Density prediction using artificial neural networks and gamma ray

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This work presents a study for density prediction of petroleum and derivatives for products' monitoring application [1]. The approach is based on pulse height distributions (PHD) pattern recognition by means of artificial neural network (ANN). Theoretical models for different materials have been developed using MCNP-X code, which was also used to provide training, test and validation data for the ANN. Simulations have been carried out, with density ranging from 0.55 to 1.28 g.cm^{-3} in order to cover the most practical situations.

Detection geometry

The gamma-ray PHD obtained by detector were used to feed an ANN, using a simplified detection geometry which consists in one 1 ¼" x ¾" NaI(Tl) scintillator detector, positioned diametrically to the ^{137}Cs (662 keV) source for recorded the gamma-ray attenuation beam. The collimated (angle beam 8.84°) gamma-ray point source has also been simulated in the MCNP-X code. A Polyvinyl Chloride tube composes a test section with 0.3175 cm thickness and 250 mm of maximum outside diameter [2]. The simulations considered six different external diameters of the pipe, ranging from 4 cm to 24 cm in steps of 4 cm.

Developing of ANN

The simulations were carried out for six different external pipe's diameters and eleven materials (M1 to M11); several combinations of materials (fluids) and external pipe's diameters were simulated and the transmitted flux has been calculated. Sixty six patterns, which are combinations of the density and external pipe's diameter were distributed uniformly throughout the search space. Among those, fifty-five were used for training and eleven for testing the ANN. A 3-layer feed-forward multilayer perceptron has been used with Back-propagation algorithm. PHD and diameter pipe are the ANN inputs and Density as output. The Test set was used for stopping criteria: cross validation in order to avoid over-training. The materials used in this work for Training and Test are presented in Table 1.

Table 1 - Type of materials.

Type	Material	Density (g.cm^{-3})
M1	Gasoline I	0.6837
M2	Oil crude	0.9730
M3	Oil hydraulic	1.2800
M4	Oil lard	0.9150
M5	Paraffin wax	0.9300
M6	8% salt water	1.0932
M7	Ethyl	0.7893
M8	Ethylene Glycol	1.1140
M9	Gasoline II	0.7210
M10	Kerosene	0.8199
M11	GLP	0.5500

The prediction results for the learning set (training and test sets) from the trained ANN are shown in Figure 1.

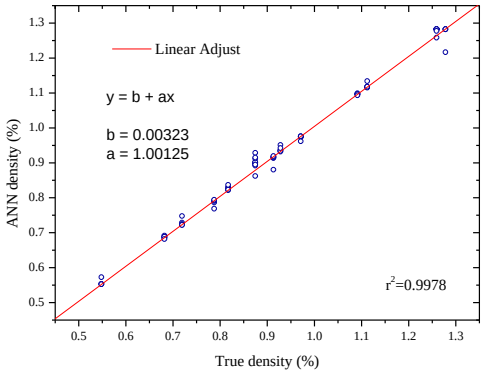

Figure 1. Results obtained for the Training set.

The linear correlation coefficient of 0.998 was obtained for density by the least-squares procedure, demonstrating a good convergence of artificial neural network about learning set. More than 97% of all data were predicted with relative error within ±5%.

References

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