Corso di Laurea in Informatica—Università di Bologna
Progetto per il Corso di Sistemi Complessi
AA 2011/2012

Ozalp Babaoglu   Moreno Marzolla
Dipartimento di Scienze dell'Informazione, Università di Bologna
Mura A. Zamboni 7, 40127 Bologna–Italy
4 April 2012

Project outline

Introduction. This project deals with the study of cascading behavior in networks. In particular, we want to study how the behavior of individuals can affect (and can be affected by) the behavior of others. This process has long been a fundamental question in social sciences, and governs many phenomena that we experience daily: the raise and fall of celebrities or political candidates, the success or failure of new products, the emergence and implosion of bubbles in the financial market, and many others. While these processes are not fully understood, they tend to begin on a small scale with a few "early adopters" which first embrace some new idea or product. Then, other individuals begin to adopt the same idea or product as they observe their friends, neighbors, or colleagues doing so. The new behavior may eventually spread through the population with the dynamics of an epidemic [1].

We can formally describe the scenario as follows. Let us consider an undirected graph G=(V, E), where each node is an individual, and there exists an undirected edge (u, v) if and only if u and v have some sort of relation (e.g., they are friends, colleagues, classmates). Individuals can choose between the "old" behavior A, and the "new" behavior B. For each edge (u, v) there is an incentive for both u and v to have identical behavior, according to a global parameter q ($0 < q < 1$). Specifically:

- if both u and v choose A, they both receive a payoff q;
- if both u and v choose B, they both receive a payoff ($1-q$);
- if u and v choose opposite behavior, they both receive 0.

Each node u follows the above rules with each of its neighbors in G. The payoff of each node is simply the sum of the payoffs from these separate interactions. Each node can repeatedly update its behavior (i.e., choosing among A and B) each time it interacts with its neighbors. A node chooses the behavior that maximizes its payoff.

Project Goal. The goal of this project is to study a basic model of cascading behavior in G, according to the following rules. Let N be the number of nodes in G, which are initially wired according to some topology (e.g., as a scale-free network, or as a random graph). Once the topology of the graph is defined, it will not change; hence, we assume that the neighbors of each node always remain the same. We first set a value for q, and we assume that each node simultaneously updates its behavior in each discrete time step t = 1, 2, 3, ... By default, all nodes are initially using A, except for a fraction β_1 ($0 < \beta_1 < 1$) of early adopters who use B. Therefore, if there are a total of N nodes, at the beginning, $\beta_1 N$ of them adopt behavior B, while $(1- \beta_1)N$ adopt A. Then, at each step, every node reevaluates its behavior using the rules described above. Note that nodes may switch from A to B or from B to A, depending on what their neighbors are doing. We are interested in determining when a small set of early adopters can eventually convert all (or almost all) of the population to the new behavior B. We want to model the system using PeerSim [2] in order to study the fraction β_t of the population that is using behavior B at step t. The evolution of β_t will depend upon the model parameters, such as:

- the graph topology and total number of nodes N;
- the initial fraction β_1 of nodes adopting B;
- the payoff value q.

Your goal is to study and understand how the above parameters affect β_t. Obviously, you are not expected to explore the (infinite) parameter space; for example, it is reasonable to expect that the graph size N will play a marginal role (or no role at all) in the number of nodes adopting B, provided that N is "large enough".

Possible extensions. There are many useful extensions that could be considered. For example, what happens if we allow the topology of G to change during the experiment? (for example, this could model a situation where individuals are influenced by people outside their immediate friends or colleagues). Also, we assumed that the payoff value q is the same for all individuals. What if each node v had its own payoff value q_v, defined according to some probability distribution (e.g., uniform distribution, Beta distribution, or some other distribution which returns a value in [0, 1])? What would happen if a node has a small probability of behaving "irrationally" (i.e., choosing the alternative which does *not* provide a greater payoff)? If you want, you can develop and analyze your own extensions to the basic model, provided that the extensions are reasonable and you demonstrate that you understand what is going on. In general, we prefer a deeper understanding of a simple model rather than a weak understanding of a complex model. Nevertheless, this should be considered as an "open" project with a few basic requirements and ample space for further experimentation.

How and what to submit

This project must be carried out *individually*. The project must be handed in electronically, by e-mail to marzolla@cs.unibo.it. **The deadline for submission is 2 July 2012, at 23:59**. Please use your university email address; the subject of your mail must be "CS Project 2011-2012"; you will receive a confirmation message (this may take a couple of days, please be patient).

> **IMPORTANT NOTE:** most of the messages I send to @studio.unibo.it are considered spam by the spam filter. Please either disable the spam filter (you can do so with the webmail interface), or explicitly check your spam folder.

Your mail must contain a compressed archive (only .tar.gz and .zip formats are accepted; avoid .rar and other formats) containing the following items:

- Source code you have developed (it is not necessary to include the source code of PeerSim);
- A short paper, in pdf format, describing the experiments that have been performed and a detailed discussion of the results.

The source code must be adequately commented. The paper can be written either in Italian or English, and should be organized like a technical paper with a title, abstract and (short) bibliography. You can use any document editor to write the paper, but only send the pdf document to us. We suggest you to write no more than 16 pages using the LaTeX or Word/OpenOffice template from Springer LNCS available at http://www.moreno.marzolla.name/teaching/CS2012/ (this is not a strict requirement). You are required to put your full name, e-mail address and personal ID number (*numero di matricola*) on the paper, on each Java source file and in your mail.

Grading policy

These are the *minimum* requirements of your project:

- You must define a PeerSim model for the behavior propagation model described in this document. Extensions of the basic model are encouraged (see below for caveats).
- You must implement the model using the cycle-driven simulation engine of PeerSim. Your simulator must be configurable by means of the standard PeerSim configuration file.
- You must use the simulator to analyze the impact of the model parameters on β_t, the fraction of people adopting B at step t, using multiple independent simulation runs.
- The paper must describe the model (and the extensions you may have implemented), the simulation experiments and the results. You should *explain* the results, not just show them. The paper might describe implementation details if necessary, but keep in mind that we can look at the source code, so be concise.

Write a simple model, focus on a limited set of experiments and demonstrate that you actually *understand* the results. You have limited time, so use it wisely.

If you are interested in these topics (e.g., you want to build a better model, or you want to study similar systems), you are encouraged to talk to us when you will be looking for a thesis topic.

References

[1] J. Kleinberg. *Cascading Behavior in Networks: Algorithmic and Economic Issues*. In Algorithmic Game Theory (N. Nisan, T. Roughgarden, E. Tardos, V. Vazirani, eds.), Cambridge University Press, 2007. Available at http://www.cs.cornell.edu/home/kleinber/agtbook-ch24.pdf

[2] PeerSim: A Peer-to-Peer Simulator. Available at http://peeersim.sourceforge.net/