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Nashpy: A Python library for the computation of Nash equilibria

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Software

- Review
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Summary

Game theory is the study of strategic interactions where the outcomes of choice depend on the choices of all participants. A key solution concept in the field is that of Nash Equilibrium (Nash and others 1950). This solution concept corresponds to a coordinate at which no participant has any incentive to change their choice.

As an example, consider the game of Rock Paper Scissors which can be represented mathematically using the following matrix:

$$A = \begin{pmatrix} 0 & -1 & 1 \\ 1 & 0 & -1 \\ -1 & 1 & 0 \end{pmatrix}$$

The rows and columns correspond to the actions available: Rock, Paper and Scissors. A value of 1 indicates that that specific row beats the corresponding column and similarly a value of -1 indicates a loss and a 0 indicates a tie. For example (A_{21}) shows that Paper (the second action) beats Rock (the first action. Using `Nashpy` the equilibrium behaviour can be computed:

```
>>> import nashpy as nash
>>> import numpy as np
>>> A = np.array([[0, -1, 1], [1, 0, -1], [-1, 1, 0]])
>>> game = nash.Game(A)
>>> for eq in game.support_enumeration():
...     print(eq)
(array([ 0.33...,  0.33...,  0.33...]), array([ 0.33...,  0.33...,  0.33...]))
```

As expected: both players should play each action randomly (each with probability 1/3).

Computing this equilibria for large games, situations where individuals have many strategic options available to them requires the use of software.implementations of known algorithms. A number of algorithms exist to compute these Nash equilibria, for example the Lemke-Howson algorithm (Lemke and Howson 1964).

Statement of need

Access to these algorithms is non trival, an example of this includes the modelling of healthcare decisions (Vincent Knight, Komenda, and Griffiths 2017) where a bespoke

theoretic result was used to design a specific algorithm for the computation of equilibria. Easily accessibly software would make that research more straightforward as no new algorithm would need to be implemented.

The most mature piece of software available for the computation of equilibria is **Gambit** (McKelvey, McLennan, and Turocy 2006). Gambit includes a python wrapper to its core C functionality however is not currently portable for example Windows is not supported. There does exist a web interface with a Gambit back end: Game theory explorer however this is not practical for reproducible research.

`Nashpy` is a Python library with all dependencies being part of the standard scientific Python stack (numpy and scipy (Jones et al. 2001–2001--)) thus it is portable. For example Windows support is regularly tested through a Windows continuous integration service (Appveyor).

`Nashpy` currently implements 3 algorithms for the computation of equilibria (currently only for 2 player games) and is extensively documented, including theoretic reference material on the algorithms: nashpy.readthedocs.io. Furthermore, the software is automatically tested using a combination of doc (this paper is also tested), unit, integration and property based tests with 100% coverage.

`Nashpy` is designed to be used by researchers but also students in courses in the fields of mathematics, computer science and/or economics. It is already currently being used in a final year course at Cardiff University. Due to the fact that the code is written entirely in Python and is open source, this makes it a positive teaching tool as students can read and understand implementation of the algorithms. `Nashpy` has been archived to Zenodo with the linkd DOI: (Vince Knight and Baldevia 2018).

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