Popular Science Summary

Over the past decades, Machine Learning (ML) has become increasingly popular as hardware computing power has increased. ML is widely used to implement Artificial Intelligence (AI), and unlike traditional computer programs, ML algorithms enable computer programs to achieve performance improvements as program inputs are updated automatically. This capability makes ML promising for a wide range of applications in other fields, including wireless fingerprinting positioning. The main objective of this project is to investigate the effect of different Multi-Input Multi-Output (MIMO) antenna topologies, the number of MIMO antennas, ML algorithms, and Channel State Information (CSI) fingerprints on the performance of ML-based fingerprinting positioning.

I will use an example to explain what is the machine learning concept. Suppose a teacher has two stacks of cards. The first pile has pictures of different animals on the front and the animal's name on the back of each card. The second set of cards also has pictures of the same group of animals, but they are taken from different angles and do not have the names of the animals on the back of the cards. The teacher shows the students the front and back of the first pile of cards and teaches them to match the pictures of the different animals with their names by identifying their features. For example, a panda has black and white fur and a big round head, and a giraffe has a long, thin neck and a huge orange-brown body. With the teacher's guidance, the students successfully mastered the ability to match the appearance of different animals with their names. The teacher then showed the students a second set of cards, and they tried to answer the names of the animals after looking at the pictures. In this type of test, students can make mistakes. After all, there is no such thing as a perfect student or teacher. For example, the teacher may not have found the best description of the animal, and the student may not be a good learner. Different students may be good at learning different subjects; some are good at learning from pictures, while others are better at learning from words. The above process of student learning is the same as the process of learning ML algorithms, where the teacher and the cards represent the data set in ML. The first pile of cards with name labels represents the training set, and the second pile of cards without name labels represents the data samples awaiting to be studied. Students represent ML algorithms, and students who are good at learning different subjects represent different ML algorithms.

In this project, the example becomes that of a teacher showing students a

series of CSI and their corresponding location coordinates. Students learn the correspondence between the two, and then students observe CSI they have never seen before and can predict the location coordinates corresponding to this new CSI. The following example can help us understand the relationship between CSI and location coordinates. Imagine a room with a mobile wireless transmitter and a fixed receiver. When a signal is transmitted, the transmitter is at location A, and the receiver receives version A of this signal. Then, the transmitter moves to another location B, in the room and sends the same signal again, and the receiver receives another version B of the same signal. Are the two versions of the received signal the same? The answer is no. During signal propagation, the same signal passes through the wireless channel differently due to the relative positions of the transceivers and the environment. These two wireless channels "distort" the signal differently to different degrees. So when the signal reaches the receiver, it already bears the imprint of the unique wireless channel it has experienced. This different imprint is the CSI, which can be associated with different transmitter locations since different transceiver relative locations constitute different wireless channels. Some ML algorithms are better at learning this correspondence than others, so this project aims to explore and compare which ML algorithms are better at learning the relationship between CSI and its corresponding location. In addition, the measurement system in this project consists of many antennas rather than a single antenna. A MIMO antenna is a receiver that can view the wireless channel from different angles. Topologies and the number of antennas also determine the richness of the CSI from the angle perspective. The CSI has different expressions, which are different fingerprints, and the choice of fingerprints also affects the positioning performance. Therefore, this project also investigates the effect of different topologies of MIMO antenna and the number of antennas and fingerprints on the positioning performance of different ML algorithms.