THE ROLE OF AGGREGATION FUNCTIONS ON AUCTIONS

BEATRIZ LÓPEZ

AGOP 2017

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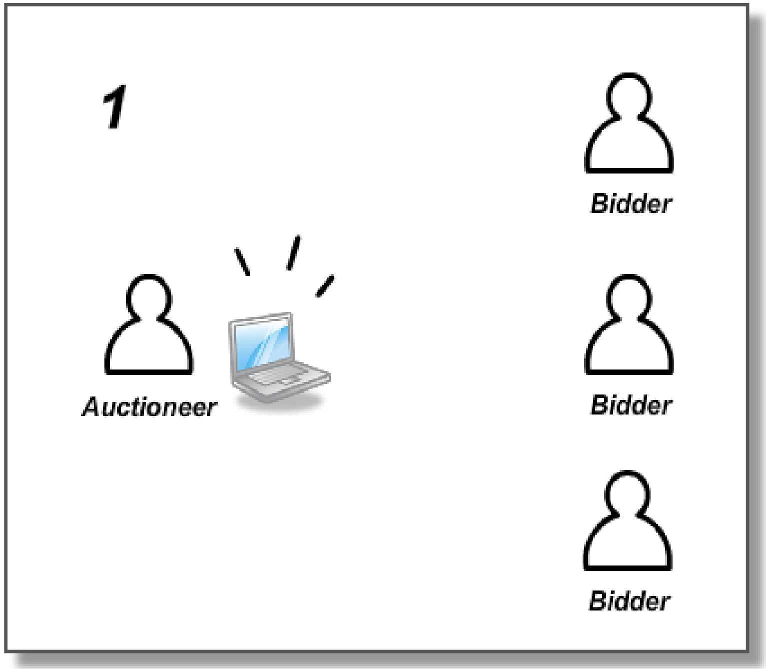
WHAT IS AN AUCTION



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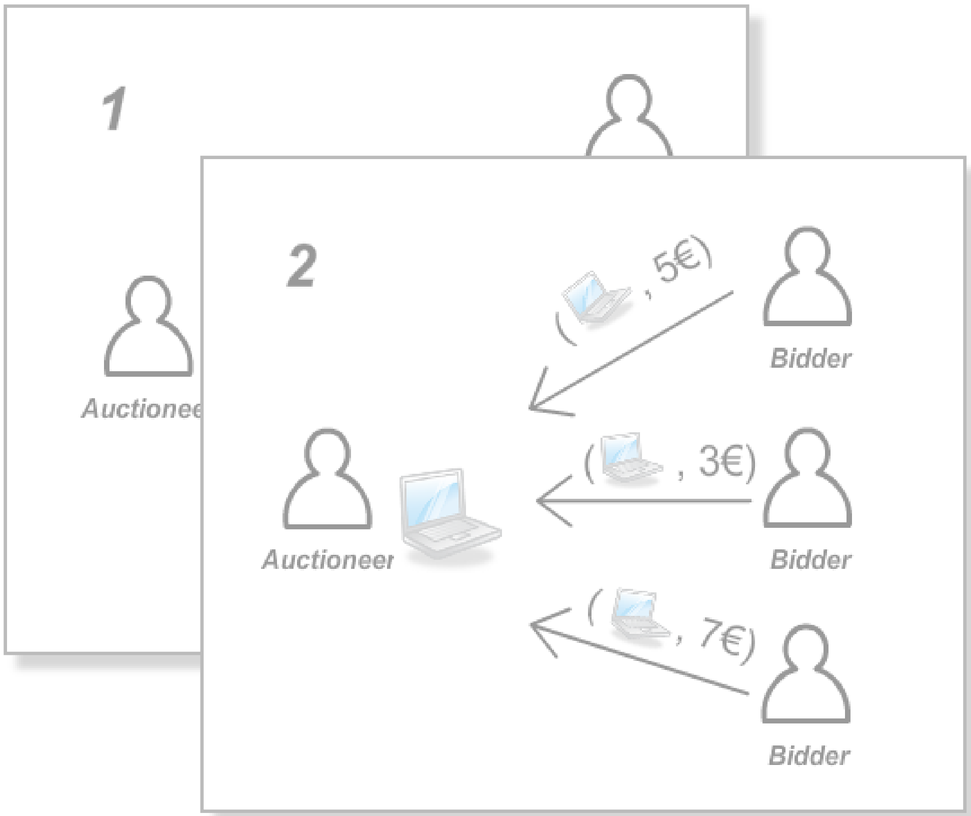
WHAT IS AN AUCTION



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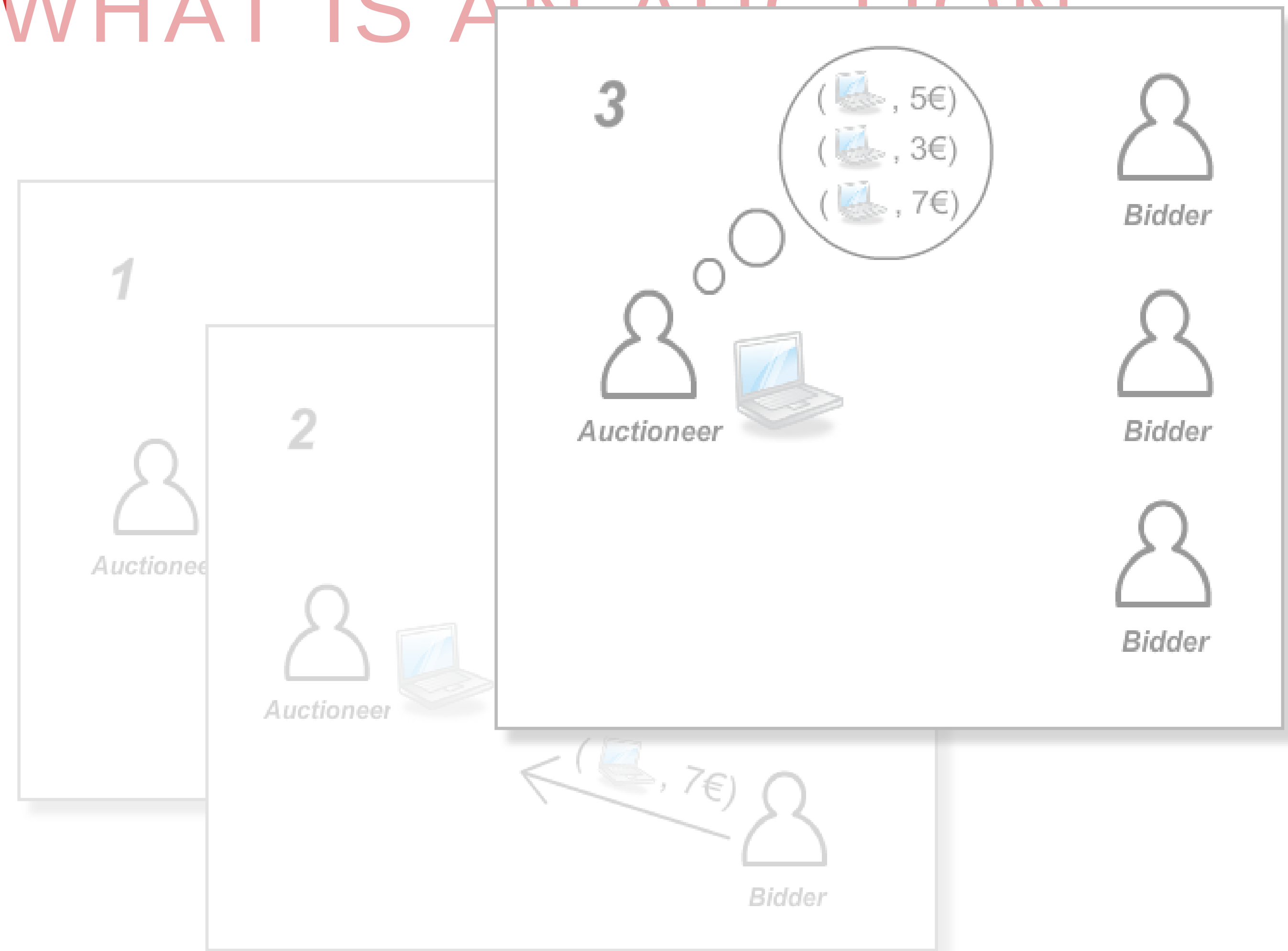
WHAT IS AN AUCTION



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WHAT IS AN AUCTION

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AUCTIONS

- **Buyers and sellers find easy to understand**
  - Eliminate the necessity to set an exact price

Resource supply
Existing demand
→ Price for resources

Leyton-Brown, K., Shoham, Y.: Mechanism design and auctions. In: Weiss, G. (ed.) Multiagent Systems, Chap. 7, 2nd edn., pp. 285–32. The MIT Press (2013)

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EXAMPLES

- **Fish market**
- **Christie's Art Auctions**
- **Grid Computing Services (GCS)**
- **Electricity market**
- **Internet advertisement**

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AUCTION TYPES

- Forward
  - One-side
    - Uni-dimension
      - Single item
        - Single-unit ...
        - Multi-unit
          - 1st price
            - Open-cry
            - Sealed bid
          - 2^{nd} price
          - …
      - Combinatorial ….
    - Multi-attribute ….
  - Double side….
- Reverse

Role of the participants | *Number of bidding sides* | *Bid composition* | *Number of diff items* | *Number of units per item* | *Payment* | *Visibility*

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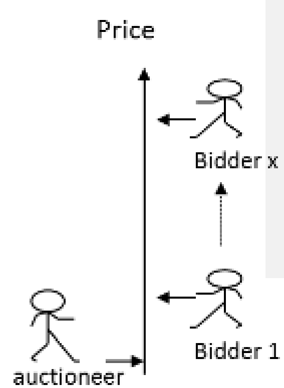
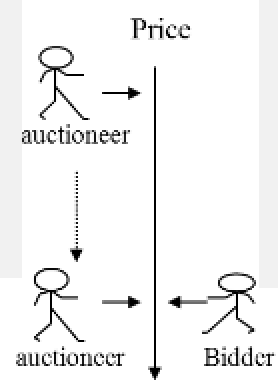
English auction



Dutch auction



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AUCTION TYPES

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            - **Sealed bid**
          - **2nd price**
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Vickrey auction: The winner pays the price of the second-highest bid.

AUCTION TYPES

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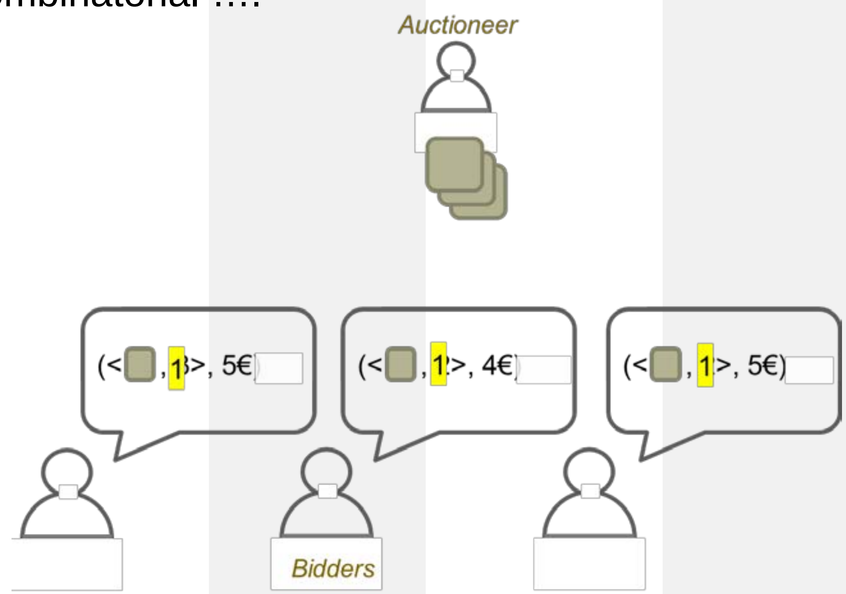

Vickrey–Clarke–Groves
The winner pays the price of the second-highest bid.

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AUCTION TYPES

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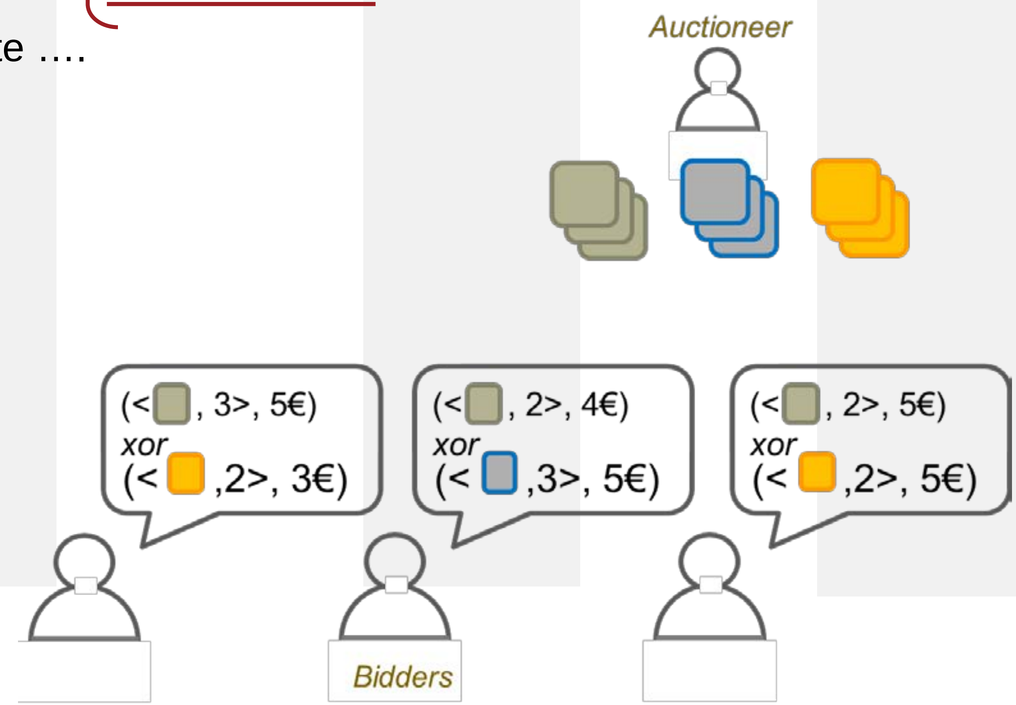

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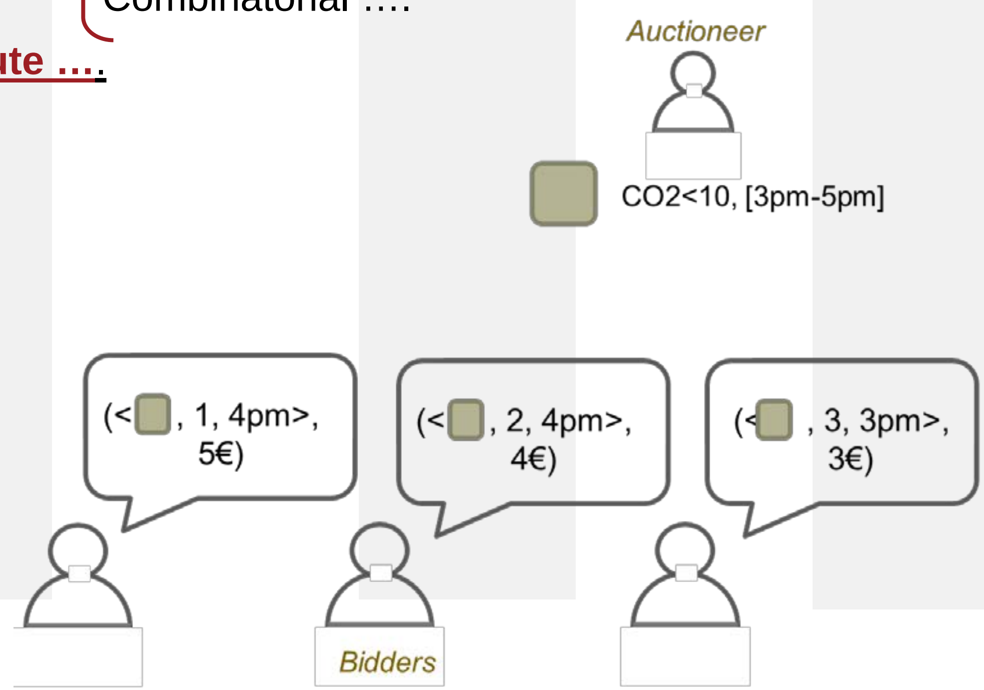

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AGENTS' GOALS

- **Bidders**
  - Maximize revenue
- **Auctioneers**
  - Maximize revenue
    - Keep agents interested in the market

K bidders K-1 bidders

Murillo, J., Munoz, V., López, B., & Busquets, D. (2008). A fair mechanism for recurrent multi-unit auctions. MATES (LNS Vol. 5244, pp. 147–158).

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MAXIMIZING REVENUES: UTILITIES

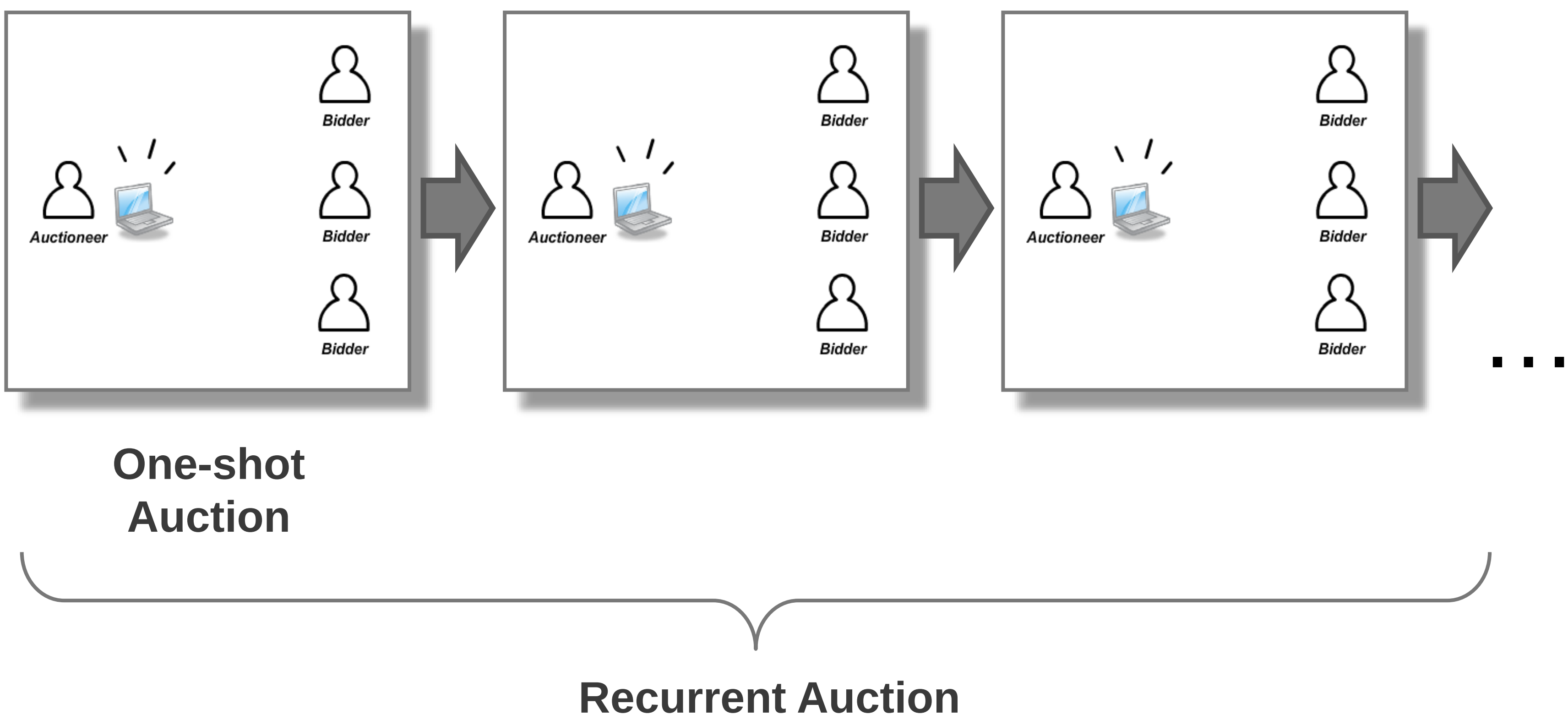
v(x) value function: Aggregation functions

	Auctioneer 	Bidders 
Forward Auction	Seller $u(x) = p - v(x)$	Buyer $u(x) = v(x) - p$
Reverse Auction 	Buyer $u(x) = v(x) - p$	Seller $u(x) = p\text{-}v(x)$

x: good, resource   u(x) = utility   p = price
outcome of the auction   v(x) = evaluate the value of x
different for every agent

KEEPING AGENTS IN THE MARKET

Social welfare measures: Aggregation functions



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MECHANISM DESIGN

- **Bidders**
  - Bidding policies: how each agent decides the bid amount (and other attributes)
- **Auctioneers**
  - Winner determination problem: how the auctioneer selects the winner(s)
  - Pricing mechanism: how the auctioneer decides the price to be paid by the winners
- **While pursuing**
  - Truthful bidding
  - A given social welfare measure
- **And conditioned by the type of good**

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TYPE OF GOOD

- Static
- Time sensitive
  - Consumable
  - Perishable
- Divisible
- Indivisible
- Controlled
- Uncontrolled

Electronic resources

Controlled

Capacity of a waste water treatment plant

Uncontrolled

Murillo Espinar, J.: Egalitarian behaviour in multi unit combinatorial auctions, Ph.D. thesis, University of Girona (2010)

OVERVIEW

What is an auction

1. **The value function**
2. **Social welfare measures**
3. **Parameter adaptation**

Summary and conclusions

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THE ROLE OF AGGREGATION FUNCTIONS ON

THE VALUE FUNCTION

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CONTEXT

- **Multi-attribute auctions**
  - Each Bid *B* is composed by its cost *b* and a set of attributes
    B=(b,AT) *AT=(at¹,…, atⁿ).*
  - *WDP:* Find the optimal Bid according to cost *b* and attributes AT
    argmax($V(b_i,AT_i)$)
- **VCG-based payment:** best bid, second price

  Winner bid: b1

  b1⁻: remove ec of b1,

  b1’: add p to b1⁻

  Second best: b2

  V(b1’)=V(b2) → $p = V^{-1}(V(b2), b1^{-})$

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Pla, A., López, B., Murillo, J., Maudet, N.: Multi-attribute auctions with different types of attributes: enacting properties in multi-attribute auctions. Expert Syst. Appl. 41(10),4829–4843 (2014)

V(b,AT) REQUIREMENTS

- **Real Valued Function**
- **Monotonicity**
- **Bijection**

Pla, A., Lopez, B., Murillo, J.: Multi criteria operators for multi-attribute auctions. In:Torra, V., Narukawa, Y., López, B., Villaret M. (eds,) MDAI 2012. LNCS, vol 7647.Springer, Heidelberg (2012)

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REAL-VALUED FUNCTION

- V(b,AT) must return a real number evaluation for each bid
  - The payment mechanism involves the score obtained by the second best bid.
- Discards multi-criteria methods which result in ranked lists or orders without a score.
  - If there is not a score or evaluation, the payment cannot be computed.

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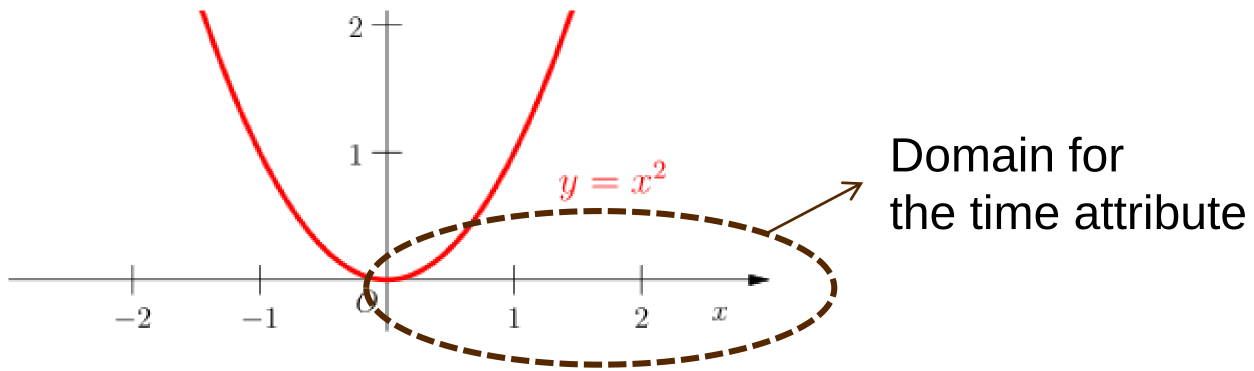
MONOTONICITY

If an attribute is improved, the score of the evaluation must also improve.

Example:

- If an attribute can only take positive values (time duration), it can be evaluated using its square.



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BIJECTION

In order to calculate the payment, V(b,AT) must have a bijective behaviour regarding the price attribute.

- **Given: V(b,AT) = x**
- **Its antifunction will be $V^{-1}(x,AT) = b$**

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EXAMPLE FUNCTIONS

PRODUCT

$$V(b_i, AT_i) = b_i * \prod_{j=1}^{j=n} at_i^j$$

WEIGHTED SUM

$$V(b_i, AT_i) = \mu_0 b_i + \sum_{j=1}^{n} \mu_j at_i^j$$

EUCLIDEAN NORM

$$V(b_i, AT_i) = \sqrt[2]{{b_i}^2 + \sum_{j=1}^{n} {at_i^j}^2}$$

WEIGHTED SUM OF FUNCTIONS

$$V(b_i, AT_i) = \mu_0 f_0(b_i) + \sum_{j=1}^{n} \mu_j f_j(at_i^j)$$

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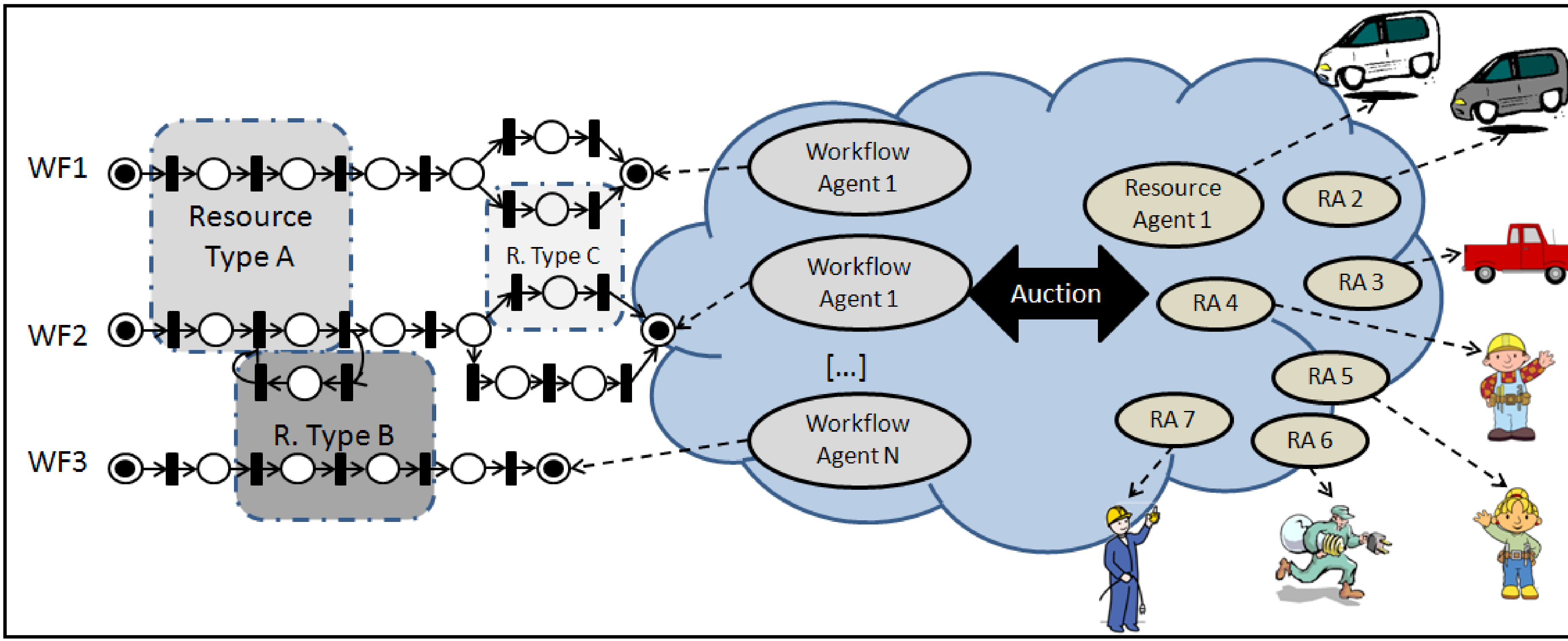
WORKFLOW SCHEDULING– EXAMPLE (i)



WORKFLOW SCHEDULING–EXAMPLE (ii)

- **Auctioneer: resource allocation**
  - 3 different business process (workflows)
  - 6 different tasks.
  - Each task has an estimated duration between 10 and 15 minutes and requires one resource of a certain type (A to D) to be executed.

- **Bidders**
  - There are 4 (A to D) types of resources provided by 8 Resource providers.
  - Each Resource Provider can perform 3 types of tasks with different qualifications (Type, time, error tolerance)

Resources	RP0	RP1	RP2	RP3	RP4	RP5	RP6	RP7
Skills	A,15,2	B,15,1	C,10,8	D,14,2	A,12,6	B,13,4	C,12,5	D,13,4
	C,14,3	D,14,2	A,14,2	B,10,1	C,13,4	D,15,4	A,13,5	B,13,5
	B,10,9	A,10,9	D,15,1	A,14,2	D,12,5	C,12,5	D,12,6	A,12,6

$\underbrace{\text{RP0 – RP3}}_{\text{Unbalanced Attributes}}$ $\underbrace{\text{RP4 – RP7}}_{\text{Balanced Attributes}}$

Truthful bidding

Cheating

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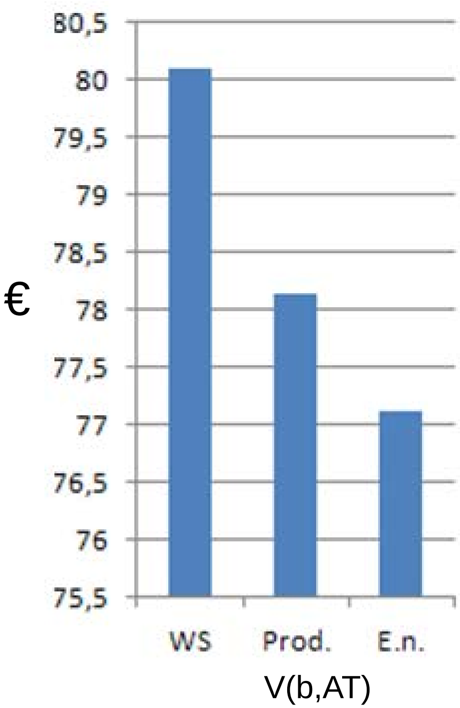
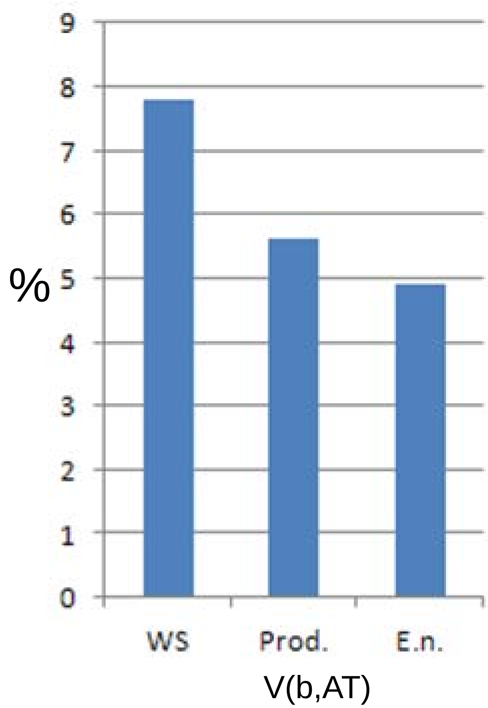
WORKFLOW SCHEDULING– EXAMPLE (iii)

Auctioneer revenues

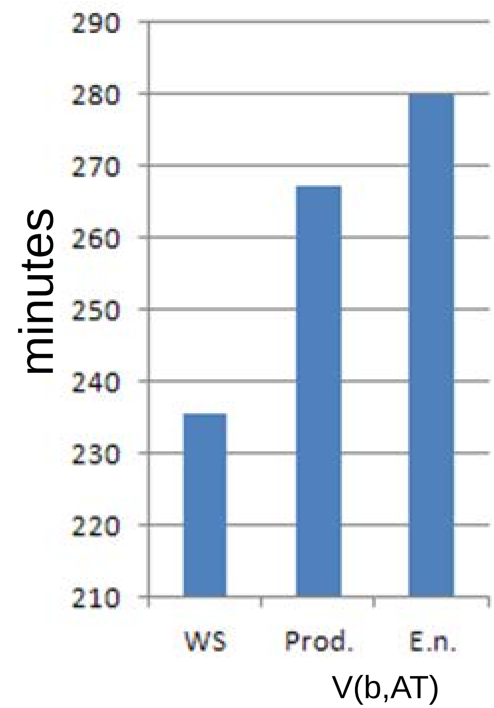
Mean Economic Cost



Mean Error Tolerance



Mean Service time



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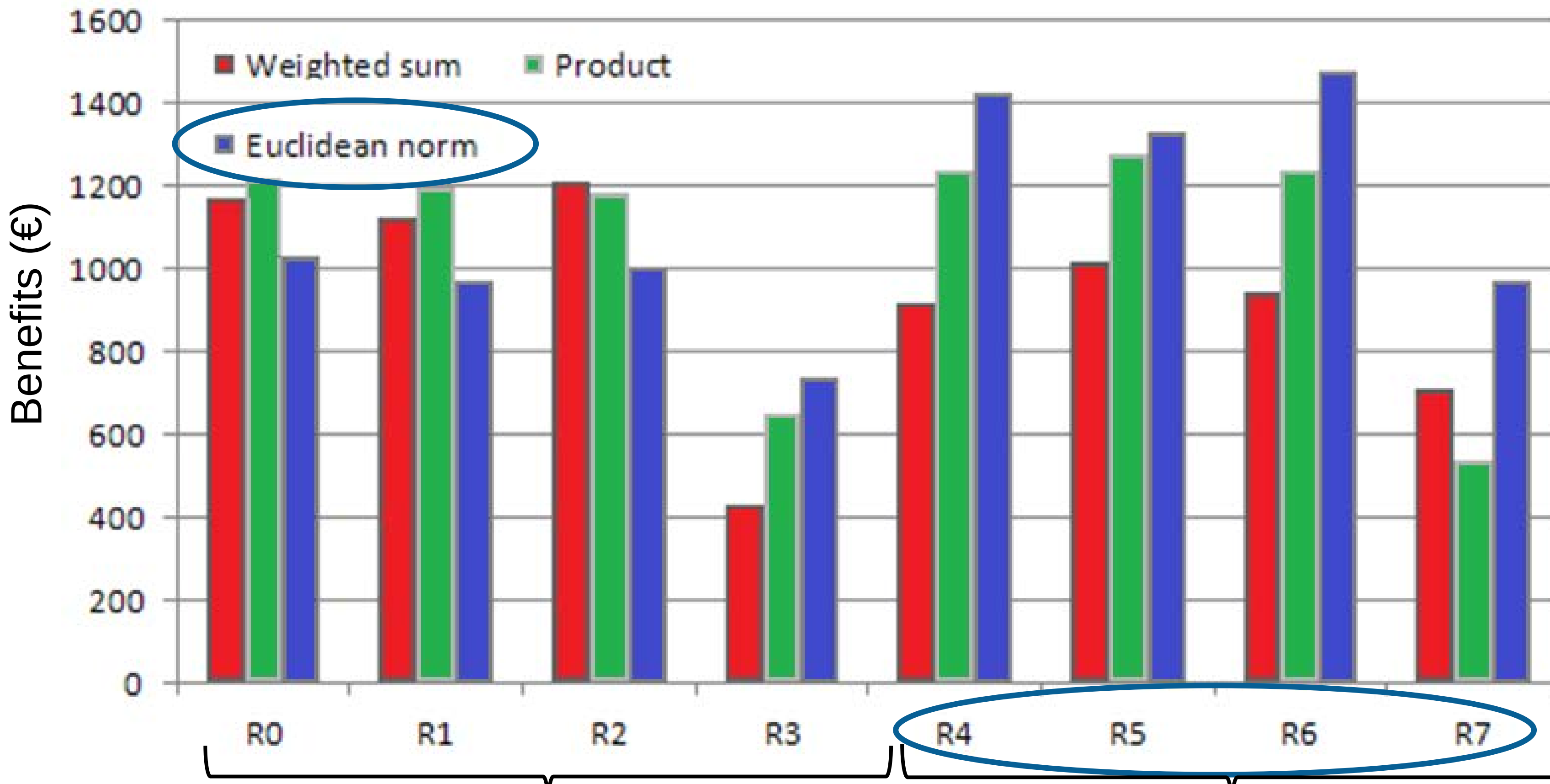
WORKFLOW SCHEDULING– EXAMPLE (iv)

Bidders profits

Euclidean norm favors balanced bidders



Unbalanced Attributes

Balanced Attributes

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WORKFLOW SCHEDULING– EXAMPLE (v)

Bidders profits

Cheaters obtain less benefits than honest bidders

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ABOUT ATTRIBUTES

Bidder-provided attributes

Unverifiable bidder attributes

Verifiable bidder attributes

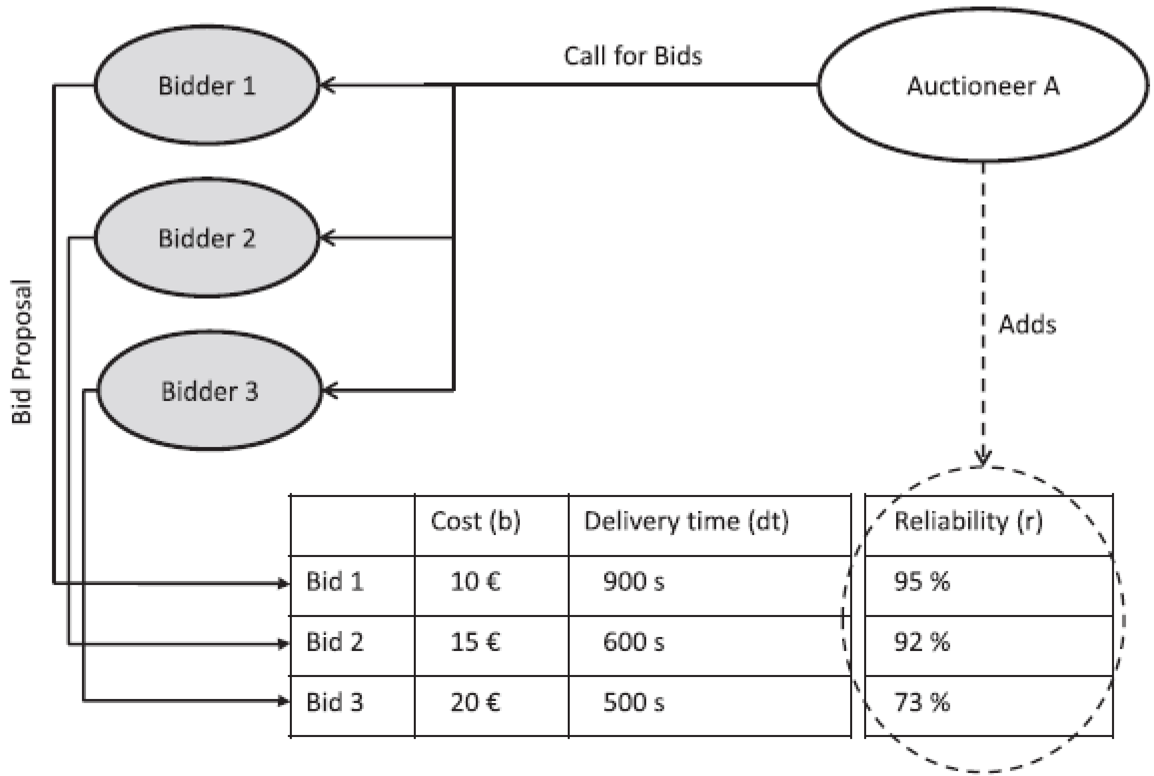
Auctioneer-provided attributes

Attribute ownership

Attribute verifiability

Pla, A., López, B., Murillo, J., Maudet, N.: Multi-attribute auctions with different types of attributes: enacting properties in multi-attribute auctions. Expert Syst. Appl. 41(10), 4829–4843 (2014)

EXAMPLE



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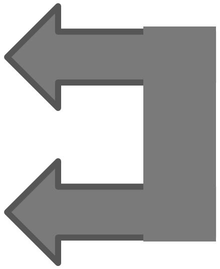
ATTRIBUTES ROLES

- **Call-for-proposals:**
  - Initial attributes : verifiable attributes
- **Bidding:**
  - Adding unverifiable attributes
- **Winner determination problem:**
  - Adding auction attributes
  - Deciding with all the attributes together (aggregation)
- **Payment:**
  - Playing all the attributes together



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BY EXAMPLE
CALL FOR PROPOSALS

Verifiable attributes

$$CFP = \langle S_0, \underbrace{(q, [1,2])}, \underbrace{(t, [60, 100])} \rangle$$

Service, task requested

Quality

Time (duration)

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BY EXAMPLE BIDDING

Verifiable attributes

Unverifiable attributes

$$CFP = \langle S_0, (q, [1,2]), (t, [60, 100]) \rangle$$

Agent a	(**100**, 1.2, 80)
Agent b	(**95**,1.2, 90)
Agent c	(**99**, 1.3, 85)

Economic price (ec)

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BY EXAMPLE
WINNER DETERMINATION

Verifiable attributes

Unverifiable attributes

Auctioneer attributes

$$CFP = \langle S_0, (q, [1,2]), (t, [60, 100]) \rangle$$

Priority (w)

Agent a	(100, 1.2, 80, **0.80**)
Agent b	(95, 1.2, 90, **0.80**)
Agent c	(99, 1.3, 85, **0.85**)

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BY EXAMPLE
WINNER DETERMINATION

Verifiable attributes

Unverifiable attributes

Auctioneer attributes

$$CFP = \langle S_0, (q, [1,2]), (t, [60, 100]) \rangle$$

	Priority (w)	Evaluation function
Agent a	(100, 1.2, 80, **0.80**)	2,00
Agent b	(95, 1.2, 90, **0.80**)	2,85
Agent c	(99, 1.3, 85, **0.85**)	2,06

$$f_0(\langle ec_i, q_i, t_i, w_i \rangle) = ec_i * \frac{1}{q_i} * t_i * w_i$$

Product as aggregation function

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BY EXAMPLE
HOW MUCH TO PAY? (i)

Vickrey:

The payment to the winner should equal the offer provided by the second best bid according to the auctioneers valuation

Simple case: economic price

Winner bid: b1 (100, ~~1.2~~, ~~80~~, ~~0.80~~)

Second best: b2 (99, ~~1.3~~, ~~85~~, ~~0.85~~)

$$\boldsymbol{p = 99}$$

How to manage more attributes?

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BY EXAMPLE
HOW MUCH TO PAY? (ii)

Vickrey and Google inspired:

Adding the remainder attributes

Winner bid: b1 (100, 1.2, 80, 0.80)

$b1^-$: remove ec of b1 (1.2, 80, 0.80)

b1': add p to $b1^-$ (p, 1.2, 80, 0.80)

Second best: b2 (99, 1.3, 85, 0.85)

f_0(b1')=f_0(b2) → $\boldsymbol{p = f_0^{-1}(f_0(b2), b1^-)}$

$\boldsymbol{p}$ =**103,16**

How to manage cheaters?

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BY EXAMPLE
HOW MUCH TO PAY? (iii)

VMA2: two case scenario

Verifiable attributes

Are the received attributes (AT') as good as the ones of the bid (AT)?

Yes ✓

No ✗

VCG payment

$\boldsymbol{p}$ =103,16

Payment reduction

Amount it should have bid to win the auction with the delivered attributes

Winner bid: b1 (100, 1.2, 80, 0.80)
$b1^{-}$: remove ec of b1
b1': add p to $b1^{-}$
Delivered b2: (100, 1.15, 90, 0.80)
$f_0(b1') = f_0(b2) \rightarrow \boldsymbol{p} = \boldsymbol{f_0^{-1}(f_0(b2), b1^{-})}$
$\boldsymbol{p}$ =85.19

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OTHER WORKS (i)

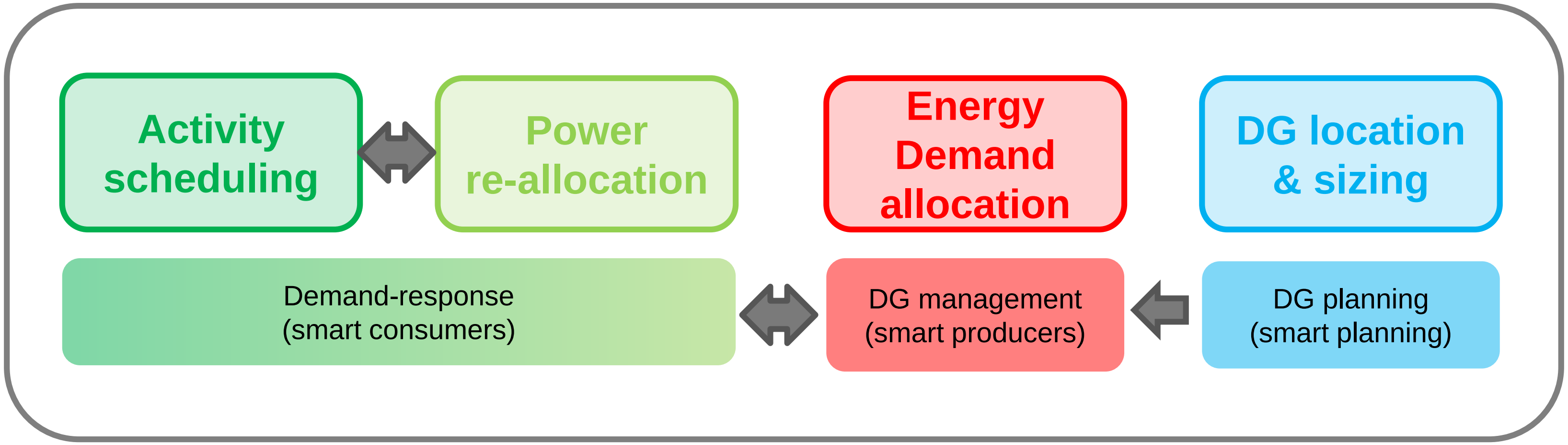
- Che, Y.-K. (1993). Design competition through multidimensional auctions. The RAND Journal of Economics, 24(4), 668–680
  - Payment: not necessarily with the same combination of attributes
- David, E., Azoulay-Schwartz, R., & Kraus, S. (2002). Protocols and strategies for automated multi-attribute auctions. In AAMAS ’02 (pp. 77–85).
  - First-price, sealed-bid
- Parkes, D. C., & Kalagnanam, J. (2005). Iterative multiattribute vickrey auctions. Management Science, 51, 435–451.
  - Iterative schema

OTHER WORKS (ii)

- Bellosta, M.-J., Kornman, S., & Vanderpooten, D. (2011). Preference-based english reverse auctions. Artificial Intelligence, 175(7–8), 1449–1467
  - Non-linear multi-criteria preference schema
- Mahr, T., & de Weerdt, M. M. (2006). Multi-attribute vickrey auctions when utility functions are unknown. In BNAIC, (pp. 221–227).
  - Multi-attribute auctions with preference orders
- Harrenstein, B. P., de Weerdt, M. M., & Conitzer, V. (2009). A qualitative vickrey auction. In EC ’09 (pp. 197–206).
  - Qualitative Vickrey Auctions
- Suyama, T., & Yokoo, M. (2004). Strategy/false-name proof protocols for combinatorial multi-attribute procurement auction. Proceedings of the third international joint conference on autonomous agents and multiagent systems. AAMAS ’04 (Vol. 1, pp. 160–167).
  - Attributes vary depending on the resource boundle assignted to tasks

APPLICATION: MANAGING ELECTRICITY

- **Demand-response (smart consumers): bring consumption near to generation**
- **Distributed Generation (DG) management (smart producers): bring generation to consumption**
- **DG planning (smart planning)**



F. Torrent-Fontbona. Optimisation methods meet the smart grid. New methods for solving location and allocation problems under the smart grid paradigm. PhD Manuscript, Universitat de Girona, 2015.

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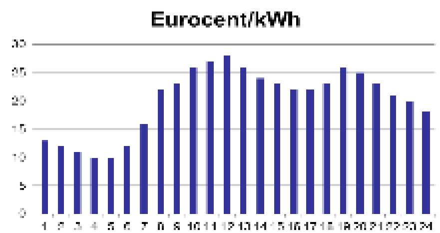
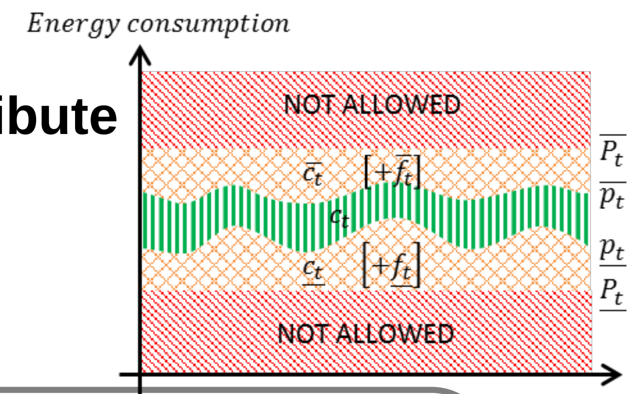
ENERGY-AWARE PROJECT SCHEDULING

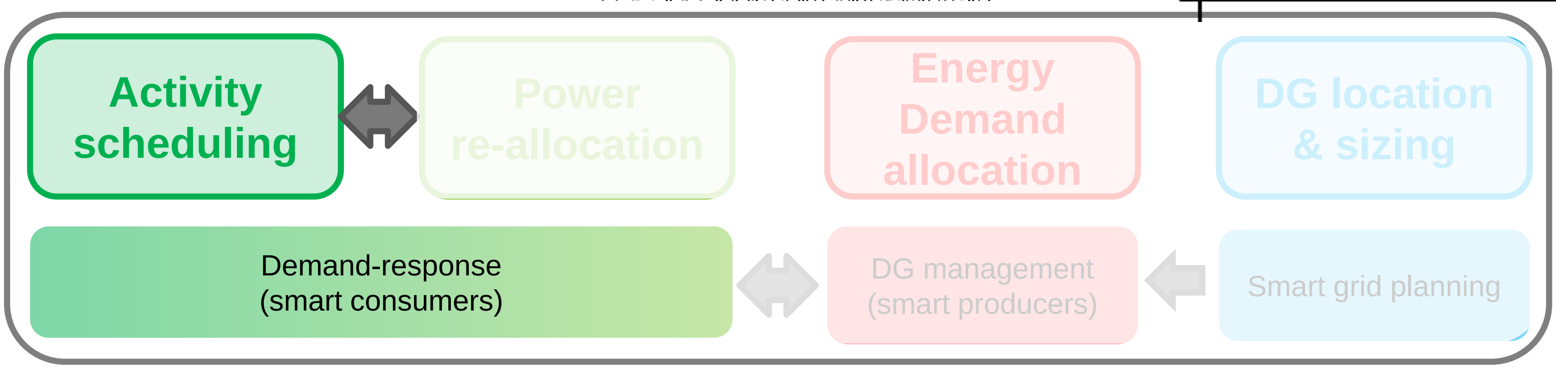
Workflow managers are concerned about multiple attributes besides energy consumption: multi-attribute scheduling

Energy consumption is not just another attribute

- Variable prices
- Profile constraints







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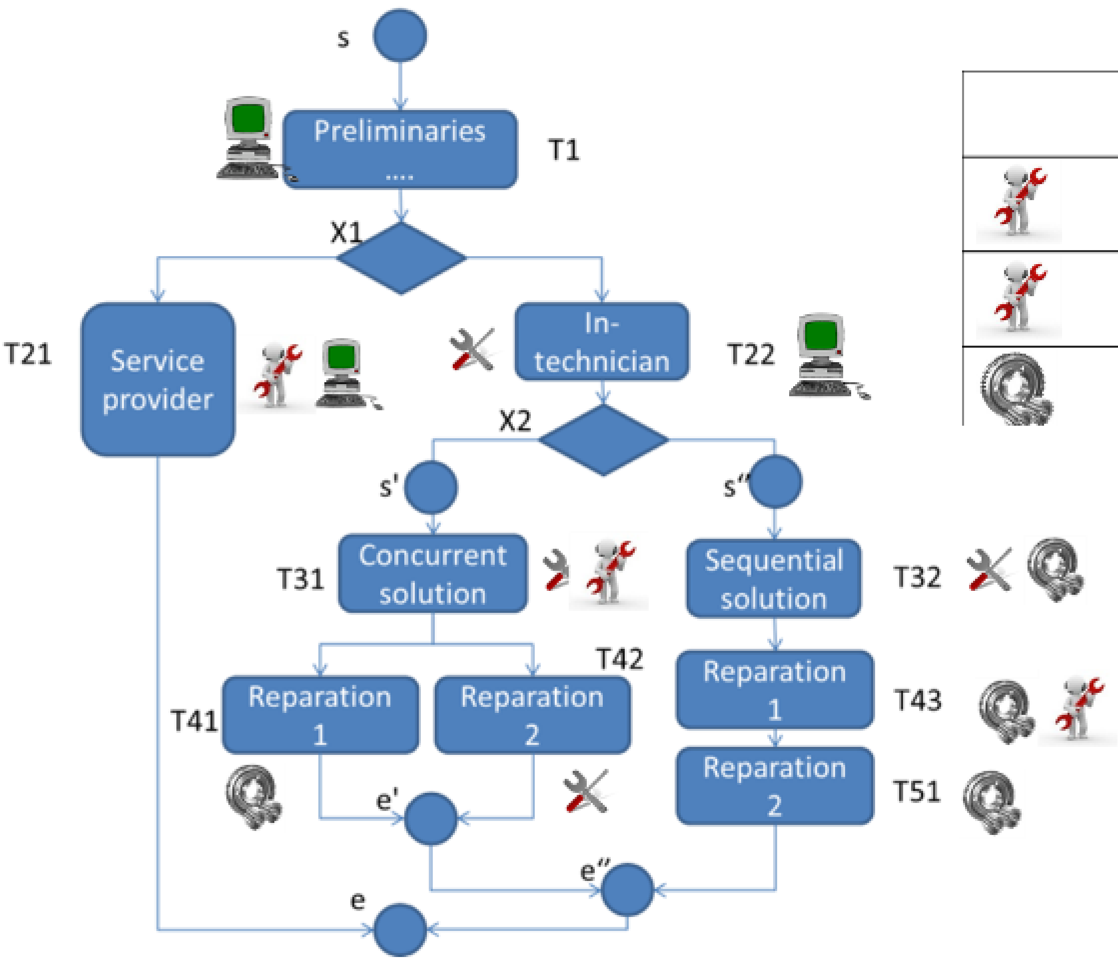
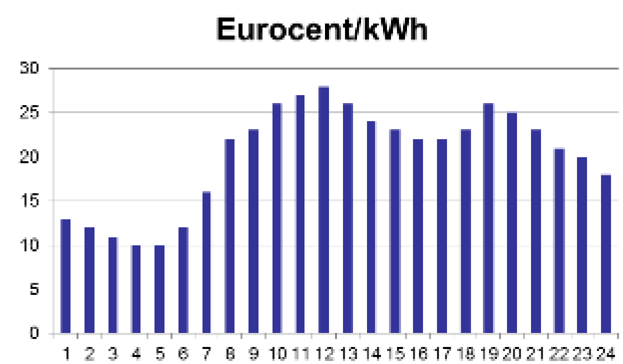
Torrent-Fontbona, F., Pla, B., López, A.: Using multi-attribute combinatorial auctions for resource allocation. In: Müller, J.P., Weyrich, M., Bazzan, A.L.C. (eds.) MATES 2014. LNCS, vol. 8732, pp. 57–71. Springer, Heidelberg (2014)

ENERGY
THE PROBLEM



	T21 - 3 €cent/h T31 - 4 €cent/h	100 €/h	T21 - 2h T31 - 1h
	T21-3 €cent/h T43-5 €cent/h	120 €/h	T21-5h T43-1h
	T32-2 €cent/h T41-1 €cent/h	60 €/h	T32-1h T41-1h



Whish is the optimal allocation of resources to tasks?

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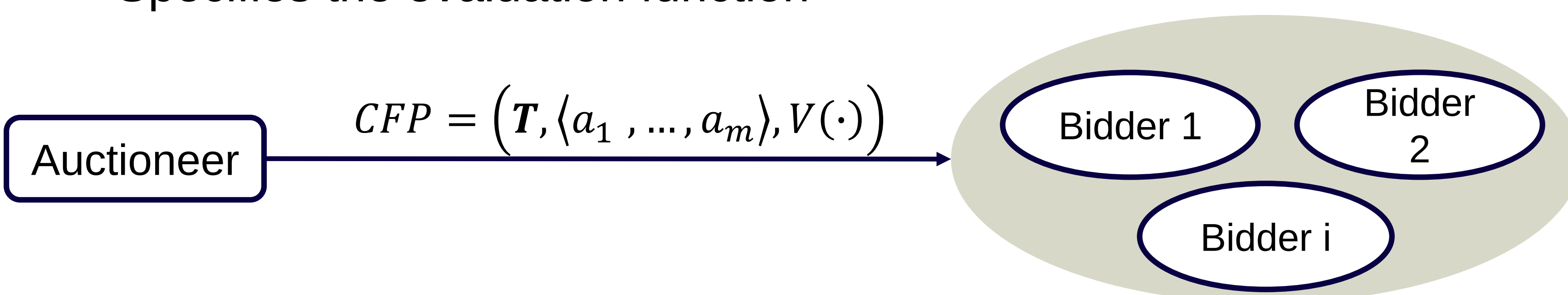
ENERGY CALL-FOR-PROPOSALS

- **An auctioneer A_0 needs to allocate a set of tasks $\boldsymbol{T} = \{T_1, \cdots, T_N\}$ with a set of attributes $a_1, \ldots, a_n$**

- **It Sends a call for proposals (CFP) to all the bidders**
  - Specifies the tasks
  - Specifies the attributes to evaluate
  - Specifies the evaluation function

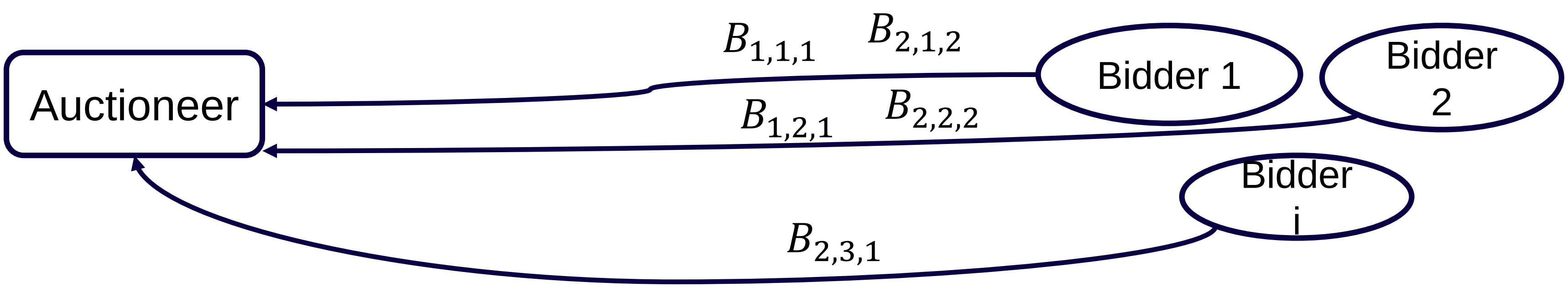


ENERGY BIDDING

Combinatorial, multi-attribute

Bidders evaluate the CFP and submit the bids with the corresponding attributes

$$B_{i,j,k} = \langle T_i @ s_{i,j,k} \colon (\mu_{i,j,k}, \varepsilon_i, \delta_i), M_{i,j,k}, E_{i,j,k}, \Delta_{i,j,k} \rangle$$



López, Ghose, Savarimuthu, Nowostawski, Winikoff and Cranefield. Towards Energy-Aware Optimisation of Business Processes Smartgreens 2014 (3rd International Conference on Smart Grids and Green IT Systems), Barcelona, 2014, 68-75.

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ENERGY WINNER DETERMINATION AND PAYMENT

- **WDP : weighted sum**

$$V(b_{i,j,k}, t_{i,j,k}, e_{i,j,k}) = w_0 * b_{i,j,k} + w_1 * t_{i,j,k} + w_2 * e_{i,j,k}$$

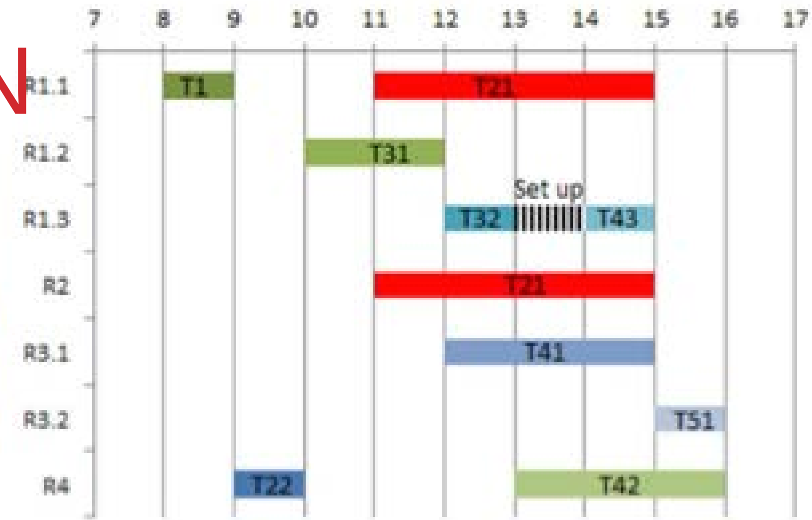
subject to $\sum_k w_k = 1, and \ w_k \in (0,1] \forall k$

- **Combinatorial optimisation problem → GA**
- **VMA2 (as explained before)**

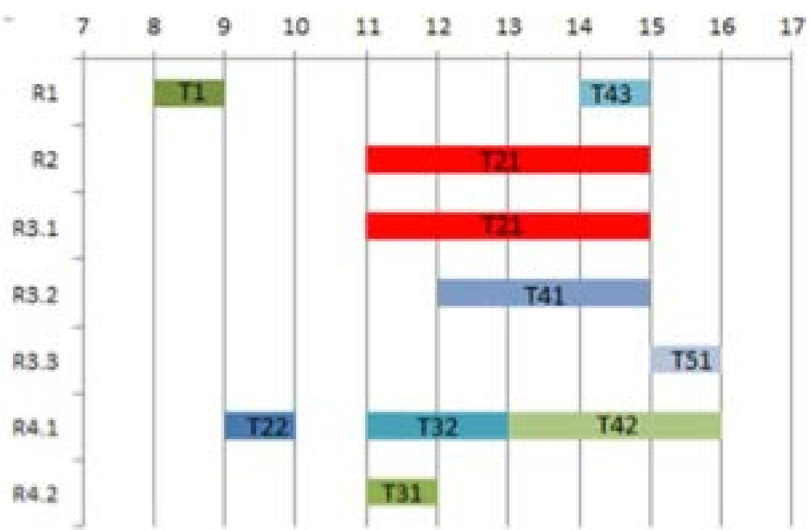
OUTCOMES.
NO AGGREGATION

	Scenario 1 Energy	Scenario 2 Money	Scenario 3 Makespan
Max $Cost_e$	11.58	15.38	12.28
Min $Cost_e$	2.84	3.97	3.02
Max $Cost_€$	1760.00	1320.00	1760.00
Min $Cost_€$	780.00	560.00	780.00
Max $Cost_t$	8.00	8.00	6.00
Min $Cost_t$	7.00	8.00	5.00

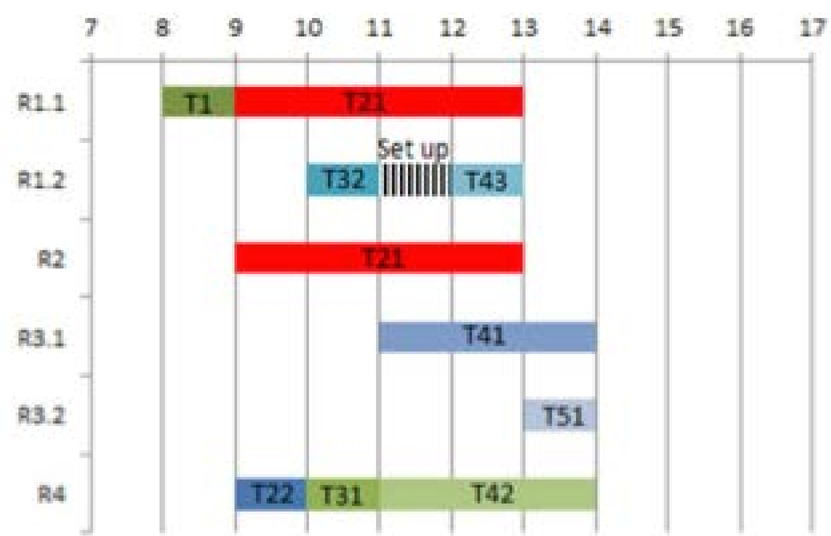
Energy wins



Money wins



Makespan wins



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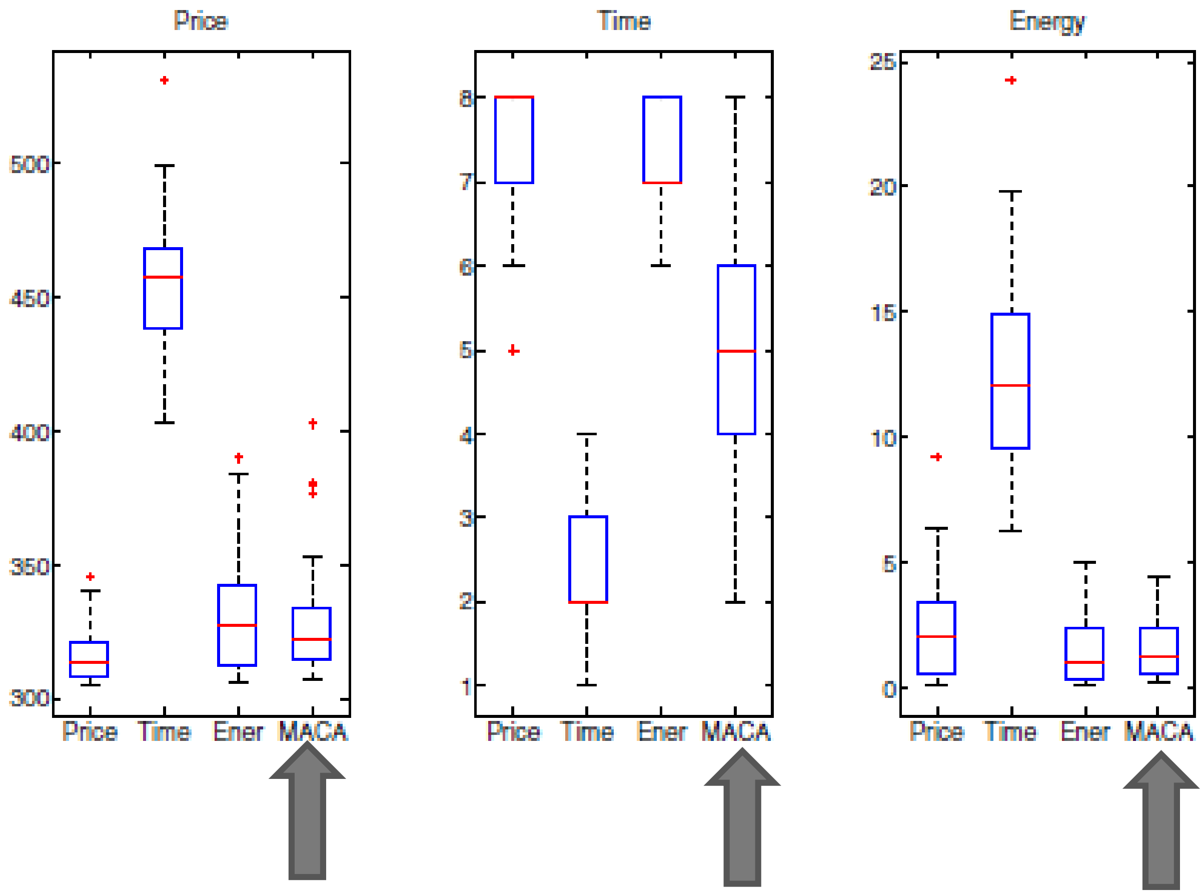
OUTCOME WITH AGGREGATION COMPARISON



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THE ROLE OF AGGREGATION FUNCTIONS ON

SOCIAL WELFARE

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GOAL

- **Given**
  - n utilities, one per agent, and an auction outcome O

    $$u_1(O), u_2(O), \dots u_n(O)$$

  - a social welfare measure sw(O)

Maximise: sw(O)

[sometimes minimize]

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APPROACHES

- **Utilitarian social welfare:** $sw_u(O) = \sum_{i=1}^{n} u_i(O)$
- **Egalitarian social welfare:**

$$sw_{e1}(O) = min_i \, u_i(O)$$

$$sw_{e2}(O) = max_i \, u_i(O) - min_i \, u_i(O)$$

$$sw_{e3}(O) = \sum_{i=1}^{n} \left| \frac{\sum_{i=1}^{n} u_i(O)}{n} - u_i(O) \right|$$

- **Nash product:** $sw_{nash}(O) = \prod_{i=1}^{n} u_i(O)$
- **Elitist social welfare:** $sw_{el}(O) = max_i \, u_i(O)$
- **Rank dictator,…..**
- **Envy-freeness (preferences), …**

Collective utilities

Chevaleyre, Y., Dunne, P.E., Endriss, U., Lang, J., Lemaître, M., Maudet, N., Padget, J.,Phelps, S., Rodriguez-Aguilar, J.A., Sousa, P.: Issues in multiagent resource allocation. Informatica 30(1) (2006)

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EGALITARIAN MECHANISM DESIGN

PRIORITIES: AUCTIONEER-PROVIDED ATTRIBUTE

QUANTITATIVE

- **Number of victories and defeats obtained**
- **Won auction coefficient**

$$w_i = 1 - \frac{1 + won(a_i)}{1 + par(a_i)}$$

- **Loss streak**

$$w_i = 1 - \frac{max(0, ml - ls(a_i))}{ml}$$

ml: tolerance threshold
ls: loss streak

QUALITATIVE

- **Use the information of the bids**
- **Fitness of the bid:** $\boxed{q_i = \frac{V(B_1')}{V(B_i')}}$
- **Bid-based won auction coefficient (BBWOC)**

$$w_i = 1 - \frac{1 + won(a_i)}{1 + \sum_{j=0}^{c-1} q_i^j}$$

- **Bid-based loss streak (BBLS)**

$$w_i = 1 - \frac{max\left(0, ml - \sum_{j=c-ls(a_i)}^{c-1} q_i^j\right)}{ml}$$

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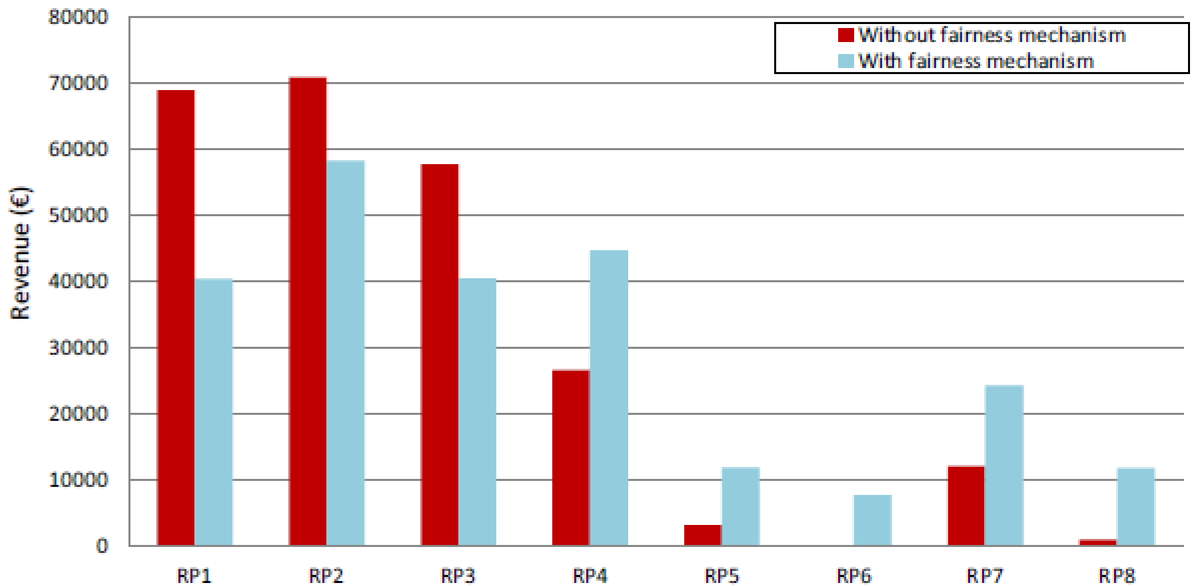
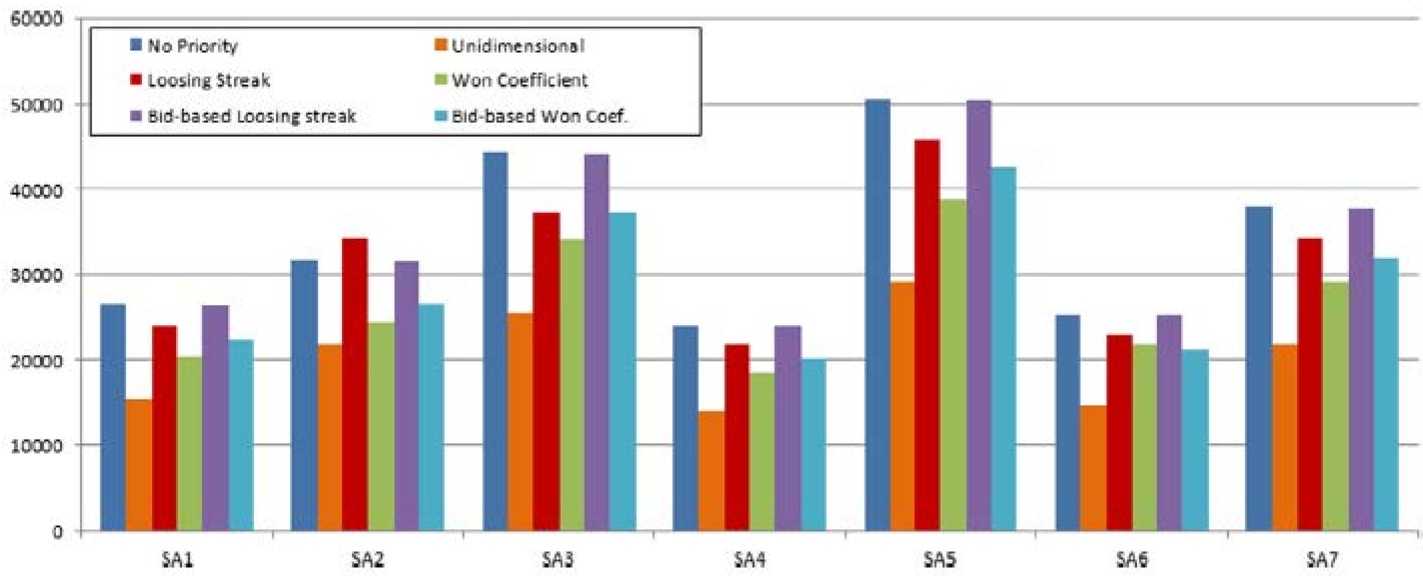
Pla, A., López, B., Murillo, J.: Multi-dimensional fairness for auction-based resource allocation. Knowl.-Based Syst. 73, 134–148 (2015)

OUTCOME
BIDDERS WEALTH RANK



Agent's Wealth rank	RP1	RP2	RP3	RP4	RP5	RP6	RP7	RP8
	2 3	1 1	3 4	4 2	6 6	8 8	5 5	7 7

OUTCOME
AUCTIONEER EXPENDITURE



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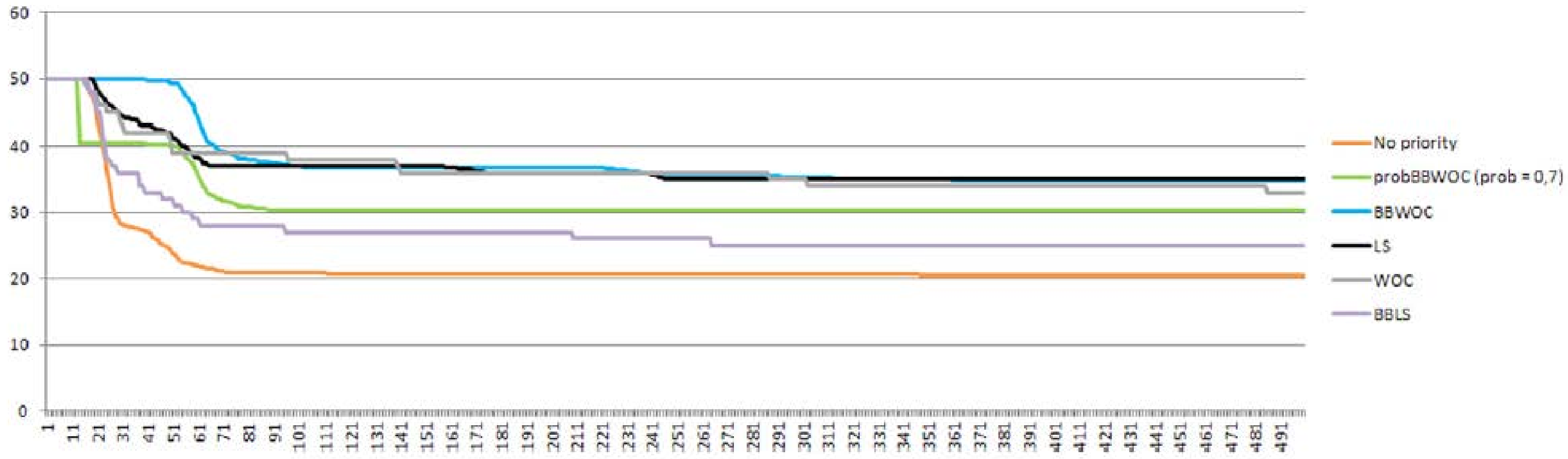
OUTCOMES
ACTIVE BIDDERS IN THE MARKET



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THE ROLE OF AGGREGATION FUNCTIONS ON

PARAMETER ADAPTATION

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MOTIVATION

Misdelivered tasks involve:

- Delays
- Budget problems
- Quality problems
- Loss of competitiveness
- …

They are due:

- Cheating behaviors
- Involuntary errors
    - Bidders may not be able to accurately estimate their abilities

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SOLUTIONS

Cheating agents:

- Incentive Compatible Mechanism
  - Vickrey Based Auction (VCG Payment rule)
  - …
- Multi-attribute auctions → use of aggregation functions

Involuntary errors and misestimating the abilities

- Porter's auction → uncertainty attribute for the WDP
- Ramchurn's auction → trust attribute for the WDP and payment
- …

Can we tune attributes according to trust?

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MULTI-ATTRIBUTE AUCTIONS AND TRUST

Trust :

- Trust values between 0 (worse) and 1 (best)
- Evaluation function V(.):
  - Trust as an auctioneer provided attribute
  - Trust for tuning / filtering the parameters of other attributes
- Learning / adaptation

$$B_i = \langle b_i, t_i, e_i \rangle$$

$$V\left(b_i, \frac{t_i}{\tau_{i,r}^{t}}, \frac{e_i}{\tau_{i,r}^{e}}\right)$$

$$\tau_{i,r+1}^{t} = \begin{cases} \tau_{i,r}^{t} + \alpha_t\left(1 - \tau_{i,r}^{t}\right) & \text{if } t_i' \leq t_i' \\ \tau_{i,r}^{t} - \beta_t \tau_{i,r}^{t} & \text{otherwise} \end{cases}$$

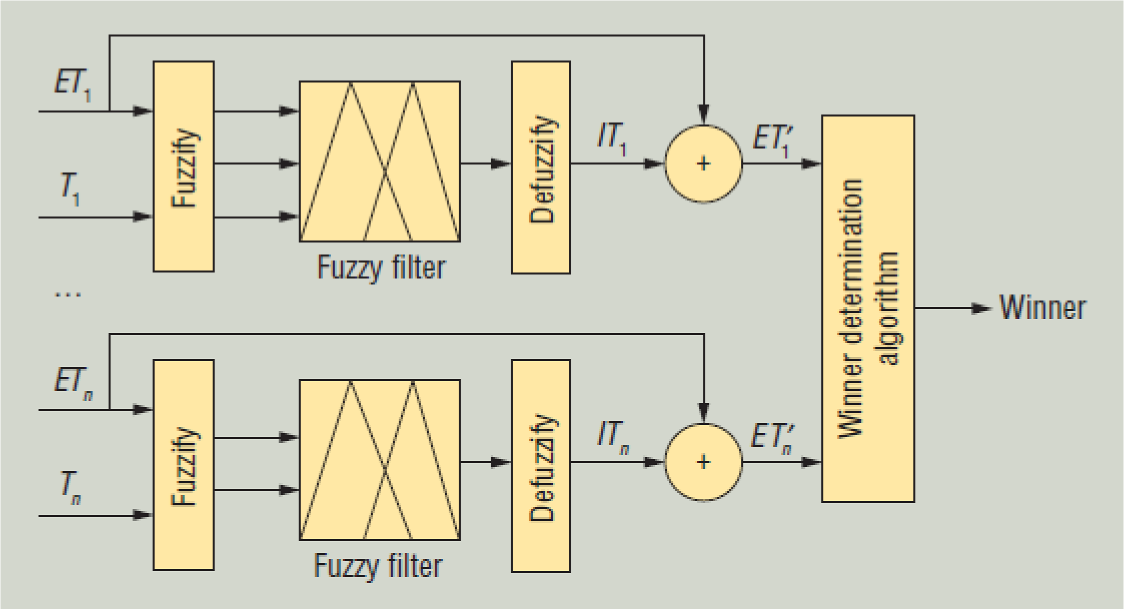
$$\tau_{i,r+1}^{e} = \begin{cases} \tau_{i,r}^{e} + \alpha_e\left(1 - \tau_{i,r}^{e}\right) & \text{if } e_i' \leq e_i' \\ \tau_{i,r}^{e} - \beta_e \tau_{i,r}^{e} & \text{otherwise} \end{cases}$$

$$\alpha_t, \beta_t \in [0,1] \qquad \alpha_e, \beta_e \in [0,1]$$

Torrent-Fontbona, F., Pla, A., López, B.: New perspective of trust through multi-attribute auctions. In: Papers from the AAAI Workshop in Incentive, Trust in E-Communities, pp. 25–31 (2015)

OTHER ADAPTATION APPROACHES

Fuzzy filtering



Lopez, B., Innocenti, B., Busquets, D. A Multiagent System to Support Ambulance Coordination of Urgent Medical Transportation. IEEE Intelligent Systems vol. 23, no. 5, pp. 50-57, Sept/Oct, 2008.

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REACHING THE END OF THE TALK:

SUMMARY AND CONCLUSIONS

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THE ROLE OF AGGREGATION FUNCTIONS ON AUCTIONS

- **The evaluation function**
  - Bidders: deciding the bid
  - Auctioneers: aggregating attributes of bids to decide the winner(s)
- **Social welfare measures**
  - Aggregation of utilities
  - Qualifying history of bids in egalitarian approaches
- **Parameter adaptation**
  - Trust mechanisms

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THANKS !

Javier Murillo

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Albert Pla

Ferran Torrent-Fontbona

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