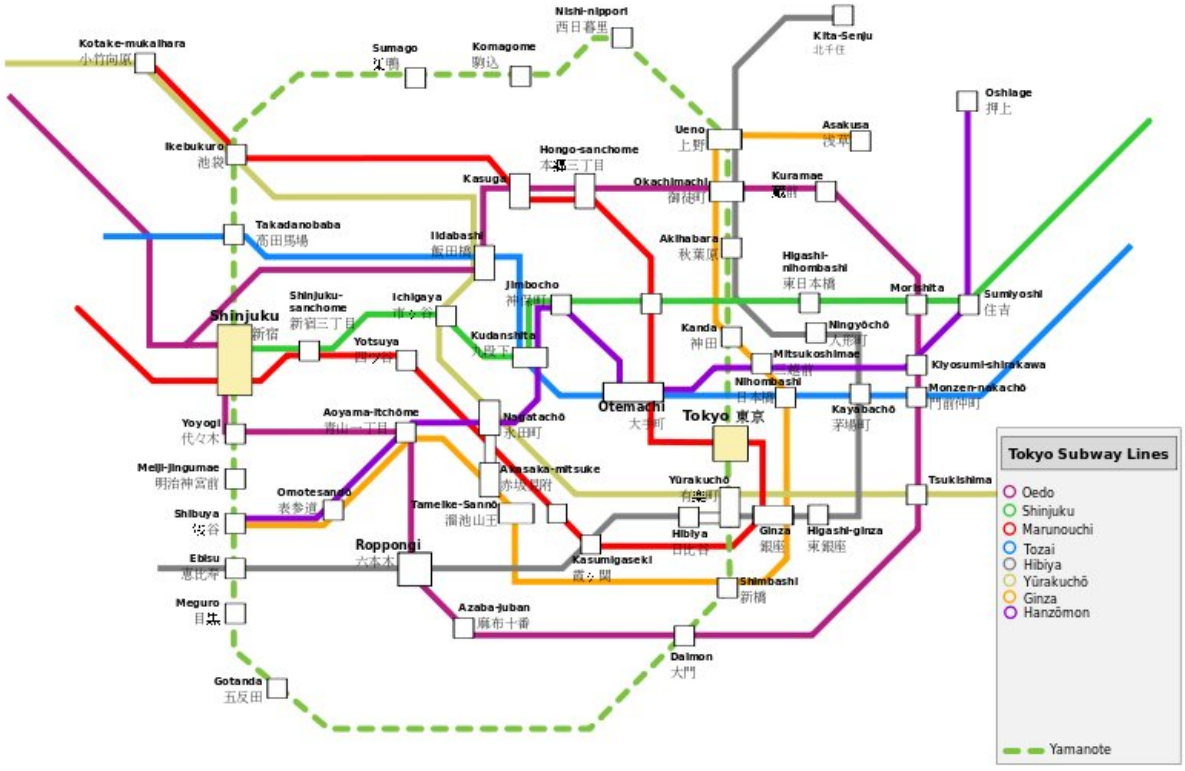
Sketching a shape based on its sound

March 29 2021



In his dissertation, mathematician Abel Stern managed to reconstruct the shape of a drum on a computer from hearing merely the lowest tones. He will obtain his Ph.D. from Radboud University on 30 March.

How is it possible to hear the shape of a drum by hearing only a limited

set of tones? This theoretical problem has been solved by mathematician Walter van Suijlekom of Radboud University. Last year, he showed how it is possible to recognize the shape of an object by studying the ways in which it can vibrate, even if only a limited range of the vibrations can be observed.

The research by Abel Stern, a Ph.D. candidate in Van Suijlekom's group, builds on this finding by taking it a step further. With a limited number of vibrations at our disposal, can we use a computer to reconstruct a shape that we have no prior knowledge of?

From single points to a map

Together with postdoc Lisa Glaser, Stern developed a technique that makes this possible. "We studied how the object conducts heat," Stern explains. "Heat waves can be described accurately using the vibrations that we do in fact have at our disposal. Just like sound, heat is very geometrical: It "feels" the shape that it flows through. When these two properties are properly balanced mathematically, it is possible to create a sketch of the object."

The new technique explores the object by simulating a series of heat sources and detecting the spacing between them. Then, based on these distances, the computer reconstructs what the object must have looked like. "It could be compared to the map of an underground rail system. If we would look at a list of individual stations and the distances between the stations, it wouldn't be of much use. But if we create an image based on this list, we could see at a glance whether it's the London Underground or the Tokyo Subway."

Heat flows through a sphere. Credit: Abel Stern

Artificial intelligence and quantum gravity

In order to reach new insights in science, it is vital to be able to make connections or to see the bigger picture. At the same time, measurements and experiments only offer a limited amount of information. When we visualize the available data by creating an image, this often yields new insights.

Computer scientists have been working on getting computers to recognize patterns in many different ways, which is a key ingredient for artificial intelligence. However, it is often still unclear why these methods work. "We are now providing a scientific foundation to an entire series of such methods, because we know exactly how determining a shape based on a limited number of vibrations works mathematically. This creates space to further refine methods of pattern recognition based on vibrations and heat."

This technique could be very useful in high energy physics. "We hope that it will eventually be possible to simulate and interpret spectral models of quantum gravity using computers. This research is a necessary part for that: after all, computers cannot process infinite numbers of vibrations."

Provided by Radboud University