Extra Credit Assignment

Special Topics in Graphics, Vision, Machine Learning

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1 Introduction

Astronomers recently captured the first ever image of a black hole, which resides at the center of the Messier 87 galaxy, and is 55 million light years away from Earth. Despite the gargantuan size of the black hole (6.5 billion times the mass of the Sun), its distance from Earth is a seemingly insurmountable barrier to getting an image of it. For reference, this feat is like capturing a hi-res image of an orange on the surface of the moon, something that would take a telescope the size of the Earth to do. However, this didn't stop some extremely creative individuals from coming up with a solution. With readings from an array of several telescopes from around the world, the Messier 87 black hole was finally captured. This image is hugely insightful into our understanding of the universe. The way it was captured required no shortage of some of the most exciting topics on the cutting edge of computing.

Figure 1: The first ever image of a black hole.

2 Problem

As described in the **Methods** section below, the way that researchers were able to simulate the necessary 13,000 kilometer telescope was to use 8 regular-sized telescopes that were spread across the world. This required especially clear weather conditions for each of the observatories. Once a few perfect nights were identified, the optical instruments began collecting data - lots of it. Each gathered around 1 petabyte of data, which was then sent to the United States and Germany for processing. Statistical "noise" was mitigated by cross-referencing the findings in all possible telescope pairings. It is only this rigorously verified data that was then used to generate a final image.
The construction of this image was no easy task. Because there are a limited number of telescopes on Earth, there are an infinite number of possible images that are perfectly consistent with the data that was collected. To fill in the gaps, state-of-the-art algorithms that employ some of the newest machine learning techniques were necessary to extrapolate pixel data from the radio signals pulled from the telescopes.

3 Methods

To capture this image, a total of 8 telescopes from around the world were used in conjunction. Data points were collected from these instruments while the Earth spun, simulating a much larger telescope in the neighborhood of the size needed to accurately depict the black hole. These telescopes provide a good starting point for the image, but there is still a long way to go after they finish their job. Data scientists spent years figuring out how to solve the issue of using a limited amount of information to construct an image that is both complete and accurate. Luckily, some of the most prominent developments in machine learning were precisely what was needed to confront this challenge.
The same reality governs both the Earth and distant cosmic objects such as this black hole. This means that ordinary, everyday photos capture objects that adhere to universal physical laws. Using regular photos, as well as things like Einstein's equations - which specifically apply to extreme environments like those near black holes - an algorithm was built to identify the most likely candidates for complete photos of this celestial anomaly. There needed to be some degree of care taken to ensure that there wasn't too much bias

introduced when incorporating what the black hole is expected to look like (as in the equations of general relativity). Millions of plain, non-scientific images were used in intermediate stages to avoid this problem. In conjunction with scientific and equation-based photos that were fed into the algorithm, more likely final products emerged as outputs that agree even with wildly variant inputs.

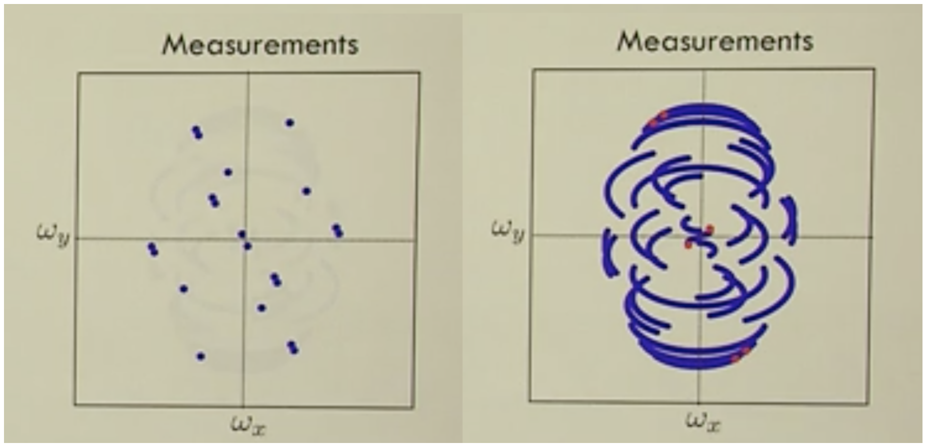

Figure 2: Though there are only 8 telescopes, as the Earth spins, there are a large number of different measurements that can be taken.

4 Results from Methods

An accurate, statistically supported ranking of possible black hole photos was finally constructed such that the best possible candidate could be delivered as the historic photo that shocked the scientific community. Upon first glance, the image is pretty blurry, but considering the difficulty of the task at hand, it is extremely impressive. Some clever insight made up for a lack of measurement capabilities, and brilliant data analysts used computation to bridge the gap between possible and impossible. In the future, better methods for getting clearer pictures of these distant entities may come to fruition, but this is surely a step in the right direction.

5 Applications

Aside from demonstrating the impressive capabilities of modern science, the first image of a black hole did justice to Einstein's famous equations, which predicted the size and shape of event horizons, like the one seen in the picture. By definition, a black hole is invisible; not even light can escape its event horizon, but wisps of plasma - amplified by gravitational lensing - are detectable on the outer edge. The image provides enough evidence of the characteristics needed to confirm whether the predictions of modern physics conform to reality. As for the algorithms used, this project delivers proof that machine learning can make up for missing data about objects that are not directly detectable.

References

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