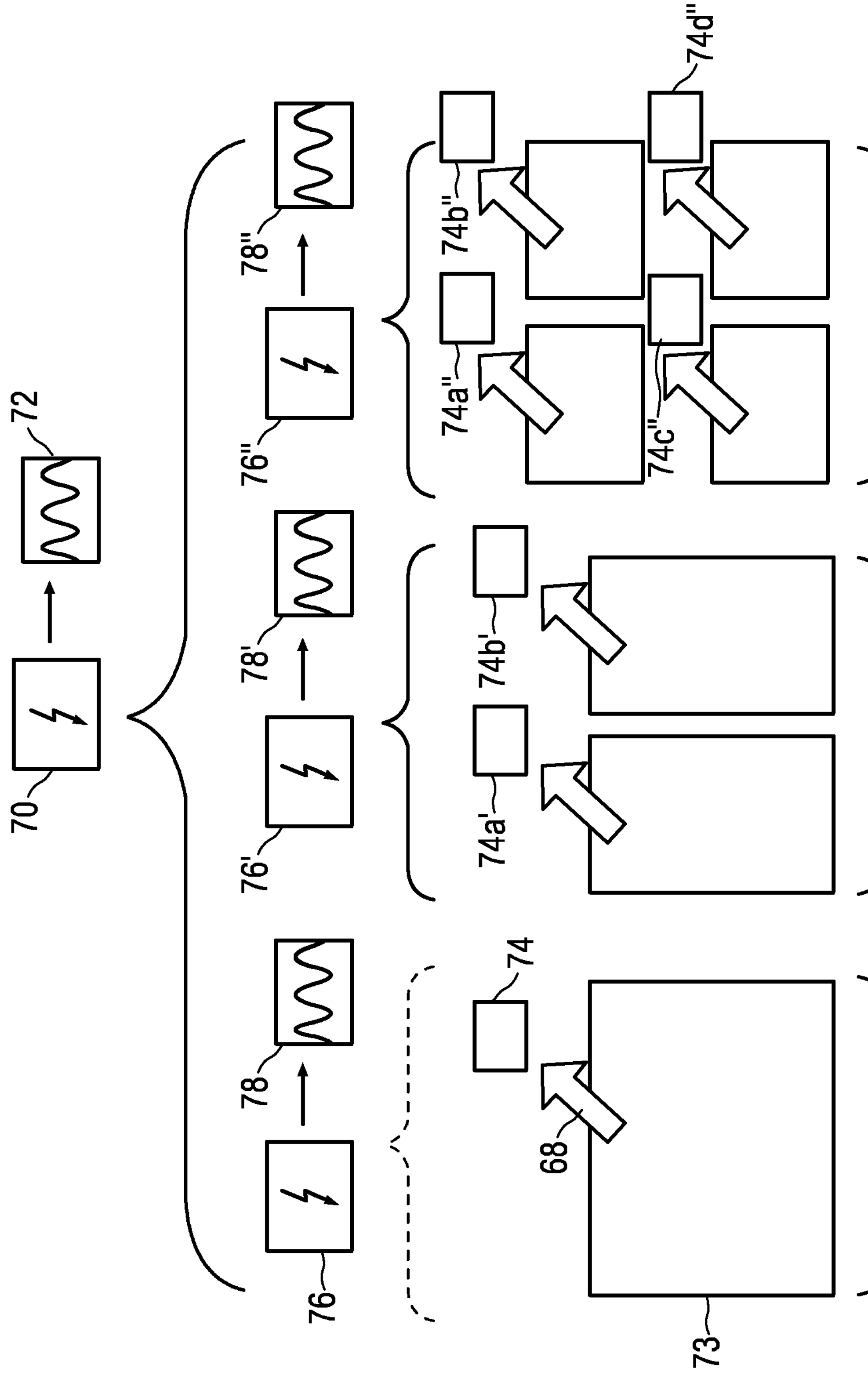


FIG. 6

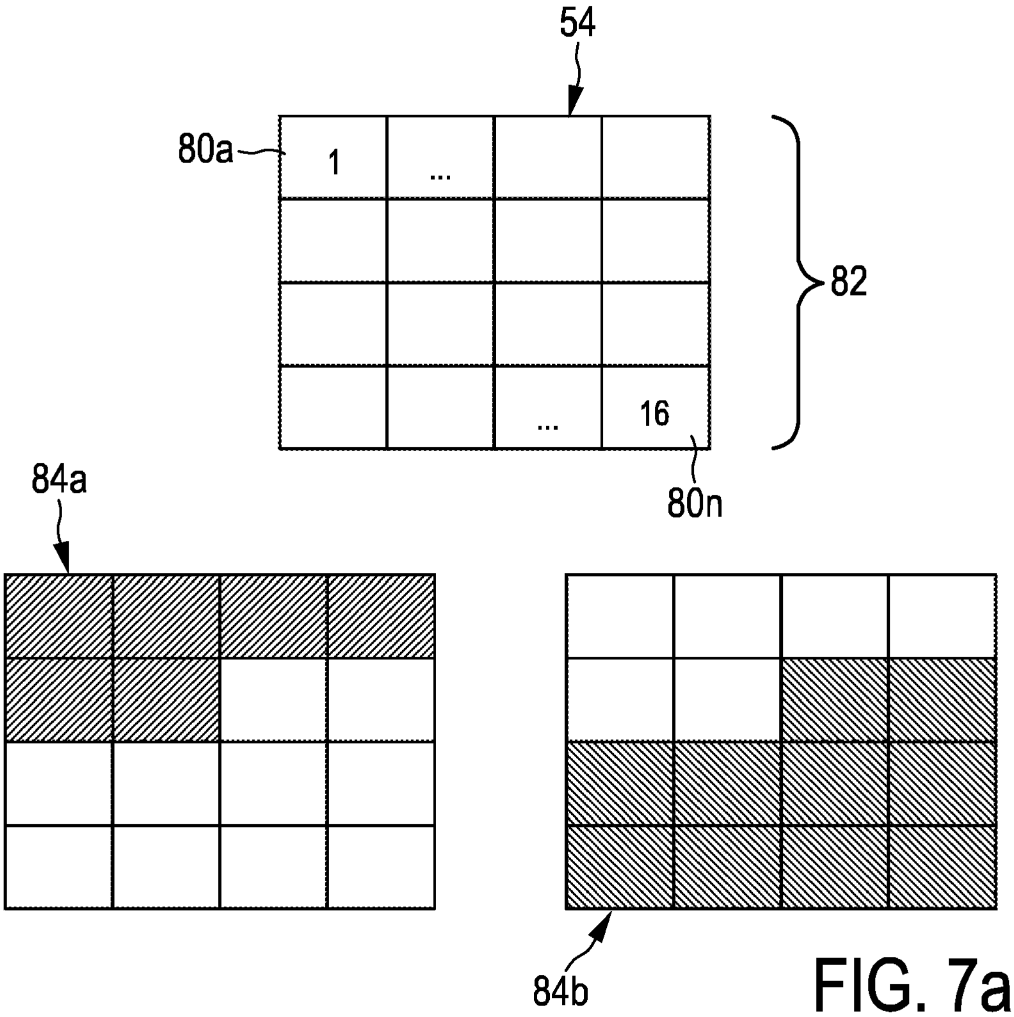


FIG. 7a

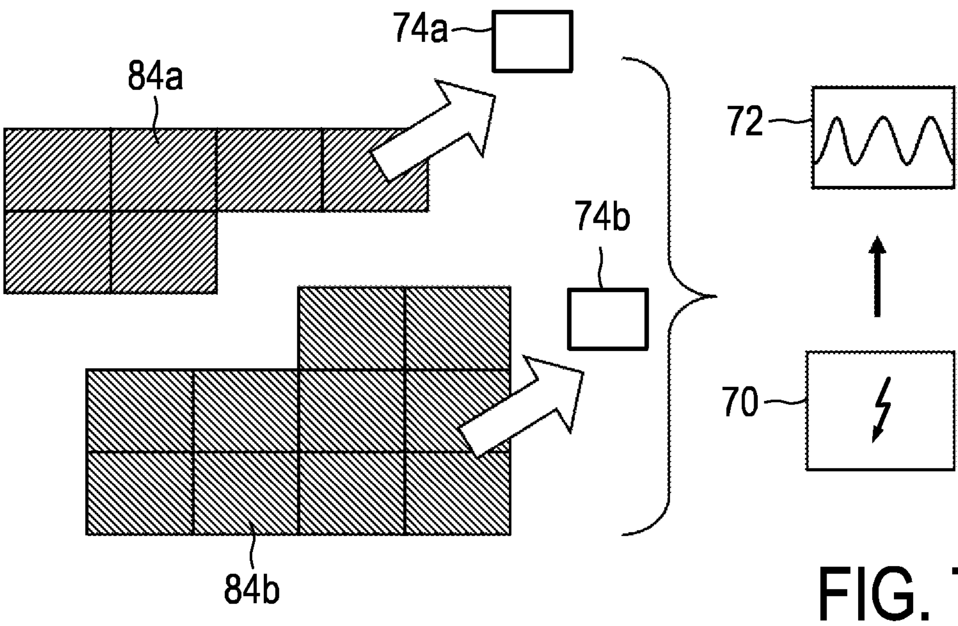


FIG. 7b

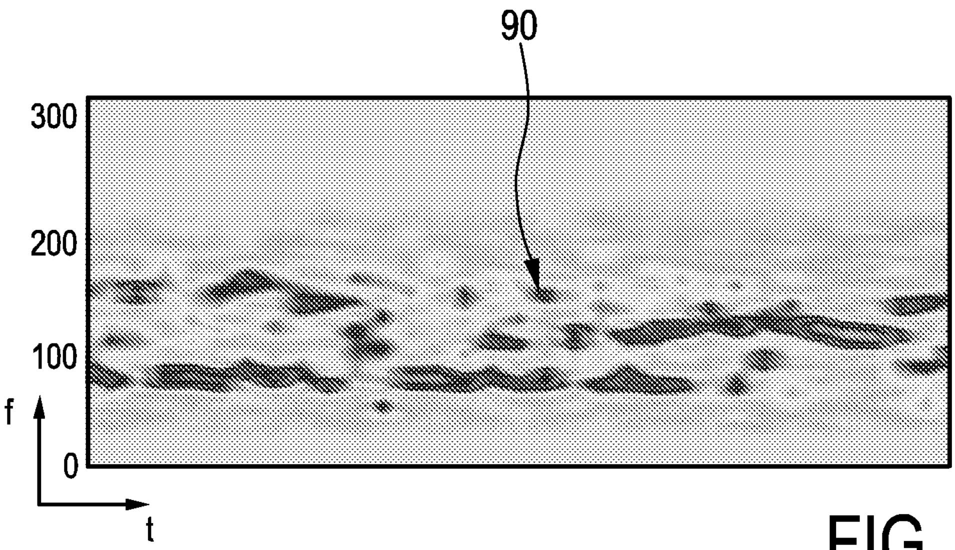


FIG. 8a

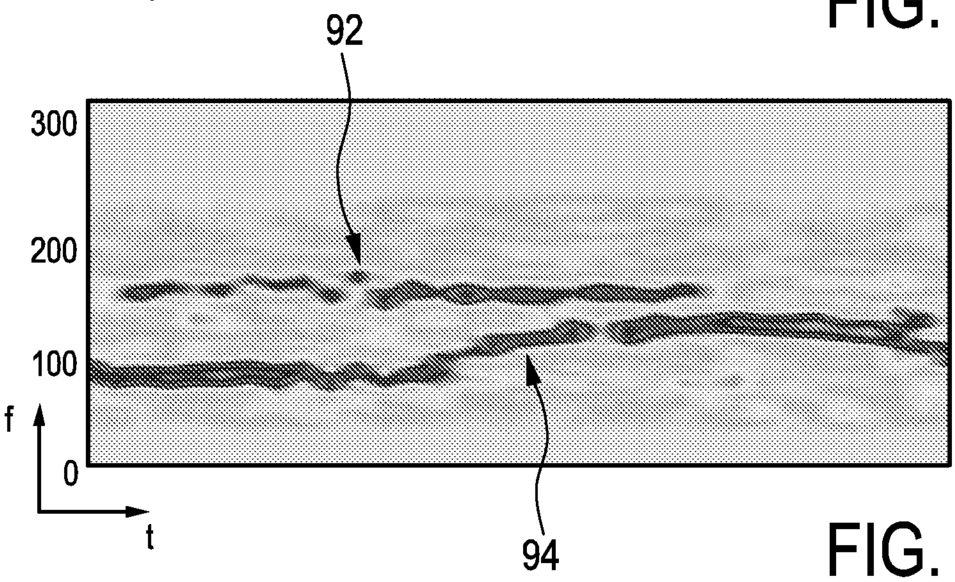


FIG. 8b

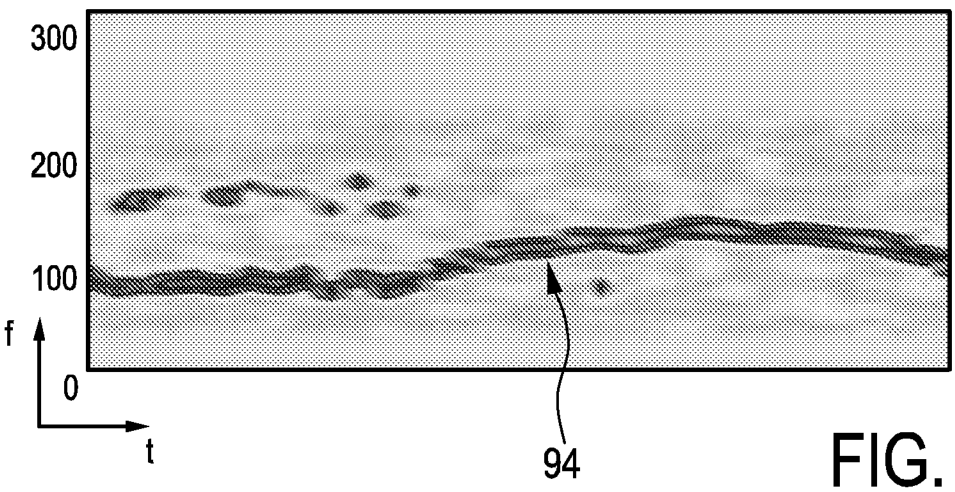
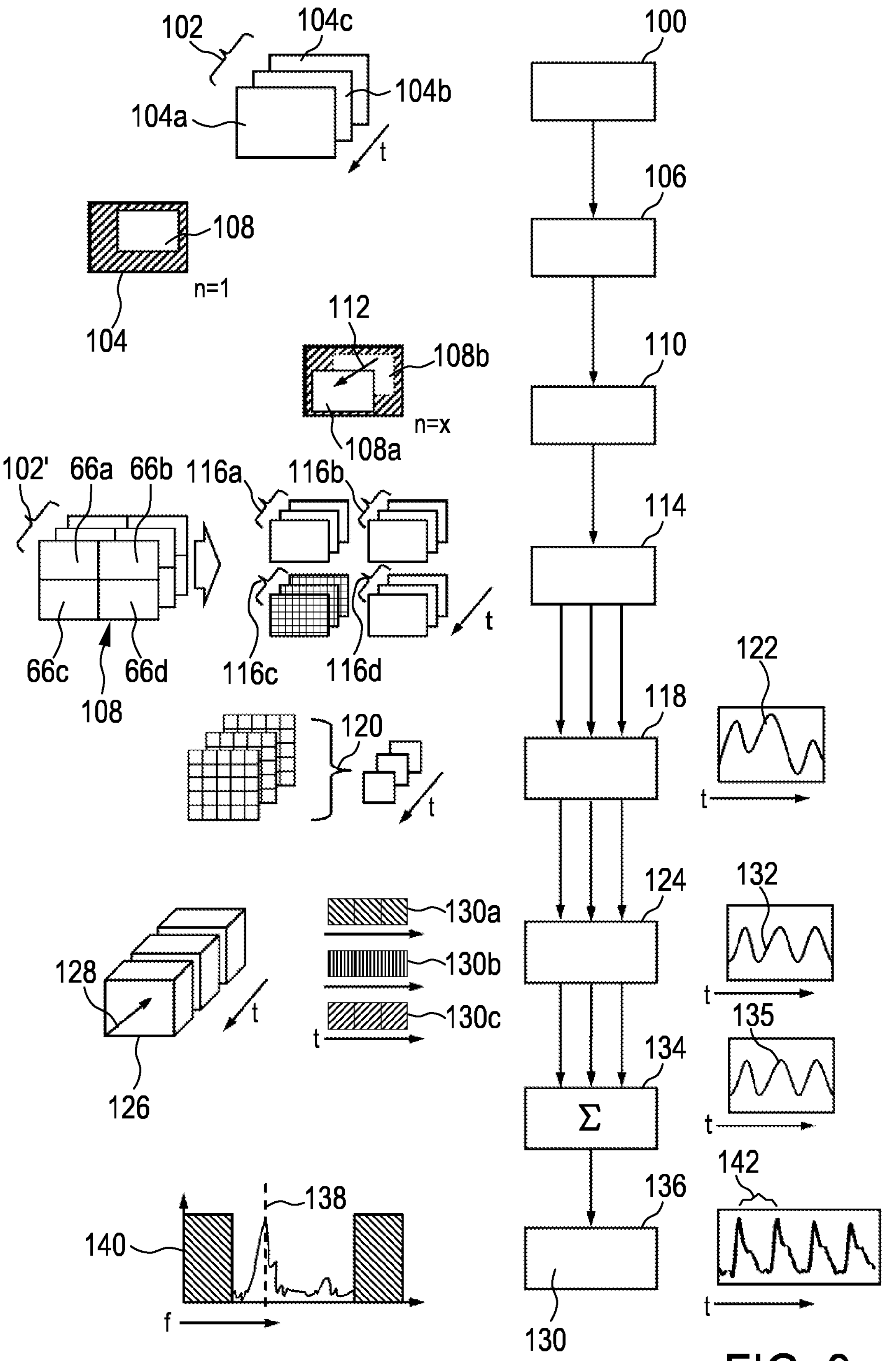


FIG. 8c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122
120
t
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124
132
130a
130b
130c
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t
t
126
134
Σ
135
t
142
138
140
136
f
t
130

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/056324

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/00 A61B5/024 A61B5/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2011/042858 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]; DE HAAN GERARD [NL]; KIRENKO IHOR) 14 April 2011 (2011-04-14) page 3, lines 13-31 page 8, line 26 - page 10, line 34 page 12, line 23 - page 15, line 3 -----	1-15
X	WO 2011/042839 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]; KIRENKO IHOR OLEHOVYCH [NL]; JEAN) 14 April 2011 (2011-04-14) page 17, paragraph 4 - page 18, paragraph 2 ----- -/--	1-15

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 January 2014	15/01/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Manschot, Jan

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/056324

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WIM VERKRUYSSE1 ET AL: "Remote plethysmographic imaging using ambient light", OPTICS EXPRESS, OSA (OPTICAL SOCIETY OF AMERICA), WASHINGTON DC, (US), vol. 16, no. 26, 22 December 2008 (2008-12-22), pages 21434-21445, XP007913060, ISSN: 1094-4087 cited in the application the whole document -----	1-8, 10-15
A	US 2011/251493 A1 (POH MING-ZHER [US] ET AL) 13 October 2011 (2011-10-13) cited in the application the whole document -----	1-15

1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2013/056324

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		EP 2486544 A1	15-08-2012
		JP 2013506526 A	28-02-2013
		US 2012195473 A1	02-08-2012
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		US 2011251493 A1	13-10-2011
		WO 2011127487 A2	13-10-2011