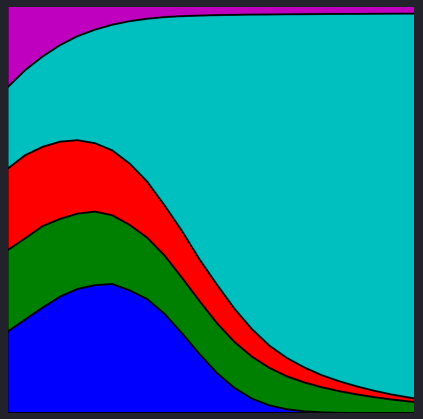
A computational approach to cooperation

Tuesday Lunch

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Software
Sustainability
Institute



Kirsty MacLeod
@kirstyjean

Following

Me: sets up flawless heat competition trial, lizards will fight over hot podium, there can only be one winner!
Lizards:

#ALlizards2017

Kirsty MacLeod
@kirstyjean

Following

Me: sets up flawless heat competition trial, lizards will fight over hot podium, there can only be one winner!
Lizards:

#ALlizards2017

$$\begin{pmatrix} (3,3) & (0,5) \\ (5,0) & (1,1) \end{pmatrix}$$

D D

1

D D

1

D C

2

D D

1

D C

2

C D

3

D D

1

D C

2

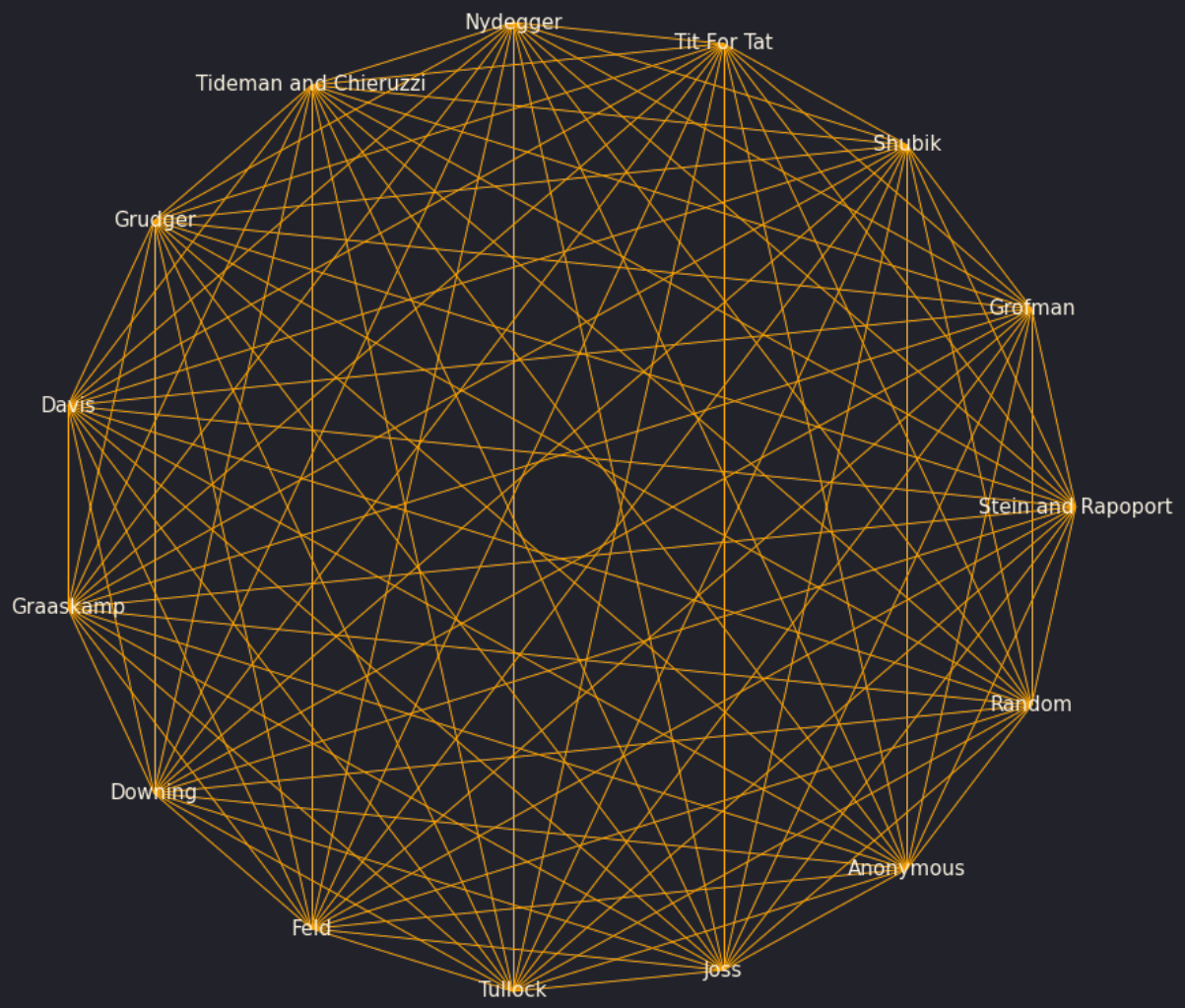
C D

3

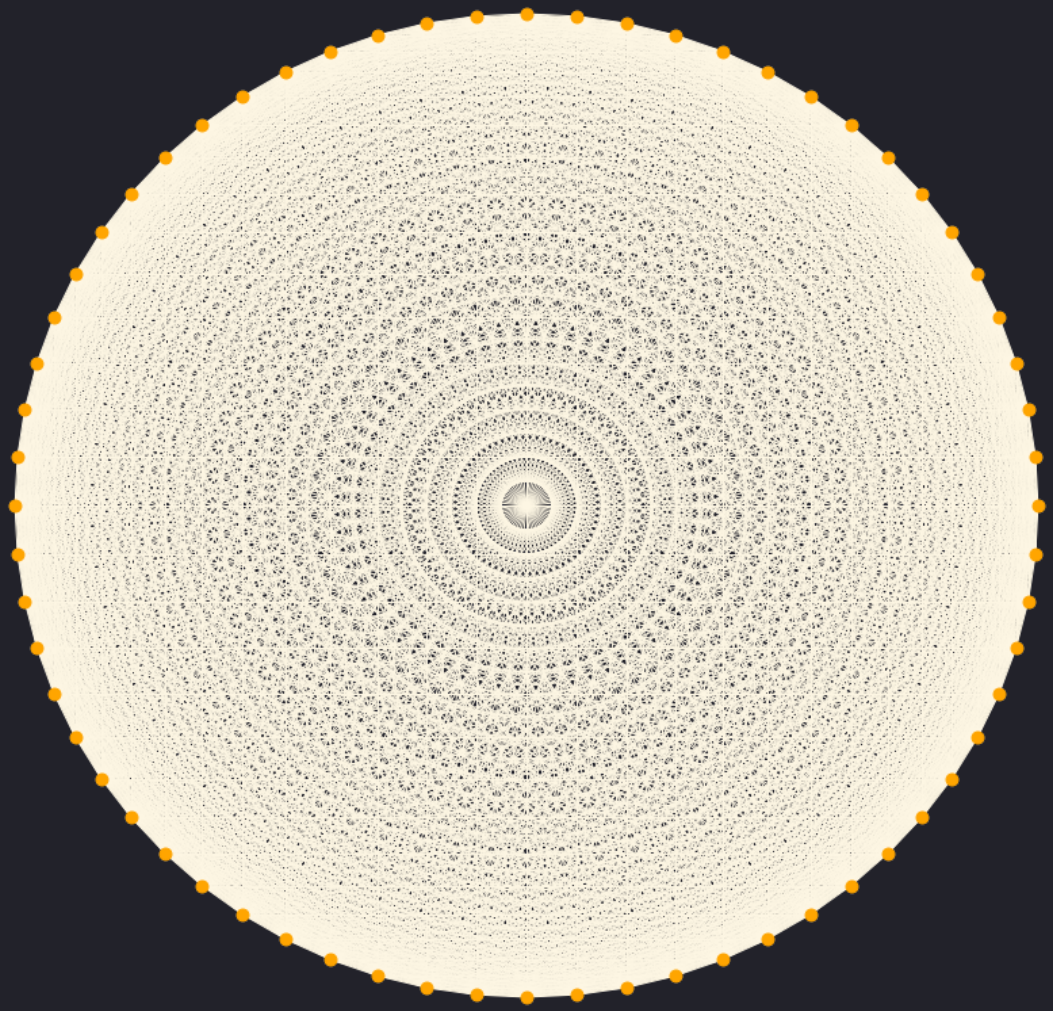
. . .

C C

n



Effective Choice in the Prisoner's Dilemma. R. Axelrod. Journal of Conflict Resolution



More Effective Choice in the Prisoner's Dilemma. R. Axelrod. Journal of Conflict Resolution

Tit For Tat

“A strategy that starts by cooperating and then mimics the previous action of the opponent."

1. Be “nice”; Do not be the first to defect
2. Do not be envious; by striving for a payoff larger than the opponent’s payoff
3. Do not be too clever
4. Reciprocate both cooperation and defection; Be provocable to retaliation and forgiveness

Reverse Tit For Tat

Suspicious Tit For Tat

Omega Tit For Tat

Adaptive Tit For Tat

Hard Tit For Tat

Reverse Tit For Tat

Suspicious Tit For Tat

Omega Tit For Tat

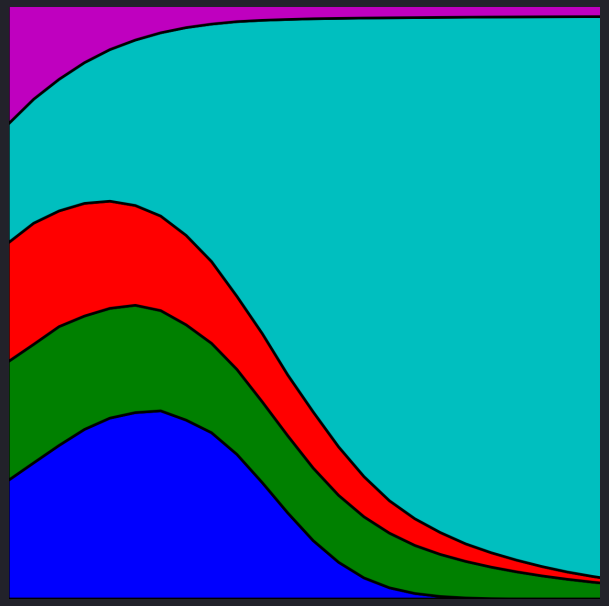
Adaptive Tit For Tat

Hard Tit For Tat

Gradual

Win Stay Lose Shift

Nice and Forgiving



An open framework for the reproducible study of the Iterated prisoner's dilemma. Vincent Knight, Owen Campbell, Marc Harper et al. Journal of Open Research Software

150 strategies from the literature

150 strategies from the literature

239 strategies available today

```
import axelrod as axl

players = [axl.SuspiciousTitForTat(),
...        axl.HardTitForTat(),
...        axl.OmegaTFT(),
...        axl.Gradual(),
...        axl.WinStayLoseShift()]

tournament = axl.Tournament(players,
...                         turns=200,
...                         repetitions=5)

result = tournament.play()
```

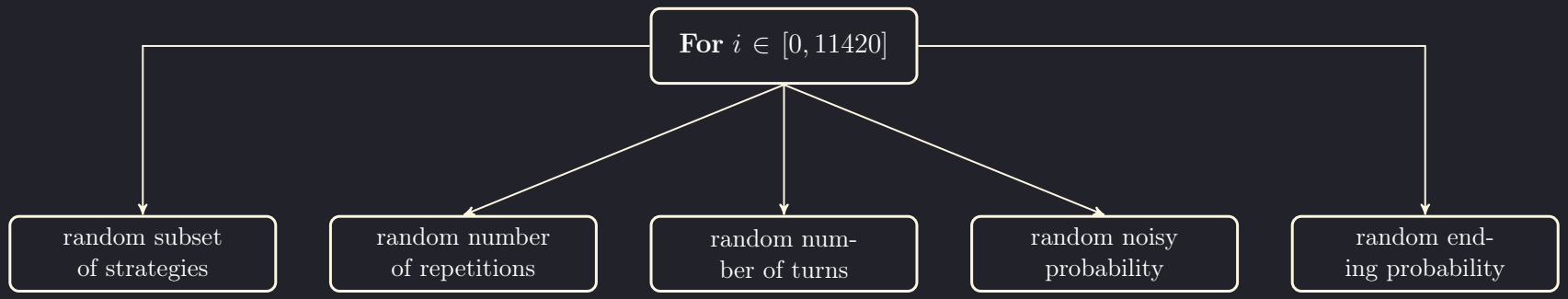
A meta analysis of tournaments and an evaluation of performance in the Iterated Prisoner's Dilemma.

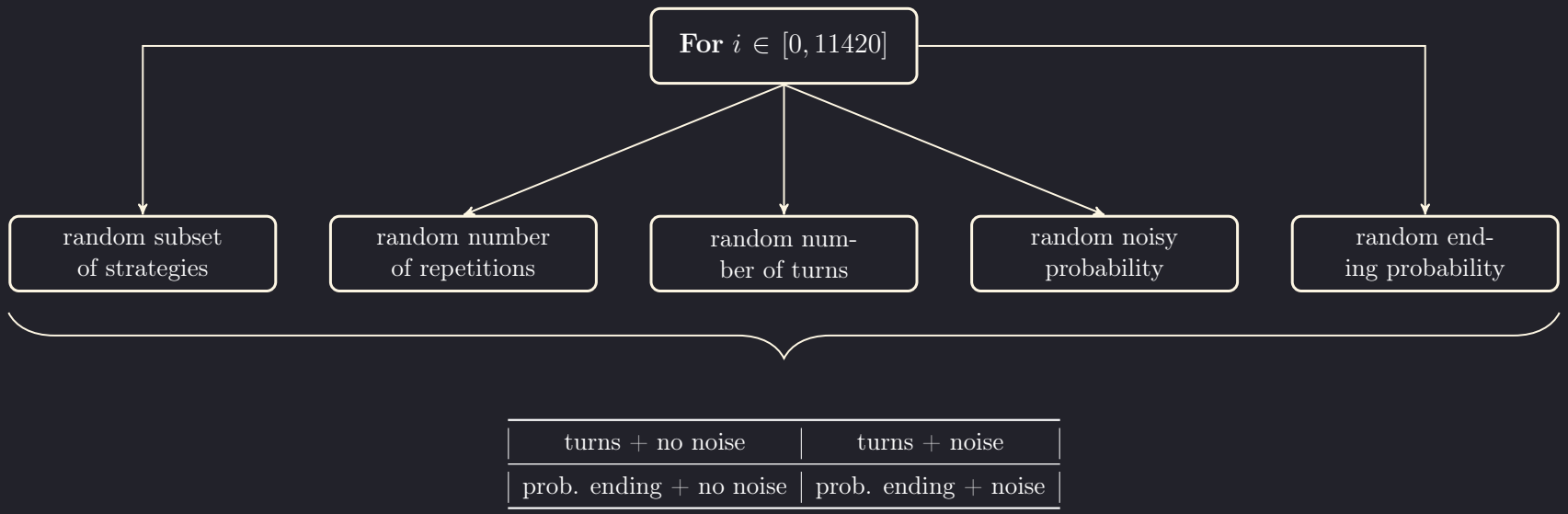
Nikoleta E. Glynatsi, Vincent A. Knight, Marc Harper

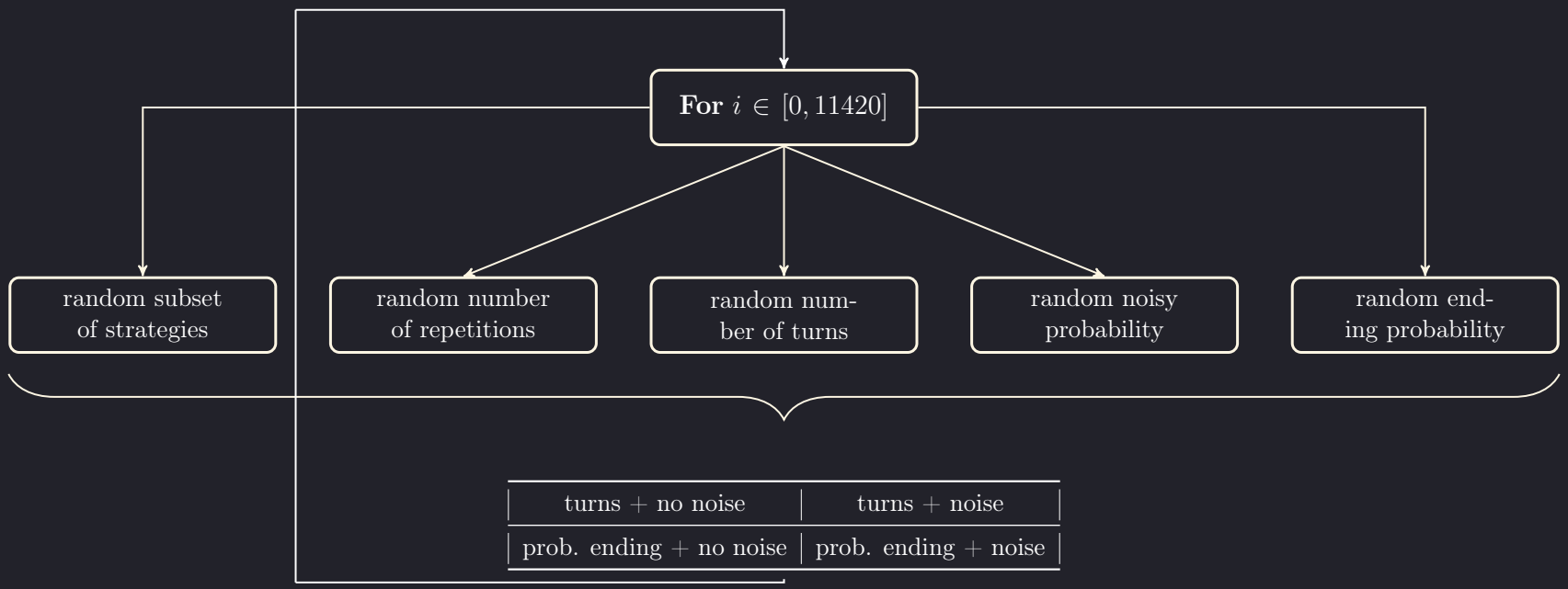
arxiv.org/abs/2001.05911

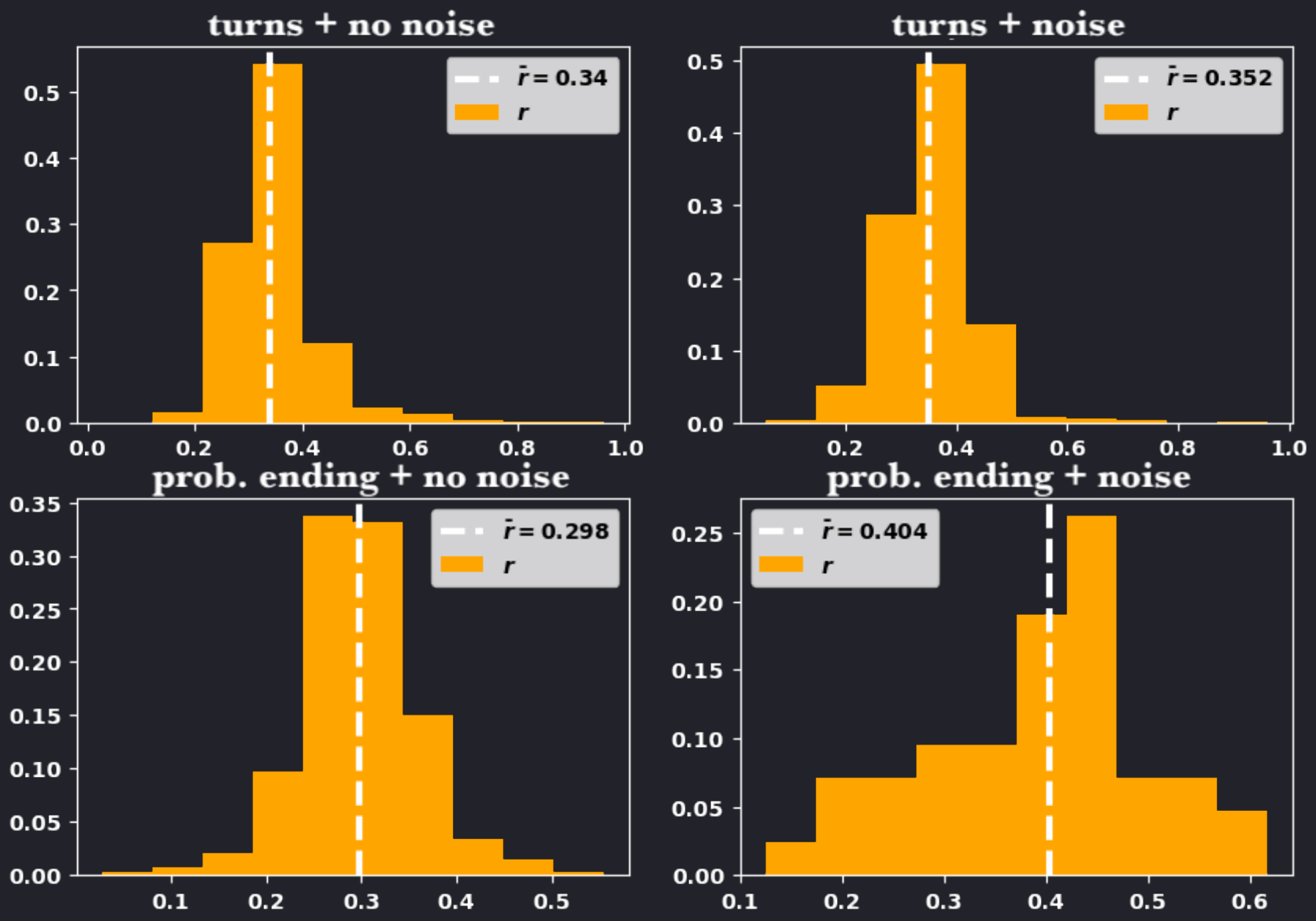
Axelrod-Python v.3.0.0. - 195 strategies

$$\boxed{\textbf{For } i \in [0, 11420]}$$


For $i \in [0, 11420]$
random subset of strategies
random number of repetitions
random number of turns
random noisy probability
random ending probability


For $i \in [0, 11420]$
random subset of strategies
random number of repetitions
random number of turns
random noisy probability
random ending probability
turns + no noise
turns + noise
prob. ending + no noise
prob. ending + noise

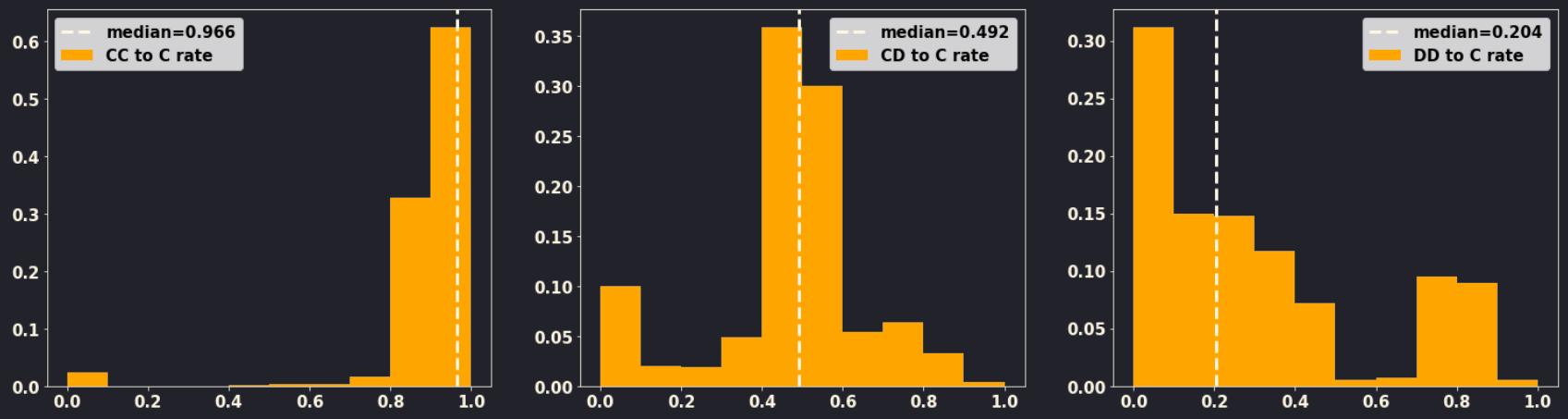

For $i \in [0, 11420]$
random subset of strategies
random number of repetitions
random number of turns
random noisy probability
random ending probability
turns + no noise
turns + noise
prob. ending + no noise
prob. ending + noise


turns + no noise
$\bar{r} = 0.34$
r
turns + noise
$\bar{r} = 0.352$
r
prob. ending + no noise
$\bar{r} = 0.298$
r
prob. ending + noise
$\bar{r} = 0.404$
r

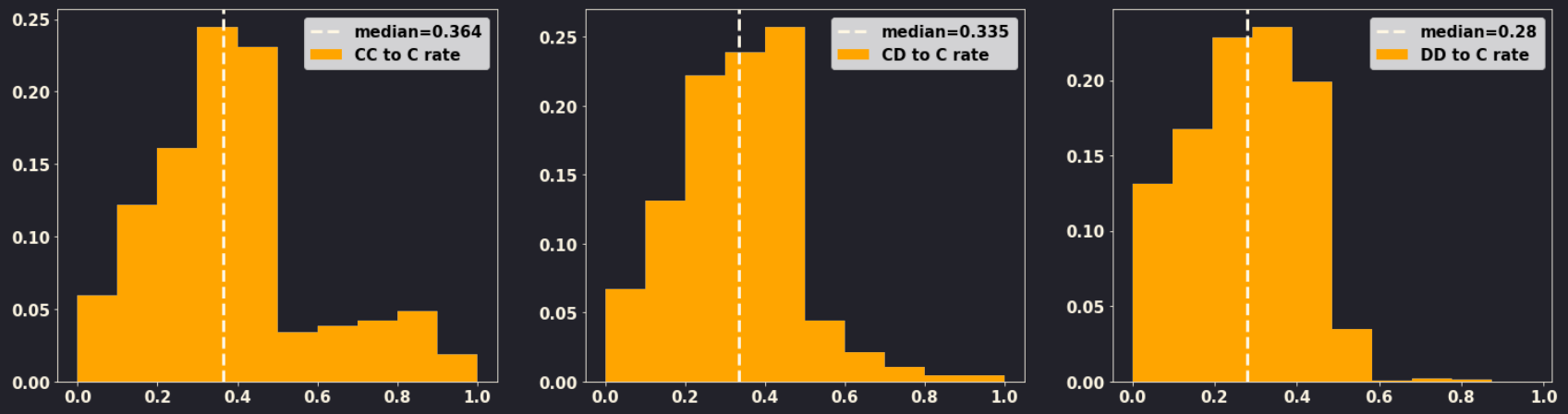
Turns
Probabilistic ending
No noise
Noise
r
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.8
1.0
Evolved HMM 5
Evolved FSM 16
EvolvedLookerUp2_2_2
Evolved FSM 16 Noise 05
PSO Gambler 2_2_2
Evolved ANN
Evolved ANN 5
PSO Gambler 1_1_1
Evolved FSM 4
PSO Gambler Mem1
Winner12
Fool Me Once
DBS
DoubleCrosser
BackStabber
Evolved ANN 5 Noise 05
Spiteful Tit For Tat
Omega TFT
PSO Gambler 2_2_2 Noise 05
EugineNier
MEM2
Nice Meta Winner
NMWE Finite Memory
NMWE Deterministic
Grudger
NMWE Long Memory
Nice Meta Winner Ensemble
EvolvedLookerUp1_1_1
NMWE Memory One
NMWE Stochastic
Alternator
ϕ
e
π
Limited Retaliate
Anti Tit For Tat
Limited Retaliate 3
Retaliate 3
Retaliate
Retaliate 2
Limited Retaliate 2
Hopeless
Arrogant QLearner
Cautious QLearner
Fool Me Forever

- ~~Do not be the first to defect~~ Do not defect on the first turn
- ~~Do not be envious~~ It's okay to be envious
- ~~Do not be too clever~~ Be clever

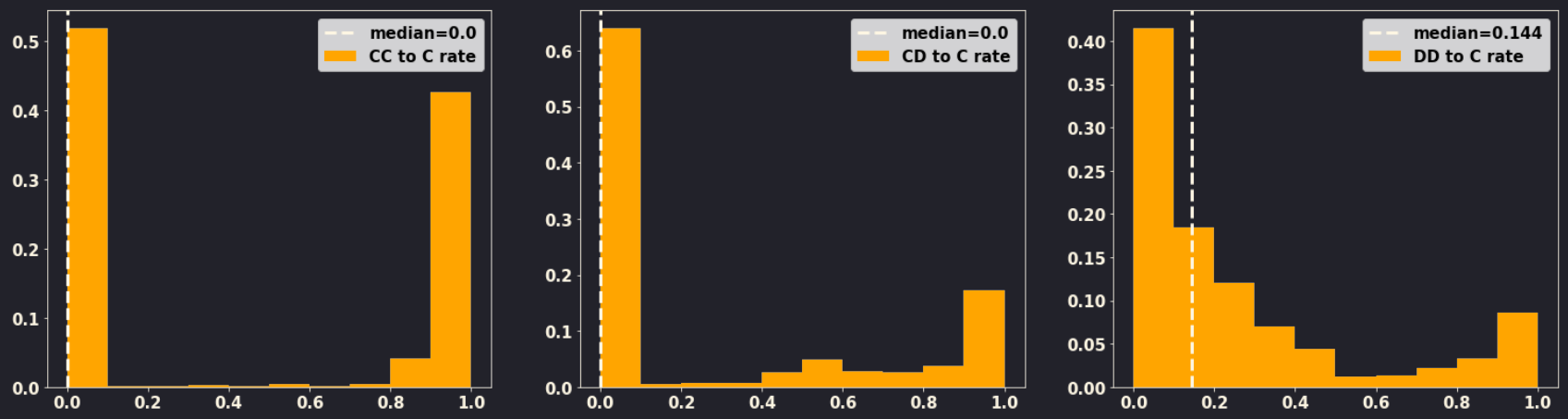
Turns + no noise



Turns + noise


median=0.364
CC to C rate
median=0.335
CD to C rate
median=0.28
DD to C rate
0.00
0.05
0.10
0.15
0.20
0.25
0.0
0.2
0.4
0.6
0.8
1.0

Probabilistic ending + no noise



- ~~Do not be the first to defect~~ Do not defect on the first turn
- ~~Do not be envious~~ It's okay to be envious
- ~~Do not be too clever~~ Be clever
- ~~Be provocable~~ Be provocable in tournaments with short matches, and generous when matches are longer

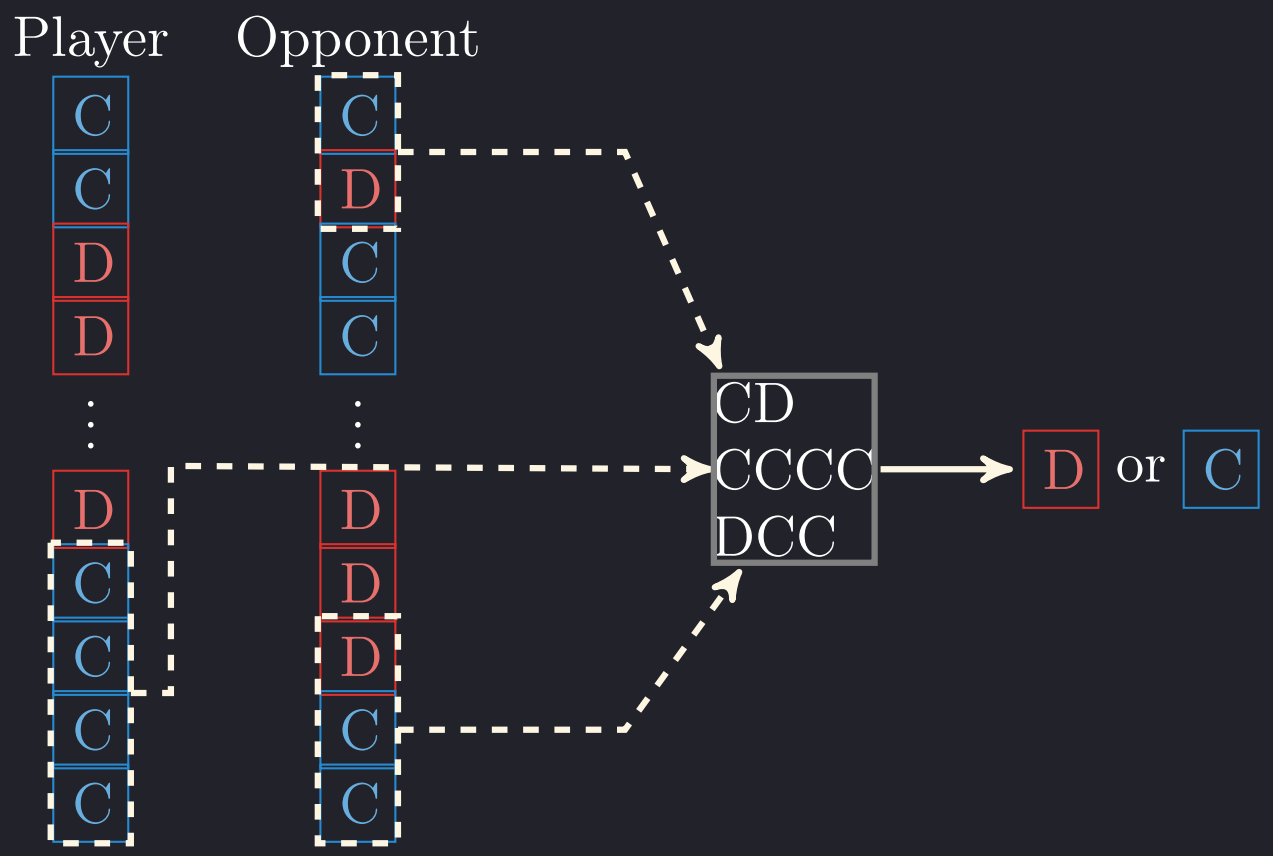
Reinforcement Learning Produces Dominant Strategies for the Iterated Prisoner's Dilemma.

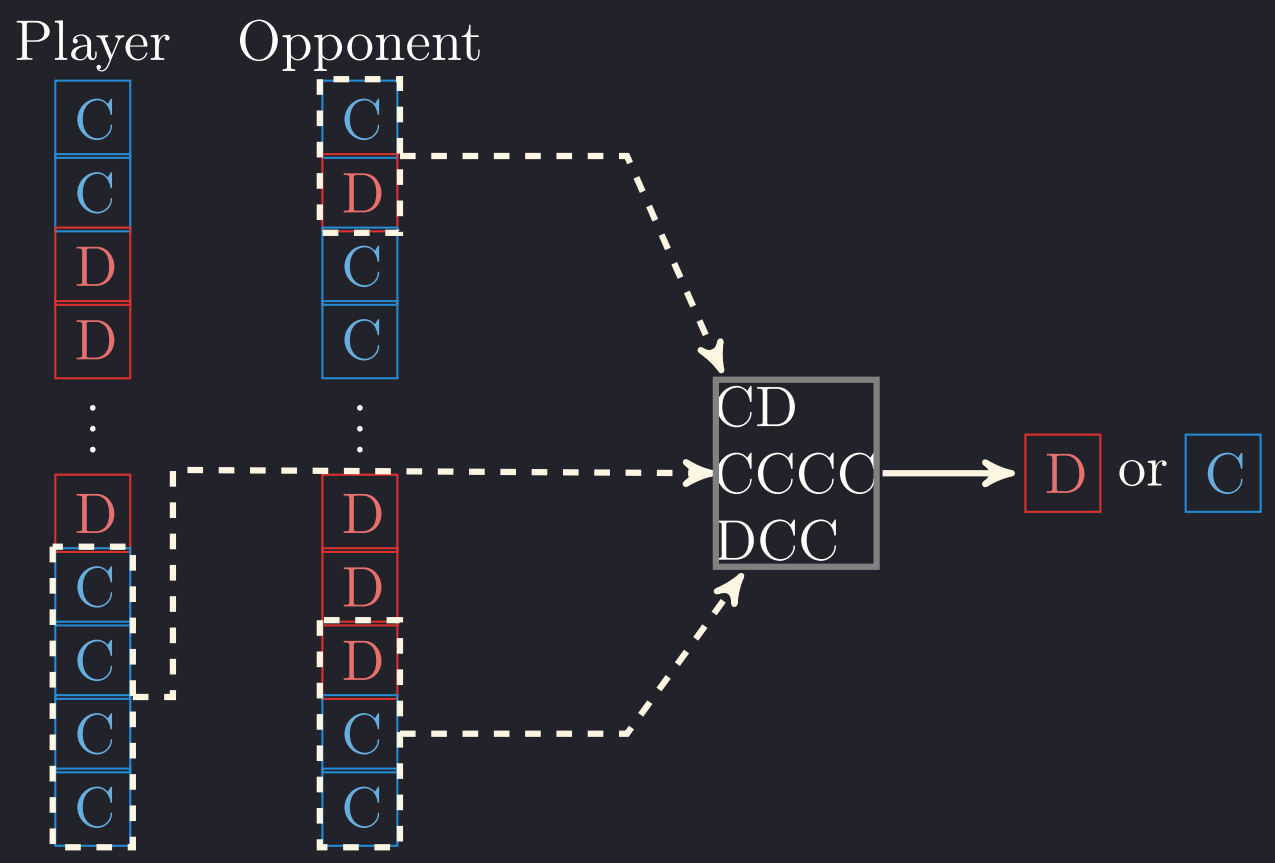
Marc Harper, Vincent Knight, Martin Jones, Georgios Koutsovoulos, Nikoleta E. Glynatsi, Owen Campbell

doi.org/10.1371/journal.pone.0188046

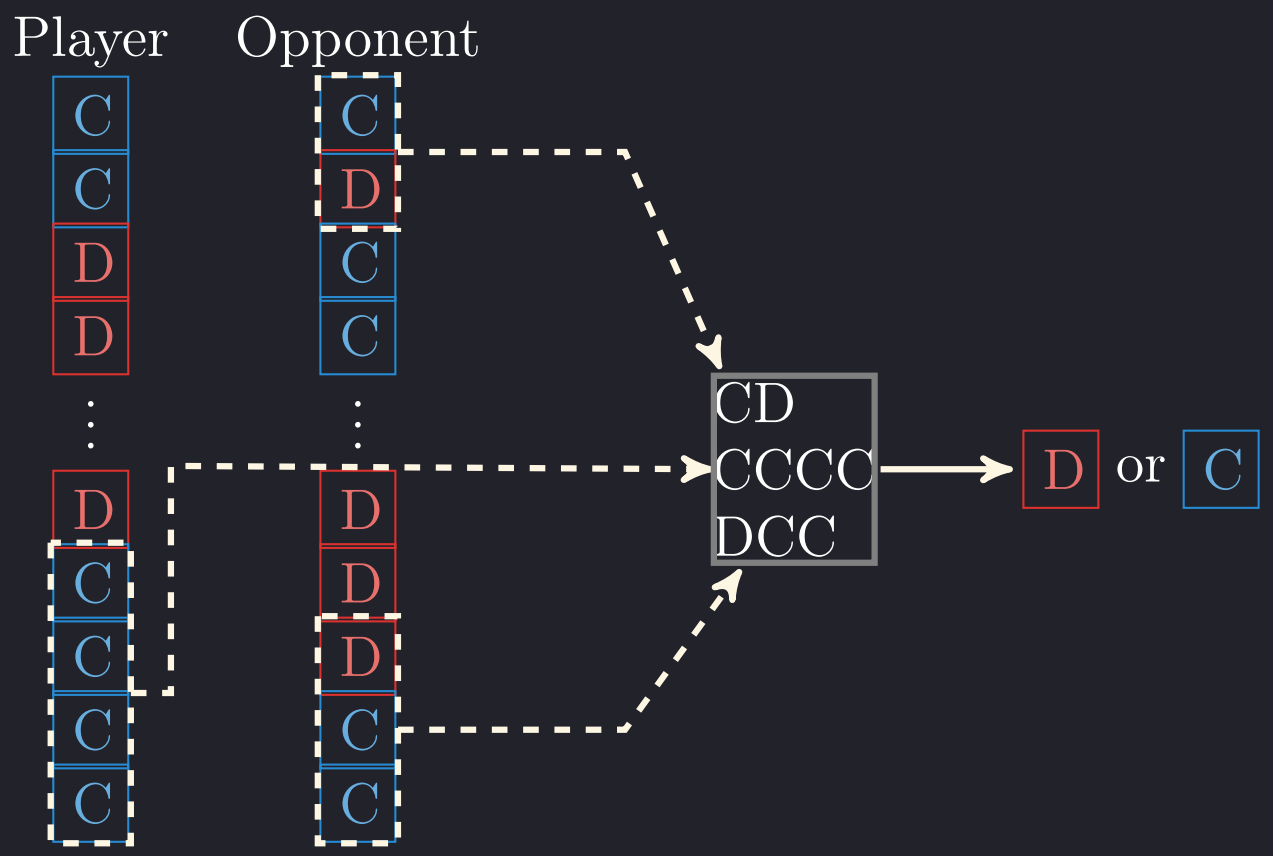
Axelrod-Python v.2.2.0 - 176 strategies

- LookerUp
- Gambler
- Artificial neural network
- Finite state machines
- Hidden markov models
- Meta strategies


Player
Opponent
C
C
D
D
D
C
C
C
C
C
D
C
C
D
D
D
C
C
CD
CCCC
DCC
D
or
C

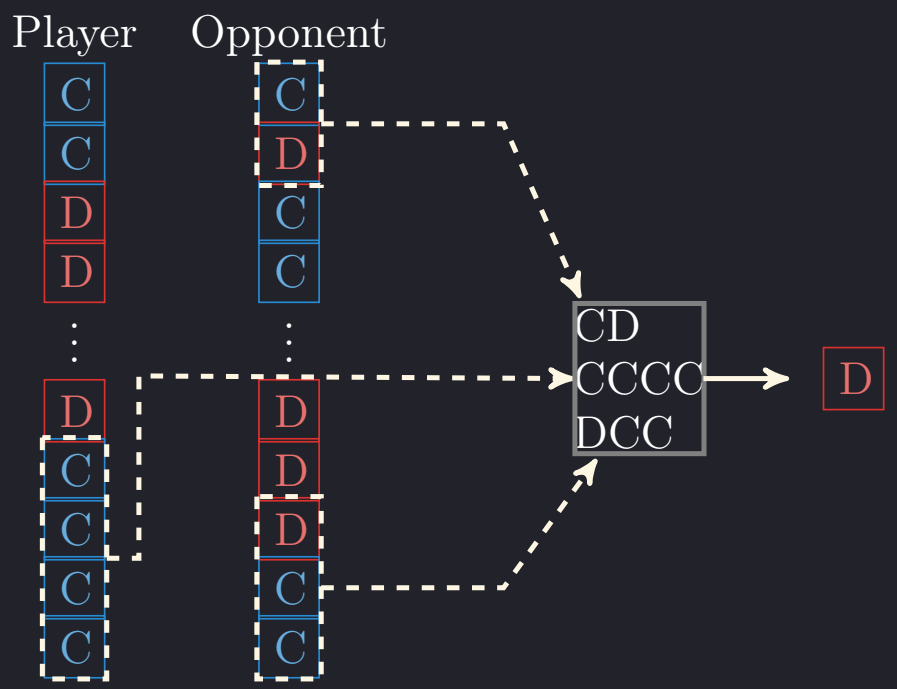


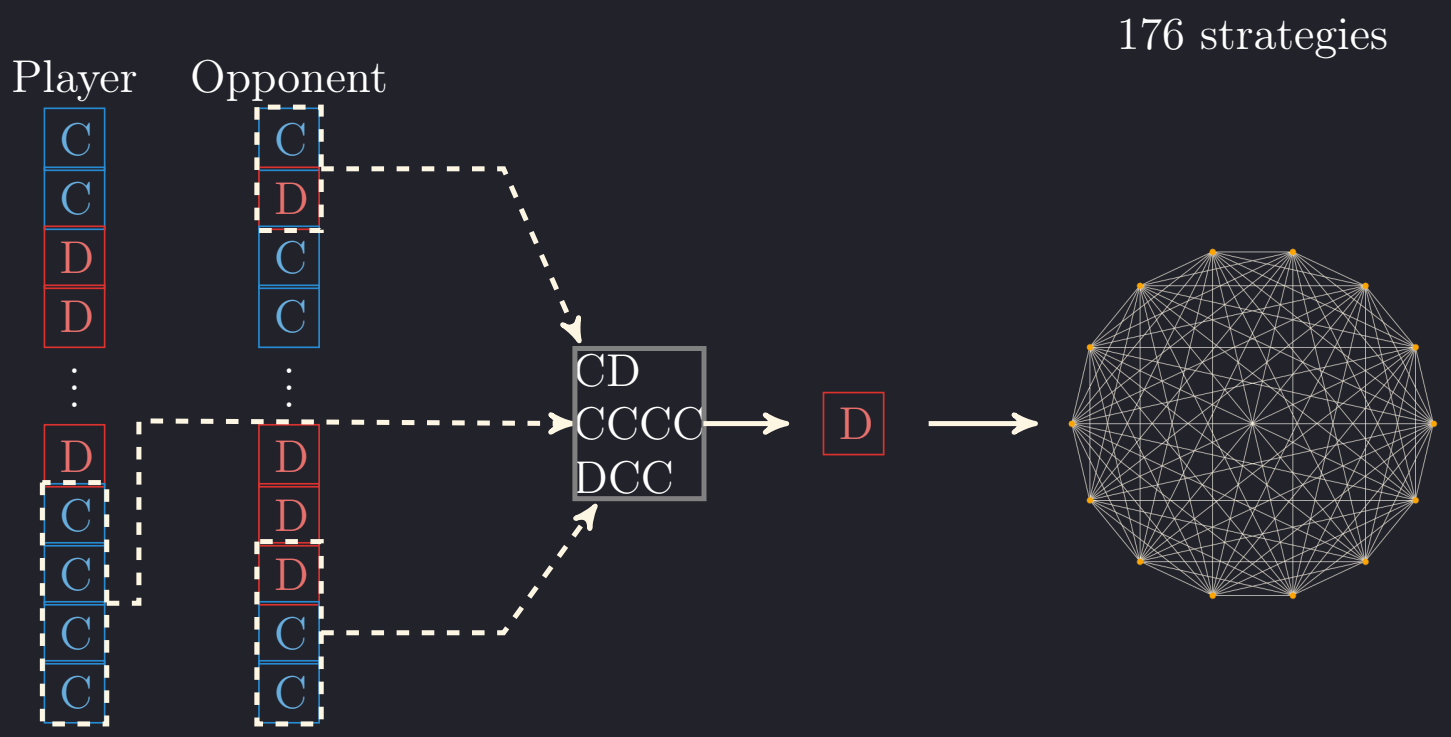
$$n_1 = 2, m_1 = 4, m_2 = 3$$

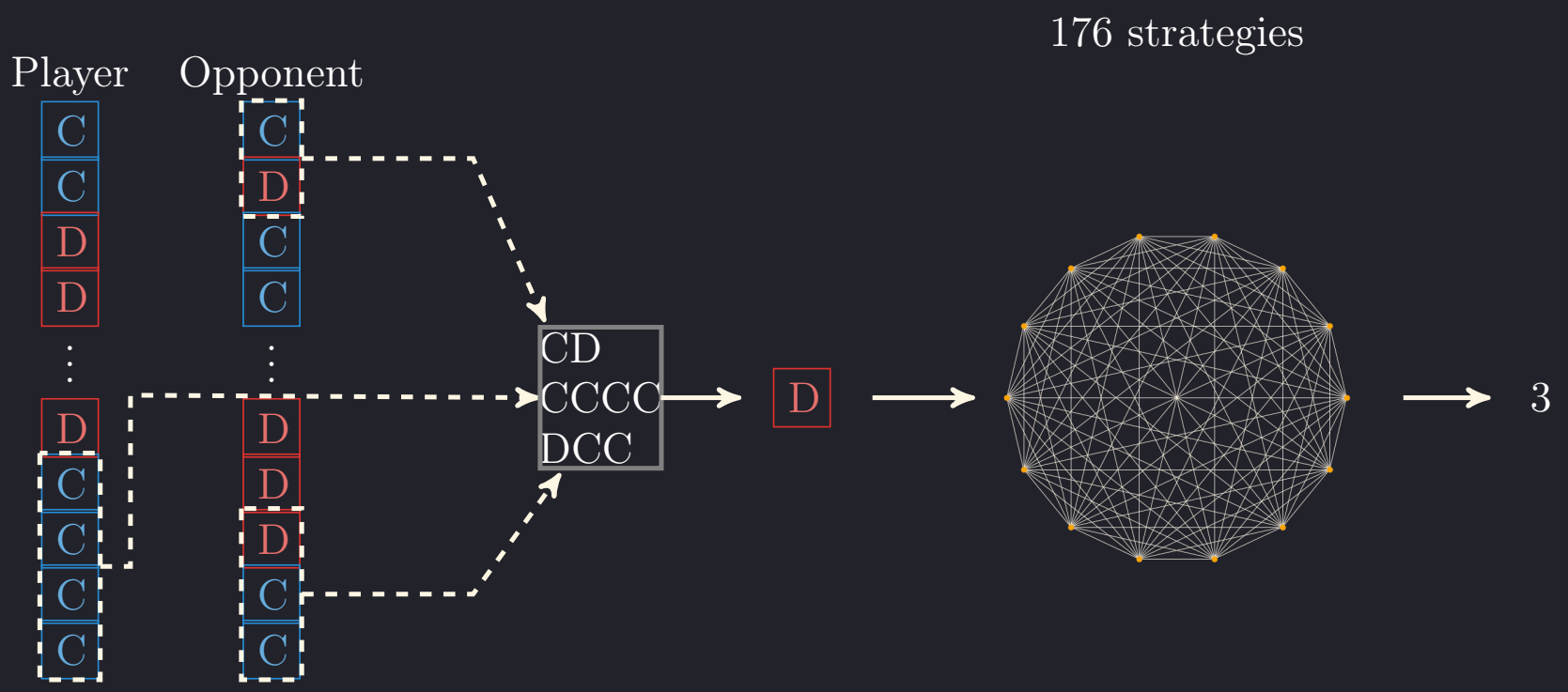


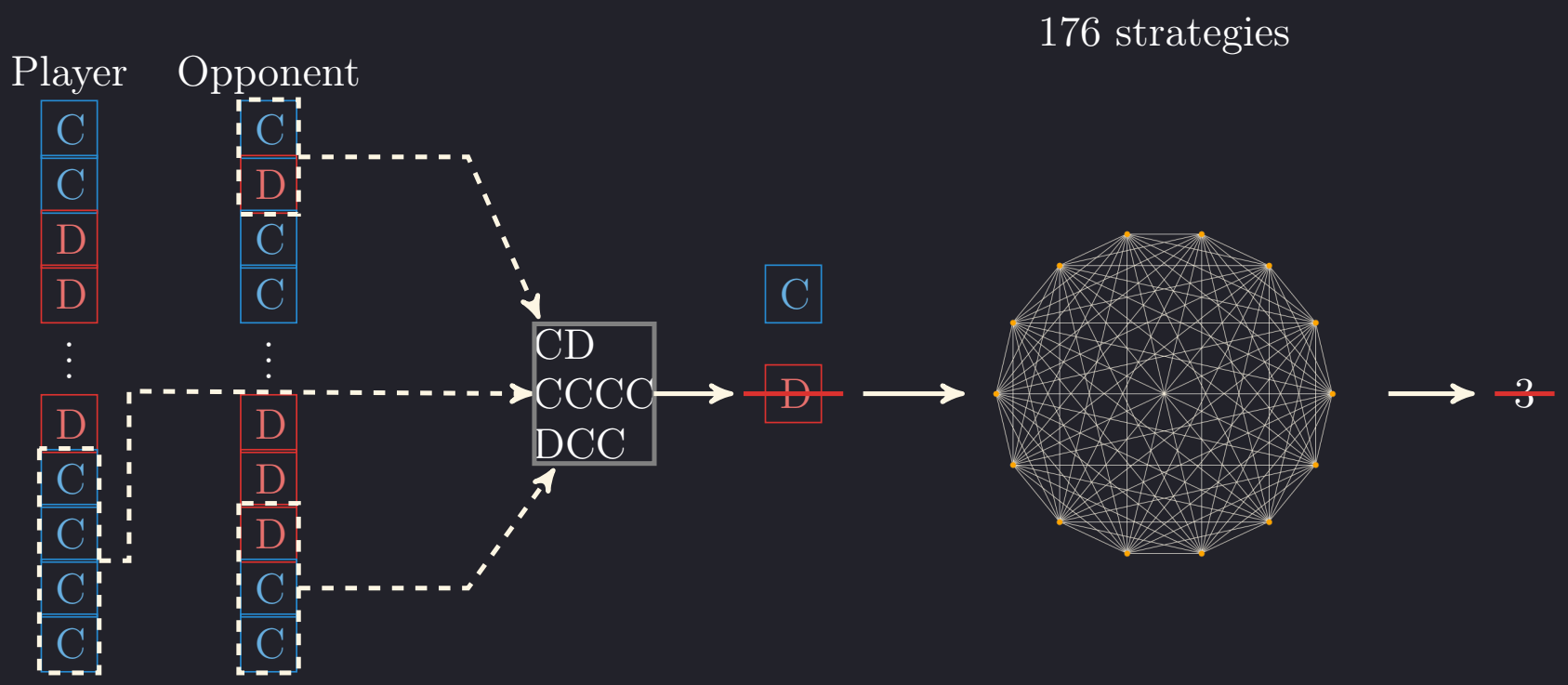
$n_1 = 2, m_1 = 4, m_2 = 3$

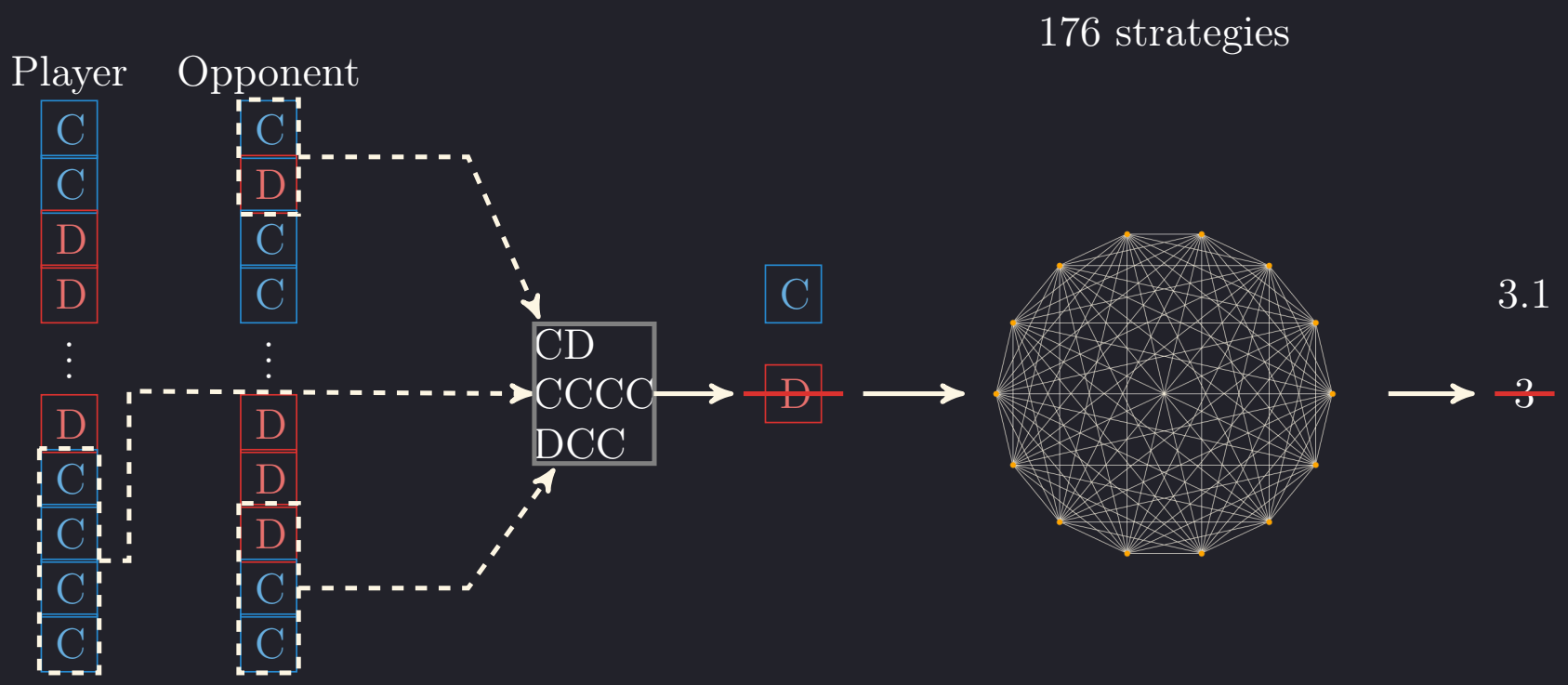
EvolvedLookerUp2_4_3


Player
Opponent
C
C
D
D
D
C
C
C
C
C
D
C
C
D
D
D
C
C
CD
CCCC
DCC
D


176 strategies
Player
Opponent
C
C
D
D
D
C
C
C
C
C
D
D
D
D
D
C
C
CD
CCCC
DCC
D


176 strategies
Player
Opponent
C
C
D
D
D
C
C
C
C
C
D
D
D
D
C
C
CD
CCCC
DCC
D
3

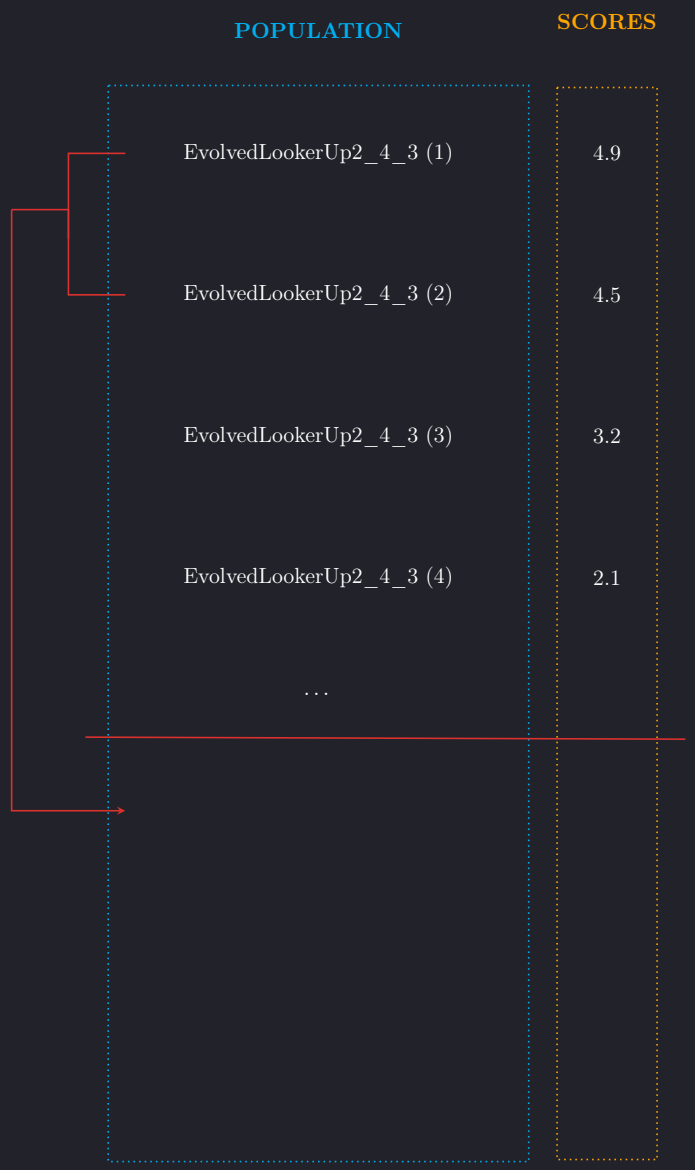

176 strategies
Player
Opponent
C
C
D
D
D
C
C
C
C
C
C
D
C
C
D
D
D
C
C
CD
CCCC
DCC
C
D
3

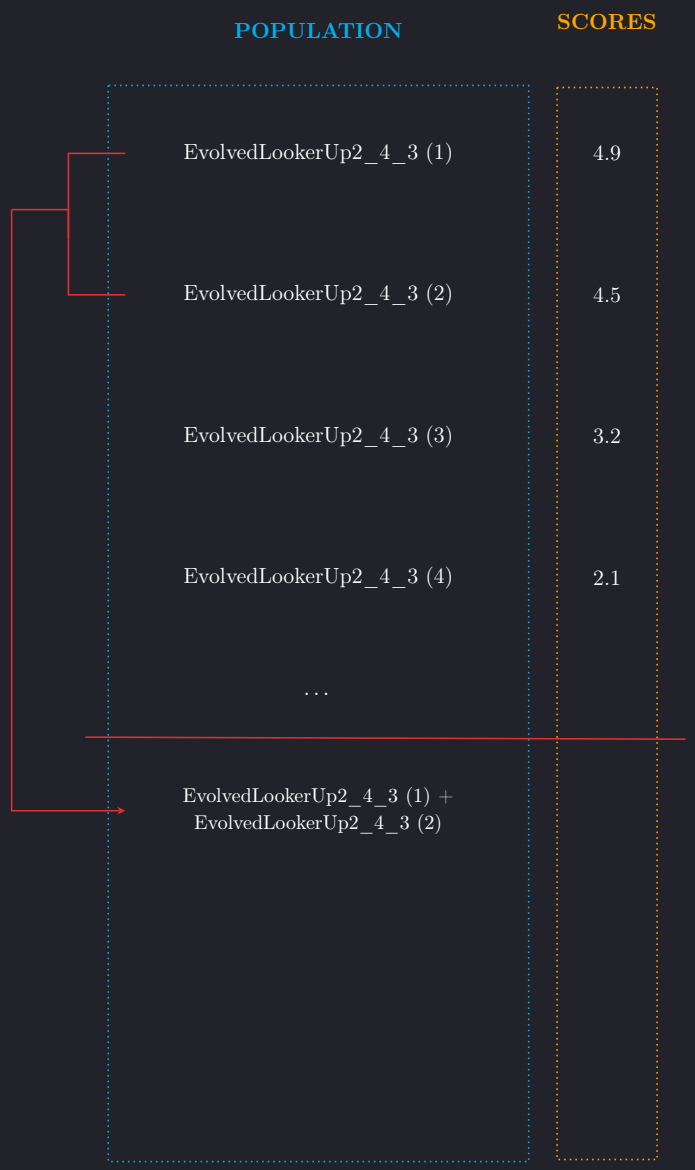

Player
Opponent
C
C
D
D
D
C
C
C
C
C
C
D
C
C
D
D
D
C
C
CD
CCCC
DCC
C
D
176 strategies
3.1
3

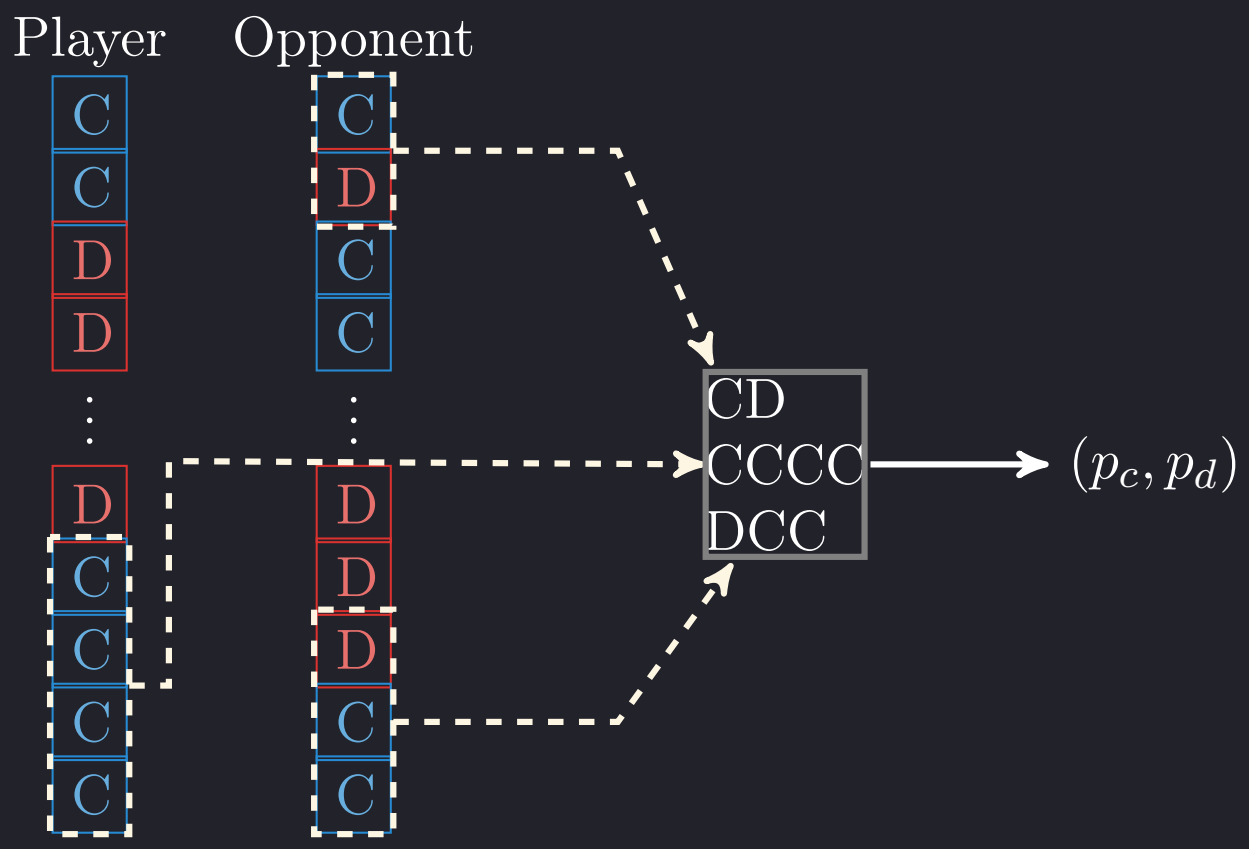
POPULATION	SCORES
EvolvedLookerUp2_4_3 (1)	4.9
EvolvedLookerUp2_4_3 (2)	4.5
EvolvedLookerUp2_4_3 (3)	3.2
EvolvedLookerUp2_4_3 (4)	2.1
...	
EvolvedLookerUp2_4_3 ($n-3$)	1.3
EvolvedLookerUp2_4_3 ($n-2$)	0.9
EvolvedLookerUp2_4_3 (N)	0

POPULATION	SCORES
EvolvedLookerUp2_4_3 (1)	4.9
EvolvedLookerUp2_4_3 (2)	4.5
EvolvedLookerUp2_4_3 (3)	3.2
EvolvedLookerUp2_4_3 (4)	2.1
...	
EvolvedLookerUp2_4_3 ($n-3$)	1.3
EvolvedLookerUp2_4_3 ($n-2$)	0.9
EvolvedLookerUp2_4_3 (N)	0

POPULATION	SCORES
EvolvedLookerUp2_4_3 (1)	4.9
EvolvedLookerUp2_4_3 (2)	4.5
EvolvedLookerUp2_4_3 (3)	3.2
EvolvedLookerUp2_4_3 (4)	2.1
...	


POPULATION
SCORES
EvolvedLookerUp2_4_3 (1)
4.9
EvolvedLookerUp2_4_3 (2)
4.5
EvolvedLookerUp2_4_3 (3)
3.2
EvolvedLookerUp2_4_3 (4)
2.1
...


POPULATION
SCORES
EvolvedLookerUp2_4_3 (1)
4.9
EvolvedLookerUp2_4_3 (2)
4.5
EvolvedLookerUp2_4_3 (3)
3.2
EvolvedLookerUp2_4_3 (4)
2.1
...
EvolvedLookerUp2_4_3 (1) +
EvolvedLookerUp2_4_3 (2)

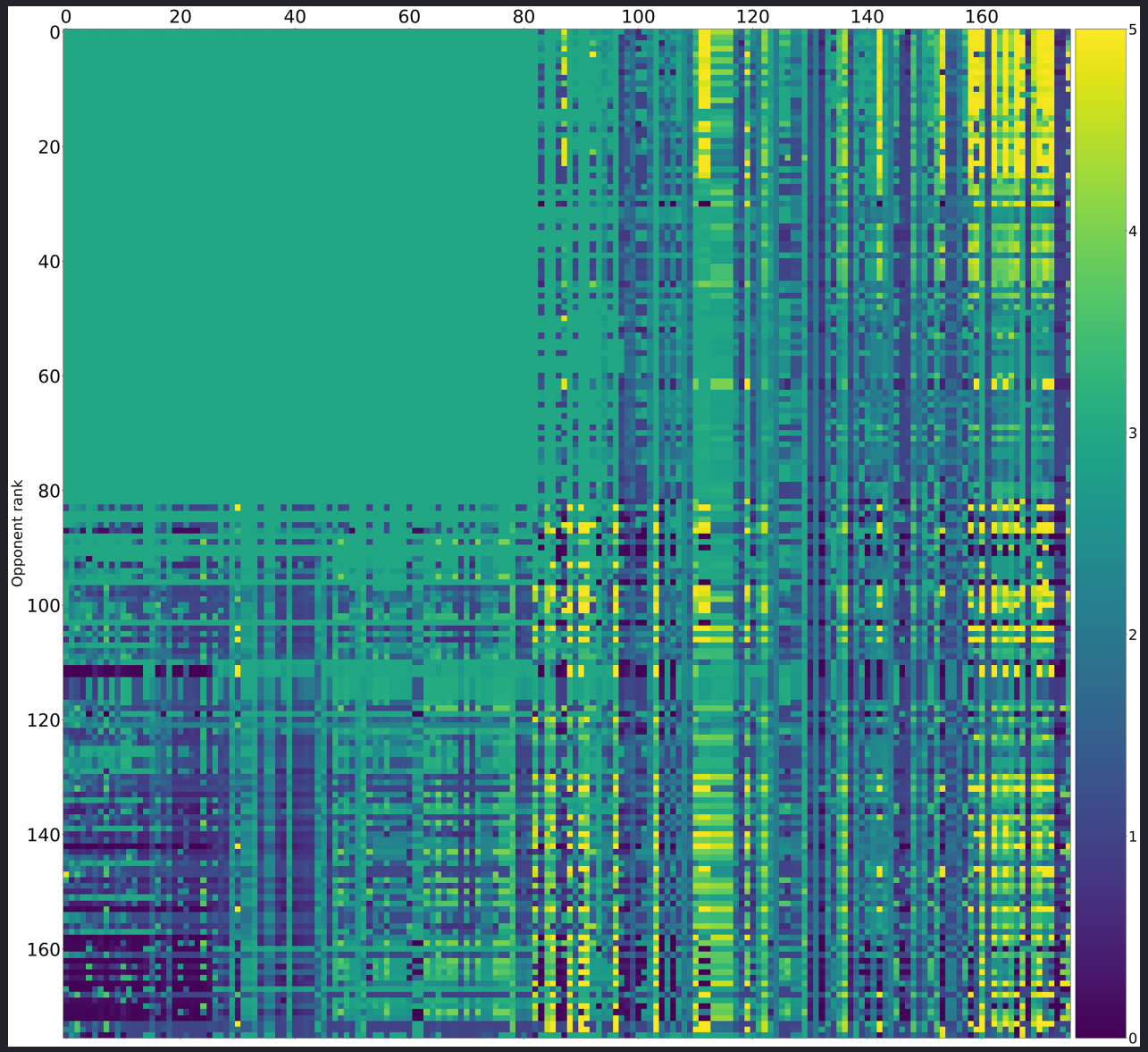

Player
Opponent
C
C
D
D
D
C
C
C
C
C
D
C
C
D
D
D
C
C
CD
CCCC
DCC
(p_c, p_d)

	mean	std	min	max
EvolvedLookerUp2_2_2*	2.173	1.070	1	8
Evolved HMM 5*	2.321	1.275	1	10
Evolved FSM 16*	2.489	1.299	1	10
PSO Gambler 2_2_2*	3.961	1.525	1	10
Evolved FSM 16 Noise 05*	6.300	1.688	1	11
PSO Gambler 1_1_1*	7.082	2.499	1	17
Evolved ANN 5*	7.287	1.523	2	11
Evolved FSM 4*	7.527	1.631	2	12
Evolved ANN*	7.901	1.450	2	12
PSO Gambler Mem1*	8.222	2.535	1	20
Evolved ANN 5 Noise 05*	11.362	0.872	8	16
DBS	12.197	1.125	9	16
Winner12	13.221	1.137	9	17
Fool Me Once	13.960	1.083	9	17
Omega TFT: 3, 8	14.275	1.301	9	19

Table: Turns + no noise tournament: Rank in each tournament of top 15 strategies (ranked by median over 50000 tournaments) * indicates that the strategy was trained.

	mean	std	min	max
DBS	1.205	0.468	1	3
Evolved ANN 5 Noise 05*	2.184	0.629	1	5
Evolved FSM 16 Noise 05*	2.626	0.618	1	9
Evolved ANN 5*	6.371	2.786	2	31
Evolved FSM 4*	7.919	3.175	3	33
Evolved HMM 5*	7.996	3.110	3	26
Level Punisher	8.337	3.083	3	26
Omega TFT: 3, 8	8.510	3.249	3	32
Spiteful Tit For Tat	9.159	3.772	3	40
Evolved FSM 16*	10.218	4.099	3	56
PSO Gambler 2_2_2 Noise 05*	10.760	4.102	3	47
Evolved ANN*	11.346	3.252	3	32
Adaptive	11.420	5.739	3	63
Math Constant Hunter	14.668	3.788	3	43
Gradual	15.163	3.672	4	49

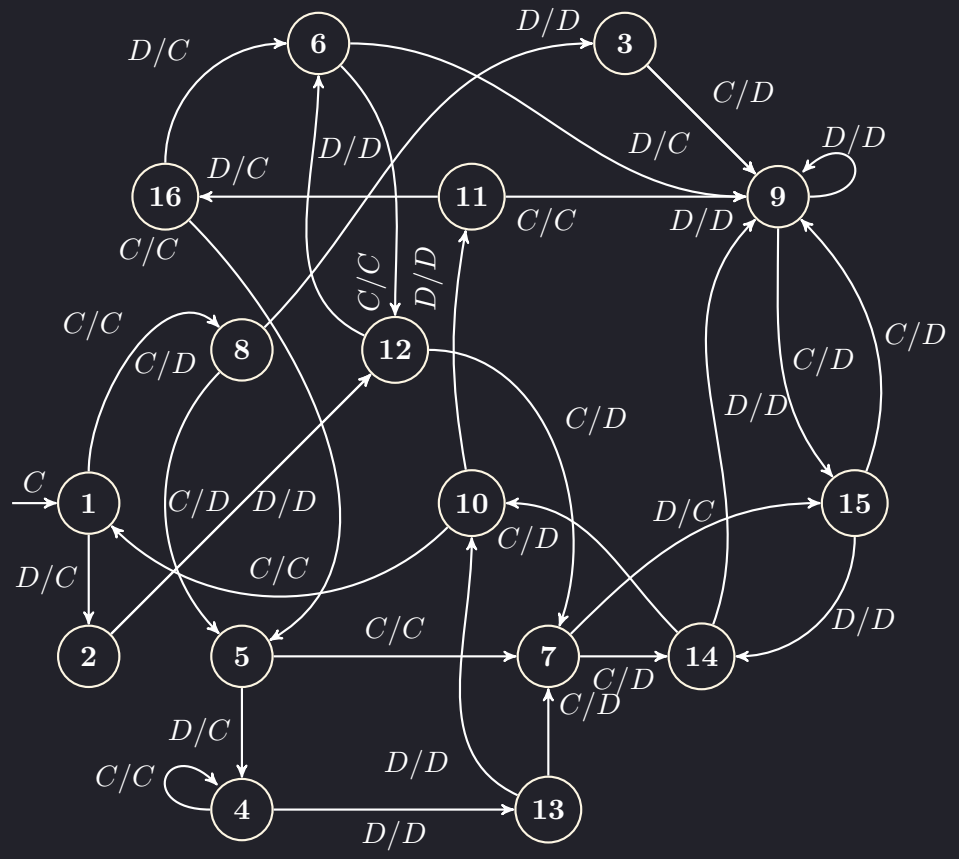
Table: Turns + noise tournament: Rank in each tournament of top 15 strategies (ranked by median over 50000 tournaments) * indicates that the strategy was trained.


0
20
40
60
80
100
120
140
160
Opponent rank
5
4
3
2
1
0

Evolution Reinforces Cooperation with the Emergence of Self-Recognition Mechanisms: an empirical study of the Moran process for the iterated Prisoner's dilemma

Vincent Knight, Marc Harper, Nikoleta E. Glynatsi, Owen Campbell

doi.org/10.1371/journal.pone.0204981



TF1 #1	TF1 #2
1: C	**1: C**
8: C	**8: C**
5: D	**5: D**
4: C	4: C
4: C	4: C
4: C	4: C
4: C	4: C
4: C	4: C

- ~~Do not be the first to defect~~ Do not defect on the first turn
- ~~Do not be envious~~ It's okay to be envious
- ~~Do not be too clever~~ Be clever
- ~~Be provocable~~ Be provocable in tournaments with short matches, and generous when matches are longer
- Self recognition mechanism

@NikoletaGlyn

http://web.evolbio.mpg.de/social-behaviour/

- Vincent Knight
- Marc Harper
- Owen Campbell
- Martin Jones
- Georgios Koutsovoulos