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(54) **SPECTRAL IMAGING**

SPEKTRALABBILDUNG
IMAGERIE SPECTRALE

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(56) References cited:
WO-A-2007/039838 US-A1- 2004 101 088
US-A1- 2008 137 803

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- **SCHLOMKA J P ET AL: "Experimental feasibility of multi-energy photon-counting K-edge imaging in pre-clinical computed tomography; Experimental feasibility of multi-energy photon-counting K-edge imaging in pre-clinical CT" PHYSICS IN MEDICINE AND BIOLOGY, TAYLOR AND FRANCIS LTD. LONDON, GB, vol. 53, no. 15, 7 August 2008 (2008-08-07), pages 4031-4047, XP020141344 ISSN: 0031-9155**

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Description

[0001] The following generally relates to spectral imaging, and finds particular application to computed tomography (CT). However, it is also amenable to other medical imaging applications and to non-medical imaging applications.

[0002] A computed tomography (CT) scanner has been used to capture perfusion information, such as flow through vascular tissue, which can be used to facilitate diagnosing patients. For instance, a brain perfusion scan provides information that can be used to facilitate identifying mal-perfusion in stroke patients. In general, a conventional computed tomography perfusion (CTP) procedure includes intravenously administering a contrast agent bolus to a patient, which causes the x-ray density of the brain to temporarily increase as the contrast agent is taken up and flows through and washes out of the vascular structure of the brain, and performing a time series of CT scans of the patient's brain. The captured data can be used to trace the contrast agent as it flows through the brain and identify ischemic tissue and/or differentiate between irreversibly damaged or necrotic tissue (the core of the infarct) and potentially reversibly damaged or at-risk tissue (the penumbra of the infarct). The differences in the absorption in the time series provide relative measures of mean transition time (MTT), cerebral blood volume (CBV) and cerebral blood-flow (CBF).

[0003] Unfortunately, it may be difficult to measure the MTT value directly with a short and dense contrast bolus due to limitations of the injection rate. Often the MTT parameter is measured indirectly with a perfusion scan, a de-convolution technique to derive CBV and CBF, and the relation $MTT = CBV/CBF$. This may have limited reliability since the de-convolution process requires operator selection of a reference vessel for the input function, and the selection is prone to error. Furthermore, the accuracy of such a technique is limited since the pharmacokinetics is a complex function and the information carried by the CTP measurements are not well-suited for deriving the hemodynamic and perfusion parameters. Moreover, the contrast agent bolus is only temporarily present within the patient, and the time interval during which the contrast agent can be visualized is limited by the residence time of the contrast agent within the patient.

[0004] Another example perfusion procedure is a multi-phase liver study. For such a study, a contrast agent based CT procedure can be used to identify hyper and/or hypo perfused regions of the liver during the aortic (contrast uptake) phase, the portal venous (contrast wash out) phase, and/or the equilibrium (no contrast) phase. Unfortunately, such a study conventionally requires administration of a contrast agent and then multiple scans (e.g., 3 to 5 scans) thereafter in order to capture the contrast agent in each of these phases as the contrast agent flows through the vessels. As such, patient dose may be high relative to protocols in which fewer scans are performed.

[0005] US2004/101088 A1 discloses multi-energy imaging of two contrast agents injected into two vessels at different delay times and reconstructing spectrally resolved images of each contrast agent.

[0006] US2008/137803 A1 discloses a diagnostic imaging system which employs an inversion table or function to convert $N+2$ measured projections at different incident spectra into material specific integrals for $N+2$ materials that comprise two non K-edge basis materials and N K-edge contrast agents.

[0007] WO2007/039838 A discloses a contrast injector used in angiography that injects contrast agent based in a desired clinical injection profile based on patient function and desired enhancement profile.

[0008] J.P. Schlomka et.al. in 'Experimental feasibility of multi-energy photon-counting K-edge imaging in pre-clinical computed tomography; Experimental feasibility of multi-energy photon-counting K-edge imaging in pre-clinical CT', Physics in Medicine and Biology, vol. 53, no. 15, 2008 discloses spectral imaging with various contrast agents.

[0009] Aspects of the present application address the above-referenced matters and others.

[0010] According to one aspect, a method, which is not claimed, includes concurrently modulating administration of at least two different contrast agents to a subject during an imaging procedure based on a modulation profile. The at least two different contrast agents exhibit different spectral characteristics. The method further includes performing a spectral decomposition of data indicative of the at least two different contrast agents, determining concentrations of the at least two different contrast agents based on the spectral reconstruction, and determining a perfusion parameter based on a ratio of the concentrations and the modulation profile.

[0011] In an embodiment, the method, which is not claimed, further includes concurrently administering at least one additional contrast agent with the at least two contrast agents, wherein the perfusion parameter is based on the concentrations of the three contrast agents and corresponding modulation profiles. At least one of the at least first and second contrast agents can be tissue specific contrast agent. However, at least one of the at least first and second contrast agents can also be a non-specific contrast agent.

[0012] According to another aspect, a method, which is not claimed, includes administering at least first and second intravenous contrast agents, each with different spectral properties, to a subject, wherein the second intravenous contrast agent is administered after a first pre-set time delay from the administering of the first contrast agent, wherein the at least first and second contrast agents are administered to a same vessel. The method further includes performing a single spectral scan of the subject after a second pre-set time delay from the administering of the second contrast agent. The method further includes generating a first image of the first contrast agent representing a first physiological phase and a second image of the second contrast agent representing a second different physiological phase.

[0013] Another aspect of the invention is represented by the system according to independent claim 1, with further

embodiments represented by dependent claims 2 - 11.

[0014] The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating the preferred embodiments and are not to be construed as limiting the invention.

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FIGURE 1 illustrates an example imaging system.

FIGURE 2 illustrates an example MTT determiner.

FIGURE 3 illustrates example contrast agent modulation profiles.

FIGURE 4 illustrates an example method.

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FIGURE 5 illustrates another example method.

[0015] FIGURE 1 illustrates a computed tomography (CT) scanner 100 that includes a stationary gantry 102 and a rotating gantry 104, which is rotatably supported by the stationary gantry 102. The rotating gantry 104 rotates around an examination region 106 about a longitudinal or z-axis 108. A radiation source 110, such as an x-ray tube, is supported by and rotates with the rotating gantry 104 around the examination region 106 and emits polychromatic radiation. A collimator 112 collimates the emitted radiation to produce a generally fan, wedge, or cone shaped radiation beam that traverses the examination region 106. A radiation sensitive detector array 118 detects photons that traverse the examination region 106 and generates projection data indicative of the examination region.

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[0016] An injector 114 is configured to inject or administer a contrast medium in the patient for a scan. As described in greater detail below, in one instance the injector is used to concurrently administer at least two different contrast agents (e.g., a contrast agent containing gadolinium or iodine, etc.) with two different spectral properties in a same vessel or in different vessels. In another instance, the injector is used to successively administer two or more different contrast agents with a delay between the administering. A modulator 116 provides a control signal indicative of the injection pattern or profile of the two or more different contrast agents, including the concentrations of the two or more different contrast agents over time. The contrast agents can alternatively be manually administered by a clinician or the like.

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[0017] A reconstructor 120 reconstructs the projection data and generates volumetric image data indicative thereof. In one instance, the reconstructor 120 employs a spectral algorithm 124 such as a K-edge algorithm. Such an algorithm allows for selective and quantitative imaging of materials with different spectral properties, such as one or more administered contrast agents. The reconstructor 120 may also employ conventional reconstruction algorithms, for example, a filtered backprojection algorithm or an iterative reconstruction algorithm.

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[0018] An image generator 126 processes the volumetric image data and generates one or more images. In one instance, this includes generating at least a first image showing a first contrast agent and a second image showing a second contrast agent. If a tissue specific contrast agent(s) is used, the contrast is substantially absorbed by the tissue and the corresponding image(s) is indicative of the tissue. If a non-tissue specific contrast agent(s) is used, the corresponding image(s) is indicative of the vessels through which the contrast flows. One or more than one of the contrast agents can be specific or non-specific. The image generator 126 can also generate other images such as a conventional CT attenuation based image, another image showing another contrast agent, a Compton effect image, a photo-electric effect image, etc.

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[0019] A patient support 128, such as a couch, supports the patient for the scan. A general purpose computing system 130 serves as an operator console. Software resident on the console 130 allows the operator to control the operation of the system 100 such as select imaging protocols including contrast agent based K-edge imaging protocols. As described in greater detail below, one such protocol includes concurrently modulating the administration of two or more different contrast agents during a scan to acquire information about organ perfusion, such as cerebral perfusion, with a time series of spectral CT scans. Another protocol includes successively administering different contrast agents, with a delay therebetween, and performing a scan to concurrently acquire information about different physiological phases in a single scan.

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[0020] In one embodiment, the scanner 100 is used to determine a perfusion parameter such as mean transit time (MTT). In one instance, this includes using a combination of concurrently modulating administration of contrast agents and a spectral scan, and determining the MTT based on the modulation technique, the contrast agents, and resulting image data. FIGURE 2 illustrates an MTT determiner 202 that determines an MTT based on an image(s) generated from the image data and the contrast agent concentrations derived from the modulation pattern or profile.

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[0021] Briefly turning to FIGURE 3, example contrast agent modulation profiles are shown. In FIGURE 3, the y-axis 302 represents the amount (e.g., milliliter per second (ml/sec), etc.) of the contrast agent administered and the x-axis 304 represents time. A first profile 306 shows an amount of a first contrast agent as a function of time, and a second profile 308 shows an amount of a second contrast agent as a function of time.

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[0022] In this example, the profiles 306 and 308 are both saw tooth in shape. In other embodiments, the profiles can be different and/or otherwise shape, such as sinusoidal or triangular. Furthermore, the profiles 306 and 308 are inversions of each other. Moreover, in this example the aggregate amount of both contrast agents over time is substantially constant

as shown at 310. In other embodiments, the aggregate amount of the contrast agents may change over time.

[0023] Returning to FIGURE 2, a suitable example modulation profile or pattern of the contrast agents can be expressed in terms of two contrast agents as shown in modulation function 1:

Modulation Function 1:

$$injection(t) = \left[0.5 + \frac{F(\omega t)}{2} \right] fl_{CA_1} CA_1 + \left[0.5 - \frac{F(\omega t)}{2} \right] fl_{CA_2} CA_2,$$

wherein $injection(t)$ represents the total amount of the contrast agent injected over time, $F()$ is the modulation function, ω represents the modulation frequency, fl_{CA_1} represents the maximal flow rate of the first contrast agent, fl_{CA_2} represents the maximal flow rate of the second contrast agent, CA_1 represents the measured concentration of the first contrast agent, and CA_2 represents the measured concentration of the second contrast agent.

[0024] Based on the modulation profile employed, for any image the measured ratio of the concentrations at any particular image point can be used to calculate an absolute transition time relative to the injection time. That is, a transition time can be determined by determining the time difference between the time when a particular ratio of the concentrations is administered and a point in an image where the ratio of the concentrations is about the same as the particular ratio of concentrations. For instance, the measured ratio at a particular image point or destination can be mapped to the modulation function shown in FIGURE 3 to determine the corresponding start time of that concentration ratio, and the difference in time represents that transition time.

[0025] The above is illustrated in the method of FIGURE 4. At 402, at least two different contrast agents having two different spectral properties are concurrently administered to a subject during an imaging procedure, using pre-determined contrast agent administration modulation patterns. At 404, the subject is scanned. At 406, a spectral reconstruction is performed on the resulting projection data, which is indicative of the at least two different contrast agents. At 408, the concentrations of the at least two different contrast agents are determined for a particular image point based on the spectral reconstruction. At 410, the MTT determiner determines an MTT for the particular image point based on a ratio of the concentrations and the contrast modulation patterns.

[0026] In another embodiment, the scanner 100 is used for multi-phase study such as a multi-phase liver study. Such studies can be used to identify hyper or hypo perfused regions (HCC or metastases) during the aortic phase, the portal venous phase and/or the equilibrium phase. As noted above, in a conventional study 3 to 5 scans may be performed after the contrast agent is injected in order to capture these phases. In this embodiment, the number of scans may be reduced via a suitable injection protocol combined with a spectral CT separation of the injected contrast agents.

[0027] An example is provided in FIGURE 5. At 502, a first contrast agent is administered for a first pre-set period of time. In one instance, the first pre-set period of time is ten (10) seconds. At 504, the next administration of a contrast agent is delayed by a second pre-set period of time. In one instance, the second pre-set period of time is ten (10) seconds. At 506, a second contrast agent is administered for a third pre-set period of time. In one instance, the third pre-set period of time is five (5) seconds. If another contrast agent is to be administered, it may also be delayed another pre-set time period. At 508, scanning is delayed by a fourth pre-set period of time. In one instance, the fourth pre-set period of time is ten (10) seconds.

[0028] At 510, a spectral CT scan is performed. Using the above protocol or other suitable protocol, during the scan the first contrast agent will be in the portal venous phase when the second contrast agent is in the aortic phase. The selective imaging capabilities of spectral CT allows the separation between the first and second contrast agents. At 512, two contrast images for two of the venous and the aortic are generated. As such, two contrast images for two of the phases can be captured in a single scan. When three or more contrast agents are administered, three or more images for the three phases are captured in a single scan.

[0029] In the above embodiments, two or more contrast agents are concurrently administered in the same vessel or successively administered in the same vessel. It is to be appreciated that administration of the contrast agents can alternatively be in different vessels. For example, the contrast agents can be administered at different injection points (left and right hemisphere, front and back lobe, etc.). Another application of this technique is to solve the inverse problem of a complex pharmacokinetic model. In other words, the free parameter of a pharmacokinetic model can be numerically determined with a proper multi contrast agent modulated injection protocol and selective imaging of the used contrast agents.

[0030] It is to be appreciated that other procedure and phases are also contemplated herein, including essentially any procedure involving tracking contrast flow through different phases is contemplated herein. For such procedure, a single scan can be performed to capture contrast in one or more of the different phases. Examples of other suitable phases include, but are not limited to, arterial, pancreatic, hepatic, liver, etc. phases.

[0031] As noted above, the reconstructor 120 can employ a K-edge algorithm. The following illustrates an example

algorithm for two K-edge substances, such as the two contrast agents in the examples herein. Generally, the radiation source 110 emits polychromatic radiation with an emission spectrum $T(E)$. The detection signal of the i -th detector channel is indicated by d_i and can be described by Equation 1:

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EQUATION 1:

$$d_i = \int dE T(E) D_i(E) \exp(-(\rho_{\text{photo}} P(E) + \rho_{\text{Compton}} C(E) + \rho_{\text{k-edge1}} K_1(E) + \rho_{\text{k-edge2}} K_2(E)))$$

10 wherein $D_i(E)$ is the spectral sensitivity of the i -th detector channel, ρ_{photo} , ρ_{Compton} , $\rho_{\text{k-edge1}}$ and $\rho_{\text{k-edge2}}$ are the density length products of the photo-electric effect, the Compton effect, the K-edge effect of the first substance and the K-edge effect of the second substance, respectively, and the energy dependent absorption spectra of the photo-electric effect, the Compton effect and the K-edge effect of the first substance and the K-edge effect of the second substance are indicated by $P(E)$, $C(E)$, $K_1(E)$ and $K_2(E)$, respectively. For N contrast materials, Equation 1 includes the following additional terms $\rho_{\text{k-edge3}} K_3(E) \dots \rho_{\text{k-edge}(2+N)} K_{N+2}(E)$.

15 **[0032]** The input to the image generator 126 includes the energy-resolved detection signals d_i for a plurality, e.g., four (4), energy bins. The emission spectrum $T(E)$ and spectral sensitivity $D_i(E)$ generally are known. The absorption spectra $P(E)$, $C(E)$, $K_1(E)$ and $K_2(E)$ are known. Since the energy dependent functions and the detection signals d_i are known and since at least four detection signals d_1 - d_4 are available for at least four energy bins b_1 - b_4 , a system of at least four equations is formed having four unknowns which can thus be solved with known mathematical methods. If more than 20 four energy bins are available, it is preferred to use a maximum likelihood approach that takes the noise statistics of the measurements into account.

[0033] The resulting density length products $\rho_{\text{k-edge1}}$ and $\rho_{\text{k-edge2}}$ are the first substance contribution and the second substance contribution, respectively, which can be used to generate a first K-edge image for the first substance and a 25 second K-edge image for the second substance. In addition, the photo-electric density length product ρ_{photo} can be used to reconstruct a photo-electric image, and the Compton effect density length product ρ_{Compton} can be used to reconstruct a Compton effect image. Generally, the Compton effect image and the photo-electric effect image show the object itself. These four images can be shown one by one, or they can be mixed, for example, a final image can show the first substance, the second substance and the Compton effect image and/or the photo-electric effect image. It is also possible 30 to reconstruct one image showing one, some or all of the four components.

[0034] It is to be understood that the spectral decomposition can be performed on projection data or in the image domain.

[0035] Although the above is explained relative to particular applications, it is to be appreciated that the embodiments can be used to determine other parameters related to perfusion such, but not limited to, blood flow, blood volume, and/or other perfusion parameters.

35 **[0036]** The invention has been described herein with reference to the various embodiments. Modifications and alterations may occur to others upon reading the description herein. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims.

40 Claims

1. A system, comprising:

45 a radiation source (110) configured to rotate about an examination region and emit polychromatic radiation that traverses the examination region;

a detector array (118), located across from the radiation source (110) opposite the examination region, configured to detect radiation traversing the examination region and generate a signal indicative thereof;

an injector (114) configured to administer at least two different contrast agents for an imaging procedure based on a contrast agent amount modulation profile; and

50 a reconstructor (120) configured to spectrally reconstruct the signal to generate first image data of the first contrast agent and second image data of the second contrast agent;

characterised in that the system further comprises

a mean transit time determiner (202) configured to determine a mean transit time based on the first and second image data and first and second contrast agent concentration derived from the contrast agent modulation profile.

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2. The system of claim 1, wherein the injector (114) is configured to concurrently administer the at least two contrast agents based on different modulation patterns.

3. The system of claim 2, wherein the modulation profile is one of triangular, saw tooth, or sinusoidal.
4. The system of any one of claims 1 to 3, wherein the injector is configured to substantially continuously vary an amount of each contrast agent with respect to time.
5. The system of any one of claims 1 to 4, wherein the injector is configured to administer the at least two different contrast agents such that an aggregate amount of the contrast agents is substantially constant over time.
6. The system of any one of claims 1 to 5, wherein the modulation profiles of the first and second contrast agents are inversely proportional.
7. The system of any of claims 1 or 2, wherein the reconstructor (120) decomposes the signal into components, including but not limited to, at least a first K-edge component and a second K-edge component, and the first image is based on the first K-edge component and the second image is based on the second K-edge component.
8. The system of any of claims 1 to 3, further including a modulator (116) configured to determine and provide the modulation profile.
9. The system of any of claims 1 to 8, wherein the mean transit time determiner (202) determines the mean transit time for a particular image point based on a ratio of the concentrations and the contrast modulation patterns.
10. The system of claim 9, wherein the mean transit time is an absolute transition time relative to the injection time.

Patentansprüche

1. System, umfassend:

eine Strahlungsquelle (110), konfiguriert, um um einen Untersuchungsbereich herum zu rotieren und polychromatische Strahlung zu emittieren, die den Untersuchungsbereich durchquert;
 ein Detektorarray (118) gegenüber der Strahlungsquelle (110), dem Untersuchungsbereich gegenüberliegend lokalisiert, konfiguriert, um Strahlung, die den Untersuchungsbereich durchquert, zu detektieren, und ein davon indikatives Signal zu erzeugen;
 einen Injektor (114), konfiguriert, um mindestens zwei unterschiedliche Kontrastmittel für eine Bildgebungsprozedur auf Basis eines Kontrastmittelmengenmodulationsprofils zu verabreichen; und
 einen Rekonstruierer (120), konfiguriert, um das Signal spektral zu rekonstruieren, um erste Bilddaten des ersten Kontrastmittels und zweite Bilddaten des zweiten Kontrastmittels zu erzeugen;
dadurch gekennzeichnet, dass das System weiter umfasst
 ein Bestimmungsgerät (202) der mittleren Transitzeitdauer, konfiguriert, um eine mittlere Transitzeitdauer auf Basis der ersten und zweiten Bilddaten und der ersten und zweiten aus dem Kontrastmittelmodulationsprofil abgeleiteten Kontrastmittelkonzentration zu bestimmen.

2. System nach Anspruch 1, wobei der Injektor (114) konfiguriert ist, um die mindestens zwei Kontrastmittel auf Basis unterschiedlicher Modulationsmuster gleichzeitig zu verabreichen.
3. System nach Anspruch 2, wobei das Modulationsprofil eines ist von dreieckig, sägezahn- oder sinusförmig.
4. System nach einem der Ansprüche 1 bis 3, wobei der Injektor konfiguriert ist, um eine Menge jedes Kontrastmittels bezüglich der Zeit im Wesentlichen kontinuierlich zu variieren.
5. System nach einem der Ansprüche 1 bis 4, wobei der Injektor konfiguriert ist, um die mindestens zwei unterschiedlichen Kontrastmittel so zu verabreichen, dass eine Gesamtmenge der Kontrastmittel im Wesentlichen über die Zeit konstant ist.
6. System nach einem der Ansprüche 1 bis 5, wobei die Modulationsprofile des ersten und zweiten Kontrastmittels invers proportional sind.
7. System nach einem der Ansprüche 1 oder 2, wobei der Rekonstruierer (120) das Signal in Bestandteile zerlegt,

einschließlich, aber nicht beschränkt auf, mindestens einen ersten K-Kantenbestandteil und einen zweiten K-Kantenbestandteil, und das erste Bild auf dem ersten K-Kantenbestandteil basiert ist und das zweite Bild auf dem zweiten K-Kantenbestandteil basiert ist.

- 5 8. System nach einem der Ansprüche 1 bis 3, weiter einschließend einen Modulator (116), konfiguriert, um das Modulationsprofil zu bestimmen und bereitzustellen.
9. System nach einem der Ansprüche 1 bis 8, wobei das Bestimmungsgerät (202) der mittleren Transitzeitdauer die mittlere Transitzeitdauer für einen besonderen Bildpunkt auf Basis eines Verhältnisses der Konzentrationen und der Kontrastmodulationsmuster bestimmt.
- 10 10. System nach Anspruch 9, wobei die mittlere Transitzeitdauer relativ zu der Injektionszeit eine absolute Übergangszeitdauer ist.

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Revendications

1. Système, comprenant :
- 20 une source de rayonnement (110) configurée pour tourner autour d'une région d'examen et pour émettre un rayonnement polychromatique qui traverse la région d'examen ;
un ensemble détecteur (118), situé de l'autre côté de la source de rayonnement (110) opposée à la région d'examen, configuré pour détecter un rayonnement traversant la région d'examen et pour générer un signal indicatif de celui-ci ;
- 25 un injecteur (114) configuré pour administrer au moins deux agents de contraste différents pour une procédure d'imagerie sur la base d'un profil de modulation d'une quantité d'agent de contraste ; et
un dispositif de reconstruction (120) configuré pour reconstruire spectralement le signal pour générer des premières données d'image du premier agent de contraste et des secondes données d'image du second agent de contraste ;
- 30 **caractérisé en ce que** le système comprend en outre
un dispositif de détermination du temps de transit moyen (202) configuré pour déterminer un temps de transit moyen sur la base des premières et secondes données d'image et des première et seconde concentrations d'agent de contraste dérivées du profil de modulation de l'agent de contraste.
- 35 2. Système selon la revendication 1, dans lequel l'injecteur (114) est configuré pour administrer de façon concomitante les au moins deux agents de contraste sur la base de différents modèles de modulation.
3. Système selon la revendication 2, dans lequel le profil de modulation est l'un parmi un profil triangulaire, en dents de scie ou sinusoïdal.
- 40 4. Système selon l'une quelconque des revendications 1 à 3, dans lequel l'injecteur est configuré pour faire varier sensiblement en continu une quantité de chaque agent de contraste par rapport au temps.
- 45 5. Système selon l'une quelconque des revendications 1 à 4, dans lequel l'injecteur est configuré pour administrer les au moins deux agents de contraste différents de sorte qu'une quantité globale des agents de contraste soit sensiblement constante dans le temps.
6. Système selon l'une quelconque des revendications 1 à 5, dans lequel les profils de modulation des premier et second agents de contraste sont inversement proportionnels.
- 50 7. Système selon l'une quelconque des revendications 1 ou 2, dans lequel le dispositif de reconstruction (120) décompose le signal en composants, incluant de manière non restrictive, au moins un premier composant de bord K et un second composant de bord K, et la première image est basée sur le premier composant de bord K et la seconde image est basée sur le second composant de bord K.
- 55 8. Système selon l'une quelconque des revendications 1 à 3, incluant en outre un modulateur (116) configuré pour déterminer et fournir le profil de modulation.

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9. Système selon l'une quelconque des revendications 1 à 8, dans lequel le dispositif de détermination du temps de transit moyen (202) détermine le temps de transit moyen pour un point d'image particulier sur la base d'un rapport de la concentration et des modèles de modulation de contraste.

5 10. Système selon la revendication 9, dans lequel le temps de transit moyen est un temps de transition absolu relatif au temps d'injection.

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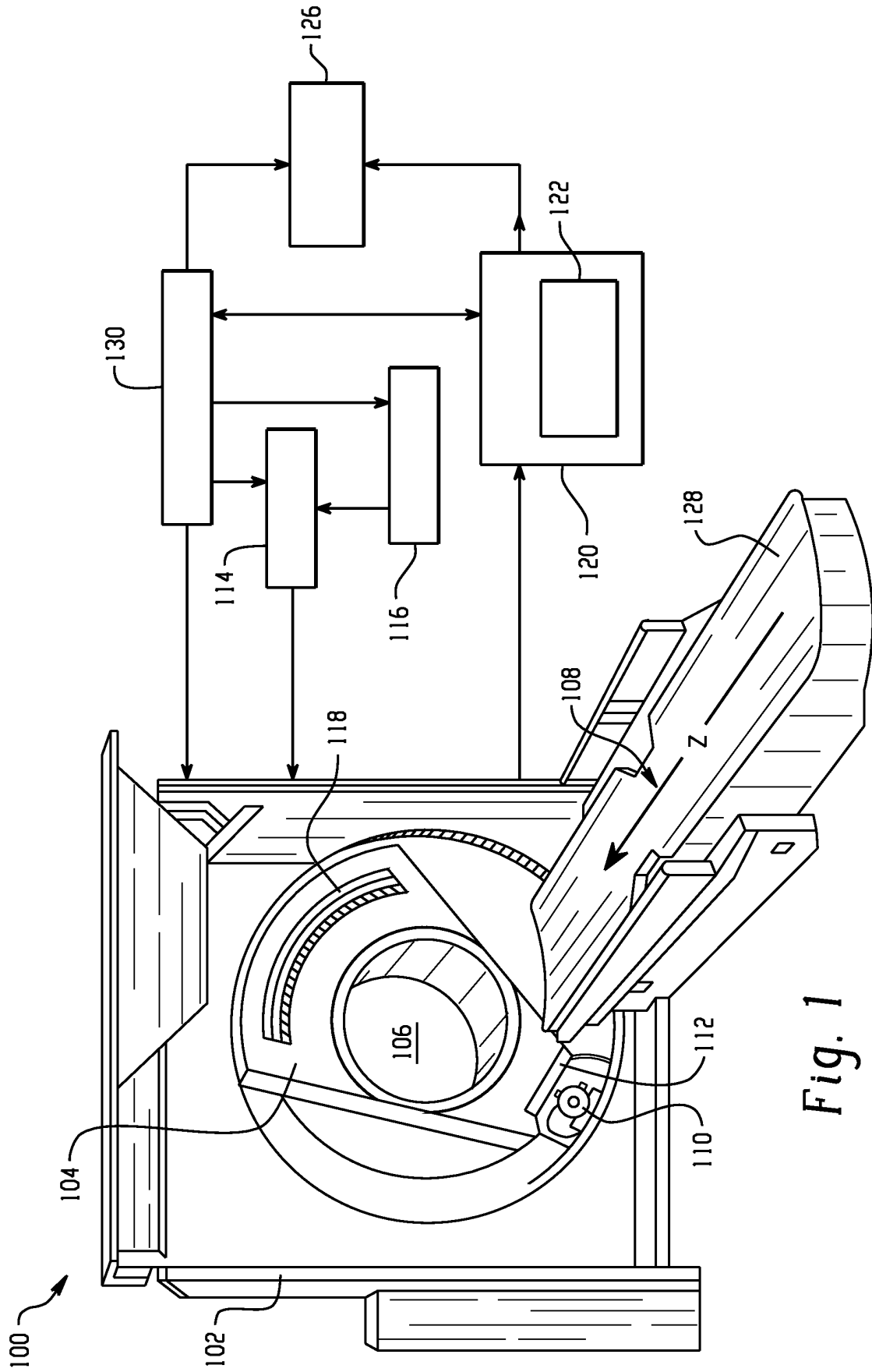


Fig. 1

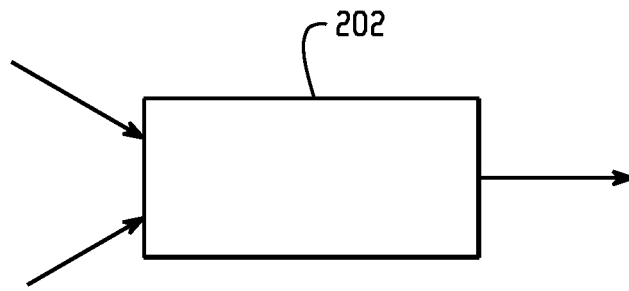


Fig. 2

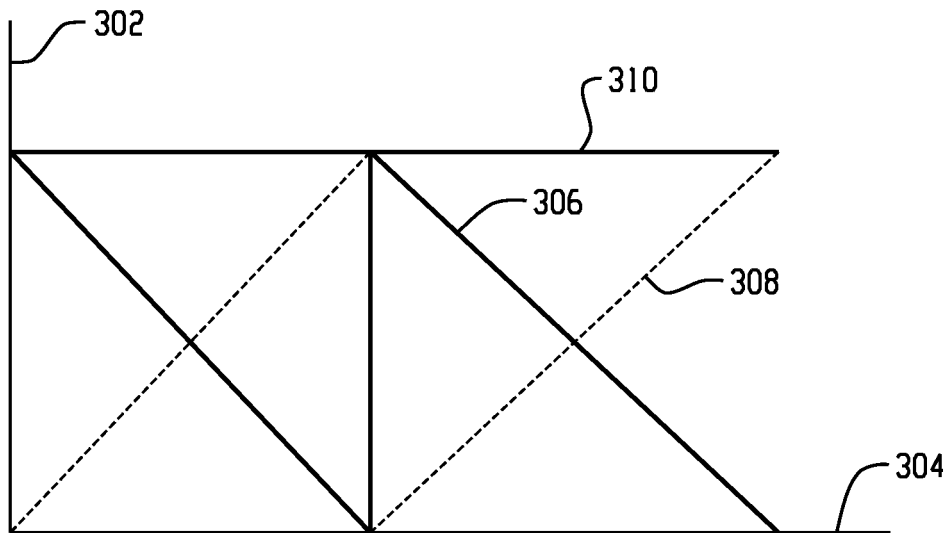


Fig. 3

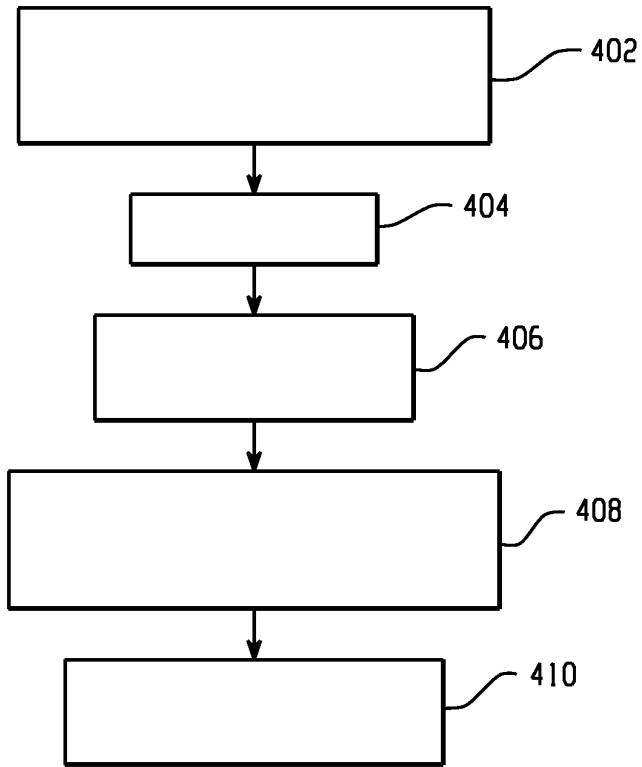


Fig. 4

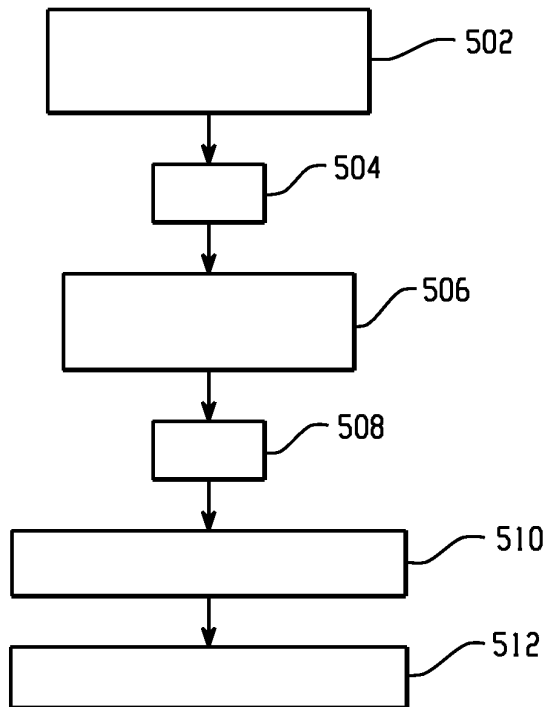


Fig. 5

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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Non-patent literature cited in the description

- **J.P. SCHLOMKA.** Experimental feasibility of multi-energy photon-counting K-edge imaging in pre-clinical computed tomography; Experimental feasibility of multi-energy photon-counting K-edge imaging in pre-clinical CT. *Physics in Medicine and Biology*, 2008, vol. 53 (15 [0008])

专利名称(译)	光谱成像		
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外部链接	Espacenet		

摘要(译)

一种方法包括基于调制分布图在成像过程期间同时调制向对象的至少两种不同造影剂的施用。至少两种不同的造影剂表现出不同的光谱特性。该方法进一步包括对指示至少两种不同造影剂的数据进行光谱分解；基于光谱重建来确定至少两种不同造影剂的浓度；以及基于浓度与造影剂的比率来确定灌注参数。调制配置文件。

Modulation Function 1:

$$injection(t) = \left[0.5 + \frac{F(\omega)}{2} \right] f_{c_{A_1}} CA_1 + \left[0.5 - \frac{F(\omega)}{2} \right] f_{c_{A_2}} CA_2,$$