PRELIMINARY DESIGN OF A MULTIMODALITY MOLECULAR IMAGING SYSTEM

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ABSTRACT

We have designed a multimodality molecular imaging system for small animals. The aim is to develop a system which can perform functional imaging, structural imaging, and molecular imaging. Our multimodality system contains five imaging modalities which are Bioluminescence Tomography (BLT), Fluorescence Molecular Tomography (FMT), Cerenkov Luminescence Tomography (CLT), X-ray Computed Tomography (CT), and Positron Emission Tomography (PET). We have designed both the hardware structure and software to make sure multimodality imaging can be achieved. Here we will report the overall design and work flow of the system.

Index Terms—multimodality molecular imaging, small animal, tomography, imaging system

1. INTRODUCTION

Multimodality imaging is a growing research field because it can provide comprehensive medical imaging [1]. PET/CT is a typical multimodality imaging technology which combines structural imaging and functional imaging together. It has been greatly used in clinical applications. Molecular imaging is a new technology using biomarkers to help image particular targets. It can be used to view cellular function or molecular process in living organisms [2]. Therefore, molecular imaging causes abroad attention. Multimodality molecular imaging is a joint of conventional imaging tools and molecular imaging. Multimodality molecular imaging can be used for earlier detection and characterization of diseases [3].

Recently multimodality molecular imaging with two modalities are very common [4][5], even tri-modal imaging appears [6]. However, multimodality system with more than three modalities has not yet been reported. In this paper, we report our design of a five-modality imaging system. Our system can be divided into two parts: hardware structure and software. The following paragraphs will introduce the hardware structure, data acquisition flow and software in detail.

2. HARDWARE STRUCTURE DESIGN

The hardware structure is the kernel of our multimodality imaging system. We integrate the devices of five modalities into one system. Fig. 1 shows the outside view of our system, where the mouse holder is obvious. The mouse holder contains anesthetic gases input and output pipes to keep the mouse under anesthesia during the experiments. Fig. 2 shows the front view of our system.

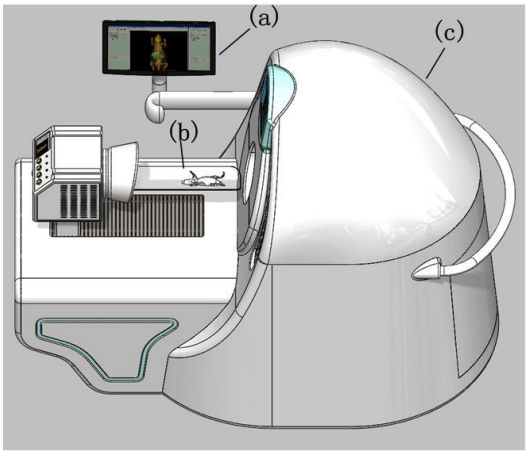

Fig. 1. Outside view of our system. (a) Screen. (b) Mouse holder. (c) Multimodality imaging gantry.

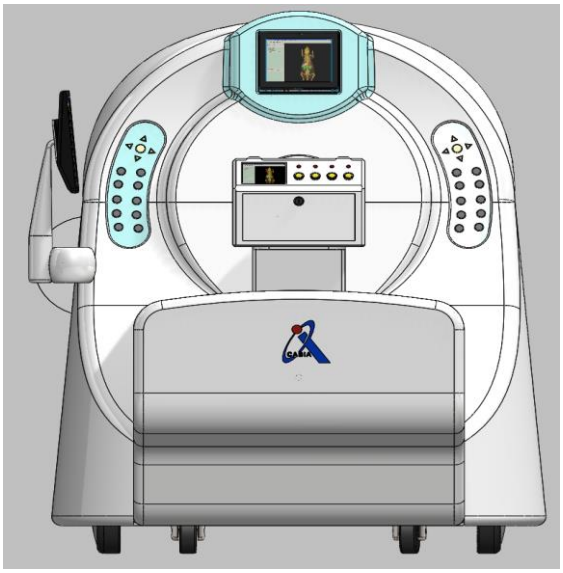

Fig. 2. Front view of our system.

The inner structure of our system is shown in Fig. 3, where all the imaging devices are fixed on the dial. As shown in Fig. 4, the dial is fixed on a servo motor. Therefore, all the imaging devices can rotate during the experiments. The position of the mouse holder is controlled by three moving stages. So we can tune the position of the mouse during the experiment.

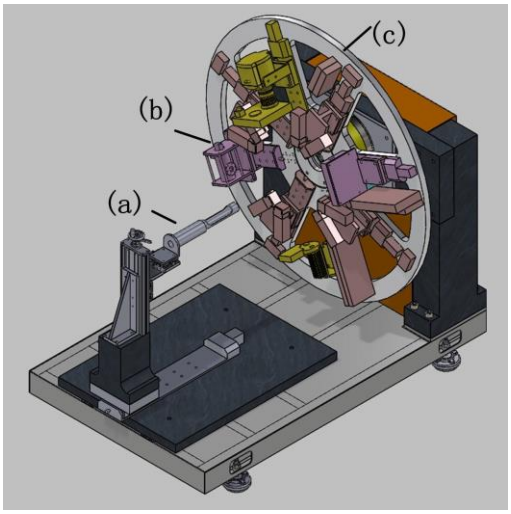

Fig. 3. Inner structure of our system. (a) Mouse holder. (b) Imaging devices. (c) Dial fixed on the motor.

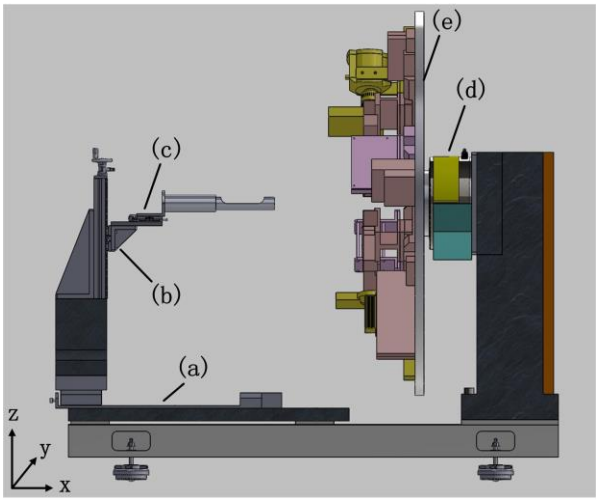

Fig. 4. Motion parts in the system. (a) Translation stage moving in x direction. (b) Lift stage moving in z direction. (c) Translation stage moving in y direction. (d) Servo motor. (e) Dial.

All the imaging devices are shown in Fig. 5. The X-ray Source and X-ray flat panel detector are used for CT imaging. The EMCCD camera is used for CLT、BLT、FMT imaging. There are eight PET flat panel detectors which are used for PET imaging. Note that each image device is fixed on a translation stage so its position on the dial can be changed.

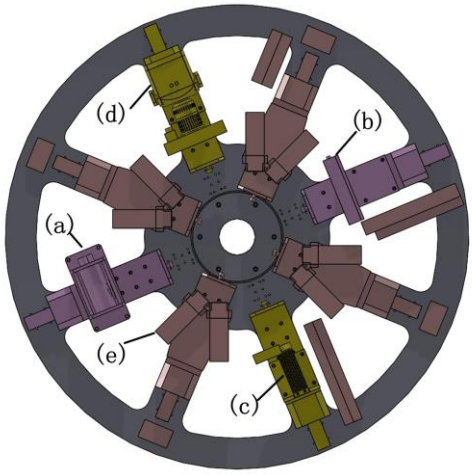

Fig. 5. Imaging devices on the dial. (a) X-ray source. (b) X-ray flat panel detector. (c) Laser source. (d) EMCCD camera. (e) PET flat panel detector.

2. DATA ACQUISITION FLOW

In this Section we introduce the data acquisition flow of our system. In the beginning of the experiment, we inject multimodality imaging probe into the mouse and put the mouse into the holder. When the mouse is anaesthetized, the translation stages drive the mouse holder into the field of view of the imaging devices. Then the system will collect PET data first, then the molecular imaging data and CT data.

During the PET data acquisition, the translation stages on the dial move and bring the CT and molecular imaging devices to the periphery while the PET detectors to the center. The layout is shown in Fig. 6 where eight PET detectors form an octagonal structure. In this way the mouse is covered by the eight detectors and most gamma rays from the mouse can be detected. During the PET data acquisition, the dial remains still.

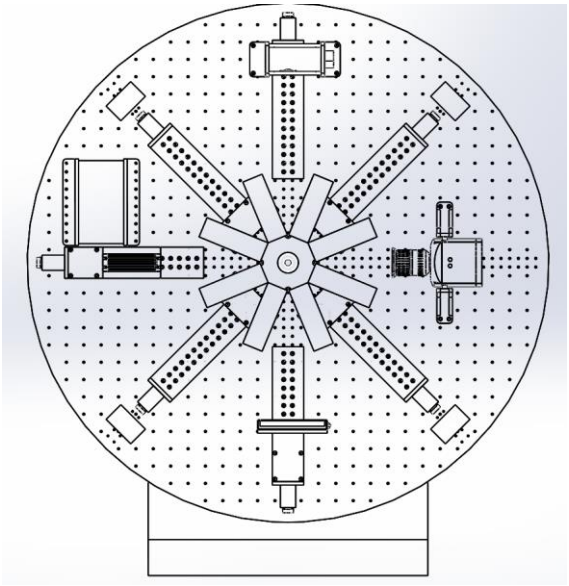

Fig. 6. The device layout for PET imaging.

After PET data acquisition, we collect molecular imaging and CT data, respectively. As shown in Fig. 7, we move the PET detectors to the periphery while CT and molecular imaging devices to the center. We perform molecular imaging first, which includes CLT, BLT and FMT. For CLT, we collect four images for 3D reconstruction. These images are collected by the EMCCD camera at 90 degrees intervals. Note that more accurate reconstruction needs more than four angles. The data acquisition of BLT is similar with CLT. While for the FMT, the laser source is used to excite the probe in the mouse. The EMCCD camera will detect the emission light of the probe. Similar with CLT, we collect four images for FMT. After molecular image data collection, we collect CT projection data with the X-ray source on. We acquire 360 projection views at 1 degree interval. 360 projection views are enough for high accurate CT imaging.

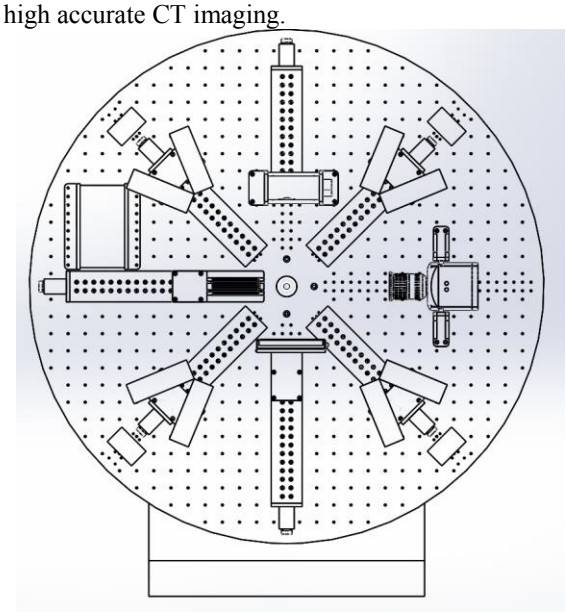

Fig. 7. The device layout for molecular imaging and CT.

When the data acquisition is finished, we perform 3D reconstruction for the five modalities and merge the results together. These operations are performed by using our multimodality imaging software. The following section will introduce the design of the software.

3. SOFTWARE DESIGN

We have designed a multimodality imaging software for our system. This software offers the functions of 3D reconstruction, multimodality image fusion, and further image processing. The multimodality imaging software is based on three softwares developed by our group. These softwares include Medical Imaging ToolKit (MITK) [7], 3Dimensional Medical Image Processing and Analyzing system (3DMed) [7], and Unified Reconstruction Software Framework for multimodal medical imaging (URSF) [8]. MITK is a C++ library for integrated medical image processing and analyzing. It contains mainstream segmentation, registration, and visualization. 3DMed is application software based on MITK with a friendly user interface. The multimodality image fusion and image processing can be implemented by MITK and 3DMed. URSF provides a unified software framework for image reconstruction. Currently it contains only CT and ultrasound reconstruction methods. However, it is easy to extend to PET and molecular image reconstruction.

Based on these softwares, the multimodality imaging software is designed to integrate URSF, MITK and 3DMed together. The 3D reconstruction is implemented based on URSF, while the image fusion and processing are done by MITK. 3DMed can be used as the user interface of our multimodality imaging software.

4. CONCLUSION

In this paper, we have reported the preliminary design of a multimodality system. This system is designed to perform PET, CT, FMT, BLT, and CLT together. These modalities are complementary. CT provides the structural imaging information which can assist image reconstruction of CLT, FMT, and BLT. Besides, PET and CLT can use single radionuclide labeled probe. PET can image disease deep in the tissue with a limit resolution of 2-3 mm. For completeness CLT can image superficial disease with better resolution [9]. Therefore, merge of PET and CLT can provide comprehensive functional imaging information.

The hardware structure design, data acquisition flow and software of our system are introduced in this paper. However, there are still lots of work to do before the real application of the system. Effective image registration and image fusion methods for different modalities are in great demand. Currently our system collects multimodality data one by one which is time-consuming. Further improvement to acquire two or more modalities at one time will be a good solution.

5. ACKNOWLEDGE

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