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The Name of the Bud

As the year was coming to an end, I received a call from my department chairman, asking me if I could teach a more popular and lucrative course, instead of the Cancer Bioinformatics course that I was scheduled to teach. I had been very excited by the cancer course and preparing my lectures all winter. I was convinced that I had finally understood how to make a good cancer progression model, which could then be coupled to the extensive theories on games against nature, supervisory control of timed automata, model building and model checking and planning for POMDP (partially observed Markov decision processes). The goal was to optimize to compute the best therapeutic solutions that would be built up from cocktails of various kinase inhibitors and other chemotherapeutic agents. But unfortunately, there were only six students registered for the class - although, one expected many more to just audit the class, without contributing to my university's revenue.

So I had to come up with a new assignment – in real time. The choices I had boiled down to just two: Finance and Social Network. Both courses sounded very topical and potentially interesting, but the department chairman, the course administrator and I decided to go with the Social Network. I was motivated by two ideas: (i) I thought it would be interesting to see if it would be possible to create an infrastructure - social and computational - to lunch something like an Occupy or Arab Spring movement. Particularly, I wanted to connect this to some of the ideas based on Schelling's book, entitled "Micromotives and Macrobehavior." (ii) I was also motivated to go over some of the new algorithmic and mathematical questions that were addressed in Easly and Kleinberg in their book, entitled "Networks, Crowds and Markets: reasoning about a highly Connected World."

I wrote up a syllabus and posted on the web[1]. Within days, the course was over-booked (limited to twenty five students with another eleven in a waiting list). We got two Teaching Assistants: Raphael, a very bright NYU undergrad and a founder of Diaspora, an open source social network, and Xingyang, a very diligent and bright NYU master's student.

[1] http://www.cs.nyu.edu/mishra/COURSES/12.SOCNET/12.socnet.html

The first lecture started with some administrivia.

Administrivia.

Course Info

- Course Title: Social Network (CSCI.GA.3033-013)
- Class Room: WWH 202
- Class Period: Wed 5 - 6:50 pm

Instructor Info

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Thinking about the social networks, one realizes quickly that not all social relations are equal – some are more equal than others. In particular, humans create different kinds of ties: *weak ties* and *strong ties*; rather some of the *strong ties* are not necessarily under one's control – most of the important ones are determined by the genetics.

But weak ties are much more interesting because they can be created and broken at will; they are sometimes genuine, sometimes deceptive; the degree of connections can be extremely small or unusually large. But *strength of weak ties* has been quite intriguing, since they contribute enormously to the structural complexity of the social networks, and they determine how social agents strategize over the weak ties as they interact.

Mark Granovetter, in his 1960 PhD thesis, wrote, "Simple process at the level of individual nodes and links can have complex effects that ripple through a population as a whole." We will use ideas from *graph theory* to represent the structure of the individual nodes and links, but will rely on more intricate ideas from *game theory* to understand how complex effects emerge from simple interactions over any individual link connecting just a pair of social agents (players).

In 1970 Granovetter wrote a PhD Thesis at Harvard University, entitled "Changing Jobs: Channels of Mobility Information in a Suburban Community," and illustrated the concept of weak ties. A paper resulting from this thesis became a sociology classic with a citation index close 20,000, though it was initially rejected. For his research, he surveyed 282 professional, technical, and managerial workers in Newton, Massachusetts, and collected statistics about the type of ties that existed between the job changer and the contact person (who provided the necessary information).

Tie strength was measured by the frequency with which the two individuals met during the period of the job transition: often (= at least once a week), occasionally (= more than once a year but less than twice a week) and rarely (= once a year or less). Of those who found jobs through personal contacts ($N = 54$), 16.7% reported seeing their contact often, 55.6%, occasionally, and 27.8%, rarely. A friend seemed less important than an acquaintance in finding a new. The sociologists have thus come to believe that "weak ties play a role in affecting social cohesion."

A classroom like ours today is an impromptu social network. Most of the students are unlikely to have known each other, and since I am teaching this class for the first time, I am probably a stranger to most of you. But, the moment, I walked into the class, we established an interconnection structure that looks like a *star graph*: S_n, whose nodes can be numbered with me at the center and starting with the number 0, and all the students numbered 1 through n. We can make now number the edges by the absolute difference in the numbers of the nodes, connected by it: So the weak tie connecting me to the 1st student is 1, to the ith student i, and so on, with the last student connected by the edge numbered n. Since the numbering is *graceful* (each of the edge has a unique numbering from 1 through $|E|$), S_n is a *graceful graph*.

But let us assume that these weak ties will evolve, becoming stronger. If the class encourages lot of informal interactions, it is likely that we will evolve in to a strong network; otherwise, we will stay weak. One way we can try to guess, where the class wants to go, would be to check what my students would like to call me: some may prefer to call me "Prof. Mishra" (formal, weak) and others "Bud" (informal, strong).

Although no pair of students knows each other and has no desire to collude, the class will try to come to some form of consensus. It could be a "Majority Game;" if majority of the class is formal, you don't want to appear disrespectful, and you will go with "Prof. Mishra;" if on the other hand the majority of the class is informal, you don't want to stand out as ceremonious, and you want to choose "Bud." So your strategy (behavior) becomes intimately related to that of total strangers, even when you don't know what you should do individually, and you know that others don't know what they should do individually, and you know that they know that you don't know what to do, etc. You will still come to some consensus (equilibrium) with a little bit of jostling of moves, counter-moves, etc., with a tipping point coming when enough of you start moving in a direction.

The structure could have been very different: perhaps, it is very fashionable to be with the minority. Instead of going with the flow, you want to act contrarian. It will be interesting for you to think about how the game may end up. These kinds of behavioral processes acting on the graph structure are what makes the social networks interesting and, to some degree, incomprehensible.

Now imagine a slightly more complex game: If a single student makes a weak-tie (by calling me "Prof. Mishra"), the class is deemed to be formal. Anyone (player P_1) trying to be informal in a "formal" class is punished and receives 0 point in the class; the others P_{-1}, all formal and respectful, in a "formal" class get rewarded with 3 points. Fine points: If everyone is formal, then the reward is moderate: just 1 points. If on the other hand, everyone is informal, making strong ties, then the class is "informal," and everyone in the class gets rewarded with 2 points.

P_1 \ P_{-1}	s	w
s	2,2	0,3
w	3,0	1,1

Table 1: Table for a strong-tie-weak-tie game.

So, you have an advantage (getting 4) if you stick to weak-tie, and not running the risk of being informal in a formal class. But by symmetry, everyone will stick to formal behavior, and the class will never be the comfortable informal social group. Thus, no one has any incentive to cooperate to create something bigger and better than what his own selfish interests dictate.

The game that we just discussed is very similar to the classical *Prisoner's Dilemma*: In which two men are arrested, but the police cannot convict them just with the evidence they have. Following the separation of the two men in two prison cells, the police offer both a similar deal – if one testifies against his partner (defects/betrays [D]), and the other remains silent (cooperates/assists [C]), the defector receives a reward and the cooperator receives the full two-year sentence. If both remain silent, both are released after a small fine. If each 'rats out' the other, each receives a one-year sentence. Each prisoner must choose either to betray or remain silent; the decision of each is kept quiet. *What should they do*?

P_1 \ P_2	C	D
C	0,0	-2,1
D	1,-2	-1,-1

Table 2: Table for a Prisoner's Dilemma game. The two strategies are C: Cooperate, that is, do not testify and D: Defect, that is testify. Note that if you add a constant (i.e. 2) to every utility value in the table, you get the same table as the one before – that is, the one used in strong-tie-weak-tie game.

Here, regardless of what the other decides, each prisoner gets a higher pay-off by betraying the other. For example, Prisoner P_1 can (according to the payoffs above) state that no matter what prisoner P_2 chooses, prisoner P_1 is better off 'ratting him out' (defecting) than staying silent (cooperating). The argument leads to the conclusion that prisoner P_1 should logically betray him. Since the game is symmetric, the other prisoner P_2 should act the same way, Thus, both, by rationality, should decide to defect, although they can see that by cooperating (an irrational behavior) they could have received a better pay-offs (released with a nominal fine). But if P_1 knows that P_2 is going to be irrational and cooperate, P_1 should defect and collect the reward – making a fool of the cooperator. So is there any argument to justify individuals' cooperative behavior, seen in a social network? There are simple biological arguments about why clonal worker bees and other social insects exhibit *eusociality*; but it does not apply very well to a genetically diverse human population in a large urban society. Going back to the prisoner's dilemma game, just described, please make a note of the fact that we have constrained the players not to communicate or threaten retaliation, and to play the game only once. Repeated games could be used to argue for the possibility of cooperation to emerge or evolve.

Before leaving the topic of cooperation, it is worth spending few sentences on the *Stag-Hunt Game*: It is thought to be a metaphor for conflict between safety and social cooperation. For that reason, it is also described as "assurance game," "coordination game," and "trust dilemma," and plays an important role in the context of evolution and stability of social networks. Jean-Jacques Rousseau described the game as follows: "If a group of hunters set out to take a stag, they are fully aware that they would all have to remain faithfully at their posts in order to succeed; but if a hare happens to pass near one of them, there can be no doubt that he pursued it without qualm, and that once he had caught his prey, he cared very little whether or not he had made his companions miss theirs." If we think about this game with two players, for a player hunting a stag, he must have the cooperation of his partner in order to succeed. A player can get a hare by himself, but a hare is worth less than a stag.

P_2 / P_1	Stag	Hare
Stag	2,2	0,1
Hare	1,0	1,1

Table 3: Table for a Stag-Hunt game. If both players hunt stag, since a stag is worth 4, they each get 2 "utils." If both players hunt hare, since a hare is worth only 1, they each get 1 "util," but they get this surely – without any risk. If the player P_1 (also, called a "row player") hunts hare, while the other, P_2 ("column player") hunts stag (and hence fail to hunt anything), then P_1 gets 1 "util" and the P_2 gets 0 "util." The other case is symmetric.

Thus a player who chooses to remain committed to "stag hunting" no matter what the other player does, runs the risk of getting a 2 or a 0, depending on whether the other cooperates in stag hunting or gets distracted by a hare. On the other hand, if he had chosen to go for "hare hunting," he would get a 1, no matter how the other player behaves. Risk avoidance considerations dictate that one must not cooperate. This game is bit more subtle than the prisoner's dilemma, but does raise similar questions about how cooperation emerges.

The question of how humans evolved cooperation (or "reciprocal altruism," in the standard jargon) has also intrigued the biologists, since it is almost never seen in other species (perhaps, with one exception: vampire bats have been found to share blood meals, but practically all examples seem indistinguishable from kin selection, where one individual helps another, but only if the other is genetically closely related). Following four speculative theories come to mind (more comments on these would be welcome):

Self-domestication: Humans seem to have domesticated themselves to live cooperatively with other humans, as a byproduct of domesticating (or being domesticated by) dogs. Perhaps, we impose a high penalty on non-cooperating, hostile and violent behavior; thus, imposing a negative selection pressure on the group. It is also speculated that there are specific individuals in the group, who take on the responsibility of imposing such penalties ("altruistic punishers") – sometimes at great costs to themselves.

Sexual Selection: Females within the species selected those males, who display more complex cognitive behaviors, e.g., empathy, forbearance, tolerance, etc. (These behaviors could be pleiotropic for other genetic advantages: e.g., better developmental genes.) Perhaps, the genetics took care of the rest: selecting for traits like empathy, which could be carried out by the so-called "mirror cells," which seem to be responsible for large-scale human cooperation.

Social Grooming: The process of social-grooming had to be replaced by a different interactive process (e.g., gossip) after the primates lost hair to become human (the "naked apes"). Human languages evolved; social-grooming carried out by extensive gossiping-behavior. The social networks were needed to carry these out, and promoted cooperation (beyond what would be expected via "kin selection").

False Theory: Human cooperation is an illusion and impermanent. It arises by a statistical misinterpretation that could be explained by Yule-Simpson effects (Simpson's Paradox).

Ti summarize, as we study social networks, we will keep, in the back of our minds, a myriad of unanswered questions: (1) Why do we cooperate? (Prisoner's Dilemma and Stag-Hunt games suggest that it would be irrational to cooperate.) (2) Why do we trust others? (What are the structures of the trust networks? Why do we have strong and weak links? Why do we abide by social contracts? How do the contracts, laws, systems of justice evolve?) (3) How can we coordinate? (Do we swarm? Flock? Mob? How do we do it?) (4) How do we do conflict resolution? (Why do we build institutions (law-courts, governments, military)? Why do we give them such power? How do we architect them? How do we change them? Revolts? Mutinies? Occupy? How do they change?) (5) How can we build the best mechanisms that allow the most fluid social interaction?

Going back to the place where we started: Do we want to be formal or informal? Spartan or Athenian? Christian or Lutheran? Follow *niti* or *nyaya*? Law or ethics? Should we live by *uncivil obedience* or *civil disobedience*?