ECONOMICS & LAW

CST 1b

ROSS ANDERSON
NICHOLAS BOHM
RICHARD CLAYTON

WHY TEACH THIS COURSE?

- Increasing importance to computer science
- Systems: Internet now so big that at many levels it's more like a market than a deterministic system
  - resource utilisation, congestion issues
  - issues for how you design protocols
- Theory: complexity theorists are starting to view the combinatorial auction as the archetypal CS problem
- Dependability - various issues
  - economics of open source vs proprietary
  - costs of testing
  - security failures often due to perverse incentives rather than purely technical causes
- Professional development - about half of you will go into consultancy / banking / civil service
- Policy - need to understand issues like copyright

AIMS AND OBJECTIVES

- Aims: give students an introduction to some basic concepts in economics and Law
- Objectives: At the end of this course, students should have a basic appreciation of economic and legal terminology and arguments.

  They should understand some of the applications of economic models to systems engineering and their interest to theoretical computer science.

  They should also understand the main constraints that markets and legislation place on firms dealing in information goods and services

OUTLINE

- Game theory - Prisoners' Dilemma, iterated game
- Classical economics - competitive markets with many buyers and sellers
- Ways in which markets fail - monopoly, asymmetric information, adverse selection
- Particular consequences for markets in information goods and services
- Auctions: English, Dutch and Vickrey auctions. Mechanism design and combinatorial auctions
- Principles of Law - contract, tort, liability, remedy, binding action, jurisdiction
- Law and the Internet - EU directives such as EUCD, DSD, IPRED
- 'Law and economics' - copyright, patent

RESOURCES

- Shapiro and Varian "Information Rules"
- Varian "Intermediate Microeconomics – A Modern Approach"

Further reading

- J K Galbraith "A History of Economics"
- Lessig "The Future of Ideas" and "Code, and other Laws of cyberspace"
- Classic economics texts, e.g. Smith
- Online resources (links from web page)
- Poundstone "Prisoners' Dilemma"
- Seabright "The Company of Strangers – A Natural History of Economic Life"
- My "Security Engineering" 2nd edition ch 7
- Krugman "The Return of Depression Economics"

STUDYING A HUMANITIES SUBJECT

- It's not like learning to program in Java, where you get a clearly testable skill...
- Wide reading is important – many ideas become clearer when approached from several different perspectives
- College libraries are a good place to start
- Use the course web page too
- Dig into some subproblem that interests you
- Think of opposing viewpoints: how would a socialist / a libertarian / a corporation / a less developed country approach this problem? What decides conflict / cooperation?
- Write proper essays!

COOPERATION OR CONFLICT?

- One way of getting what you want is to produce something of value and then trade for it

  'Economics'

- Another way is to take what you want - by force, via the ballot box or whatever

  'Politics'

- Choices between cooperation and conflict are made at all sorts of levels, every day, by people & animals

- They can evolve in complex combinations, e.g., airlines collude to set prices, and passengers then ask government to intervene

- The tool we most use to tease them out and analyse them is game theory

Game Theory

- The study of problems of cooperation and conflict among independent decision-makers
- Focus on games of strategy, rather than of chance; abstract to players, choices, payoffs, strategies, ...
- There are games of perfect information (e.g., chess) and of imperfect information, which interest us more
- Example: matching pennies. Alice and Bob choose 'H' or 'T' and reveal their choices simultaneously. If they are different, Alice gets Bob's penny; else Bob gets Alice's
- We write this game in 'strategic form' as

		Bob: H	Bob: T
Alice	H	−1, 1	1, −1
	T	1, −1	−1, 1

- This is a zero-sum game: Alice's gain = Bob's loss
- A strategy is an algorithm whose input is the game state (history) + whose output is your play

DOMINANT STRATEGY EQUILIBRIUM

- Consider the following game:

		Bob	
		Left	Right
Alice	Top	1, 2	0, 1
	Bottom	2, 1	1, 0

- No matter what Bob plays, Alice is better off playing 'Bottom'
- No matter what Alice plays, Bob is better off playing 'Left'
- Each player has a dominant strategy - an optimal choice regardless of what the other does
- Thus we have a 'dominant strategy equilibrium'

Nash Equilibrium

- Consider this game:

		Bob	
		left	right
Alice	Top	2, 1	0, 0
	Bottom	0, 0	1, 2

- Here each player's optimal strategy depends on what the other player does, or perhaps more accurately, what they think the other will do

- We say that two strategies are in Nash equilibrium when A's choice is optimal given B's choice, and vice versa

  Here there are two (symmetric) Nash equilibria, top left and bottom right

- Analogy: local optima

PURE VS MIXED STRATEGIES

- If we limit each player's strategy to a deterministic algorithm, then games exist with no Nash equilibrium. For example, 'scissors-paper-stone':

Bob

Alice	Scissors	Paper	Stone
Scissors	0	1, −1	−1, 1
Paper	−1, 1	0	1, −1
Stone	1, −1	−1, 1	0

Alice plays scissors → Bob wants to play stone → Alice wants to play paper → ...

- Solution (obvious to computer scientists): randomise the algorithm. This is called a 'mixed' strategy, while deterministic strategies are called 'pure'
- Here, Nash equilibrium is random choice with equal weights, and payoff = 0
- In general, a Nash equilibrium exists in mixed strategies for the sort of games discussed in this lecture

PRISONERS' DILEMMA

- (Nash, 1950:) Two prisoners are arrested on suspicion of planning a bank robbery. The police tell them separately: if neither of you confesses you each get one year for firearms possession; if one confesses he goes free and the other gets 6 years; both confess and you both get 3 years

		Benjy	
		confess	deny
Alfie	confess	−3, −3	0, −6
	deny	−6, 0	−1, −1

- (Confess, confess) is a dominant strategy equilibrium

  But it is not optimal for the villains – they get 3 years each, when if they had both kept quiet they'd have got 1 each

- Is this a problem?
- If so, what's the solution?

PRISONERS' DILEMMA (2)

- P.D has been found to model a very wide range of real-life issues
  - defence spending
  - fishing quotas
  - free riders in file-sharing systems
  - social behaviour
  - ...
- The simplistic view that 'it serves the prisoners right' doesn't travel to all of these
- Tough but inescapable conclusion: if the game truly is as described – a one-off – there is no escape. Each side will cheat rather than cooperate, and the result will be in some sense suboptimal
- To fix it you have to change the game. Introduce externalities, for example – laws, treaties, omerta
- The most interesting fix is to move from a one-off game to an iterated game

THE EVOLUTION OF COOPERATION

- If PD is played repeatedly, new strategies become available
- 'Tit-for-tat': cooperate at round 1, then at round n do what the other guy did at round n − 1
- Large simulation competitions run by Axelrod at U Mich played off strategies against each other under varying conditions
- For example, in the presence of noise, tit-for-tat gets locked into (defect, defect) too easily, so you should try cooperating from time to time to give the other player a chance to respond
- It came to be realised that strategy evolution could explain a lot...

MORE GAMES...

- Chicken – two kids drive cars at each other (Russell suggested it as a model for superpower nuclear confrontation)

	swerve	drive on
swerve	2, 2	1, 3
drive on	3, 1	0, 0

Here the Nash equilibria are (3, 1), (1, 3)

- Deadlock – you're going to defect but it would be nice if the other guy was a sucker + cooperated

	cooperate	defect
cooperate	1, 1	0, 3
defect	3, 0	2, 2

- Bully – example of an asymmetric game. Recall the 'Wisdom of Solomon'

		deadlock player: give in	deadlock player: persist
chicken player	give in	2, 1	1, 3
	persist	3, 0	0, 2

Also models general confrontations where one party is more aggressive

GAME THEORY & BIOLOGICAL EVOLUTION

- John Maynard Smith proposed the 'Hawk-Dove' game as a simple model of animal behaviour. Consider a mixed population of aggressive and docile individuals

	Hawk	Dove
Hawk	$\frac{V-C}{2}, \frac{V-C}{2}$	$V, 0$
Dove	$0, V$	$\frac{V}{2}, \frac{V}{2}$

- Doves share; hawks fight (with risk of death); hawks take food from doves
- If $V > C$, whole population becomes hawk (dominant strategy)
- If $C > V$, one hawk will be happy (most interactions are with doves); one dove will have payoff 0, while hawks have payoff $\frac{V-C}{2} < 0$. Equilibrium for hawk probability p that sets hawk payoff = dove payoff, i.e.

$$p\,\frac{V-C}{2} + (1-p)V = (1-p)\frac{V}{2}$$

$$\Leftrightarrow \quad pV - pC + 2V - 2pV = V - pV$$

$$\Leftrightarrow \quad -pC = -V$$

$$\Leftrightarrow \quad p = V/C$$

EVOLUTION OF IDEAS OF JUSTICE

- Brian Skyrms, 'Evolution of the Social Contract'
- Suppose we have 3 types of people
  Fairmen demand half of a resource
  Greedies demand $2/3$
  Modests demand $1/3$

Two greedies fight and waste all the resource; two modests take $1/3$ each and waste the rest.

- Two Nash equilibria
  - All players are Fairmen
  - Half are greedies and half modests
- Evolution: if initial population of Fairmen is $> \frac{1}{3}$, they come to dominate. But if Fairmen can recognise each other, so they interact preferentially with each other, they can win from a much smaller initial share
- Of great interest to philosophers - and potential use to builders of P2P systems?

CLASSIC APPLICATION TO ECONOMICS

- Competition laws in most countries forbid price-fixing cartels
- But similar behaviour can arise from a pricing game, with no overt or covert collusion!
- Say it costs \$250 to fly someone to Boston and back to London. Do you collude and charge \$500, or compete and charge \$255?
- Maybe you try charging \$500 and see how the other airlines respond. If they 'defect' by competing, play tit-for-tat. Every so often, hike prices and give them a chance to cooperate...
- If you're a regulator, how do you cope?
- Next lecture – more on monopoly

BROADER IMPLICATIONS

- Anthropology — 10,000 years ago we were 'the shy, murderous ape'. Now we collaborate globally in many ways, living in largely peaceful societies (See Seabright, 'Company of strangers')
- Cooperation supported by many institutions from markets to religions — "Do unto others as you'd have them do unto you" found in many places from Confucius to Gospels
- The formalisation by Nash, Axelrod, Maynard Smith etc opened up many applications in social & biological sciences
- Politics: models of civil war, of conflict, of when religions are dominated by fundamentalists
- Criminologists: model the Mafia and other gangs as alternative means of contract enforcement
- Computer science: peer-to-peer systems, strategic behaviour in networks, ...