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Column

How Many Turns? It Is Smaller Than We Thought

If you were a taxi driver, it would be very interesting to ask the following question. How many turns on average it would take when driving in a city? Or put it differently, how many intermediate streets one has to pass over in order to reach one street from another?

The above question is as a matter of fact a small world problem. Let's transform an ordinal street network into an interconnected graph, namely a street topology with the set of nodes representing the individual named streets, and links if pairs of streets are intersected. The number of turns or the number of intermediate streets is actually the shortest distance between two randomly chosen nodes with the graph. Before answering what this number is, we shall take a retrospective view on the development of so-called small world problem.

The small world problem was initially defined in the context of social networks, in which each person is represented as a node and possible acquaintances such as friends, colleagues, and relatives are a link between a pair of nodes. The "six degrees of separation" nicely states that on average any two arbitrarily chosen persons are separated by just six intermediate persons in a large population. It means that you are not more than six hand-shakings away to anyone else. Is this really true? In the 60s, Stanley Milgram, a psychologist at Harvard University, designed an elegant experiment to test the small world problem. The experiment did show that some randomly selected individuals in Kansas and Nebraska are linked to two targeted persons living in the Boston area with a short chain of acquaintances, no more than 6 persons. A more recent experiment using email contact has led to similar result in a worldwide setting. http://smallworld.columbia.edu/

The small world problem made a theoretical breakthrough in 1998 by two researchers at Cornell University. So-called small world network is a kind of transitional phenomenon between chaos and order. It has two distinguished properties: a short average separation between nodes and highly clustering among immediate nodes. The first property is clear enough, while the second can be said to be "the friends of a friend are likely to be friends" in a social context. The transitional phenomenon between chaos and order is also referred to as a hidden order, i.e. a kind of order with apparently disordered things. Many follow-up studies have found the existence of small world properties with a wide range of real-world systems such as the Internet, ecosystems, food web, scientific citation and social networks.

Coming back to the street topology, it is a small world as well with the two above-mentioned properties. It is found that the average separation between two randomly chosen streets is about 4. It is short enough in particular when compared to total number of hundreds of streets in an urban street network. On the other hand, streets are highly clustered, which means streets interconnected with a given street are likely to be interconnected. So a street topology is a small world.

"Yes, it is a small world, so what?" This is one of the interesting questions put forward when I presented my work in a recent workshop on Complex Artificial Environments. Since small world networks have efficient behavior, I tend to say that a street topology or a geographic system in general with small world properties is very efficient in terms of traffic flows, information diffusion and transportation.