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Graphical User Interface for a Dual-Module EMCCD X-ray Detector Array

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Abstract

A new Graphical User Interface (GUI) was developed using Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) for a high-resolution, high-sensitivity Solid State X-ray Image Intensifier (SSXII), which is a new x-ray detector for radiographic and fluoroscopic imaging, consisting of an array of Electron-Multiplying CCDs (EMCCDs) each having a variable on-chip electron-multiplication gain of up to 2000 $\times$ to reduce the effect of readout noise. To enlarge the field-of-view (FOV), each EMCCD sensor is coupled to an x-ray phosphor through a fiberoptic taper. Two EMCCD camera modules are used in our prototype to form a computer-controlled array; however, larger arrays are under development. The new GUI provides patient registration, EMCCD module control, image acquisition, and patient image review. Images from the array are stitched into a 2k $\times$ 1k pixel image that can be acquired and saved at a rate of 17 Hz (faster with pixel binning). When reviewing the patient's data, the operator can select images from the patient's directory tree listed by the GUI and cycle through the images using a slider bar. Commonly used camera parameters including exposure time, trigger mode, and individual EMCCD gain can be easily adjusted using the GUI. The GUI is designed to accommodate expansion of the EMCCD array to even larger FOVs with more modules. The high-resolution, high-sensitivity EMCCD modular-array SSXII imager with the new user-friendly GUI should enable angiographers and interventionalists to visualize smaller vessels and endovascular devices, helping them to make more accurate diagnoses and to perform more precise image-guided interventions.

Keywords

Image Guided Interventions; Graphical User Interface; Solid State X-ray Image Intensifier (SSXII); Electron-Multiplying CCD (EMCCD); Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW); System

1. Introduction

To provide clinical functionality for the new high resolution solid-state x-ray image intensifier (SSXII) [1-5], consisting of an array of Electron Multiplication Charge-Coupled Devices (EMCCD), a new Graphical User Interface (GUI) was developed and implemented using Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW). The high-resolution, high-sensitivity EMCCD modular-array based SSXII imager with the new user-friendly GUI should enable angiographers and interventionalists to visualize smaller vessels and endovascular devices, helping them to make more accurate diagnoses and to perform more precise image-guided interventions.

2. Methods and Materials

2.1 EMCCD Array

EMCCDs are enhanced CCD image sensors with the unique feature that includes variable on-chip amplification of up to 2000 times provided in a matrix of $1k \times 1k$, $8\text{-}12\text{ }\mu\text{m}$ square pixels which we digitize to 12-bit depth. These low noise light sensors view an x-ray phosphor through a fiberoptic taper used to enlarge the field of view (FOV); however, an array of these modules is being built to further extend the FOV. Figure 1 shows the 1×2 EMCCD camera array.

The 1×2 array includes two identical cameras connected to a National Instruments (NI) PCIe-1430 dual-channel CameraLink pc board. The PCIe-1430 has two completely independent and asynchronous camera channels, which enables the fast parallel image acquisitions of the two EMCCDs.

2.2 SSXII System

Figure 2 shows an overview of the SSXII acquisition system with two EMCCDs.

The trigger adapter converts the 5 V trigger pulse from the Toshiba Infinix angiography x-ray system, used for detector synchronization, to 2.5 V, which is input to the SSXII. When the camera trigger mode is set to external trigger mode, the cameras start the integration period at the beginning of the external trigger from the x-ray generator.

3. Results and Discussion

The new Graphical User Interface (GUI) was developed and implemented using LabVIEW (NI, Austin, TX). Figure 3 shows the patient registration page, which is shown upon start-up.

Currently, the “Register” button is enabled for registering a patient, and the “Clear” button is to clear the input lines. Other functions e.g., search old patients, delete, urgent, etc., will be implemented. Upon a click of the “Register” button, the patient is registered, the patient directory and sub-directory is created, and the GUI is switched to the “Acquisition” page shown in Figure 4 with simulated image.

The images from camera #0/1 are then saved to the patient directory. The “Acq Frame Rate” is the acquisition/saving speed. Currently, the GUI can display and save 2k×1k images at a rate of 17 Hz (i.e., save 17 images for camera #0 and save 17 images for camera #1 in one second). Faster rates can be achieved with pixel binning. The “Flat Field Correction” and display of the mean and standard deviation (SD) of the selected region-of-interest are also built into the software. The left side of the playback page (Figure 5) shows the patient directory, in which the root of the directory is the patient ID (e.g. RB-10-001), and the sub-folder is the date_acq-mode_run# (e.g., 20100406_fluoroscopy_run001).

The operator can browse the patient directory and the images will be displayed on the right side of the playback page. Upon the mouse click of an image file, the operator has the option to display the selected file (e.g. by camera#0) or the selected file plus the file acquired by the other camera (e.g. by camera#1) by specifying the “Click Disp Option”. The images can also be navigated by moving the slider (the number on the slide is the file index) below the displayed image with the “Drag Disp Option” to select whether to display the image from camera#0, or camera#1, or camera#0 plus camera#1. The camera parameters can be accessed by pressing the “Get #0/1 Status” button on the “Camera Settings” page shown in Figure 6.

At the top of the “Camera Settings” page, the “Camera Selection” control enables the user to select the cameras in use: camera #0, camera #1, or both camera #0 and #1. The first column of the “Status String”, is the status key-word, e.g. “G” is for video gain; the second column is the name of the status; the third column is the hexadecimal value of the status. Each time the “Get#0/1 Status” button is pressed, a text file containing all the statuses will be generated. The two cameras' parameters, which include the exposure time, trigger mode, and EMCCD gain (Figure 6), can be accessed and modified.

The GUI provides a user-friendly interface that allows the operator to acquire and save images using the SSXII. Patient registration, patient image navigation, and camera parameter acquisition and control are built into the software. The initial 1×2 EMCCD camera array can be expanded for larger FOVs. Images such as that appearing in Fig. 4 are now being acquired for the first time by such an EMCCD-based array detector.

4. Conclusions

A new Graphical User Interface (GUI) gives users the control and acquisition capability for a unique new EMCCD-camera array. The GUI is designed to accommodate expansion of the current dual-module EMCCD camera array to substantially larger arrays for increased FOVs. The control and acquisition capabilities, along with the electron multiplication gain, high-resolution, high-sensitivity, and real-time imaging capabilities of the EMCCD camera array should provide angiographers and interventionalists with an improved ability to visualize details of small vessels and endovascular devices, making diagnoses and image-guided interventions more accurate.

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Figure 1. 1x2 EMCCD camera array

Figure 2. SSXII acquisition system with two EMCCDs

The screenshot shows a patient registration form with the following elements:

- Buttons:** Urgent, Routine, Start Study, Finish Study, Register, Update, Cancel, Clear, Other Info.
- Study_Date_Time:** 04:47 PM, 15/07/2010 (with a calendar icon).
- Accession_No:** (empty text field).
- Study_Protocol:** Manual (dropdown menu).
- First Name:** 20100715 (text field).
- Last Name:** (empty text field).
- Patient ID:** 20100715-xray (text field).
- Date of Birth:** 07/15/2010 (with a calendar icon).
- Age:** 0 (text field).
- Sex:** Other (dropdown menu).

Figure 3. Patient registration page

Figure 4. Acquisition page with a $1k \times 2k$, 2-module simulated image displayed

Figure 5. Playback page

Figure 6. Camera settings page