Prediction of Volume Fractions and Flow Regime Using Nuclear Technique and Deep Rectifier Neural Network

A. C. M. Moura[1], C. M. N. A. Pereira[2], C. M. Salgado[3]
E-mail:ana.carolina.moura1212@gmail.com, cmnap@ien.gov.br, marquesotero@gmail.com

[1] IEN; [2] SEINS, IEN; [3] DIRA, IEN

Keywords: Volume Fractions, Flow Regime, gamma-rays, Deep Learning.

During the extraction of oil, from submerged rocks, it is necessary to know the flow rate of oil, water, and gas that flow through the pipes of the oil plant. This real-time knowledge allows for better performance management in plant production. Therefore, this report presents an approach to the use of artificial neural network techniques to obtain, simultaneously, the three-volume fractions in multiphase flows (gas, water, and oil), and the active flow regime (Annular, Stratified and Homogeneous), through the interpretation of the height of pulse distributions collected through radiation detectors. These distributions are generated and collected through simulations performed in the computer MCNPX code [1]. This code allows the creation of an environment similar to the interior of a pipeline found on oil plants. In addition, the MCNPX code also performs the calculation of radioactive counts using the Monte Carlo Statistical Method. In this context, the proposed project presented here involves the creation of a simulated PVC tube that is filled with three fluids. Outside the PVC tube, there will be a radioactive source, and on the opposite side, four detectors are responsible for detecting the pulses that spread and cross the duct. In each detector reading, 81 pulses are collected. These pulses generate a pattern for each volume fraction of the fluids deposited in the duct.

Since the introduction of artificial neural networks (ANN) to the scientific community by Rosenblatt (1958) [2], until the modern days, a myriad of ANNs architectures and procedures have been developed over the years, improving and adjusting the ANNs, making these machine learning models capable to solve a diverse range of complex real-world problems.

However, for a long period, the most used ANN activation function was the logistic sigmoid. The ANNs that implement the Rectified Linear Unit (ReLU) function demonstrate a far better learning capacity them the ANNs activated with sigmoid functions, having the capacity to use more hidden layers and as a result, these ANNs are able to solve more complex problems [3]. Nowadays, ANN architectures that use the ReLU activation function are called Deep Rectifier Neural Networks (DRNNs). The first results of using DRNN to solve the problem addressed is shown in Table 1.

Table 1 - Preliminary results of the developed DRNN architecture.

	Train	Test	Product
Nº examples	1578	658	395
Accuracy in the detection of the Regime (%)	100	100	100
Mean percentage error in Air Fraction Prediction	4.145	5.093	5.215
Mean of percentage error in Water Fraction Prediction	5.496	6.886	8.118
Mean percentage error in Oil Fraction Prediction	5.681	5.975	6.55

This study is the continuation of another work where it uses ANNs with few layers [4]. The proposed approach here is to use a DRNN model to classify the flow type regime, inside the tube, and also, simultaneously, predict the volume fraction of the fluids with lower relative errors, as Figure 1 shows.

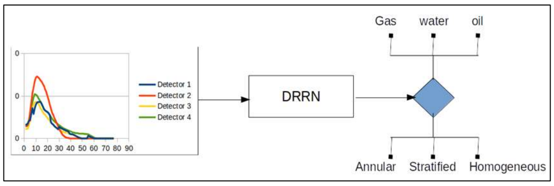

Figure 1. The DRNN based proposed approach.

References

[1] PELOWITZ, D. B. MCNPX TM User's Manual, Version 2.5.0, LA-CP-05-0369, Los Alamos National Laboratory (2005).
[2] ROSENBLATT F., The perceptron: A probabilistic model for information storage and organization in the brain. Psychological Review 65(6) (1958) 386-408.
[3] XAVIER, G.; BORDES, A.; BENGIO, Y. Deep Sparse Rectifier Neural Networks. Journal of Machine Learning Research 15 (2011).
[4] SALGADO, W.L.; DAM, R.S.F.; SALGADO, C.M. Optimization of a flow regime identification system and prediction of volume fractions in three-phase systems using gamma-rays and artificial neural network, Applied Radiation and Isotopes 169 2020 doi.org/10.1016/j.apradiso.2020.109552.