Learning from ants how to build transportation networks

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Temnothorax rugatulus. Credit: Arizona State University

Using mathematical modeling and field data, researchers at the mathematics department at Uppsala University have found the basic rules that allow ants to build efficient and low cost transport networks without discarding robustness. The study is now published in the Royal Society journal *Interface*.

We live in a world that is deeply interconnected. Nowadays, transportation networks are fundamental to exchange resources and information from a point to another, from a person to another. Every day we travel on roads, we use electricity and water that are carried from distant plants, we connect to the internet to read about facts happened on

the other side of the world. Ideally, we would like to be able to travel between cities on the shortest way possible, but sometimes we have to follow long detours.

Almost everyone in his life has experienced a black out: sometimes the breakdown of a cable is enough to compromise the distribution of electricity in a whole suburb. However, we all know how expensive it is to install new cables at home, and we can imagine the cost of building a highway.

Thus network planners struggle to build transportation systems that are efficient and robust, but also not too expensive, trying to find the best compromise between competing design goals.

Searching for inspiration, researchers have turned towards nature, observing the spontaneous formation process of natural transportation networks, from ant trails to leaf veins.

A two-year long field study recently provided a large data set consisting of several trail networks built by the Australian meat ant to connect different nests spread over a wide territory.

'What is amazing about these ants is that they don't rely on engineering to plan their networks, however it turns out that they are able to find a specific balance between cheapness, efficiency and robustness,' explains Tanya Latty, researcher in biology at the University of Sydney.

Researchers from the department of mathematics at Uppsala University have developed a model to understand how these networks have formed. Using data and numerical simulations, they were able to identify a general mechanism of local cost minimization as the basic rule that leads to a balance between competing design goals. The study showed that when building a new nest, the ants connect it to the closest nest available

and possibly to a tree, that is where the ants feed, if it is not too far away.

'Once we have found what nature does, we have tried to apply the same simple rules to predict what would happen to man-made system, electric grids for example, if they were built by these ants,' says Arianna Bottinelli, PhD student at Uppsala University.

It turns out that, when building a new suburb, it is sufficient to connect it to the closest city area to ensure that the whole power network will be relatively cheap but also quite efficient on the long run. Then robustness can be increased or decreased by changing the frequency with which new suburbs are connected to service centers, in this specific example to power plants.

'It is a further step towards the understanding of nature and an attempt to use what we observe there to improve and advise the design of human-made systems,' says David J.T. Sumpter, Professor at the Department of Mathematics at Uppsala University.

More information: Bottinelli A, van Wilgenburg E, Sumpter DJT, Latty T. 2015 Local cost minimization in ant transport networks: from small-scale data to large-scale trade-offs. *J. R. Soc. Interface* 20150780. dx.doi.org/10.1098/rsif.2015.0780

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