International Journal of Electrical and Computer Engineering (IJECE)
Vol. 12, No. 5, October 2022, pp. 5093~5103
ISSN: 2088-8708, DOI: 10.11591/ijece.v12i5.pp5093-5103

Efficient time-series forecasting of nuclear reactions using swarm intelligence algorithms

Hala Shaker Mehdy[1], Nariman Jabbar Qasim[2], Haider Hadi Abbas[3], Israa Al_Barazanchi[4], Hassan Muwafaq Gheni[5]
[1]College of Education, Computer Science, Al-Mustansiriya University, Baghdad, Iraq
[2]Civil Engineering Department, Al Esraa University College, Baghdad, Iraq
[3]Computer Technology Engineering Department, Al-Mansour University College, Baghdad, Iraq
[4]Computer Engineering Techniques Department, Baghdad College of Economic Sciences University, Baghdad, Iraq
[5]Computer Techniques Engineering Department, Al-Mustaqbal University College, Baghdad, Iraq

Article Info

Article history:

Received Jul 11, 2021
Revised May 26, 2022
Accepted Jun 14, 2022

Keywords:

Analysis
Artificial intelligence
Energy
Nuclear reaction
Prediction
Swarm intelligence
Time-series

ABSTRACT

In this research paper, we focused on the developing a secure and efficient time-series forecasting of nuclear reactions using swarm intelligence (SI) algorithm. Nuclear radioactive management and efficient time series for casting of nuclear reactions is a problem to be addressed if nuclear power is to deliver a major part of our energy consumption. This problem explains how SI processing techniques can be used to automate accurate nuclear reaction forecasting. The goal of the study was to use swarm analysis to understand patterns and reactions in the dataset while forecasting nuclear reactions using swarm intelligence. The results obtained by training the SI algorithm for longer periods of time for predicting the efficient time series events of nuclear reactions with 94.58 percent accuracy, which is higher than the deep convolution neural networks (DCNNs) 93% accuracy for all predictions, such as the number of active reactions, to see how the results can improve. Our earliest research focused on determining the best settings and preprocessing for working with a certain nuclear reaction, such as fusion and fusion task: forecasting the time series as the reactions took 0-500 ticks being trained on 300 epochs.

Corresponding Author:

Israa Al_Barazanchi
Computer Engineering Techniques Department, Baghdad College of Economic Sciences University
Baghdad, Iraq
Email: israa44444@gmail.com, israa.albarazanchi@baghdadcollege.edu.iq

1. INTRODUCTION

The massive work done on nuclear physics in the 1950s, 60s and 70s was mainly focused on nuclei close to stability, due to the limited ability to produce unstable nuclei as mentioned in [1]. Thus, the knowledge on nuclear physics extracted in that period was mostly based on the about 300 stable nuclei (compare to the about 6,000 nuclei that has been predicted by theory to be particle bound). This knowledge was in the 80s found to be incomplete when it became possible to study unstable nuclei at facilities such as CERN, RIKEN in Japan, MSU in USA, GANIL in France and several other places as mentioned in [2]. One of the first discoveries that changed the traditional view of nuclear physics was that of a neutron halo structure observed by researcher in [3]. To explore nuclei further and further away from stability is not an easy task and demands an ongoing development of production and detection techniques. The evolution of the nuclear chart where the development from about 800 isotopes in the 40s to about 3000 isotopes today is visualized. Within the last 20 years about 1/3 of all known isotopes has been discovered and hence the basis for extending nuclear theories to unstable nuclei has been greatly improved as mentioned in [4]. When investigating nuclei far from stability one meets the problems of low production yield and very short half-life thus the time between production and measurement has to be very short. The world of today is a place where scientists are constantly asked if their research is relevant and can benefit society as mentioned in [5]. Nuclear physics is not an exception to this rule which is clearly seen in the many different ways in which nuclear physics is used in everyday life-though it may not always be visible (just think of how nuclear magnetic resonance (NMR) became magnetic resonance (MR) to get rid of the word Nuclear). All nuclei, surrounding and inside of us, are created somewhere in the universe and most of these through the nuclear synthesis which connects astrophysics to nuclear physics as mentioned in [6]. According to the big bang model the first nuclei were created only 3 minutes after the big bang and at that time the early universe was composed of about 3/4 of h and 1/4 of, he and minute amounts of a few other light nuclei as mentioned in [7]. After another 200 million years according to new measurements from Wilkinson microwave anisotropy probe (WMAP) stars start to form by gravitational collapse of huge gas clouds containing H and He. Through the collapse the cloud heats up and eventually the temperature is high enough for nuclear burning to set in as mentioned in [8]. In this nuclear fusion process first burned to Him and, if the star is massive enough, the He is then burned to heavier nuclei. This repetitive process continues, if the star is massive enough, until the burning reaches Ni (A 60) which has the largest binding energy per nucleon and thus fusion is no longer energetically favorable as mentioned in [9].

Nuclear radioactive management and efficient time series for casting of nuclear reactions is a problem to be addressed if nuclear power is to deliver a major part of our energy consumption. So far this has been done simply by storing the nuclear reactions in old mines. A novel technique called swarm intelligence (SI) where the long-lived nuclear reactions are transmuted, by a neutron flux created by an accelerator, into more neutron rich isotopes with a shorter half-life has been proposed. An obvious advantage of this method is the reduction of nuclear waste, but it also produces additional energy though less profitable than the conventional reactor. In this method the nuclear burning is said to done sub critically since an exterior neutron flux is necessary to sustain the nuclear burning process and therefore is very unlikely to cause a nuclear melt-down. Our goal is to further the field of nuclear science and artificial intelligence by demonstrating how an artificial intelligence (AI) based SI algorithm could be trained to forecast the efficient time series events during nuclear reactions on python programming-based environment.

- Compare SI algorithms with past research and achievements on effective time series forecasting of nuclear reactions and after reactions by evaluating the reactions using SI processing.
- Use a swarm intelligence-based analytic method on the unified open-source dataset to gain a better understanding of nuclear processes with less data loss and greater precision.
- Develop an innovative swarm intelligence-based analytical system based on novel methodology that produces good results for nuclear reactions and predicts unforeseen side-effects during time series forecasting.
- Swarm analysis was used to understand certain patterns and reactions within the dataset during the forecasting of nuclear reactions in terms of swarm intelligence.
- Give an overview of previous research and accomplishments in the use of SI as a tool for predicting and forecasting time series-based nuclear reactions.

2. LITERATURE REVIEW

The field of nuclear physics was almost born together with the application of X-ray imaging by the work of researcher in [10] in the late 19th century. X-ray imaging is possible since X-rays interact stronger with heavier nuclei and thus have a shorter range in bones (made mostly of Ca) than in tissue (mainly composed of H, C and O). Today X-ray imaging is an indispensable tool for doctors and dentists in their daily work in locating fractures and finding holes in teeth, respectively as mentioned in [11]. Taking X-ray images from different angles makes it possible to generate 3-D imaging of the harder parts of the human interior via computerized axial tomography (CT or CAT scanning) as mentioned in [12]. When trying to look at the softer parts of the human interior X-rays are obviously not a good idea since soft tissue has more or less the same nuclear composition as mentioned in [13]. One way of overcoming this problem is by the so called tracer method. In this method one places a radioactive isotope in an organic molecule which binds to or is collected in the kind of tissue on which information is needed as mentioned in [13]. When the radioactive isotope reaches the area of interest the host molecule is trapped and likewise the radioactive isotopes which can then be seen by gamma-cameras. A more precise variant is that of positron emission tomography (PET) which uses radioactive isotopes that decays by emitting positrons (beta-plus decay) as mentioned in [14]. The positron then annihilates with one of the nearby electrons and emits two 511 keV gamma-rays which are then detected in coincidence. Another way to access information on the structure of the softer tissue in the human body is to use NMR or MR which basically measures the relaxation time of the proton spin after is has been perturbed as mentioned in [15]. The essence is that the relaxation time is dependent on the molecule or surrounding in which the hydrogen nucleus is situated as the reactions are shown in Figure 1. The NMR technique has the advantage, compared to tracer methods and computed axial tomography (CAT) scanning, that it produces images with more contrast, better resolution and give a complete image of the region, where tracer methods only show the area where the tracer is present as mentioned in [16]. Cancer therapy is by far the largest field in decease treatment where nuclear physics is applied and an especially important one since one million people in the EU alone is diagnosed with cancer every year. Treatment is done by irradiating the tumor with either gamma-rays or ions and thereby destroying the deoxyribonucleic acid (DNA) of the cancer cells as mentioned in [17]. Using gamma-rays is today the most widespread method to treat cancer since they are easily produced as bremsstrahlung when high energy electrons are stopped in a thick target. Unfortunately, photons have a very flat depth-to-dose profile, that is the energy deposited per length only varies slowly with the deposition depth and deposits the same dose within a factor of two over a range of 20 cm as mentioned in [18]. This problem could be overcome by irradiating the tumor with ions, protons in most cases, whose depth-to-dose profile grows with the implantation depth up to a maximum situated at the average range of the proton and has an increased radio biological efficiency (RBE).

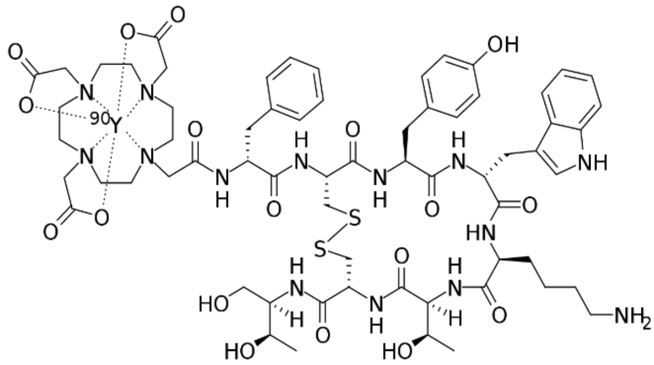


Figure 1. The chemical structure of nuclear reaction with the help of radio biological efficiency [19]

In recent years' cancer therapy with heavier ions (C) has been developed and is now being used on humans two places in the world (GSI, Germany and China, Japan). Nuclear reactions are used since it is the optimum ion for killing most cells in the tumor and least in the healthy tissue surrounding the tumor. Furthermore, irradiating tumors with C has the advantage that nuclear reactions take place when the beam is implanted in the patient and lighter carbon isotopes, like C and C, are produced as mentioned in [20]. These carbon isotopes decay via beta-plus decay and hence the dose deposition can be monitored on-line via PET. Furthermore, the idea of using radioactive isotopes for cancer therapy has been discussed since the subsequent decay of the ion would add extra "killing power" to the tumor. For more information on cancer therapy with heavy ions see the nice review on the work done at GSI in Germany as mentioned in [21].

Another method for cancer treatment has been investigated, e.g. at ISOLDE at CERN, where a radioactive alpha-emitter is attached to an organic molecule which binds to the tumor. When the radioactive isotope arrives at the tumor the idea is that the ionizing radiation kills the cancer cells while the surrounding tissue is left undamaged. This method has been tested on mice and shows very promising results as mentioned in [22]. This field is of course well known, hated, or loved, and one that must be taken seriously if our blue planet is to survive in the long run. Especially with the third world closing in on the industrialized countries the amounts of fossil fuels will probably not last very long, and our environment will most probably suffer very severely (e.g. the greenhouse effect) as mentioned in [23]. In this perspective nuclear power production must be looked at as an alternative at least for a limited period until possible renewable energy sources can support most of the earths energy consumption as mentioned in [24]. Apart from the subjects mentioned above many others exists within the realm of modern nuclear physics, e.g. the search for super heavy nuclei, solid state physics, radiocarbon dating, material analysis by neutron scattering and the search for physics beyond the standard model as shown in the Figure 2.

A new fusion reactor is currently being designed by the international collaboration ITER (ITER meaning "the way" in Latin) using magnetic confinement as JET. Nuclear fusion could also be achieved by use high energy heavy ion beams or very intense laser beams to compress a small capsule, containing the nuclear fuel, causing it to heat dramatically and thereby starting the fusion process as shown in Figure 3. This method is called inertial confinement fusion (ICF).

Two facilities are currently being built in France and Turkey using laser beams to obtain ICF. Laser driven ICF is probably best suited for research whereas accelerator driven ICF most likely will be used if ICF should be implemented in a commercial fusion reactor as mentioned in [25]. Hopefully, these new reactors will be the last experimental reactor before nuclear fusion can be utilized commercially to cover the energy shortage in the world. Unfortunately, this will probably still take another 50 years as mentioned in [26]. Today only nuclear fission is used for energy production in reactors where uranium and plutonium are made to fission by neutron bombardment, arising as product of the fission, thus making the process "self-fueling" when a sufficient neutron flux is obtained. This unfortunately holds the possibility of nuclear run-away processes which results in a total destruction of the power-plant and a huge radioactive pollution of a large area (think of Chernobyl which was not a nuclear melt-down but still had a great impact). Thus, reactors without this dangerous feature must be developed, in my perspective, if nuclear power is to be allowed by the public as a major energy source.

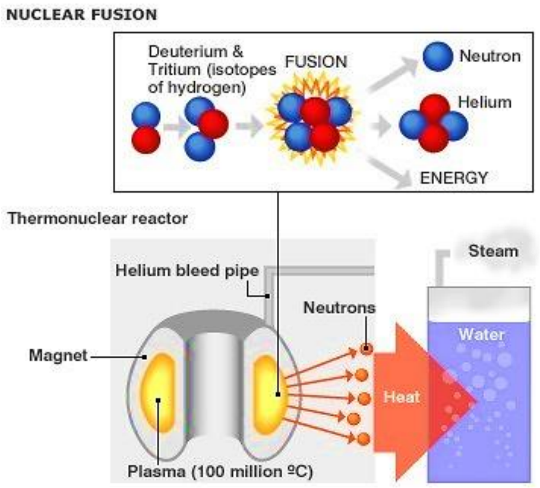


Figure 2. The basic components of natural processing of nuclear reaction in thermonuclear reactor [27]

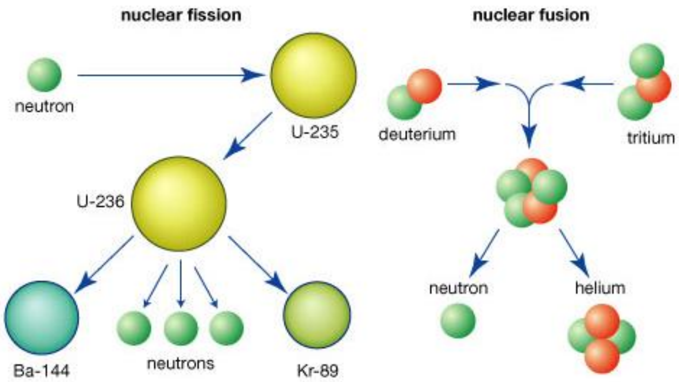


Figure 3. The variation of nuclear fission and nuclear fusion with separation [28]

3. METHOD

The Python programming language was used to create the language model and related scripts, which is a common language for SI activities. Keras, PyTorch, and TensorFlow are among of the frameworks that can be used for these tasks. Though any of these frameworks would be suitable for our research, we chose Google's TensorFlow because of its widespread use and plenty of tutorials and high-quality documentation. This research study uses the graphics processing unit (GPU) variant of TensorFlow to enable GPU acceleration and train the models faster by using 300 epochs of training as testing. The code is organized into numerous scripts that handle various duties, such as downloading and prepping datasets, as well as scripts that detail the SI processing and scripts that train and operate it. The code was utilized as a starting point for this study. Although the system also used nuclear reaction test cases for multiple testing objectives, this machine was the primary on which the python-based system trained the model.

3.1. Swarm intelligence algorithm

A swarm algorithm is a subset of AI and is a metaheuristic optimization algorithm. It draws its inspiration from the processes of natural selection in mother nature and involves similar biological processes such as selection, crossover, and mutation to solve optimization problems. A typical SI algorithm encapsulates these processes as shown in Figure 4.

a. Initialization of particles: a population of possible solutions to the problem is randomly generated or seeded, or both, varying through the search space.
b. Calculation of fitness: similar to the process of natural selection, a proportion of the population is selected to procreate and generate newer solutions based on their fitness, i.e. fitter individuals have a higher chance of breeding.
c. Fitness operators: fitness operators are like breeding processes and inheritance. Genes of parents undergo recombination (crossover) to produce offspring with similar traits and then genomes of the offspring are mutated to imitate natural mutation.
d. Heuristics and velocity: Additionally, heuristics may be used to minimize crossover (breeding) from parents that are too similar, this supports diversity and helps prevent premature convergence.
e. Termination on target: the generational process, processes from 2-4: selection, fitness operators, and heuristics are repeated through many generations of iterations until certain condition (s) for termination is fulfilled. Some conditions for termination are:
   - Solution (s) satisfying the minimal requirements is found.
   - Fixed number of generations of iterations.
   - Set amount of allocated computational time allowed.
   - Newer generations of populations do not generate better solutions.
   - Any combination of the above or others.

A fitness function is also implemented alongside the SI for the nuclear reactions. It determines how an individual is performing in regard to solving the problem. It is used for the selection process where fitter individuals have a greater chance at mating and producing offspring. Rendering weaker populations to gradually dwindle through generations.

3.2. Nuclear reactions with swarm intelligence

The idea behind this project is to first design a sound swarm simulation, capable of replicating swarms in real life, true-to-life and lifelike swarms. Measurements will then be defined to determine the performance of a swarm. The SI algorithm will use the measurements as a form of nuclear reactions to select fitter individuals to breed; the higher the fitness of an individual, the more chance of it producing offspring. Through multiple generations of swarm programming, certain behaviors should be emulated and emerge from the swarms as their parameters are being tuned by the swam intelligence algorithm. The swarms will have different specializations tailored to the scenarios and there will be multiple. Nuclear reactions were introduced to the simulation, extending from the original SI algorithm. The purpose of introducing nuclear reactions is to coax the SI algorithm into optimizing the swarm for nuclear reactions avoidance. Doing so, the simulation may emulate behaviors like the bait ball, exhibited by swarms in the presence of nuclear reactions as shown in Figures 5 and 6. The additional steering behavior for nuclear reactions avoidance steers an individual nuclear reaction to move away from the nearest nuclear reactions within the radius.

Nuclear reactions were introduced into the mix as well, extending from the algorithm. The purpose of introducing nuclear reactions is to coax the swarm intelligence (SA) Algorithm into optimizing the swarm for prey seeking also as shown in Figures 7 and 8 with randomly scattered 256 preys. The simulation may emulate behaviors exhibited by swarms in the presence of nuclear reactions. The additional steering behavior for reactions seeking steers an individual nuclear reaction to move towards the nearest nuclei within the radius. Because it is not trivial for a typical swarm intelligence algorithm to generate a swarm that performs well in everything, different specializations were introduced into the simulation for the nuclear reactions. Specializations represent basic tasks that swarms would perform such as, having a fast-moving swarm, avoiding nuclear reactions, and seeking reactions. The concept is that with different specializations, the swarm intelligence algorithm would ideally combine different swarms performing well in their specializations together, thus producing newer swarms which should perform relatively well in all specializations.

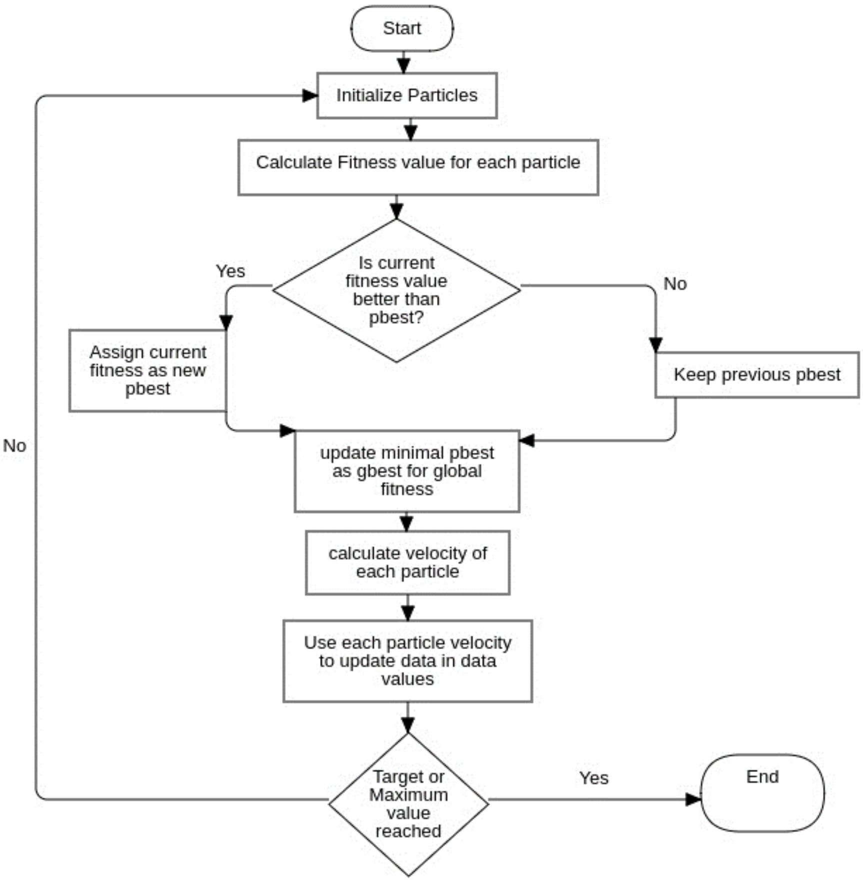
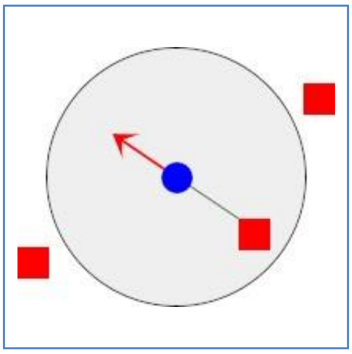


Figure 4. The flowchart of swarm intelligence



Nuclear Reaction: Steer to move away from the nearest nuclear reaction

Figure 5. Nuclear reaction steering behavior

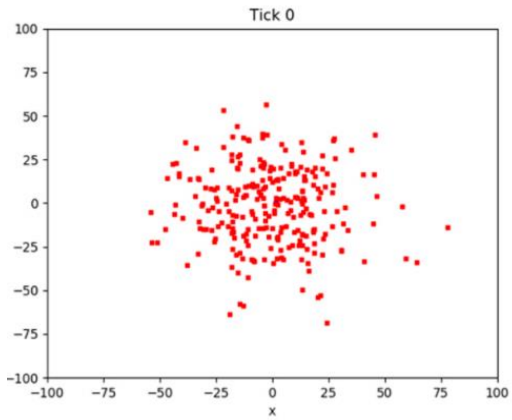
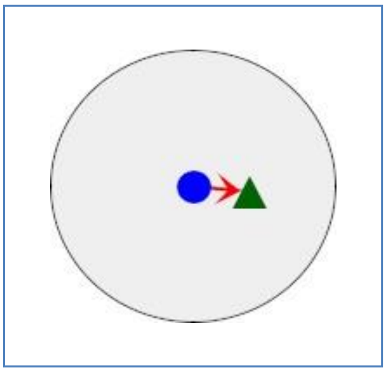


Figure 6. A swarm of 256 nuclear reactions in the swarm simulation with tick is 0

3.3. Nuclear radioactive isotopes separation with swarming

In the early era of nuclear physics radioactive isotopes were often investigated via decay products emerging from thick production targets. This method of course had the disadvantage that the decay products (especially baryons) loose much of their kinetic energy inside the target. In modern nuclear physics the exotic nuclei are often produced, separated, and then transported to a decay or reaction area. With these new methods it is possible to either stop a low energy beam <100 keV in a very thin foil to detect decay products or make an energetic beam react with a secondary target. The techniques developed for separating the radioactive isotopes from the stable have had a major impact on the quality and possibilities in nuclear physics, thus making it feasible to perform detailed decay experiments on nuclei with production rates of less than 1 ion per second. Since radioactive isotopes do decay it is necessary to produce them when trying to investigate their properties. For the isotopes with relatively short half-life's (days to minutes) collection and off-line analysis has been feasible since it became possible to accelerate beams. But today where most isotopes of interest have half-life's less than seconds it is necessary to produce and measure decays/reactions on-line. The presence of different reaction channels produces a cocktail beam of many stable and radioactive isotopes. This mixed beam is then tagged (that is each ion is identified by mass and charge) through one or several analyzing magnets, energy loss detectors, and time-of-flight. before it arrives at the experimental setup. The tagging of individual ions makes it possible to perform "many" experiments at the same time since many isotopes occur in the beam at the same time.



Swarm: Steer to move towards the nearest swarm

Figure 7. Randomly scattered 256 preys in the swarm simulation

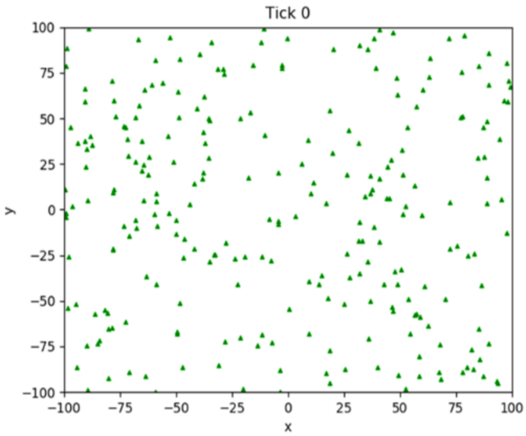


Figure 8. Nuclear reaction steering behavior

4. RESULTS

The swarm intelligence algorithm is not limited and only marginal at best for exhibiting interesting swarm behaviors. Extending and/or augmenting from the original nuclear reaction is necessary to produce interesting behaviors. The tuning of multiple objectives for a warm intelligence algorithm is nontrivial and optimal results cannot be expected from simple tunings. By applying our trained modelled algorithm, multiple objectives are divided and conquered (optimized) at lower levels to be recombined to achieve overall optimizations. Results show evidence that swarm intelligence algorithm is capable of optimizing multiple objectives separately, but is negligible in optimizing all the objectives together. However, it is still possible for nuclear reactions to be seoerated using the swarm intelligence algorithm to optimize the objectives as a whole, given enough generations of iteration; like nature, the advent of human evolution did not occur until many generations later. Certain behaviors emerging from the resulting swarm of nuclear reactions were observed, such as swarm cohesion and reactions on nucleus as shown in Figure 9 with the total energy vs nuclear reaction for nuclear particles emitted in the break-up of nucleus using the swarm intelligence algorithm. Therefore, this research paper is successful in achieving the objectives set out; behaviors can be manufactured with proper measurements/objectives and specialized swarm intelligence algorithm for multiple objectives and efficient time series forecasting of nuclear reactions.

As an improvement of the experiment, it would be very useful to have detection of the heavy residue from the reaction, since this would allow for coincidence measurements which potentially is much cleaner, and possibly extension of the angular coverage with the analysis of total energy in comparison with the nuclear radioactivity to scan the relative energy between the ion and the proton is shown in Figure 10. This could be achieved by a dedicated spectrometer at nuclear reactions, which at the present time is under consideration. Apart from this other consideration should be made before the continuation of the experiment. Some of these are addressed in the outlook and improvements at the end of this research paper.

When using a thick target in resonant elastic scattering experiments with swarm intelligence algorithm the ions scan the relative energy between the ion and the proton while stopping in the target from 0-500 ticks as shown in Figures 11 and 12. This makes the experiment very efficient, since time consuming step-wise scanning of the resonance energy is avoided, but also more difficult to analyses because the reaction position, and thereby resonance energy, has to be extracted from the nuclear energy and angle. It is feasible to extract the resonance energy unambiguously if the incoming ion has a larger energy-loss per length than the elastic scattered particle (proton) and if none of the involved nuclei have an excited state which can be excited by the maximum resonance energy [29]–[31].

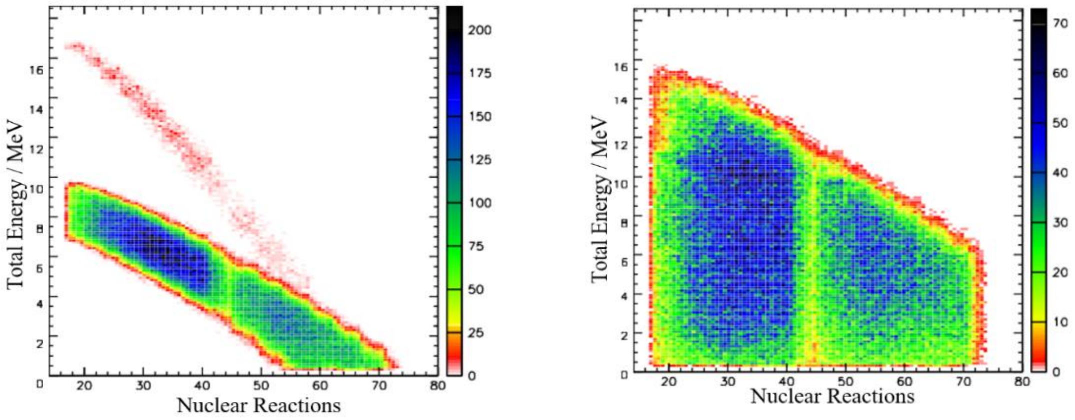


Figure 9. Total energy vs nuclear reaction for nuclear particles emitted in the break-up of nucleus using the swarm intelligence algorithm

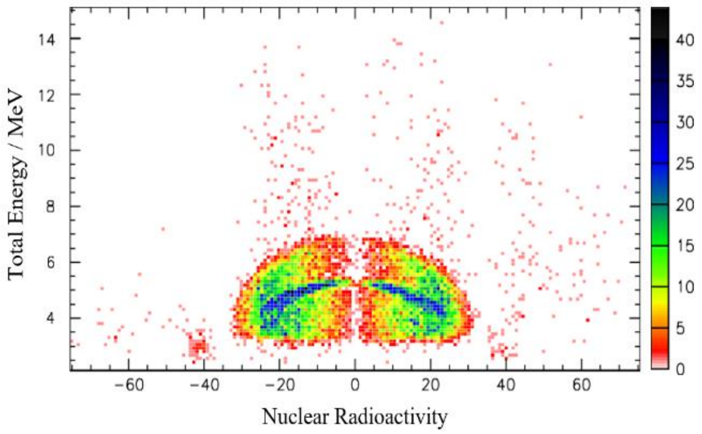


Figure 10. The analysis of total energy in comparison with the nuclear radioactivity to scan the relative energy between the ion and the proton using swarm intelligence

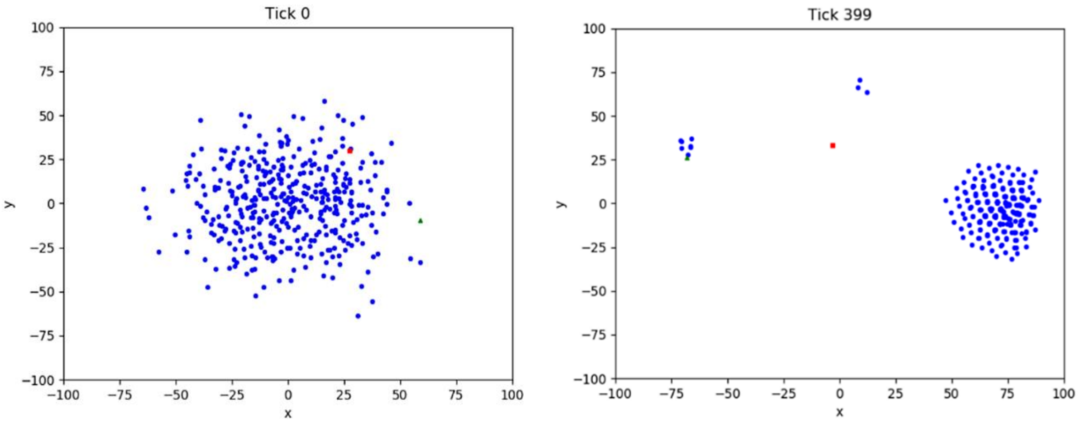


Figure 11. Starting at random positions (top left), swarms can achieve relative swarm cohesion (top right) for the purpose of efficient forecasting of nuclear reaction

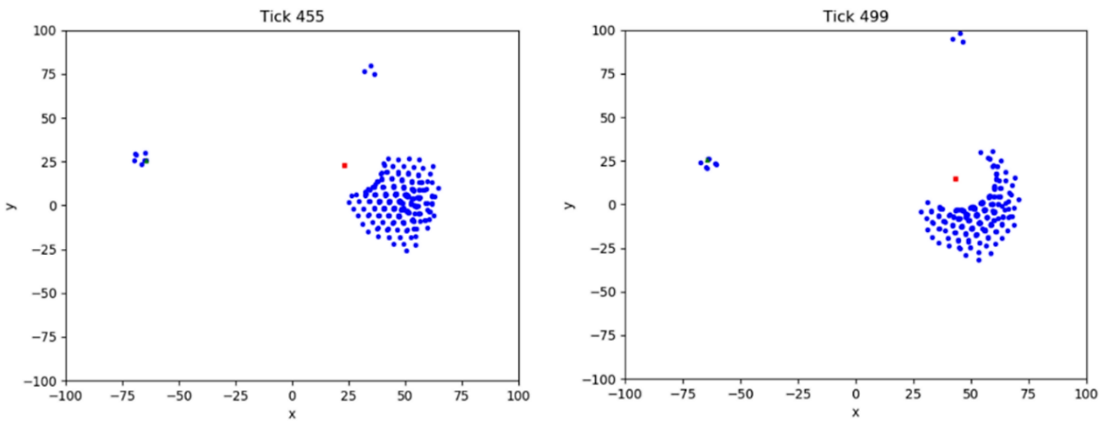


Figure 12. Nuclear reaction avoidance was first observed in preparation of a nuclear ion ball, mimicking the beginnings of a miniature bait reaction in swarm intelligence (top right)

5. DISCUSSION

This research work also provides an overview of previous works and achievements on utilization of swarm intelligence as a tool for the predicting the forecasting of the time series based nuclear reactions in comparison with deep convolution neural network (DCNN). The elements heavier than swarm intelligence are formed by bombarding the nuclei by a neutron flux. This process is a balance between neutron capture and beta-decay, but it eventually leads to heavier nuclei. There are two scenarios for this process either the nuclear reactions where the neutron flux is moderate and thus all the nuclei along the path are very close to stability, or the nuclear radioactivity where the neutron flux is high, and the path lies far from stability. The process requires a very high neutron flux and most likely takes place in super novae explosions which can occur when an old star die. To be able to reproduce the abundance of nuclei in the universe, as it is observed today, it is crucial to know many different properties, such as cross-sections, half-life's, and decay channels, for a great variety of nuclei. Today, many researchers are trying to measure the properties for the nuclei involved in the swarm intelligence but unfortunately many of these nuclei are very far from stability and beyond our reach today. Many of these still unknown nuclei will be possible to produce soon at the next generation of facilities producing radioactive isotopes. Table 1 shows the comparison of proposed work with the existing literature.

Table 1. Comparison of proposed work with the existing literature

Article	Technique	Accuracy
[32]	Natural language processing	90.00%
[33]	Deep convolutional neural network (DCNN)	93.00%
Proposed	Swarm intelligence algorithm	94.58%

6. CONCLUSION

Due to the nature of our work, we could not devote much time to anyone training session, so we had to experiment with many different settings and data preprocessing methods over 300 training periods. With more time, the research team would like to build on the results obtained by training the swarm intelligence algorithm at longer time intervals to predict the effective time series of nuclear reaction events with an accuracy of 94.58%, which is higher than DCNN, such as the number of active reactions to know How you can improve your results. This may necessitate the use of large datasets, since datasets that were very good and new to train when completed would be too small to avoid overfitting. Our initial problem formulation included investigating the ideal conditions and preprocessing for working with a specific nuclear reaction, such as fusion and fission task: forecasting the time series as proposed system took 0-500 ticks in the result section during the specific time series with the help of swarm intelligent algorithm during the specific time series. Even though the reactions were hampered by a lack of resources, the fact that we were able to overcome this and still reach excellent accuracy levels for the dataset obtained from open-source repositories led us to conclude that the suggested system was a success in general. This study was able to identify the specific issues that exist in the field of AI-powered swarm intelligence-based algorithms in predicting the efficient time series analysis and events for various nuclear reactors.

REFERENCES

[1] C. David, M. Freslier, and J. Aichelin, “Impact parameter determination for heavy-ion collisions by use of a neural network,” *Physical Review C*, vol. 51, no. 3, pp. 1453–1459, Mar. 1995, doi: 10.1103/PhysRevC.51.1453.

[2] S. A. Bass, A. Bischoff, J. A. Maruhn, H. Stöcker, and W. Greiner, “Neural networks for impact parameter determination,” *Physical Review C*, vol. 53, no. 5, pp. 2358–2363, May 1996, doi: 10.1103/PhysRevC.53.2358.

[3] F. Haddad *et al.*, “Impact parameter determination in experimental analysis using a neural network,” *Physical Review C*, vol. 55, no. 3, pp. 1371–1375, Mar. 1997, doi: 10.1103/PhysRevC.55.1371.

[4] N. Costiris, E. Mavrommatis, K. A. Gernoth, and J. W. Clark, “A global model of β−-decay half-lives using neural networks,” *HNPS Proceedings*, vol. 15, Jan. 2020, doi: 10.12681/hnps.2640.

[5] S. Akkoyun, T. Bayram, S. O. Kara, and N. Yildiz, “Consistent empirical physical formulas for potential energy curves of 38-66Ti isotopes by using neural networks,” *Physics of Particles and Nuclei Letters*, vol. 10, no. 6, pp. 528–534, Nov. 2013, doi: 10.1134/S1547477113060022.

[6] C. M. Bishop, *Neural networks for pattern recognition*. Oxford University Press, 1996.

[7] S. Hayken, “Neural networks: a comprehensive foundation,” Prentice-Hall International, Inc., Englewood Cliffs, 1994.

[8] R. Frühwirth, “Selection of optimal subsets of tracks with a feed-back neural network,” *Computer Physics Communications*, vol. 78, no. 1–2, pp. 23–28, Dec. 1993, doi: 10.1016/0010-4655(93)90140-8.

[9] P. Abreu *et al.*, “Classification of the hadronic decays of the Z0 into b and c quark pairs using a neural network,” *Physics Letters B*, vol. 295, no. 3–4, pp. 383–395, Dec. 1992, doi: 10.1016/0370-2693(92)91580-3.

[10] S. Abachi *et al.*, “Direct measurement of the top quark mass,” *Physical Review Letters*, vol. 79, no. 7, pp. 1197–1202, Aug. 1997, doi: 10.1103/PhysRevLett.79.1197.

[11] B. Abbott *et al.*, “Search for scalar leptoquark pairs decaying to electrons and jets in p¯p collisions,” *Physical Review Letters*, vol. 79, no. 22, pp. 4321–4326, Dec. 1997, doi: 10.1103/PhysRevLett.79.4321.

[12] D. H. Gloeckner and R. D. Lawson, “Spurious center-of-mass motion,” *Physics Letters B*, vol. 53, no. 4, pp. 313–318, Dec. 1974, doi: 10.1016/0370-2693(74)90390-6.

[13] B. N. Parlett, *The symmetric eigenvalue problem*. Society for Industrial and Applied Mathematics, 1998, doi: 10.1137/1.9781611971163.

[14] P. Maris, J. P. Vary, and A. M. Shirokov, “Ab initio no-core full configuration calculations of light nuclei,” *Physical Review C*, vol. 79, no. 1, Jan. 2009, doi: 10.1103/PhysRevC.79.014308.

[15] M. T. Hagan and M. B. Menhaj, “Training feedforward networks with the marquardt algorithm,” *IEEE Transactions on Neural Networks*, vol. 5, no. 6, pp. 989–993, 1994, doi: 10.1109/72.329697.

[16] D. J. C. MacKay, “Bayesian interpolation,” *Neural Computation*, vol. 4, no. 3, pp. 415–447, May 1992, doi: 10.1162/neco.1992.4.3.415.

[17] D. W. Marquardt, “An algorithm for least-squares estimation of nonlinear parameters,” *Journal of the Society for Industrial and Applied Mathematics*, vol. 11, no. 2, pp. 431–441, Jun. 1963, doi: 10.1137/0111030.

[18] F. D. Foresee and M. T. Hagan, “Gauss-Newton approximation to Bayesian learning,” in *Proceedings of International Conference on Neural Networks (ICNN’97)*, 1997, vol. 3, pp. 1930–1935., doi: 10.1109/ICNN.1997.614194.

[19] S. Q. G. Haddad and H. A. R. Akkar, “Intelligent swarm algorithms for optimizing nonlinear sliding mode controller for robot manipulator,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 11, no. 5, pp. 3943–3955, Oct. 2021, doi: 10.11591/ijece.v11i5.pp3943-3955.

[20] S. K. Bogner, R. J. Furnstahl, P. Maris, R. J. Perry, A. Schwenk, and J. P. Vary, “Convergence in the no-core shell model with low-momentum two-nucleon interactions,” *Nuclear Physics A*, vol. 801, no. 1–2, pp. 21–42, 2008, doi: 10.1016/j.nuclphysa.2007.12.008.

[21] A. M. Shirokov, J. P. Vary, A. I. Mazur, and T. A. Weber, “Realistic nuclear Hamiltonian: Ab exitu approach,” *Physics Letters B*, vol. 644, no. 1, pp. 33–37, Jan. 2007, doi: 10.1016/j.physletb.2006.10.066.

[22] B. R. Barrett, P. Navrátil, and J. P. Vary, “Ab initio no core shell model,” *Progress in Particle and Nuclear Physics*, vol. 69, pp. 131–181, Mar. 2013, doi: 10.1016/j.ppnp.2012.10.003.

[23] S. C. Pieper and R. B. Wiringa, “Quantum Monte Carlo calculations of light nuclei,” *Annual Review of Nuclear and Particle Science*, vol. 51, no. 1, pp. 53–90, Dec. 2001, doi: 10.1146/annurev.nucl.51.101701.132506.

[24] K. Kowalski, D. J. Dean, M. Hjorth-Jensen, T. Papenbrock, and P. Piecuch, “Coupled cluster calculations of ground and excited states of nuclei,” *Physical Review Letters*, vol. 92, no. 13, Apr. 2004, doi: 10.1103/PhysRevLett.92.132501.

[25] E. Epelbaum, H. Krebs, D. Lee, and U.-G. Meißner, “Ab initio calculation of the hoyle state,” *Physical Review Letters*, vol. 106, no. 19, May 2011, doi: 10.1103/PhysRevLett.106.192501.

[26] A. M. Shirokov, A. I. Mazur, I. A. Mazur, and J. P. Vary, “Shell model states in the continuum,” *Physical Review C*, vol. 94, no. 6, Dec. 2016, doi: 10.1103/PhysRevC.94.064320.

[27] S. S. Oleiwi, G. N. Mohammed, and I. Al_Barazanchi, “Mitigation of packet loss with end-to-end delay in wireless body area network applications,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 12, no. 1, pp. 460–470, Feb. 2022, doi: 10.11591/ijece.v12i1.pp460-470.

[28] H. R. Abdulshaheed, Z. T. Yaseen, A. M. Salman, and I. Al_Barazanchi, “A survey on the use of WiMAX and Wi-Fi on vehicular ad-hoc networks (VANETs),” *IOP Conference Series: Materials Science and Engineering*, vol. 870, no. 1, Jun. 2020, doi: 10.1088/1757-899X/870/1/012122.

[29] Z. A. Jaaz, M. E. Rusli, N. A. Rahmat, I. Y. Khudhair, I. Al Barazanchi, and H. S. Mehdy, “A review on energy-efficient smart home load forecasting techniques,” in *2021 8th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI)*, Oct. 2021, pp. 233–240., doi: 10.23919/EECSI53397.2021.9624274.

[30] Z. A. Jaaz, I. Y. Khudhair, H. S. Mehdy, and I. Al Barazanchi, “Imparting full-duplex wireless cellular communication in 5G network using apache spark engine,” in *2021 8th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI)*, Oct. 2021, pp. 123–129., doi: 10.23919/EECSI53397.2021.9624283.

[31] S. S. Hameed, H. R. Abdulshaheed, Z. L. Ali, and H. M. Gheni, “Implement DNN technology by using wireless sensor network system based on IOT applications,” *Periodicals of Engineering and Natural Sciences (PEN)*, vol. 10, no. 2, 128, Mar. 2022, doi: 10.21533/pen.v10i2.2831.

[32] S. Myllynen, *Utilization of artificial intelligence in the analysis of nuclear power plant requirements*, Aalto University School of Engineering, 2019.

[33] Z. A. Jaaz, S. S. Oleiwi, S. A. Sahy, and I. Albarazanchi, “Database techniques for resilient network monitoring and inspection,” *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 18, no. 5, pp. 2412–2420, Oct. 2020, doi: 10.12928/telkomnika.v18i5.14305.

BIOGRAPHIES OF AUTHORS

Hala Shaker Mehdy have a Bachelor's degree in Computer Science from Anbar University in Iraq, 2003-2004 and a Master's degree from the Southern Federal University in Russia. I am currently working as a lecturer at Al-Mustansiriya University in Baghdad. My research interests include information technology, artificial intelligence, data security, and internet of things. She can be contact at email: hmprogeram@yahoo.com.

Nariman Jabbar Qasim received the B.S. degree in computer and communication engineering from RUC, Iraq, in 2009 and the M.S. degrees in computer science and communication from AUL, Lebanon in 2013, respectively. Currently, he is a Lecture at the Department of Civil Engineering, Al-Esraa University college Baghdad, Iraq. His research interests include artificial intelligence, distributed computing, database systems, Image processing, cellular and mobile networks. She can be contacted at email: Nariman@esraa.edu.iq.

Haider Hadi Abbas received the B. Sc. degree in electronics and communication engineering from Baghdad University in 1994, Baghdad, Iraq, the M. Sc. degree in electronics engineering from University of Technology in 1997, Baghdad, Iraq, and Ph. D. degree in communications engineering from Baghdad University, Baghdad, Iraq in 2001. He has been an assistant professor of data and information security since 2014. He has authored more than 25 refereed journal and conference papers. His research interest includes data and information security, machine learning, internet of things, cloud related issues. He can be contacted at email: haider.hadi@muc.edu.iq.

Israa Al_Barazanchi received her Bachelor of Computer Science (BCS) from Department of Computer Science, Baghdad college of economic science university-Iraq-Baghdad in June 2002. In January 2010, she entered the master's program at the Faculty of Information and Communication Technology, Graduate School of Computer Science (Internetworking Technology), Universiti Teknikal Malaysia. She is Currently a student Doctor of Philosophy in Information and Communication Technology. She is a lecturer in Computer Engineering Techniques Department. Editor-in-chief for international union of universities journal. Member of Editor board in many Scopus journals for computer science field. Head of Researcher group. Member in many conferences panel and communications events. She is a Reviewer of various high impact factor journals. Her research activities are WBAN, WSN, WiMAX, WiFi on vehicular ad-hoc networks (VANETs), communications, networking signal processing, IOT, smart systems, blockchain. She can be contacted at email: israa.albarazanchi@baghdadcollege.edu.iq; israa44444@gmail.com.

Hassan Muwafaq Gheni received his Bachelor (B.Sc) of Electrical and Electronic Engineering from Department of Electrical Engineering, Babylon university-Iraq-hilla in June 2016. In February 2018, he entered the master's program at the Faculty of Electrical and Electronic Engineer, Universiti Tun Hussein Malaysia. He is a lecturer at Al-Mustaqbal university college/Department of Computer Techniques Engineering. His research interest is optical communication, IoT, wireless sensor network, communications, V2V system, Artificial intelligent. He can be contacted at email: hasan.muwafaq@mustaqbal-college.edu.iq.