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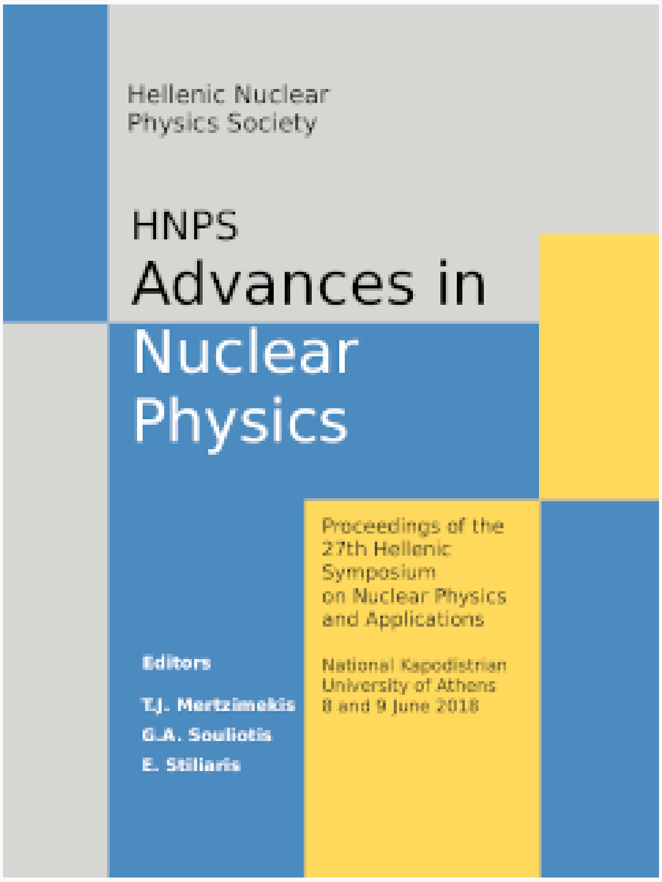

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Application of Artificial Neural Networks on improving predictions of nuclear radii

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Abstract Artificial Neural Networks (ANN) are mathematical computing paradigms imitating the operations of biological neural systems. Their nonlinear nature and ability to learn from the environment make them highly suited to solve real-world problems from those that are still under development. In the field of Physics there are many problems which cannot be adequately solved with the physics–based methods and the use of ANN may yield better results. In the present work ANNs have been tested in predicting nuclear radii considering as input the atomic and mass numbers, exclusively. The performance of different supervised ANNs is evaluated. The dataset used for the training and testing was based on evaluated data of nuclear radii available in IAEA tables.

Keywords Artificial Neural Networks, nuclear charge radii

INTRODUCTION

Information about the size and nuclear matter distribution (which are some of the most important characteristics of a nucleus) in unstable (radioactive) nuclei is usually extracted from experiments colliding radioactive nuclear beams with nuclear targets. As this is a non–trivial and time–consuming task, scientists often rely on phenomenological models than can provide reliable predictions. In that direction, a relation for the nuclear charge radius, ie. $R=r_0A^{1/3}$, is often used, which is derived from the liquid–drop model This is a rough estimate and in many cases falls short. The purpose of this work is to assess whether Artifical Neural Networks (ANN) [1] are capable of predicting nuclear charge radii given the atomic and mass numbers for a given nucleus. The two ANNs compared inhere are the Feed Forward Neural Networks (FFNN) and the Radial Basis Function (RBF). Those two have been chosen as they are the most widely used regression ANNs.

METHODOLOGY

All tests were performed using the neural network tools built in Matlab. In the experiments the data were divided according to the rule: 70% for training, 15% for validation and 15% for testing. After some preliminary experimentation the most suitable structure for the FFNN was found to be the one in Fig. 1 which has two nodes as input, two hidden layers (the first with 10 nodes, the second with 5) and one output node.

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In the first experiment the predictive power of our neural networks was tested. Experimental data from all regions of the isotopic chart were fed to the model [2]. The first data set was constructed from a random selection of 300 nuclei from the 909 known from measurements. After getting trained, the two networks were used to predict radii for the remaining 609 nuclei. The difference of the predicted radii from the experimentally measured was plotted in Fig. 2 and 3 below.

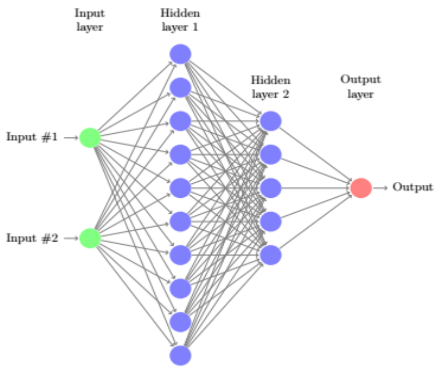

Figure 1. The adopted FFNN structure

In order to test the capability of our networks to predict radii of heavier nuclei than those they have received training for, a second experiment was performed using as data set a random selection of 400 nucleus with mass number smaller than 150. Finally the difference of the predicted radii from the experimentally measured resulted in Fig. 4.

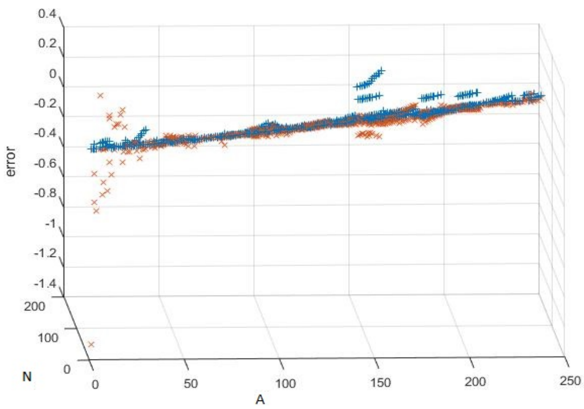

Figure 2. Results of FFNN. With blue are the experimental errors and with orange the difference between NN prediction and experimental data

RESULTS AND DISCUSSION

After analyzing the data in the figures above it is clear that FFNN's predictions have shown consistently better correlation with our experimental data compared to the results of RBF. Unfortunately both ANN's have relatively bad predictions in smaller nucleus (those with A<50) showing that they cannot "understand" the nuclear phenomena that are shown more intensely in small nuclei.

The results of the second experiment are more astounding. We can clearly see that in this case for nuclei having mass number 170 and above the RBF has shown extreme inconsistency with our experimental data. This is not the case for FFNN, which its error starts to accumulate late in the superheavy region, after A=230.

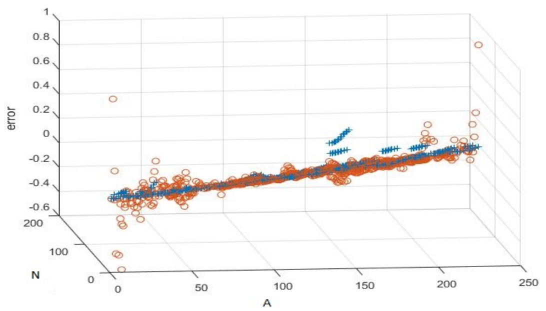

Figure 3. Results of RBF. With blue are the experimental errors and with orange the difference between NN prediction and experimental data

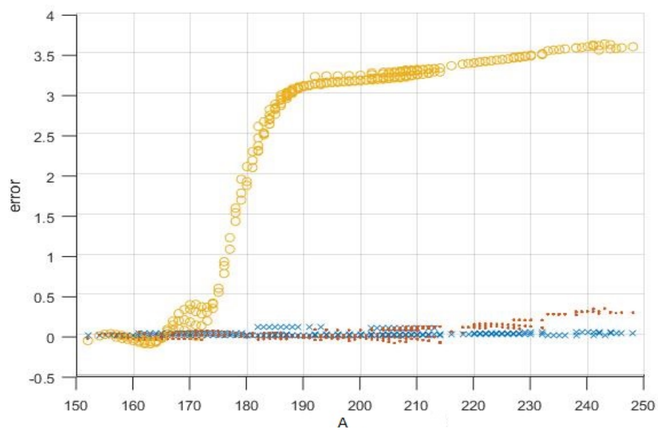

Figure 4. Results of our two networks with 400 randomly selected nucleus. With blue are the experimental errors, with orange the difference between FFNN's results and the experimental radii and with yellow the deference between RBF's results and the experimental ones.

CONCLUSIONS

The Feed Forward Neural Network (FFNN) has shown promising results and can be proven useful in predicting unknown radii in exotic regions of the isotopic chart. For this reason in our future work we will pursue radii predictions in the superheavy region of the isotopic map and we will compare the FFNN results with existing models. The plan is to apply and test additional ANN models on the same data set in the near future.

References

[1] C.M. Bishop, *Pattern Recognition and Machine Learning*, Springer, Singapore (2006)
[2] I. Angeli and K.P. Marinova, At. Data Nucl. Data Tables 99, 69 (2013)