How does innovation take hold in a community? Math modeling can provide clues

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Mathematical models can be used to study the spread of technological innovations among individuals connected to each other by a network of peer-to-peer influences, such as in a physical community or neighborhood. One such model was introduced in a paper published yesterday in the *SIAM Journal on Applied Dynamical Systems*.

Authors N. J. McCullen, A. M. Rucklidge, C. S. E. Bale, T. J. Foxon, and W. F. Gale focus on one main application: The adoption of energy-efficient technologies in a population, and consequently, a means to control energy consumption. By using a network model for adoption of energy technologies and behaviors, the model helps evaluate the potential for using networks in a physical community to shape energy policy.

The decision or motivation to adopt an energy-efficient technology is based on several factors, such as individual preferences, adoption by the individual's social circle, and current societal trends. Since innovation is often not directly visible to peers in a network, social interaction—which communicates the benefits of an innovation—plays an important role. Even though the properties of interpersonal networks are not accurately known and tend to change, mathematical models can provide insights into how certain triggers can affect a population's likelihood of embracing new technologies. The influence of social networks on behavior is well recognized in the literature outside of the energy policy domain: network intervention can be seen to accelerate behavior change.

"Our model builds on previous threshold diffusion models by incorporating sociologically realistic factors, yet remains simple enough for mathematical insights to be developed," says author Alastair Rucklidge. "For some classes of networks, we are able to quantify what strength of social network influence is necessary for a technology to be adopted across the network."

The model consists of a system of individuals (or households) who are represented as nodes in a network. The interactions that link these individuals—represented by the edges of the network—can determine probability or strength of social connections. In the paper, all influences are taken to be symmetric and of equal weight. Each node is assigned a current state, indicating whether or not the individual has adopted the innovation. The model equations describe the evolution of these states over time.

Households or individuals are modeled as decision makers connected by the network, for whom the uptake of technologies is influenced by two factors: the perceived usefulness (or utility) of the innovation to the individual, including subjective judgments, as well as barriers to adoption, such as cost. The total perceived utility is derived from a combination of personal and social benefits. Personal benefit is the perceived intrinsic benefit for the individual from the product. Social benefit depends on both the influence from an individual's peer group and influence from society, which could be triggered by the need to fit in. The individual adopts the innovation when the total perceived utility outweighs the barriers to adoption.

When the effect of each individual node is analyzed along with its influence over the entire network, the expected level of adoption is seen to depend on the number of initial adopters and the structure and properties of the network. Two factors in particular emerge as important to successful spread of the innovation: The number of connections of nodes with their neighbors, and the presence of a high degree of common connections in the network.

This study makes it possible to assess the variables that can increase the chances for success of an innovation in the real world. From a marketing standpoint, strategies could be designed to enhance the perceived utility of a product or item to consumers by modifying one or more of these factors. By varying different parameters, a government could help figure out the effect of different intervention strategies to expedite uptake of energy-efficient products, thus helping shape energy policy.

"We can use this model to explore interventions that a local authority could take to increase adoption of energy-efficiency technologies in the domestic sector, for example by running recommend-a-friend schemes, or giving money-off vouchers," author Catherine Bale explains. "The model enables us to assess the likely success of various schemes that harness both the householders' trust in local authorities and peer influence in the adoption process. At a time when local authorities are extremely resource-constrained, tools to identify the interventions that will provide the biggest impact in terms of reducing household energy bills and carbon emissions could be of immense value to cities, councils and communities."

One of the motivations behind the study—modeling the effect of social networks in the adoption of energy technologies—was to help reduce energy consumption by cities, which utilize over two-thirds of the world's energy, releasing more than 70% of global CO2 emissions. Local authorities can indirectly influence the provision and use of energy in urban areas, and hence help residents and businesses reduce energy demand through the services they deliver. "Decision-making tools are needed to support local authorities in achieving their potential contribution to national and international energy and climate change targets," says author William Gale.

Higher quantities of social data can help in making more accurate observations through such models. As author Nick McCullen notes,"To further refine these types of models, and make the results reliable enough to be used to guide the decisions of policy-makers, we need high quality data. Particularly, data on the social interactions between individuals communicating about energy innovations is needed, as well as the balance of factors affecting their decision to adopt."

More information: Multiparameter Models of Innovation Diffusion on Complex Networks, N. J. McCullen, A. M. Rucklidge, C. S. E. Bale, T. J. Foxon, and W. F. Gale, *SIAM Journal on Applied Dynamical Systems*, 12(1), 515. (Online publish date: March 26, 2013). The source article is available for free access at the link below until June 27, 2013:
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