

Introduction to Game Design

9/26/08: Prisoner's Dilemma / TFT

Buying a Car

- Assume buyer and seller of car are not looking to cheat each other – just settle on a fair price
- Both buyer and seller take the car to an independent used-car dealer
- \$500 to purchase, would sell for \$800
- What would a fair price be for the car?

\$650?

- Splitting the difference is usually considered fair – by doing so, the buyer would get an \$800 car for only \$650, seller would get dealer's price plus half the profit
- This is **not** a unique solution
- **Either** the buyer or the seller could choose to be obstreperous, and the other would have little choice but to accept
- The more **unreasonable** player wins! (sucks, doesn't it?)

Honor Among Thieves

- You have stolen the Hope Diamond (for shame!) and are now trying to fence it
- You learn that Mr. Big is very interested in purchasing the diamond
- You know Mr. Big to be highly intelligent, notoriously greedy, and a double-crosser
- You and Mr. Big agree to exchange the diamond for \$50 million dollars

Negotiation

- Mr. Big first suggests that you meet in a deserted field for the exchange – that way there are no witnesses
- You suggest hiding the diamond in Troy, while he hides the money in Rochester – then phoning each other for directions
- Why not keep the diamond?
- What if he's thinking the same thing?

The Dilemma:

	Mr. Big sticks to agreement	Mr. Big cheats <i>His best chance?</i>
You stick to agreement	Deal goes through: you get money, Mr. Big gets the diamond	You get nothing, Mr. Big walks away with the money and the diamond
You cheat <i>Your best chance?</i>	You walk away with the money and the diamond, Mr. Big gets nothing	A lot of trouble for nothing: you keep diamond, Mr. Big keeps money

Reason this!

- No matter what Mr. Big does, you're better off cheating – if Mr. Big leaves the money, you are \$50 million richer and still have the diamond. If Mr. Big cheats, then it's a good thing you did too!
- *However* - you're both in the same boat. Since Mr. Big will reason as you do, you both will have wasted your time, for you have reasoned your way out of a deal beneficial to both parties. Stick with the agreement
- *But* - what if he cheats with you thinking the only thing to do is to not cheat? you shouldn't have stole the diamond, but you have, so you should just go along with the deal to get it off your hands!

Real Life Examples?

- How do you know the contractor won't skip town with your down payment? How does he know you won't stop payment on your check?
- How do kids swap toys?
- Real estate escrow

Tucker's Prisoner's Dilemma

The police apprehend two criminals who together have committed a serious crime. There is no direct evidence that these two people actually committed the crime, and all the police can actually prove is an instance of excessive speeding. The prosecutor would very much like to close the case, and therefore she makes the following proposal separately to the two prisoners, whom she has placed in separate cells:

Tucker's Prisoner's Dilemma

“Here’s the plea bargain: If you will confess to the crime and implicate your accomplice, thereby helping us to resolve this case, I will set you free, and we’ll forget about that little matter of speeding. In this case your accomplice will be locked up in prison for ten years, and the whole matter will be closed forever. This offer is valid, however, only if your accomplice does not confess to the crime and thus does not help us in clearing up this matter. If he also confesses, then, of course, your confession is not of much value, as we will know everything without it. In this case, each of you will be jailed for five years.

Tucker's Prisoner's Dilemma

If neither of you confesses, we shall, alas, be unable to convict you, but we'll be very severe on that rather nasty incident of speeding, and you will both be imprisoned for one year. Finally, I must inform you that I made this very same offer to your accomplice. I await your answer tomorrow at 10 o'clock. You can be free by eleven!"

Tucker's Prisoner's Dilemma

	Accomplice 2 does not rat out (cooperates)	Accomplice 2 rats out (defects)
Accomplice 1 does not rat out (cooperates)	-1, -1	-10, 0
Accomplice 1 rats out (defects)	0, -10	-5, -5

What does Logic Tell Us?

- Two equally logical statements lead to opposite results
- Since there is a contradiction, prisoner's dilemmas cannot actually exist (!!)
- If they do, anything can be deduced from them
- Vacuous statements must be accepted as truth
- It is logical both to confess and not to confess

Rational Players

- Presumably, rational players would want to mutually cooperate for the biggest **total** payoff
- Players do **not** get to choose which of the mutual decisions is the rational one
- The fact that rational players **want** logic to lead to mutual cooperation is irrelevant

Problems with Dramatization

- By phrasing the dilemma in this manner, it is possible to allow emotional factors that are irrelevant in its “purest form”
- E.g., You’re a nice person and would feel terrible taking advantage of another – it’s against your moral code
- Think of it as a friendly casino game – the players cannot communicate with each other beforehand, and any pair of players can only play **once**

Play to Win!

	B cooperates	B defects
A cooperates	20, 20	0, 30
A defects	30, 0	10, 10

What Constitutes a Prisoner's Dilemma?

- **Ranking** of the payoffs
- A **temptation** payoff for single defection
- A **reward** payoff for mutual cooperation
- A **punishment** payoff for mutual defection
- A **sucker** payoff for single cooperation
- The reward payoff must be greater than the **average** of the temptation and sucker payoffs
- The common good must be served by mutual cooperation

Prisoner's Dilemmas in Literature

- “In everything, do to others what you would have them do to you”

-Matthew 7:12

- “Ethical behavior is that which can be universalized”

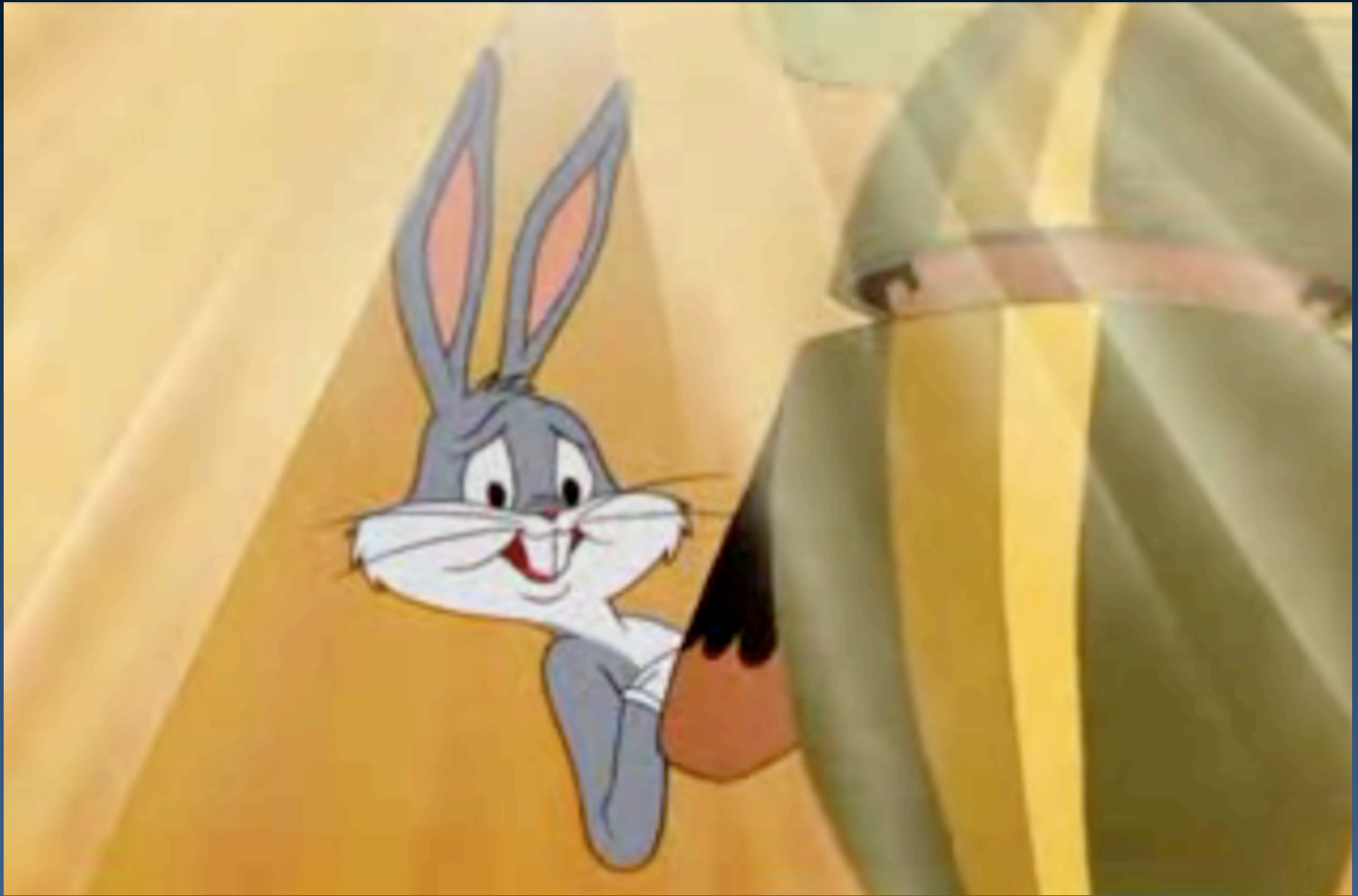
-Immanuel Kant

- “Each one of a gang, so placed, is not so much greedy of reward, or anxious to escape, as fearful of betrayal. He betrays eagerly and early that he may not himself be betrayed”

-Edgar Allen Poe

Tosca

- Opera written by Puccini in 1900
- Scarpia the police chief has sentenced Cavaradossi to death
- If Tosca sleeps with Scarpia, he will order the firing squad to fire blanks
- She consents, on the condition that he give irrevocable orders first
- Mutual defection – Tosca stabs Scarpia as they embrace, squad fires real bullets



What Can be Done?

- “The hopelessness that one feels in such a game as this cannot be overcome by a play on the words ‘rational’ and ‘irrational’; it is inherent in the situation.”

-R. Duncan Luce and Howard Raiffa

Multiple Players

The Problem of Common Pastures

- Village has a common pasture
- Ten farmers, each has one cow
- Enough grass so that the 10 cows get fat
- Soon one farmer can afford an additional cow – little change is noticed
- The second and third farmers each buy another cow - all cows become visibly thinner
- The seventh farmer buys a second cow, the seventeen cows are now so thin they're less valuable than the original ten
- The tenth farmer buys a second cow – all twenty cows starve to death

The Problem of Common Pastures

	Majority buys another cow	Majority does not buy another cow
You buy another cow	<p>2, 2</p> <p>I have two thin cows</p>	<p>4, 1</p> <p>I have two fat cows</p>
You do not buy another cow	<p>1, 4</p> <p>I have one super-thin cow</p>	<p>3, 3</p> <p>I have one super-fat cow</p>

Iterated Prisoner's Dilemmas

- In a one-shot prisoner's dilemma, strategies don't need to consider retaliation
- If I confess and my accomplice doesn't, then I don't need to worry about revenge for ten years
- If we both confess, my accomplice will have nothing to avenge when we're set free in 5 years
- Now, we need to consider trust to a greater degree, for your accomplice can retaliate much sooner
- Complex long-term strategies are now available

The Flood- Dresher Experiment

- An experiment performed at RAND to test iterated prisoner's dilemmas
- Two friends, Armen Alchain of UCLA, and John D. Williams of RAND were recruited as guinea pigs

The Payoffs

	AA cooperates	AA defects
JW cooperates	3, 3	0, 5
JW defects	5, 0	1, 1

Armen Alchain vs. John D. Williams

- Initial comments:
- AA: JW will defect – sure win. Hence if I cooperate, I lose
- JW: Hope he's bright

Armen Alchain vs. John D. Williams

Game	AA	JW
1	Defect	Cooperate
	<i>What is he doing?!!</i>	He isn't but maybe he'll wise up

Armen Alchain vs. John D. Williams

Game	AA	JW
2	Defect	Cooperate
	Trying mixed?	Okay, dope

Armen Alchain vs. John D. Williams

Game	AA	JW
3	Defect	Defect
	Has he settled on Defect?	Okay, dope

Armen Alchain vs. John D. Williams

Game	AA	JW
4	Defect	Defect
	Perverse!	It isn't the best of all possible worlds

Armen Alchain vs. John D. Williams

Game	AA	JW
5	Cooperate	Defect
	I'm sticking to Defect since he will mix for at least 4 more times	Oh ho! Guess I'll have to give him another chance

Armen Alchain vs. John D. Williams

Game	AA	JW
6	Defect	Cooperate
		Cagey, ain't he? Well...

Armen Alchain vs. John D. Williams

Game	AA	JW
7	Defect	Cooperate
		In time he could learn, but not in 10 moves, so...

Armen Alchain vs. John D. Williams

Game	AA	JW
8	Defect	Defect
	If I mix occasionally, he will switch, but why will he ever switch from Defect?	

Armen Alchain vs. John D. Williams

Game	AA	JW
9	Defect	Defect
	Prediction. He will stick with Defect until I change from Defect.	I have control of the game to a large extent, so AA had better appreciate this and get on the bandwagon

Armen Alchain vs. John D. Williams

Game	AA	JW
10	Defect	Defect
		Probably learned by now

Armen Alchain vs. John D. Williams

Game	AA	JW
11	Defect	Cooperate
		I'll be damned! But I'll try again

Armen Alchain vs. John D. Williams

Game	AA	JW
12	Cooperate	Cooperate
		That's better

Armen Alchain vs. John D. Williams

Game	AA	JW
13	Cooperate	Cooperate
		Ha!

Armen Alchain vs. John D. Williams

Game	AA	JW
14	Cooperate	Cooperate
		(bliss)

Armen Alchain vs. John D. Williams

Game	AA	JW
15	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
16	Defect	Cooperate
		The stinker

Armen Alchain vs. John D. Williams

Game	AA	JW
17	Cooperate	Defect
		He's crazy. I'll teach him the hard way.

Armen Alchain vs. John D. Williams

Game	AA	JW
18	Cooperate	Defect
	I'm completely confused. Is he trying to convey information to me?	Let him suffer.

Armen Alchain vs. John D. Williams

Game	AA	JW
19	Defect	Defect

Armen Alchain vs. John D. Williams

Game	AA	JW
20	Defect	Defect
		Maybe he'll be a good boy now

Armen Alchain vs. John D. Williams

Game	AA	JW
21	Defect	Cooperate
		Always takes time to learn

Armen Alchain vs. John D. Williams

Game	AA	JW
22	Cooperate	Cooperate
		Time

Armen Alchain vs. John D. Williams

Game	AA	JW
23	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
24	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
25	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
26	Defect	Cooperate
		Same old story

Armen Alchain vs. John D. Williams

Game	AA	JW
27	Cooperate	Defect
		To hell with him

Armen Alchain vs. John D. Williams

Game	AA	JW
28	Defect	Defect

Armen Alchain vs. John D. Williams

Game	AA	JW
29	Defect	Defect

Armen Alchain vs. John D. Williams

Game	AA	JW
30	Defect	Defect
	Some start	Once again

Armen Alchain vs. John D. Williams

Game	AA	JW
31	Defect	Cooperate
	JW is bent on sticking with Defect. He will not share at all as a price of getting me to stick to Cooperate	Damn he learns slow!

Armen Alchain vs. John D. Williams

Game	AA	JW
32	Cooperate	Cooperate
		On the beam again

Armen Alchain vs. John D. Williams

Game	AA	JW
33	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
34	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
35	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
36	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
37	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
38	Defect	Cooperate
		The f...er! CENSORED

Armen Alchain vs. John D. Williams

Game	AA	JW
39	Cooperate	Defect

Armen Alchain vs. John D. Williams

Game	AA	JW
40	Defect	Defect
		Always try to be virtuous

Armen Alchain vs. John D. Williams

Game	AA	JW
41	Defect	Cooperate
		Old stuff

Armen Alchain vs. John D. Williams

Game	AA	JW
42	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
43	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
44	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
45	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
46	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
47	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
48	Cooperate	Cooperate
	<i>He will not share</i>	

Armen Alchain vs. John D. Williams

Game	AA	JW
49	Defect	Cooperate
		He's a shady character and doesn't realize we're playing a 3 rd party, not each other

Armen Alchain vs. John D. Williams

Game	AA	JW
50	Cooperate	Defect

Armen Alchain vs. John D. Williams

Game	AA	JW
51	Defect	Cooperate
		He <i>requires</i> great virtue but he doesn't have it himself

Armen Alchain vs. John D. Williams

Game	AA	JW
52	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
53	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
54	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
55	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
56	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
57	Cooperate	Cooperate
	He will not share	

Armen Alchain vs. John D. Williams

Game	AA	JW
58	Cooperate	Cooperate
	He does not want to <i>trick</i> me. He is satisfied. I must teach him to share	

Armen Alchain vs. John D. Williams

Game	AA	JW
59	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
60	Defect	Cooperate
		A shiftless individual - opportunist, knave

Armen Alchain vs. John D. Williams

Game	AA	JW
61	Cooperate	Cooperate
		Goodness me! Friendly!

Armen Alchain vs. John D. Williams

Game	AA	JW
62	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
63	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
64	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
65	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
66	Cooperate	Cooperate
	He won't share	

Armen Alchain vs. John D. Williams

Game	AA	JW
67	Defect	Cooperate
	He'll punish for trying!	He can't stand success

Armen Alchain vs. John D. Williams

Game	AA	JW
68	Cooperate	Defect

Armen Alchain vs. John D. Williams

Game	AA	JW
69	Defect	Defect
	I'll try once more to share - by taking	

Armen Alchain vs. John D. Williams

Game	AA	JW
70	Defect	Defect
		This is like toilet training a child - you have to be very patient

Armen Alchain vs. John D. Williams

Game	AA	JW
71	Defect	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
72	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
73	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
74	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
75	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
76	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
<i>77</i>	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
78	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
79	Cooperate	Cooperate
		Well.

Armen Alchain vs. John D. Williams

Game	AA	JW
80	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
81	Defect	Cooperate
		He needs to be taught about that

Armen Alchain vs. John D. Williams

Game	AA	JW
82	Cooperate	Defect

Armen Alchain vs. John D. Williams

Game	AA	JW
83	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
84	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
85	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
86	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
87	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
88	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
89	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
90	Cooperate	Cooperate
	When will he make a last minute grab of Defect? Can I beat him to it as late as possible?	

Armen Alchain vs. John D. Williams

Game	AA	JW
91	Cooperate	Cooperate
		Good

Armen Alchain vs. John D. Williams

Game	AA	JW
92	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
93	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
94	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
95	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
96	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
97	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
98	Cooperate	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
99	Defect	Cooperate

Armen Alchain vs. John D. Williams

Game	AA	JW
100	Defect	Defect

Final Score

- AA: 268
- JW: 244
- Mutual cooperation: 49 times
- Comments?

The Best Strategy?

- Is it theoretically possible for cooperation to develop in a world where everybody is governed by their own self interests?
- In 1979, political scientist Robert Axelrod asked several well-known scientists to participate in a competition
- Send in a computer program of (what they consider to be) an optimal strategy
- Programs played against each other in a round-robin style

Axelrod's Competitions

	Program 2 cooperates	Program 2 defects
Program 1 cooperates	3, 3	0, 5
Program 2 defects	5, 0	1, 1

Axelrod's Competitions

- Number of rounds per 'battle' was not revealed to the programmers
- Strategy with highest cumulative score would be declared the winner
- Twelve programs entered, some were highly sophisticated
- Three additional programs - ALL C, ALL D, RANDOM

The Winner?

- Submitted by famous social psychologist Anatol Rapoport
- **Simplest** of the twelve
- 1) Cooperate in the first round
- 2) Thereafter, do whatever the opponent did in the previous round
- Called “Tit-for-Tat”, known as TFT in game theory literature

Invincible?

- Axelrod sought to find a strategy to beat TFT
- Three were found – one which was highly competitive, another was even more “forgiving” than TFT, so what’s the best choice?
- Axelrod ran a second competition, having already published the first

The Second Competition

- 62 programs from 6 countries and 8 fields of science entered
- Axelrod submitted the three programs that beat TFT
- Rapoport entered TFT a second time
- Rapoport won **again!**
- The program that was more forgiving ranked 21st, the competitive program ranked in the bottom 50%

Traits of Winning Programs

- **Niceness** – Program wouldn't initiate competition
- **Forgiveness** – Program wouldn't hold a grudge
- **Provocability** – Willingness to retaliate
- **Responsiveness** – Taking the opponent's strategy into consideration
- **Transparency** - not taking length into consideration

Is TFT the Perfect Strategy?

- Rapoport himself warned not to overvalue TFT too much
- Sometimes it reacts too violently, there are many social situations where TFT is too harsh
- E.g., an “innocent” misunderstanding can lead to eternal competition, unless the opponent includes an “out of turn” pardon

The Moral

It's good to be good

but don't let others take advantage of you!