Using Economic Modeling to Predict User Behavior

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Abstract
Economic modeling provides a useful method for describing and predicting complex user behaviors.

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Introduction
One of the defining characteristics of *social media* websites such as Facebook, Flickr, YouTube, Delicious, and Twitter is that most of the value one gains by participating on these websites depends upon content generated by other users. In other words, I visit Facebook not because Facebook is inherently useful, but to see what other users have posted.

In order to design systems which motivate individual contributions that form a valuable whole, it is therefore important to consider two different levels of analysis: the individual level, and the group or system level.

Individual-level analyses involve looking at an individual's behavior on the system, such as motivations for individuals to choose tags [2] or how individuals form social capital on Facebook [3]. When designing these systems, individual-level outcomes of a technological intervention might include increased contributions, increased use, or more time and effort spent on the site.

System-level analyses ask a different type of question: they concern properties of the system as a whole. Does a given technological change cause an increase or decrease in the total amount of content? Do these tags aggregate to form a meaningful "folksonomy"? What makes a video highly popular or "viral"?

Some system-level properties are simply aggregates of individual properties. Obviously, when everyone contributes more information, the total quantity will increase. However, many system-level properties are not this simple; rather, the relationship between individual behaviors and system-level properties is often complex and difficult to understand. Wash and MacKie-Mason [1], ask what happens if you require a minimum contribution to access a social media site. They find that some people increase their contribution and others decrease. It is very difficult to understand how this rule will affect the total amount of content on a site—a *system-level* property—because it will result in different *individual behaviors*.

Figure 1: Sample Assumptions (from Wash and MacKie-Mason Mason [1])

1. Users make choices rationally
2. *More is better*: Having more information is always better
3. *Diminishing returns*: As you get more information, each additional piece of information isn’t worth as much
4. *Costly contribution*: Contributing information requires time and effort, which increases as you contribute more
5. *Increasing costs*: As you contribute more information, it gets increasingly costly to contribute each additional piece of information

6.a *Informative Pool*: Only information from other people is useful to me; I already know my own information.

6.b *Collaborative Pool*: I value having all information, including my own, in a social media site.

Economic Modeling

Many interesting questions regarding online behavior can be characterized as looking at the relationship between individual behavior and system-level properties. However, relationships like this are not unique to online settings. Much work has been done in the field of economics relating individual decisions to larger settings, including organization-level properties (like profitability), industry-level properties (like competition and welfare), or even economy-wide properties (like GDP). Economists have developed a very useful tool for doing this type of analysis: *economic modeling* (and its cousin, game theoretic modeling).

Economic models are formal mathematical models of human behavior. Researchers begin with a set of assumptions about individual preferences. These preferences describe what types of outcomes individuals like more than other outcomes. An example set of assumptions can be seen in Figure 1. The nice thing about making assumptions explicit is that you can see why they are needed, and how the theory might break down without them.

Once the assumptions are set, the researcher formalizes the assumptions into “utility functions” that describe how a person might make decisions. Figure 2 has an example utility function. These functions are intended to be descriptive of decision-making outcomes; each individual is assumed to make the decision that results in the highest utility and hence the most preferred outcome. (Note, however, these functions are not necessarily descriptive of the decision-making process; I doubt that users do such calculations in their head when making decisions.)

Once formalized like this, the researcher can then mathematically calculate a stable *equilibrium*. This calculation is necessary because each user’s decision depends in part on what other people decide; finding a set of decisions where no one wants to change their decision (an equilibrium set) is one way of predicting outcomes. Once calculated, then the researcher can vary parameters (e.g. introduce new technologies that

Figure 2: Sample Utility Function (from Wash and MacKie-Mason [1])

$$U_i(x_i) = v(X_{-i} + \alpha x_i) - c_i(x_i)$$

U_i: Utility for user i
x_i: Contribution from user i
X_{-i}: Total contribution from everyone else
$v(X)$: Value from total contribution X
$c_i(x_i)$: Cost of contributing x_i

add or relax constraints) and see how decisions change.

Additionally, economic models allow researchers to explicitly model system-level properties of interest. Wash and MacKie-Mason model the total quantity of contribution as the sum of each individual's contributions, and then mathematically describe the circumstances when a minimum contribution threshold will lead to an increase in total contributions.

Benefits of Economic Models

Economic modeling is useful to the CHI community primarily because it can explicitly describe the complex relationship between individual-level behaviors and system-level properties, and make predictions about those system-level properties even when the connection is non-trivial.

Another benefit of economic modeling is that it allows the researcher to test out counter-factual ideas—"what-if" scenarios that don't necessarily exist in the real world. Scenarios like "what would happen if I changed X?" can be explicitly modeled and compared: Who does this affect? What secondary effects happen? Does this change result in an overall system-level improvement? Indeed, many papers that utilize economic models begin by modeling a well-known situation, and then modify one or two parameters and use the model to generate counter-factual predictions (hypotheses) about what will change.

Another beneficial feature of these models is that it is possible to model concepts and quantities that aren't easily measurable in the real world. For example, models often make claims about *utility*: a measure of an individual's overall satisfaction with an outcome. Utility is certainly something that is very difficult to measure; however it is possible to model utility mathematically and show which types of people end up at a higher utility (and therefore, a more preferred outcome). Further, economic models can be used to specify relationships between measurable quantities, like the number of contributions, and unmeasurable quantities, like the value obtained from the whole of everyone's contributions (utility). For example, Wash and MacKie-Mason make predictions about what type of users will increase contribution, and what type of users will decrease; those predictions were based on unobservable characteristics (technically, the marginal cost of contributing, or how difficult it is to contribute). If the cost decreases and the total quantity of contributions increases, then necessarily utility is also increased.

There is one more benefit of a good economic model: it forces the researcher to thoroughly and completely think through all of the possible outcomes, and explicitly state the assumptions that are necessary for the argument in the paper. Formal mathematical modeling is a technique for rigorous thought experiments; it provides a credible and explicit statement of what happens and why. Thought experiments are very valuable in research; they allow us to identify many interesting ideas and describe complex outcomes. When conducting thought experiments, it is hard to provide evidence that all possible contingencies and outcomes were considered. Mathematical models like economic models can provide this evidence.

Limitations of Economic Models

Economic modeling nicely complements existing empirical research; it describes explicit, causal connections between individual behaviors, between individual-level behavior and system-level outcomes, and it describes these relationships in explicit detail that makes the important assumptions clear. However, when constructing economic models one must make simplifying assumptions so that the model is tractable and simple (see Figure 1 for examples). Assumptions are the workhorse of economic models, but they are also heavily criticized, because results from a model only generalize to the extent that the assumptions hold true. Economic modeling is only one tool in researchers' toolbox and should not be used in isolation. This is not an empirical research method; findings from economic models should be considered hypotheses that need empirical validation.

Often researchers must make more restrictive assumptions than they would like, to make the model analytically tractable. Chief among these assumptions is the *rational actor* assumption: humans will behave as if they are rational actors, choosing the most preferred outcome and thinking through all possible contingencies. This assumption can be contentious if one misinterprets it to mean all individual humans necessarily think rationally at all times. A more correct interpretation is that the rational actor assumption primarily describes observable outcomes: What decisions to people make? What behaviors can be seen? An economic model then deduces expected outcomes by calculating what a rational actor would do in that situation. There are many reasons why human behavior can be described approximately rational even when the though process that leads to the behavior is decidedly not rational; as a first approximation of behavior, the rational actor assumption provides fairly accurate predictions. As long as the modeler avoids obvious instances of cognitive biases, using the rational actor model to make behavioral predictions when doing economic modeling results in credible and accurate hypotheses.

Conclusion

Economic models allow researchers to conduct rigorous thought experiments, explicitly describe system-level properties of CSCW systems, and provide concrete hypotheses that can be empirically tested. Economic modeling can create a better understanding of participation and contribution in social media systems, helping system designers make predictions that bridge the gap between individual behavior and value for everyone.

References

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