Application of neural networks in the analysis of gamma spectra collected during UAV flights

Daan Van Dyck

Master of Nuclear Engineering Technology

INTRODUCTION AND PROBLEM STATEMENT

In the characterization of nuclear contamination, UAVs with radiological equipment are an interesting approach for radiation mapping because of their autonomy and flexibility. Yet, UAVs have limitations and combined with the dynamic character of a flight this will present gamma spectra with poor statistics. To tackle the difficulties in quantification and identification, a new approach with neural networks is proposed, where a model is trained on similar data as collected by the UAV system.

RESEARCH OBJECTIVES

The goal of this Master's thesis is the development of a neural network that can differentiate between the spectra of a ^{137}Cs source and background of spectra of maximum 5 seconds.

Subsequent goals are:

- Validate the model with a benchmarking dataset and quantify how it performs
- Compare the model with a standard method (i.e., MultiSpect)
- Research limits of the neural network architecture and quantify them

MATERIAL AND METHODS

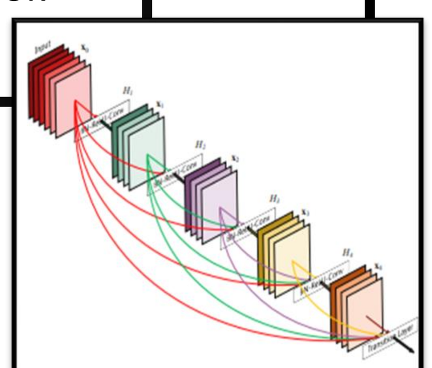
Data collection:

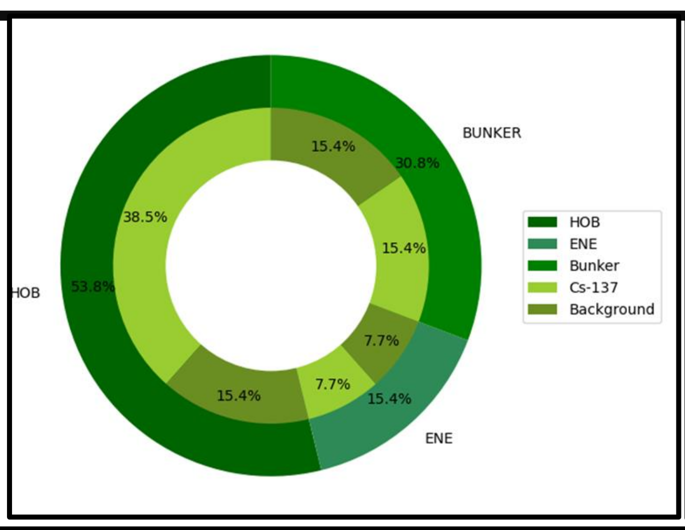
- Training set of 6500 spectra of 5 seconds with various background scenarios and from 3 different distances (0, 13 and 30 cm) with Kromek SIGMA50 CsI(Tl) detector
- Validation set of 2090 spectra with differences in source to detector distances and measurement times

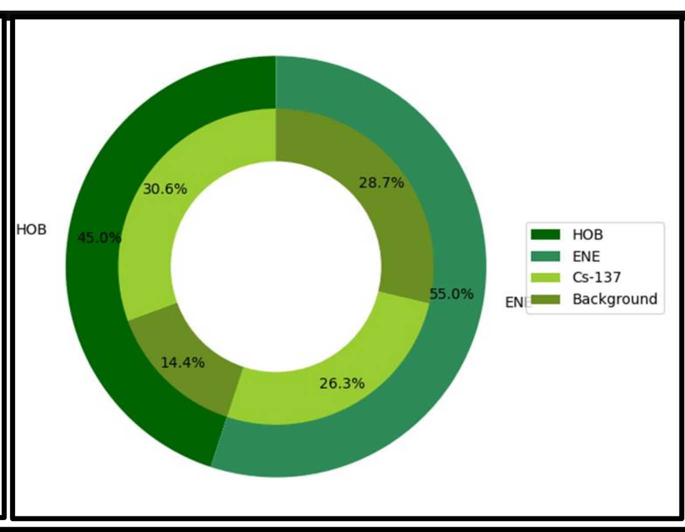
Data pre-processing with Python in SPYDER

Development of a DenseNet [5] architecture with TensorFlow in Jupyter Notebook

➔Train-test split of 90%

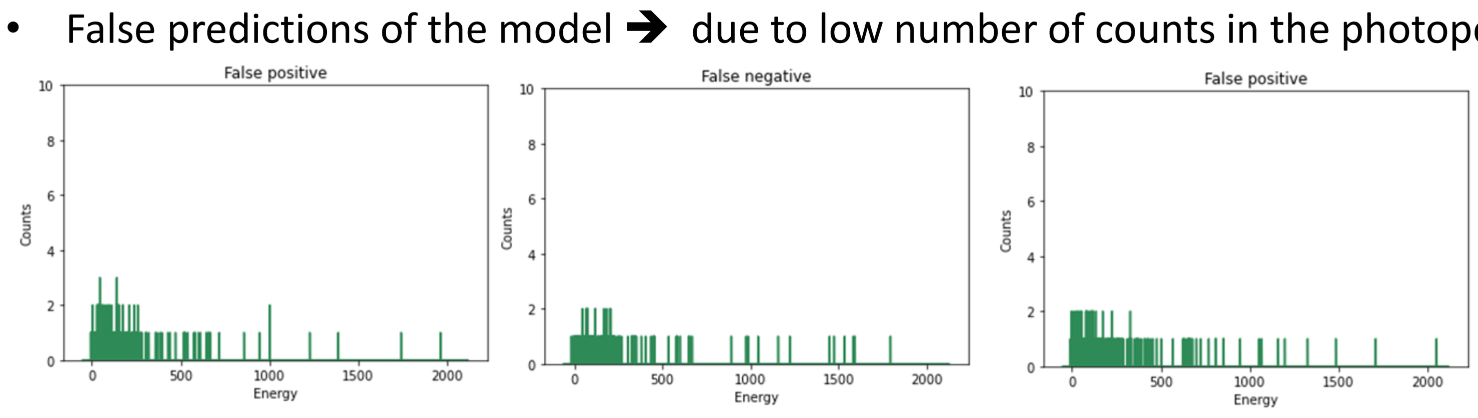




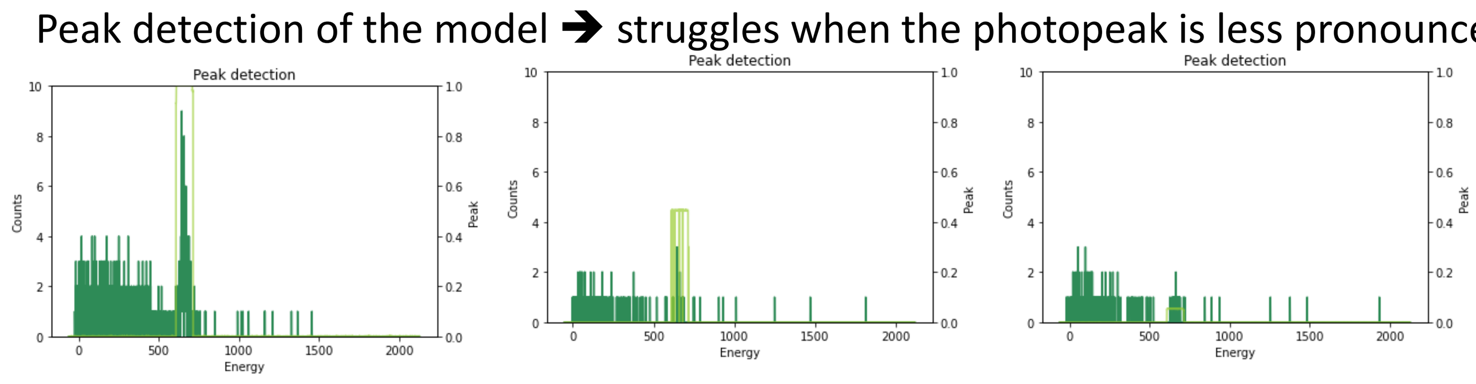


RESULTS

- Model is trained in 16 epochs (± 4 minutes)➔ 99% training accuracy, 97% test accuracy$
- False predictions of the model ➔ due to low number of counts in the photopeak:



- Peak detection of the model ➔ struggles when the photopeak is less pronounced



RESULTS

Model is trained in 16 epochs (± 4 minutes)➔ 99% training accuracy, 97% test accuracy

Validation set accuracy:

Model ➔ 85.32 %   MultiSpect ➔ 44%

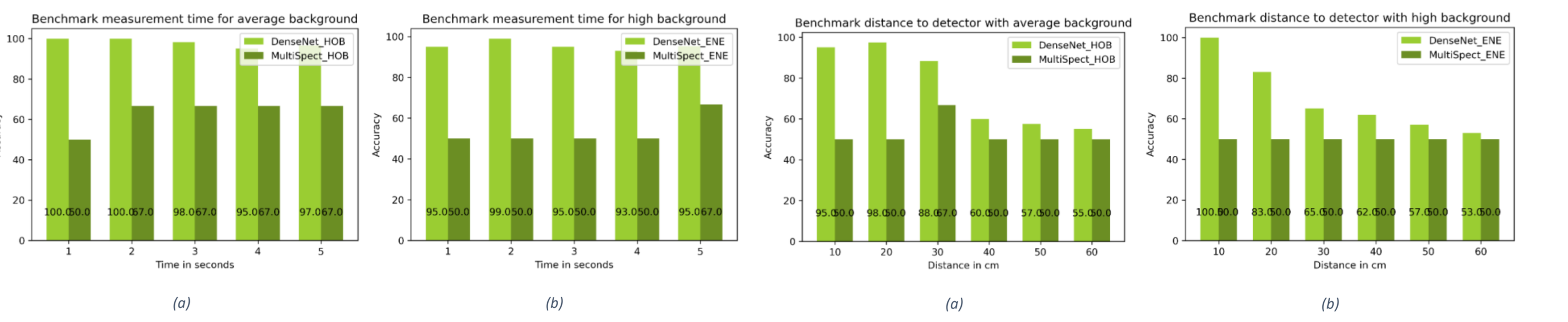
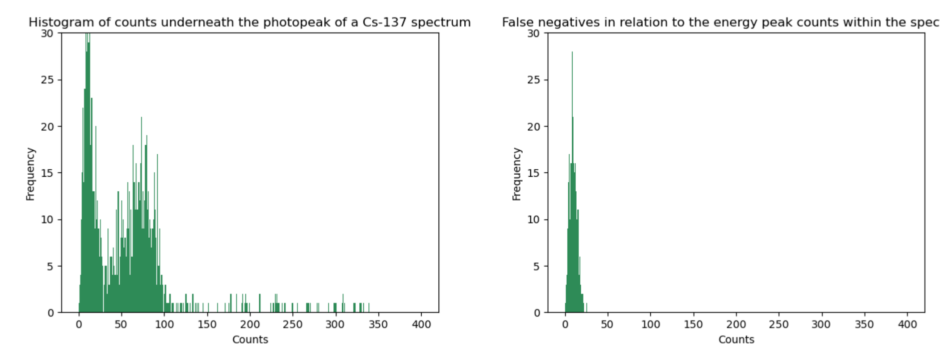


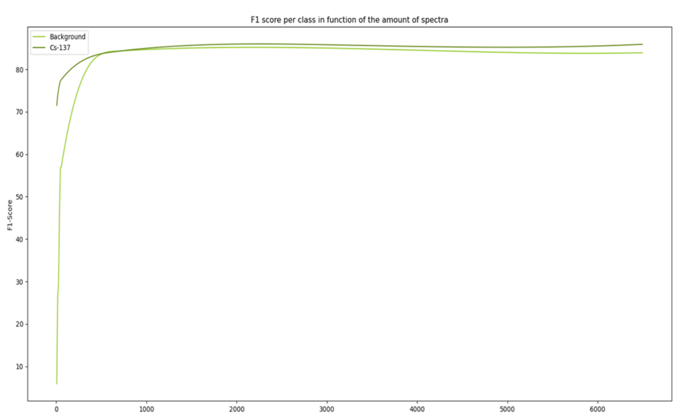
Figure 1 Comparison of model and MultiSpect on benchmarking set with differences in measurement times

Figure 1 Comparison of model and MultiSpect on benchmarking set with differences in height measurements

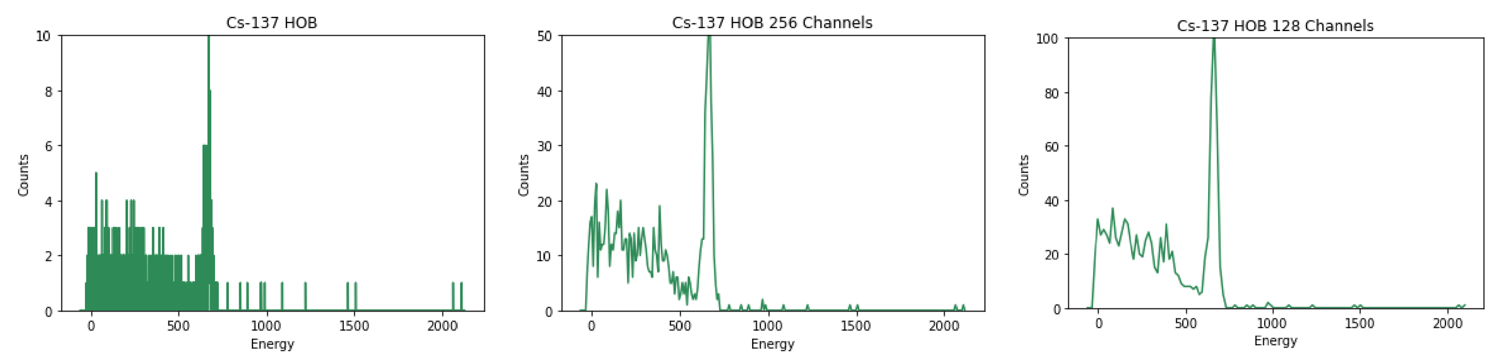
- Model struggles when activity is lower than certain level ➔ Quantifying the minimal counts within the photopeak ➔ minimal counts in photopeak = [34 ± 3] counts



- Minimal data needed to train the model ➔ ± 500 spectra with various background scenarios



Reducing the number of channels improves accuracy and speed of the model:



Channels	4096	256	128
Time per epoch	15 seconds	5 seconds	8 seconds
Accuracy	85.32%	86.60%	88,90%
F1-score	85.32%	86.60%	88.89%
Peak detection	97%	96.41%	97.38%

CONCLUSION

In conclusion, with the use of a strong variety of background situations, this method is an effective means for automated radionuclide identification and could be expanded with more radionuclides. The model reached an accuracy of 85% on the validation set, MultiSpect only achieved 44%. At the base of misclassified spectra by the model was a low number of counts in the photopeak, the minimum amount needed for good results was 34±3 counts. Reducing the number of channels within the spectrum lead to little improvements in accuracy.

REFERENCES

[1] IAEA, "Environmental Consequences Of The Chernobyl Accident And Their Remediation: Twenty Years Of Experience," *Radiol. Assess. REPORTS Ser.*, p. 180, 2006.

[2] IAEA, "The Fukushima Daiichi Accident: Radiological Consequences," *Fukushima Daiichi Accid. Vol. 4/5*, vol. 4, p. 237, 2015.

[3] IAEA, "The Radiological Accident in Goiânia," *Radiol. Accid. Goiânia*, p. 157, 1988.

[4] J. W. MacFarlane *et al.*, "Lightweight aerial vehicles for monitoring, assessment and mapping of radiation anomalies," *J. Environ. Radioact.*, vol. 136, pp. 127–130, 2014, doi: 10.1016/j.jenvrad.2014.05.008.

[5] G. Huang, Z. Liu, L. Van Der Maaten, and K. Q. Weinberger, "Densely connected convolutional networks," *Proc. - 30th IEEE Conf. Comput. Vis. Pattern Recognition, CVPR 2017*, vol. 2017-Janua, pp. 2261–2269, 2017, doi: 10.1109/CVPR.2017.243.

Supervisors / Co-supervisors / Advisors

Prof. Dr. Johan Camps

Prof. Dr. Wouter Schroeyers

sck cen | UHASSELT | KU LEUVEN