Multi-agent decision making: preference reasoning and voting theory

Outline

- Preferences
- Several kinds of preferences
- Preferences in multi-agent decision making
- Voting theory (social choice)
- In multi-agent AI scenarios:
  - Missing and imprecise preferences
  - Computational concerns
  - Large set of candidates
  - Candidate set with a combinatorial structure

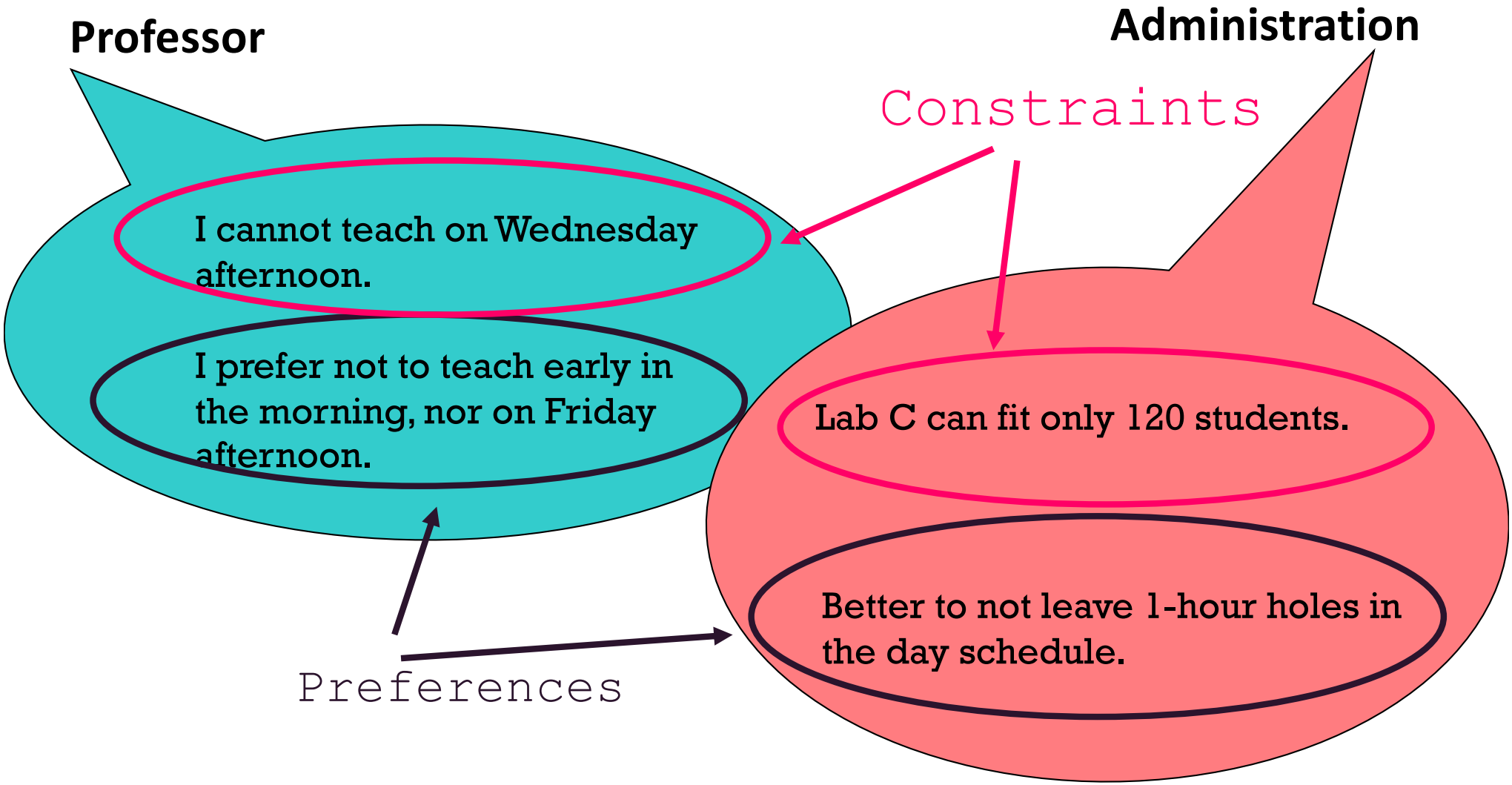
Preferences

- Preferences are **ubiquitous** in **everyday decision making**
  - Essential ingredients in every reasoning tool
- Preferences are **orderings** over possible options
  - Options: candidates, car, computers, books, movies …
- Preferences can model **levels of acceptance**, or **costs**
  - Preferences are tolerant constraints
  - Constraints are strict requirements that must be satisfied

Preferences

- **If all constraints**, possibly
  - no solution, or
  - too many of them, all apparently equally good
- Some problems are **naturally modelled** with preferences
  - I don't like meat, and I prefer fish to cheese
- **Constraints and preferences** may be present in the same problem
  - Ex. Timetabling, ..

University timetable



Several kinds of preferences

- **Unconditional**
  - *I **prefer** taking the bus*
- **Conditional**
  - *I **prefer** taking the bus **if it's raining***
- **Multi-agent**
  - *I like blue, my husband likes green,*

    what color for the new car?

Several kinds of preferences

- **Quantitative**
  - **Numbers**, or ordered set of objects
    - *My preference for ice cream is 0.8, and for cake is 0.6*

- **Qualitative**
  - **Pairwise comparisons**
    - *Ice cream is better than cake*

Two main ways to model compactly preferences

- **Several kinds of preferences**
- **Two compact ways to model preferences**
  - **Soft constraints**

    for modeling **quantitative** and **unconditional** preferences
    - *Ex., My preference for ice cream is 0.8, and for cake is 0.6*
  - **CP-nets**

    for modeling **qualitative** and **conditional** preferences
    - *Ex., Red wine is better than white wine if there is meat*

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II PART

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Preferences for collective decision making in multi-agent systems

- Several **agents**
- **Common** set of **possible decisions**
- **Each agent** has its **preferences** over the possible **decisions**
- **Goal**: to choose one of the decisions, **based on the preferences** of the agents
  - or a set of decisions
  - or a ranking over the decisions

- **AI scenarios** add:
  - Imprecision
  - Uncertainty
  - Complexity concerns
  - Combinatorial structure of the decisions

Applications

- Doodle

  Doodle®

  - **Several time slots** under consideration
  - Participants **accept** or **reject** each time slot
    - Very simple way **to express preferences** over time slots
    - Very little information communicated to the system
  - **Collective choice**: a single time slot
    - The one with most acceptance votes from participants

- Other applications
  - Group recommender systems
  - Meta-search engine

How to compute a collective decision?

- Let the **agents** **vote** by expressing their **preferences** over the **possible decisions**
- **Aggregate** the **votes** to get a **single decision**

- Let's look at **voting theory**
  - Agents = Voters
  - Decisions = Candidates
  - Preferences
  - Chosen decision = winner

Voting theory
(Social choice)

- **Voters**
- **Candidates**
- **Each voter** expresses its **preferences** over the **candidates**
- **Goal**: to choose **one candidate** (the winner), based on the voters' preferences
  - Also many candidates, or ranking over candidates
- **Voting Rules** (functions) **to achieve the goal**

Some voting rules

- Plurality
  - **Voting**: each voter provides the most preferred decision
  - **Selection**: the decision preferred by the largest number of voters
- Majority: like plurality, over 2 options

Plurality

- **Voting**: the most preferred decision
- **Selection**: the decision preferred by the largest number of agents
- **Example:**
  - 6 voters
  - 3 candidates:

Profile

Voter 1 **Voter 2** **Voter 3** **Voter 4** **Voter 5** **Voter 6**

Winner

Another voting rule

- Approval (m options)
  - **Voting:**
    each voter approves any number of options
  - **Selection:** option with most votes

Voting rule used in Doodle

Another voting rule

- Borda
  - **Voting**: each voter provides a rank over all options
  - **Score of an option**: number of options that it dominates
  - **Selection**: option with greatest sum of the scores

Borda

rank	Voter 1	Voter 2	Voter 3	Voter 4	Voter 5	Borda Count	Winner
3		3 				9	
2		2 				8	
1		1 		1 	1 	7	
0		0 		0 	0 	6	

Some desirable properties

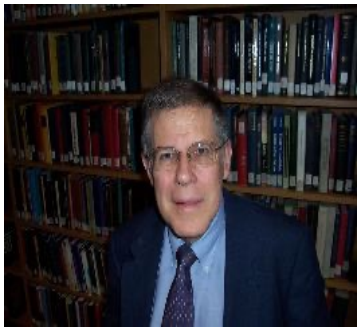
- Unanimity (efficiency)
  - If all voters have the same top choice, it is selected
- Non-dictatorship
  - There is no dictator
  - Dictator: voter such that his top choice always wins, regardless of the votes of other voters
- Non-manipulability
  - There is no incentive for agents to misrepresent the preferences

Two classical impossibility results

- **Arrow's theorem (1951)**
  - Totally ordered preferences
  - It is **impossible** to find a **voting rule** with some desirable properties including
    - unanimity
    - non-dictatoriality

Nobel prize
in Economics 1972

- **Gibbard-Sattherwaite's theorem (1973)**
  - Totally ordered preferences
  - it is **impossible** to have a reasonable **voting rule** that is
    - non-dictatorial
    - non-manipulable



- These impossibility results hold also when we allow partially ordered preferences