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(54) METHOD AND SYSTEM FOR TEMPORAL CALIBRATION OF AN INTRAVASCULAR IMAGING SYSTEM

VERFAHREN UND SYSTEM ZUR ZEITKALIBRIERUNG EINES INTRAVASKULÄREN ABBILDUNGSSYSTEMS

PROCÉDÉ ET SYSTÈME POUR ÉTALONNAGE TEMPOREL D'UN SYSTÈME D'IMAGERIE INTRAVASCULAIRE

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Description

FIELD

[0001] In part, the disclosure relates generally to the field of vascular system and peripheral vascular system imaging and data collection.

BACKGROUND

[0002] Interventional cardiologists incorporate a variety of diagnostic tools during catheterization procedures in order to plan, guide, and assess therapies. Fluoroscopy is generally used to perform angiographic imaging of blood vessels. In turn, such blood vessel imaging is used by physicians to diagnose, locate and treat blood vessel disease during interventions such as bypass surgery or stent placement. Intravascular imaging technologies such as optical coherence tomography (OCT) and acoustic technologies such as intravascular ultrasound (IVUS) and others are also valuable tools that can be used in lieu of or in combination with fluoroscopy to obtain high-resolution data regarding the condition of the blood vessels for a given subject.

[0003] Intravascular optical coherence tomography is a catheter-based imaging modality that uses light to peer into coronary artery walls and generate images thereof for study. Utilizing coherent light, interferometry, and micro-optics, OCT can provide video-rate in-vivo tomography within a diseased vessel with micrometer level resolution. Viewing subsurface structures with high resolution using fiber-optic probes makes OCT especially useful for minimally invasive imaging of internal tissues and organs. This level of detail made possible with OCT allows a clinician to diagnose as well as monitor the progression of coronary artery disease. Angiography is a noninvasive x-ray imaging method that collects data from outside the body during injection of a radio-opaque contrast fluid.

[0004] Given the complexity of the various technologies described above and the associated complexity of the datasets each of them generate, co-registering such datasets is difficult. If the relevant systems, such as for example an angiography system and an OCT system, are not calibrated to one another, the likelihood of achieving accurate co-registration is low.

[0005] US Patent Publication No. US 2012/004529 describes an automatic display of previously-acquired endoluminal images. US Patent Publication No. US 2007/027390 describes a system for performing and monitoring minimally invasive interventions. Accordingly, a need therefore exists to provide suitable calibration methods and systems suitable for increasing coregistration accuracy. Embodiments of the disclosure address these challenges and others.

SUMMARY

[0006] In part, the disclosure relates to a multimodal diagnostic system and components thereof configured to co-register two or more of the following OCT, rVUS, FFR, and angiography. In one embodiment, OCT images and angiography images are co-registered after calibrating a combined OCT and x-ray imaging system to determine a time delay to align or synchronize the two sets of frames of image data. In one embodiment, the time delay is determined based upon a minimum value from multiple calibration trials. As discussed herein, angiography systems can be used to obtain a cine sequence or set of cine images. Such a set or sequence includes one or more images that are obtained over time. This set of images is effectively a short movie with each image being a frame that can track and show movement and cardiovascular system changes as the heart progresses through the cardiac cycle.

[0007] The initiation of an x-ray based imaging system such an angiography system can be caused by one or more control signals sent from one or more control systems. Similarly, the initiation of an intravascular imaging system such an OCT system can be caused by one or more control signals sent from one or more control systems to a patient interface unit or PIU. During an OCT data collection session, the optical fiber and associated lens positioned to send and receive light rotates within a blood vessel. The PIU to which an intravascular data collection probe connects receives a control signal which causes the probe tip to rotate and then translates the probe tip as part of a pullback through the blood vessel.

[0008] Initially, the probe tip captures an image along a ray or scan line as it rotates prior to translation along a support. In one embodiment, an angiography initiating control signal is transmitted prior to transmitting an OCT initiating control signal. As a result, the angiography system captures one or more frames of angiography images such as J frames of angiography data prior to capturing a first frame of OCT image data. The first frame of OCT image data can include images obtained while the probe tip rotates prior to being translated along a vessel during a pullback.

[0009] In part, in one embodiment, the disclosure relates to a method of calibrating an optical coherence tomography system and an angiography system. The method includes generating N sets of optical coherence tomography (OCT) image data, wherein each of the N sets of OCT image data is obtained by performing N ex vivo pullbacks of an ex-vivo data collection probe comprising a marker; generating N sets of angiography image data comprising a plurality of two- dimensional images, wherein each of the N sets of angiography image comprise a plurality of two-dimensional images of the marker in two or more different spatial positions; generating N sets of OCT frames using the N sets of OCT image data obtained during the N ex vivo pullbacks; determining an initial frame of the OCT probe pullback from the plurality of OCT frames for each set N; determining an initial angiography frame that corresponds to the initial frame of OCT probe pullback for each set N; determining a time delay between the initial OCT frame and the initial angiography frame for each set N such that N time delays are determined; selecting a minimum time delay from the N time delays; and aligning OCT and angiography frames using the minimum time delay.

[0010] In one embodiment of the method, determining the initial angiography frame includes determining a first angiography frame indicative of movement of a marker attached to the OCT probe and selecting a second angiography frame preceding the first angiography frame as the initial angiography frame. In one embodiment, N ranges from 2 to 12. In one embodiment, the method further includes initiating the OCT pullback at an initiation time, wherein a computing device stores the initiation time in memory. In one embodiment of the method, determining the initial frame of the OCT probe pullback includes identifying the OCT frame corresponding to the initiation time as the initial frame of an ex vivo pullback. In one embodiment, determining the initial angiography frame includes using a computing device to track pixel changes in angiography frames to identify marker movement. In one embodiment, a frame rate of the OCT system is greater than the frame rate of the angiography system.

[0011] In part, in one embodiment, the disclosure relates to a system for calibrating a combination intravascular and extravascular imaging system as defined in claim 8.

[0012] The computing device can include, in an embodiment, a calibration method stored in the one or more memory device as instructions to cause the computing device to determine the initial angiography frame that corresponds to the initial frame of OCT probe pullback. The computing device can include, in an embodiment, a calibration method stored in the one or more memory device further comprising instructions to cause the computing device to align OCT and angiography frames using the minimum time delay.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The figures are not necessarily to scale, emphasis instead generally being placed upon illustrative principles. The figures are to be considered illustrative in all aspects and are not intended to limit the disclosure, the scope of which is defined only by the claims.

Figure 1 is a schematic diagram of a data collection system that collects intravascular data and extravascular data during overlapping periods of time suitable for calibration using one or more methods of the disclosure.

Figure 2 is a schematic diagram of various data collection events and time periods that can be calibrated using one or more of the systems and methods described herein.

Figure 3 is a schematic diagram illustrating various steps and events that can be implemented and tracked in conjunction with calibrating a multimodal imaging system and determining a calibration time period T3 according to an embodiment of the disclosure.

Figure 4 is a schematic diagram illustrating various steps of an exemplary temporal calibration method suitable for increasing co-registration accuracy in a multimodal imaging system according to an embodiment of the disclosure.

Figure 5A is a schematic diagram of a data collection system that collects intravascular data and extravascular data during overlapping periods of time suitable for calibration using one or more methods of the disclosure.

Figure 5B is a schematic diagram that depicts three x-ray image frames of a blood vessel being imaged using the system of Figure 5A that correspond to three points in time when a marker is not moving and then movement starts and then movement continues during an OCT pullback of a probe according to an embodiment of the disclosure.

Figure 6 illustrates an apparatus for performing temporal calibration according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0014] The following description refers to the accompanying drawings that illustrate certain embodiments of the present disclosure. Other embodiments are possible and modifications may be made to the embodiments without departing from the scope of the disclosure. Therefore, the following detailed description is not meant to limit the present disclosure; rather, the scope of the present disclosure is defined by the claims.

[0015] Intravascular data collection such as imaging of a blood vessel can be performed by inserting a catheter comprising a data collection probe into an artery and advancing it until it reaches a region of interest within a blood vessel, such a coronary artery. An angiography system can obtain external angiographic images of that vessel, such as a cine sequence, during the imaging of the blood vessel. In one embodiment, the region of interest is imaged by pulling the data collection probe through the catheter while optical, acoustic, or other sensors in the probe collect intravascular data. The process of pulling the data collecting probe through a region of interest in a blood vessel is referred to as a pullback in one embodiment. According to the disclosure, it is advantageous to initiate the angiography image capture prior to initiating the pullback for purposes of subsequently co-registering the angiographic and intravascular image data sets.

[0016] Co-registration of two or more imaging technologies such as angiography and OCT, for example, is challenging to implement. As disclosed herein, OCT /

angiography or x-ray based coregistration ("angiography coregistration") methods facilitate visualization of a position of or a subset of an OCT image on a corresponding angiography image acquired at a similar point in time. Such coregistration methods can be implemented using hardware, software, or combinations thereof.

[0017] In part, the disclosure relates to various systems, components thereof, and methods for use in a catheter lab or other facility to perform one or more calibration processes to improve co-registration accuracy with respect to data collected with regard to a subject. In one embodiment, the data can include one or more cine sequences obtained using an x-ray system such as an angiography system. Further, the data can include intravascular data. An example of intravascular data is OCT data which can be obtained using an intravascular imaging probe and an OCT system. The OCT data can be stored in computer-readable memory as scan lines, images, or in other data formats. Intravascular ultrasound data is another type of intravascular data.

[0018] Figure 1 shows a system 10 that includes various data collection subsystems suitable for collecting data, detecting a feature of, sensing a condition, and imaging a region of interest in a subject using one or more imaging modalities or otherwise generating diagnostic data. The region of interest in a subject can include a blood vessel 15. In one embodiment, an intravascular data collection probe is pulled back through the vessel 15.

[0019] Examples of such probes include OCT, IVUS, FRR, or other data collection probes. The probe includes one or more of a guidewire, a pressure sensing wire-based probe, an optical fiber and other components. An optical fiber 18 is shown extending from where the probe would be disposed in the vessel 15. The tip of a given data collection probe can include a marker. These markers are identified by M as shown herein in the non-invasively acquired image frames such as the x-ray generated images. As shown in Figure 1, a series of overlapping sequential angiography images are shown from a top down perspective with the dots corresponding to markers M shown over the sequence of their movement through the vessel 15. In one embodiment, the marker M is a radiopaque marker that is part of the data collection probe. For example, in one embodiment, a radiopaque marker M can be disposed near a lens or other beam-directing element of a probe. The points F in the OCT frames are included to illustrate a feature F that changes its appearance as the pullback progresses. In this way, different cross-sections of the blood vessel being imaged with different features F correspond to different positions in the angiography frames.

[0020] For a probe that includes an optical beam director or lens, the optical fiber is in optical communication with the beam director or lens. A torque wire can be part of the probe defines a bore in which an optical fiber is disposed. In addition, the probe also includes the sheath such as a polymer sheath (not shown) which forms part of a catheter. The optical fiber, which in the context of an OCT system is a portion of the sample arm of an interferometer, is optically coupled to a patient interface unit (PIU) as shown. The PIU can be operated using various controls that can be used to initiate the pullback of the probe through the vessel.

[0021] The data collection system 10 includes a non-invasive imaging system 20 such as a nuclear magnetic resonance, x-ray, angiography, computer aided tomography, or other suitable noninvasive imaging technology. As shown as a non-limiting example of such a noninvasive imaging system, an angiography system such as suitable for generating cines is shown. The angiography system can include a fluoroscopy system. The noninvasive imaging system collects extravascular or peripheral imaging data while the intravascular imaging probe pulled back through the vessel generates cross-sectional views 50 as shown. Theses intravascular images 50 can be cross-sectional view, longitudinal views, or other views generated using data from an intravascular data collection probe.

[0022] The noninvasive imaging system 20 and the PIU are in communication with separate data storage and processing systems 55, 57 or can be in communication with one data storage and processing system 60. One or more of such systems 55, 57, or 60 can be used individually or integrated together. These systems can be implemented as a workstation or server in one embodiment or generally as a computing device. A computing device may include a server computer, a client user computer, a personal computer (PC), a laptop computer, a tablet PC, a desktop computer, a control system, a microprocessor or any computing device capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that computing device. Further, while a single computing device is illustrated, the term "computing device" shall also be taken to include any collection of computing devices that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the software features or methods such as interface.

[0023] In one embodiment, the computing device is an optical coherence tomography computer programmed to perform one or more temporal calibration methods as described herein. The programs, instructions, and control signal information and related co-registration methods that can use a calibration time can be implemented using software instructions stored in memory 65 or as a hardware-based integrated circuit 68. In one embodiment, an external database 70 is used to store image frames, calibration time periods, co-registered OCT and x-ray images and other information described herein with respect to the systems and collected image data. The time delay outputs of multiple calibration trials can be stored in memory such as database 70 or in the systems described herein and ranked to select a minimum time delay using one or more processors or computing devices. In one embodiment, memory 65 receives an OCT pullback initiation time corresponding to one the OCT probe pullback starts. This initiation time can be correlated with a corresponding captured OCT frame, which can be identified as the initial frame of the OCT pullback.

[0024] The patient interface unit includes a probe connector suitable to receive an end of the probe and be optically coupled thereto. The PIU includes suitable joints and elements based on the type of data collection probe being used. In addition to being pulled back, the probe tip is also typically rotated by the PIU. In this way, a blood vessel of the subject 10 can be imaged longitudinally or via cross-sections.

[0025] In turn, the PIU is connected to one or more intravascular data collection systems 55 or 60 as described herein. The intravascular data collection system 55, 60 can be an OCT system, an IVUS system, another imaging system, and combinations of the foregoing. For example, the system 60 in the context of a probe being an OCT probe can include the sample arm of an interferometer, the reference arm of an interferometer, photodiodes, a control system, and patient interface unit.

[0026] The intravascular image data such as the frames of intravascular data generated using the data collection probe can be routed to the data collection processing system 60 coupled to the probe via PIU. The noninvasive image data generated using system 20 can be transmitted to, stored in, and processed by one or more computing devices. A video frame grabber device such as a computer board configured to capture the angiography image data from system 20 can be used in various embodiments as part of systems 55, 57, or 60.

Calibration and Co-registration

[0027] In one embodiment of a coregistration method, a set of angiography data such a cine sequence of images is acquired during an OCT pullback. Thus, as an OCT imaging probe is pulled back through a blood vessel as it rotates, the marker M disposed on or in the OCT probe moves with it and is identifiable and trackable in the set of simultaneously captured angiography frames. If a coregistration calibration method of the angiography system and the OCT system is not performed or is inadequate to calibrate the relevant imaging system, the OCT frames and the angiography frames may not be aligned.

[0028] In turn, this results in a failure to coregister the x-ray and optical imaging datasets. In addition, the failure to align the OCT and angiography datasets could result in errors such as positional cursor errors. Thus, the cursor used by a clinician or other system operators used to show where the OCT image was taken on the angiography image may be out of sync by several frames. This can cause a lack confidence in system users such that they doubt that the on screen cursor is actually showing them what it purports to show them. Additional details relating to the problems of a time lag and misalignment of OCT image frames and angiography image frames is described in more detail with regards to Figure 2 and calibration system 100.

[0029] In one embodiment, two steps are performed to achieve accurate coregistration in conjunction with a calibrated multimodal imaging system such as an OCT and angiography system. The first step is identifying or locating a reference point or section of an intravascular data collection probe throughout a set of image frames such as angiography frames that constitute a cine sequence. The reference point or section can include a marker, a probe tip, a lens, a pressure transducer, a beam director, or other probe locus, portion, component or combinations thereof. All of the foregoing can be used as markers M shown in the relevant figures.

[0030] Thus, for an OCT imaging probe, a lens is used to direct and receive light and collect data that corresponds to depth measurements such that a tomographic image of the imaged region can be generated. The second factor is temporally aligning the angiographic and OCT data sets. In part, the disclosure relates to calibration methods that can be performed when installing an OCT system in catheter lab to operate in conjunction with an angiography system. The calibration of an OCT system is also performed when an angiography system is changed that is used in conjunction with the OCT system. When a change in such a multimodal imaging system occurs, re-calibration is often necessary to prevent or fix co-registration anomalies.

[0031] The calibration methods described herein improve the accuracy when co-registering a set of intravascular data, such as for example, a set of OCT images, and a set of peripheral or extravascular data such as a set of angiography images. In part, the disclosure relates to determining the relative time period between OCT and angiographic data sets. This time period can be determined and the can be used as a temporal calibration factor for the angiography coregistration software.

[0032] As shown in Figure 2, in an angiography coregistration system, OCT and angiography image data are acquired simultaneously during an OCT catheter pullback with regard to blood vessel A physical event E1 in the real world (such as the initiation of the OCT catheter pullback) occurs at a certain point in time, indicated by the "Event" arrow such as a zero point in time, T0 or some other origin or reference point. This physical event E1 is subsequently captured in an OCT image frame, which can be considered as a second event E2 that is stored into computer memory at a future point in time "T1" after the physical event. Thus, the event capturing of the pullback initiation using OCT is event E2 which corresponds to the imaging of the blood vessel 15. The angiography system lags the OCT system such that the angiography image capture of the blood vessel 15 and the moving OCT probe disposed therein is delayed by a delay period T3 relative to the OCT image capture.

[0033] Similarly, the same physical event E1 is also captured in an angiography image frame that is stored into computer memory at a future point in time "T2" after the physical event E1 and after its OCT capture E2 as effectively a third event E3. The time periods T1 and T2 represent the finite time required to generate, transmit, and process the OCT and angiography images, respectively. In one embodiment, the time period T1 ranges from about several microseconds to about several seconds. In one embodiment, the time period T2 ranges from about several microseconds to about several seconds. In one embodiment, the time period T3 ranges from about several microseconds to about several seconds. The frame rate of an OCT system ranges from about 20 frames per second to about 1000 frames per second. The frame rate of a non-invasive imaging system such as an x-ray-based system ranges from about 10 frames per second to about 60 frames per second.

[0034] Since T1 and T2 may be different, a fixed time period T3 exists between when the OCT frame is stored into computer memory E2 and when the corresponding angiography frame is stored into computer memory E3. If this time period T3 is not compensated for, OCT frame positions are displayed on the incorrect angiography frame. In turn, such a failure to compensate for such a time lag T3 can lead to inaccuracies in coregistration. As described herein, T3 can be accurately determined using a calibration method.

[0035] In turn, with a T3 value determined using the systems and methods described herein, the OCT and angiography data sets can be temporally aligned. After alignment using the determined T3 value the OCT frame positions can be displayed on the correct angiography frame using the systems described herein. One or more calibration systems 100 can be used to determine T3. The calibration system can be implemented using one or more of the components of system 10 of Figure 1, system 110 of Figure 5A and system 120 of Figure 6.

[0036] Figure 3 illustrates a schematic representation of various image frames and method steps for determining the time period T3. First, an OCT pullback is acquired with simultaneous angiography. The frames shown at the top portion of Figure 3 are frames of intravascular image data such as OCT data frames. An OCT image feature F is visible at a position within each OCT data frame and changes position when the OCT pullback commences. The frames below that include a top down view of an exemplary blood vessel are extravascular image data such as angiography data frames. Both datasets are generated, transmitted, processed, and stored in a central computer. The OCT dataset includes frames of OCT image data numbered from 1 to 8. In contrast, three frames of angiography image data numbered 1 to 3 are also shown. The OCT dataset includes a series of time stamped frames in the computer memory, where each timestamp represents the time at which the frame entered computer memory. The corresponding series of time stamped angiography frames is also present in computer memory. The timestamps are generated by a common system clock but are applied to each dataset independently. In one embodiment, the common system clock is the clock of the data processing system 60. The computer memory can be part of system 60 for example of Figure 1 and similar data processing systems as described herein.

[0037] Next, a determination is made as to which OCT frame represents the initial frame of the pullback. A human may inspect the OCT image data and estimate which frame represents the initial frame of the pullback. Alternatively, a computing device can be used to determine the initial frame of the pullback such as by automatically logging the time at which a command was sent to initiate the OCT pullback. Machine vision and image processing software can also be used by a computing device to determine the initial frame of the pullback. In the example shown in Figure 3, the initial OCT frame is the third frame of the dataset.

[0038] Next, a determination is made as to which angiography frame represents the closest point in time to the initial OCT frame. This determination may also be made either by a human user or an automatic computer routine. Either a human user or a computer algorithm may inspect the angiography data and estimate which frame corresponds to the initial frame of the pullback. In the example shown in Figure 3, the initial angiography frame is the second frame of the dataset. The radio-opaque marker M will not appear to move until the subsequent angio frame 3, since the initial OCT pullback frame 3 is generated with the catheter at an initial resting position. Knowing the time stamps associated with OCT frame 3 and angiography frame 2, the time period T3 can be calculated and applied to realign the two datasets. Figure 4 includes an overview of these method steps and other related or supplemental steps as shown. Exemplary steps 10 to 80 are shown. Steps can be omitted as optional, performed simultaneously, or performed out of order in one or more embodiments.

[0039] In one embodiment, the disclosure relates to the implementation of various steps or a subset thereof. The steps include acquiring OCT data during OCT probe pullback; acquiring angiography data during OCT probe pullback; determining initial frame of OCT probe pullback from set of OCT frames; determining initial angiography frame that corresponds to initial frame of OCT probe pullback; determining time delay between initial OCT frame and initial angiography frame; selecting minimum time delay from multiple calibration trials; aligning OCT and angiography frames using minimum time delay; and displaying one or more aligned OCT and angiography frames.

[0040] Figure 5A is a schematic diagram of an exemplary multimodal system that include an angiography system shown as non-invasive system 20 and an OCT system that includes a probe with a marker M that has been pulled back through the blood vessel 15 shown. Figure 5B shows the angiography frames corresponding to the pullback performed using the system of Figure 5A. At a time prior to the initiation of the pullback A1, there is no marker motion. As shown, movement of the marker M occurs from rest moving from top to bottom from times A1 to A3 in the three angiography frames shown. Angiography frame motion is detected using machine vision, human inspection, or another mechanism.

[0041] In one embodiment, the angiography frame that is selected as the frame corresponding to initial probe or marker M movement is the frame before the frame for which motion is detected. Thus, even if there is movement at time A2, if the first frame that is detected as having movement is at time A3, A3 is not selected as the frame having initial movement. Instead, the frame before it, the middle frame corresponding to time A2 is selected. If frame A2 were detected as the frame having initial marker or probe motion then as part of the calibration method the first frame A1 would be set as the initial movement angiography frame. This approach effectively sets the origin at which motion starts earlier to help improve calibration results.

[0042] In general, in one embodiment frames of angiography data are processed, scanned or viewed to identify the occurrence of marker M movement or another probe feature. Once a frame has been identified as depicting probe movement, the frame immediately prior to that is identified for the purposes of the calibration method and the determination of time T3 as the angiography frame having initial movement. This process of adjusting for movement errors has been found to improve system calibration by reducing the likelihood that the frame of initial movement is missed.

[0043] Figure 6 illustrates a system 120 for conducting the temporal calibration methods described herein. The systems of Figures 1 and 5A and as otherwise described herein can also be used. An imaging catheter 125 is placed on a support 130 within the field of view of the X-ray system 20 such as an angiography system. In one embodiment, the imaging catheter includes an intravascular imaging probe such as an OCT probe. The OCT probe can be pulled back within a bore defined by the catheter. In one embodiment, the X-ray system 20 is activated first and acquires a cine sequence. If the OCT catheter includes a radio-opaque feature, such as a marker M, that moves in tandem with the catheter pullback, this motion will subsequently be visible on the acquired cine sequence.

[0044] In one embodiment, a marker M disposed on the probe such as near the lens of the OCT probe translates within the bore of a catheter along the support 130 as one or more motors in the PIU pull a torque wire in which is disposed an optical fiber in optical communication with a lens or beam director. Each frame of the angiography dataset is transmitted to an OCT computer, digitized by a frame grabber, and time stamped as the frame is stored in memory.

[0045] At the same time, an OCT dataset is generated by an OCT engine and transmitted to the same OCT computing device. Each OCT frame is time stamped as it enters memory. In this way the methods described herein such as shown in Figure 2 can be executed and T3 can be calculated. The process of pulling an imaging probe back along a support while being imaged by an x-ray system can be performed a plurality of times to determine a set of candidate T3 values for the intravascular and X-ray based systems. As described herein, selecting the appropriate T3 value improves co-registration of frames generated by an intravascular system such as OCT and a non-invasive system such as angiography.

[0046] Based upon experimentation and testing to address errors detected during co-registration trials, it has been determined advantageous to conduct the temporal calibration procedure described above multiple times. By performing the calibration method multiple times it is possible to determine a more accurate assessment of T3. Performing multiple iterations of the calibration method to generate a set of T3 values addresses two sources of error. The first of these sources of T3 errors or variation is that OCT and angiography datasets are generated asynchronously (i.e., the OCT and angiography systems are independent devices with no master clocking mechanism). The second source of T3 errors or variation is that because the angiography frame rate is typically much lower than the OCT frame rate, the calculated value of T3 may vary by up to +/- one angiography frame period.

[0047] As a result of the lack of a master clocking system and the potential misalignment of frames due to frame rate differences, performing the calibration procedure multiple times and selecting the minimum value of T3 as a calibration parameter is performed. This optimization of the T3 calibration delay period by repeated calculation and minimum value selection allows for an accurate assessment of the actual lag time period T3 between the OCT and angiography datasets. Once a suitable T3 value has been determined, the OCT and angiography frames can be aligned on the same temporal reference frame. Each T3 in an exemplary set of T3 values can range from about 1 millisecond to about 500 milliseconds.

[0048] The smallest value in the set of N time delays is selected. The smallest value has been determined to be a suitable estimate from N samples. In one embodiment, N ranges from 2 to 15. In one embodiment, N ranges from 4 to 10. When a minimum T3 value from a set of N values is obtained, it can be used to identify an angiography frame, such as frame 2 in Figure 3 which will have a relatively small amount of motion when compared for example to frame 3. The greater time lag associated with frame 3 results in the occurrence of a spatial positional error. This error can be understood in terms of an angiography frame being shown as co-registered with a particular OCT or other intravascular imaging frame while the distance between wherein the respective frames are incorrectly aligned and as much as between greater than 0 mm to about 3 mm apart in terms of their actual respective location in a subject.

Non-limiting Software Features and Embodiments for Implementing Angiography and Intravascular Data Calibration

[0049] The following description is intended to provide an overview of device hardware and other operating components suitable for performing the methods of the disclosure described herein. This description is not intended to limit the applicable environments or the scope of the disclosure. Similarly, the hardware and other operating components may be suitable as part of the apparatuses described above. The disclosure can be practiced with other system configurations, including personal computers, multiprocessor systems, microprocessor-based or programmable electronic devices, network PCs, minicomputers, mainframe computers, and the like.

[0050] Some portions of the detailed description are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations can be used by those skilled in the computer and software related fields. In one embodiment, an algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations performed as methods stops or otherwise described herein are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, transformed, compared, and otherwise manipulated.

[0051] Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "comparing" or "aligning" or "synchronizing" or "operating" or "generating" or "co-registering" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[0052] The present disclosure, in some embodiments, also relates to the apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer.

[0053] The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below.

[0054] Embodiments of the disclosure may be implemented in many different forms, including, but in no way limited to, computer program logic for use with a processor (e.g., a microprocessor, microcontroller, digital signal processor, or general purpose computer), programmable logic for use with a programmable logic device, (e.g., a Field Programmable Gate Array (FPGA) or other PLD), discrete components, integrated circuitry (e.g., an Application Specific Integrated Circuit (ASIC)), or any other means including any combination thereof. In a typical embodiment of the present disclosure, some or all of the processing of the data collected using an OCT probe, an FFR probe, an angiography system, and other imaging and subject monitoring devices and the processor-based system is implemented as a set of computer program instructions that is converted into a computer executable form, stored as such in a computer readable medium, and executed by a microprocessor under the control of an operating system. Thus, user interface instructions and triggers based upon the completion of a pullback or a co-registration request, for example, are transformed into processor understandable instructions suitable for generating OCT data, performing image procession using various and other features and embodiments described above.

[0055] Computer program logic implementing all or part of the functionality previously described herein may be embodied in various forms, including, but in no way limited to, a source code form, a computer executable form, and various intermediate forms (e.g., forms generated by an assembler, compiler, linker, or locator). Source code may include a series of computer program instructions implemented in any of various programming languages (e.g., an object code, an assembly language, or a high-level language such as Fortran, C, C++, JAVA, or HTML) for use with various operating systems or operating environments. The source code may define and use various data structures and communication messages. The source code may be in a computer executable form (e.g., via an interpreter), or the source code may be converted (e.g., via a translator, assembler, or compiler) into a computer executable form.

[0056] The computer program may be fixed in any form (e.g., source code form, computer executable form, or an intermediate form) either permanently or transitorily in a tangible storage medium, such as a semiconductor memory device (e.g., a RAM, ROM, PROM, EEPROM, or Flash-Programmable RAM), a magnetic memory device (e.g., a diskette or fixed disk), an optical memory device (e.g., a CD-ROM), a PC card (e.g., PCMCIA card), or other memory device. The computer program may be fixed in any form in a signal that is transmittable to a computer using any of various communication technologies, including, but in no way limited to, analog technologies, digital technologies, optical technologies, wireless technologies (e.g., Bluetooth), networking technologies, and internetworking technologies. The computer program may be distributed in any form as a removable storage medium with accompanying printed or electronic documentation (e.g., shrink-wrapped software), preloaded with a computer system (e.g., on system ROM or fixed disk), or distributed from a server or electronic bulletin board over the communication system (e.g., the internet or World Wide Web).

[0057] Hardware logic (including programmable logic for use with a programmable logic device) implementing all or part of the functionality previously described herein may be designed using traditional manual methods, or may be designed, captured, simulated, or documented electronically using various tools, such as Computer Aided Design (CAD), a hardware description language (e.g., VHDL or AHDL), or a PLD programming language (e.g., PALASM, ABEL, or CUPL).

[0058] Programmable logic may be fixed either permanently or transitorily in a tangible storage medium, such as a semiconductor memory device (e.g., a RAM, ROM, PROM, EEPROM, or Flash-Programmable RAM), a magnetic memory device (e.g., a diskette or fixed disk), an optical memory device (e.g., a CD-ROM), or other memory device. The programmable logic may be fixed in a signal that is transmittable to a computer using any of various communication technologies, including, but in no way limited to, analog technologies, digital technologies, optical technologies, wireless technologies (e.g., Bluetooth), networking technologies, and internetworking technologies. The programmable logic may be distributed as a removable storage medium with accompanying printed or electronic documentation (e.g., shrink-wrapped software), preloaded with a computer system (e.g., on system ROM or fixed disk), or distributed from a server or electronic bulletin board over the communication system (e.g., the internet or World Wide Web).

[0059] Various examples of suitable processing modules are discussed below in more detail. As used herein a module refers to software, hardware, or firmware suitable for performing a specific data processing or data transmission task. In one embodiment, a module refers to a software routine, program, or other memory resident application suitable for receiving, transforming, routing and processing instructions, or various types of data such as angiography data, OCT data, timestamps, calibration periods, marker position data, movement data, pixel information, calibration trial data and other information of interest as described herein.

[0060] Computers and computer systems described herein may include operatively associated computer-readable media such as memory for storing software applications used in obtaining, processing, storing and/or communicating data. It can be appreciated that such memory can be internal, external, remote or local with respect to its operatively associated computer or computer system.

[0061] Memory may also include any means for storing software or other instructions including, for example and without limitation, a hard disk, an optical disk, floppy disk, DVD (digital versatile disc), CD (compact disc), memory stick, flash memory, ROM (read only memory), RAM (random access memory), DRAM (dynamic random access memory), PROM (programmable ROM), EEPROM (extended erasable PROM), and/or other like computer-readable media.

[0062] In general, computer-readable memory media applied in association with embodiments of the disclosure described herein may include any memory medium capable of storing instructions executed by a programmable apparatus. Where applicable, method steps described herein may be embodied or executed as instructions stored on a computer-readable memory medium or memory media. These instructions may be software embodied in various programming languages such as C++, C, Java, and/or a variety of other kinds of software programming languages that may be applied to create instructions in accordance with embodiments of the disclosure.

[0063] The aspects, embodiments, features, and examples of the disclosure are to be considered illustrative in all respects and are not intended to limit the disclosure, the scope of which is defined only by the claims. Other embodiments, modifications, and usages will be apparent to those skilled in the art without departing from the scope of the claimed disclosure.

[0064] The use of headings and sections in the application is not meant to limit the disclosure; each section can apply to any aspect, embodiment, or feature of the disclosure.

[0065] The use of arrow heads showing directionality in a given figure or the lack thereof are not intended to limit or require a direction in which information can flow. For a given connector, such as the arrows and lines shown connecting the elements shown in the figures information can flow in one or more directions or in only one direction as suitable for a given embodiment. The connections can include various suitable data transmitting connections such as optical, wire, power, wireless, or electrical connections.

[0066] Throughout the application, where compositions are described as having, including, or comprising specific components, or where processes are described as having, including or comprising specific process steps, it is contemplated that compositions of the present teachings also consist essentially of, or consist of, the recited components, and that the processes of the present teachings also consist essentially of, or consist of, the recited process steps.

[0067] In the application, where an element or component is said to be included in and/or selected from a list of recited elements or components, it should be understood that the element or component can be any one of the recited elements or components and can be selected from a group consisting of two or more of the recited elements or components.

[0068] The use of the terms "include," "includes," "including," "have," "has," or "having" should be generally understood as open-ended and non-limiting unless specifically stated otherwise.

[0069] The use of the singular herein includes the plural (and vice versa) unless specifically stated otherwise. Moreover, the singular forms "a," "an," and "the" include plural forms unless the context clearly dictates otherwise. In addition, where the use of the term "about" is before a quantitative value, the present teachings also include the specific quantitative value itself, unless specifically stated otherwise.

[0070] It should be understood that the order of steps or order for performing certain actions is immaterial so long as the present teachings remain operable. Moreover, two or more steps or actions may be conducted simultaneously.

[0071] Where a range or list of values is provided, each intervening value between the upper and lower limits of that range or list of values is individually contemplated and is encompassed within the disclosure as if each value were specifically enumerated herein. In addition, smaller ranges between and including the upper and lower limits of a given range are contemplated and encompassed within the disclosure. The listing of exemplary values or ranges is not a disclaimer of other values or ranges between and including the upper and lower limits of a given range.

Claims

1. A method of calibrating an optical coherence tomography system and an angiography system comprising:

generating N sets of optical coherence tomography (OCT) image data, wherein each of the N sets of OCT image data is obtained by performing N pullbacks of an ex vivo data collection probe comprising a marker;
generating N sets of angiography image data comprising a plurality of two-dimensional images, wherein each of the N sets of angiography image comprise a plurality of two-dimensional images of the marker in two or more different spatial positions; using a computing device:
generating N sets of OCT frames using the N sets of OCT image data obtained during the N pullbacks;
determining an initial frame of the OCT probe pullback from the plurality of OCT frames for each set N;
determining an initial angiography frame that corresponds to the initial frame of OCT probe pullback for each set N;
determining a time delay between the initial OCT frame and the initial angiography frame for each set N such that N time delays are determined;
selecting a minimum time delay from the N time delays; and
aligning OCT and angiography frames using the minimum time delay.

2. The method of claim 1 wherein determining the initial angiography frame comprises determining a first angiography frame indicative of movement of a marker attached to the OCT probe and selecting a second angiography frame preceding the first angiography frame as the initial angiography frame.

3. The method of claim 1 wherein N ranges from 2 to 12.

4. The method of claim 1 further comprising initiating the OCT pullback at an initiation time, wherein a computing device stores the initiation time in memory.

5. The method of claim 4 wherein determining the initial frame of the OCT probe pullback comprises identifying the OCT frame corresponding to the initiation time as the initial frame of a pullback.

6. The method of claim 2 wherein determining the initial angiography frame comprises using a computing device to track pixel changes in angiography frames to identify marker movement.

7. The method of claim 1 wherein a frame rate of the OCT system is greater than the frame rate of the angiography system.

8. A system for calibrating a combination intravascular and extravascular imaging system comprising:

an ex vivo optical coherence tomography (OCT) probe comprising a marker, wherein the probe is configured to collect ex vivo OCT data, when the probe is disposed within an imaging zone of an angiography system;
an optical coherence tomography data processing system comprising:

one or more memory devices;
a control signal input in electrical communication with the one or more memory devices, wherein the control signal input is in electrical communication with a controller programmed to initiate N pullbacks of the OCT probe during which N sets of ex vivo OCT data is collected, and transmit each pullback initiation time to the one or more memory devices; and
a computing device programmed to:

generate N sets of a plurality of OCT frames based upon the N sets of ex vivo OCT data and to receive angiography data comprising N sets of angiography frames from said angiography system;

determine an initial frame of the OCT probe pullback from the plurality of OCT frames for each set N;
determine an initial angiography frame that corresponds to the initial frame of OCT probe pullback for each set N;
determine a time delay between the initial OCT frame and the initial angiography frame for each set N such that N time delays are determined;
select a minimum time delay from the N time delays; and
align OCT and angiography frames using the minimum time delay.

9. The system of claim 8 wherein the computing device comprises a calibration method stored in the one or more memory devices as instructions to cause the computing device to determine the initial angiography frame that corresponds to the initial frame of the OCT probe for each pullback.

10. The system of claim 9 wherein the calibration method further comprises instructions to cause the computing device to align OCT frames and angiography frames using the minimum time delay.

11. The system of claim 8 further comprising a display, wherein the computing device is programmed to display one or more of such aligned frames.

12. The system of claim 8 wherein a frame rate of the optical coherence tomography data processing system is greater than a frame rate of the angiography system.

13. The system of claim 8 wherein the computing device is programmed to track pixel changes in angiography frames to identify marker movement.

14. The system of claim 8 wherein the computing device is programmed to store a time an OCT pullback is initiated in the one or more memory devices.

Patentansprüche

1. Verfahren zum Kalibrieren eines optischen Kohärenztomographiesystems und eines Angiographiesystems, das Folgendes beinhaltet:
Erzeugen von N Sätzen von Optische-Kohärenztomographie-(OCT)-Bilddaten, wobei jeder der N Sätze von OCT-Bilddaten durch Durchführen von N Pullbacks einer Ex-vivo-Datenerfassungssonde erhalten werden, die einen Marker umfasst:
Erzeugen von N Sätzen von Angiographiebilddaten, die mehrere zweidimensionale Bilder umfassen, wobei jeder der N Sätze von Angiographiebilddaten mehrere zweidimensionale Bilder des Markers in zwei oder mehr unterschiedlichen räumlichen Positionen umfassen; mit einem Computergerät:

Erzeugen von N Sätzen von OCT-Frames anhand der N Sätze von während der N Pullbacks erhaltenen OCT-Bilddaten;
Bestimmen eines Anfangsframe des OCT-Sonden-Pullback von den mehreren OCT-Frames für jeden Satz N;
Bestimmen eines Angiographie-Anfangsframe, der dem Anfangsframe von OCT-Sonden-Pullback für jeden Satz N entspricht;
Bestimmen einer Zeitverzögerung zwischen dem OCT-Anfangsframe und dem Angiographie-Anfangsframe für jeden Satz N, so dass N Zeitverzögerungen bestimmt werden;
Auswählen einer Mindestzeitverzögerung aus den N Zeitverzögerungen; und
Ausrichten von OCT- und Angiographie-Frames mittels der Mindestzeitverzögerung.

2. Verfahren nach Anspruch 1, wobei das Bestimmen des Angiographie-Anfangsframe das Bestimmen eines ersten Angiographie-Frame, der Bewegung eines an der OCT-Sonde angebrachten Markers anzeigt, und das Auswählen eines zweiten Angiographie-Frame vor dem ersten Angiographie-Frame als den Angiographie-Anfangsframe beinhaltet.

3. Verfahren nach Anspruch 1, wobei N im Bereich von 2 bis 12 liegt.

4. Verfahren nach Anspruch 1, das ferner das Einleiten des OCT-Pullback zu einer Einleitungszeit beinhaltet, wobei ein Computergerät die Einleitungszeit im Speicher speichert.

5. Verfahren nach Anspruch 4, wobei das Bestimmen des Anfangsframe des OCT-Sonden-Pullback das Identifizieren des OCT-Frame entsprechend der Einleitungszeit als Anfangsframe eines Pullback beinhaltet.

6. Verfahren nach Anspruch 2, wobei das Bestimmen des Angiographie-Anfangsframe das Benutzen eines Computergeräts zum Verfolgen von Pixeländerungen in Angiographie-Frames zum Identifizieren von Markerbewegung beinhaltet.

7. Verfahren nach Anspruch 1, wobei eine Framerate des OCT-Systems größer ist als die Framerate des Angiographie-Systems.

8. System zum Kalibrieren eines intravaskulären und extravaskulären Kombinationsabbildungssystems, das Folgendes umfasst:

eine Ex-vivo-Optische-Kohärenztomographie-(OCT)-Sonde, die einen Marker umfasst, wobei die Sonde zum Erfassen von Ex-vivo-OCT-Daten konfiguriert ist, wenn die Sonde in einer Abbildungszone eines Angiographiesystems angeordnet ist;
ein Optische-Kohärenztomographiedaten-Verarbeitungssystem, das Folgendes umfasst:

ein oder mehrere Speichergeräte;
einen Steuersignaleingang in elektrischer Kommunikation mit den ein oder mehreren Speichergeräten, wobei der Steuersignaleingang in elektrischer Kommunikation mit einer Steuerung ist, programmiert zum Einleiten von N Pullbacks der OCT-Sonde, während derer N Sätze von Ex-vivo-OCT-Daten erfasst werden, und Senden jeder Pullback-Einleitungszeit zu den ein oder mehreren Speichergeräten; und
ein Computergerät, programmiert zum:

Erzeugen von N Sätzen von mehreren OCT-Frames auf der Basis der N Sätze von Ex-vivo-OCT-Daten und zum Empfangen von Angiographiedaten, die N Sätze von Angiographie-Frames umfassen, von dem genannten Angiographiesystem;
Bestimmen eines Anfangsframe des OCT-Sonden-Pullback von den mehreren OCT-Frames für jeden Satz N;
Bestimmen eines Angiographie-Anfangsframe, der dem Anfangsframe von OCT-Sonden-Pullback für jeden Satz N entspricht;
Bestimmen einer Zeitverzögerung zwischen dem OCT-Anfangsframe und dem Angiographie-Anfangsframe für jeden Satz N, so dass N Zeitverzögerungen bestimmt werden;
Auswählen einer Mindestzeitverzögerung aus den N Zeitverzögerungen; und
Ausrichten von OCT- und Angiographie-Frames mittels der Mindestzeitverzögerung.

9. System nach Anspruch 8, wobei das Computergerät ein Kalibrationsverfahren beinhaltet, das in den ein oder mehreren Speichergeräten als Befehle gespeichert ist, um zu bewirken, dass das Computergerät den Angiographie-Anfangsframe bestimmt, der dem Anfangsframe der OCT-Sonde für jedes Pullback entspricht.

10. System nach Anspruch 9, wobei das Kalibrationsverfahren ferner Befehle umfasst, um zu bewirken, dass das Computergerät OCT-Frames und Angiographie-Frames mittels der Mindestzeitverzögerung ausrichtet.

11. System nach Anspruch 8, das ferner ein Display umfasst, wobei das Computergerät zum Anzeigen eines oder mehrerer solcher ausgerichteter Frames programmiert ist.

12. System nach Anspruch 8, wobei eine Framerate des Optische-Kohärenztomographiedaten-Verarbeitungssystems größer ist als eine Framerate des Angiographiesystems.

13. System nach Anspruch 8, wobei das Computergerät zum Verfolgen von Pixeländerungen in Angiographie-Frames zum Identifizieren von Markerbewegung programmiert ist.

14. System nach Anspruch 8, wobei das Computergerät zum Speichern einer Zeit programmiert ist, zu der ein OCT-Pullback in den ein oder mehreren Speichergeräten eingeleitet wird.

Revendications

1. Procédé d'étalonnage d'un système de tomographie en cohérence optique et d'un système d'angiographie, comprenant les étapes consistant à :

générer N ensembles de données d'image de tomographie en cohérence optique (OCT), chacun des N ensembles de données d'image OCT étant obtenu en réalisant N retraits d'une sonde de collecte de données ex vivo comprenant un marqueur ;
générer N ensembles de données d'image d'angiographie comprenant une pluralité d'images bidimensionnelles, chacun des N ensembles de données d'image d'angiographie comprenant une pluralité d'images bidimensionnelles du marqueur dans au moins deux positions spatiales différentes ;
au moyen d'un dispositif informatique :

générer N ensembles de trames OCT au moyen des N ensembles de données d'image OCT obtenues pendant les N retraits ;
déterminer une trame initiale du retrait de sonde OCT parmi la pluralité de trames OCT pour chaque ensemble N ;
déterminer une trame d'angiographie initiale qui correspond à la trame initiale d'un retrait de sonde OCT pour chaque ensemble N ;
déterminer un retard entre la trame OCT initiale et la trame d'angiographie initiale pour

chaque ensemble N, de manière à déterminer N retards ;
sélectionner un retard minimum parmi les N retards ; et
aligner des trames OCT et d'angiographie au moyen du retard minimum.

2. Procédé selon la revendication 1, dans lequel la détermination de la trame d'angiographie initiale comprend les étapes consistant à déterminer une première trame d'angiographie représentative d'un mouvement d'un marqueur fixé à la sonde OCT et à sélectionner une seconde trame d'angiographie antérieure à la première trame d'angiographie en tant que trame d'angiographie initiale.

3. Procédé selon la revendication 1, dans lequel N est de l'ordre de 2 à 12.

4. Procédé selon la revendication 1, comprenant en outre l'étape consistant à déclencher le retrait OCT à un moment de déclenchement, un dispositif informatique stockant le moment de déclenchement en mémoire.

5. Procédé selon la revendication 4, dans lequel la détermination de la trame initiale du retrait de sonde OCT comprend l'étape consistant à identifier la trame OCT correspondant au moment de déclenchement en tant que trame initiale d'un retrait.

6. Procédé selon la revendication 2, dans lequel la détermination de la trame d'angiographie initiale comprend l'étape consistant à utiliser un dispositif informatique pour suivre des variations de pixel dans des trames d'angiographie pour identifier un mouvement de marqueur.

7. Procédé selon la revendication 1, dans lequel une fréquence de trames du système OCT est supérieure à la fréquence de trames du système d'angiographie.

8. Système d'étalonnage d'un système combiné d'imagerie intravasculaire et extravasculaire, comprenant :

une sonde de tomographie en cohérence optique (OCT) ex vivo comprenant un marqueur, la sonde étant configurée pour collecter des données OCT ex vivo quand la sonde est disposée dans une zone d'imagerie d'un système d'angiographie ;
un système de traitement de données de tomographie en cohérence optique, comprenant :

un ou plusieurs dispositifs de mémoire ;
une entrée de signal de contrôle en communication électrique avec les un ou plusieurs dispositifs de mémoire, l'entrée de signal de contrôle étant en communication électrique avec un contrôleur programmé pour déclencher N retraits de la sonde OCT pendant lesquels N ensembles de données OCT ex vivo sont collectés, et transmettre chaque moment de déclenchement de retrait aux un ou plusieurs dispositifs de mémoire ; et
un dispositif informatique programmé pour :

générer N ensembles d'une pluralité de trames OCT sur la base des ensembles de données OCT ex vivo et recevoir des données d'angiographie comprenant N ensembles de trames d'angiographie en provenance dudit système d'angiographie ;
déterminer une trame initiale du retrait de sonde OCT parmi la pluralité de trames OCT pour chaque ensemble N ;
déterminer une trame d'angiographie initiale qui correspond à la trame initiale d'un retrait de sonde OCT pour chaque ensemble N ;
déterminer un retard entre la trame OCT initiale et la trame d'angiographie initiale pour chaque ensemble N, de manière à déterminer N retards ;
sélectionner un retard minimum parmi les N retards ; et
aligner des trames OCT et d'angiographie au moyen du retard minimum.

9. Système selon la revendication 8, dans lequel le dispositif informatique comprend un procédé d'étalonnage stocké dans les un ou plusieurs dispositifs de mémoire en tant qu'instructions pour amener le dispositif informatique à déterminer la trame d'angiographie initiale qui correspond à la trame initiale de la sonde OCT pour chaque retrait.

10. Système selon la revendication 9, dans lequel le procédé d'étalonnage comprend en outre des instructions pour amener le dispositif informatique à aligner des trames OCT et des trames d'angiographie au moyen du retard minimum.

11. Système selon la revendication 8, comprenant en outre un écran, le dispositif informatique étant programmé pour afficher une ou plusieurs de telles trames alignées.

12. Système selon la revendication 8, dans lequel une fréquence de trames du système de traitement de données de tomographie à cohérence optique est supérieure à une fréquence de trames du système d’angiographie.

13. Système selon la revendication 8, dans lequel le dispositif informatique est programmé pour suivre des variations de pixel dans des trames d’angiographie pour identifier un mouvement de marqueur.

14. Système selon la revendication 8, dans lequel le dispositif informatique est programmé pour stocker un moment de déclenchement d’un retrait OCT dans les un ou plusieurs dispositifs de mémoire.

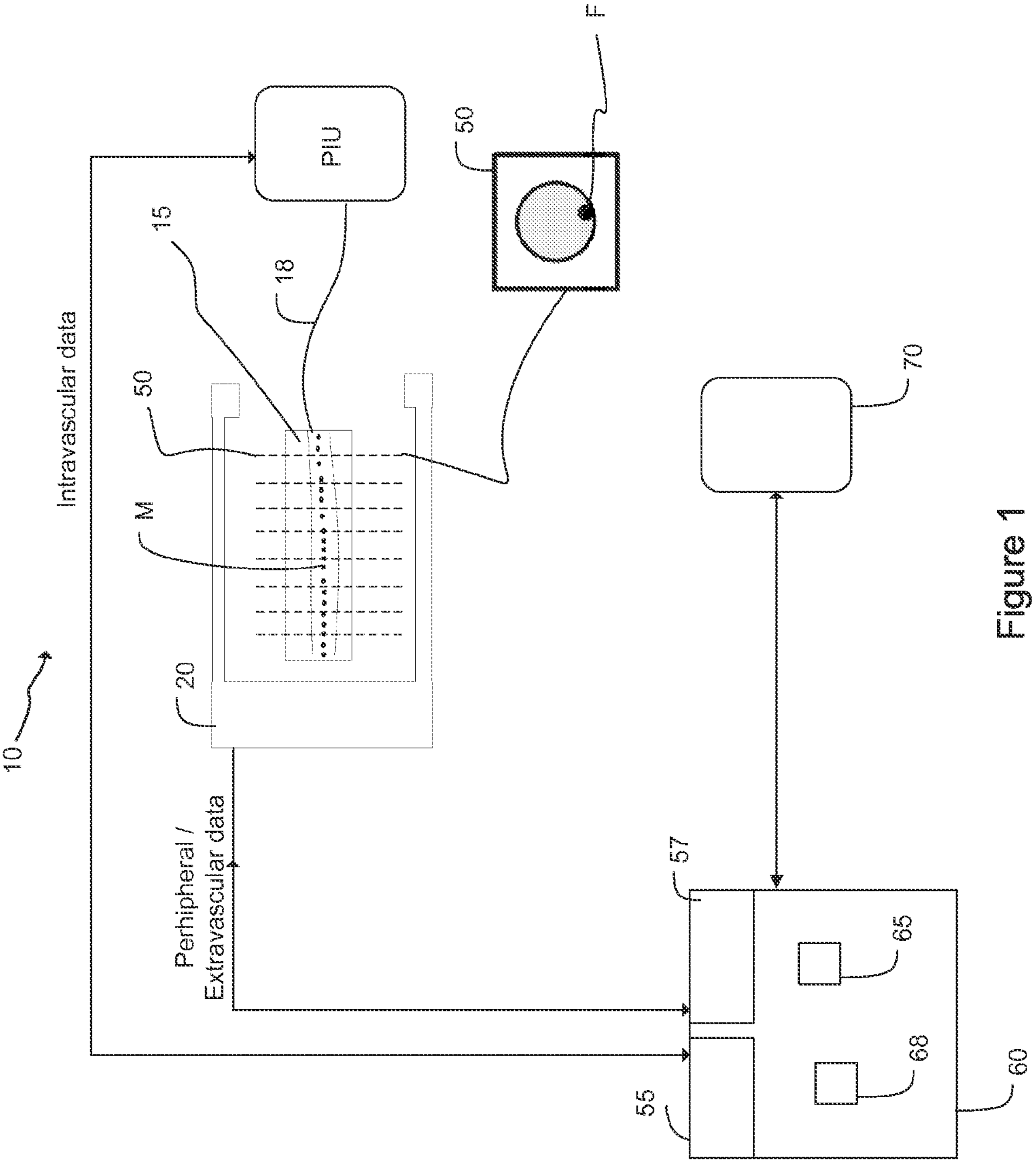
10
Intravascular data
PIU
15
18
50
M
50
F
20
70
Perhiperal / Extravascular data
57
65
68
55
60

Figure 1

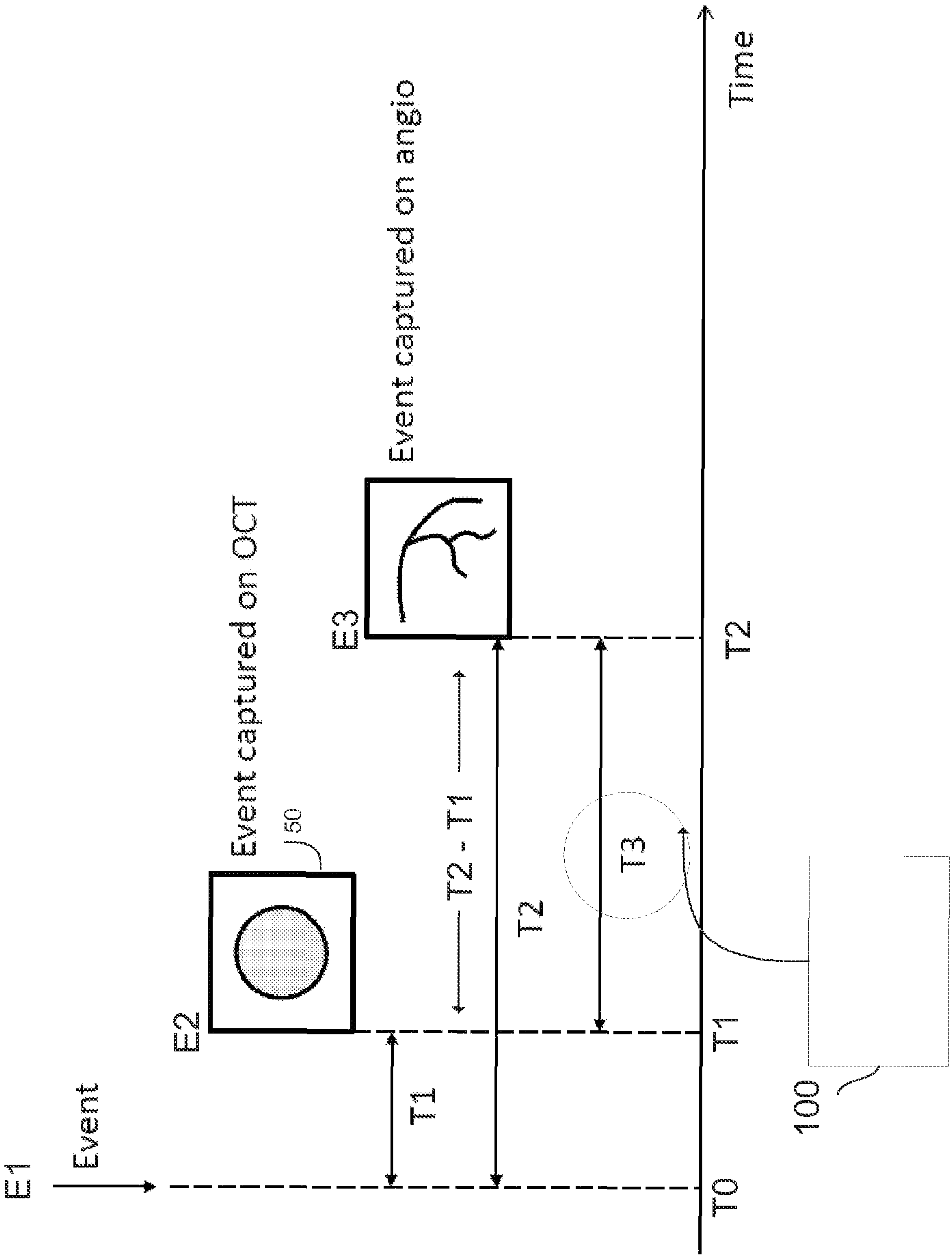
E1
Event
T0
T1
E2
50
Event captured on OCT
T2 - T1
T2
T3
E3
Event captured on angio
T1
T2
Time
100

Figure 2

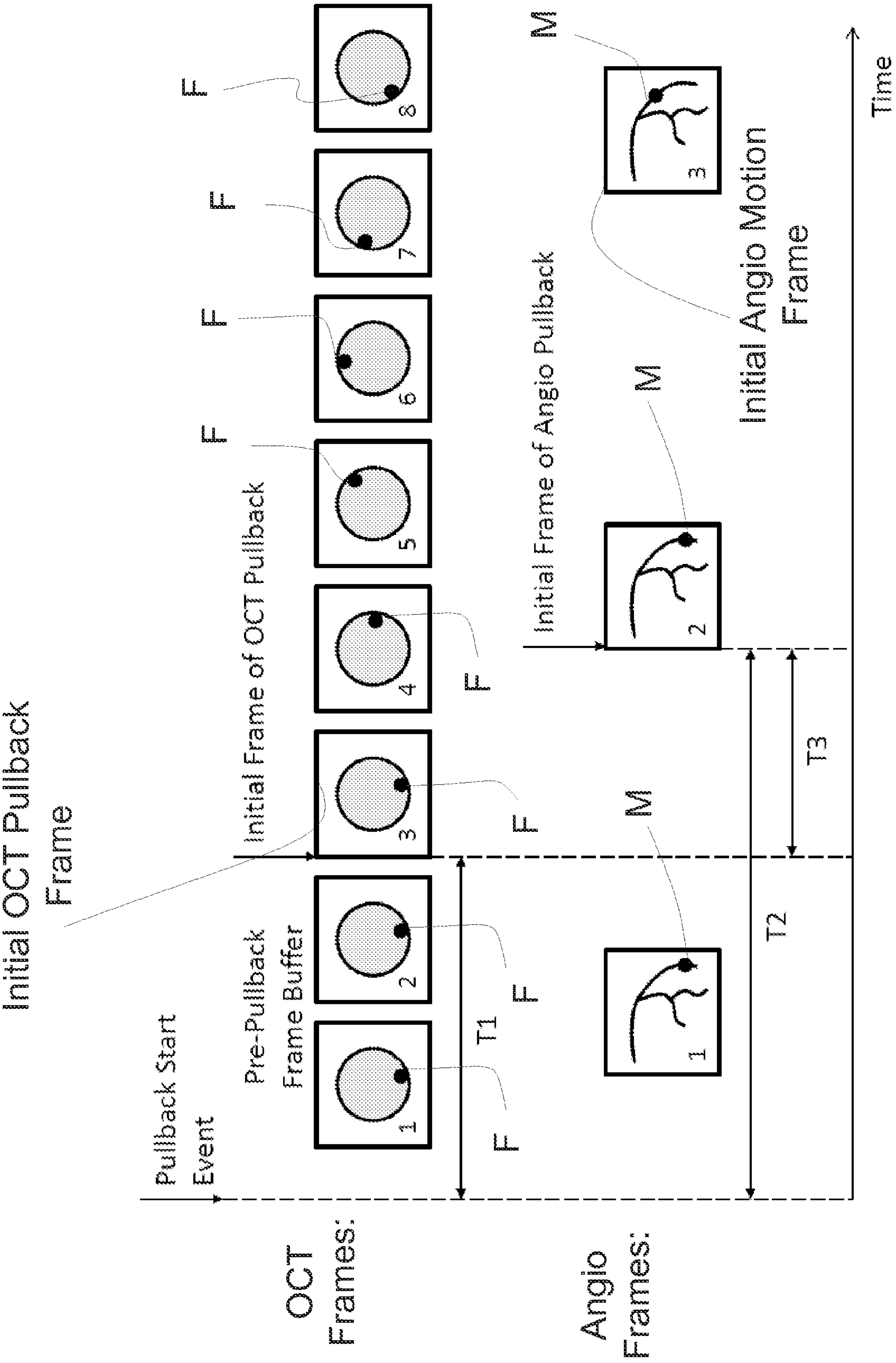
OCT Frames:
Angio Frames:
Pullback Start Event
Pre-Pullback Frame Buffer
Initial OCT Pullback Frame
Initial Frame of OCT Pullback
Initial Frame of Angio Pullback
Initial Angio Motion Frame
1
2
3
4
5
6
7
8
F
F
F
F
F
F
F
F
1
2
3
M
M
M
T1
T2
T3
Time

Figure 3

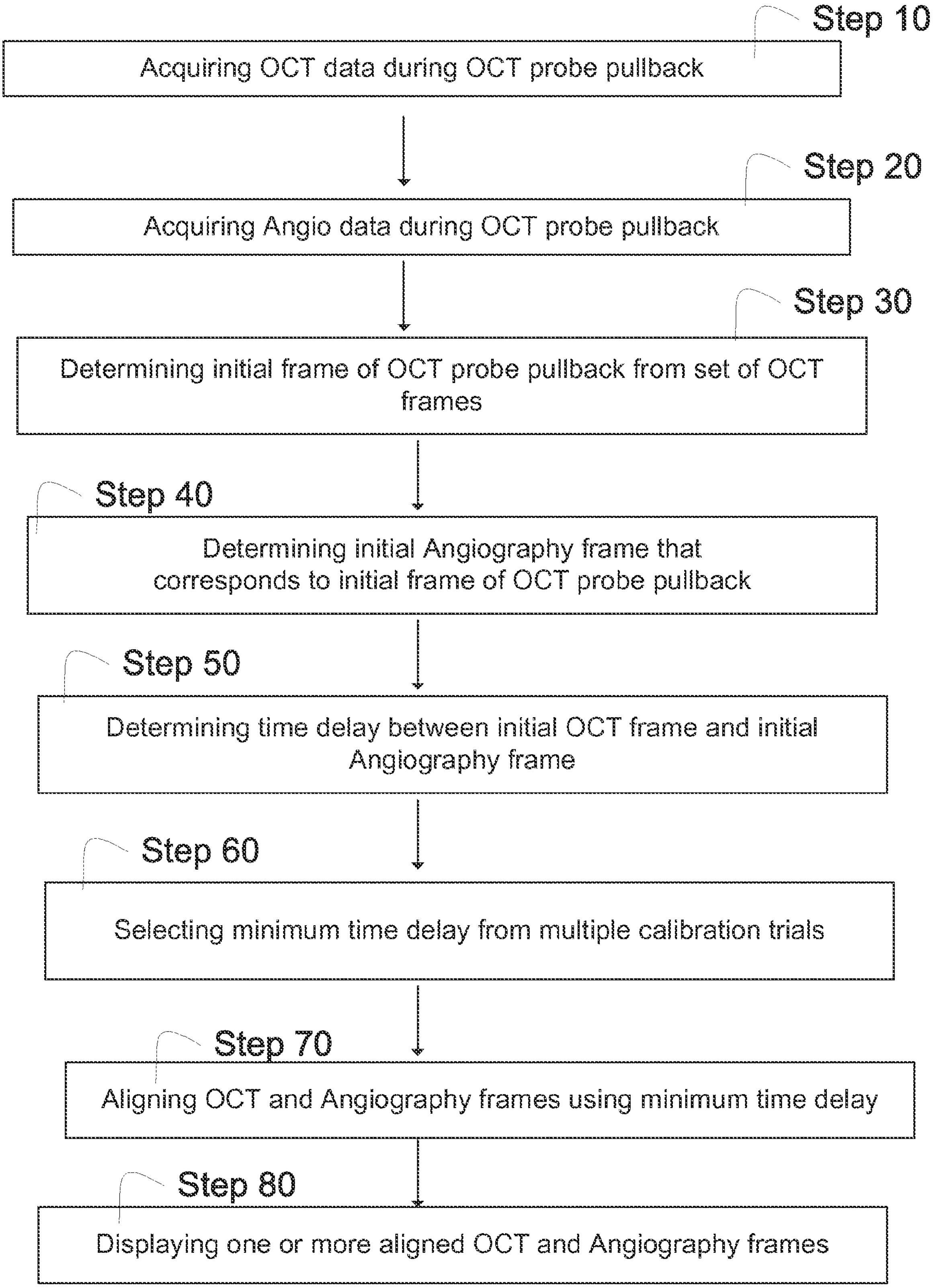
Step 10
Acquiring OCT data during OCT probe pullback
Step 20
Acquiring Angio data during OCT probe pullback
Step 30
Determining initial frame of OCT probe pullback from set of OCT frames
Step 40
Determining initial Angiography frame that corresponds to initial frame of OCT probe pullback
Step 50
Determining time delay between initial OCT frame and initial Angiography frame
Step 60
Selecting minimum time delay from multiple calibration trials
Step 70
Aligning OCT and Angiography frames using minimum time delay
Step 80
Displaying one or more aligned OCT and Angiography frames

Figure 4

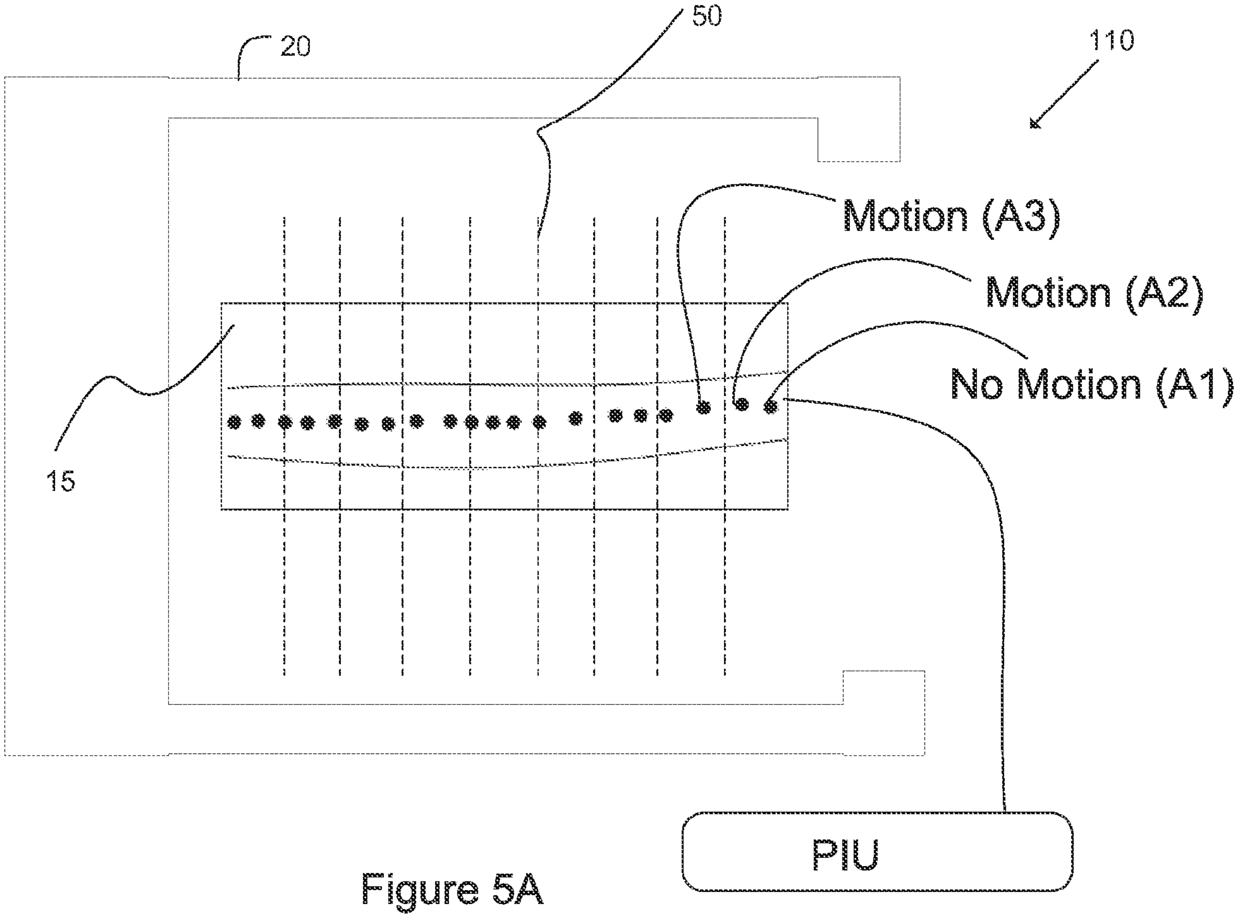

Figure 5A

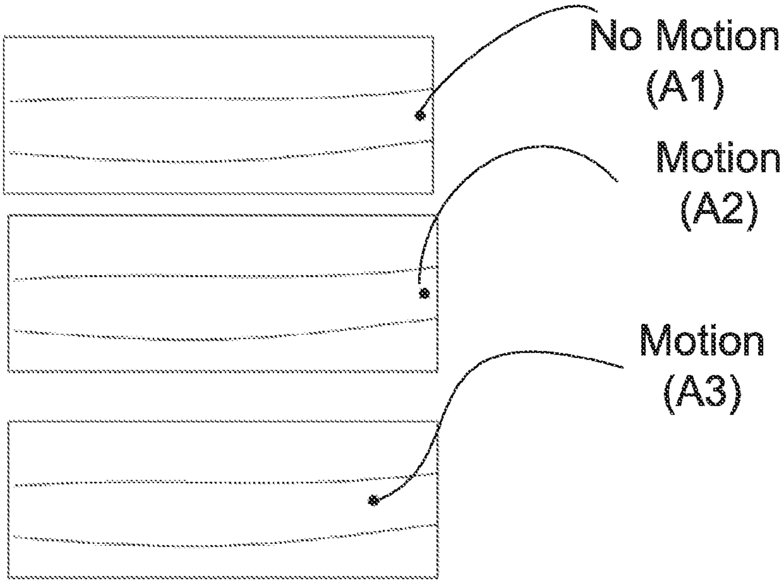

Figure 5B

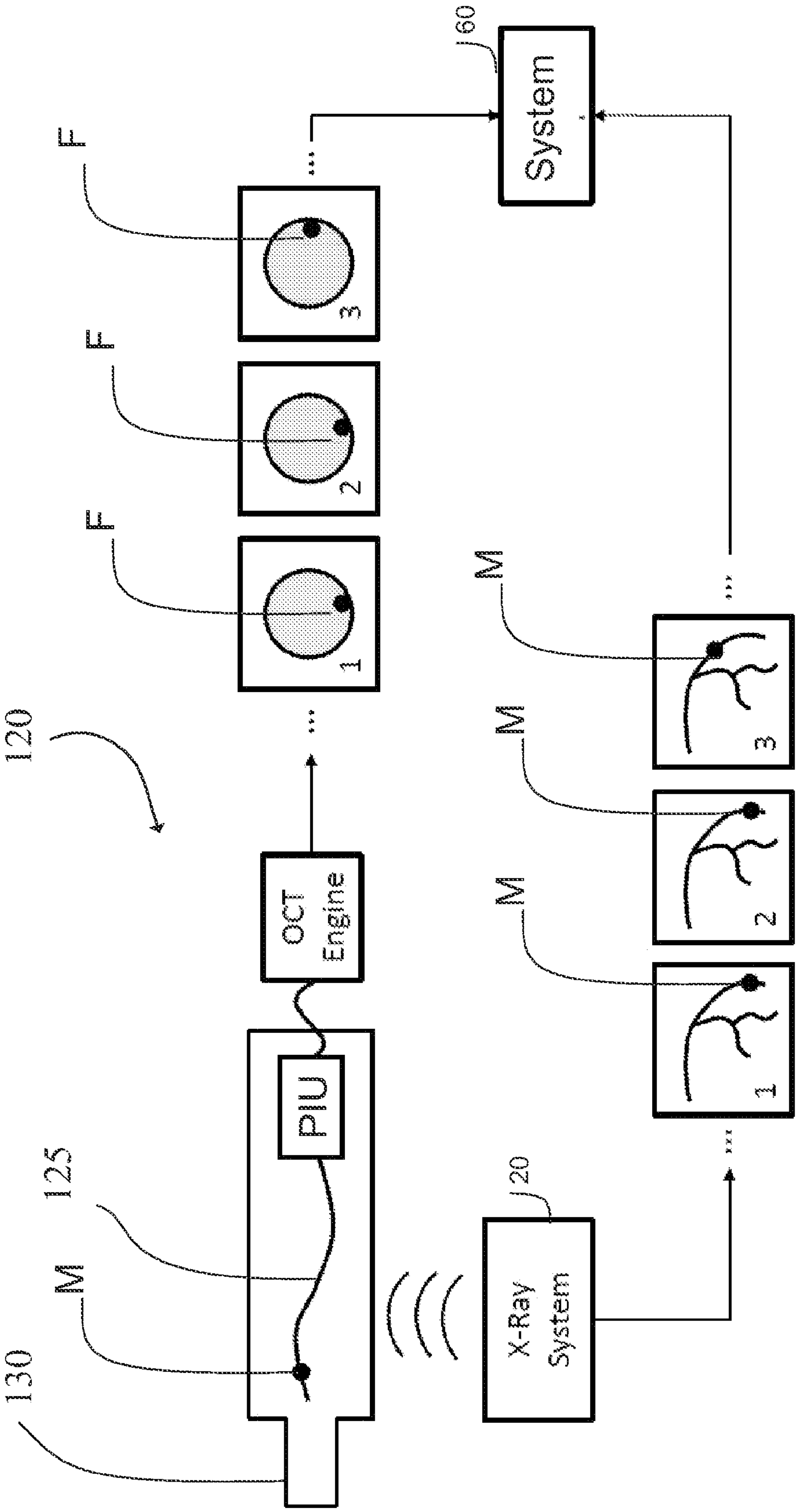
130
M
125
PIU
OCT Engine
120
X-Ray System
20
...
1
2
3
M
M
M
...
F
F
F
1
2
3
...
System
60

Figure 6

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 2012004529 A **[0005]**
- US 2007027390 A **[0005]**

专利名称(译)	时间校准血管内成像系统的方法和系统		
公开(公告)号	EP3190954B1	公开(公告)日	2020-01-15
申请号	EP2015750872	申请日	2015-07-30
[标]申请(专利权)人(译)	光学实验室成像公司 ADLER戴斯蒙德		
申请(专利权)人(译)	LIGHTLAB IMAGING，INC. ADLER，戴斯蒙德		
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摘要(译)

本公开部分地涉及使用血管内图像数据和血管外图像数据对血管成像的系统以及用于校准此类系统的方法。 在一实施例中，执行多次校准试验以确定多个时滞值。 在一个实施例中，最小时滞值用于对准血管内图像数据和血管外时滞数据。

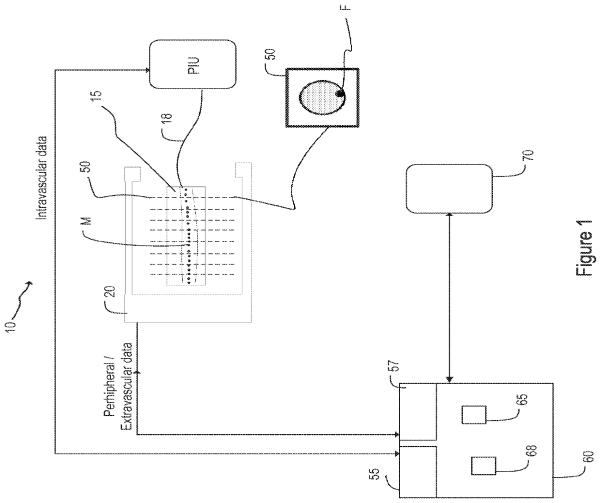

Figure 1