An online change of activity in energy spectrum for detection on an early intervention robot

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***Abstract*— With the growth of industrial risks and the multiplication of CBRNe (Chemical Biological Radiological and explosive) attacks through toxic chemicals, biological or radiological threats, public services and military authorities face with increasingly critical situations, whose management is strongly conditioned by fast and reliable establishment of an informative diagnostic. Right after an attack, the five first minutes are crucial to define the various scenarii and the most dangerous for a human intervention. Therefore the use of robots is considered essential by all stakeholders of security. In this context, the SISPEO project (*Système d'Intervention Sapeurs Pompiers Robotisé*) aims to create/build/design a robust response through a robotic platform for early intervention services such as civil and military security in hostile environments. CEA LIST has proposed an adapted solution to detect and characterize nuclear and radiological risks online and in motion, using a miniature embedded CdZnTe (CZT) crystal Gamma-ray spectrometer.**

This paper presents experimental results for this miniature embedded CZT spectrometer and its associated mathematical method to detect and characterize radiological threats online and in motion.

***Index Terms*— Radiological measurements, Embedded electronics, Micro-sized Spectrometer, Gamma-ray Spectrometer, Radionuclide identification, Robotic platform**

I. Introduction

THE CdZnTe (CZT) crystal detector allows gamma-ray spectrum measurements at room temperature with enough intrinsic resolution to be associated with a mathematical method for spectrometric analysis.

This paper presents experimental results for this miniature embedded CZT spectrometer on the SISPEO robotic platform and its associated methodology to detect radiological threats online and in motion. Section II presents the miniature embedded CZT spectrometer integration on the robot. In section III, the approach to detect and identify radioisotopes is described and results are discussed in section IV. Section V concludes this paper.

This work was supported in part by the frame of the FUI program (*Fonds Unique Interministériel*) SISPEO Grant.

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II. CZT Spectrometer Integration on Robot

In the context of the SISPEO project, the principle was to design a specific CBRNe platform on a robot provided by ECA Robotics Company. It is major to achieve an as fast as possible detection and identification especially in case of emergency involving potential nuclear or radiological threats. The industrial version of the CEA LIST miniature embedded CZT spectrometer [1] is provided by IMS Company as presented on Figure **1**. One of the advantages provided by this detector [2] is to allow gamma-ray spectra fast and efficient measurements at room temperature with high intrinsic energy resolution, ~3% at 661 keV (^{137}Cs), required for radioisotopic separation in case of mixt signals due to more than one radionuclide detected.

Figure 1: IMS miniature embedded CdZnTe crystal gamma-ray spectrometer

This device was integrated on the SISPEO robot and once communication established with the spectrometer an especially designed algorithm method allows spectra measured analysis online and in motion to provide to the user direct results management and reading on the pilot screen. The robot driver manages this device directly from the pilot driver PC, he can activate it and get every 2 second(s) a new spectrum to be analyzed through a specific library to name the radionuclide in case of a detection. At the same time this spectrum is analyzed in details on the expert PC as presented on Figure **2** and Figure **3**.

Figure 2: Pilot driver PC

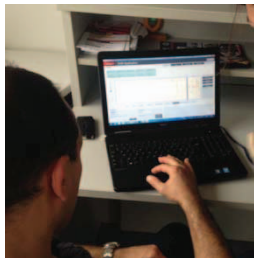

Figure 3: Expert PC

Figure 4 shows the CZT spectrometer embedded on the SISPEO robot during validation tests.

Figure 4: SISPEO robotic platform

III. Identification Approach

In the proposed approach, the process consists in two steps, detection followed by identification. The detection step consists to analyze the variation between two consecutive spectra. Then the identification is based on a distance calculation [3] from the current spectrum to a set of isotope reference stored in a database. Each spectrum represents data collected during 2 seconds as presented in Figure 5. After normalization based on Equation 1, the unknown spectrum is then compared to a database built on standard radioisotopes reference spectra to determine with a given level of confidence the nature of the radioisotope detected according to a statistical match between the measured and reference spectra.

$$c'(n) = \frac{c(n)}{\sqrt{\sum_{i=0}^{N} c(i)^2}} \qquad (1)$$

- C (n) - Number of counts in channels for the n input spectrum,
- C '(n), the new number of counts in the standard spectrum,
- N - the number of channels in the spectrum,

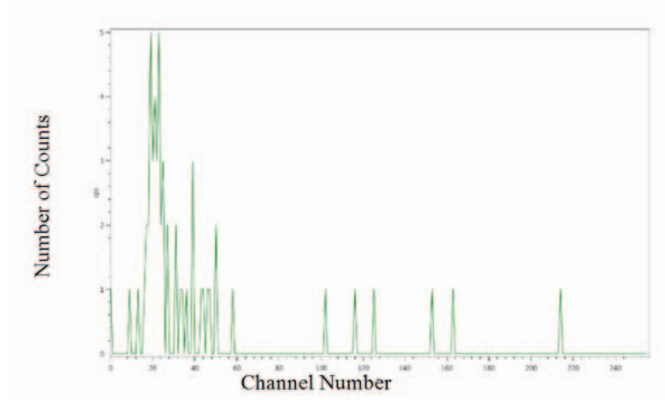

Figure 5: 1s ^{137}Cs spectrum

IV. Results

The following configuration is used to perform spectra acquisitions; SISPEO robot with embedded CZT and an expert PC [4]. A specific Graphical Unit Interface, Figure 6, has been developed to show identification results. The user can select a list of isotope references to be compared to the unknown source for identification and set algorithm parameters.

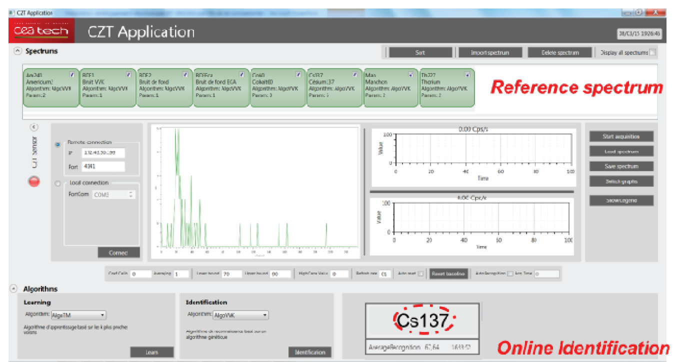

Figure 6: Specific GUI for the expert PC

A. Static sources identification

In order to validate the approach, we record a data base made of background and 4 isotopes measurements, ^{241}Am, ^{137}Cs, ^{60}Co and ^{152}Eu. All spectra are changed into normalized vectors. First test sets are performed for sensitivity evaluation of our approach with various energy emissions kinds. Tests are performed in laboratory conditions.

The background counting rate measured during the test campaign is of 6 counts per second in the total spectrum. Table I provides the lower counting rate limit that enable the system to identify a given radioisotope.

TABLE I Static results

Unknown isotope	Isotope counts in the spectrum
^{241}Am	26
^{137}Cs	22
^{152}Eu	24
^{60}Co	30

In each case the system was able to identify the isotope. The activity identification limit depends on the background counting rate.

B. *Identification of unknown isotope in motion*

To evaluate the dynamic response of our system, we set an experimental real scene in a specific area on which we placed various radioactive sources of different nature. In comparison with the static mode described in section A we added a liquid source of ^{99}Tc. Before the demonstration the new model was stored in the database. The driver, without any localization information on the sources, tries to find and identify the different contamination area as presented on Figure **7**, using the SISPEO robot including the embedded CZT.

Figure 7: Test area where various sources of different nature have been placed

The system shows the ability to detect and identify in motion radioisotopes in place even low activity sources thanks to the CZT crystal fully integrated detector performances (see Figure **8**). However, a case was proved difficult since one of the sources was shielded in a led container.

Figure 8: Detection of 60Co source

V. Conclusion

The proposed method shows the ability of the overall system to detect and identify radioisotopes using a CdZnTe fully integrated gamma-ray spectrometer embedded on a robot at low statistics in the count rate when in motion. The main limitation is the number of mixed sources that the method is able to identify at the same time.

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