(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 754 388 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
16.07.2014 Bulletin 2014/29

(21) Application number: **13000202.5**

(22) Date of filing: **15.01.2013**

(51) Int Cl.:
A61B 5/00 *(2006.01)* ***A61B 5/02*** *(2006.01)*
G01N 21/17 *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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(54) System and method for quality-enhanced high-rate optoacoustic imaging of an object

(57) The invention relates to a system (100) and method for optoacoustic imaging of an object (1) comprising an image acquisition unit (10) for acquiring a first sequence (201) of tomographic optoacoustic images of a region of interest of the object (1), wherein the image acquisition unit (10) comprises an illumination device (11) for irradiating the region of interest of the object (1) with electromagnetic radiation, in particular light, and a detection device (12) for repeatedly collecting acoustic waves emerging from the object upon irradiating the object (1) and for generating the first sequence (201) of tomographic optoacoustic images of the region of interest from the repeatedly collected acoustic waves.

In order to allow for an acquisition of sequences of tomographic optoacoustic images of high image frame rate and high image quality, in particular video sequences of tomographic optoacoustic images exhibiting less motion and/or noise perturbations than conventional video sequences, a processing unit (20) is provided for generating a second sequence (202) of one or more tomographic optoacoustic images from the first sequence (201) of tomographic optoacoustic images based on an analysis of one or more tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images and/or at least one property of the object (1) while acquiring the first sequence (201) of tomographic optoacoustic images and/or at least one property of the acquisition unit (10) while acquiring the first sequence (201) of tomographic optoacoustic images.

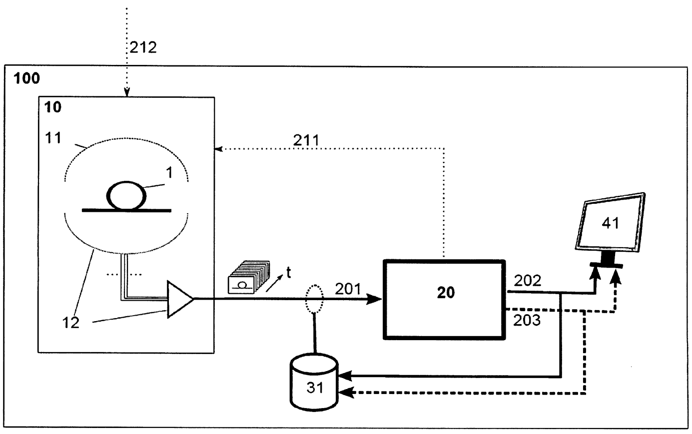

Fig. 1

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Description

[0001] The present invention relates to a system and method for optoacoustic imaging of an object according to the independent claims.

[0002] Optoacoustic imaging is based on the photoacoustic effect, according to which ultrasonic waves are generated due to absorption of electromagnetic radiation by an object, e.g. a biological tissue, and a subsequent thermoelastic expansion of the object. Excitation radiation, in particular laser light, can either be pulsed radiation with very short pulse durations or continuous radiation with a modulated amplitude or frequency.

[0003] Using tomographic reconstruction with a view from multiple projections allows for a generation of a full view of the sample, enabling imaging based on optical absorption of both intrinsic and extrinsic tissue chromophores for biomedical imaging.

[0004] Therefore, in contrast to conventional optical imaging, fluorescence or light emission in general are not prerequisites for generating contrast in optoacoustic imaging. Its key advantage is that heavy scattering present in biological tissues does not obscure the spatial resolution, because the detected phenomena are sound waves that are far less disturbed by tissue due to the lower frequency. Optoacoustic resolution is limited by the focusing and detection band of the ultrasound transducer and the frequency-dependent acoustic attenuation. At the same time, optoacoustics provides a high, wavelength-dependent penetration depth of up to several centimeters within the near-infrared optical imaging window (650 to 950nm) or other suitable wavelengths.

[0005] By imaging absorbance at multiple excitation wavelengths, multispectral optoacoustic tomography (MSOT) can provide molecular specificity to reveal absorbers with distinct spectral absorbance.

[0006] In contrast to optical imaging, in ultrasound and also optoacoustic imaging the information required to create an image is generated within a very short time after the absorption of a single pulse. While both sensitivity and signal to noise ratio (SNR) in optical imaging can be increased by increasing exposure time, ultrasonic and also optoacoustic imaging require a repetition of the acquisition process to compensate for noise and SNR. On the other hand, this promotes the ability of optoacoustic imaging to capture very fast processes at a repetition rate that is only limited by the source of illumination and the performance of the signal acquisition system. Furthermore, a final optoacoustic image already represents the full reality and does not necessarily require any additional, corrective measurements to compensate for, e.g., auto-fluorescence of tissue or similar.

[0007] Signal acquisition in optoacoustics is done using ultrasound transducers or hydrophones. In common implementations, a single transducer is rotated around a sample in order to create a tomographic view of the sample. Thus, a prerequisite of utmost importance to acquire optoacoustic images at a high rate is an ultrasound transducer array which allows for acquiring sufficient data to reconstruct an image without moving the transducer to enable capturing a static setting. With hybrid approaches being very well feasible, detection geometries in optoacoustics can be divided into arc or bowl shape approaches and linear geometries. Depending on the desired characteristics, detectors can either be shaped to predominantly detect signals from a two dimensional plane or a three dimensional volume.

[0008] Similar to ultrasound, noise influences in the reconstructed image contain contributions of both systemic and thermal noise as well as other, extrinsic sources that are received in the analog chain before AD conversion of the acquired signal.

[0009] Based on the aforementioned setting, each individual acquisition is perturbed by a certain amount of noise that determines the overall noise level of a system. Whilst measures in hardware and system design (such as shielding of setting and cables) can be taken to reduce significant external sources, a lot of parasitic signals will still be measured by the analog part of the detection chain. For clinical imaging, the exposure threshold of skin is regulated by the FCC dependent on repetition rate and exposed area, so the signal and thus signal to noise ratio (SNR) cannot be improved by increasing laser power. Moreover, in general, in images which are based on multiple images acquired for one setting, the SNR and resulting perturbations by noise increase. Based on these perturbations, noise reduction algorithms need to be applied to improve the quality of acquired images.

[0010] Key applications for optoacoustic imaging are in the field of imaging of endogenous contrast in tissue. In the predominantly used near-infrared domain the key absorbers are hemoglobin and melanin, providing a unique anatomical contrast without any additional agents. Using multispectral acquisition for functional and molecular imaging, individual absorbers can be separated and quantified, allowing e.g. for blood oxygen saturation measurements and detecting necrosis. Another clinically relevant example is detecting melanin content in lymph nodes for cancer diagnosis.

[0011] The number of applications is even increased by using exogenous contrast agents such as fluorescent dyes as known from optical imaging, activatable probes, fluorescent proteins or nanoparticles. They can be targeted to specific sites using functional groups, where even different numbers of optoacoustic absorbers can be combined to even simultaneously track different processes.

[0012] There are a number of applications where a high actual image rate is crucial. In motion-rich settings, an acquisition relying on averaging is likely to produce blurry images that need to be co-registered for multispectral analysis, while an image resulting from a single frame acquisition will suffer from a relatively high noise level. One example for such a setting is imaging of small vasculature with the diameter approaching the spatial resolution, where averaging will blur tiny features. The same applies for imaging of fast kinetic processes in an organism, where averaging shadows fast changes. Other examples include monitoring an arterial input function of an injected substance, tissue perfusion measurements, blood flow imaging, drug delivery monitoring and pharmacokinetic modeling.

[0013] The invention is based on the problem to provide a system and method for optoacoustic imaging allowing for an acquisition of sequences of tomographic optoacoustic images of high image frame rate and high image quality, in particular video sequences of tomographic optoacoustic images exhibiting less motion and/or noise perturbations than conventional video sequences.

[0014] This problem is solved by the system and method according to the independent claims.

[0015] The system for optoacoustic imaging of an object according to the invention comprises an image acquisition unit for acquiring a first sequence of tomographic optoacoustic images of a region of interest of the object, wherein the image acquisition unit comprises an illumination device for repeatedly emitting electromagnetic radiation to the region of interest of the object and a detection device for repeatedly collecting acoustic waves emerging from the object upon excitation of the object and for generating the first sequence of tomographic optoacoustic images of the region of interest from the repeatedly collected acoustic waves. The system further comprises a processing unit for generating a second sequence of one or more tomographic optoacoustic images from the first sequence of tomographic optoacoustic images based on an analysis of one or more tomographic optoacoustic images of the first sequence of tomographic optoacoustic images and/or at least one property of the object while acquiring the first sequence of tomographic optoacoustic images and/or at least one property of the acquisition unit while acquiring the first sequence of tomographic optoacoustic images.

[0016] The method for optoacoustic imaging of an object according to the invention comprises acquiring a first sequence of tomographic optoacoustic images of a region of interest of the object by irradiating the region of interest of the object with electromagnetic radiation and repeatedly collecting acoustic waves emerging from the object upon irradiating the object and generating the first sequence of tomographic optoacoustic images of the region of interest from the repeatedly collected acoustic waves. The method further comprises generating a second sequence of one or more tomographic optoacoustic images from the first sequence of tomographic optoacoustic images based on an analysis of one or more tomographic optoacoustic images of the first sequence of tomographic optoacoustic images and/or at least one property of the object while acquiring the first sequence of tomographic optoacoustic images and/or at least one property of the irradiation of the object and/or the collection of acoustic waves while acquiring the first sequence of tomographic optoacoustic images.

[0017] In the following, the term "tomographic optoacoustic image" will be also referred to as "image" for reasons of simplification. Further, the term "sequence of tomographic optoacoustic images" will be also referred to as "video" or "video sequence" or "video stream". Moreover, the term "electromagnetic radiation" in the sense of the present invention relates to any electromagnetic radiation by means of which acoustic waves or pulses can be generated in an object under investigation upon irradiating the object. Preferably, the term "electromagnetic radiation" relates to visible light and/or non-visible light, e.g. in the infrared or ultraviolet spectral range, but also includes radio frequency radiation and/or microwave radiation.

[0018] The solution according to the invention is based on the approach to acquire a first sequence of images from a region of interest of the object and to derive a second image or a second sequence of images from the first sequence of images, in particular by processing the first sequence of images, wherein the derivation or generation of the second image or second sequence of images from the first sequence of images depends on information relating to one or more images of the first sequence of images and/or information relating to the object or the acquisition unit or acquisition process while the first sequence of tomographic images is acquired. In particular, the information relating to one or more images of the first sequence of images is obtained by an analysis of the one or more images of the first sequence. Preferably, information relating to the object reflects properties of time-variant processes of the object or within the object, like respiration, heartbeat or blood flow, while the images of the first sequence of images are acquired from the object. Likewise, information relating to the acquisition unit or acquisition process reflects parameters of the acquisition process under which images of the first sequence of images are acquired, for example the intensity of the electromagnetic radiation that excites the object, in particular the irradiation laser power.

[0019] Preferably, based on the dependence of the strength of the optoacoustic signal on incident irradiation power, in particular light intensity, the acquired signals and/or images have to be or can be corrected for wavelength-dependent light fluence in tissues in order to obtain quantitative images. Depending on the complexity of the setting, this can be done by using a generic map of light fluence or an individual map adapted to the situation before image reconstruction on the acquired signals, or after the image reconstruction on the final image.

[0020] By means of the approach according to the invention it is possible to significantly improve the quality of the originally acquired first sequence of images, e.g. by suppressing motion-related effects or noise perturbations. At the same time, a high frame rate of the improved video images is achieved or maintained, wherein the frame rate of the second sequence of images is not or not considerably reduced compared to the original frame rate of the first sequence of images. Moreover, the spatial resolution of the images of the second sequence is not or not significantly reduced compared to the resolution of the images of the first sequence. As a result, by means of the invention it is possible to record and playback an improved (second) video sequence of a particular phenomenon on or within the object. Further, the invention allows for a quantitation of results and an analysis of dynamic and pharmacokinetic parameters in order to provide a powerful biological research platform that outperforms established imaging modalities.

[0021] In summary, by means of the invention high image rate, preferably real-time, optoacoustic images are obtained which allow for acquiring images of fast processes in vivo with high resolution and significantly reduced influences of noise and motion. In this way, the invention allows for studying anatomy, molecular contrast and fast processes in biological tissues by adding the temporal dimension to existing optoacoustic imaging approaches.

[0022] According to a preferred embodiment of the invention, the at least one property of the object relates to temporal, in particular periodic, changes at or within the object, in particular due to respiration, pulse or blood flow, while acquiring the first sequence of tomographic optoacoustic images. Preferably, the at least one property of the object is acquired by means of an external device, which is in particular adapted for observing temporal changes at or within the object, in particular due to respiration, pulse or blood flow. By monitoring a property or properties of the object while the image acquisition process, an information on relevant time-variant processes within the object can be obtained. The obtained information can be considered in the processing step in which the second sequence of images is derived from the first sequence of images such that, e.g., motion-related effects or artifacts due to respiration, heartbeat or blood flow in the images of the first sequence can be eliminated when deriving the second sequence of images. In this way, motion-related artifacts in the images can be eliminated or at least significantly reduced easily and reliably.

[0023] Alternatively or additionally, the at least one property of the object is derived from one or more tomographic optoacoustic images of the first sequence of tomographic optoacoustic images. For example, the first sequence of images is analyzed with respect to recurring, in particular periodic, variations or movements, e.g. a movement of the heart or chest, available in the images. Based on this analysis, the effects of the identified variations or movements on the images are eliminated or at least reduced subsequently. By means of this embodiment, motion-related artifacts in the images can be eliminated or at least significantly reduced in a particularly easy and reliable manner.

[0024] According to a further preferred embodiment, the acquisition unit is adapted to be controlled by control signals from, wherein the control signals are generated by the processing unit and/or by an external device, which is in particular adapted for observing a time-variant process in the object, in particular respiration, heartbeat or blood flow of the object, to allow for an acquisition of the first sequence of tomographic optoacoustic images at specific instants, in particular at less motion-perturbed instants, e.g., at timeframes with no respiratory activity or certain periods of the heart cycle. By mean of this, e.g., possible motion-related artifacts or noise perturbations in the images can be avoided or at least reduced significantly ab initio. Therefore, this embodiment represents a very efficient way to obtain high-rate video images of the object with reduced or eliminated motion and/or noise perturbations.

[0025] Preferably, the processing unit is adapted for generating the second sequence of tomographic optoacoustic images based on an analysis of a subsequence of tomographic optoacoustic images of the first sequence of tomographic optoacoustic images. A subsequence of images may comprise at least two consecutive tomographic optoacoustic images of the first sequence of tomographic optoacoustic images or may comprise at least two tomographic optoacoustic images of the first sequence which are spaced apart by one or more further images. By analyzing a subsequence of the first sequence of images significantly more relevant information is obtained in order to remove, e.g., motion-related effects when the second sequence of images is derived from the first sequence of images. Thus, a high-rate second sequence of images with reduced or eliminated motion-related perturbations can be obtained in a very reliable and simple manner.

[0026] It is preferred that the processing unit is adapted for generating the second sequence of tomographic optoacoustic images based on an analysis of a quality of one or more tomographic optoacoustic images of the first sequence of tomographic optoacoustic images.

[0027] According to a further preferred embodiment of the invention, the processing unit is adapted for generating the second sequence of tomographic optoacoustic images based on an analysis of tomographic optoacoustic images of the first sequence of tomographic optoacoustic images with respect to their individual properties, in particular signal-to-noise ratio, contrast, blur, sharpness or histogram. Based on the result of this analysis, each of the analyzed images is processed, in particular improved, or assessed in the processing unit before the second sequence of images is derived from these images. When assessing the images it can be decided whether to keep and to include an image or a weighted version of the image into the second sequence of images or to discard the image. This is a very efficient way to achieve a high image quality of the second sequence of images without significantly reducing the high frame rate of the original sequence.

[0028] Preferably, the processing unit is adapted for generating the second sequence of tomographic optoacoustic images from the first sequence of tomographic optoacoustic images based on an analysis of properties, in particular signal-to-noise ratio, frequency spectrum or noise patterns, of the repeatedly collected acoustic waves prior to generating the first sequence of tomographic optoacoustic images from the repeatedly collected acoustic waves. Other than in the above-mentioned embodiment, in which the already reconstructed images of the first sequence are analyzed, in this embodiment the so-called raw data, i.e. the ultrasound detector signals corresponding to the repeatedly detected acoustic waves, are analyzed. By means of analyzing the raw data of the images information can be obtained which would be - due to the reconstruction step - no longer present in the reconstructed images of the first sequence of images. Thus, this embodiment allows for an efficient and reliable elimination or reduction of motion- and/or noise-related perturbations in the images.

[0029] Alternatively or additionally, the processing unit is adapted for generating the second sequence of tomographic optoacoustic images based on an analysis of tomographic optoacoustic images of the first sequence of tomographic optoacoustic images regarding properties of the tomographic optoacoustic images with respect to each other, in particular with respect to a similarity of the images, a correlation of the images, a standard deviation or k-means. By means of analyzing images, in particular a subsequence of images, of the first sequence of images with respect to each other, further additional information is obtained which is not contained in each of the individual images alone. In particular, this relates to the desire of separating the information contained in the images of the first sequence of images from the contained perturbing influences of noise and motion. By considering this additional information when a second sequence of images is derived from the first sequence of images, the quality of the individual images can be increased, resulting in a particularly high image quality and video rate of the second sequence of images. The upper bound to the improvement of quality is given by the identification of the overall information contained in the analyzed subsequence of images as compared to the noise contained in the images of the analyzed subsequence. In a particular embodiment, the referred quality is related in particular to, but not limited to, the signal-to-noise ratio of the individual images of the second sequence of images. In another embodiment this relates to a similarity of images in the first sequence of images with the desire to reduce the impact of apparent object motion on the second sequence of images, resulting in a less motion perturbed second sequence of images.

[0030] According to a further preferred embodiment of the invention, the processing unit is adapted for generating the second sequence of tomographic optoacoustic images based on an analysis of tomographic optoacoustic images of the first sequence of tomographic optoacoustic images using a feature tracking algorithm by means of which a temporal behavior of one or more individual contributions, e.g. an imaged part of the object, to tomographic optoacoustic images of the first sequence is analyzed and/or tracked. By this means, a time-dependent individual contribution of an imaged part of the object can be identified and its influence on the images, in particular the image quality, can be reduced or eliminated in a reliable and efficient manner.

[0031] Preferably, the processing unit is adapted for generating the second sequence of tomographic optoacoustic images based on an analysis of statistical properties of tomographic optoacoustic images of the first sequence of tomographic optoacoustic images. Alternatively or additionally, the processing unit is adapted for processing the second sequence of tomographic optoacoustic images based on an analysis of statistical properties of tomographic optoacoustic images of the second sequence of tomographic optoacoustic images. Preferably, the analysis of statistical properties comprises a separation of the tomographic optoacoustic images of the sequence of tomographic optoacoustic images into contributing components, in particular by means of at least one of a principal component analysis (PCA), a independent component analysis (ICA), a multi-variant data analysis, a vortex component analysis (VCA), a matrix factorization, a fitting procedure, a deconvolution procedure, an image co-registration algorithm, a moving average processing or a selective frame dropping processing. The analysis of statistical properties provides a highly expressive basis for processing the first sequence of images, in particular for deriving the second sequence of images from the first sequence of images so that a high frame rate second sequence of images exhibiting high quality is obtained.

[0032] In another preferred embodiment the image acquisition unit is adapted to utilize photon absorption information from previous tomographic optoacoustic images of the same object to assess and/or change or adjust an amplification of signals corresponding to acoustic waves originating from deeper inside of the object in order to correct for reduced light fluence in deep tissue. By means of this embodiment, current images obtained from an object can be corrected in order to eliminate or reduce adverse effects due to a decrease of light fluence in increasing depths within the object, wherein the relevant information, on which the correction of the current images is based, is determined from previously acquired images. Because the relevant information preferably relates to absorption properties of the object, the relevant information is called absorption information. In total, also this embodiment contributes to further increased image quality of the high-rate video sequences obtained with the invention. In particular, this is due to the increased dynamic range on the analog-to-digital conversion in deeper regions of the object, where emitted acoustic waves are weaker due to the attenuation of the exciting radiation in the object.

[0033] It is preferred that the processing unit is adapted for generating the second sequence of tomographic optoacoustic images by selecting and/or discarding individual tomographic optoacoustic images of the first sequence of tomographic optoacoustic images based on the analysis of the one or more tomographic optoacoustic images of the first sequence of tomographic optoacoustic images. Preferably, the processing unit is adapted for generating a replacing tomographic optoacoustic image which is inserted into the second sequence of tomographic optoacoustic images in the case that a tomographic optoacoustic image of the first sequence of tomographic optoacoustic images has been discarded, wherein the replacing tomographic optoacoustic image is generated based on two or more preceding and/or following images, in particular by interpolating and/or extrapolating the preceding and/or following images, of the first sequence of tomographic optoacoustic images being adjacent to the discarded tomographic optoacoustic image. These preferred embodiments represent, alone or in combination, a very simple and reliable way in order to improve the image quality, in particular with respect to motion artifacts and/or noise, of the second sequence of images.

[0034] According to another preferred embodiment of the invention, the processing unit is adapted for generating the second sequence of tomographic optoacoustic images by moving averaging of tomographic optoacoustic images of the first sequence of tomographic optoacoustic images, wherein each time at least two subsequent tomographic optoacoustic images of the first sequence of tomographic optoacoustic images are averaged, whereby a SNR improvement of the images is obtained. This approach is of particular interest when images are acquired at a very high image rate, in particular in deep penetration optoacoustic imaging. In some cases, a reduction of the temporal resolution and blurring of the image may occur, e.g. in motion-rich settings. These effects can be, however, efficiently and reliably corrected or eliminated by means of the present invention and the other preferred embodiments.

[0035] According to a further embodiment of the invention, the at least one property of the acquisition unit, on which the derivation of the second sequence of images from the first sequence of images is based, relates to an intensity of the electromagnetic radiation with which the object is excited while acquiring the first sequence of tomographic optoacoustic images. By this means, in the generation of the second sequence of images from the first sequence of images conditions of the acquisition unit, i.e. the illumination intensity, while images of the first sequence were acquired are considered, which allows for an even better and reliable generation of a high-rate second sequence of images exhibiting high quality. In one embodiment this additional information may be used to amplify or weight the image of the first sequence in its contribution to the second sequence of images. In another embodiment, this information can also be used as an additional quality metric for assessing the individual properties of the images of the first sequence of images. This is based on the assumption that the noise floor of the acquisition unit is static, while the photoacoustic signal relates linearly to the incident radiation, resulting in a higher signal-to-noise ratio for images acquired at increased radiation intensity.

[0036] According to a particularly preferred embodiment, the illumination device is adapted for illuminating the object with electromagnetic radiation at multiple wavelengths and the processing unit is adapted for analyzing the first sequence and/or the second sequence of tomographic optoacoustic images at the multiple wavelengths. This particularly advantageous approach is also referred to as multispectral optoacoustic imaging (MSOT), wherein multispectral processing of the acquired image data of the first and/or second high frame rate video sequence is carried out by associating absorbers with individual pixels and thus allowing for localizing absorbers based on their spectral absorption profile over multiple excitation wavelengths. Because of the per-pixel evaluation, it is of particular advantage to correct the acquired images for motion and noise to allow the so-called spectral unmixing algorithms to provide reliable spectrally-dependent information.

[0037] In a further particularly preferred embodiment the system comprises a display unit for displaying a video stream of the first sequence of tomographic optoacoustic images and/or the second sequence of tomographic optoacoustic images and/or a storage unit for storing the first sequence of tomographic optoacoustic images and/or the second sequence of tomographic optoacoustic images.

[0038] In a preferred embodiment the second sequence of images is displayed in the form of individual images or a video, including real-time video. Real-time in the sense of the invention relates to image frame rates of at least 10 image frames per second.

[0039] Moreover, features extracted or identified after processing of the first sequence of images may be further displayed on the display alone or superimposed on images and/or a video stream of the second sequence of images and/or of the first sequence of images. Superposition may be established by using a combination of gray-scale and color representation. The term "features" in this context preferably relates to any information which is contained in the images and which can be identified in the processing step.

[0040] Preferably, also features which were extracted or derived by the processing unit from the first sequence of images can be displayed by the display unit, in particular together with the video stream of the first and/or second sequence of images. The extracted features can relate, e.g., to a respiration frequency of the object, a temporal behavior of optoacoustic signals in dependence of the presence of a contrast agent within the object or a difference image. For example, the extracted or derived features are displayed by the display unit as a graph indicating dynamic changes of tracked components and/or a graph indicating dynamic changes of individual pixels and/or a graph or parametric map of at least one established biological kinetic parameter which has been derived from changes in pixel values.

[0041] In particular, with a typical pharmacokinetic curve that starts at a concentration value and picks up for a certain period of time, the so-called rise time, to a peak value, so-called peak enhancement, respective biological kinetic parameter relate to at least one of

- Cmax (peak enhancement, maximum concentration, e.g. absorption and/or concentration at the peak time point is 2.5 fold enhanced as compared to the baseline),
- area under the curve (AUC), i.e. an integral under the above-mentioned curve,
- Tmax (rise time, time to peak, i.e. time from start of injection to peak point),
- uptake rate (maximum slope, wash-in rate, steepness of rising slope of the curve),
- clearance rate (elimination rate, i.e. rate at which the substance is removed from the blood stream, steepness of dropping slope),
- perfusion index (AUC/Tmax),
- half-life (i.e. time to half elimination) or rates resulting from modeling of rate constants in different compartmental models of varying complexity.

[0042] Preferably, the display unit is designed to display overlay images or overlay sequences of images, wherein at least two different kinds of images are displayed in a superposition. For example, anatomical images of the object are superimposed with molecular-specific images of the object. Likewise, a sequence of anatomical images can be overlaid with a sequence of molecular-specific images. By means of this representation of the image information extracted by means of the processing and/or analyzing steps according to the invention, a high degree of additional diagnostically conclusive information is provided.

[0043] Preferably, the image acquisition unit is designed as a handheld device and/or a portable device and/or an endoscopic device. In most situations or cases of handheld, portable and/or endoscopic applications, there is a certain relative movement between the image acquisition probe, i.e. the image acquisition unit, and the object. Therefore, the present invention is of particular advantage in combination with these applications, because possible motion-related artifacts in the sequences of images can be easily and reliably reduced or eliminated.

[0044] In the following, further preferred embodiments for suppressing background noise and artifacts in the images of the first sequence of images will be described.

[0045] For example, a movement of the image acquisition unit relative to the object or a movement of the object relative to the image acquisition unit is detected or tracked, e.g. by means of a mechanical or optical sensor in the, preferably handheld or portable, image acquisition unit. Based on this information, a noise reduction or noise rejection can be performed, e.g. by means of a correlation between sequential and/or time-spaced frames.

[0046] Alternatively or additionally, a controlled relative motion between the object and the image acquisition unit can be induced intentionally. In this way, noise becomes un-correlated while SNR becomes improved by exploitation of the effect that image signals will always appear in a position corresponding to the induced (or captured) motion, whereas noise, and in particular artifacts and reflections, will appear in positions which will have a random distribution and therefore can be filtered out by cross-correlation, un-mixing of time components and similar methods.

[0047] Further advantages, features and examples of the present invention will be apparent from the following description of following figures:

Fig. 1 shows a schematic representation of the system according to the invention; and

Fig. 2 shows a schematic representation of the processing unit.

[0048] Fig. 1 shows a schematic representation of the system 100 according to the invention. The system 100 comprises an image acquisition unit 10 for acquiring images of an object 1, which can be preferably be a biological tissue, a processing unit 20, a storage unit 31 and a display unit 41.

[0049] The image acquisition unit 10 comprises an illumination device 11 for, in particular uniformly, illuminating the object 1 in a desired imaging region by pulsed or frequency modulated laser light.

[0050] The image acquisition unit 10 further comprises a detection device 12 for capturing ultrasound waves generated in a three-dimensional imaging region of the object 1 upon illumination. The detection device 12 comprises an array of ultrasound detection elements, wherein the number of detector elements and/or the area covered by the array of detector elements are dimensioned such that ultrasound waves emanating from the whole imaging area of the object 1 can be detected simultaneously. This allows for creating a full tomographic optoacoustic image from the acquired ultrasound waves for each of the illumination pulses, so that acoustic waves are collected repeatedly and a first video sequence 201 of respective tomographic optoacoustic images is obtained, wherein each of the illumination pulses serves as a frame, i.e. a time frame, of the first video sequence 201 of the tomographic optoacoustic images.

[0051] It should be noted that power fluctuations in the excitation chain, i.e. the illumination device 11, of the system 100 may contribute to noise signals, wherein, dependent on the utilized technology, the power of the illumination device 11, in particular the laser power, can vary from pulse to pulse and can thus can have an impact on the information contained and/or displayed in the final image. However, in many settings this impact can be corrected by using laser integrated power measurement devices and a dependent amplification of the detected optoacoustic signals in terms of low power pulses. Such measurements can also be used as a metric to select or weigh frames in one of the algorithms described below in more detail.

[0052] In the processing unit 20 the first video sequence 201 of tomographic optoacoustic images is analyzed and/or processed according to the invention, in particular by effecting analyzing and/or processing steps according to the preferred embodiments of the invention. The output of the processing unit 20 is a second video sequence 202 of tomographic optoacoustic images exhibiting improved properties as well as so-called metadata 203 of various kinds, for example images, values or graphs.

[0053] In the storage unit 31 the first video sequence 201 of tomographic optoacoustic images and/or the improved second video sequence 202 of tomographic optoacoustic images and/or the metadata 203 generated by the processing unit 20 can be stored.

[0054] In the display unit 41 the first video sequence 201 of tomographic optoacoustic images and/or the improved second video sequence 202 of tomographic optoacoustic images and/or the metadata 203 generated by the processing unit 20 can be displayed.

[0055] Fig. 2 shows a schematic representation of the processing unit 20 shown in fig. 1. The processing unit 20 comprises a core processor 21 that performs the analyzing and/or processing operations on the first video sequence 201 of tomographic optoacoustic images according to the invention including preferred embodiments thereof.

[0056] Preferably, the processing unit 20 comprises a frame component analysis device 22 for analyzing the first video sequence 201 of tomographic optoacoustic images with respect to contributing components. Moreover, the processing unit 20 preferably comprises a frame component correction device 23 for correcting components contributing to tomographic optoacoustic images of the first sequence 201 and for generating the second video sequence 202 of tomographic optoacoustic images exhibiting increased quality, wherein the generation of the second video sequence 201 is based on the result of the correction of components contributing to tomographic optoacoustic images of the first sequence 201.

[0057] The core processor 21 and/or the frame component analysis device 22 and/or the frame component analysis device 22 also generate metadata 203, such as images, values and graphs, which describe or relate to phenomena in the first video sequence of tomographic optoacoustic images.

[0058] In a further preferred embodiment, the output of the core processor 21 and/or the frame component analysis device 22 and/or the frame component analysis device 22 can optionally be analyzed by a data analysis device 24, by means of which the metadata 203 can be further enriched.

[0059] In the following, further aspects of the invention as well as further aspects of preferred embodiments of the invention are described by referring to fig. 1 and 2.

[0060] The optoacoustic imaging system 100 is able to acquire, store and process a time series of two or three dimensional tomographic video images of the same area in the imaged object 1 at a high frame rate using stationary illumination 11 and detection devices 12, allowing for the use of algorithms for improving SNR and coping with motion artifacts. Fast image generation is enabled by pulsed excitation, where each pulse generates an instantaneous snapshot image.

[0061] Because ultrasonic responses generated by the pulsed illumination are comparatively weak and undergo further attenuation when traveling to the detector through tissue and water, the use of single pulse image frames would provide only a limited amount of measurement data points available without any redundancy to cope for bad signals, as any noise in system and acquisition is added individually on top of the captured data.

[0062] In order to improve SNR and to cope with motion artifacts, multiple repeatedly acquired images are analyzed and/or processed according to the invention such that the quality of the individual images is improved while the effective frame rate is kept high, i.e. at a maximum, and thus the usability for imaging fast processes in the object is maintained.

[0063] This allows for investigating high-resolution changes of optical contrast features of the same area inside the imaged object and fast processes in living organisms that cannot be revealed by other imaging modalities.

[0064] Preferred frame rates in order to be able to fulfill the aforementioned aims start from 10 frames per seconds. Upper bounds to the frame rate are only given by hardware limitations such as repetition rate of the excitation source or data rate of processing systems.

[0065] Excitation is delivered using preferably uniformly distributed illumination 11 of the imaging region of the object 1. It can either be of pulsed nature with pulse widths in the order of nanoseconds, or of continuous nature with either frequency or intensity modulation applied. In any of the mentioned cases the illumination wavelength can optionally be adapted in the course of the measurement at any given rate.

[0066] The stationary optoacoustic detector array 12 can be of any curved or linear shape that can acquire acoustic waves from sufficient projections of the imaged object 1 for any imaging instant in order to make time consuming mechanical detector movements unnecessary.

[0067] Another aspect of the invention relates to the high data rate processing unit 20 which is connected with the image acquisition unit 10, in particular with the detection device 12, and which provides computational power and algorithms to capture and analyze and/or process the first video sequence 201.

[0068] It is of particular importance that the signals of sufficient or ideally all detectors of the array 12 can be captured in one acquisition cycle. Apart from individual processing algorithms it is an object of the present invention to analyze a time series, i.e. a sequence 201, of images and identify extrinsic, parasitic influences such as noise and motion that deteriorate the individual video frames.

[0069] In a preferred manifestation, a moving average processing on the first video sequence 201 of images can be executed in order to remove independent influences while retaining the effective video frame rate.

[0070] Other preferred aspects include a selection process in which the quality of individual video frames by using metrics, such as blur, mutual information, similarity or image correlation, is assessed. Based on these metrics, i.e. criteria, it is an option to discard individual, highly noise or motion affected video frames completely in order to increase overall quality and signal to noise ratio as a trade-off with retained information frame rate. This allows amendment of the captured first video stream 201 to an improved, final second video stream 202.

[0071] In another aspect, temporal patterns of individual contributions to the content of the individual images of the first video sequence 201 can be used in the frame component analysis device 23 to both classify the contributions and retrieve information about change processes in the images that might themselves be important aspects of the measurement. This preferably includes periodic motion patterns, such as the breathing rate of an animal that leads to repeated, periodic contractions of the rib cage and represents a major source of motion and can thus be progressively used in processing both past and future video frames.

[0072] If calculated on-line during the measurement in the data analysis device 24, this also allows for capturing health indicators such as breathing or heart rate as well as a metric for motion of the detection device 12 and thus image reliability in handheld imaging. Therefore, in a preferred embodiment of the system according to the invention, the detection device 12, and optionally the illumination device 11, is or are integrated in a handheld probe which can be grasped or touched by hand and, e.g., positioned onto the surface of an object under investigation, e.g. a patient.

[0073] This information, in particular relating to breathing, heart rate, blood flow or motion of the object 1 and/or motion of the detection device 12, when captured and processed in real time can also be used in a feedback loop 211 as a control data for the image acquisition unit 10. For example, by means of information relating to breathing or heart rate of the object 1 or relative motion between the object 1 and the image acquisition unit 10 a corresponding feedback signal is generated and fed to the image acquisition unit 10, wherein the image acquisition unit 10 is controlled by the feedback signal such that, e.g., optoacoustic images are only acquired at certain time frames or times of the breathing cycle, cardiac cycle or blood circulation.

[0074] The acquired and/or derived data can be stored in the storage device 31. Image data relating to sequences of tomographic optoacoustic images can be stored before (first sequence 201) any processing steps and/or after (second sequence 202) processing in the processing unit 20. Moreover, also additional metadata 203 generated in the course of processing can also be stored in the storage device 31.

[0075] The stored data can be analyzed immediately or at a later point in time by the data analysis device 24. In a real time processing enabled system, the processed second sequence of images and/or the unprocessed first sequence of images, so-called raw data, can also be visualized on the display device 41.

[0076] Noise and motion correction of the images of the first sequence 201 is especially advantageous when high speed changes in contrast need to be tracked that cannot be revealed using mechanisms that reduce the frame rate of the acquired data. Examples are fast changes in contrast when perfusing biological tissue with a marker substance, where certain image features increase in signal.

[0077] According to the invention, the generation of the second high frame rate video sequence 202 of images of absorbing structures is achieved by means of a post-processing of the first high frame rate video sequence 201 of the acquired images. Here, a particularly advantageous task is multispectral processing of the acquired image data of the first high frame rate video sequence 201 by associating absorbers with individual pixels and thus allowing for localizing absorbers based on their spectral absorption profile over multiple excitation wavelengths. This approach is often referred to as multispectral optoacoustic imaging (MSOT). Because of the per-pixel evaluation it is essential to correct the acquired images for motion and noise to allow the so-called spectral unmixing algorithms to work.

[0078] According to a preferred embodiment of the invention, the acquisition in the described high speed measurement system 100 can optionally be triggered using external device (not shown) by means of which at least one property of the object 1 relating to temporal, in particular periodic, changes at or within the object 1 can be acquired while the first sequence of tomographic optoacoustic images is acquired. Temporal changes may comprise, e.g., changes due to respiration, pulse or blood flow. The external device is designed to produce an according control signal 212 for controlling the image acquisition unit 10. For example, the external device can be an electrocardiogram (ECG) or a breathing rate monitoring system by means of which the image acquisition can be triggered, in particular started, in motion-free moments between breathing cycles or at certain moments in the cardiac cycle to further increase the image quality.

[0079] In the following, further particularly preferred embodiments of the invention will be discussed.

[0080] In one preferred embodiment, the optoacoustic detection device 12 encircles the object 1 in a full or partial circle or arc. By means of focusing the sensitivity of the individual detector elements of the array in a direction perpendicular to the imaging plane, the imaged area is thus restricted to signals emitted in a quasi two-dimensional plane. If focusing is reduced or completely omitted, signals are captured from the whole three-dimensional area enclosed by the detection device 12.

[0081] The illumination device 11 irradiates laser pulses onto an area of the object 1 being slightly larger than the imaging plane in order to provide uniform illumination of the whole imaging area. Detection device 12 and illumination device 11 are preferably static with respect to each other, in order to allow for repeated imaging of the same area without a change in the setting.

[0082] The object 1 can be translated perpendicular to the imaging plane to select the area to image. By means of this setup it is possible to generate high frame rate data of one imaging area. Multiple imaging areas can be covered by fast translation of the object 1, or additional detection and illumination device pairs 12/11 that operate independently. Exemplary applications of this embodiment are pre-clinical imaging of small animals or clinical imaging of peripherals, such as hand, finger or feet.

[0083] An important step in improving the quality of the final video stream 202 in the core processing device 21 is the assessment of the quality of the individual frames, as this allows for subsequent, quality-dependent processing of the input data 201. In this embodiment, the quality improvement of the output video stream 201 is achieved by elimination of low quality video frames, which improves the overall quality of the video. This is mainly appropriate with high video frame rates, where processing time is very important. As a decrease in frame rate, or a varying frame rate in general is not desirable in most applications, frames that are dropped due to their insufficient quality are substituted by interpolating and/or extrapolating the neighboring good frames.

[0084] In order to assess the quality of a video frame, two different types of video frame metrics, i.e. criteria, can be applied: First, individual image metrics on the one hand assess the quality of the frame only with respect to itself. Examples include image SNR with respect to background area, contrast and different blur and sharpness related metrics. Second, mutual metrics on the other hand classify an image with respect to other images. Standard deviation, k-means, similarity, image correlation and mutual information based on both intensity and feature-based metrics are examples. They are very advantageous for the quality improvement in motion-perturbed measurements as they allow for identifying video frames acquired at time points with corresponding positions of the object 1. Depending on the pro-rata contributions of motion and noise to the acquired video, a number of reasonable metrics need to be combined. Individual image metrics can identify noisy frames, while mutual metrics help to find frames that show the same setting to help identify motion compensated frames. In the case of pre-clinical imaging with small animals, this is largely dependent on the region that is measured.

[0085] As additional information, the metrics for the individual frames are provided as metadata 203 on the output of the processing device. This allows for user feedback on the quality of the video stream.

[0086] This advantageously enables the per-pixel monitoring of even small intrinsic contrast changes in the measured subject which would have otherwise been hidden and obscured by noise and motion. An example of such fast change is the change in blood oxygenation as the oxygen content in the breathing air supply of a live animal or human is changed. This allows judgment of the degree of vascularization and thus blood perfusion in tissue.

[0087] In a further embodiment, the video frame images are processed using statistical metrics in the frame component analysis device 22. The input to this step can either be the original first video stream 201, or the second video steam 202 already pre-processed by the core processing device 21. The incoming video stream 201 is separated in contributing components using methods of blind source separation or equivalent approaches. A method that has proven efficient and robust is principal component analysis (PCA) that relies on orthogonality of contributing components, but comparable algorithms from that domain can work equally well. The resulting components are then classified into actual signal sources, meaning actual changes in contrast in certain pixels, and unwanted contributions such as motion and noise. As these methods include an indicator on the temporal behavior of a contribution, this can be used in the frame component correction device 23 to identify noise and motion as these usually show a very high frequent behavior, while changes in signal are assumed to be relatively slow changing in comparison with a significant trend.

[0088] While this differentiation is very simple for the human eye by looking either at the moving component picture or its temporal profile, an automatic decision process needs to take into account various parameters. Essential are means of Fourier transform or similar, which visualize the frequency content in individual components and an evaluation of the mean contribution and the significance in relation to the complete video stream.

[0089] Depending on the application it is important to define the respective thresholds to separate slow varying signal components from usually more high frequent motion and noise components. A-priori knowledge of patterns can also be applied using fitting and deconvolution procedures or tracking algorithms. With this differentiation into perturbations and actual signal being made, the correction device 23 can re-assemble a final video stream 202 that is free of the unwanted contributions of noise and motion.

[0090] The separation into components also allows further, even more simple processing tasks such as smoothening or selective filtering on the individual components. As an example, a moving average processing step on components representing ideal white noise would automatically lower their influence and thus improve from the dataset without further actions being necessary.

[0091] The extracted meta content or meta data 203 retrieved from the separation in the frame component analysis device 22 can serve to identify patterns in the motion or noise components, that can be provided as a visual feedback, i.e. displayed in display 41, in addition to the final video stream 202. This is not restricted to the temporal profiles of certain contributions, but also their localization. This possibility to reveal and analyze spatio-temporal events with optical contrast enables very powerful applications.

[0092] In another embodiment, binning procedures to separate frames, i.e. images, based on a certain stadium can be applied in the data analysis device 24 using mutual video frame metrics to identify different groups of frames. One example is the separation of heartbeat cycle into systolic and diastolic segments that can help create high quality snapshots in a motion-rich scenario.

[0093] In a further embodiment, the output of the frame component analyzing device 22 can help in the data analysis device 24 to identify physiological parameters of the imaged object 1 by analyzing the temporal profiles of certain contributors. This includes breath rate and heart rate recognition based on motion components, as these are periodic changes in the video streams 201 and/or 202.

[0094] In a real-time system 100, the physiological parameters of the imaged object 1 can in turn be used in a feedback loop as a control signal 211 which triggers the image acquisition unit 10 in moments with predicted low motion, e.g. in between breathing cycles.

[0095] In yet another aspect of the invention, the output video images 202 can be evaluated for dynamic changes within the entire images or certain pixels in the processing unit 20. This allows for visualization of changes either as a graph or as a parameter map indicating parameters characterizing the change in value of a certain pixel by either plain observation or some pharmacokinetic modeling. This allows for utilizing the image acquisition unit 10 as a device which enables visualizing a bio-distribution of injected agents and modeling their kinetic behavior within the imaging region.

[0096] Important parameters to be observed may include, but are not limited to, peak enhancement, area under the curve, rise time, time to peak, wash-in rate or perfusion index, mean residence time, volume of distribution, clearance, CMax, TMax, bioavailability and various rate constants that allow fitting a pharmacokinetic model. Regarding these parameters it is referred to respective detailed elucidations and examples given above.

[0097] Depending on the specific kinetics of interest, this may be applied to single wavelength video sequences or multispectral video sequences, wherein the latter allow for assessment of biological properties of tissue and organ function, where there is currently no other imaging modality that can deliver equally high frame rates with functional contrast.

[0098] In another embodiment, the illumination wavelength can be changed during the acquisition, so that illumination pulses of different wavelength capture different contrast inside the imaged object to further enrich the dataset in another dimension, i.e. by a spectral dependence of the optoacoustic image data. This features the powerful tool of Multispectral Optoacoustic Tomography (MSOT) that has been previously used on static settings to reveal absorbers based on their absorption profile. With an interleaved processing of the individual frames acquired at different wavelengths, the aforementioned features can be applied to hugely improve the possibilities for fast MSOT for which motion-free data sets to characterize the absorption spectrum of individual pixels are essential. Here, the MSOT benefits significantly from improved quality of the video stream 202 obtained by means of the invention. Another important benefit in employing this method lies in the ability to trace contrast changes also if they are caused by multiple absorbers. As an example, a labeled drug to increase blood circulation could produce contrast in a decisive wavelength where the attached contrast agent absorbs, but also change the amount and thus the absorption by blood.

[0099] In another embodiment, an optional compression step can be incorporated in the course of video frame processing in order to simplify data transfer and reduce required storage space. This compression can either happen in a combined processing step as a side product of any of the algorithms employed, or in a subsequent step using commonly known data or video compression mechanisms.

[0100] In yet another embodiment, the detection device 12 collects data from a three dimensional volume within the object 1 from only one side of the object 1. Detection elements are either arranged on parts of a sphere in order to allow focusing on the imaging area, or in a linear manner in order to cover a broader and less wide area with substantially less or no focusing. In most applications it makes sense to arrange illumination device 11 and detection device 12 on the same side of the object 1 - however a uniform illumination of the imaging area needs to be granted, and still the illumination device 11 needs to be fixed with respect to the detection device 12. This arrangement allows for greater flexibility in selecting the imaging area and mounting in a handheld device. In handheld operated mode however, the imaging rate needs to be very high in order to fulfill the requirement of a quasi-static setting. In general, the detection geometry of this embodiment allows for whole body small animal imaging and handheld clinical imaging.

[0101] In another embodiment, the described imaging system can be applied to humans using either handheld or endoscopic imaging by modifying the acquisition device 10 accordingly.

[0102] Dependent on the acquisition rate the system supports, some or all components of the processing unit 20 detailed above may need to be implemented in dedicated hardware to achieve the necessary throughput.

Claims

1. System (100) for optoacoustic imaging of an object (1) comprising an image acquisition unit (10) for acquiring a first sequence (201) of tomographic optoacoustic images of a region of interest of the object (1), wherein the image acquisition unit (10) comprises

   - an illumination device (11) for irradiating the region of interest of the object (1) with electromagnetic radiation, in particular light, and
   - a detection device (12) for repeatedly collecting acoustic waves emerging from the object upon irradiating the object (1) and for generating the first sequence (201) of tomographic optoacoustic images of the region of interest from the repeatedly collected acoustic waves,

   characterized by
   a processing unit (20) for generating a second sequence (202) of one or more tomographic optoacoustic images from the first sequence (201) of tomographic optoacoustic images based on
   - an analysis of one or more tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images and/or
   - at least one property of the object (1) while acquiring the first sequence (201) of tomographic optoacoustic images and/or at least one property of the acquisition unit (10) while acquiring the first sequence (201) of tomographic optoacoustic images.

2. System (100) according claim 1, wherein the at least one property of the object (1) relates to temporal, in particular periodic, changes at or within the object, in particular due to respiration, pulse or blood flow, while acquiring the first sequence (201) of tomographic optoacoustic images.

3. System (100) according to claim 1 or 2, wherein the at least one property of the object (1) is acquired by means of an external device, which is in particular adapted for observing temporal changes at or within the object (1), in particular due to respiration, pulse or blood flow.

4. System (100) according to one of the foregoing claims, wherein the at least one property of the object (1) is derived from one or more tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images.

5. System (100) according to one of the foregoing claims, wherein the processing unit (20) is adapted for generating the second sequence (202) of tomographic optoacoustic images based on an analysis of a subsequence of tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images.

6. System (100) according to one of the foregoing claims, wherein the processing unit (20) is adapted for generating the second sequence (202) of tomographic optoacoustic images based on an analysis of tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images with respect to their individual properties, in particular signal-to-noise ratio, contrast, blur or sharpness.

7. System (100) according to one of the foregoing claims, wherein the processing unit (20) is adapted for generating the second sequence (202) of tomographic optoacoustic images from the first sequence (201) of tomographic optoacoustic images based on an analysis of properties, in particular signal-to-noise ratio, frequency spectrum or noise patterns, of the repeatedly collected acoustic waves prior to generating the first sequence (201) of tomographic optoacoustic images from the repeatedly collected acoustic waves.

8. System (100) according to one of the foregoing claims, wherein the processing unit (20) is adapted for generating the second sequence (202) of tomographic optoacoustic images based on an analysis of tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images regarding properties of the tomographic optoacoustic images with respect to each other, in particular a similarity of the images, a correlation of the images, a standard deviation or k-means.

9. System (100) according to one of the foregoing claims, wherein the processing unit (20) is adapted for generating the second sequence (202) of tomographic optoacoustic images based on an analysis of tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images using a feature tracking algorithm by means of which a temporal behavior of one or more individual contributions, e.g. an imaged part of the object (1), to tomographic optoacoustic images of the first sequence (201) is analyzed and/or tracked.

10. System (100) according to one of the foregoing claims, wherein the processing unit (20) is adapted for generating the second sequence (202) of tomographic optoacoustic images based on an analysis of statistical properties of tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images.

11. System (100) according to one of the foregoing claims, wherein the processing unit (20) is adapted for processing the second sequence (202) of tomo-

graphic optoacoustic images based on an analysis of statistical properties of tomographic optoacoustic images of the second sequence (202) of tomographic optoacoustic images.

12. System (100) according claim 10 or 11, wherein the analysis of statistical properties comprises a separation of the tomographic optoacoustic images of the sequence of tomographic optoacoustic images into contributing components, in particular by means of a principal component analysis (PCA).

13. System (100) according to one of the foregoing claims, wherein the acquisition unit (10) is adapted to be controlled by control signals (211, 212) from

- the processing unit (20) or
- an external device, which is in particular adapted for observing a time-variant process in the object (1), in particular respiration, heartbeat or blood flow of the object (1),

to allow for an acquisition of the first sequence (201) of tomographic optoacoustic images at specific instants, in particular at less motion-perturbed instants, e.g., at timeframes with no respiratory activity or certain periods of the heart cycle.

14. System (100) according to one of the foregoing claims, wherein the image acquisition unit (10) is adapted to utilize photon absorption information from previous tomographic optoacoustic images of the same object (1) to change amplification of signals corresponding to acoustic waves originating from deeper inside of the object (1) in order to correct for reduced light fluence in deep tissue.

15. System (100) according to one of the foregoing claims, wherein the processing unit (20) is adapted for generating the second sequence (202) of tomographic optoacoustic images by selecting and discarding individual tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images based on the analysis of the one or more tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images.

16. System (100) according to claim 15, wherein the processing unit (20) is adapted for generating a replacing tomographic optoacoustic image which is inserted into the second sequence (202) of tomographic optoacoustic images in the case that a tomographic optoacoustic image of the first sequence (201) of tomographic optoacoustic images has been discarded, wherein the replacing tomographic optoacoustic image is generated based on two or more preceding and/or following images, in particular by interpolating and/or extrapolating the preceding and/or following images, of the first sequence (201) of tomographic optoacoustic images being adjacent to the discarded tomographic optoacoustic image.

17. System (100) according to one of the foregoing claims, wherein the processing unit (20) is adapted for generating the second sequence (202) of tomographic optoacoustic images by moving averaging of tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images, wherein each time at least two subsequent tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images are averaged.

18. System (100) according to one of the foregoing claims, wherein the at least one property of the acquisition unit (10) relates to an intensity of the electromagnetic radiation with which the object (1) is irradiated while acquiring the first sequence (201) of tomographic optoacoustic images.

19. System (100) according to one of the foregoing claims, wherein the illumination device (11) is adapted for irradiating the object (1) with electromagnetic radiation, in particular light, at multiple wavelengths and the processing unit (20) is adapted for analyzing the first sequence (201) and/or the second sequence (202) of tomographic optoacoustic images at the multiple wavelengths.

20. System (100) according to one of the foregoing claims, comprising

- a display unit (41) for displaying a video stream of the first sequence (201) of tomographic optoacoustic images and/or the second sequence (202) of tomographic optoacoustic images and/or
- a storage unit (31) for storing the first sequence (201) of tomographic optoacoustic images and/or the second sequence (202) of tomographic optoacoustic images.

21. System (100) according to one of the foregoing claims, wherein the image acquisition unit (10) is designed as a handheld device.

22. Method for optoacoustic imaging of an object (1) by acquiring a first sequence (201) of tomographic optoacoustic images of a region of interest of the object (1) comprising the following steps:

- irradiating the region of interest of the object (1) with electromagnetic radiation, in particular light, and
- repeatedly collecting acoustic waves emerging

from the object upon irradiating the object (1) and generating the first sequence (201) of tomographic optoacoustic images of the region of interest from the repeatedly collected acoustic waves,

characterized by

generating a second sequence (202) of one or more tomographic optoacoustic images from the first sequence (201) of tomographic optoacoustic images based on

- an analysis of one or more tomographic optoacoustic images of the first sequence (201) of tomographic optoacoustic images and/or
- at least one property of the object (1) while acquiring the first sequence (201) of tomographic optoacoustic images and/or at least one property of the irradiation of the object and/or the collection of acoustic waves while acquiring the first sequence (201) of tomographic optoacoustic images.

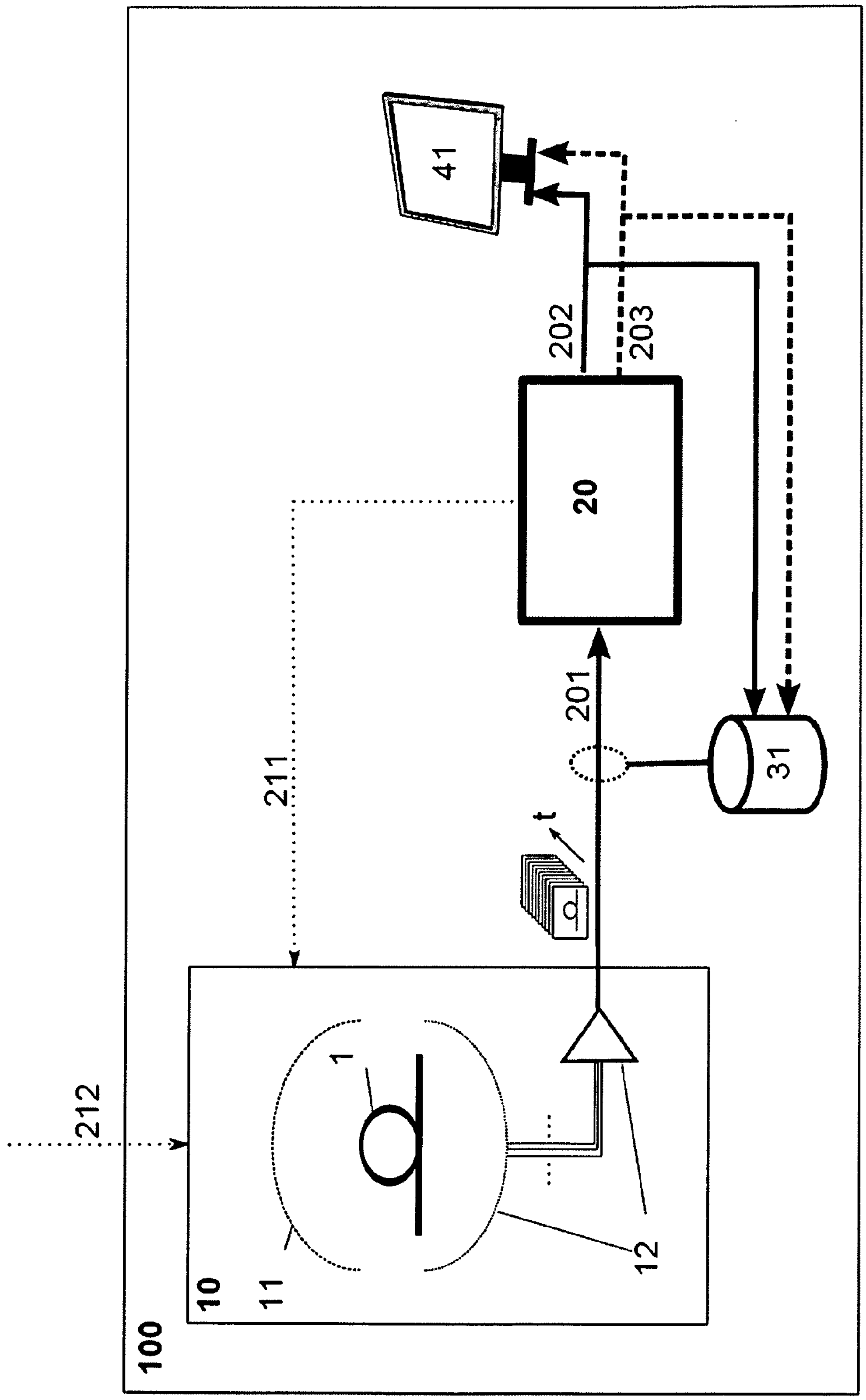

Fig. 1

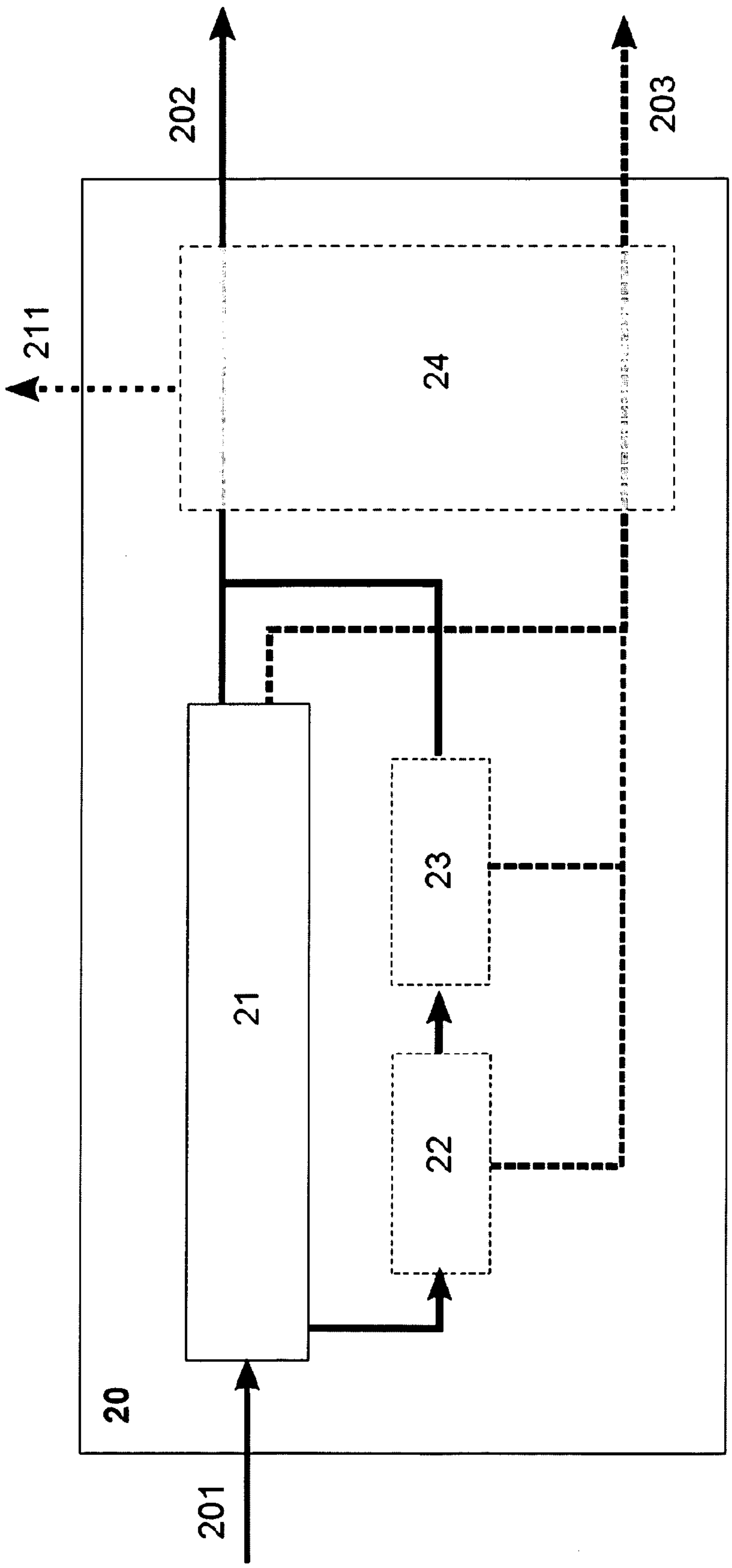

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 13 00 0202

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	ADRIAN TARUTTIS ET AL: "Motion clustering for deblurring multispectral optoacoustic tomography images of the mouse heart", JOURNAL OF BIOMEDICAL OPTICS, S P I E - INTERNATIONAL SOCIETY FOR OPTICAL ENGINEERING, US, vol. 17, no. 1, 1 January 2012 (2012-01-01), pages 16009-1, XP007921966, ISSN: 1083-3668, DOI: 10.1117/1.JBO.17.1.016009 [retrieved on 2012-02-06] * the whole document *	1,2, 4-13, 15-17, 19,20,22	INV. A61B5/00 A61B5/02 G01N21/17
X	TARUTTIS ADRIAN ET AL: "Imaging the small animal cardiovascular system in real-time with multispectral optoacoustic tomography", PHOTONS PLUS ULTRASOUND: IMAGING AND SENSING 2011, SPIE, 1000 20TH ST. BELLINGHAM WA 98225-6705 USA, vol. 7899, no. 1, 10 February 2011 (2011-02-10), pages 1-8, XP060007417, DOI: 10.1117/12.874242 [retrieved on 2011-02-17] * the whole document *	1-20,22	TECHNICAL FIELDS SEARCHED (IPC): A61B G01N
X	US 2012/123256 A1 (RAZANSKY DANIEL [DE] ET AL) 17 May 2012 (2012-05-17) * paragraph [0083]; figures 1-10 *	1,14-16, 19-22	
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1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	12 June 2013	Apostol, Simona

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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L : document cited for other reasons

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EUROPEAN SEARCH REPORT

Application Number
EP 13 00 0202

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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X	US 2010/249570 A1 (CARSON JEFFREY J L [CA] ET AL) 30 September 2010 (2010-09-30) * paragraphs [0059] - [0083], [0091] - [0128]; claims 1-15,24; figures 1-8 * -----	1,2, 13-22	

TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	12 June 2013	Apostol, Simona

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12-06-2013

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专利名称(译)	用于物体的质量增强的高速光声成像的系统和方法		
公开(公告)号	EP2754388A1	公开(公告)日	2014-07-16
申请号	EP2013000202	申请日	2013-01-15
申请(专利权)人(译)	亥姆霍兹慕尼黑中心DEUTSCHES FORSCHUNGSZENTRUMFÜRGESUNDHEIT UND UMWELT GMBH		
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IPC分类号	A61B5/00 A61B5/02 G01N21/17		
CPC分类号	A61B5/0095 A61B5/7203 A61B5/7221 A61B5/7292 G01N21/1702 G01S15/89		
外部链接	Espacenet		

摘要(译)

本发明涉及一种用于对象（1）的光声成像的系统（100）和方法，包括图像获取单元（10），用于获取对象的感兴趣区域的断层光声图像的第一序列（201）。），其中图像采集单元（10）包括用于利用电磁辐射，特别是光照射物体（1）的感兴趣区域的照明装置（11），以及用于重复采集声波的检测装置（12）在照射物体（1）时从物体射出，并从重复采集的声波中产生感兴趣区域的断层光学声像的第一序列（201）。为了获得层析成像的序列高图像帧速率和高图像质量的光声图像，特别是表现出比传统视频序列更少的运动和/或噪声扰动的断层光声图像的视频序列，提供处理单元（20）用于生成第二序列（202）。基于对断层摄影光学图像的第一序列（201）的一个或多个断层光声图像和/或对象的至少一个属性的分析，来自断层摄影光学图像的第一序列（201）的一个或多个断层光学声学图像（1）同时获取断层摄影光学图像的第一序列（201）和/或获取单元（10）的至少一个属性，同时获取断层摄影光学声学的第一序列（201）图片。

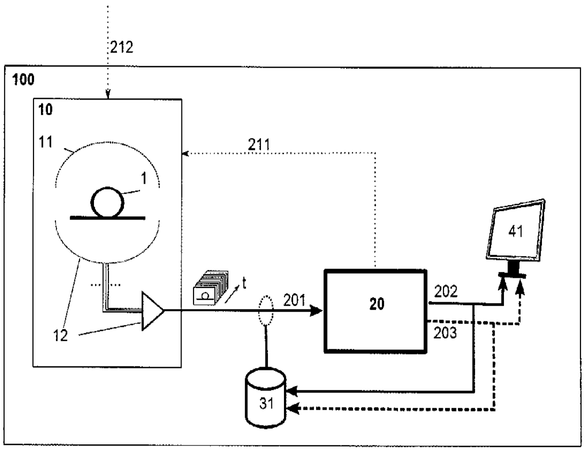

Fig. 1