Mechanism Design and Computationally-Limited Agents

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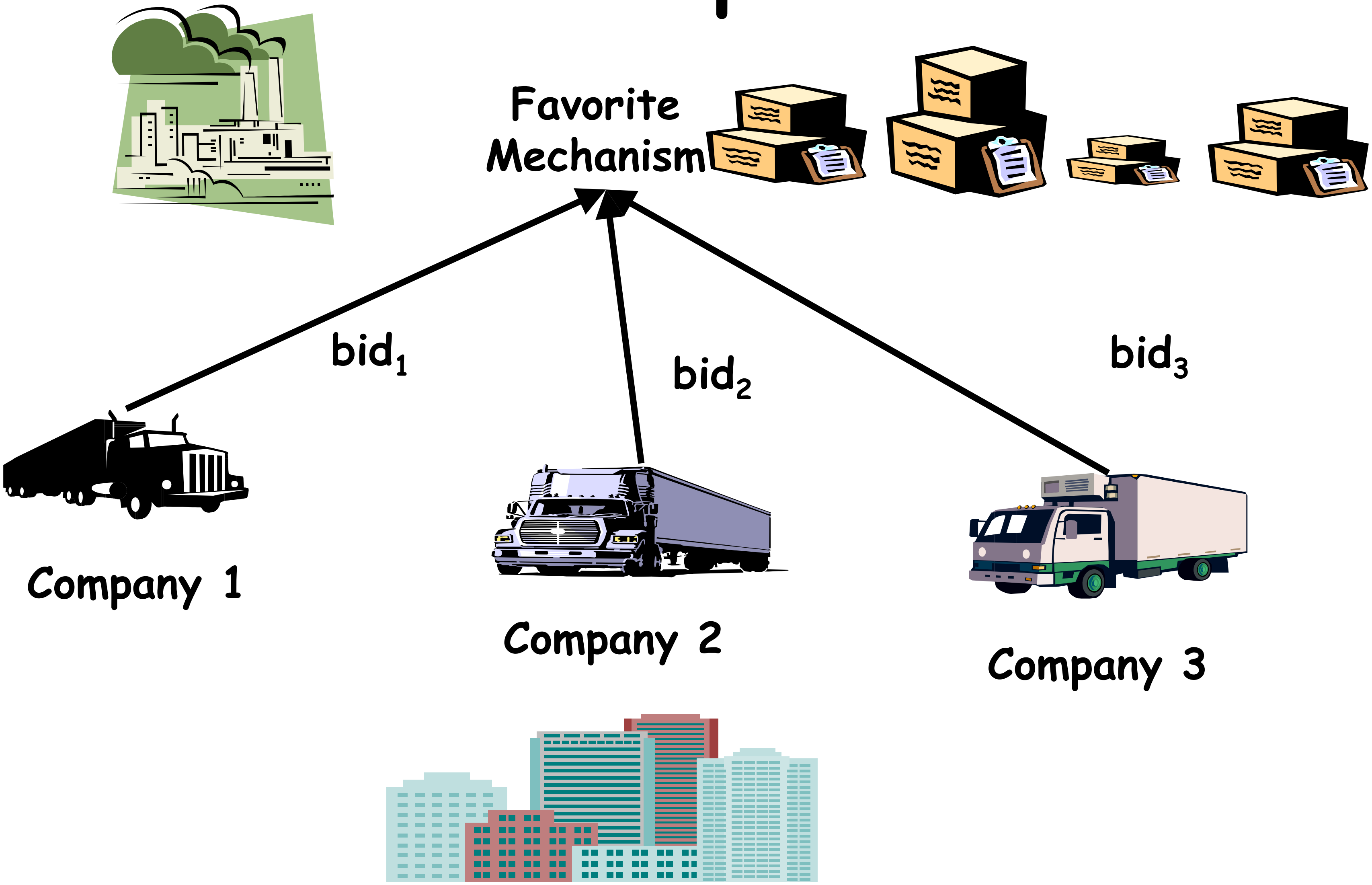
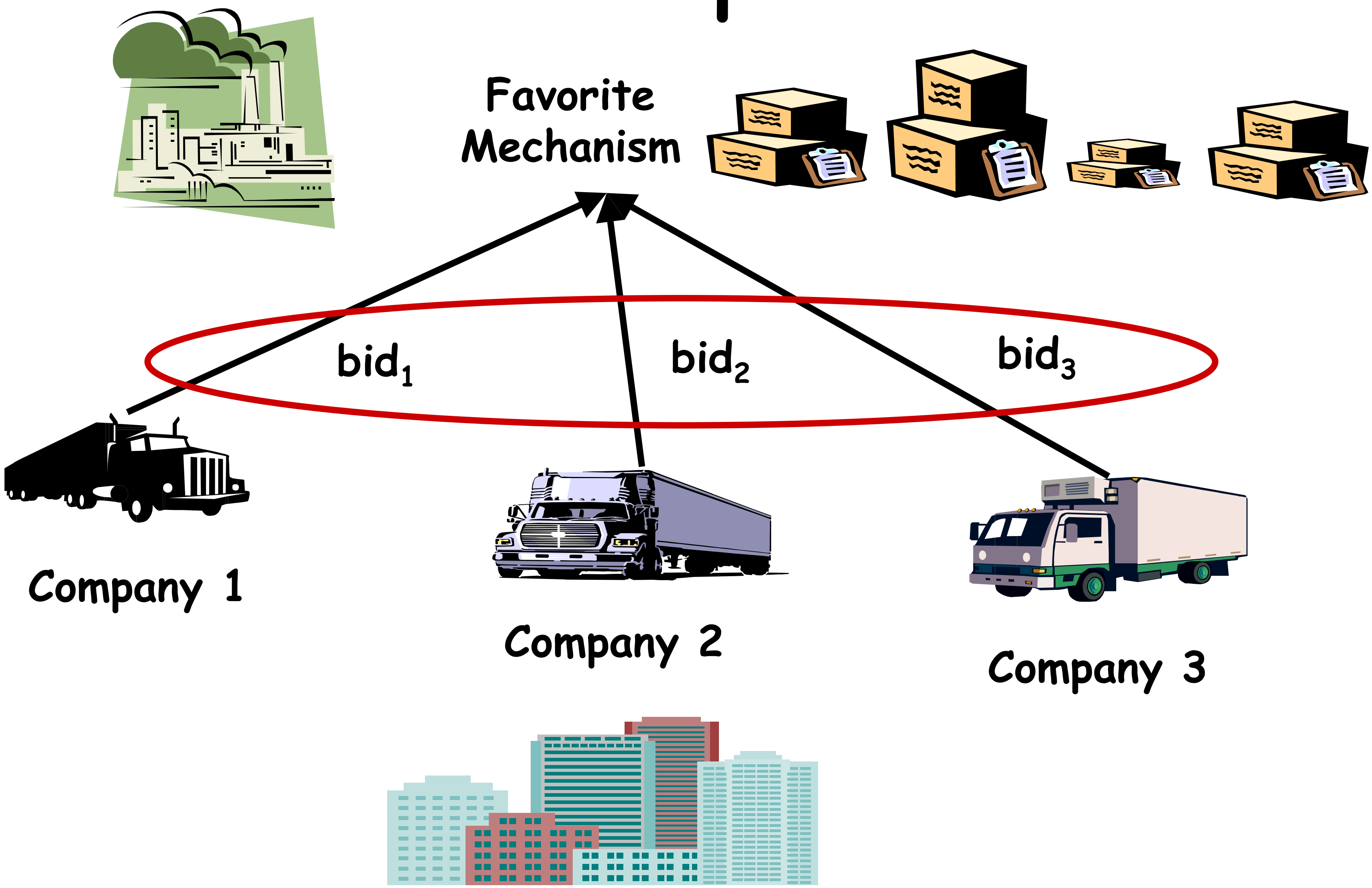
Example


Favorite
Mechanism
bid1
bid2
bid3
Company 1
Company 2
Company 3

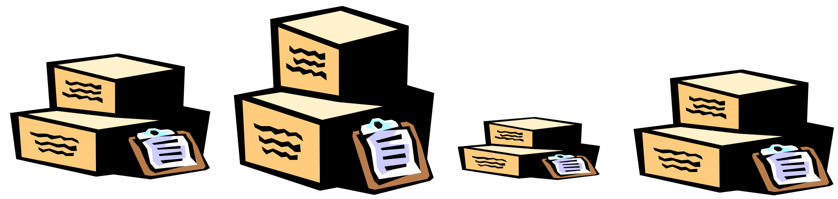
Example

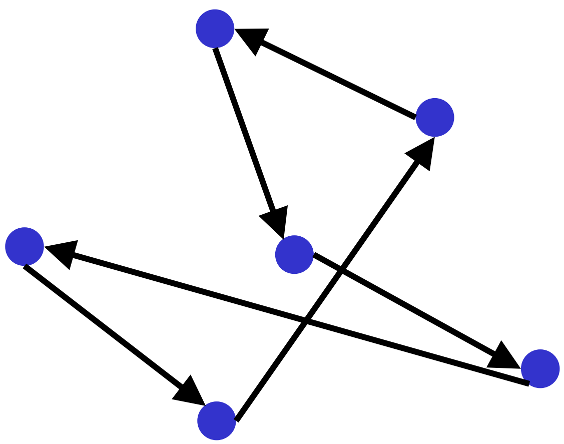


Favorite Mechanism
bid$_1$
bid$_2$
bid$_3$
Company 1
Company 2
Company 3

Value complexity

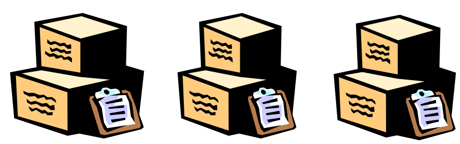
Favorite
Mechanism



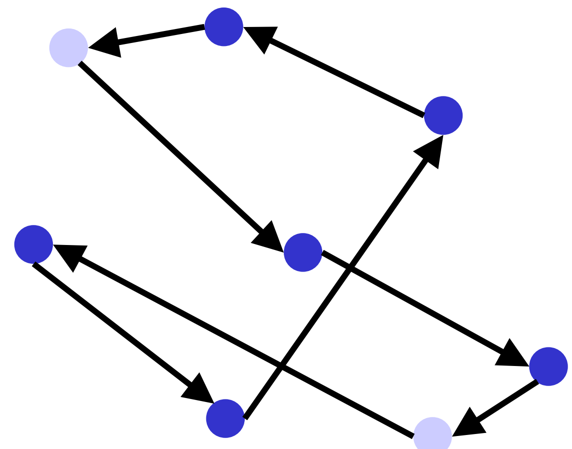


Current delivery
schedule

Bid ?



Deliveries
committed to



Delivery schedule
with additional
package

Value complexity

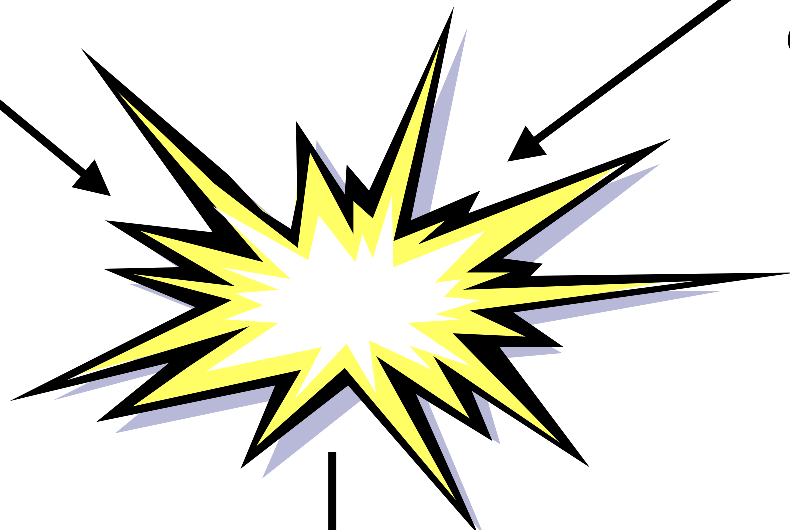
- Agents need values in order to participate (preferences)
- Figuring out values can have high computational overhead

- How should computational issues be handled game theoretically?
- Do computational issues have strategic implications?

Our approach

Resource bounded reasoning from AI

Game theory and mechanism design

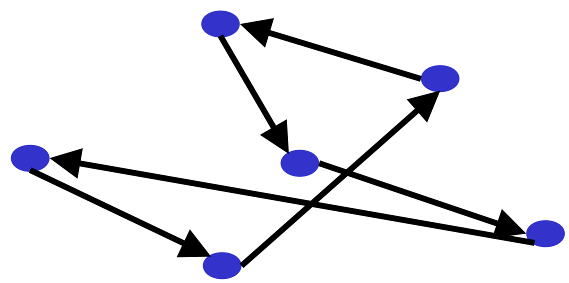


A Model of bounded rationality

Mechanism design for deliberative agents

Deliberative agents

- Deliberative agent — an agent that computes or gathers information



- Agents have
  - Anytime algorithms
  - Performance profile deliberation control
  - Cost functions which limit their deliberative capabilities

Anytime algorithms

- Anytime algorithms approximate values
  - Return a solution at any time
  - Solution improves over time

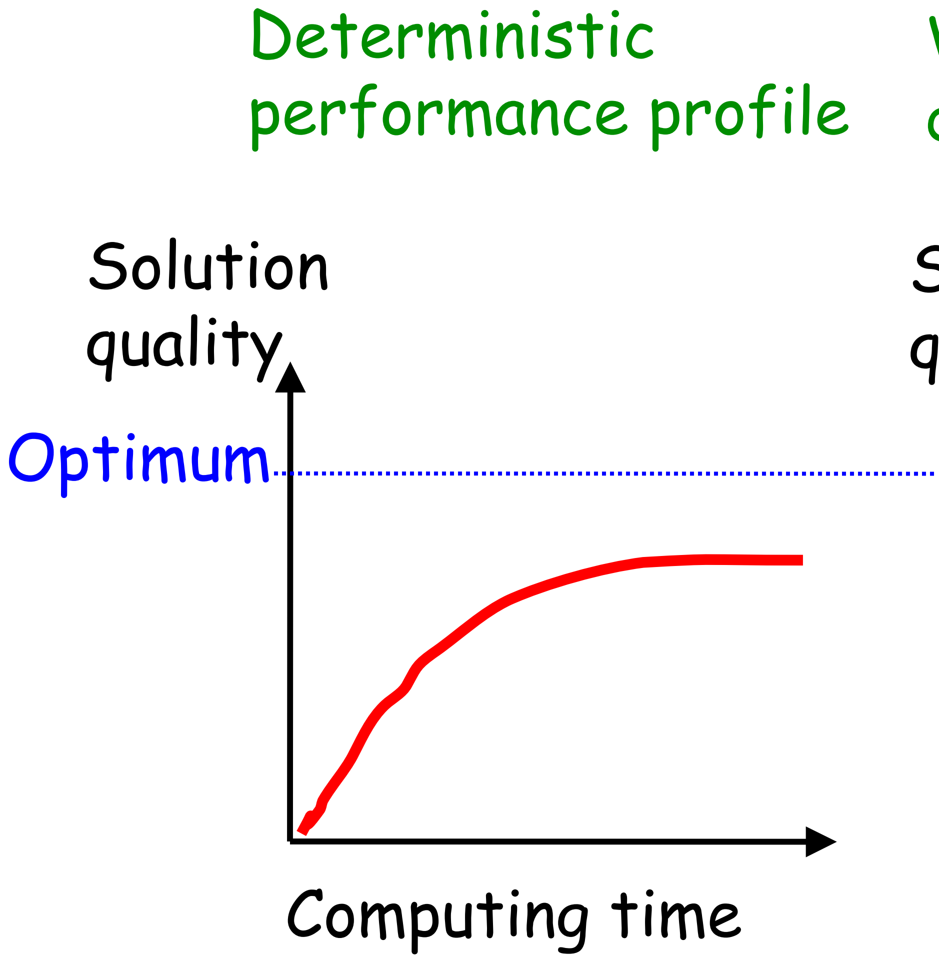
  ⇒ Allows a tradeoff between computing time and solution quality

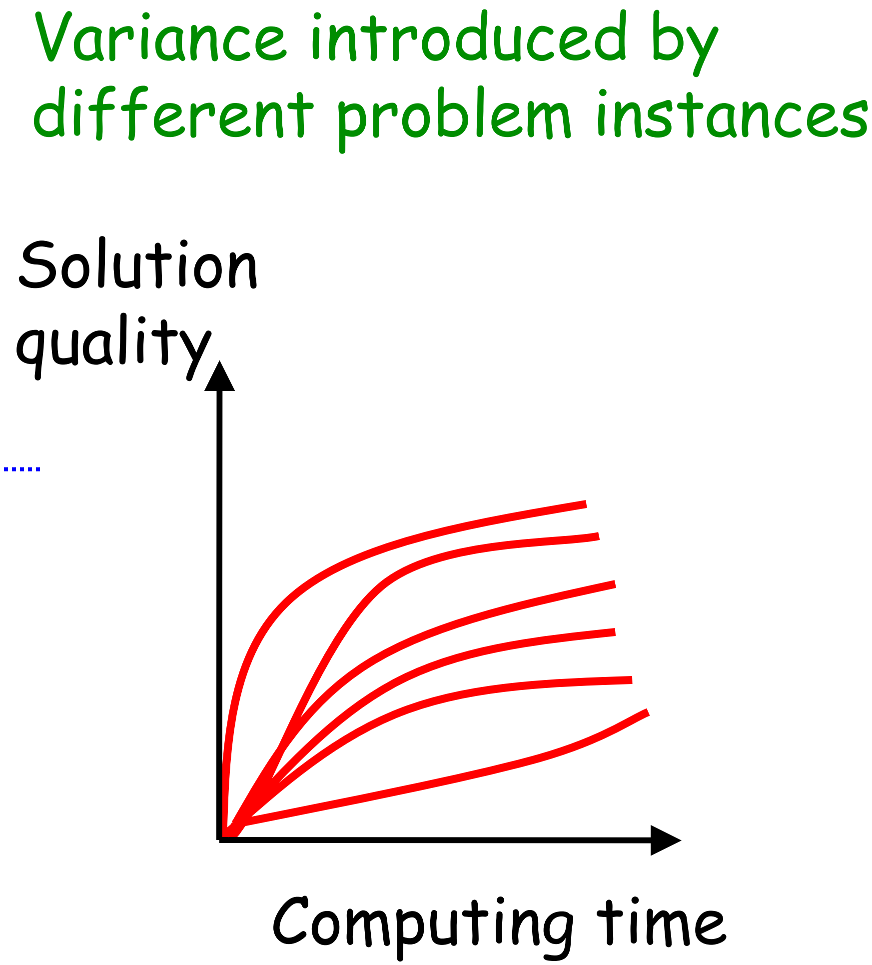
- Examples
  - Iterative refinement algorithms: Local search, simulated annealing
  - Search algorithms: Depth first search, branch and bound

Performance profiles

- Performance profiles describe how computing changes solution quality
  - Characterize quality of algorithm's output as a function of computing time
- Use performance profiles to build deliberation control policies
- Representation is important
  - Earlier methods were not fully descriptive
  - They did not capture all possible ways an agent could control its deliberation

Performance profiles





[Horvitz 87, 89, Dean & Boddy 89]

Table-based performance profile

[Zilberstein & Russell 91, 96]

Solution quality

								.08	.19	.24
							.15	.30	.17	.39
					.16	.10	.16	.25	.30	.22
		.08	.04	.17	.20	.22	.30	.24	.19	.15
	.09	.10	.20	.22	.23	.37	.31	.13	.15	
q	.11	.14	.33	.18	.21	.18	.08			
	.22	.17	.25	.24	.15	.13				
	.40	.31	.15	.19	.05					
	.15	.20	.03							
	.03									

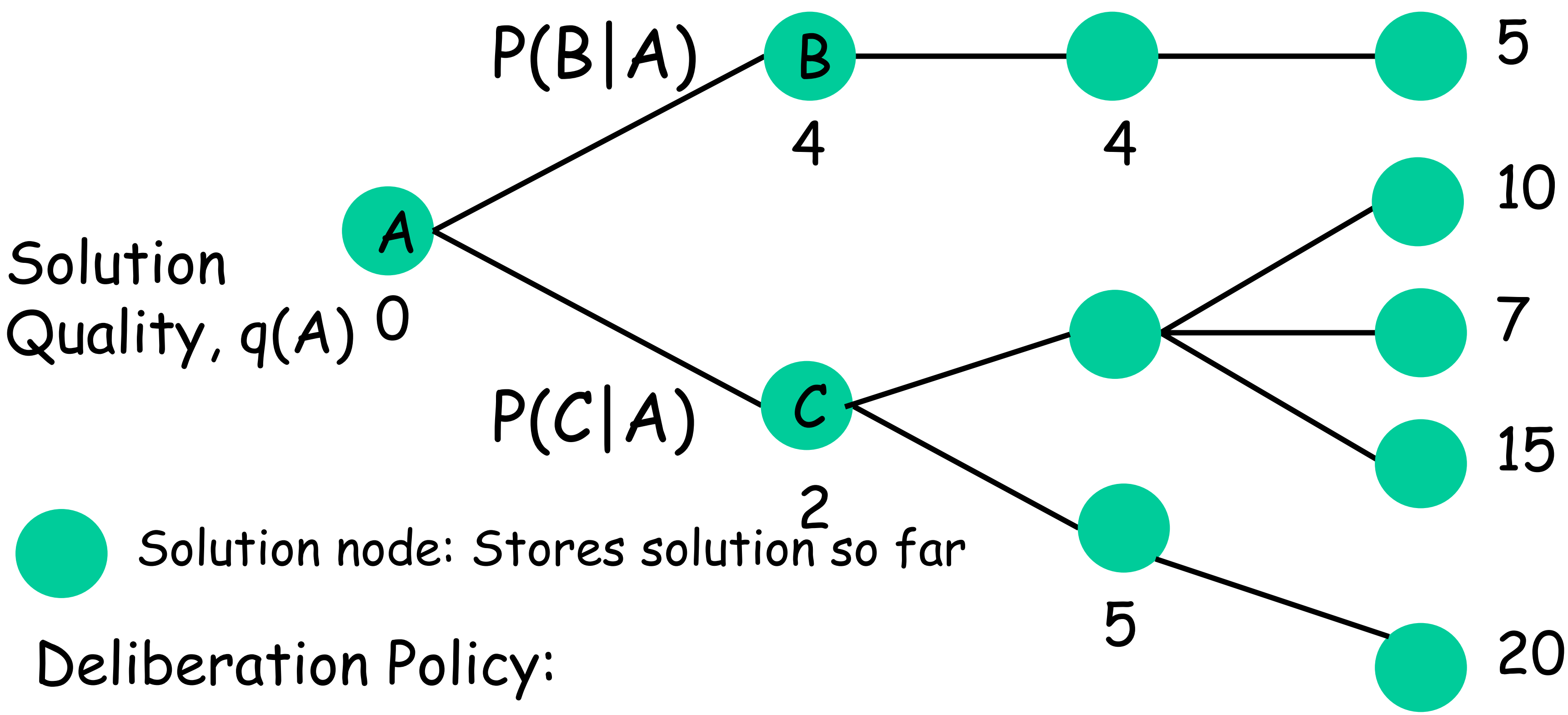
t

Computing time

Conditioning on solution quality so far [Hansen & Zilberstein 01]

Ignores conditioning on the path

Performance profile tree



Deliberation Policy:

$\pi(q(n),t)=\text{argmax}_d\,[q(n)-\text{cost}(t)$ if $d=\text{stop}$, $\sum_{n'} P(n'|n)V(q(n'),t+\Delta t)$ $d=\text{continue}]$

Where

$V(q(n),t)=\max_d\,[q(n)-\text{cost}(t)$ if $d=\text{stop}$, $\sum_{n'} P(n'|n)V(q(n'),t+\Delta t)$ $d=\text{continue}]$

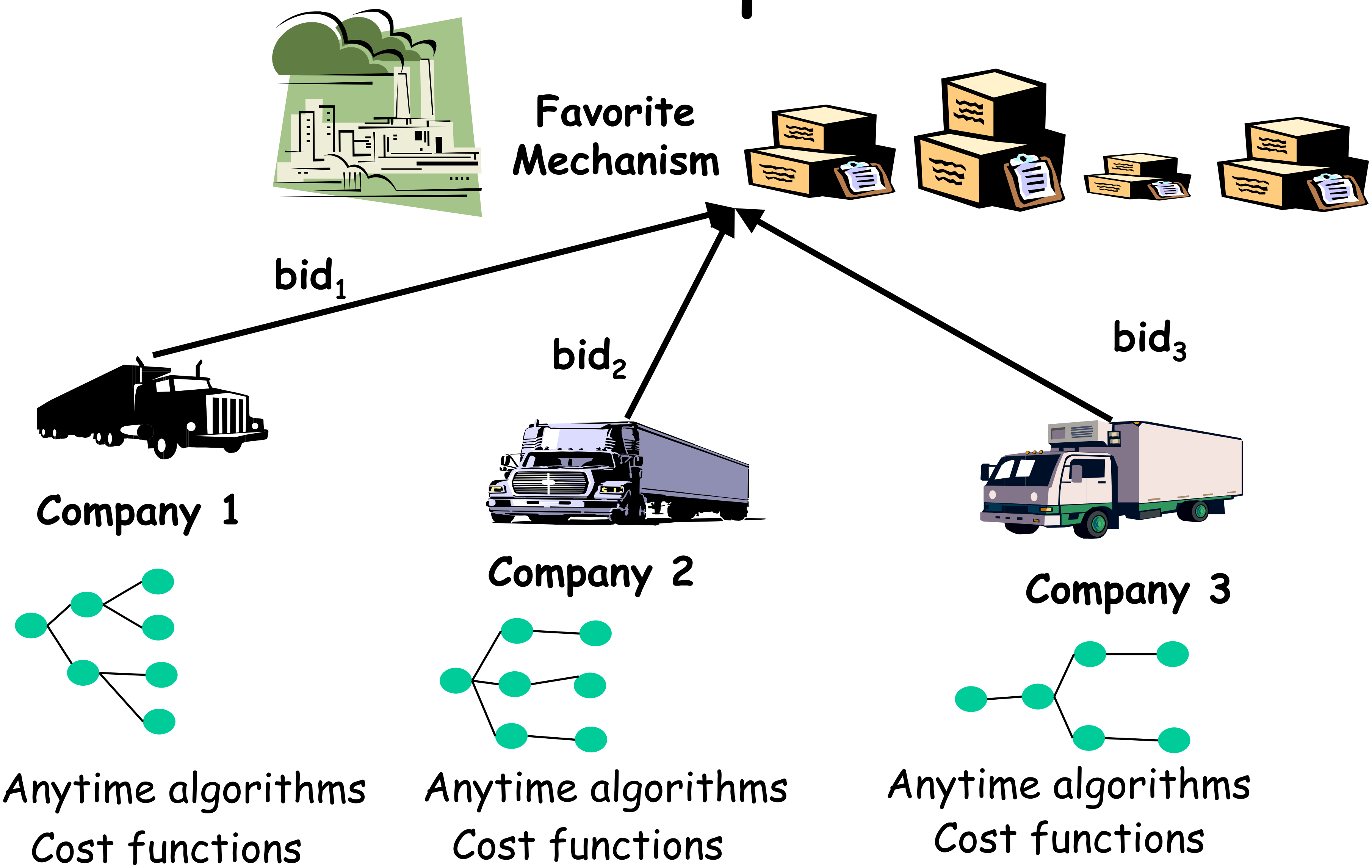
$n' \in \{$nodes at depth Δt in the subtree rooted at node $n\}$

Properties of performance profile trees

- Fully descriptive - allows conditioning on everything including
  - Path of solution quality
  - Path of other solution features
  - Problem instance features

- Can model uncertainty from
  - Randomized algorithms
  - Lack of knowledge about what algorithms other agents use
  - Problem instances

Example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Anytime algorithms
Cost functions
Anytime algorithms
Cost functions
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Cost functions

Strategies of Agents

- A strategy includes both the deliberating actions as well as other (bidding) actions

DS=set of deliberation states, DA = set of deliberation actions,
c^z = action of deliberating for one step on problem z

Vickrey Auction

(Bidding at time T)

S_i:Time X DS $\rightarrow$ DA X R

$S_i(t,ds)=(c^z,\emptyset)$ if $t \neq T$

$S_i(t,ds)=(c^z,V(n_i(T)))$ if $t=T$

Ascending Auction

S_i:Time X DS X Price$\rightarrow$ DA X {stay, leave}

$S_i(t,ds,p)=(c^z,a)$ $a\in$ {stay,leave}

Strategic Deliberation

- Good estimates of other agents' values allow an agent to tailor its bidding strategy

- Strategic deliberating:

  An agent uses some of its computational resources to approximate another's valuation

Auctions and strategic deliberating

	Auction mechanism	Classical Counter-speculation	Strategic deliberation	
			Deadlines	Costly
Single item for sale	First price sealed-bid	yes	yes	yes
	Descending	yes	yes	yes
	2nd price sealed bid	no	no	**yes**
	Ascending	no	no	**yes**
Multiple items for sale	Generalized Vickrey On which ⟨agent, bundle⟩ pair to allocate next computation step ?	no	**yes**	**yes**

Computational Limitations and Mechanisms

- Allow agents to submit their tools for determining preferences
    - Performance profiles, algorithms, cost functions, problem instances.....
  - Truthful revelation, no strategic deliberation
  - Unreasonable assumptions
    - Can the mechanism handle all this information?
    - Can the agents practically submit all this information ?

Computational Limitations and Mechanisms

- Restrict to (interesting) mechanisms where agents only reveal (partially) computed results
  - Strategic deliberation may occur in any direct mechanism
  - Indirect mechanisms do not solve the problem:
    - Strategic deliberation can still occur
    - Issues with "non-truthfulness"

The Future?

- Allow the mechanism to help with some deliberation control
  - What information should the agents submit?
  - How to guarantee that truthful revelation will occur?
  - Who is solving the preference problems?
- Embrace strategic deliberation
  - If an agent is good at solving a certain type of problem, let it solve it for everyone!
  - Interesting incentive issues