Corso di Laurea in Informatica - Università di Bologna

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AA 2015/2016

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Practicalities

General Information, how and what to submit

The student is required to complete both Part I and Part II of project described below. The project must be carried out individually. The project must be handed in electronically, by email to

francesco.gavazzoATgmail.com.

The deadline for submission is 1 July 2016, at $23:59$. Please use your official university email address (studio.unibo.it); the subject of your mail must be

"CS Project 20152016"

You will receive a confirmation message (this may take a couple of days, please be patient). 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 or NetLogo);
- A short paper, in pdf format, describing the experiments that have been performed and a detailed discussion of the results (see the project description for details).

The source code must be adequately commented and well written (following good programming habits). 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 you must send only the pdf version to us. This project must be done individually. No sharing of source code or technical papers is allowed, either in part or in full. However you can − and are actually encouraged to −

discuss any issues with your fellow students and/or with the instructors. We suggest you write no more than 16 pages using the Latex or Word/OpenOffice template from Springer LNCS.

- Doc template: `http://www.moreno.marzolla.name/teaching/complex-systems/2013-2014/word_template.zip`
- Latex template: `http://www.moreno.marzolla.name/teaching/complex-systems/2013-2014/latex_template.zip`

You are required to put your full name, email address and personal ID number (numero di matricola) on the paper, on each source file and in your mail.

Grading policy

These are the minimum requirements of your project:

- You must define models as required in project description. Extensions and personalization to the basic model are encouraged.
- You must implement the model. In case you select PeerSim as the simulation tool, you should use the cycle-driven simulation engine of PeerSim; your simulator must be configurable by means of the standard PeerSim configuration file.
- The paper must describe and justify the model (and the extensions you have implemented, if any), the simulation experiments and the results. You need to justify your designing choices, formulate previsions and compare them with the results you obtained with simulations. You have to explain the results, and possibly interpreting them. You can find informal examples below. The paper might describe implementation details if necessary (i.e. if these are of theoretical relevance), 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. Be modular: try to understand the basic features of the model you want to build, and construct a simple model exhibiting all of these. Proceed gradually to enrich this model in a modular way. This will make things much simpler and faster (besides, it will make your work much more scientifically appreciable and readable). 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 are looking for a thesis topic.

Project Description

In this project we will make simple experiments in order to see the *emergence* of social behaviours in populations. The main theoretical tool used is *evolutionary game theory* which, combined with computer simulation, constitutes a rich framework for the study and analysis of emergent behaviours.

Part I

Introduction. In class you studied the *Prisoners' Dilemma* [4, 5, 6]. The Prisoners' Dilemma is a non-zero sum, non-cooperative game, that has been used to model several real world scenarios. In its most basic form the game is played between two or more agents, and the whole game is played in a single round. Each player has two choices: *cooperate* or *defect*. Based on the adopted strategies, each player receives a payoff following the principle 'defection always pays more, mutual cooperation beats mutual defection, and alternating between strategies doesn't pay'. Although useful, the Prisoners' Dilemma has several limitations: being played in a single round this game does not allow to see how players' strategies evolve during a match. To overcome this problem the *Iterated Prisoners' Dilemma* game was designed. Each round of this game consists of a single round Prisoners' Dilemma game, and at the end of each round each players can modify his/her strategy according his/her previous experience. Although much more informative than its single-round version, the Iterated Prisoners' Dilemma is rather abstract and offers a limited form of interactions between players, which de facto do not organize themselves as a *society*. Social groups are characterized by the presence of a global coordinated behaviour that serves to regulate the individual behaviours of its members. The emergence of such global behaviour is one of the main features of what makes a simple group of agents a society. In [2] Axelrod attributes this behaviour to the existence of social norms. A social norm is said to exist within a given social setting when individuals act in a certain way and are punished when seen not to be acting in accordance with the norm. In [1] Axelrod uses tools from evolutionary game theory in order to provide an analysis of the conditions in which norms can be established in populations of self-interested individuals. In his experiments, a population of agents repeatedly play a simple game, called the *Norm Game*, in which agents make decisions about whether to comply with a desired norm of cooperation and whether to punish those who are seen to violate this norm. These decisions may result in certain penalties or rewards, with the strategies of agents being determined through an evolutionary process, in which the more successful strategies are reproduced. The game can be further refined in order to provide agents with a more sophisticated social behaviour (see Part II for details), thus resulting in the so-called *Meta-Norm Game*. In this project you are required to implement and experiment with simple variations of these games, studying the emergence of norms in social contexts.

The Game, Informally. The games we are interested in are of the following form: we have a population of agents organized as a network. When an agent i is connected to another agent j, we say that i can be seen by j. Each agent has the possibility of committing a crime[1] and a specific inclination of doing so. We can thus imagine to have moral agents who (almost?) never commit crimes as well as criminals who take (almost) all the opportunities of committing a crime. Moreover, an agent will commit a crime not only according to his/her inclinations, but also according to the possibility of being observed during the criminal act. Such a possibility is proportional to the number of agents that could see him/her committing the crime. Of course agents more inclined to have criminal behaviours would not care too much about the possibilities of being discovered.

The game is played as follows: an agent i chooses whether to act criminally or not according to his/her inclinations and the possibility of being observed. If the criminal act is committed, then the agent i receives a payoff $T = 3$, whereas other agents are slightly hurt, receiving a payoff $H = -1$. However, if agent i commits a crime, then he/she could be seen doing so by other agents. Those that will actually see i can decide whether to punish him/her or not. The punishment is heavy, and i would receive a payoff $P = -9$. However, the punishment is somewhat costly and the punisher has to pay an enforcement cost $E = -2$. This a single round of the game, and a

[1] To maintain the analogy with the Prisoners' Dilemma, we also say that the individual has the opportunity ti defect.

more accurate description can be found in the next paragraph.

It is clear that agent's behaviour is determined by three factors: the probability of being observed, the inclination to commit a crime, and the inclination to punish other agents. The latter two attributes de facto determine the strategy an agent is playing.

At the end of the round, each agent compares his/her new payoff (also called *fitness*) with the one he/she had at the beginning of the round. If he/she improved or remained stable, then he/she will keep playing as he/she did so far. If his/her payoff got worse, then the agent will change his/her strategy. This amounts to modifying his/her inclination to commit crimes and punish other agents. For example, going to jail (receiving a punishment) could be seen as a successful re-educational process for an agent i, meaning that after the punishment agent i's inclination to commit a crime has decreased. On the other hand, prison could be a bad solution for some agents: a punishment could lead to increasing the agent's inclination to commit crimes, or even make him/her more violent (thus increasing his/her inclination to punish other agents). All these possibilities can be modelled via a list of specific attributes encoding the reactions of agents to these kinds of situations (e.g. attribute α of an agent i could specify that if more than $n\%$ of the agents that can see i punish him/her for a crime he/she committed, then the inclination of i to punish will increase of $m\%$).

The Project. You are required to implement and experiment with the above game, following the formal specifications given in the next paragraph. You have to design several experiments modelling several real-world scenarios, and to observe and document the emergence of specific behaviours related to such social contexts. Possible experiments could try to confirm or refute assertions like:

1. Severe societies tend to make individuals more violent but also more honest.
2. Permissive societies force individuals to be less violent, but too permissive societies tend to make individuals quite poor (low fitness), thus having a bad welfare.

Your claims should be much more detailed than the above ones. You have to provide arguments to the thesis you want to experiment with (you do not have to be original, you could take inspiration from results in political, economical and natural sciences), justify the parameters you choose for the simulations, make previsions and compare them with the actual results you observe. That is, you have to be scientific.

If you have in mind scenarios from other fields (e.g. artificial intelligence, biology etc…) that could be modelled with games like the above one, you are very welcome to play with them (but, to be completely sure they are adequate, please send me an email with your proposal).

I would like to see several proposed claims and relative simulations, each of them with different designing choices and with lot of emphasis on how different behaviours *emerge* from (even unrelated) individual attitudes. The take home message of this project is to have a grasp of how (basic) evolutionary game theory and computer simulations constitute a valid framework for studying and analyzing emergent phenomena.

Formal Definition of the Game. We consider a set $\mathcal{I}$ of agents. Agents are denoted by letters $i, j, \ldots$. A population is a graph $G = (V, E)$ whose nodes are agents and whose edges represent interactions between agents. We denote the set of edges as E and

$$E[i] = \{j \mid (i, j) \in E\}.$$

If $j \in E[i]$, then we say that agent j can see agent i or that agent i can be seen by agent j. For an agent i we define the probability of actually being seen as

$$S_i = 1 - \frac{1}{|E[i]|}.$$

That is, the more agents can see i, the more likely i will actually be seen[2].

Each agent i has two attributes:

- *Boldness* B_i: this attribute describes the inclination of the agent to commit a criminal act.

[2] The above definition has to be a little refined. Suppose i is isolated, i.e. $E[i] = \emptyset$. Then $\frac{1}{|E[i]|}$ is undefined. We can fix this problem in two ways. One way is to require the edge relation to be reflexive, i.e. $\forall i \in \mathcal{I}. i \in E[i]$. This informally captures the idea that an agent can see his/herself. As a consequence, we will have $|E[i]| \geq 1$ for all agents i, and thus S_i will be always defined (in particular, if $E[i] = 1$, then $S_i = 0$, which is consistent with our intuition).
The other solution simply modifies the definition of S_i as follows:

$$S_i = \begin{cases} 1 - \frac{1}{|E[i]|} & if\ E[i] \neq \emptyset \\ 0 & if\ E[i] = \emptyset \end{cases}$$

- *Vengefulness* V_i: this attribute describes the inclination of the agent to punish other agents.

An agent i commits a crime if the probability of being seen is smaller than its boldness:

$$S_i < B_i.$$

Taking $B_i \in [0,1]$ we can model several behaviours. Limit cases are:

- A saint agent i that never commits crimes: we take $B_i = 0$.

- A criminal agent i that always commits crimes: we take $B_i = 1$.

It follows that on a formal level an agent is nothing but a tuple $i = (B_i, V_i, F_i)$, where $B_i, V_i \in [0,1]$ and $F_i \in \mathbb{Z}$. The value F_i represent agent i's fitness.

We want to study the evolution of agents' attitude to commit crimes and punish criminals according to their experience. A round k of the game is played as described in Figure 1.

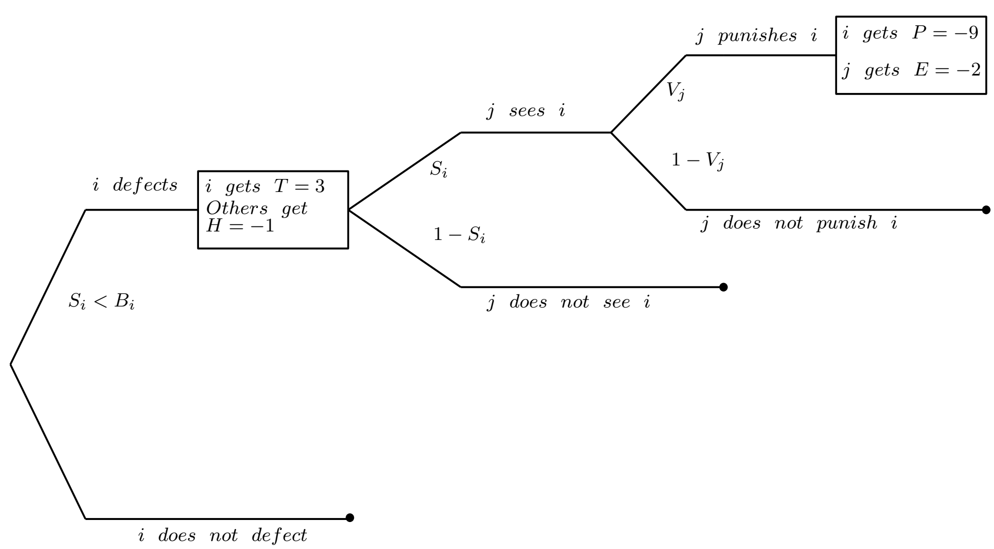

Figure 1: A round of the Norm Game.

At the end of the k-th round of the game, agent i compares his/her new fitness $F_i(k)$ with the one he/she has at the end of the previous round $F_i(k-1)$. For $k = 1$ agent i compares his/her new fitness with the initial one (which is defined by the user according a specific model). If $F_i(k) \geq F_i(k-1)$ then i will not change his/her attitudes. If $F_i(k) < F_i(k-1)$, then i will change his/her behaviours. To make things a bit more realistic we consider

two further attributes: α and β. That is, an agent is a tuple $i = (B_i, V_i, F_i, \mu)$ for $\mu \in \{\alpha, \beta\}$. These attributes describe how an agent reacts to punishments: an agent with attribute α will learn from punishments in a certain measure. If the punishment he/she receives are less than a fixed value K (e.g. less than 50% of his/her neighbors punish him/her), then he/she learns the lesson and decreases her attitude to commit crimes (B_i) of specific factor D (e.g. 20%). However, if such agent receives too many punishments (i.e. more than K), then he/she becomes hostile, increasing her vengefulness V_i of a multiple of D (e.g. 40%).
An agent with attribute β has a more 'criminal mind'. If he/she is punished no more than a fixed value H, then he/she will react emotively becoming more inclined to vengeance, increasing V_i of a ratio C. However, if he/she gets punished more than H, then he/she wants to recover her fitness as fast as possible, thus increasing her inclination to commit crimes B_i of a factor C'.

These are just examples of possible updates. You are strongly encouraged to formulate new updates (of course justifying them) and to experiment with them.

Part II

Previous game introduced social behaviour of a very limited form. Individuals committing a crime are subject to the judgment of their neighbors, which, in that case, represent a so called *social reaction*. However, a society is characterzied by a higher-order behaviour, meaning that a social reaction will be itself subject to a social reaction. Suppose for example that agent i commits a crime and that the social reaction of his/her neighbors is not to punish him/her. The very decision of not having punished i is itself subject to a social reaction, e.g. disappointment. This reaction can be made concrete by allowing agents (A) seeing those agents (B) that did not punish i, to punish agents in B. This of course would encourage people to punish criminals.

The act of punishing agents that do not punish criminals is a so-called *meta-norm*. The *Meta-Norm* game **??** is an extension of the Norms game that takes into account social reactions to social reactions to single agents' actions. The game essentially works as follows: if agent i chooses to commit a crime, and agent j choose not to punish i, and i and j have a common neighbour k, and k observes j not punishing i, then k can punish j. Again, j receives the penalty $P = -9$ and k receives an expenses $E = -2$. A formal description of the game is given in Figure 2, where a comparison between the Iterated Prisoners' Dilemma and the Norm game are sketched. Such a connection can be explained as follows: the Iterated Prisoners' Dilemma game can be said to present a 0-level of social behavior, since agents' actions are subject to the judgment of no other agent. The Norm game presents a 1-level social behaviour, since agents' actions are subject to the judgment of the society (roughly, other agents). Such judgment is not itself subject to the society judgment. Finally, the Meta-Norm game presents a 2-level social behaviour, since each agent action is subject to the judgment of the society, and that very judgment is itself subject to the judgment of the society. Clearly we could continue this stratification, thus obtaining an hierarchy of games.

In this second part of project you simply have to proceed as indicated in the first part, this time working with meta-norm-like games, rather than with norm-like ones.

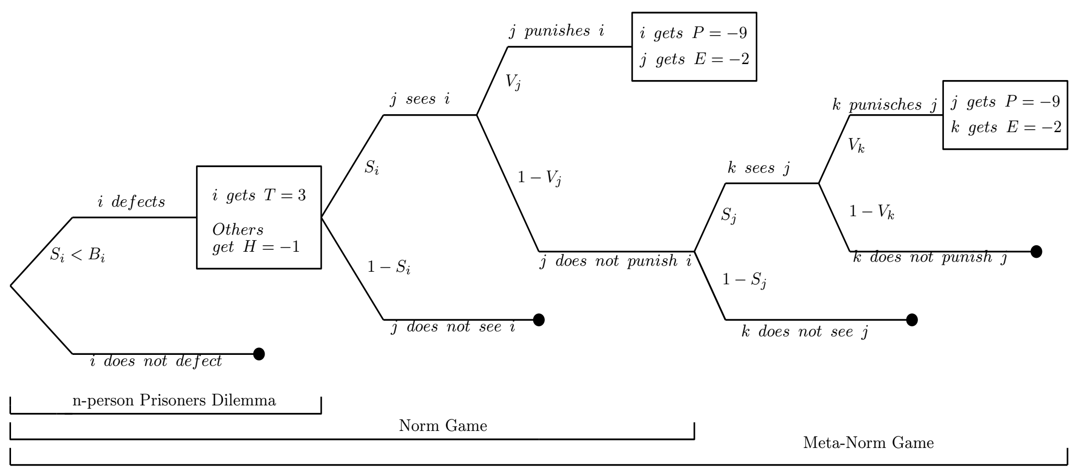

Figure 2: A round of the Meta-Norm Game.

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[1] R. Axelrod. *An Evolutionary Approach to Norms.* American Political Science Review 80, 1986.

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[3] R. Axelrod. *The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration.* Princeton University Press, 1997.

[4] M.J. Osborne. A. Rubinsten. *A Course in Game Theory.* MIT Press, 1994.

[5] M.J. Osborne. *An Introduction to Game Theory.* Oxford University Press, 2004.

[6] E. Rasmusen. *Games and Information: An Introduction to Game Theory.* Wiley-Blackwell, 2006.