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Data acquisition and processing software package for Medipix2

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Abstract

The semiconductor pixel detector Medipix2 [1] (256×256 square pixels, $55 \times 55\,\mu m^2$ each) is a superior imaging device in terms of spatial resolution, linearity and dynamic range. This makes it suitable for various applications such as radiography, neutronography, and micro–tomography. The software package for acquisition and data processing has been developed to control and manage complex measurements. The solution features an open and very flexible modular architecture with custom made plugin support. Plugins can control parts of the acquisition system as well as perform real-time data processing and use these results as feedback for controlling further steps of measurements. This allows us to control, e.g. data acquisition, position and rotation of the sample (stepper motors), source parameters, temperature, etc. in a synchronized way. An example is the adaptive tomography plugin which adaptively controls the measurement and benefits from preprocessing performed by other plugins such as the beam-hardening correction of measured projections.

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Keywords: Medipix; Software; Radiography; Tomography; Beam-hardening

1. Introduction

This paper describes the acquisition and data processing system for the Medipix2 device [1]. Medipix2 is a semiconductor pixel detector (256×256 pixels, $55 \times 55\,\mu m^2$ each) for single-photon counting. Each pixel contains two discriminators, two 3-bit thresholds adjustments and a 13-bit pseudo-random counter. This device offers very good spatial resolution and unlimited dynamic range which makes it suitable for radiographic and tomographic measurements. Complex experiments such as tomographic measurements require controlling different devices in synchronized way. The need arises to enable controlling of this type of experiments without repetitive and error-prone manual control. The software package was designed to allow control of complex experiments with Medipix2 devices.

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2. Software architecture

The software package has an open and very flexible modular architecture with custom-made plugin support enhancing its functionality to fit experimental needs. A simplified schema of the system is given in Fig. 1.

2.1. Hardware libraries

Medipix2 devices are connected to the personal computer by a hardware interface (MUROS/National Instruments card [2], USB [3]). One hardware library corresponds to each interface type. This library has exclusive access to the connected devices and provides a set of exported functions for interface hardware control, detection and diagnostics. Through these functions the Control library can access each Medipix2 device in an interface independent way.

2.2. Medipix control library

The Medipix control library can handle in principle an unlimited number of Medipix devices which can be

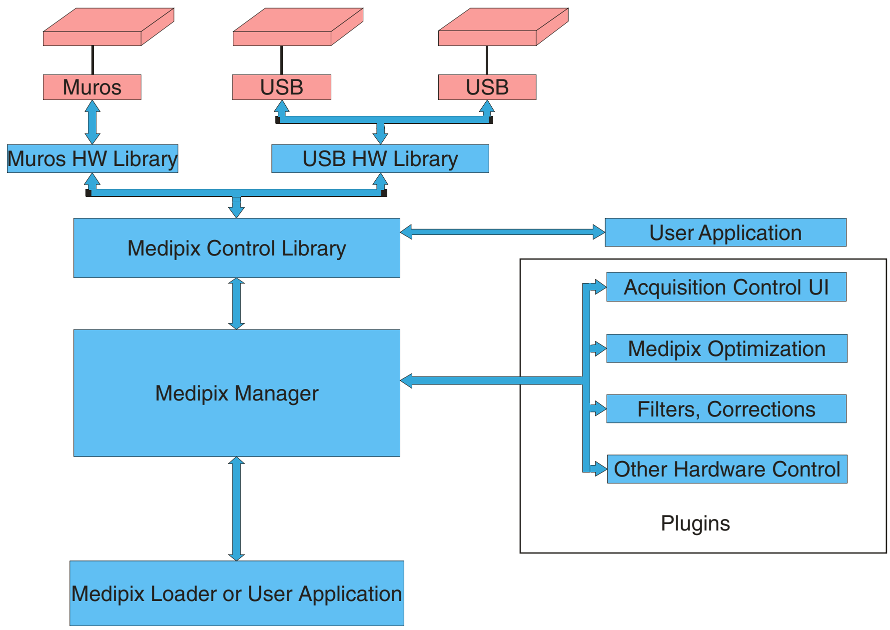

Fig. 1. Architechture of the software package.

connected to PC via different interfaces. The library provides synchronized access to these devices, multiple acquisition control, data buffer handling and configuration management. A custom-made external application can use the library directly. The library also provides event notification about acquisition progress. Events are directed to the Manager library or to some external application.

2.3. Medipix manager

A Medipix Manager library handles plugin management and mediates access to the Medipix Control library. It provides synchronization and communication between plugins and maintains the public register of functions, events and filter chains.

2.4. Plugins

Plugins can contain user interface, control experiment-specific hardware as well as perform online data processing or control the entire experiment. They can access through the Manager the Control library functions or also functions offered by other plugins. Each plugin can add its own functions or call any of the already registered functions. The plugins can also define new events or can be notified when an existing event occurs.

2.5. Medipix loader

The Medipix Loader is responsible for Medipix Manager initialization and for building a tray menu from registered items.

3. Adaptive tomography

An example of a complex measurement that can be controlled by the software presented is a tomographic measurement (see Fig. 2). Such experiment can be performed by a dedicated tomography plugin that can control the entire measurement. Stepper motor movement control functions (provided by another independent plugin) are requested from the Manager library. The tomography plugin then also registers itself to be notified about events from data acquisition and motor movements and creates a filter chain containing a filter for beam-hardening correction. During measurement the plugin can evaluate the reconstruction from projections already taken and use this information for adaptive control of further steps. This enables us to decide whether additional projections will increase the quality of reconstruction and to find angles at which these projections should be taken. The projections measured by the system automatically pass through the created chain of filters containing the beam hardening correction.

3.1. Plugins

The rotation of the sample is controlled via USB by a stepper motor plugin. This plugin controls several stepper motors in the experiment (e.g. rotation of sample, *X*–*Y*-position of Medipix2 detector) and registers in Manager its functions for movement and configuration (e.g. acceleration, maximal speed, calibration) of all motors. The plugin raises an event when a motor reaches its destination.

Real-time data-processing plugins can contain “filters” which can be chained to very effective data-processing

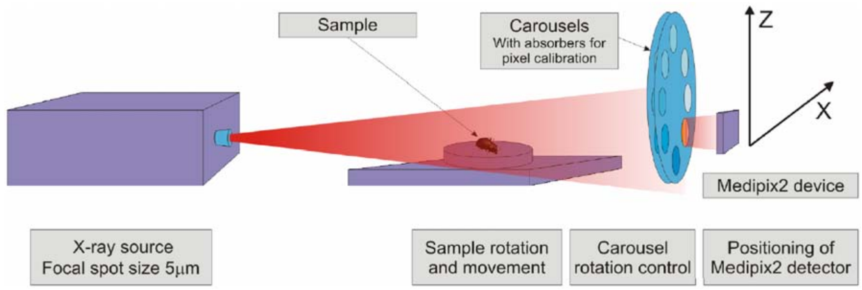

Fig. 2. Setup for tomographic measurements.

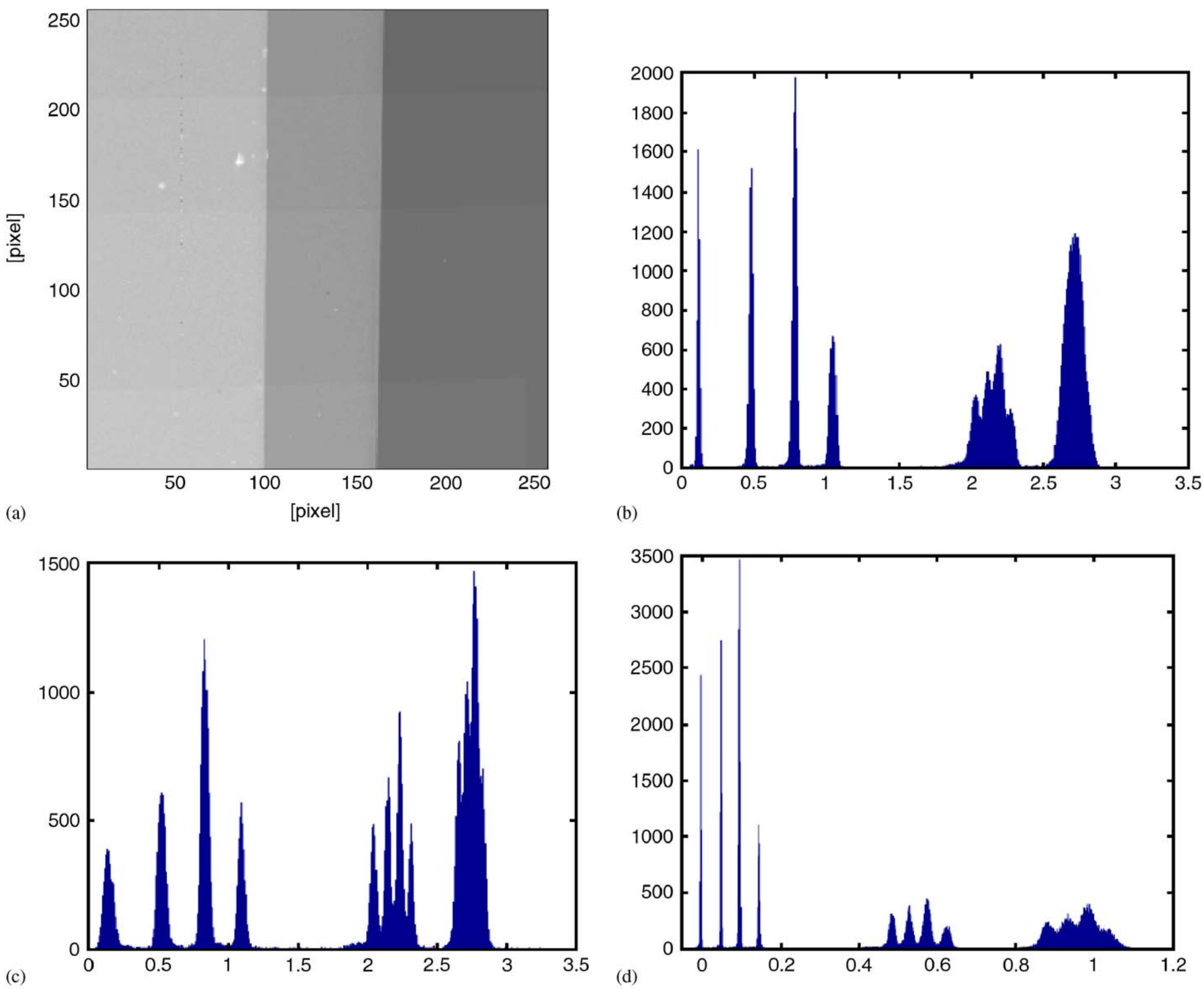

Fig. 3. (a) Image of overlapping Al plates of different thicknesses. Histograms of negative logarithms of normalized images (~thickness) after corrections; (b) flat-field correction with open beam; (c) flat-field correction with 1 mm Al plate; (d) BH correction.

sequences. In this way a plugin can get the result of processing chain of filters instead of raw data. An example of such filter is the X-ray beam-hardening correction which is used by tomography plugin to suppress beam-hardening effect.

The phenomenon of beam-hardening arises due to the preferential attenuation of lower-energy X-rays in a polychromatic spectrum as it penetrates through the material. This results in a change in spectral profile. In general the change is towards a profile with a higher average energy which penetrates more efficiently than does the initial spectrum, hence the term hardening applies. When a non-homogenous object is inspected, the X-ray spectrum varies across the image. As each pixel of Medipix2 device has a unique dependence of detection efficiency on energy, additional image non-uniformities are introduced. Therefore, per-pixel beam-hardening correction has to be performed to suppress this effect.

The beam-hardening correction [4] plugin offers a filter function for suppressing the beam-hardening effect. The correction is made by calibration of each pixel response to an equivalent absorber thickness. The data for calibration can be obtained automatically with the help of tailored-made carrousel with calibration samples of different thicknesses. Carrousel movement is driven by two stepper motors.

The difference between standard flat-field correction and beam-hardening correction is shown in Fig. 3. It can be clearly seen that the flat-field correction using open beam image removes non-uniformities in the thinnest parts of the object. Using a 1 mm thick aluminum plate improves the resolution for the thick parts, but introduces "noise" in the thin parts (distributions corresponding to thin parts become wider, see Figs. 3b, c). Best resolution is achieved using beam hardening correction with possible discrimination of all 12 thickness levels (see Fig. 3d).

4. Experimental setup and results of the first tests

The experimental setup [5] is shown in Fig. 4. Test objects were measured under the following conditions:

- A tungsten X-ray tube operated at 90 kV and 0.1 mA with focal spot size of 5 μm.
- A 300 μm silicon sensor with bias voltage of 100 V.
- Equalized threshold level of individual pixels corresponding to about 6 keV.
- Temperature of the Medipix2 device was stabilized by water cooling system at 15°C.

The beam-hardening correction plugin used for calibration a set of aluminum foils and plates with thickness from 0.05 to 2.7 mm.Between each pair of calibration points the pixel response was estimated using an exponential interpolation.

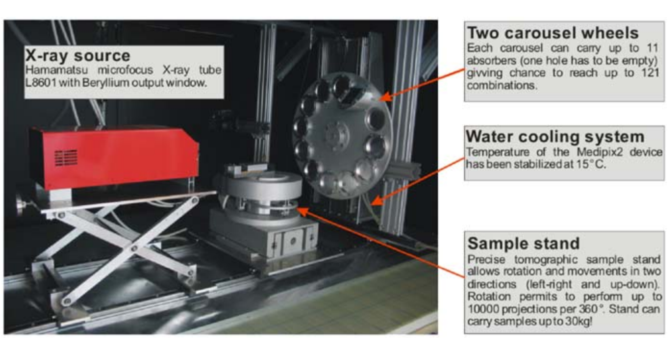

Fig. 4. View of the experimental setup.

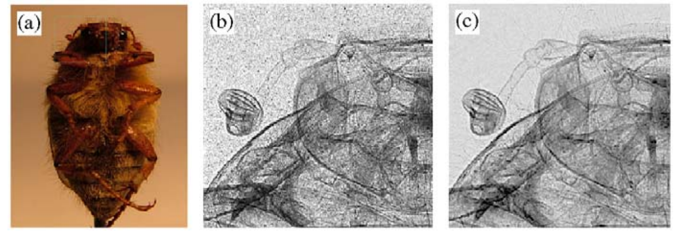

Fig. 5. (a) Maybeetle photo; (b) projection without correction; (c) projection with beam-hardening correction.

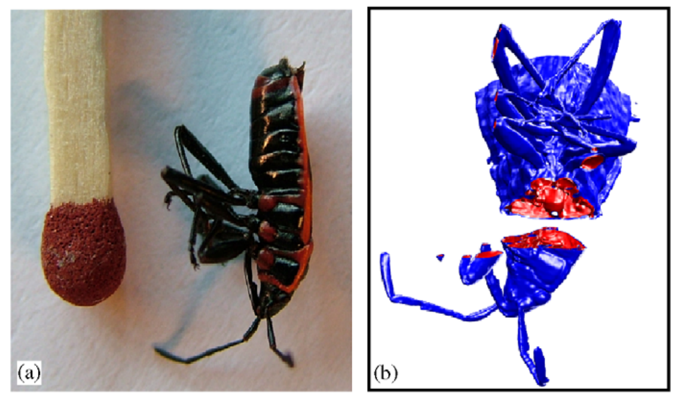

Fig. 6. (a) Photo of beetle; (b) 3D reconstruction of beetle.

The difference between projection with and without beam-hardening correction is illustrated in Fig. 5 on the measurement of a maybeetle.

The 3D image created from tomographic reconstruction of slices of the sample object (beetle) is shown in Fig. 6. The reconstruction was performed from 180 projections, each with exposition time of 10 s. The back-projection algorithm [6] has been used for tomographic reconstruction.

5. Conclusions

The complete data acquisition and processing software package has been developed and successfully tested in various measurements. The resulting applications include:

- Adaptive X-ray tomography.
- X-ray dynamic defectoscopy [7], X-ray inspection of crack evolution inside loaded solid bodies. Tomographic measurements are performed during load and defects are evaluated.
- Neutron transmission micro-tomography [8].

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References

[1] CERN Medipix colaboration, http://www.cern.ch/MEDIPIX/
[2] D. San Segundo Bello, M. Van Beuzekom, P. Jansweijer, H. Verkooijen, J. Visschers, Nucl. Instr. and Meth. A 509 (2003) 164.
[3] Z. Vykydal, J. Jakůbek, M. Platkevič, S. Pospíšil. USB interface for Medipix2 pixel device enabling energy and position detection of heavy charged particles, contribution to the 7th IWORID, 4–7 July 2005. Grenoble, France.
[4] J. Jakubek, D. Vavrik, S. Pospisil, J. Uher, Nucl. Instr. and Meth. A. 546 (1–2) (2005) 113.
[5] D. Vavrik, J. Jakubek, T. Holy, M. Jakubek, Z. Vykydal, Experimental system for high resolution X-ray transmission radiography, in: IWORID 2005.
[6] A.C. Kak, M. Slaney, Principles of Computerized Tomographic Imaging, IEEE Press, New York, 1988.
[7] D. Vavrik, J. Jakubek, S. Pospisil, J. Visschers, J. Zemankova, Non-destructive Observation of Damage Processes in Precracked Specimens by X-ray Dynamic Defectoscopy. The Annals of the Marie Curie fellowships, Vol. 3, Office for Official Publications of the European Communities, Luxembourk, 2004, pp.69–75, ISBN92-92-894-72332.
[8] J. Jakubek, T. Holy, E. Lehmann, S. Pospisil, J. Uher, J. Vacík, D. Vavřík. Properties of neutron pixel detector based on Medipix-2 device. in: Proceedings of one IEEE Nuclear Science Symposium published on CDROM, 16–22 October 2004, Roma, Italy.