Impact Objectives

- Undertake research into discrete algorithms on computational geometry and their practical applications to computer vision and VLSI design
- Use theoretical computer science to solve commodities transportation problems

Value-adding through computational geometry

***Dr Tetsuo Asano** is a computer scientist and former president of the **Japan Advanced Institute of Science and Technology** who has designed computer algorithms that have contributed to addressing real-world challenges*

Can you begin by telling us a little about your background as a computer scientist?

For many years, I have been working as a researcher in theoretical computer science. Through this work, I have designed many algorithms, which describe how to solve a problem using a computer, for use within various industries. I think it is very important to work on a real problem provided by industry, because working with companies can help broaden the view of a researcher (and possibly that of industry too). I am especially interested in computational geometry, which is one branch of algorithm design for problems related to geometry, such as finding the shortest route between two points. Car navigation systems now use computational geometry, and this relates to my current research.

You have made important contributions to research on discrete algorithms in computational geometry and their practical applications to computer vision and VLSI design. Can you outline what the main impact of this was?

I have contributed to computer vision for fingerprint recognition systems and the technique is now widely used in practice. The most difficult question was how to make an algorithm tolerant against different finger pressure. I formulated the problem as a geometric optimisation problem and proposed an efficient algorithm considering the geometric property of force. Another contribution to VLSI design is to find a good layout pattern. To design an integrated circuit, for a huge number of wire connections, we want to realise them by mutually non-overlapping orthogonal wires in two or more layers. I provided a fundamental idea about the problem in VLSI in 1977 together with a Japanese company.

When you realised that mathematical knowledge was critical to progressing your research how did you address this challenge?

I graduated from a department of electrical engineering and as a result did not have deep mathematical knowledge. When I became interested in the problem of proving the existence of two equidistant curves between a pair of points, I needed a deep knowledge in mathematics. Fortunately, I had some friends who had enough knowledge in mathematics to help me in giving a mathematical proof. I was, and am, very happy to have so many friends in my life who are willing to help.

Do you collaborate with other academic institutions and industry? If so, how valuable are these to your research?

I have two close friends I have collaborated with - one is based at British Columbia University in Vancouver, Canada and the other at the Max-Planck Institute for Information in Germany. There was a time when I visited them almost every year to spend between a week and a few months with them. This enabled us to exchange ideas for our research and this culminated in having many joint works with them and their colleagues. I also had close contacts with Japanese companies and the joint research produced many results in computer vision and computer-aided manufacturing. Ultimately, working in collaboration with others has given rise to ideas and solutions that would likely have never surfaced were it not for their input. ●

Algorithms help solve a transportation problem

*A researcher based at **Kanazawa University** is working on a means of solving commodities transportation problems by using theoretical computer science, specifically computational geometry*

As we travel ever further into the 21st century, our lives become increasingly reliant on algorithms. They help to shape our lives in many ways, often without our knowledge. Algorithms use information built up to generate and shape predictions, such as the personal recommendations offered by Netflix or Spotify. However, algorithms are capable of doing so much more than generating recommendations.

In fact, it could be said that this is the very minimum that algorithms can do. Put simply, an algorithm is a list of rules within the field of mathematics and computer science followed in order to solve a particular problem. Having the rules (or instructions) in the correct order is extremely important and there is a systematic process followed.

Dr Tetsuo Asano has an extensive background in the power and potential importance of algorithms. Asano is a computer scientist with more than 40 years of experience conducting research within computational geometry, which is a field of algorithm theory in theoretical computer science. He is currently engaged in a project that aims to solve a novel problem by using algorithms.

SHORTEST ROUTE BETWEEN TWO POINTS

Based within Kanazawa University in Japan, Asano is a former president of the Japan Advanced Institute of Science and Technology (JAIST). His current work sits within computational geometry, which seeks to design efficient methods to solve computational problems. It does so by describing solutions in terms of geometry, such as finding the shortest path between two points. 'Using fast modern computers, we can find a shortest route between any two points in the entirety of Europe in less than one microsecond,' Asano highlights. 'One of the most important problems in computational geometry is to compute the convex hull of a point set in the plane that is the smallest convex polygon containing all of the points in its interior. It was shown that the problem can be solved just by sorting many values in increasing order,' he explains. 'Another problem is called a point-location problem. Suppose you move into an unknown city with your family and you must find a primary school for your child to go to. If a map dissecting the city area into regions showing which school is nearest is available, you could find the right one quickly, says Asano.

'Dissecting a map in such a way is a hallmark of computational geometry, a field that can be applied to pattern recognition, computer graphics, operations research, computer-aided design and manufacturing, robotics and many other areas'

When the problem is described in terms of computational geometry, where a set of points in the plane are given, any arbitrary point can quickly be solved, in terms of which point is closest to it. 'Dissecting a map in such a way is a hallmark of computational geometry, a field that can be applied to pattern recognition, computer graphics, operations research, computer-aided design and manufacturing, robotics and many other areas,' he observes.

DRIVING RESEARCH FORWARD

Asano has now embarked on a project that seeks to propose a new framework for solving a transportation problem, one that involves 'nodes' which serve as suppliers of one commodity and in need of another commodity. If we imagine there are many nodes, each with different commodities, is there a specific set of trips that can be made by vehicles available at all nodes to meet all demands in an efficient way? Asano's work seeks to answer this question. 'Traditionally, one vehicle is assumed to move around a given network to pick and deliver goods, and the problem is to find the most economical way to visit nodes. It is known as a travelling-salesperson problem,' outlines Asano. 'However, our project is different from those studies. We use many vehicles instead of just one, which belong to all nodes. Another difference is that a vehicle can send some commodities to an adjacent node along an edge and it brings back some other commodities from the neighbour. So, each vehicle only travels between neighbours,' he explains.

A key part of this research is mathematics. Asano explains that he relies on mathematics as opposed to any tools or experiments. 'Ultimately, I assume a conjecture or hypothesis and then set out to prove it,' he enthuses. 'Of course, this is not always successful, but no work is ever wasted. This methodology means that testing or validating any findings is inherent anyway; there have been times I have proved an algorithm works correctly by mainly using mathematical induction,' he says.

So far, this team has managed to obtain some reasonably fast algorithms if a network contains one cycle. However, the quest is to solve the problem in general terms, and it has been proven that the problem is extremely difficult to solve for a general graph. 'The next step is to extend the idea behind the project to an efficient algorithm for finding a schedule for sending vehicles in two or more steps to meet all demands,' he comments.

JAIST

JAIST is one of 86 national universities in Japan. It has no undergraduate programmes, which is very different from others. 'In Japan, it is usual for undergraduate students to proceed to master's and doctoral courses without changing places. But JAIST has no undergraduate programme, so it is not so easy to recruit students from other universities,' observes Asano. 'As the president of JAIST, I invited many foreign students, which resulted in attracting excellent Japanese students too. Now, more than half of the students are from foreign countries. Moreover, I worked hard to recruit doctoral course students. Ultimately, JAIST provides students and researchers with a comfortable environment to conduct their studies,' he says. ●

> *'Using fast modern computers, we can find a shortest route between any two points in the entirety of Europe in less than one microsecond. One of the most important problems in computational geometry is to compute the convex hull of a point set in the plane that is the smallest convex polygon containing all of the points in its interior'*

Project Insights

FUNDING

Ministry of Education, Culture, Sports, and Science and Technology (MEXT), KAKENHI, Grants-in-Aid for Scientific Research, 'Designing algorithms for commodity transportation on a planar graph modeling a map'

COLLABORATORS

Professor Ryuhei Uehara, JAIST

CONTACT DETAILS

Dr Tetsuo Asano

E: asano@staff.kanazawa-u.ac.jp
W: www.jaist.ac.jp/~t-asano/e-index

BIO

Dr Tetsuo Asano is a computer scientist and the ex-president of the JAIST. He has previously studied and worked at Osaka University and Osaka Electro-Communication University. His main research interest is in computational geometry. In 2001, he was elected as a fellow of the Association for Computing Machinery 'for his contributions to discrete algorithms on computational geometry and their practical applications to computer vision and VLSI design'. Asano is also a fellow of the Institute of Electronics, Information and Communication Engineers and the Information Processing Society of Japan.

KANAZAWA UNIVERSITY 1862—1949— 金沢大学