An equation for friendship

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If only they had been there in 1939: Plugging in numbers representing the friendliness between pairs of nations at the outset of World War II, researchers at Cornell University used a computer program to successfully predict which countries joined the Allied Powers and which lined up with the Axis. They got all of the countries right except Denmark and Portugal.

The group's work, reported last week in the *Proceedings of the National Academies of Science*, had less to do with history than with a long-established theory in social psychology called "structural balance," which describes how relationships in a social network evolve over time.

"Structural balance is an appealing and powerful theory, but it had a big missing piece," said Jon Kleinberg, a computer science professor who was part of the team. That gap was a way of showing how small shifts in individual relationships result in particular, predictable outcomes in larger alliances. Crunching a lot of numbers, the team hit upon a method to do just that.

About the middle of the 20th century, social psychologists began studying the dynamics of "relationship triangles" involving three people, companies or other entities that are bound together in a network.

They observed that certain combinations of friendly and antagonistic relationships were stable. These included three mutual friends, or two friends who shared a common enemy.

Other relationship triangles were unstable but likely to evolve into stable configurations.

For instance, among a group of three enemies, the two who disliked each other the least tended to team up against the third, resulting in the two-friends-with-a-shared-enemy scenario. As an example, Kleinberg pointed to the aftermath of the 2008 Democratic primary, when former Democratic rivals Barack Obama and Hillary Rodham Clinton teamed up against Republican John McCain.

A triangle containing one person with two friends who don't get along is inherently unstable. As many people know from personal experience, staying friends with a duo of enemies is hard. "You'd like them to reconcile," Kleinberg said, but each of them wants you "to team up against the other one."

In addition to noting the dynamics within triangles, the structural balance theory makes predictions about the larger network. Once all relationship triangles within a network evolved to their balanced states, psychologists observed, the members of that network either would be entirely friendly or would divide into two opposing camps.

The theory was used to help scholars understand shifting allegiances in international relations and to analyze the way companies compete in business. But though it did a good job explaining the "end state" of a stable social network, Kleinberg said, "it left everyone in the dark as to how everyone gets to that state."

The Cornell team's breakthrough was figuring out, through a series of mathematical calculations and computer simulations, a process by which structural balance can be achieved. Their big insight was that shifts between positive relationships and negative ones don't happen at once. Rather, they occur incrementally, with each one affecting - and being affected by - the incrementally shifting nature of the other relationships in the network.

Alliances and animosities don't just turn on and off in a vacuum. Instead, friendships get nudged in a more positive or more negative direction depending on who else is involved. "Everyone is updating their relationships all the time," Kleinberg said.

Previously, mathematicians got stuck trying to simulate how changes in individual relationships led to a globally balanced state, he said. Running computer simulations that took more incremental shifts into account allowed the Cornell team to (mostly) "predict" the Axis-Allies split, which provided validation for their model.

The discovery impressed scientists long baffled by the mechanism behind structural balance.

"It's a very interesting paper," said Daron Acemoglu, an economist at the Massachusetts Institute of Technology who was not involved in the research. "It has potential applicability to a range of situations."

One of those situations could be the study of online networks, Kleinberg said.

For example, companies such as Facebook and Twitter want to make sure their networks don't split into polarized camps. Knowing how the predictions of structural balance theory unfold in the real world could help them design their networks in a way that keeps them cohesive.

But, he added, "This is abstracted reality; it's not reality. Realistic scenarios are messier."

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