Introduction

GeigerCam: Measuring Radioactivity with Webcams

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Measurements of Radioactivity

Measuring radioactivity has a long history and innumerable academic and commercial applications in nuclear safety, defense, medicine, biology, materials, etc. Even entry-level devices start in the $20-30 range which is too expensive for casual applications or mass deployment. The wide field of applications and the public interest, spurred by recent events, makes the development of a low-cost device very desirable.

We show that only a minor modification to the imaging sensor is necessary to transform a $20-30 webcam into a radioactivity detector with surprisingly large capabilities. In contrast to standard devices such as Geiger counters, our approach can also classify the type of radiation and possible sources. Our solution would provide cheap sensors to provide onboard detection in subway and trains and measure the radioactivity of a given sample.

Radioactivity

Radioactivity or radioactive decay is the process by which an atomic nucleus emits particles. The particles are characterized by their ability to liberate electrons from atoms and molecules - hence their name. Target material that is subject to such radiation can change its chemical and physical properties. In organic compounds, such as tissue, this leads to free radicals and biological damage.

Radioactivity

- **α**: Helium core
- **β**: Electron
- **γ**: Electromagnetic radiation
- **n**: Neutron

- **A**: Tissue
- **R**: Nuclear fission in reactors
- **W**: Nuclear weapons

- **Type**
  - **Particle**
  - **Mean travel distance in**
  - **Particle Measurement**
  - **Sources**
  - **Misc**

- **α particle**: Photon (R, W), Uranium (R, W, nuclear fuel), Americium (smoke detectors)
- **β particle**: Carbon-14, Chlorine-36, Strontium-90
- **γ particle**: Cobalt-60, Caesium-137, Americium-241
- **n particle**: Neutron

We use a low-cost Logitech C310 HD Webcam and remove all components in front of the imaging sensor as they would absorb all α particles, and β particles to a large degree. This constitutes both the lens and the infrared filter.

Due to the partly very faint signals of the particle impacts we want to measure, we operate the camera with extreme exposure and gain values. Visible light completely saturates the sensor at those settings and makes it impossible to measure the much weaker signal of the particle impacts.

To optically insulate the sensor we cover it with 8 µm thick aluminium foil. This is sufficient to block all incoming light and at the same time thin enough to let γ particles pass in sufficient quantities. Aluminium is also highly reflective in the infrared range and thus serves as substitute for the infrared filter that was removed before.

Radioactivity

Radioactive decay causes skin damage and makes it impossible to measure due to the partly very faint signals. A thresholding operation is used to generate a histogram of the observed impact energies, which allows to identify the type of radiation.

Conclusions

Preliminary measurements show reliable detection rates for α and β particles as well as γ radiation at high levels. For a radiation we achieve a relative hit count of $1.0 \times 10^3 \pm 0.17$ compared to the reference device, i.e. we count less hits but the error in doing so is low. The small value can be explained by the significantly smaller area of the sensor and to a lesser degree by the absorbing aluminium foil. Using this factor as a calibration value for the camera we can reliably measure the radioactivity of a given sample.

β particles can also be measured with high precision (error < 5%) but the relative hit rate depends on the material of the measurement sample - this indicates that the sensor’s sensitivity varies with the particles’ energy. At high doses γ radiation can be measured as well. The clear acoustical low detection rate can be explained by small spatial extent of the camera’s sensor.

We could not detect neutrons even for strong sources and further modifications would be needed to do so, such as submersion in helium gas.

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Software

After the hardware modification has removed optical and thermal radiation noise, the imaging sensor still exhibits thermal and electronic device noise. To improve the signal-to-noise-ratio we use real-time image processing on the direct video feed of the camera.

A thorough analysis of the per-pixel background noise showed that it is exponentially distributed and can thus be tackled by single exponential smoothing.

We also encountered frequent single pixel burst, where just a single pixel exhibits an above-noise value for a single frame. We attribute this to noise of both the sensor and the read-out electronics, and remove it by convoluting each frame with a ring filter.

For each frame a per-pixel confidence value is calculated to identify potentially hit pixels. We obtain it by multiplying the per-pixel probabilities of having hit before and after the convolution. A thresholding operation is sufficient to get a clean image that serves as input to our analysis step.

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