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General Regression Neural Networks for Estimating Radiation Workers Internal Dose

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ABSTRACT

Doses from intakes of radionuclides cannot be measured, but must beassessed from monitoring, such as urinary excretion measurements and whole body counting. This work deals with the application of general regression neural networks (GRNN) for several cases selected with the aim to cover a wide range of practices in the nuclear fuel cycle and medical applications. GRNN are a class of neural networks widely used for the continuous function mapping. An important advantage of the GRNN is that training is very fast and adding new data is almost free. Good applications possibilities of the GRNN are verified on real data.

Keywords: General Regression Neural Networks, Radiation, Internal Dose

INTRODUCTION

The determination of internal doses is an essential component of individual monitoring programs for workers. It may be needed for members of the public, who may have intake of radionuclides in nuclear medicine and also in normal life following accidental releases of radionuclides into the environment. Assessment of internal doses can be divided into two phases, namely:

- Determination of the amount of radioactive material in the human body, in body organs or in wounds by direct measurements and/or by indirect methods such as excretion analysis or air monitoring.
- Interpretation of the monitoring data in terms of intake and/or internal dose taking into account many influencing factors and assumptions, such as the physical and chemical characteristics of the radioactive substance, the mode of intake, the biokinetic and energy absorption, the individual parameters, etc.

Internal exposure measurements are usually applied to workers in sectors listed below:

- Nuclear reactors
- Radioisotopes production
- Handling of open sources in medical research and other applications, including radiopharmaceuticals
- Handling of volatile substances and aerosols
- Processing with plutdnium or other transuranic elements
- Mining, treatment and use of minerals and thorium compounds.
- Uranium mining and exploration.
- Places with increased radioactivity.
- Response to radiological incidents/accidents.

This paper describes the basic structure and validation of general regression neural networks with several examples of the practical use of the code [1-4]. GRNN, falls into the category of probabilistic neural networks. The advantage of using a probabilistic neural network is its ability to converge to the basic function of the data with only few training samples available. The additional knowledge needed to get the fit in a satisfying way is relatively small and can be done without additional input by the user. This makes GRNN a very useful tool to perform predictions and comparisons of system performance in practice [5].

General Regression Neural Networks:

Figure 1 is a graphical representation of GRNN in terms of a neural network. GRNN consists of four layers: input, pattern, summation and output.

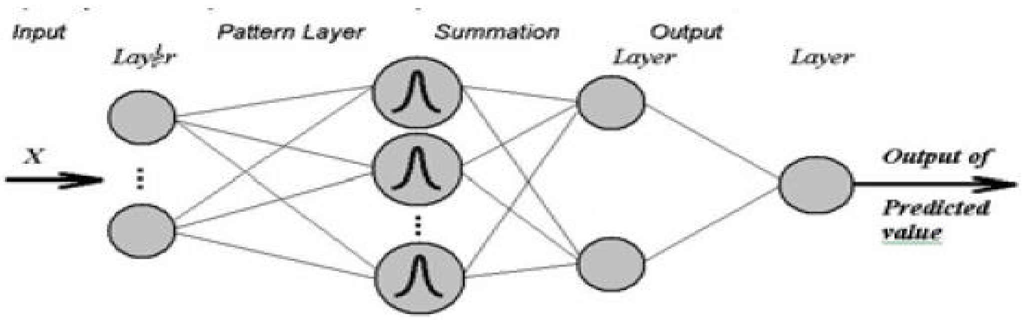

Figure 1: Geneneral Regression Neural Network

The input layer transfers an input signal into the next pattern layer. The number of neurons in the pattern layer is equal to the number of training samples (N), each neuron corresponding to a training sample. The summation layer consists of two neurons. Each of these neurons computes a weighted sum of the output from a previous layer. The weights correspond to the links between the neurons. The output layer neuron transfers the output value [5-6].

RESULTS AND DISCUSSION

The work deals with the application of GRNN for several cases selected with the aim to cover a wide range of practices in the nuclear fuel cycle and medical applications. The cases were:
1. Acute inhalation of ^{131}I in some Egyptian hospitals.
2. Acute ingestion and inhalation of ^{210}Po.
3. Whole body counting for workers inhaled ^{13I}I during maintenance of NPP.

The first case is real [1] and all the rest cases have been taken from published data [2, 3, and 4]. The original data base has been split in to two data sets: training and spare. The last one is used as an self-regulating in order to estimate the quality of trained network. The basic information of the training and predicting data sets for various data have been illustrated in three cases.

The selection of cases to be evaluated was made on the basis of the radioisotope or mixture present in the case scenario, complexity present in the data set (e.g. multiple types of monitoring data) and special issues to be considered in this study.

Case 1: Acute inhalation of I-131 in some Egyptian hospitals

In a previous study, we have estimated the internal radiation doses due to inhalation of ^{131}I by workers in nuclear medicine units of three Egyptian hospitals. 24 hrs urine samples of 11 workers were weekly collected for 6 weeks. The ^{131}I activity in their samples was measured using Hyper Pure

Germanium (HPGe) detector [1].

The General Regression Neural Networks have been trained with the committed effective dose for workers exposed to radiation in three radiological (rad.) facilities in the first and second week. GRNN predict doses values for the five workers from the third to the sixth week, the percentage error between the monitoring values in [Ref.1] and the estimated values have been calculated using formula (1) and the results for workers in different facilities have been shown in tables (1,2&3) and figures(2,3&4).

$$\text{Percent Error} = \frac{\text{GRNN Estimate Value} - \text{Monitoring Value}}{\text{Monitoring Value}} \times 100\% \qquad (1)$$

Table 1: GRNN estimate doses values (mSv) and percentage error for five workers in the 1st (rad.) facility

Workers	3rd Week		4th Week		5th Week		6th Week	
	GRNN	% error	GRNN	% error	GRNN	% error	GRNN	% error
1st Worker	0.0179	0.555556	0.0675	0.0915	0.1289	0.846154	0.0915	0.543478
2nd Worker	0.0476	0.833333	0.755	0.657895	0.0897	0.333333	0.0865	0.574713
3rd Worker	0.00995	0.5	0.189	0.526316	0.1387	0.928571	0.3475	0.714286
4th Worker	0.0926	0.430108	0.01586	0.875	0.0347	0.857143	0.0418	-
5th Worker	0.0745	0.666667	0.0478	0.416667	1.156	0.344828	0.0497	0.6

Table 2: GRNN estimate doses values (mSv) and percentage error for two workers in the 2nd (rad.) facility

Workers	3rd Week		4th Week		5th Week		6th Week	
	GRNN	% error	GRNN	% error	GRNN	% error	GRNN	% error
1st Worker	0.01395	0.357143	0.01785	0.833333	0.00646	0.615385	0.00477	0.625
2nd Worker	0.00496	0.8	0.1986	0.7	0.0995	0.5	0.15	

Table 3: GRNN estimate doses values (mSv) and percentage error for three workers in 3rd (rad.) facility

Workers	3rd Week		4th Week		5th Week		6th Week	
	GRNN	% error	GRNN	% error	GRNN	% error	GRNN	% error
1st Worker	0.1194	0.5	0.675	0.735294	0.0447	0.666667	0.0436	0.909091
2nd Worker	0.02979	0.7	0.0595	0.833333	0.1387	0.928571	0.0892	0.888889
3rd Worker	0.01685	0.882353	0.00338	0.588235	0.001984	0.8	0.00804	0.5

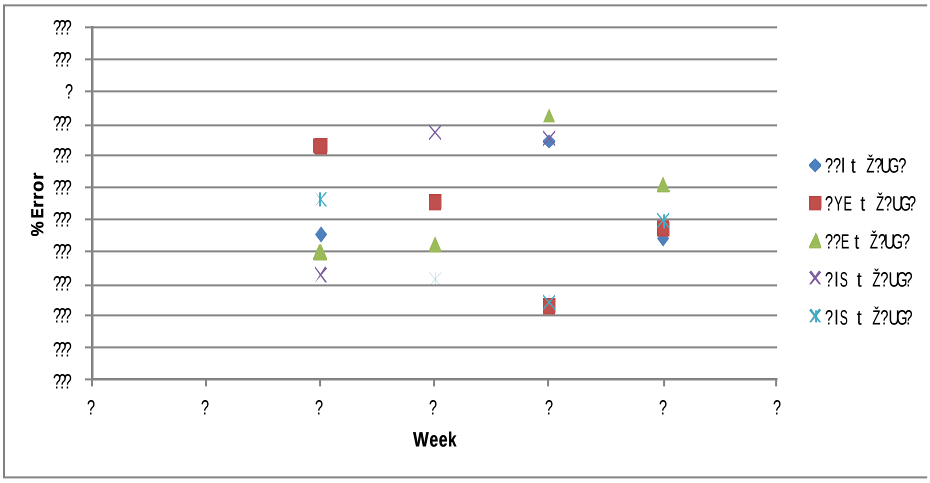

Figure 2: Percentage error from the 3rd to the 6th week for five workers in the 1st (rad.) facility

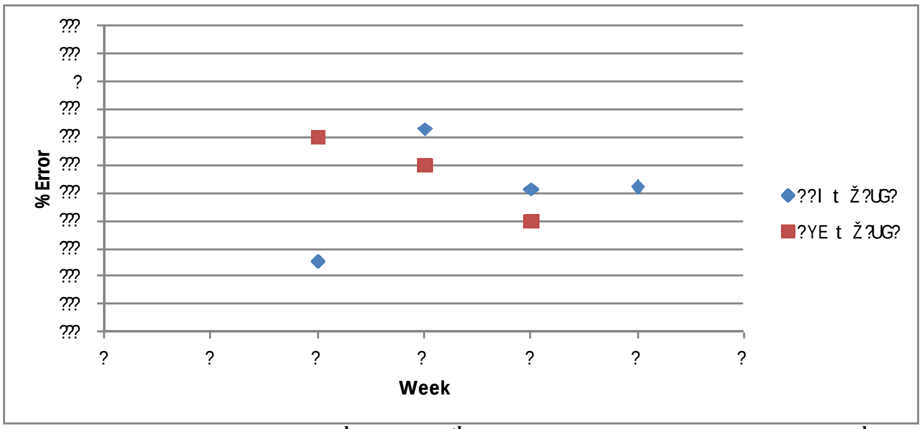

Figure 3: Percentage error from the 3rd to the 6th week for two workers in the 2nd (rad.) facility

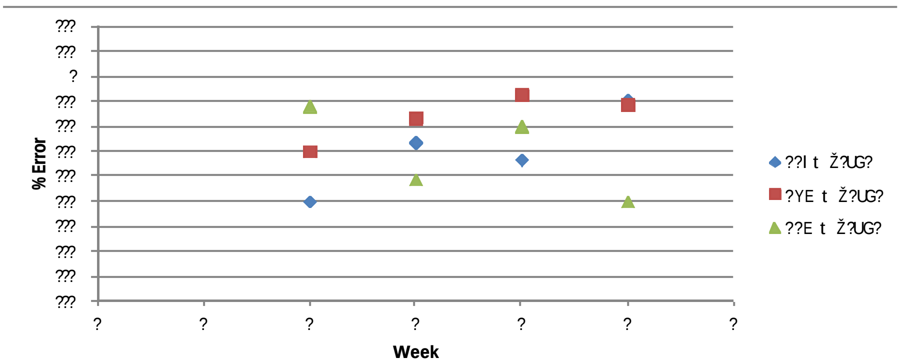

Figure 4: Percentage error from the 3rd to the 6th week for three workers in 3rd (rad,) facility

Case 2: acute ingestion and inhalation of Po-210

This is a real case, has been taken from publication [2]. In this study, the urinary excretion of five persons aged from 23-48 years from Germany provided their 24-hr urine samples. Information on the suspected day of exposure to ^{210}Po was also acquired. Samples were measured between 6 and 12 days after the possible exposure. The polonium isotopes were determined by alpha spectrometry with Canberra PIPS detectors.

In this case the GRNN have be trained for two contaminated persons and the network results for inhalation, Ingestion for five persons have been shown in table (4) and the percentage error in figure (5).

Table 4: GRNN estimate of effective doses values and percentage error for the possible contaminated persons

Persons No.	Volume of 24-h-urine sample	Ingestion (mBq)		Inhalation (mBq)	
		GRNN	% error	GRNN	% error
1st Person	2.74	6.54	0.909091	63.9	0.930233
2nd Person	1.5	4.56	0.869565	48.8	0.813008
3rd Person	2.25	6.15	0.806452	64.1	0.620155
4th Person	2.01	1.69	0.588235	16.85	0.882353
5th Person	3.42	13.53	0.514706	135.5	0.805271

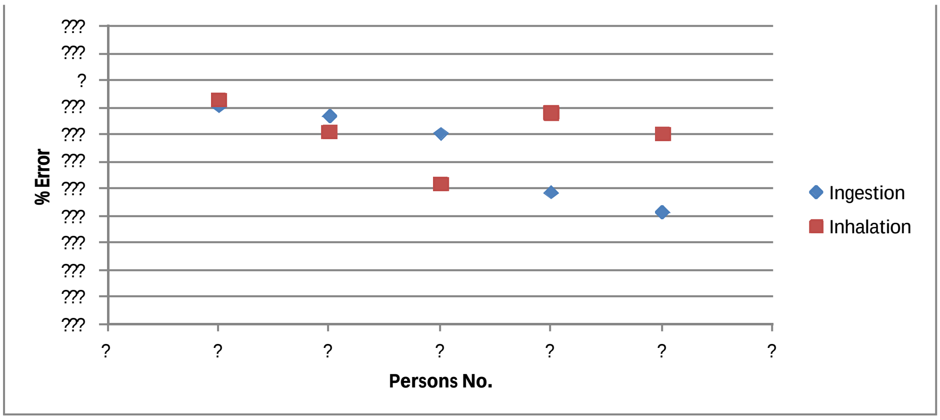

Figure 5: percentage error of effective doses values for the possible contaminated persons

<u>Case 3: whole body counting for workers inhaled I-131 during maintenance of Nuclear Power Plant (NPP)</u>

During a maintenance period at a Korean nuclear power plant, internal exposure of radiation workers occurred by the inhalation of $^{13?}$I released into the reactor building from a primary system opening. The internal radioactivity measurements of the radiation workers contaminated by $^{13?}$I were immediately conducted using a whole body counter and whole body counting was performed again a few days later. The intake calculated by hand, based on both the entrance records to radiation controlled areas and the measurement results of the air concentration for ^{131}I in these areas were compared with the results of whole body counting [4].

Table 5 shows GRNN estimate of Whole body counting for inhalation of ^{131}I and Figure (6) shows the percentage error for five workers during maintenance of (NPP).

Table 5: GRNN estimate of Whole body counting for inhalation of 1[131] and percentage error for five workers during maintenance of (NPP)

Persons No.	Whole body counting					
	Time after intake (Days)	Initial count (Bq)		Time after intake (Days)	Recount (Bq)	
		GRNN	% error		GRNN	% error
1st Person	0.39	12230	0.81103	12.46	4525	0.832785
2nd Person	0.23	4795	0.498029	11.43	2166	0.505282
3rd Person	0.57	13050	0.911162	11.86	2475	0.60241
4th Person	0.31	5520	0.647948	12.6	5730	0.967853
5th Person	0.41	1542	0.387597	9.38	980	0.406504

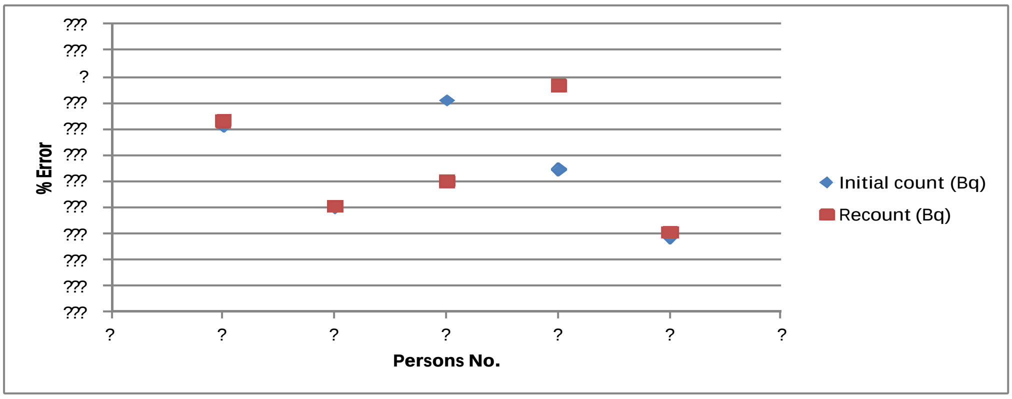

Figure 6: Percentage error f of Whole body counting for inhalation of ^{131}I and percentage error For five workers during maintenance of (NPP)

The results in all the above cases show that the percentage error in predicting workers doses using GRNN is in the range between 0.1 to 1%. The time taken for either training or predicting each case does not exceed five minutes.

CONCLUSION

The work presents the application of general regression neural networks for prediction of internal doses for workers in nuclear medicine The algorithm calculates the statistically most likely value of each output from a given set of inputs, all taken from the training set. Results show that General regression neural networks give small percentage error when compared to the monitoring data. Also GRNN have the following characteristics fast learning, treatment of spare data well and small computing time.

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