Characterization of wireless personal dosimeter prototype for Interventional Radiology medical operators

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I. INTRODUCTION

- Interventional Radiology (IR) is a minimally invasive diagnostic and therapeutic procedures performed using radiological devices to obtain image guidance:
  - high levels of exposure of patients and medical staff to X-rays can induce detrimental effects
  - international guidelines in radiation protection restrict the number of procedures that operators can undertake [NCRP 133].
- External monitoring is currently acquired through passive personal dosimeters [effective dose (whole body) and equivalent dose (hands, arms, legs,...)].
- The authors present the characterization and calibration of a wireless dosimeter prototype to perform on line monitoring of the staff during interventional procedures, by using a CMOS Active Pixel Sensor as radiation detector.

II. THE ACTIVE PERSONAL DOSIMETER

- Main features of the commercially available active personal dosimeters:
  - semiconductor technology
  - real-time evaluation of dose and/or dose rate
  - alarm at a pre-set dose and/or dose rate level (opt.).
- Performance is not satisfactory for X-ray fields used in IR procedures (low energies and pulsed fields) [Villani, 2013]. With pulsed X-ray beams the response decreases:
  - as the dose equivalent rate increases
  - from 10 to 40% when pulse rate increases from 1 to 20 ps.
- We propose a device based on an Active Pixel Sensor (APS) based on the following requirements:
  - sensitivity from 5 to several tens of keV photons (X-ray) dose and dose rate measurement accuracy better than 10%
  - wireless device
  - small form factor and lightweight (wearable).
- System architecture:
  - Sensor
  - Digital signal processing unit
  - Control unit
  - Wireless interface
  - Graphical user interface.

III. THE DOSIMETER PROTOTYPE RAPID-0

- A first dosimeter prototype, RAPID-0, has been constructed using commercial components (sensor board, microcontroller with wireless module) and a custom board where are hosted the CPLD for data elaboration and services.
- CMOS image sensors can be used as ionizing radiation detectors [Servoli, 2012].
- The selected sensor (11.43 x 11.43 mm\textsuperscript{2} package form factor) is a standard VGA (640 x 480 pixels), 5.6 x 5.6 µm\textsuperscript{2} pixel size, optimized for 30 fps.

IV. THE CALIBRATION PROCEDURE

- Photon detection is carried out by using a clustering algorithm to reconstruct the photon energy grouping all the pixels where the signal has been divided.
- Only a limited number of pixels shares the signal generated by the photon with a weak dependence from photon energy, in the tens of keV range.
- Single photon identification can thus be used to measure the photon flux.
- The sensor response to the X-ray radiation has been calibrated using monochromatic (fluorescence) or quasi-monochromatic (transmission) photon beams.
- The calibration coefficient is known with a precision better than 5%.
- The prototype has also been tested in real Interventional Radiology procedures. The 10 Hz acquisition rate allows to follow closely the X-ray tube operations.
- A precise monitoring of the absorbed dose during the procedure hence become possible.

V. TEST WITH DIFFUSED X-RAYS

- The prototype has been calibrated using monochromatic (fluorescence) or quasi-monochromatic (transmission) photon beams.
- The sensor performance as an X-ray radiation detector has been evaluated with a dedicated experimental set-up.
- Two dosimetric observables have been assessed from the frames acquired by the sensor using a clustering algorithm.
- Two different dosimetric quantities being compatible with the real time requirements have been defined from a subset of the collected data.

VI. CONCLUSIONS

- Intervencion radiology (IR) is a minimally invasive diagnostic and therapeutic procedures performed using radiological devices to obtain image guidance:
  - high levels of exposure of patients and medical staff to X-rays can induce detrimental effects
  - international guidelines in radiation protection restrict the number of procedures that operators can undertake [NCRP 133].
- External monitoring is currently acquired through passive personal dosimeters [effective dose (whole body) and equivalent dose (hands, arms, legs,...)].
- The authors present the characterization and calibration of a wireless dosimeter prototype to perform on line monitoring of the staff during interventional procedures, by using a CMOS Active Pixel Sensor as radiation detector.

References

- [NCRP 133] National Council on Radiation Protection and Measurement, NCRP, “Radiation protection for procedures performed over a frame shows a linear correlation with measured dose by TLD.

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