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Emerging technology snapshot

Advances in Radiological and Nuclear Detection

As radiological and nuclear (RN) sources become more commonly used in commercial products there is a need for enhanced detection of RN sources to secure against proliferation. Existing detection tools include Geiger-Mueller detectors and proportional counters, such as solid-state semiconductor detectors and scintillators. Techniques in development include the use of machine learning algorithms to discriminate neutrons and gamma rays, the integration of quantum dots in detectors, remote methods of radiation monitoring and the use of robots to reduce human exposure.

Enabling Science and Technology

Algorithms

The integration of machine learning and neural network algorithms have seen tremendous growth in the last five years. Frequently seen applications include signal analysis and gamma/neutron discrimination, localization, and data fusion to improve localization and to control navigation of autonomous systems that are doing the detection.

Optimization

Optimization is often used to improve the aforementioned algorithms, particularly in terms of guiding navigation and training neural networks to improve the detection process. Optimization is also used to improve the shape and thickness of crystals or other materials that are used in the detectors.

Quantum sensing

Gamma-ray position-sensitive transition-edge sensor (TES) microcalorimeters can be used to detect multiple radionuclides, while research on superconducting quantum interference devices (SQUID) has shown these to be even more effective. RN detectors are also more efficient with the integration of graphene or crystalline quantum dots.

Remote sensing

Unmanned aerial and ground vehicles can employ a variety of detectors to detect radiation in nuclear power plants and spent fuel containers. Challenges with remote sensing include the need to correct the readings when trying to identify strongly localized, noised or overlapping peculiarities of gamma rays.

Robots

Robots are used for detecting and localizing radiation, particularly at nuclear sites or during nuclear accidents, to reduce the threat to human health. Multi-robot systems can search for radioactive sources; however, challenges persist with the large amount of computation that is required, which results in low search efficiency. Data fusion is a proposed solution.

"Quantum sensing is an exciting area where fundamental science creates new capabilities to meet needs in non-proliferation and has relevance to industry and other applications."

Cameron Geddes, Director of Berkeley Lab's Accelerator Technology & Applied Physics Division. Quantum Sensing Workshop Held at Berkeley Lab, Apr. 19, 2023.

Signals

Academic

The Polytechnic University of Milan, a top academic institution in the field, produces high quality research including a recent review on trends in using machine learning in radiation detectors.

Government

The US Department of Energy (DOE) is a leader in research on algorithms, optimization, and quantum sensing for RN detection and is the top funder of research in the field.

Collaboration

The universities of Texas (USA), Coventry and Sheffield (UK) recently found AdaBoost to be the preferred classifier out of six machine learning algorithms for detecting illicit radioactive materials due to the high recall and minimal false negatives.

Defence

The US Department of Defense has funded research to develop a supervised machine learning algorithm called Advanced Learning-Enable Radioactive Threat Search to detect threat-based anomalies.

Corporate

Radiation Monitoring Devices (RDM) Inc is working on tools and technologies to improve the detection of diverted, misused, or sabotaged nuclear materials, including developing control and data processing algorithms.

"The latest advancements in radiation detection are putting frontline officers' operational needs and challenges front and center by prioritizing technological development that simplifies and supports their work."

Alina Smyslova, Deputy Program Director, US DOE National Nuclear Security Administration. Advancing Radiation Detection Instruments for Nuclear Security, Oct 9, 2023.

Impact

Social

Public opposition and safety concerns have led some countries to phase out nuclear power. Enhanced RN sensing technologies could help ease community concerns and enable nuclear energy scale-up.

Policy

Improved RN detection helps support Canada's commitment to the multilateral Non-Proliferation Treaty – the cornerstone of international nuclear arms control and nuclear security. (22)

Economic

Enhanced detection of RN sources will be instrumental for meeting the safety requirements to employ small modular reactors (SMR)s, which are expected to offset extant energy costs.

Environmental

SMRs are expected to provide a clean energy alternative; monitoring SMR functionality will require detecting leaks and tracking radiation to be at appropriate and safe levels. Enhancements in radiation detection, such as through quantum sensing, will be beneficial for this.

Defence

Enhanced sensing of RN sources will support border security, preventing the flow of contraband into Canada; specifically, by enhancing radiation portal monitoring capabilities. It further supports safeguards and non-proliferation of sensitive RN materials.

"On the nuclear non-proliferation side, there are huge benefits to using AI—to find proliferators, to look for signals in the haystack. On the nuclear weapons side, there's a lot of potential benefits. The question: is anyone looking at how to put it all together?"

Jill Hruby, Under Secretary for Nuclear Security at the Department of Energy and Administrator of the National Nuclear Security Administration (NNSA). NTI Brings Together Experts to Discuss Implications of AI Technologies for Nuclear and Biosecurity, Oct. 31, 2023.

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Produced in partnership by the National Research Council and Defence Research and Development Canada.

Derived from: Wiseman, E. Scientometric study on advances in detection and identification of radiological and nuclear sources. December, 2023.

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PDF: catalogue number NR16-437/2024E-PDF, ISBN 978-0-660-70515-6

February 2024 • Également disponible en français