# An open reproducible framework for the study of the iterated prisoner's dilemma

Owen Campbell Marc Harper Vincent Knight Karol Langner

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## 1 Introduction

This paper introduces a software package: the Axelrod python library [28]. The Axelrod-Python project has the following stated goals:

- To enable the reproduction of previous Iterated Prisoner's Dilemma research as easily as possible.
- To produce the de-facto tool for any future Iterated Prisoner's Dilemma research.
- To provide as simple a means as possible for anyone to define and contribute new and original Iterated Prisoner's Dilemma strategies.

This library is motivated by an ongoing discussion in the academic community about reproducible research [8, 24, 25, 14]. The library is:

- Open: all code is released under an MIT license;
- Reproducible: at the time of writing there is an excellent level of integrated tests with 99.59% coverage;
- Documented: all features of the library are documented for ease of use.
- Extensive: over 100 strategies are included.

Before describing the package in more detail in Section 1.2, an overview of some previous Iterated Prisoner's Dilemma research will be given.

### 1.1 Review of the literature

As stated in [5]: "*few works in social science have had the general impact of [Axelrod's study of the evolution of cooperation]*". In 1980, Axelrod wrote two papers: [1, 2] which described a computer tournament that has been at the origin of a majority of game theoretic work [4, 5, 6, 7, 9, 10, 11, 12, 13, 15, 16, 17, 18, 20, 21, 22, 23, 26, 27]. As described in [5] this work has not only had mathematical impact but has also led to insights in biology (for example in [26], a real tournament where Blu Jays are the participants is described) and in particular to the study of evolution.

The tournament is based on an iterated game (see [19] or similar for details) where two players repeatedly play the normal form game of (1) in full knowledge of each others playing history to date. An excellent description of the *one shot* game is given in [12] which is paraphrased below:

Two players must choose between *Cooperate* ($C$) and *Defect* ($D$):

- If both choose $C$, they receive a payoff of $R$ (**R**eward);

- If both choose $D$, they receive a payoff of $P$ (**P**punishment);
- If one chooses $C$ and the other $D$, the defector receives a payoff of $T$ (**T**emptation) and the cooperator a payoff of $S$ (**S**ucker).

$$\begin{pmatrix} R, R & S, T \\ S, S & P, P \end{pmatrix} \quad \text{such that } T > R > P > S \text{ and } 2R > T + S \tag{1}$$

The game of (1) is called the Prisoner's Dilemma. Numerical values of $(R, S, T, P) = (3, 0, 5, 1)$ are often used in the literature. Axelrod's tournaments (and further implementations of these) are sometimes referred to as Iterated Prisoner's Dilemma (IPD) tournaments, an overview of published tournaments is given in Table 1.

| Year | Reference | Number of Strategies | Type | Source Code |
|---|---|---|---|---|
| 1979 | [1] | 13 | Standard | Not immediately available |
| 1979 | [2] | 64 | Standard | Not immediately available |
| 1991 | [5] | 13 | Noisy | Not immediately available |
| 2002 | [26] | 16 | Wildlife | Not applicable |

Table 1: An overview of published tournaments

In [20] describes how incomplete information can be used to enhance cooperation, in a similar approach to the proof of the Folk theorem for repeated games [19]. This aspect of incomplete information is also considered in [21, 5, 17] where "noisy" tournaments randomly flip the choice made by a given strategy. In [22] incomplete information is considered in the sense of a probabilistic termination of each round of the tournament.

As mentioned before, IPD tournaments have been studied in an evolutionary context: [11, 17, 23, 27] consider this in a traditional evolutionary game theory context. These works investigates particular evolutionary contexts within which cooperation can emerge as stable. Often these works consider direct opposition to another strategy and disregard the population dynamics, for example in [17] a simple machine learning algorithm outperforms a strategy found in [23].

Further to these evolutionary ideas, [7, 9] are examples of using machine learning techniques to evolve particular strategies. In [3] Axelrod describes how similar techniques are used to genetically evolve a high performing strategy from a given set of strategies. Note that in his original work Axelrod only used a base strategy set of 12 strategies for this evolutionary study. This is noteworthy as [28] now boasts over 90 strategies that are readily available for a similar analysis.

## 1.2 Description of the Axelrod python package

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# 2 Reproducing previous tournaments

# 3 New strategies, tournaments and implications

# 4 Conclusion

## References


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