FROM RESEARCH TO INDUSTRY

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REAL-TIME RADIONUCLIDE IDENTIFICATION IN GAMMA-EMITTER MIXTURES BASED ON SPIKING NEURAL NETWORK

Bobin, C., Bichler, O., Lourenço, V., Thiam, C., Thévenin*, M.

CEA, LIST, CEA/Saclay, 91191 Gif-sur-Yvette Cedex, France

*Corresponding author: Mathieu.Thevenin@cea.fr

1. Context and Motivations

Natural γ-emitters can be used to hide a radioactive material trafficking. Portal monitors used in homeland security applications require a fast response time (<10 s). Alarms are triggered on count rate variations. In a second time radionuclide identification is performed by an operator.

Objective: automated fast online radionuclide identification working at low-statistics is required for security and monitoring applications.

2. The Proposed Approach

Classification problem → neural network

In spiking neural networks: data is encoded using spikes processed sequentially. In our case pulses obtained from a γ-detector are equivalent to spikes.

The problem is to estimate the probability that a given radionuclide is the cause of the current event observed on a specific channel.

→ typical Bayesian classification

A sequential Bayesian Neural Network to identify a specific γ-emitter in a mixture is proposed.

3. Implementation of the Algorithm (Fig. 1)

For a mixture of radionuclides, for each triggered pulse, the code is executed for the corresponding channel i (amplitude coding).

Then, the code calculates the posterior probability $Pr(A_k|i)$ that a radionuclide A_k is the cause of the activation of the channel i.

$$Pr(A_k|i) = \frac{Pr(A_k).Pr(i|A_k)}{\sum_1^n Pr(A_j).Pr(i|A_j)} = \frac{Pr(A_k).w_{ik}}{\sum_1^n Pr(A_j).w_{ij}}$$

The prior probability $Pr(A_k)$ (Fig. 2) is an estimator of the proportion of the radionuclide A_k in the mixture. It is calculated using a counter C_k incremented by the posterior probability.

With $Pr(i|A_k) = w_{ik}$ the probability to have the channel i activated given a radionuclide A_k. The w_{ik} are initalized using the individual spectrum of each radionuclide of the database.

The identification of the presence of a radionuclide A_k is performed by a logarithmic activation Act function applied on $Pr(i|A_k)$.

4. Validation of the approach

Validation of the convergence of $Pr(A_j)$ toward the mixture proportion

- mixture of 5 radionuclides (^{60}Co, ^{133}Ba, ^{137}Cs, ^{207}Bi, ^{241}Am) using 2048-channel spectra measured with the high-efficiency NaI(Tl);
- mixture spectrum is used to generate random trains of pulses used as input (illustrated by step 3 in Fig. 1); repeated 100 times;
- algorithm convergence is tested by means of Monte-Carlo calculations according to increasing numbers of amplitudes.

No deviation with the expected proportion (Tab. 1).

Validation of the capability of the approach to identify radionuclides in mixture (observed outputs are Id_k) at low-statistics:

- tests on mixture containing 40% of ^{60}Co, 35% of ^{133}Ba and 25% of background (20 counts.s^{-1} in the high-efficiency NaI(Tl) detector);
- decision after 240 counts corresponding to a 3 s mean duration.

On 10000 repeated tests: 5 false alarms on the presence of ^{207}Bi and none for ^{137}Cs; ^{133}Ba not identified twice and ^{60}Co always identified.

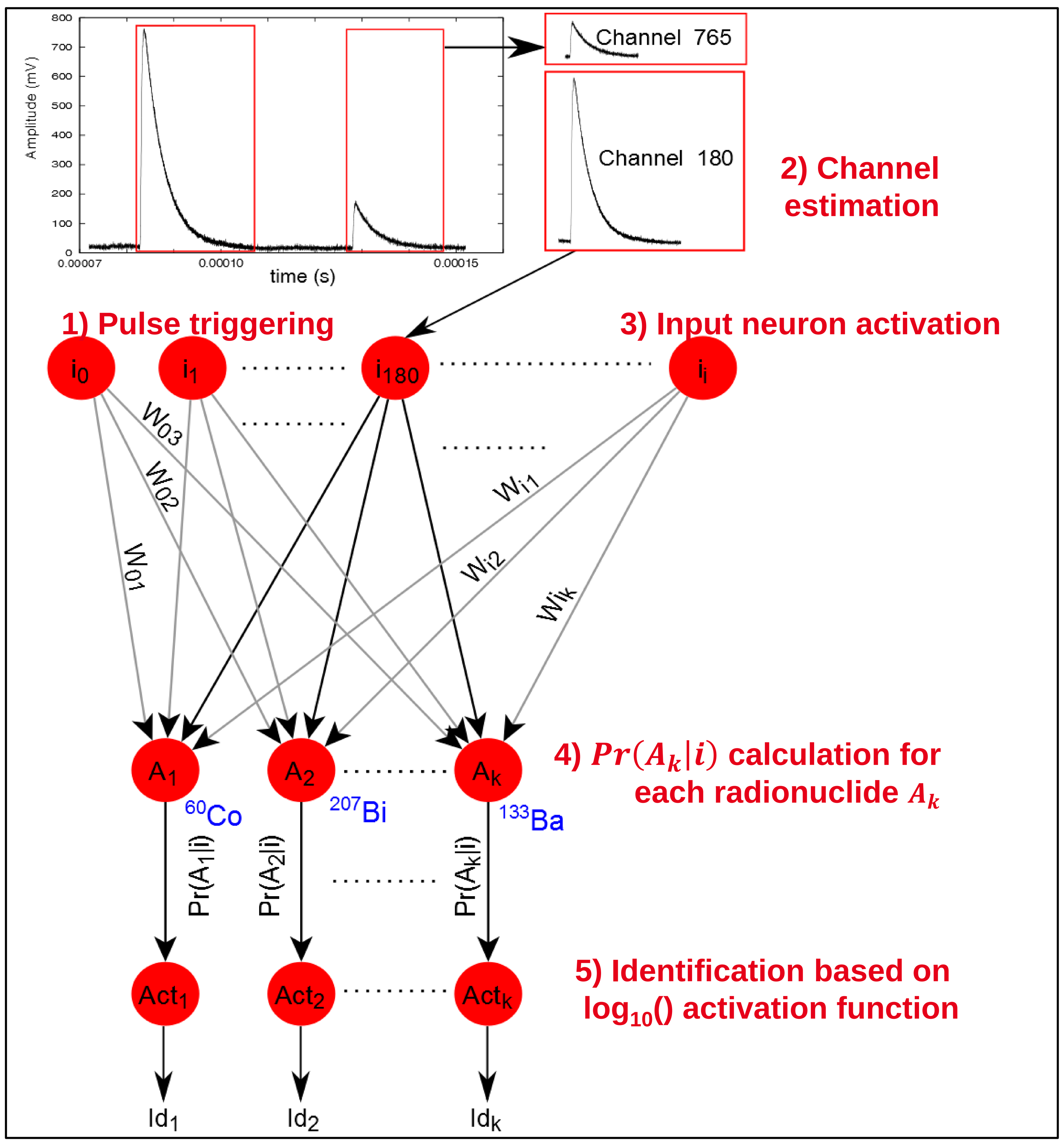

Figure 1: *schematic view of the proposed approach.*

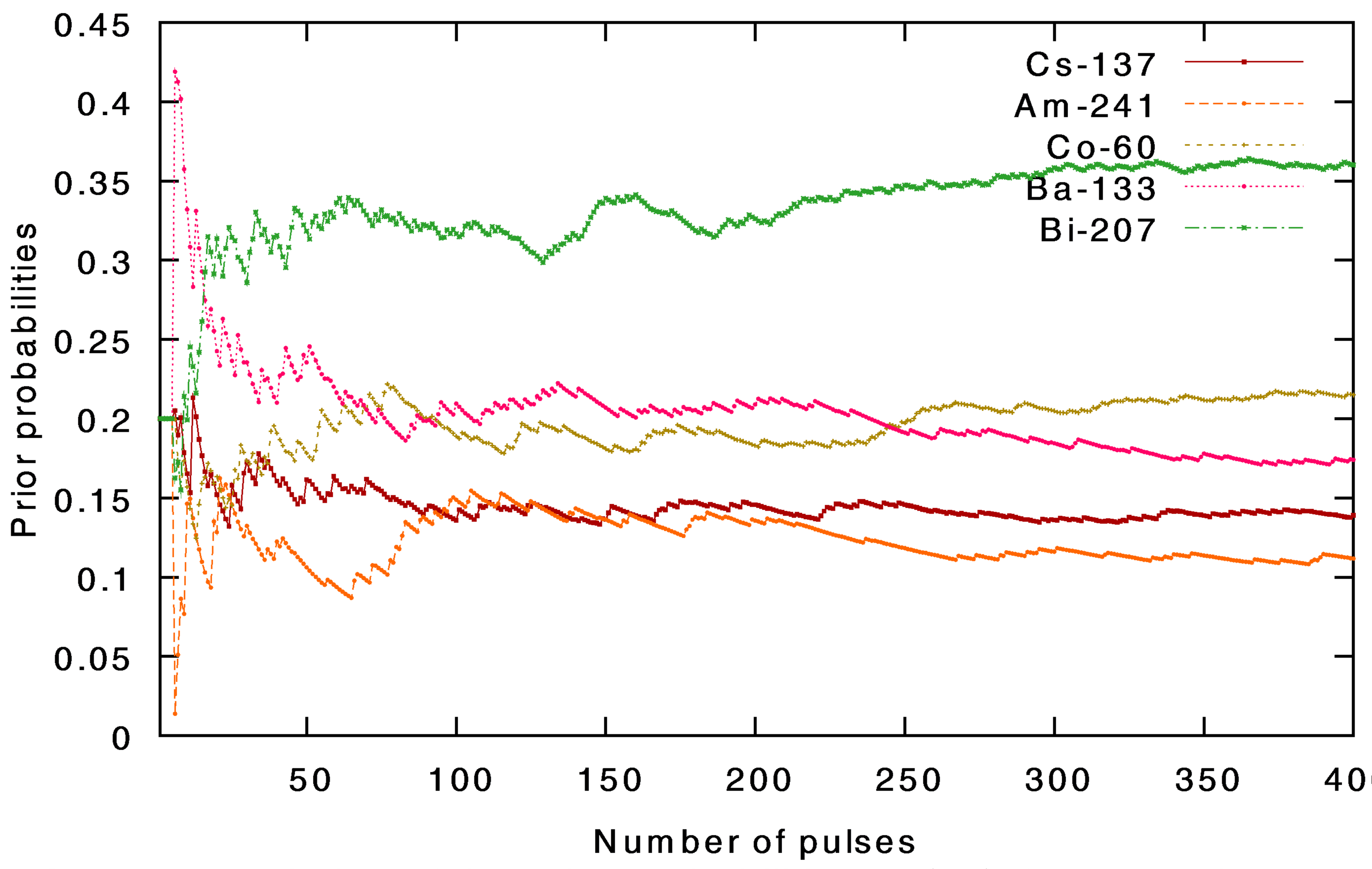

Figure 2: *evolution of the prior probablilties $Pr(A_k)$ for 400 pulses.*

Tab 1: *simulation results of quantification of radionuclides in a mixture.*

Counts	50% ^{60}Co	10% ^{133}Ba	25 % ^{137}Cs	0% ^{207}Bi	15% background
50	0.435 (83)	0.090 (60)	0.211 (76)	0.072 (34)	0.193 (73)
100	0.443 (65)	0.100 (55)	0.207 (60)	0.066 (34)	0.184 (55)
200	0.460 (50)	0.092 (36)	0.218 (53)	0.051 (22)	0.179 (52)
500	0.475 (32)	0.091 (23)	0.224 (41)	0.040 (15)	0.171 (46)
1000	0.476 (27)	0.092 (22)	0.231 (28)	0.034 (14)	0.167 (36)
5000	0.482 (13)	0.094 (12)	0.231 (26)	0.025 (9)	0.167 (33)
10000	0.493 (9)	0.097 (5)	0.240 (11)	0.017 (5)	0.153 (15)
50000	0.498 (6)	0.099 (5)	0.249 (6)	0.004 (1)	0.149 (5)

5. Conclusion and Perspectives

- Quantification of radionuclide in mixtures validated;
- fast identification of radionuclides in mixtures validated;
- small number of pulses (<500);
- background noise immunity;
- tested with a high-efficiency NaI(Tl) detector;
- no energy calibration;
- embeddable in a microcontroller for real-time processing.

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