

CPS 196.2

Introduction to Computational Economics

Instructor: Vincent Conitzer
(Assistant Professor of Computer Science & Economics)

conitzer@cs.duke.edu

TA: Mingyu Guo
(Ph.D. student in Computer Science)

mingyu@cs.duke.edu

Course web page: <http://www.cs.duke.edu/courses/fall07/cps196.2/>

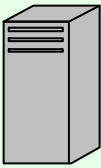
What is Economics?

- “the social science that studies the production, distribution, and consumption of valuable goods and services” [[Wikipedia, Jan. 07](#)]
- Some key concepts:
 - Economic **agents** or **players** (individuals, households, firms, ...)
 - Agents’ current **endowments** of goods, money, skills, ...
 - Possible **outcomes** ((re)allocations of resources, tasks, ...)
 - Agents’ **preferences** or **utility functions** over outcomes
 - Agents’ **beliefs** (over other agents’ utility functions, endowments, production possibilities, ...)
 - Agents’ possible **decisions/actions**
 - **Mechanism** that maps decisions/actions to outcomes

An economic picture

$$v(\text{server}) = 200$$

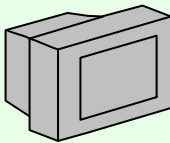



\$ 800

$$v(\text{TV}) = 100$$

$$v(\text{laptop}) = 400$$




\$ 600

$$v(\text{laptop}) = 200$$

$$v(\text{server}, \text{TV}) = 400$$



\$ 200



After trade (a more efficient outcome)

$$v(\text{server}) = 200$$

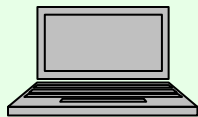


\$ 1100

... but how do we
get here?
Auctions?
Exchanges?
Unstructured trade?

$$v(\text{television}) = 100$$

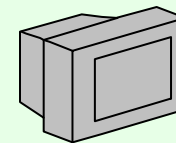
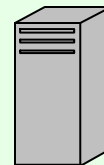
$$v(\text{laptop}) = 400$$



\$ 400

$$v(\text{laptop}) = 200$$

$$v(\text{server}, \text{television}) = 400$$



\$ 100



Some distinctions in economics

- **Descriptive vs. normative economics**
 - Descriptive:
 - seeks only to describe real-world economic phenomena
 - does not care if this is in any sense the “right” outcome
 - Normative:
 - studies how people “should” behave, what the “right” or “best” outcome is
- **Microeconomics vs. macroeconomics**
 - Microeconomics: analyzes decisions at the level of individual agents
 - deciding which goods to produce/consume, setting prices, ...
 - “bottom-up” approach
 - Macroeconomics: analyzes “the sum” of economic activity
 - interest rates, inflation, growth, unemployment, government spending, taxation, ...
 - “big picture”

What is Computer Science?

- “the study of the theoretical foundations of information and computation and their implementation and application in computer systems” [Wikipedia, Jan. 07]
- A **computational problem** is given by a function f mapping inputs to outputs
 - For integer x , let $f(x) = 0$ if x is prime, 1 otherwise
 - For an initial allocation of resources x , let $f(x)$ be the (re)allocation that maximizes the sum of utilities
- An **algorithm** is a fully specified procedure for computing f
 - E.g. sieve of Eratosthenes
 - A **correct algorithm** always returns the **right** answer
 - An **efficient algorithm** returns the answer **fast**
- Computer science is also concerned with building **larger artifacts** out of these building blocks (e.g. personal computers, the Internet, the Web, search engines, spreadsheets, artificial intelligence, ...)

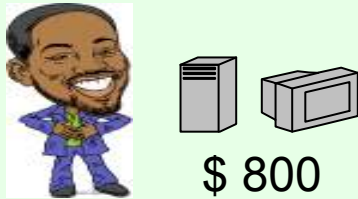
Resource allocation as a computational problem (*Part 1 of the course*)

input

output

$v(\text{server, monitor}) = \400

$v(\text{laptop}) = \$600$



$v(\text{server, monitor}) = \500

$v(\text{laptop}) = \$400$

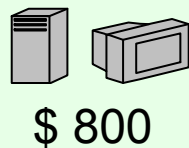


Here, gains from trade (\$300) are divided evenly (not essential)

Economic mechanisms

“true” input

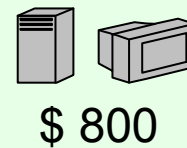
$$v(\text{server, printer}) = \$400$$
$$v(\text{laptop}) = \$600$$



agent 1's
bidding
algorithm

agents' bids

$$v(\text{server, printer}) = \$500$$
$$v(\text{laptop}) = \$501$$

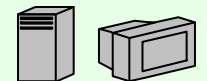


exchange
mechanism
(algorithm)

result



\$ 800



\$ 400

$$v(\text{server, printer}) = \$500$$
$$v(\text{laptop}) = \$400$$



agent 2's
bidding
algorithm

$$v(\text{server, printer}) = \$451$$
$$v(\text{laptop}) = \$450$$



\$ 400

*Exchange mechanism designer
does not have direct access to
agents' private information*

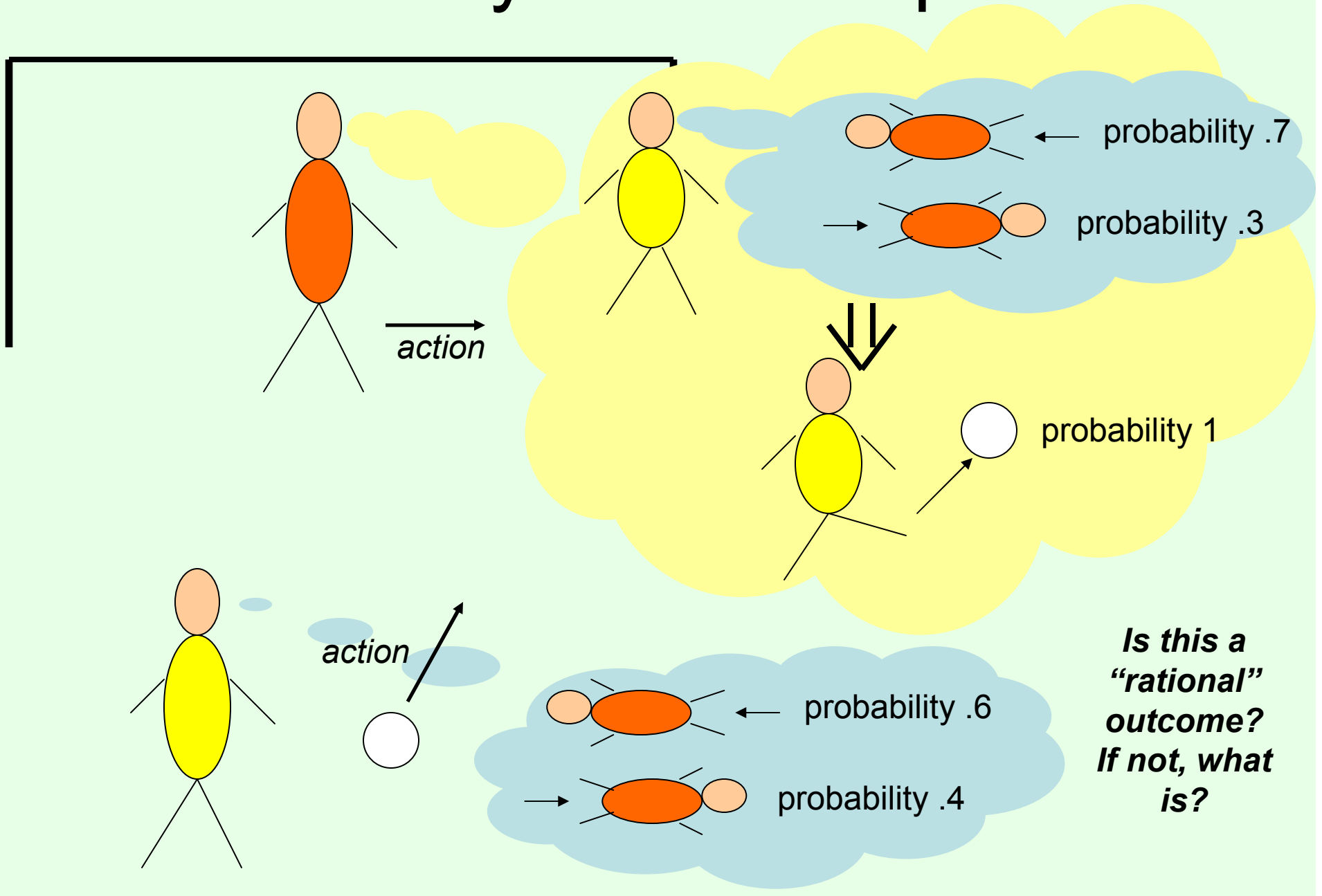
*Agents will selfishly respond to
incentives*

Game theory

(Part 2 of the course)

- Game theory studies settings where agents each have
 - different preferences (utility functions),
 - different actions that they can take
- Each agent's utility (potentially) depends on all agents' actions
 - What is optimal for one agent depends on what other agents do
 - Very circular!
- Game theory studies how agents can rationally form beliefs over what other agents will do, and (hence) how agents should act
 - Useful for acting as well as predicting behavior of others

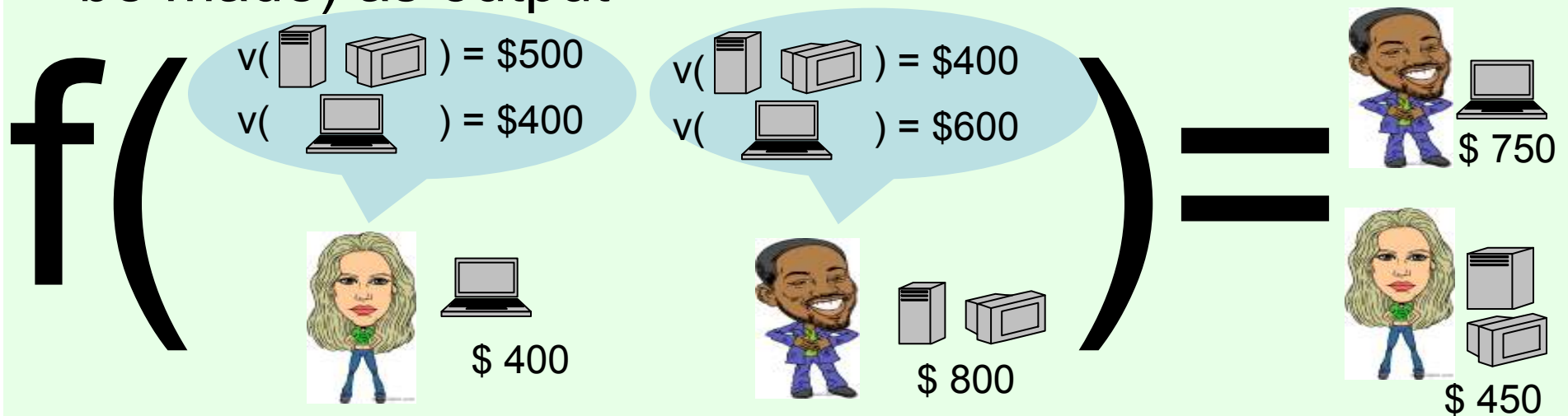
Penalty kick example



Mechanism design

(Part 3 of the course)

- **Mechanism** = rules of auction, exchange, ...
- A **function** that takes **reported preferences** (bids) as input, and produces **outcome** (allocation, payments to be made) as output



- The **entire function** f is **one** mechanism
- E.g. the mechanism from part 1: find allocation that maximizes (reported) utilities, distribute (reported) gains evenly
- Other mechanisms choose different allocations, payments

Mechanism design...

- Mechanism = game
- We can use game theory to predict what will happen under a mechanism
 - if agents act strategically
- When is a mechanism “good”?
 - Should it result in outcomes that are good for the **reported** preferences, or for the **true** preferences?
 - Should agents ever end up **lying** about their preferences (in the game-theoretic solution)?
 - Should it always **generate the best allocation**?
 - Should agents ever **burn money**?(!?)
- Can we solve for the optimal mechanism?

How are we going to solve these problems? (*Part 0*)

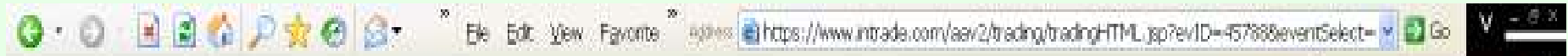
- This is **not** a programming course
- Will use optimization software
 - GNU Linear Programming Kit (GLPK)
 - Linear programming, mixed integer linear programming

Uses of LP, MIP in this course

	Linear programming	Mixed integer linear programming
Part 1 (expressive marketplaces)	Winner determination in auctions, exchanges, ... with partially acceptable bids	Winner determination in auctions, exchanges, ... without partially acceptable bids
Part 2 (game theory)	Dominated strategies Minimax strategies Correlated equilibrium	Nash equilibrium
Part 3 (mechanism design)	Designing optimal mechanisms that use randomization	Designing optimal mechanisms that do not use randomization

Other settings/applications

Prediction markets



intrade

Username:
 Password:

Home **Join** Trade Here Help Forum

Trading Categories

- All Markets
- Politics
- 2008 US Election
 - 2008 Republican Pres Nominee (Others on Request)
 - 2008 Republican Vice-Pres Nominee (Others on Request)
 - 2008 Democratic Pres Nominee (Others on Request)
 - 2008 Democratic Vice-Pres Nominee (Others on Request)
 - 2008 US Presidential Election - Winning Individual (See Specific Rules)
 - 2008 US Presidential Election Winner (Political Party)
 - 2008 US House of Representatives Control
 - 2008 US Senate Control
 - 2008 Presidential Election Combinations (Others on Request)
 - Michael Bloomberg to run as Independent in 2008?
 - Who will announce a run for President in 2008?
 - Dropouts from 2008 Presidential Race
 - Voter Turnout - 2008 Presidential Election

Next Event to Start >
 On-Running Events >
 Closed Contracts >

Contract Search:

Suggest a Contract >

[Refer A Friend](#)

[Affiliates](#)

[Blogs](#)

Visited Events:

3:10:58PM EDT

Contract	Best to Sell			Best to Buy			Last	Vol	Change
	BQTY	Bid	Offer	AQTY	Ask				
Trade 2008PRELCLINTON(O)	2	41.3	42.1	36		42.2	10.75	+1.1	
Trade 2008PRES.GOLDBART	18	15.6	15.8	30		15.6	15.75	+0.0	
Trade 2008PRELOBAMA	3	10.6	11.5	1		10.6	11.15	-0.4	
Trade 2008PRELTHOMPSON(O)	1	5.5	5.5	3		5.5	6.05	+0.1	
Trade 2008PRELOMONEY	1	9.9	9.3	87		9.0	10.55	-0.5	
Trade 2008PRES.GORE	13	4.3	4.5	5		4.3	45.35	-0.2	
Trade 2008PRELODDOMBERG	7	1.6	2.3	10		1.5	1.55	-0.3	
Trade 2008PRES.MULLEN	14	2.7	2.8	3		2.7	16.75	+0.0	
Trade 2008PRES.EDWARDS	11	3.4	4.2	3		3.4	50.07	-0.5	
Trade 2008PRELWARNER	0	-	1.0	100		0.1	1.65	0	
Trade 2008PRES.ALLEN	0	-	1.0	100		0.1	4.71	0	

Order Book

2008PRES.CLINTON(O)

Bid		Offer	
Qty	Price	Price	Qty
2	41.3	42.1	36
46	41.1	42.2	1753
100	41.8	42.5	56
50	40.2	42.7	200
27	40.2	42.0	28

Hillary Clinton to win 2008 US Presidential Election

Contract Rules & Info

Order Ticket

Quantity:

Limit Price: 0-100

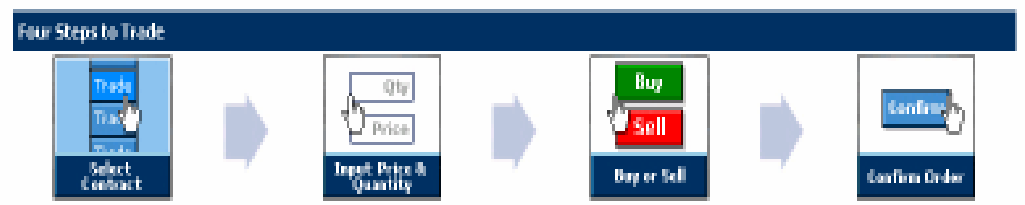
Lifetime:

Advanced Order

Risk Reward Profile









Risk		
Reward		

*Zero Fees for order makers.



*Don't forget you must Join first, in order to trade.

Financial securities (in Part 1)

- Tomorrow there must be one of   
- Agent 1 offers \$5 for a security that pays off \$10 if  or 
- Agent 2 offers \$8 for a security that pays off \$10 if  or 
- Agent 3 offers \$6 for a security that pays off \$10 if 
- Can we accept some of these at offers **at no risk?**

How to incentivize a weather forecaster (in Part 3)

$$P(\text{☀}) = .5$$

$$P(\text{☁}) = .3$$

$$P(\text{⚡}) = .2$$

$$P(\text{☀}) = .8$$

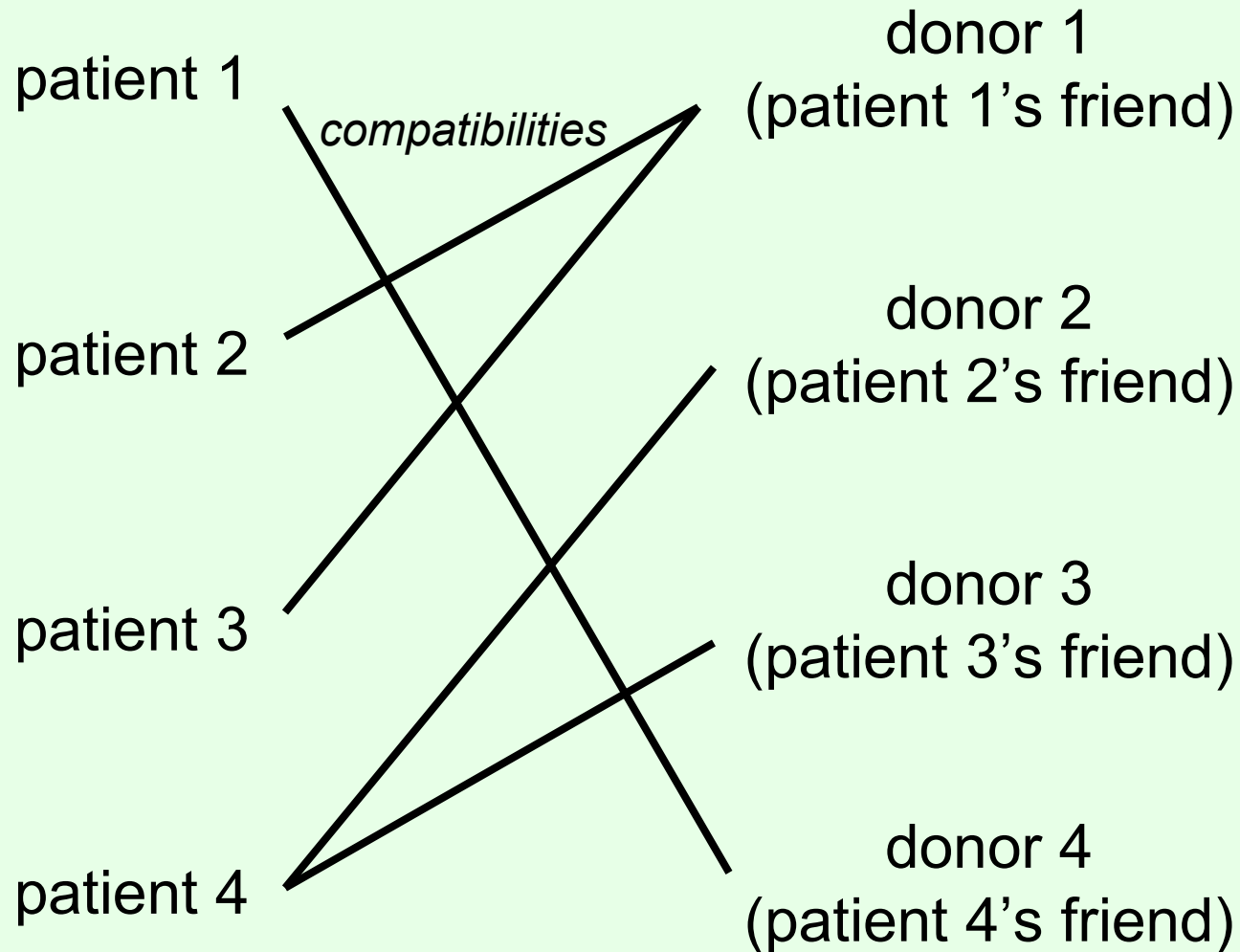
$$P(\text{☁}) = .1$$

$$P(\text{⚡}) = .1$$



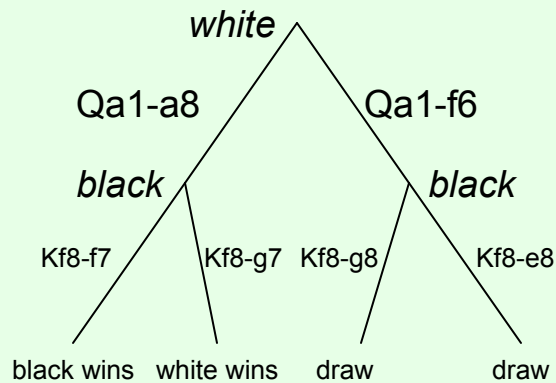
- Forecaster's bonus can depend on
 - Prediction
 - Actual weather on predicted day
- Reporting true beliefs should maximize expected bonus

Kidney exchange (Part 1)



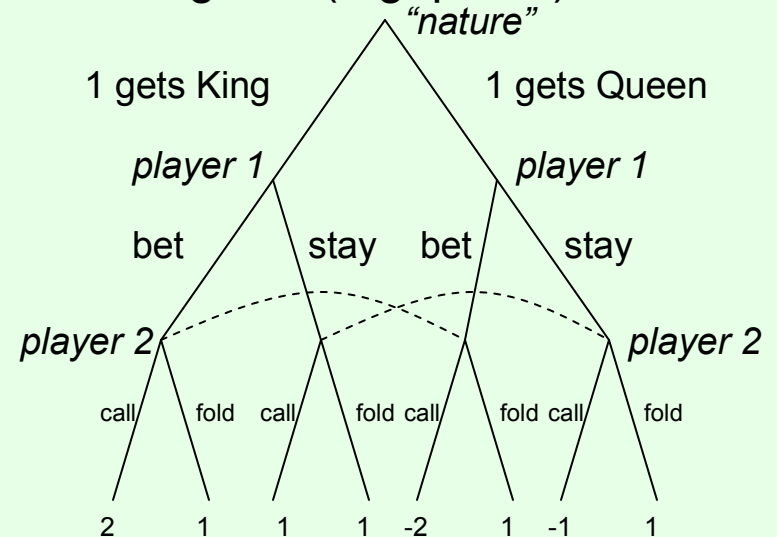
Game playing & AI (in Part 2)

perfect information games:
no uncertainty about the state of the game (e.g. tic-tac-toe, chess, Go)



- Optimal play: value of each node = value of optimal child for current player (**backward induction**, minimax)
- For chess and Go, tree is too large
 - Use other techniques (heuristics, limited-depth search, alpha-beta, ...)
- Top computer programs (arguably) better than humans in chess, not yet in Go

imperfect information games: uncertainty about the state of the game (e.g. poker)



- Player 2 **cannot distinguish** nodes connected by dotted lines
 - Backward induction fails; need more sophisticated game-theoretic techniques for optimal play
- Small poker variants can be solved optimally
- Humans still better than top computer programs at full-scale poker
- Top computer (heads-up) poker players are based on techniques for game theory

Why should economists care about computer science?

- Finding efficient allocations of resources is a (typically hard) **computational problem**
 - Sometimes beyond current computational techniques
 - If so, unlikely that **any** market mechanism will produce the efficient allocation (even without incentives issues)
 - Market mechanisms must be designed **with computational limitations in mind**
 - New algorithms allow new market mechanisms

Why should economists care about computer science...

- **Agents** also face difficult computational problems in participating in the market
 - Especially acting in a game-theoretically optimal way is often **computationally hard**
 - Game-theoretic predictions **will not come true** if they cannot be computed
 - Sometimes bad (e.g. want agents to find right bundle to trade)
 - Sometimes good (e.g. do not want agents to manipulate system)

Why should computer scientists care about economics?

- Economics provides high-value computational problems
- Interesting technical twist: **no direct access to true input**, must incentivize agents to reveal true input
- Conversely: Computer systems are increasingly used by **multiple parties** with different preferences (e.g. Internet)
- Economic techniques must be used to
 - **predict** what will happen in such systems,
 - **design** the systems so that they will work well
- Game theory is relevant for **artificial intelligence**
 - E.g. computer poker