Can computers help us find dark matter?

Dark matter is one of the biggest mysteries in modern physics. It is invisible and acts like a glue that holds galaxies together. Scientists believe that it should make up 85 % of matter in the universe, but it has not yet been found anywhere. If humans can't find it, could it be possible to teach a computer to find it for us?

Everything you can see in the universe is made up of elementary particles — the air around you, the computer you are reading this on, and you, yourself. These elementary particles cannot – to current knowledge – be divided into smaller pieces. The Standard Model, in its current formulation, classifies all known such particles. However, the model is believed to be incomplete and more types of particles should exist, for example *dark matter*.

We have a large amount of evidence for the existence of dark matter but we know very little about what it is. In fact, we know more about what it is not, than what it actually is. This makes it difficult to look for. One approach is to simply look for something that is out of the ordinary – something *anomalous*.

One experiment where dark matter may be found for the first time is ATLAS, an experiment at the world's largest particle accelerator – the Large Hadron Collider (LHC) at CERN. At the LHC, particles called *protons* are accelerated to extremely high speeds (more than 1 000 000 000 km/h) and then brought together to collide. These high-energy collisions produce an explosion of new particles – some of which could be dark matter. ATLAS produces a lot of data, more than what is possible to store. As a consequence, ATLAS is forced to discard data without being able to analyze it first. This means that ATLAS could have measured dark matter, but the proof of its existence was accidentally thrown in the bin.

An artificial intelligence (AI) called an *autoencoder* can learn to recognize patterns in data and how to compress it. This can be used to solve the problems mentioned. If the autoencoder learns to recognize patterns of Standard Model data, and then is shown data with new patterns in it, the autoencoder would notice and alert us.

In this thesis, simple autoencoders were tested with data consisting of images of how the detectors sees particles in ATLAS. More specifically, images of jets were used. A *jet* is a group of particles from "particle explosions" that travel in fairly the same direction. According to theory, dark matter could also create jets. The method was tested on a simpler problem: compressing and distinguishing two Standard Model types of jets called *boosted W-boson jets* and *QCD-jets*. The autoencoder learned to compress and recognize QCD-jets, and then tried to distinguish them from boosted W-boson jets. The compression was successful for both types of jets, only giving a 5 % error for 95 % of the data when compressing threefold. The anomaly detection however failed, possibly because the jets are too similar for the simple autoencoder to distinguish. Using a more complex autoencoder could solve the problem.

Popular Science Summary of Master's Thesis: *Investigation of Autoencoders for Jet Images in Particle Physics*. Jessica Lastow. Department of Physics, Lund University, Sweden.