A Customized Data Acquisition Software for a Three-Dimensional Cubic Electronic Detector Array for Radiotherapy

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***Abstract*—A customized data acquisition software has been designed which allows to acquire data from a radiotherapy 3D cubic electronic detector array consisting of 23 x 23 active detector elements distributed in 5 matrixes. The software provides reliable data acquisition for different irradiation rates and beam energies available in radiotherapy linear accelerators (linacs). The sensor array is connected to a specialized multichannel current input analog to digital converter managed by an FPGA which communicates with a PC via USB interface and a STM32 microprocessor to synchronize the data acquisition.**

Keywords— radiotherapy, 3D detector, active matrix

I. Introduction

Advances in radiotherapy technology have transformed high-precision high-dose radiotherapy treatments into routine patient treatment modalities worldwide. Accessibility to these advanced treatments justify the need for more accurate 3D quality assurance (QA) and radiation dose verification prior to initiating the actual treatment on a patient.

Unavailability of a 3D electronic detection systems for this purpose, prompted us to develop a 3D cubic electronic detector array based on active matrixes. The active-matrix concept [1] [2] allows for fast data readout of many detector elements while sharing data channels (multiplexing).

This study describes a prototype 3D cubic electronic detector array and its specialized acquisition system including customized software tailored to the needs encountered in radiotherapy.

The software consists of three separate domains: control software, which manages the FPGA and the STM32 signals; The acquisition software and the data analysis software.

II. Three-Dimensional Cubic Electronic Detector Array Prototype

A. The 3D Detector Array

The 3D cubic detector array consists of a 30 x 30 x 15 cm^3 PMMA phantom (Figure 1) with five active matrixes (AMs).

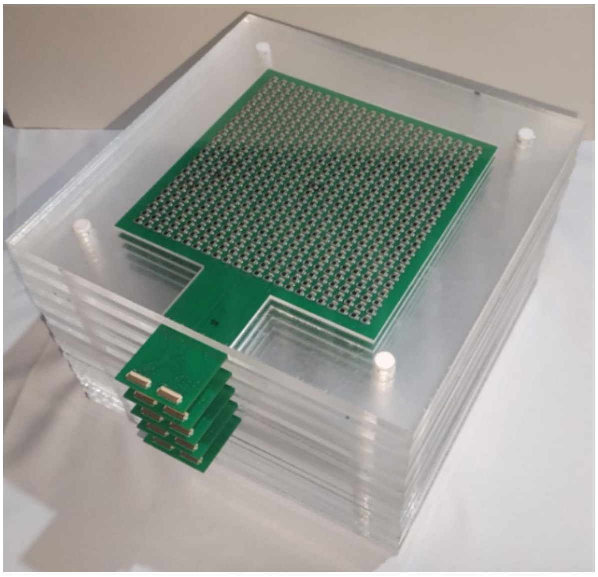

Figure 1- 3D detector array with the five active matrixes.

During operation, a radiotherapy beam percent depth doses curves (PDDs), profiles, and output factors can be acquired simultaneously with few monitor unit (radiotherapy linac dose settings), and without beam scans, as performed in a water phantom. This is a significant time savings for the user. Each AM has 529 detector elements (with a total of 2645 elements in the 3D detector array) distributed in 23 columns and 23 rows with 0.8 cm separation between elements and with a 20 x 20 cm^2 detection area (Figure 2).

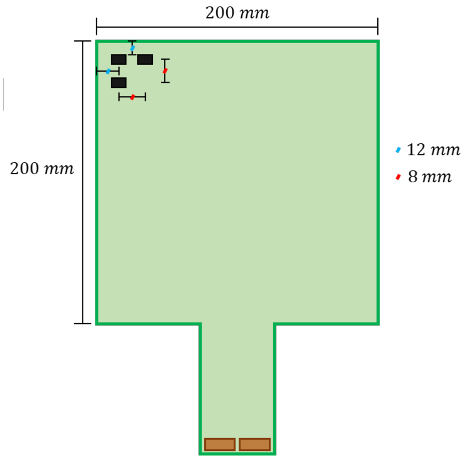

Figure 2 - spatial disposition of the active elements in the matrix.

B. Detector Element and Active Matrix

A detector element in an active matrix consists of a photodiode, capacitor, and a MOSFET (Figure 3). When a radiation beam hits the photodiode, charges are released and then accumulate in the capacitor [3].

During data collection, the charge accumulated in the capacitor is read by a current input analog to digital converter where is digitalized and then the raw value stored in a high-speed volatile memory. All the charges accumulated in the board are "hard reset" by control electronics before a capture process.

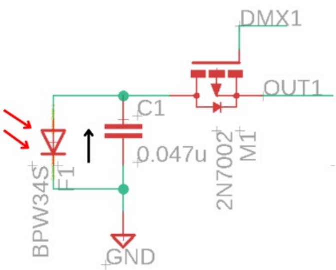

Figure 3- Active detector element.

C. Acquisition hardware

The acquisition hardware is made up of several cards, being the main one the DDC264EVM [4] (Figure 4), an evaluation module with four DDC264 [5], 64 channels current input, 20-bit analog-to-digital (A/D) converter, controlled by a Xilinx Spartan FPGA which provides the glue logic, signals needed and stores the data temporary in 16 MB of memory. For transfer the captured data to the PC, the board has a Cypress USB interface.

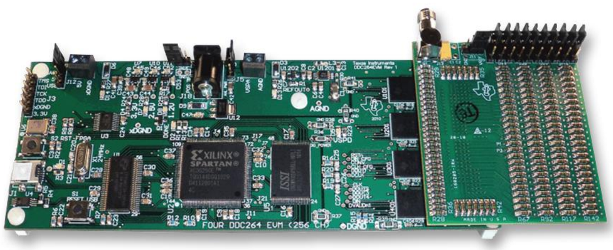

Figure 4 - DDC264EVM Main data acquisition board.

The active matrixes are connected to analog multiplexers controlled and synchronized by and STM32 board, the Figure 5 shows a representation of the connectivity between the active matrix and the PC.

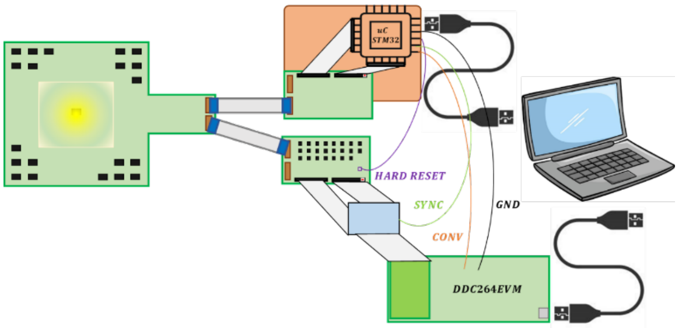

Figure 5 – Pictorial diagram of the connectivity.

The Figure 6 shows how actually the active matrixes are connected to the acquisition system.

Figure 6 - Connectivity of the acquisition system.

III. The Software

The software can be separated into three main components according to their function:

A. Control Software

Consist in the firmware and software that generates and controls the signals for capture and move the data. The FPGA configuration (Verilog) accepts several parameters that controls the timing and acquisition made by the DDC devices, that parameters are critical for a proper data capture. The parameters can be read and set dynamically through the USB interface.

B. Acquisition Software

For proper configuration of the acquisition system, it is necessary an acquisition software where the user can set the parameters according to the current experience. This software consists of a library that serves as an interface for the hardware and a capture software that takes, organizes and stores the data on the PC.

Because the software provided by the manufacturer of the DDC264EVM lacks proper documentation and doesn't adjust to the application, a custom library in C++ was made analyzing the signals and realizing some inverse engineering.

The capture software (Figure 7) was programmed in C# and consist in a console application that accept configuration parameters in the command line which are used to configure the FPGA and the DDC in the main acquisition board.

```
DataCapture: Adquisition software for the DDC264EVM
Miguel Risco-Castillo (c) 2024 Version: 2.5

  --ccf n Sets CONV_CONFIG to n, default: 0
  --cfl n Sets CFGLOW to n, default: 0
  --cfh n Sets CFGHIGH to n, default: 7
  --cvl n Sets CONV_LOW_INT to n, default: 1600
  --cvh n Sets CONV_HIGH_INT to n, default: 1600
  --chc n Sets CHANNEL_COUNT to n, default: 256
  --nvi n Sets NDVALID_IGNORE to n, default: 0
  --nvr n Sets NDVALID_READ to n, default: 256
  --ro    Read only configuration registers
  --wcf   Write configuration registers
  --y     Do not request "press s" confirmation

Example: DataCapture --chc 128 --nvr 512
```

Figure 7- Screenshot example of the capture software.

C. GUI and Analysis Software

The final component of the software consists of the graphic user interface and the data analysis software which was built in Matlab and takes the data captured by the previous software components and give to the data a meaningful significance.

The Figure 8 shows a capture of the first stage of the data analysis, where the raw data is calibrated by using a previously acquired transfer functions for each detector element of the matrixes.

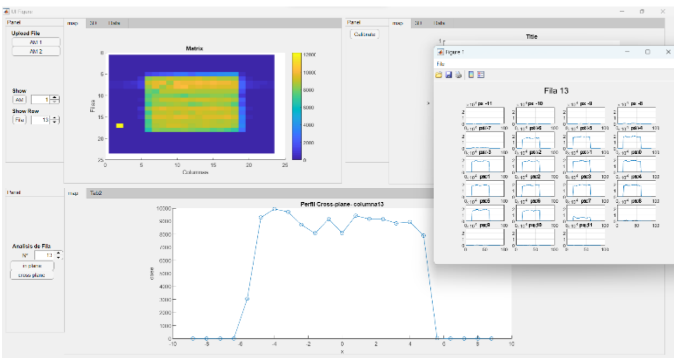

Figure 8- GUI and Analysis Software

The Figure 9 shows the next stage of the analysis software with the data already processed and shows it in a 3-dimensional way.

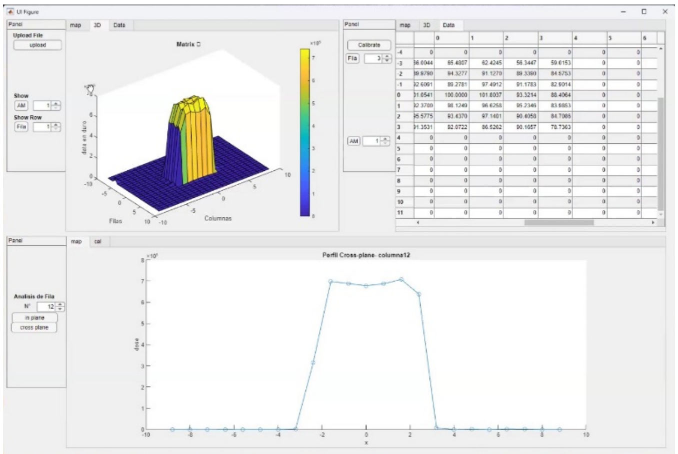

Figure 9 – 3-dimensional representation of the acquired data.

Finally, the acquired calibrated data can be interpolated for a smoother representation. The Figure 10 shows a reduced field of exposition of the first matrix.

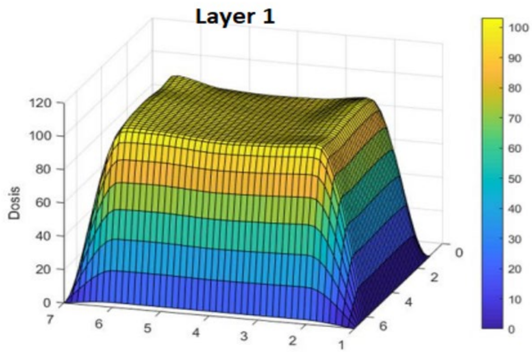

Figure 10 - Example of interpolated data from the first matrix.

Although the analysis software has not yet been completed, the current development has made it possible to verify the feasibility of data acquisition from a 3-dimensional detector [6].

IV. Conclusion

A fully software chain for data acquisition and analysis for a prototype of 3-dimensional electronic detector array for radiotherapy was implemented.

The control and acquisition software components successfully complete the configuration and data formatting/storing.

It was possible to build own libraries and tools to customize the appropriate timing and data capture and where was not possible with the available libraries and software.

The designed software allows to verify the feasibility of acquiring linac commissioning data with a three-dimensional electronic detector array.

Further research and implementation are needed to complete the GUI and analysis software.

Figure 11 - linac and the acquisition system setup.

V. References

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