Nuclear Physics Experiments and Machine Learning

Master of Science thesis project

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Machine Learning for interpreting Nuclear Physics experiments

The classical picture of spherical nuclei is far from the reality of the true nuclear structure. Shape coexistence is a nuclear phenomenon, where the nucleus exists in two stable shapes at the same excitation energy. Nuclear properties provide unique information on the impetuses that foster changes to the nuclear structure of rare isotopes. In some neutron-rich nuclei, 0^+ states are predicted to exhibit shape coexistence. Therefore they are compelling to study, but experimentally challenging. At low energies, where the only energetically allowed decay mode is $0^+ \to 0^+$, conversion electron spectroscopy is the only viable technique to probe their properties.

At the National Superconducting Cyclotron Laboratory at Michigan State University Sean Liddick's group employs conversion electron spectroscopy to study these transition rates. When a neutron-rich nucleus beta decays, a neutron transforms into a proton and emits an electron β. The excited nucleus can then interact electromagnetically with the surrounding orbital electrons. This can result in the ejection of an internal conversion electron e^- from the atom. Because this process is essentially simultaneous in time, it is pivotal to differentiate between the electron β emitted from the nucleus and the internal conversion electron e^- emitted from the atom.

This project attempts to use supervised machine learning algorithms as a means to distinguish between one and two electron events and predict the electron(s) corresponding initial position(s) in a scintillator.

We chose to use convolutional neural networks to combat our problem. Convolutional neural networks (CNN) are a class of deep neural networks optimized for analyzing images. CNNs provide the computer with the ability to see. This will allow us to treat each scintillator event as a visual image, so the computer can see where the electron by looking at all of the non-zero pixels. For more information see the Master of Science Thesis of Robert Solli

The milestones are as follows

1. Spring 2020: Analyze simulated data with Convolutional Networks and reproduce results from simulations
2. Fall 2020: Include reinforcement learning and autoencoders and analyse data from experiments at Michigan State University
3. Spring 2021: Finalize thesis project.

The thesis is expected to be handed in May/June 2021.