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Turning optimal classifiers into anomaly detectors

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This study investigates the adaptation of leading classifiers, such as Transformers and Convolutional Graph Neural Networks, as anomaly detectors using different training techniques. The focus lies in their utilization with proton-proton collisions simulated by the DarkMachines collaboration, where some exotic signatures are aimed to be detected as anomalies.

Adaptations of these architectures, named Particle Transformers and ParticleNet, have been proved to be the state-of-the-art for the jet tagging task. An event-level approach is studied in this project, where the kinematical information of various physical objects is provided: jets, b-tagged jets, leptons, and photons.

Our main interest is how to turn classifiers into anomaly detectors. To this end, we have investigated three different strategies. First, the Deep Support Vector Data Description (SVDD) technique, in which the input information is encoded in a latent space of lower dimension and the loss function is computed as the distance to a centre point. In second place, the DROCC technique (Deep Robust One-Class Classification) assumes that background points lie in a low-dimensional manifold that is locally-linear and a modified distance metric is implemented as an adversarial loss function in order to identify the anomalies. The third technique consists of generating a modified background sample in which a certain amount of noise is introduced. By performing supervised learning to classify the normal and the noisy background events, the trained algorithm is able to evaluate if any event deviates from a "normal" collision.

The purpose is to investigate the anomaly detection capabilities of these architectures in comparison to more established techniques described in the Unsupervised Challenge Paper of the DarkMachines initiative. The outcome of this comparative analysis should provide valuable insights into the application and future developments of unsupervised learning techniques in high-energy physics research, specifically how to turn optimal classifiers into good anomaly detection algorithms.

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