A Framework for Indirect Reciprocity

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Non-random assortment (kin selection) is required for cooperation to overtake a population of defectors. If individuals get to seek out their partners can they acquire the knowledge necessary to sort themselves into groups with cooperators.

Researchers have taken different approaches to investigate the evolutionary stability of various strategies often introducing subtle differences into the overall basic framework. These small variations often make it difficult to directly compare results published by different researchers.

There are variations on exactly how the population is evolved after each round.

# Scoring Strategy (Nowak & Sigmund Nature 1998)

Using these scales for measuring reputation, the authors proposed a simple rule for assessing an action taken by a donor. The rule, now known as *scoring* in the literature, stipulates that cooperating is always good and defecting is always bad regardless of the reputations of the agents involved in the interaction.

Using the image score reputation scale and the scoring assessment rule, the authors investigated the ability of several donor strategies to promote the emergence of cooperation:

* Donate if, and only if, the image score of the potential recipient is greater than a threshold *k*
* Donate if the image score of the potential donor is greater than a threshold *k* AND the image score of the donor is less than a threshold *h*
* Donate if the image score of the potential recipient is greater than a threshold *k* OR the image score of the donor is less than a threshold *h*
* Donate if, and only if, the image score of the potential donor is less than a threshold *h*

Using computer simulations, the authors found that, under certain conditions, the first three strategies lead to the emergence of cooperation while the last strategy did not.

Using the binary image scale and the scoring assessment rule, the authors investigated the evolutionary stability of several donor strategies:

* Donate if, and only if, the image of the potential recipient is good

Using this simplified reputation model, the authors derived equations that describe the population dynamics. From these equations, the authors determined conditions under which cooperation will emerge.

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To use the reputation tracking scales described above, a reputation *assessment rule* must be used to determine whether the action taken by an agent is deemed bad or good. The authors propose a simple assessment rule that is now referred to as *scoring*. The scoring assessment rule considers defection to be bad and cooperation to be good regardless of the reputations of the agents participating in the interaction.

The authors introduce a simple strategy now referred to as *scoring* in the literature. The strategy consists of a simple assessment rule for tracking agent reputations and a simple action rule that an agent can use to decide whether to donate to the potential recipient.

The authors proposed a simple action rule that only depends on the reputation of the recipient. When using the image score form of reputation assessment, the rule specifies to cooperate when the recipient’s reputation is greater than a specified threshold *k*. When using the simplified good/bad image form of reputation assessment, the rule specifies to cooperate if the agent has a good reputation and defect otherwise.

# Problems with Scoring

Since the publication of this paper much debate has ensued regarding whether the proposed scoring assessment rule and proposed donor strategies provide a good model of how cooperation through indirect reciprocity emerged in human societies. The following objections are often raised in the literature that cites this paper:

* The factor that determines whether an agent will receive donations in the future is its own reputation. However, an agent following the first donor strategy listed above does not consider its own reputation when deciding whether to donate [6].
* The scoring assessment rule dictates that refusing to donate is bad regardless of the reputation of the potential donor. However, the first donor strategy dictates that an agent should refuses to donate to a bad agent. Following this strategy is irrational since it causes the agent itself to become bad and thus puts the agent in a situation where it will not receive donations in the future [8].
* Given the previous critique, the rational strategy is for the agent to donate to all agents regardless of their reputations. However, this rewards defectors and thus jeopardizes the chances that cooperation will emerge as a dominant strategy [?].

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The image scoring strategy only takes into account the reputation of the potential recipient: an agent should donate to a potential recipient if that recipient has a good reputation and refuse to donate otherwise. There are at least two criticisms that can be leveled at this strategy. First, the factor that determines whether the agent will receive donations in the future is its own reputation. However, an agent following the scoring strategy does not consider its own reputation when deciding whether to donate or not [6]. Second, the strategy dictates that an agent refuses to donate to a bad agent. However, following this strategy causes the agent itself to become bad and thus puts the agent in a situation where it will not receive donations in the future [8]. Third, the assessment rule gives agents a good score for cooperating regardless of the reputation of the recipient. (…) Because of these two issues, it is questionable whether a rational agent would actually follow the scoring strategy.

# Standing (Sugden)

An alternative strategy, attributed to Sugden [5], is the *standing* strategy. The assessment rule used by the standing strategy discriminates between justified and unjustified defections. Defecting against a bad agent is labeled as justified while defecting against a good agent is labeled as unjustified. An agent is given a bad reputation if they engage in unjustified defection but otherwise labeled as good. An agent following the standing strategy focuses on maintaining its good standing. Therefore, the action rule used by agents following this strategy dictates that the agent should cooperate if they have a bad reputation or if the recipient has a good reputation.

This standing strategy seems to overcome the deficiencies of the scoring strategy and several authors have analyzed the relative performance of the two strategies using computer simulations.

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Obviously, different assessment rules and action rules are possible and, since the publishing of this paper, much debate has ensued regarding which assessment rule and action rule combination is most likely to lead to a cooperative outcome[5][7][8].

Much of that debate has focused on whether scoring or standing constitutes an evolutionarily stable strategy that promotes cooperation.

Some authors have analytically evaluated the possible strategies… (MORE HERE…)

Analytic strategies make simplifying assumptions in order to make the problem tractable…

Here I am concerned about the approaches taken by the authors to evaluate the strategies and not about the results of the experiments.

# Ohtsuki 2004

In [9] the authors analyze the evolutionary stability of all 4096 assessment rule and action rule pairs. The authors analyzed the evolutionary stability of each action rule given a fixed, shared assessment rule and publically known and shared reputation scores for agents. Therefore, strategies do not need to compete against agents that have an alternative view of reputation.

# Leimar 2000

In [6], the authors consider a model in which the population is divided among *g* groups each consisting of *n* members. During each generation, *m* rounds of donor-recipient interactions are played. For each round, two individuals are chosen randomly with one playing the role of the potential donor and the other playing the role of the potential recipient. The donor chooses to donate or not based on its action rule. Its decision may depend on its own reputation, the reputation of the potential recipient or both. The reputations of agents are public and determined based on an assessment rule that is shared by all agents. If the potential donor provides help to the potential recipient, then the usual pay-offs are provided to the players.

After the completion of *m* interactions, the local within-group and global cross-group reproductive probabilities for each action rule are determined as follows. For each group, the pay-offs earned by each action rule in the previous generation are summed and normalized to produce the local within-group reproductive probability for each action rule. To produce the global cross-group reproductive probabilities, the pay-offs earned by each action rule are summed and normalized across all groups.

The action rule followed by each individual in the next generation is determined as follows. With probability p, the individual’s action rule is derived from the local group using the within-group reproductive probability. With probability 1-*p*, the individual’s action rule is derived using the global cross-group reproductive probability. When determining the action rule for an individual in the next generation, a mutation occurs with probability *μ*. When a mutation occurs, the individual’s action rule is selected from among all available action rules with equal probability.

In order to improve the fidelity of the model as it relates to real world scenarios, the authors introduce a probability ε that an agent will take an action that is different from the action prescribed by its strategy. (Implementation error)

(perception error)

The authors conduct two different sets of experiments. In the first set of experiments, they take the scoring assessment rule as a given and evaluate the evolutionary stability of several different action rules.

The authors investigate two assessment rules: *scoring* and *standing*. For the scoring assessment rule, the form of the rule in which an agent’s reputation is an integer between -5 and +5 is used. For the standing assessment rule, the binary good/bad assessment is used.

In the context of the scoring assessment rule, the authors consider three different actions rules:

* The agent provides help if its own image score is less than a threshold *h*
* The agent provides help if the recipient’s image score is greater than or equal to a threshold *k*. This is the action rule proposed in [1].
* The agent provides help if its own image score is less than a threshold *h* and the recipient’s image score is greater than or equal to a threshold *k*
* (Other strategies not studied by [1])

The authors evaluate the success of these strategies using computer simulations.

In the context of the standing assessment

In [8], the authors use a variation of the approach used in [6]. The assessment rule is limited to the simplified binary version in which the agent’s reputation can be one of two values: good or bad. In addition, each agent tracks a private assessment of other agents’ reputations and this assessment is not necessarily based on observing all interactions.

The authors clearly define a strategy as consisting of two parts: assessment rule and action rule. The assessment rule determines how an agent assigns a new reputation to a donor based on the agent’s last action and the reputation of the two participants when the action was taken. Given two possible actions that a potential donor can take, two possible reputation scores for the potential donor, two possible reputation scores for the potential recipient and two possible reputation scores that can be assigned to the potential donor there are 256 possible assessment rules to consider. The authors consider three assessment rules: scoring, standing and judging. The composition of each of these rules is described in the following table.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Observed Situation** | | | **Assigned Reputation** | | |
| **Donor Reputation** | **Recipient Reputation** | **Donor Action** | **Scoring** | **Standing** | **Judging** |
| Good | Good | Donate | Good | Good | Good |
| Good | Bad | Donate | Good | Good | Bad |
| Bad | Good | Donate | Good | Good | Good |
| Bad | Bad | Donate | Good | Good | Bad |
| Good | Good | Refuse | Bad | Bad | Bad |
| Good | Bad | Refuse | Bad | Good | Good |
| Bad | Good | Refuse | Bad | Bad | Bad |
| Bad | Bad | Refuse | Bad | Bad | Bad |

The action rule determines the action that an agent should take based on the reputation of the two participants. Given two possible reputation scores for the potential donor, two possible reputation scores for the potential recipient and two possible actions that an agent can take there are 16 possible action rules to consider. The authors consider six of these assessment rules: CO, SELF, AND, OR, ALLD and ALLC. The composition of each of these rules is described in the following table.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Situation** | | **Action to Take** | | | | | |
| **Donor Reputation** | **Recipient Reputation** | **SELF** | **CO** | **AND** | **OR** | **ALLC** | **ALLD** |
| Good | Good | Refuse | Donate | Refuse | Donate | Donate | Refuse |
| Good | Bad | Refuse | Refuse | Refuse | Refuse | Donate | Refuse |
| Bad | Good | Good | Donate | Donate | Donate | Donate | Refuse |
| Bad | Bad | Good | Refuse | Refuse | Donate | Donate | Refuse |

Considering all possible combinations to the three 3 assessment rules and 6 actions rules listed above, 14 strategies can be constructed. The authors use computer simulations to evaluate the evolutionary stability of these 14 strategies in three different ways. First the authors conduct experiments in which all 14 strategies are present. In this case, they evaluate the performance of the strategies for different cost benefit ratios. In the second set of experiments, the authors keep the assessment rule fixed and evaluate the performance of the different actions rules in that environment. In the final set of experiments, the authors keep the action rule fixed and evaluate the performance of the different assessment rules in that environment.

Given this model, the assessment rules are fixed and not subject to evolutionary pressures.

In [13], the authors investigate the co-evolution of assessment rules and action rules in the context of the door-recipient game. The model employed by the authors considers evolution at two levels. At the base level, the authors consider the evolution of action strategies in the context of a fixed assessment rule. On top of this base level, the authors consider the evolution of social norms in the context of competition between groups of agents called tribes.

Let be a tribe of agents and be the *jth* member of that tribe. Let be the social norm used by tribe *Ti*, be the strategy followed by agent *aij* and be the reputation of agent *aij*. The reputation of each agent is considered public shared information.

The simulation proceeds in rounds and each round consists of two stages. During the first stage, each agent participates in one donor-recipient game with every other member of its tribe. The payouts received by each agent are tracked in order to calculate the fitness of each individual in the tribe.

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