Multi-Attribute Auctions: Application to Workflow Management Systems

Albert Pla Planas

Supervisors:
Dra. Beatriz López and Dr. Javier Murillo
Departament EEEA

Universitat de Girona

eXiT
Control Engineering and Intelligent Systems

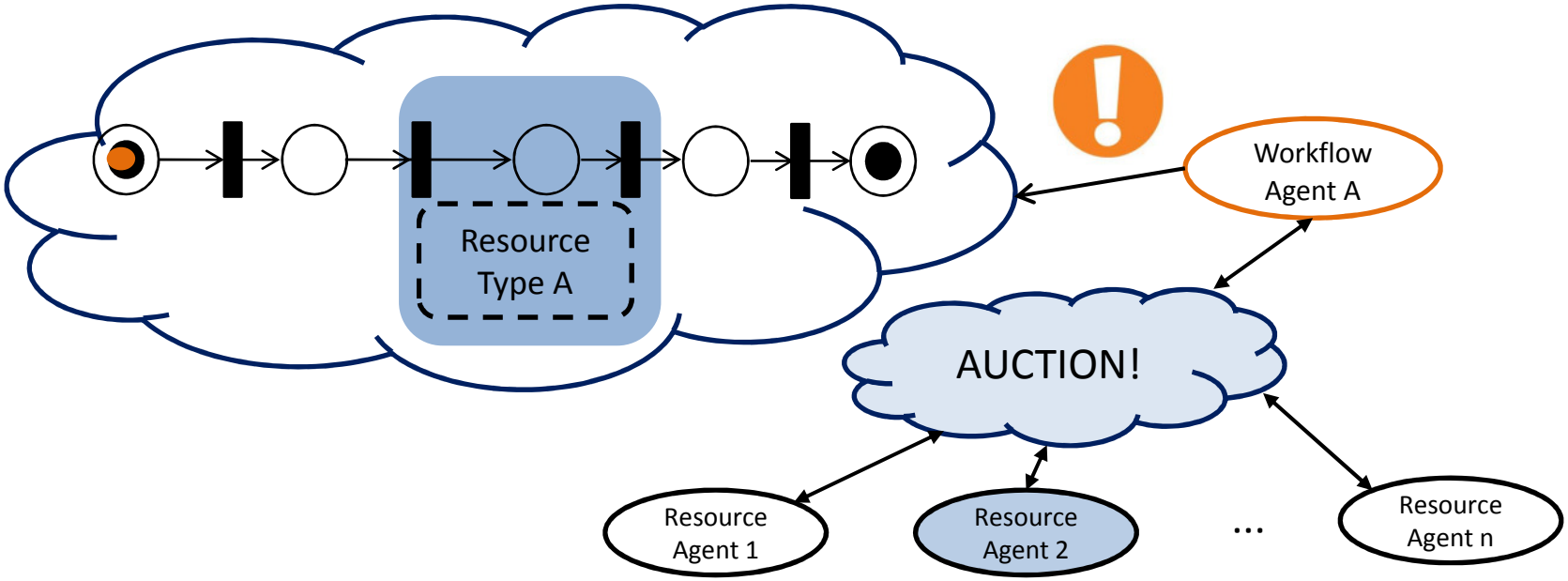
Index

- Introduction
- Auctions for multi-attribute resource allocation
- PUMAA: Preserving utility multi-attribute auctions
- FMAAC: Framework for multi-attribute auction customization
- Multi-dimensional fairness for multi-attribute auctions
- Conclusions

Introduction

Auctions in workflow management systems

- Auctions allow an optimal allocation for just-in-time:
  - Competitive market
  - Optimization according to a given criteria.



Auctions in workflow management systems

- Just-in-time resource allocation

- Special domains:
  - Production not known in advance
  - Production under demand / Supply chain under demand
  - Handling unexpected tasks (provoked by faults)
  - Unknown resource status
  - Outsourced resources

WMS: Multi-dimensional allocation problem

- Workflow managers are not only concerned by costs:
- Workflow managers are concerned about multiple attributes:
  - Economic costs
  - Product quality
  - Delivery times
  - Licenses / ISO standardizations
  - CO_2 emissions
  - Energy consumption
  - …

WMS: Multi-dimensional allocation problem

- Multi-criteria allocation problem
  - Number of attributes considered in the allocation > 1
  - Modifying one attribute can condition the value of the rest
- Multi-attribute auctions
  - Number of attributes involved in the auction >1
  - Bids composed by several attributes.
  - Usually economic cost plus another attribute.

- Develop a multi-attribute auction mechanism for allocating resources and tasks in workflows

Resource allocation in the supply chain issues

- Example: Smartphone manufacturer.
  - Needs to provide a bundle of smartphones in two days.
    Deadline = 2800 minutes
  - Sequentially outsources the manufacturing of the phone parts and ensembles them.
  - Maximum Budget = 200€


+

+

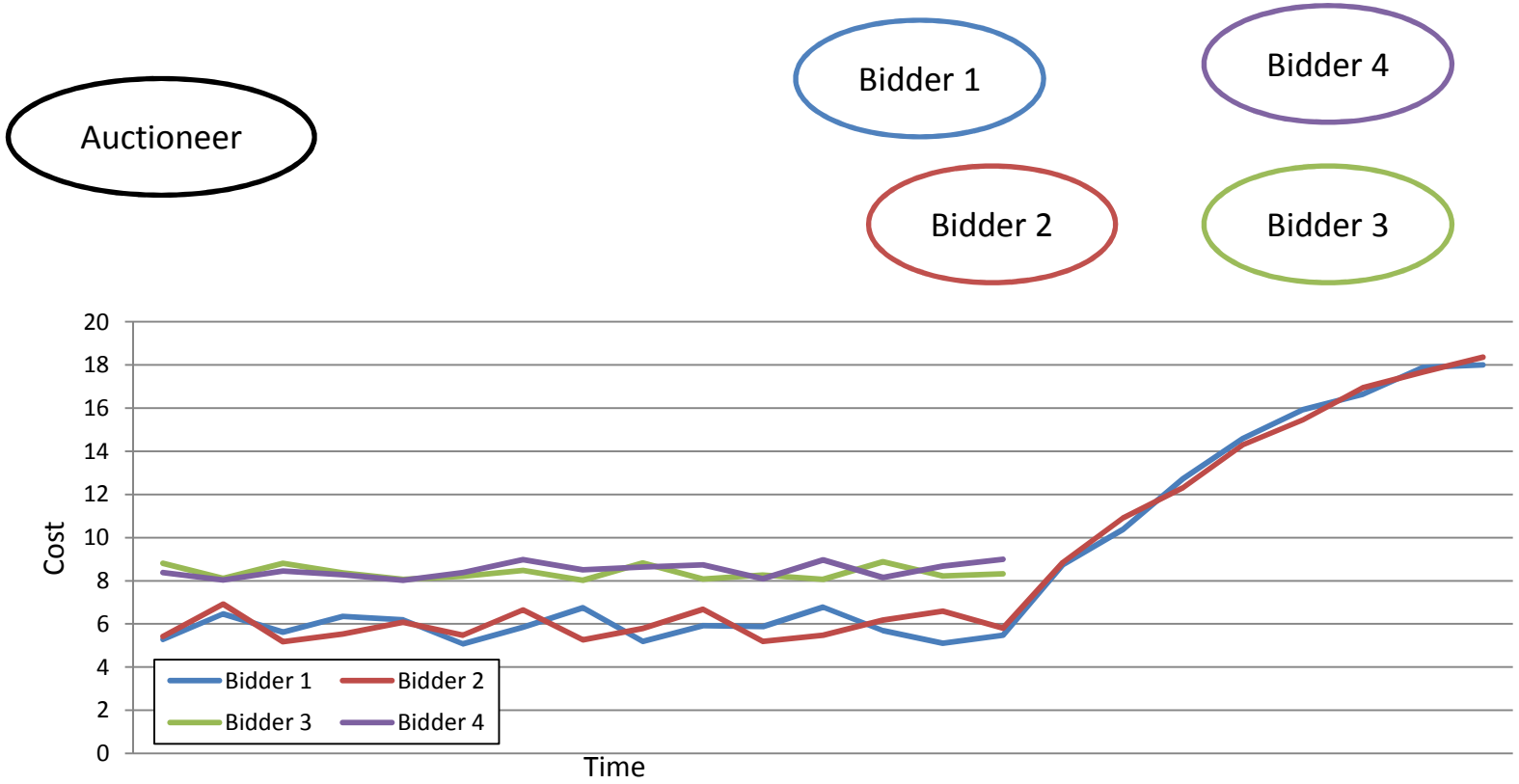
=


Max time = 2800
Max cost = 200€

	Can invest	Can invest	
Agreement:	900 mins 80 €	1000 mins 60 €	900 mins 800 mins 60 €
	850 mins 120 €	1200 mins 55 €	
Provided:	900 mins 80 €	1100 mins	

Recurrent auctions issues

- Always the same participants in the market.
- **Bidder drop problem (BDP)**: Unsatisfied bidders leave the auction and the stronger bidders create an oligopoly.



Challenges

- Multi-attribute incentive compatibility
  - Encourage resource providers (RP) to reveal their **true values** in terms of **cost** and **attributes** (respect their agreements)
- Workflow related issues
  - **Misdelivered tasks**
  - Delays, budget problems, quality problems…
- Recurrent auctions' issues
  - **Bidder drop problem**
  - **Fairness** in multi-criteria problems

Challenges vs. Contributions

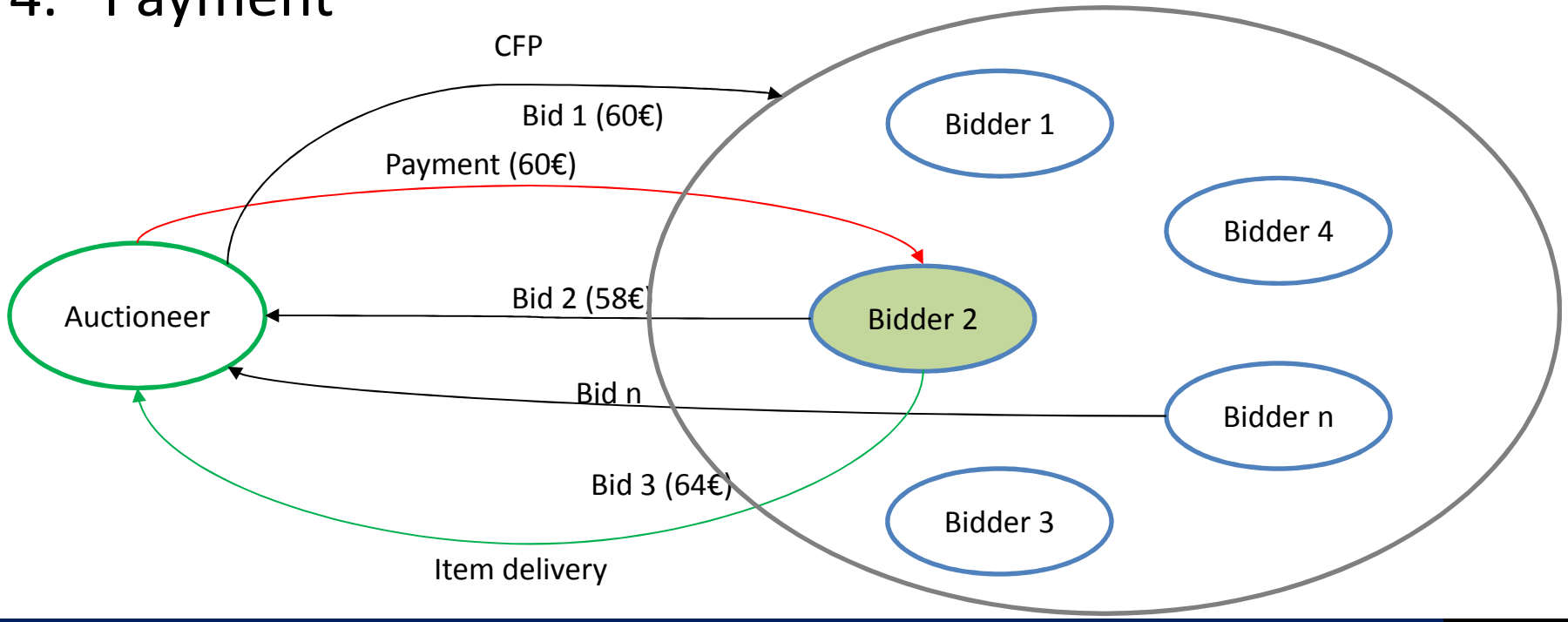
- Multi-attribute IC
- Workflow related issues
- Recurrent auctions' issues

- PUMAA
  - Design of a multi-attribute auction for task allocation
  - Multi-criteria requirements study
- FMAAC
  - Study attribute types in auctions
  - Develop a framework for customizing multi-attribute auctions
- Multi-dimensional fairness
  - Multidimensional-fairness mechanism for MARA.
  - Fair version of PUMAA
  - Minimize the bidder drop problem

Auctions for Multi-Attribute Resource Allocation (MARA)

Background: Auction protocol steps

1. Call for proposals (CFP)
2. Bidding
3. Winner determination problem (WDP)
4. Payment



Background: Auction Properties

- Mechanism Properties
  - Incentive Compatibility
    - Encourage truthful bidding
  - Efficiency
    - Best allocation possible
  - Buyer optimality
    - Best possible price
  - Individual-rationality
    - It is not harmful to participate
  - Budget-balance
    - No need of external subsidy
- Allocation properties
  - Social Welfare
    - Utilitarian
    - Egalitarian
  - Robustness
    - Reduce utility loss
    - Provide alternative solutions
  - Reliable
    - Confidence of success

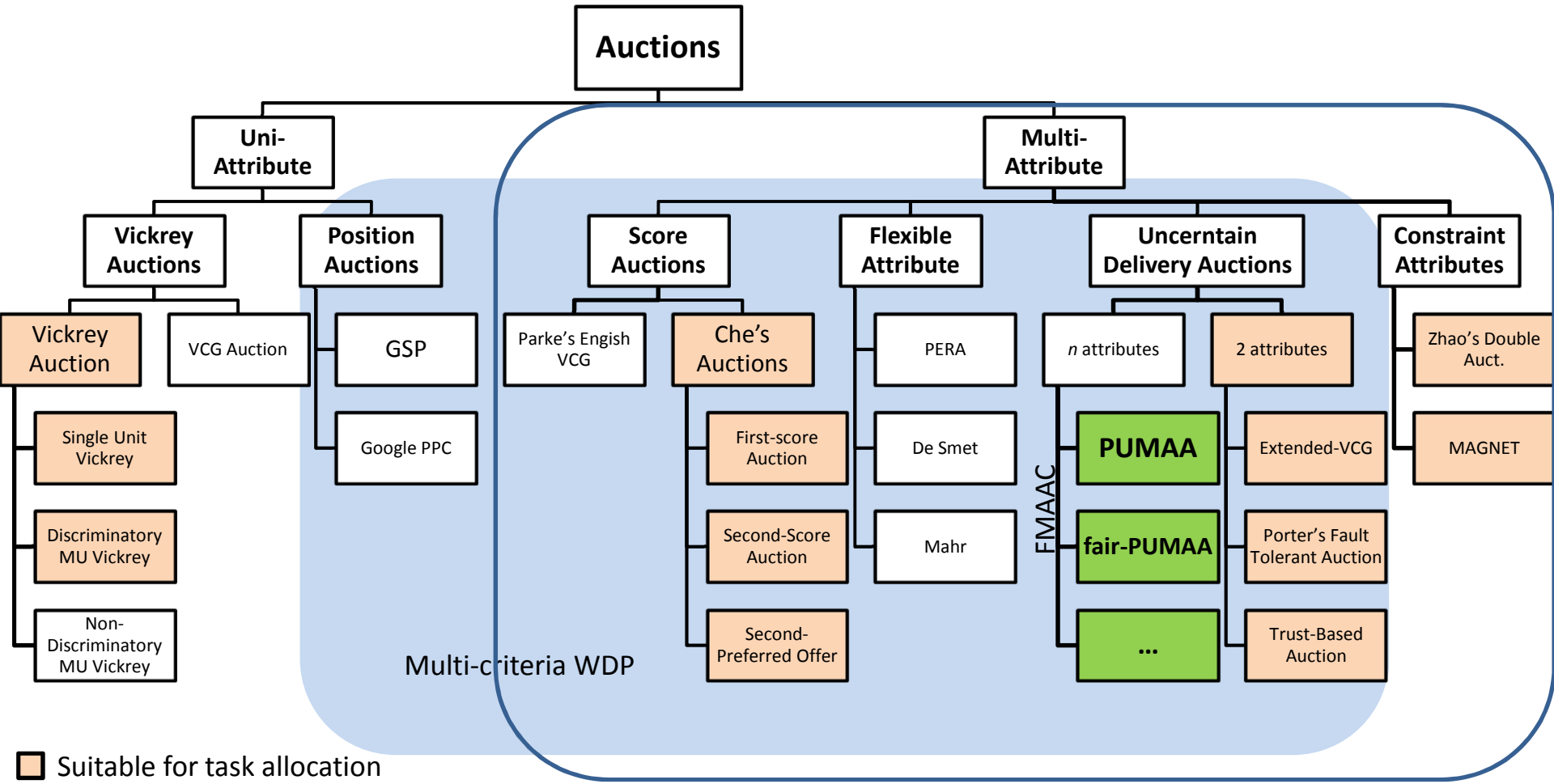
Auction state of the art

		Type			Auction Propperties					Allocation Properties				Particularities			
		Sides	Items auctioned	1st / second price	Efficient	Incentive Compatible	Buyer-optimal	Individually rational	Budget Balance	BDP considered (fairness)	Robustness	Reliability	Social Welfare	Multi-criteria WDP	Bidder's attributes	Task allocation suitable	Procurement suitable
UniAttribute	Vickrey Auction	One	1	2	✓	✓	✗	✓	✓	✗	✗	✗	Util.	✗	1	✓	✓
	MU Discriminatory Vickrey	One	n of the same type	2	✓	✗	✗	✓	✓	✗	✗	✗	Util.	✗	1	✓	✓
	MU non Discriminatory Vickrey	One	n of the same type	2	✓	✓	✗	✓	✓	✗	✗	✗	Util.	✗	1	✓	✓
	VCG Auction	One	n	2	✓	✓	✗	✓	✓	✗	✗	✗	Util.	✗	1	✓	✓
	GSP	One	n	2	✗	✗	✗	✓	✓	✗	✗	✗	Util.	✗	1	?	?
	Google GSP	One	n	2	✓	✓	✗	✓	✓	✗	✗	✗	Util.	✗	1	?	?
Multi-attribute	Che's first-score	One	1	1	✗	✗	✓	✓	✓	✗	✗	✗	Util.	✓	n	✓	✓
	Che's second-score	One	1	2	✓	✓	✗	✓	✓	✗	✗	✗	Util.	✓	n	✓	✓
	Che's second-preferred-offer	One	1	2	✓	✗	✗	✓	✓	✗	✗	✗	Util.	✓	n	✓	✓
	Parkes Modified VCG	One	1	English 1st	✓	Nash-Bayes	✗	✓	✓	✗	✗	✗	Util.	✓	n	✗	✓
	David's English auction	One	1	English 2nd	✓	✓	✗	✓	✓	✗	✗	✗	Util.	✓	n	✗	✓
	PERA	One	1	depends	✓	depends	depends	✓	✓	✗	✗	✗	Util.	✓	n	✗	✓
	De Smet auction	One	1	depends	✓	depends	depends	✓	✓	✗	✗	✗	Util.	✓	n	✗	✓
	Mahr unkown utility func.	One	1	2	✓	✗	✗	✓	✓	✗	✗	✗	Util.	✓	n	✓	✓
	VCG trust extension	One	1	2	✗	✗	✗	✓	✓	✗	✓	✗	Util.	✓	2	✓	✓
	Porter's fault tolerant	One	1	2	✓	✓	✗	✓	✓	✗	✓	✓	Util.	✓	2	✓	✓
	Ramchurn's trust	One	1	2	✓	✓	✗	✓	✓	✗	✓	~	Util.	✓	2	✓	✓
		One	n	2	✓	✓	✗	✓	✓	✗	✗	✗	Util.	✗	2	✓	✓
	Zhao's double auction	Double	n	2	✓	✓	✗	✓	✓	✗	✗	✗	Util.	✗	2	✓	✓
	PUMAA	One	1	2	✓	✓	✗	✓	✓	✗	✓	~	Util.	✓	n	✓	✓

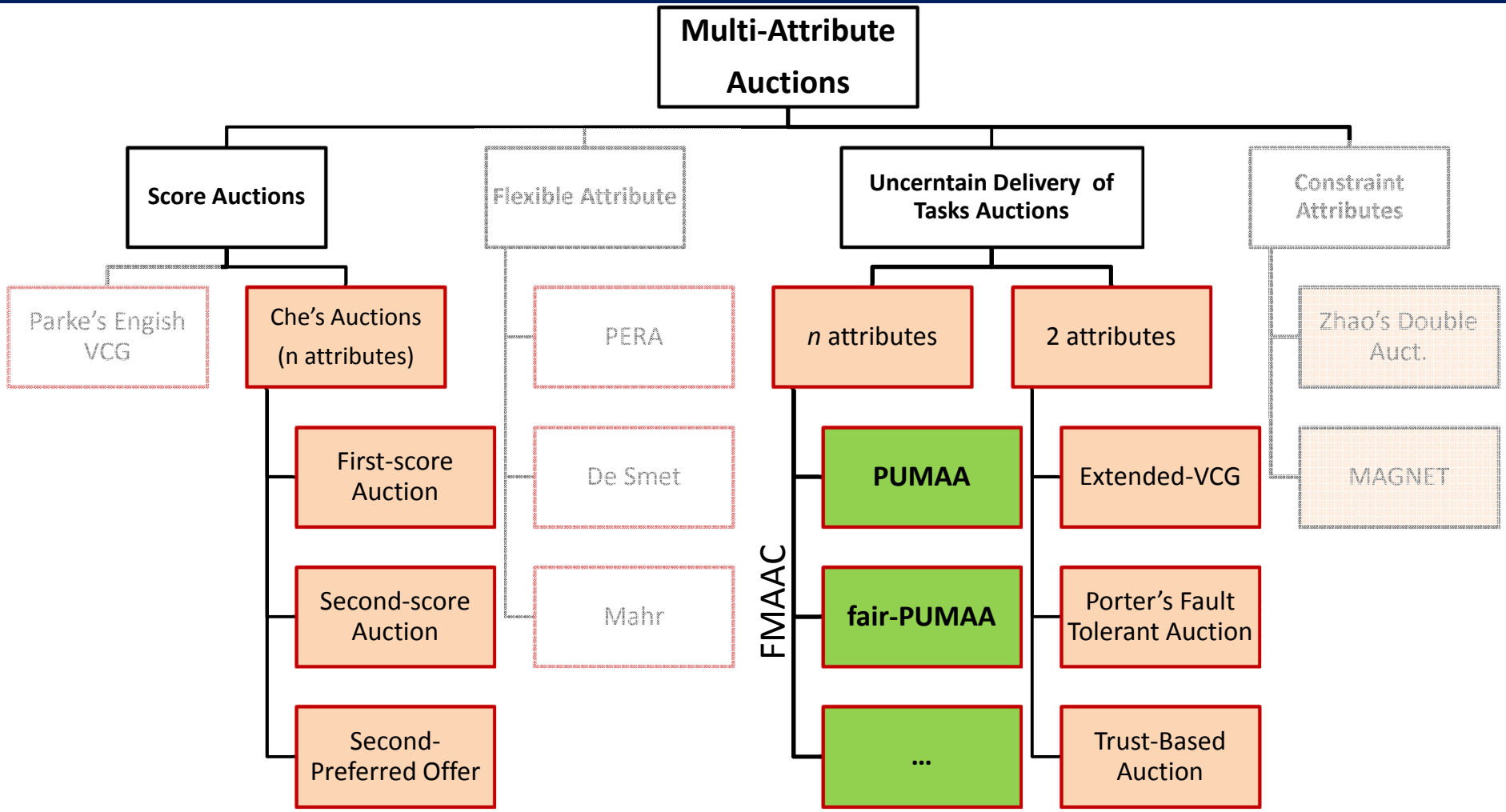
Auction dimensionality

	Uni-attribute auction	Multi-attribute auction
Uni-criteria WDP	Vickrey Auction Multi-unit Vickrey Auctions VCG Auction Generalized Second Price English Auctions Dutch Auctions	Zhao's Double Auction MAGNET
Multi-criteria WDP	Google PPC Auction	Che's Auctions Parkes Modified VCG David's English Auction PERA De Smet Auction Mahr Auction VCG-POS Porter's Fault Tolerant Auc. Ramchurn's Trust Auc.

Multi-attribute resource/task allocation



Multi-attribute resource/task allocation



PUMAA:
Preserving Utility Multi-attribute Auctions

Requirements

- Reverse auction mechanism for task & resource allocation
- Several attributes
- Incentive Compatible
  - Economic cost (bidders bid their real economic aims)
  - Attributes (bidders submit the attributes they intend to deliver)
- Tolerance to uncertainty of task delivery
  - The delivered attributes may vary from the ones agreed
- Robustness (avoid utility loss)

[2] *Multi-Attribute Auction Mechanism for Supporting Resource Allocation in Business Process Enactment.* A Pla, B López, J Murillo STAIRS@ECAI 2012, 228-239

Assumptions & limitations

- Unknown task schedule (allocated on-the-go)
  - Discards COP solvers, genetic algorithms, etc.
- Tasks are always developed (in better or worst conditions)
- The variation of the task attributes affects agents utilities
- Bidding strategies are out of the thesis scope
- No externalities: Bidders are just concerned in the present auction

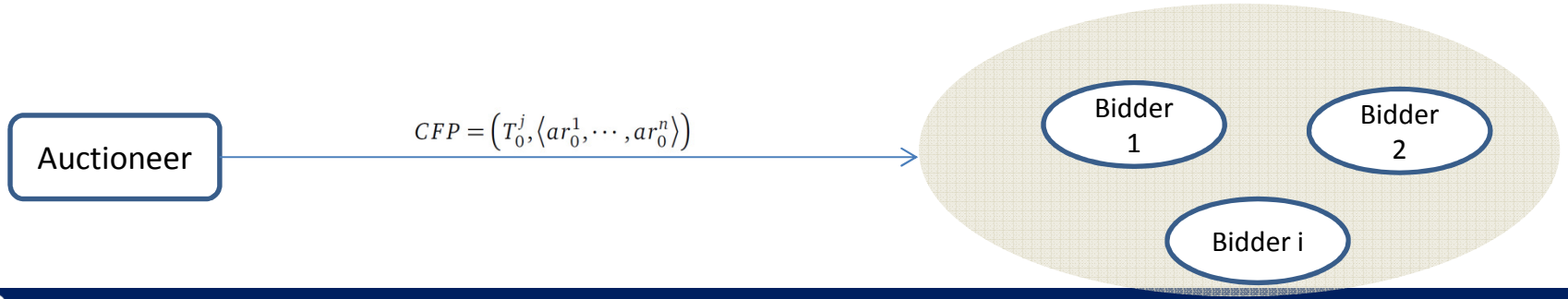
1. PUMAA: Call for Proposals

- An auctioneer a_0 needs to allocate a task T^j

$$T^j = \left\langle pa_1^j, \cdots, pa_m^j \right\rangle$$

- Sends a call for proposals (CFP) to all the bidders
  - Specifies the task
  - Specifies the attribute requirements

$$CFP = \left(T_0^j, \left\langle ar_0^1, \cdots, ar_0^n \right\rangle \right)$$



2. PUMAA: Bidding

- Bidders (a_i) evaluates the CFP and submits a bid

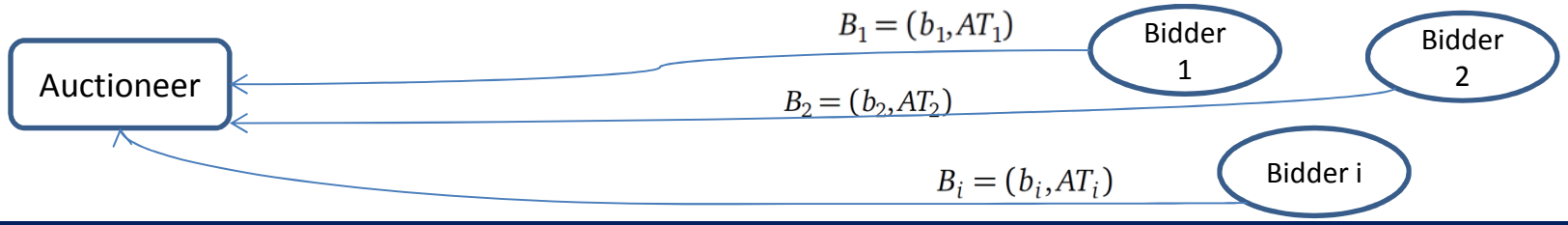
$$B_i = (b_i, AT_i)$$

- Utility of a bidder:

$$b_i^t = v_i(T_0^j, AT_i^t)$$
$$u_i(p_i, b_i^t) = p_i - b_i^t$$

- Truthful or untruthful bid

$$B_i = (b_i, AT_i) | b_i = b_i^t \vee AT_i = AT_i^t$$
$$B_i = (b_i, AT_i) | b_i \neq b_i^t \vee AT_i \neq AT_i^t$$



3. PUMAA: Winning determination problem

- The winner is determined by an **evaluation function V_0**

$$V_0(b_i, AT_i)$$

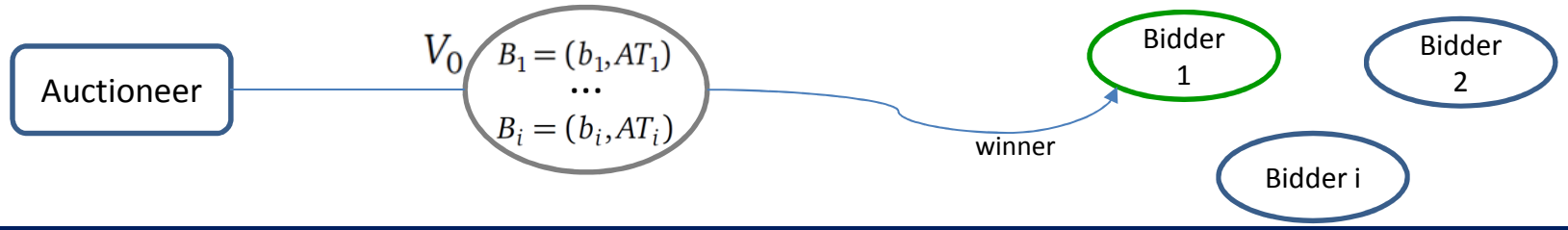
$$argmin_i(V_0(b_i, AT_i))$$

- The evaluation function will maximize the auctioneer a_0's expected utility $\bar{u}$.

$$\bar{u}_0(T_0^j, b_i, AT_i) = v_0(T_0^j) - f_0(b_i, AT_i)$$

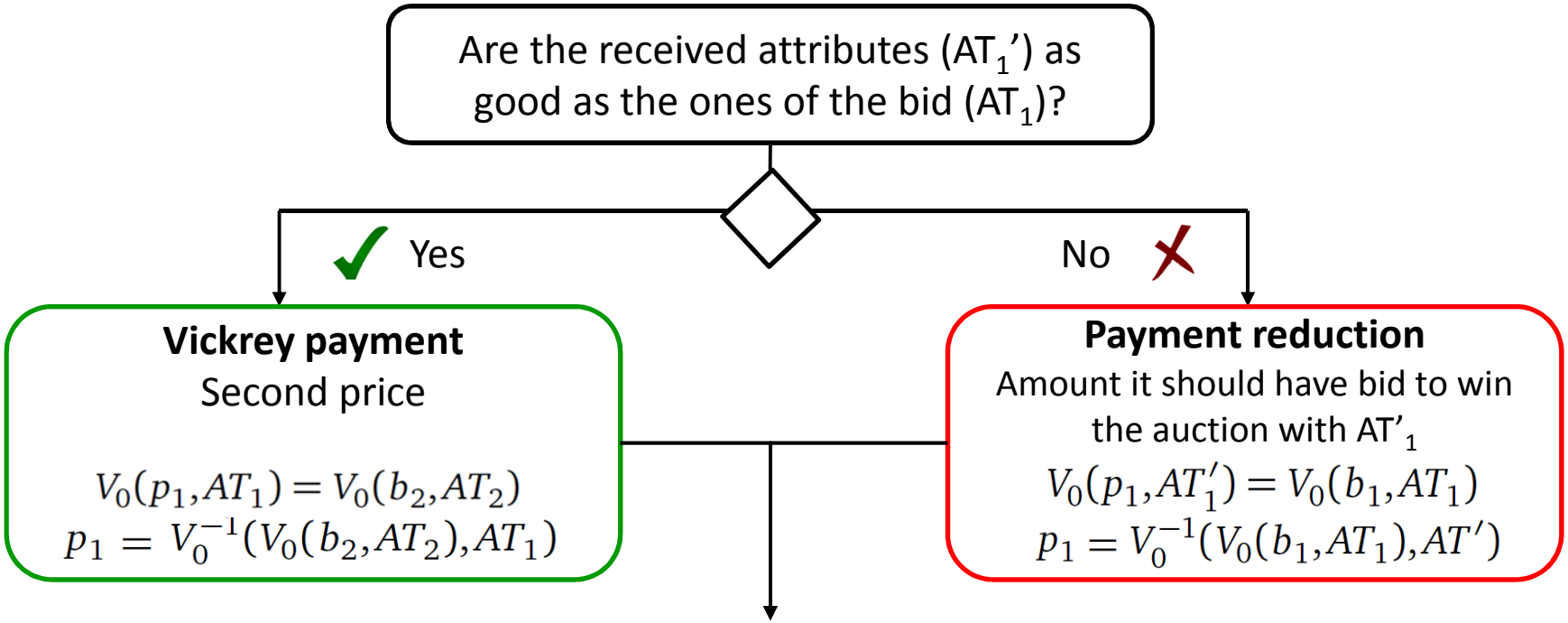
valuation of the attributes (e.g. V_0)

Value of the task



4. PUMAA: Payment rule

- Conditional Vickrey-based payment:



$$p_1 = \begin{cases} V_0^{-1}(V_0(b_2, AT_2), AT_1) & \text{if } AT_1' \succeq AT_1 \\ V_0^{-1}(V_0(b_1, AT_1), AT') & \text{if } AT_1' \prec AT_1 \end{cases}$$

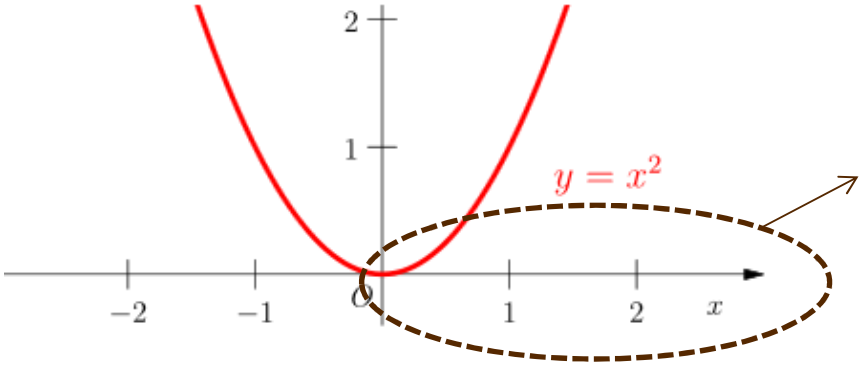
Evaluation (V_0) function requirements

- Real Valued Function
  - V_0(b,AT) must return a real number evaluation for each bid
    - The payment mechanism involves the numeric evaluation obtained by the second best bid.
  - Discards multi-criteria methods which result in ranked lists or orders without numeric valuations.
    - If there is not a numeric evaluation, the payment cannot be computed

[3] *Multi Criteria Operators for Multi-attribute Auctions* A Pla, B López, J Murillo Modeling Decisions for Artificial Intelligence (MDAI) 2012, 318-328.

Evaluation function requirements

- Monotonicity
  - If an attribute is improved, the score of the evaluation must also improve.
  - Ensures that, for every possible value in the attribute domain, V_0 (b,AT) will return a value.
  - Only applied in the range of values an attribute can take.
    - Example: If an attribute can only take positive values (time duration), it can be evaluated using its square function.



Evaluation function requirements

- Bijection
  - In order to calculate the payment, $V_0(b,AT)$ must have a bijective behavior regarding the economic attribute.
  - Given:

    $$V_0(b,AT) = x$$

    its reverse function will be

    $$V_0^{-1}(x,AT) = b$$

    where b can be just one value
  - Need of distinguish between economic attribute b and AT
  - Avoid vertical asymptotes to avoid payments of infinite value

Evaluation function examples

- Product

$$V_0(b_i, AT_i) = b_i * \prod_{j=1}^{n} at_i^j$$

$$p_1 = \begin{cases} \frac{b_2 * \prod_{j=1}^{j=n} at_2^j}{\prod_{j=1}^{n} at1^j} & \text{if } AT_1' \succeq AT_1 \\ \frac{b_1 * \prod_{j=1}^{j=n} at_1^{j'}}{\prod_{j=1}^{n} at_1^j} & \text{if } AT_1' \prec AT_1 \end{cases}$$

- Weighted sum

$$V_0(b_i, AT_i) = \mu_0 b_i + \sum_{j=1}^{n} \mu_j at_i^j$$

$$p_1 = \begin{cases} \frac{\mu_0 b_2 + \sum_{j=1}^{n} \mu_j (at_2^j - at_1^j)}{\mu_0} & \text{if } AT_1 \succeq AT_1^v \\ \frac{\mu_0 b_1 + \sum_{j=1}^{n} \mu_j (at_1^{j'} - at_1^j)}{\mu_0} & \text{if } AT_1 \prec AT_1^v \end{cases}$$

- Mathematical norms
  - E.g. Euclidean norm

$$V_0(b_i, AT_i) = \sqrt{{b_i}^2 + \sum_{j=1}^{n} (at_i^j)^2}$$

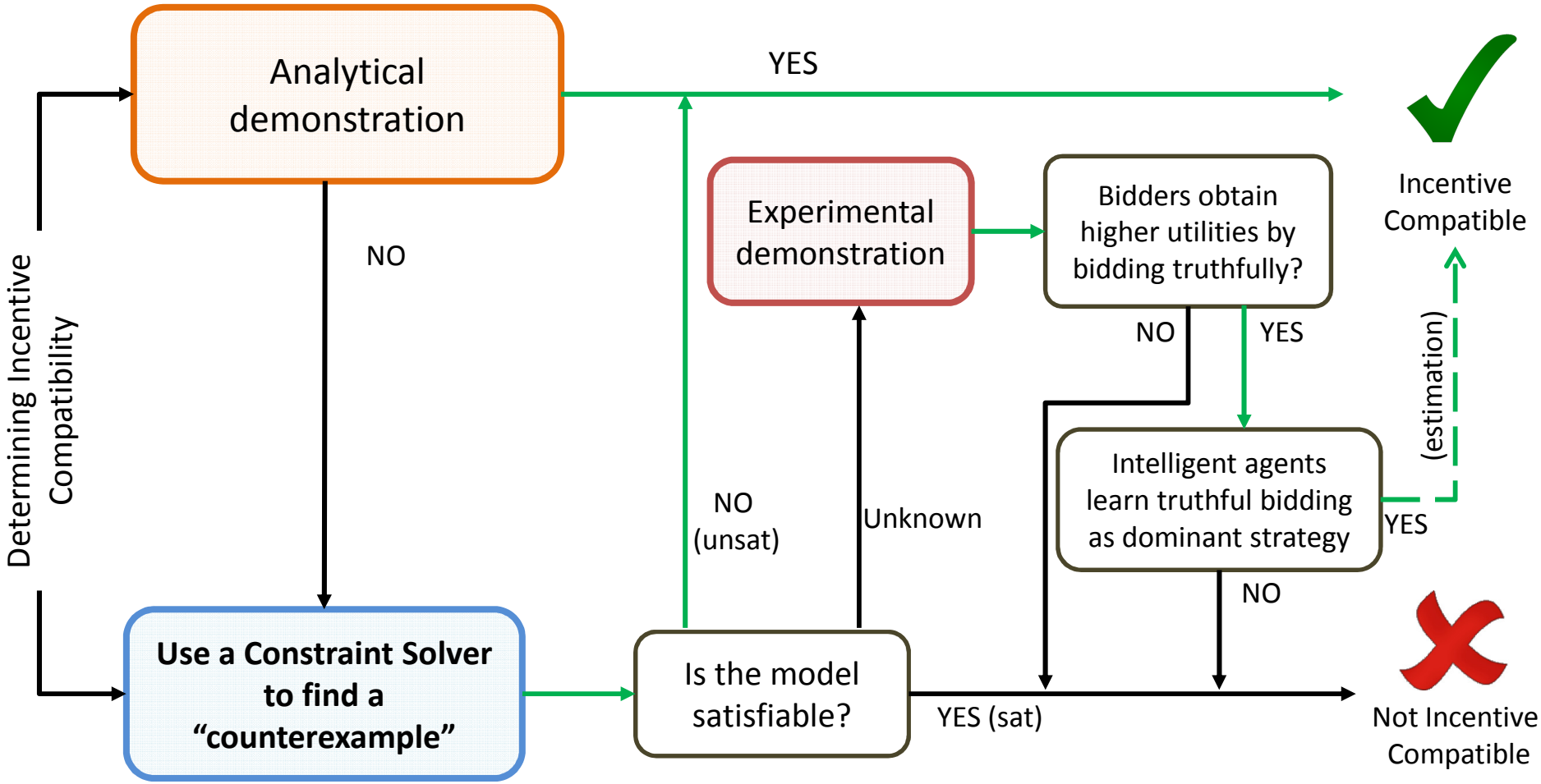
$$p_1 = \begin{cases} \sqrt{{b_2}^2 + \sum_{j=1}^{n} ((at_2^j)^2 - (at_1^j)^2)} & \text{if } AT_1' \succeq AT_1 \\ \sqrt{{b_1}^2 + \sum_{j=1}^{n} ((at_1^{j'})^2 - (at_1^j)^2)} & \text{if } AT_1' \prec AT_1 \end{cases}$$

- Weighted sum of functions

$$V_0(b_i, AT_i) = \mu_0 g_0(b_i) + \sum_{j=1}^{n} \mu_j g_j(at_i^j)$$

$$p_1 = \begin{cases} \frac{g_0'\left(\mu_0 g_0(b_2) + \sum_{j=1}^{n} \left(\mu_j g_j(at_2^j) - \mu_j g_j(at_i^j)\right)\right)}{\mu_0} & \text{if } AT_1' \succeq AT_1 \\ \frac{g_0'\left(\mu_0 g_0(b_1) + \sum_{j=1}^{n} \left(\mu_j g_j(at_1^{j'}) - \mu_j g_j(at_1^j)\right)\right)}{\mu_0} & \text{if } AT_1' \prec AT_1 \end{cases}$$

PUMAA: Incentive compatibility



PUMAA: Incentive compatibility

- Finding a counter example with a constraint solver
  - Incentive compatible: For any feasible bid, the bidder's utility is higher by submitting the truthful attribute information:

$$\forall i \in \mathbb{N}, \forall (b_i, b_i^t, AT_i, AT_i^t) \in \mathbb{R} > 0 : \left\{ (u_i(b_i, AT_i, p) \leq u_i(b_i^t, AT^t, p')) | (b_i^t \neq b_i') \vee (AT_i \neq AT_i^t) \right\}$$

  - ¿Is there any case not fulfilling this condition?

  - Modeling the mechanism using an inequation system.
  - Modeling the case where lying is better.

  - If the inequation system is solvable → **NOT INCENTIVE COMPATIBLE**
  - If the inequation system has no solution → **INCENTIVE COMPATIBLE**

[4] *How to Demonstrate Incentive Compatibility in Multi-Attribute Auctions* A Pla, B López, J Murillo Congrés Català d'Intel·ligència artificial (CCIA) 2013 FAIA 256, 303-306

PUMAA: Incentive compatibility

- Inequation system for the weighted sum

$$
\left.
\begin{array}{ll}
\text{(a)} & a(AT_1) \neq a(AT_1') \vee b_1 \neq b_1' \\
\text{(b)} & \mu_1 b_1 + \mu 2 a(AT_1) < \mu 1 b_2 + \mu 2 a(AT_2) \\
\text{(c)} & win = \begin{cases} 1 & \text{if } (\mu_1 b_2 + \mu_2 a(AT_2)) > \mu_1 b_1^t + \mu_2 a(AT_1')) \\ 0 & \text{otherwise} \end{cases} \\
\text{(d)} & win(\frac{\mu_1 b_2 + \mu_2 a(AT_2) - \mu_2 a(AT_1')}{\mu_1} - b_1^t) < (\frac{\mu_1 b_1 + \mu_2 a(AT_1) - \mu_2 a(AT_1')}{\mu_1} - b_1^t) \\
\text{(e)} & \mu_1 + \mu_2 = 1 \\
\text{(f)} & 0 < \mu_1 < 1 \\
\text{(g)} & 0 < \mu_2 < 1
\end{array}
\right\}
$$

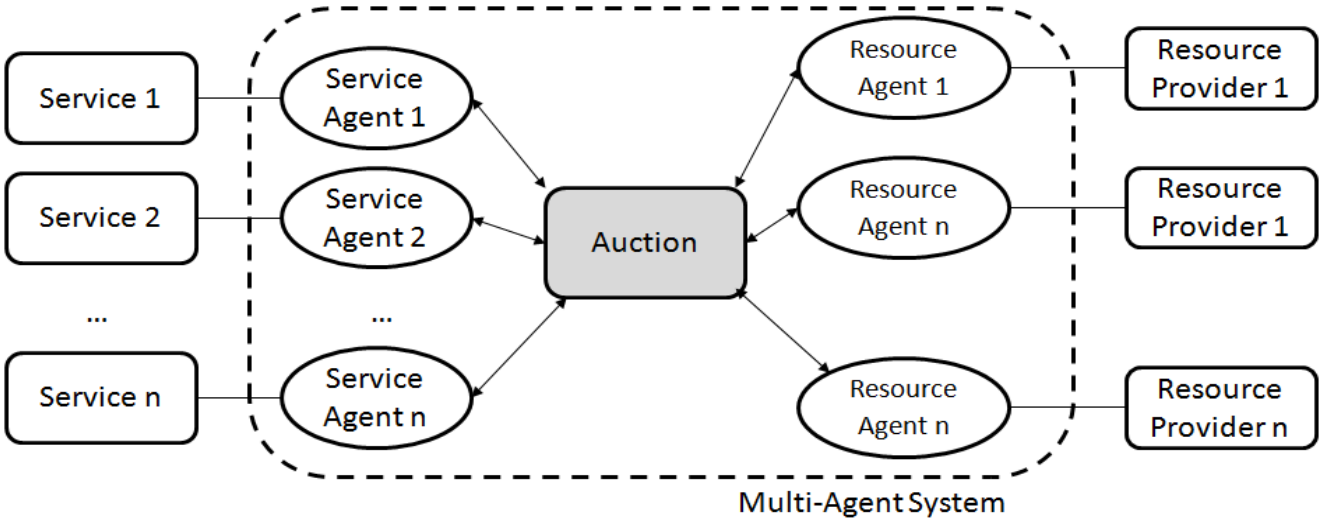
- Using Z3 constraint solver (real arithmetic logic):

Not solvable → **Incentive Compatible**

PUMAA: Other properties

- Efficiency ✓
- Buyer optimality ✗
- Budget-balance ✓
- Social welfare — Utilitarian
- Robustness — Reduce utility loss
- Reliability ≈

PUMAA Results – Simulation environment



- Real data-based multi-agent system simulation
- Service agent
  - Requires resource with specific skills
  - Different priority / deadline
  - Probability of occurrence
- Resource provider agent
  - Requires resource with specific skills
  - Different execution time per task
  - Bidding strategy:
    - Honest, adaptive or cheating

[5] *Petri net-based process monitoring: A workflow management system for process modelling and monitoring,* A Pla, P Gay, J Meléndez, B López Journal of Intelligent Manufacturing, 2012 1-16

PUMAA Results: Experiments

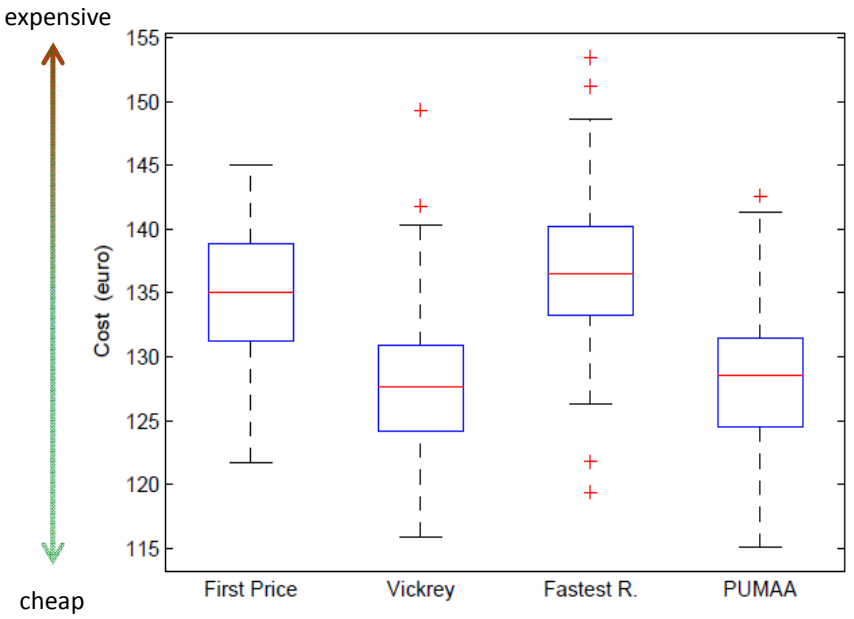
Experiment	Goal	Scenarios	Methods evaluated	Metrics
1	**Uni-attribute vs multi-attribute**	Synthetic data **Real data**	**1. First price** **2. Fastest resource** **3. Vickrey MA** **4. PUMAA**	**• Task allocation cost** **• Delays produced**
2	Strategy proofness	Synthetic data Real data Reinforcement Learning	1. PUMAA Different bidding strategies	• Bidders utility • Auctioneers utility • Dominant strategies
3	Evaluation function influence	Product Weighted sum Euclidean norm	1. PUMAA different evaluation functions	• Auctioneer's utility • Bidder's utility • Type of allocation
4	**Utility preservation and robustness to cheaters**	**Ascendant number of cheaters**	**1. PUMAA** **2. Che's SP**	**• Auctioneer's utility** **• Service cost** **• Delays produced**

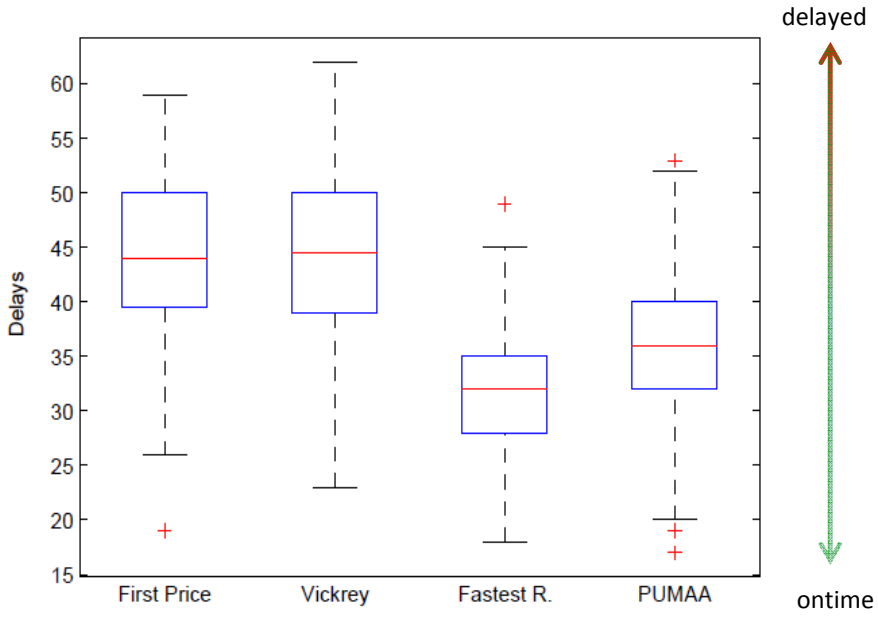
[2] *Multi-Attribute Auction Mechanism for Supporting Resource Allocation in Business Process Enactment*. A Pla, B López, J Murillo STAIRS@ECAI , Montpellier 2012, 228-239

[6] *Workflow resource allocation through auctions* A Pla, B López, J Murillo Artificial Intelligence and Logistics (AILOG@IJCAI), Barcelona 2011, 55

PUMAA Results: Uni-attribute vs. Multi-attribute

- Service cost allocation cost
- Delays produced

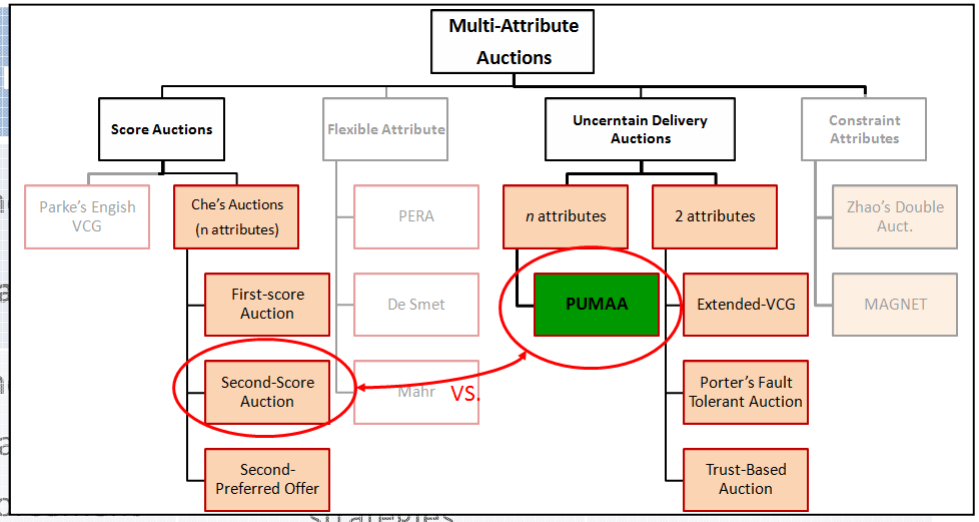




- PUMAA obtains the best balance between attributes: low cost / few delays

PUMAA Results: Experiments

Experiment	Goal	Sce
1	Uni-attribute vs multi-attribute	Synth Rea
2	Strategy proofness	Synth Rea Reinfo

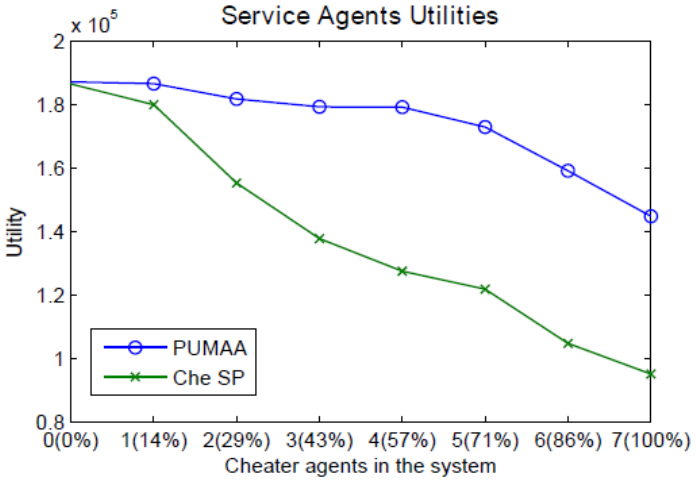


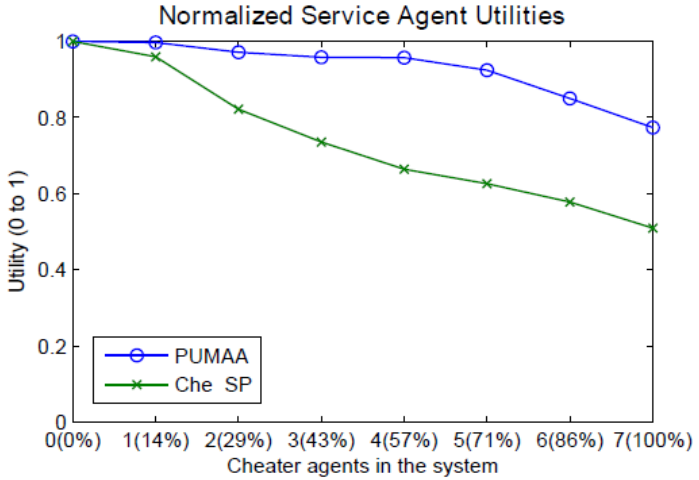
4	**Utility prservation and robustness to cheaters**	**Ascendent number of cheaters** [0 cheaters, 1 cheater, … , all cheaters]	**1. PUMAA** **2. Che's Second price**	• **Auctioneer's utility** • **Service costs** • **Delays produced**

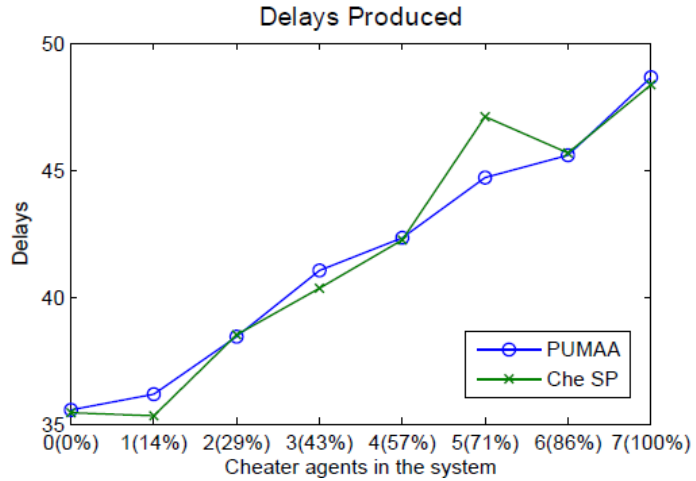
[2] *Multi-Attribute Auction Mechanism for Supporting Resource Allocation in Business Process Enactment*. A Pla, B López, J Murillo STAIRS@ECAI , Montpellier 2012, 228-239

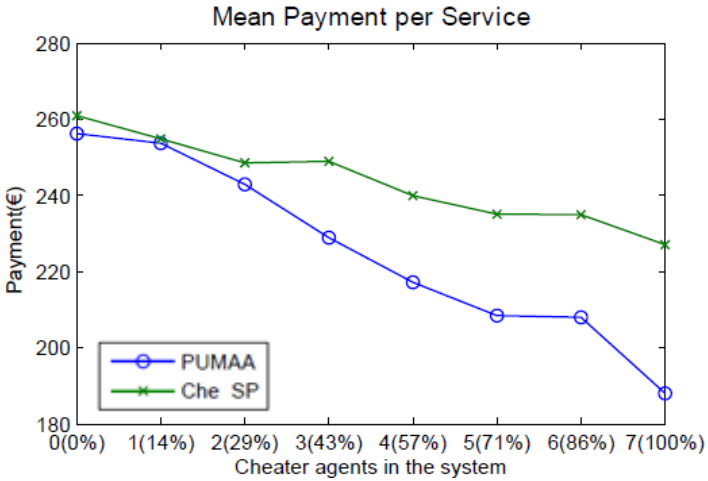
[6] *Workflow resource allocation through auctions* A Pla, B López, J Murillo Artificial Intelligence and Logistics (AILOG@IJCAI), Barcelona 2011, 55

PUMAA – Results: Utility preservation









FMAAC: Framework for Multi-attribute Auction Customization

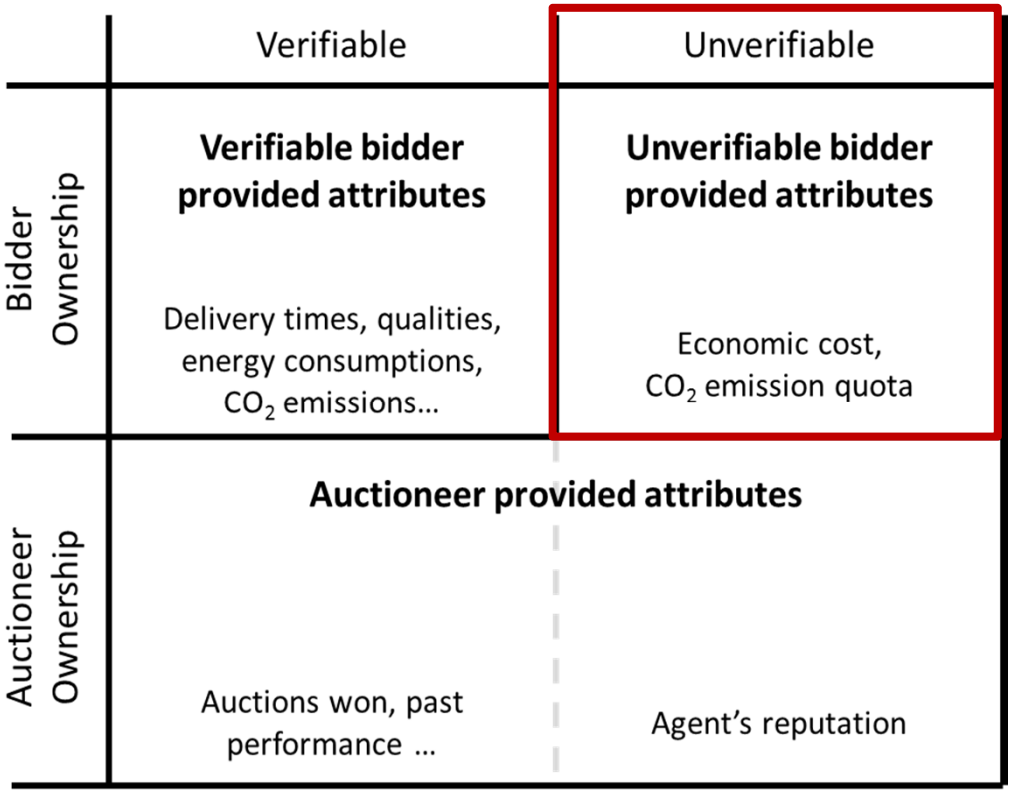
Framework for Multi-attribute Auction Customization

- Study the types of attributes which can appear in a multi-attribute auction
- Using such study, design a framework for customizing multi-attribute auctions

Attribute typologies in multi-attribute auctions

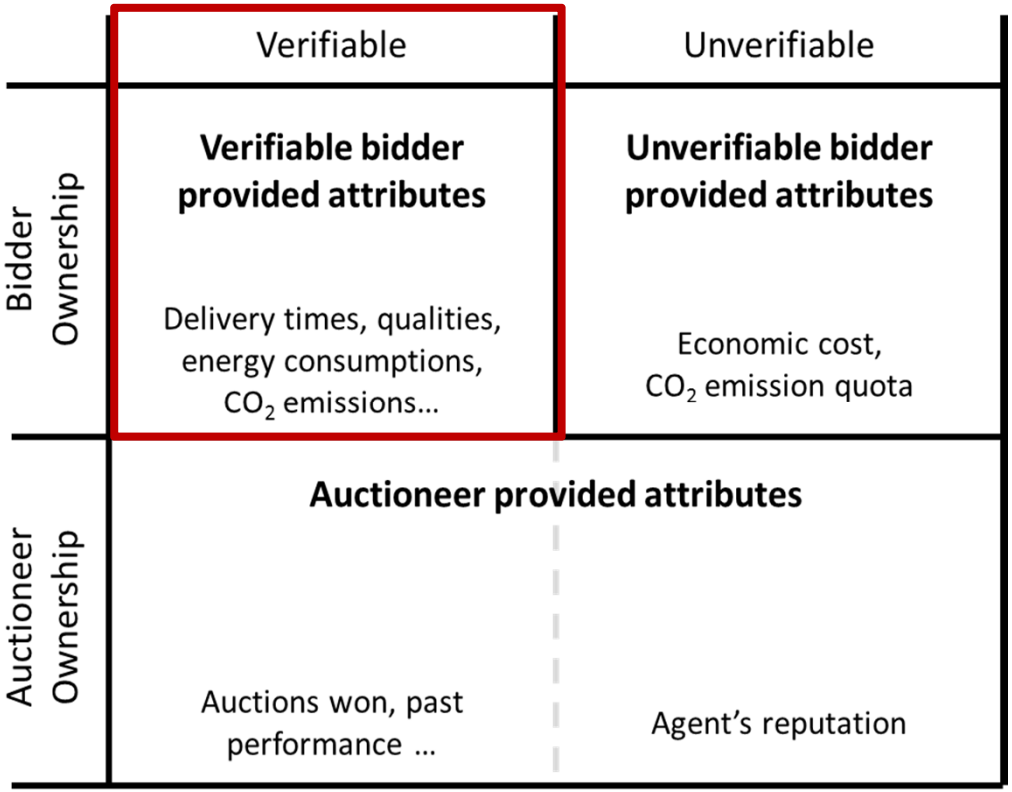
- Study the kind of attributes appearing in different auctions:
  - GSP, Vickrey, Porter's auction, Che's auctions, etc.
- Ownership
  - Who is introducing the attribute into the auction
  - **Bidder-provided** or **auctioneer-provided**
- Verifiability
  - Can the auctioneer check the veracity of the attribute
  - **Verifiable** or **unverifiable**

Unverifiable bidder-provided attributes



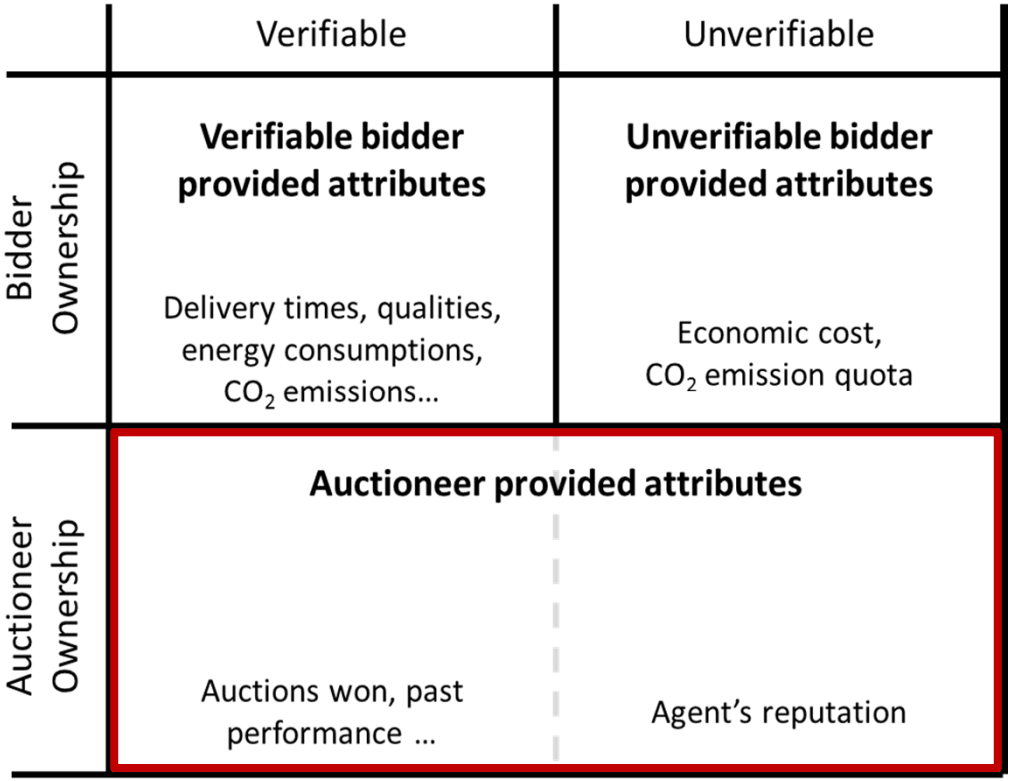
- Unverifiable bidder-provided attrs.
  - Real value only known by the bidder
  - Currency of the auction
  - True-value not known by auctioneer
  - Appear in all auctions
  - Only *1 attribute*

Verifiable bidder-provided attributes



- Verifiable bidder-provided attrs.
  - The auctioneer can check if the attribute is truthful
  - Checking before payment
  - Appear only in multi-attribute auctions
  - *n attributes*

Auctioneer-provided attributes



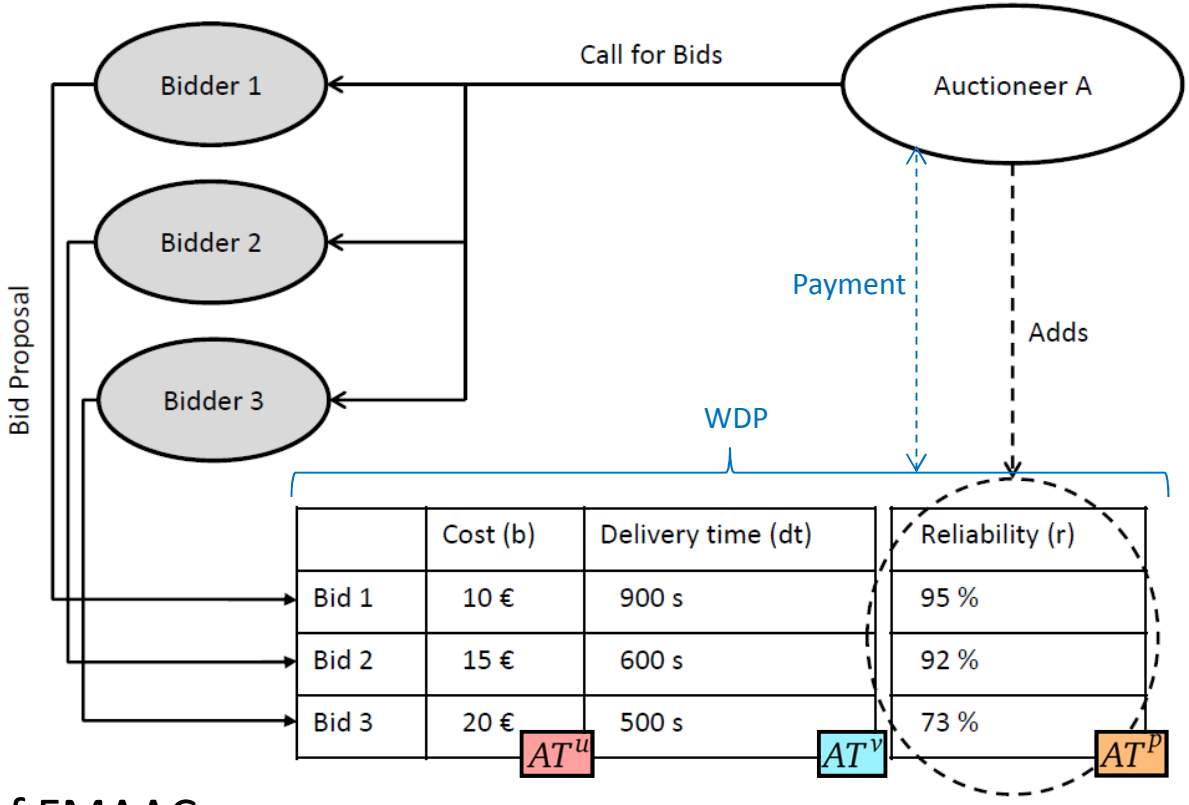
- Auctioneer-provided attrs.
  - Introduced by the auctioneer
  - Describe auctioneer's believes and information regarding past auctions
  - Uni and multi-attribute auctions
  - *n attributes*
  - Multi-attribute auctions

FMAAC

- **F**ramework for **M**ulti-**A**ttribute **A**uction **C**ustomization
- Generalizes PUMAA to include auctioneer-provided attributes
- Allow mechanism designers to cover new problems using information collected in recurrent auctions:
  - Egalitarian allocations
  - Reliable allocations

[7] *Multi-Attribute Auctions with Different Types of Attributes: Enacting Properties in Multi-Attribute Auctions*, A Pla, B López, J Murillo, N Maudet Expert Systems with Applications 41(10), 2014, 4829-4843

FMAAC



- Steps of FMAAC:
  1. Call for proposals
  2. Bidding
  3. Winner determination
  4. Payment
  5. Attribute information process

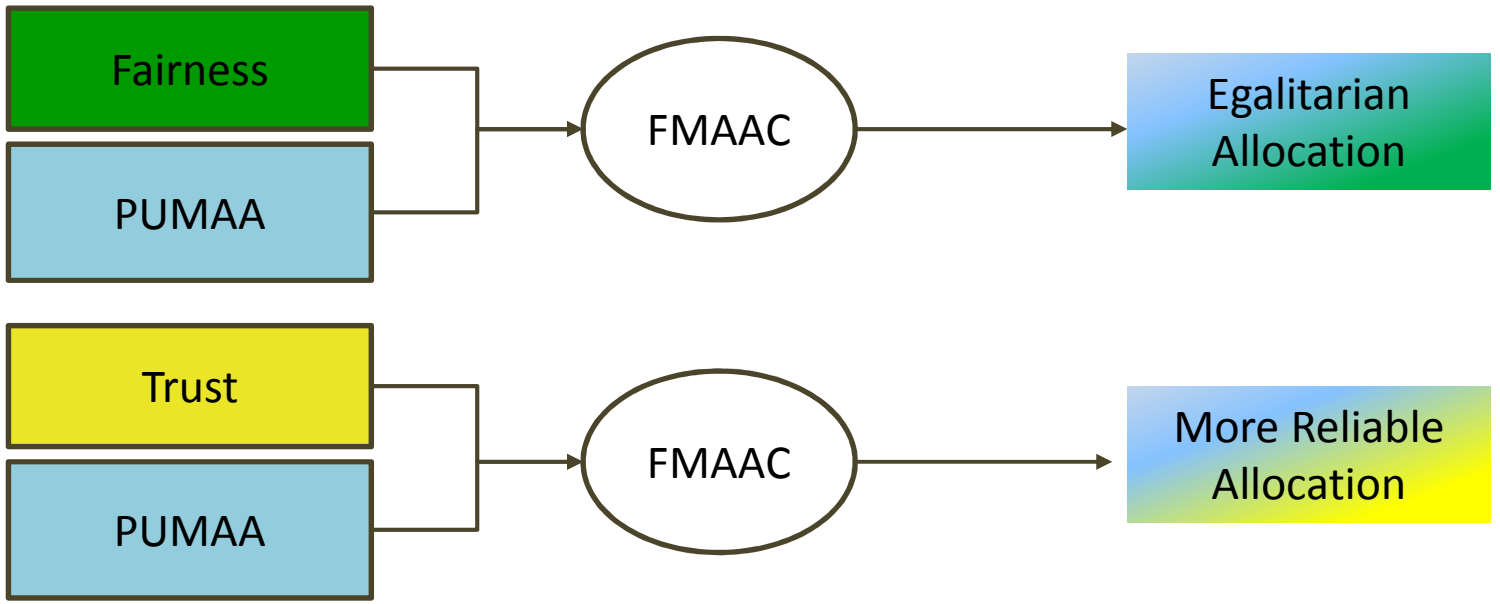
[7] *Multi-Attribute Auctions with Different Types of Attributes: Enacting Properties in Multi-Attribute Auctions*, A Pla, B López, J Murillo, N Maudet Expert Systems with Applications 41(10), 2014, 4829-4843

FMAAC: Steps

	PUMAA	FMAAC
CFP	proposes: AT^v	=
Bidding	bid submission: $AT^u AT^v$	=
WDP	bid evaluation: $V_0(AT^u AT^v)$	Bid structure: $AT^u AT^v + AT^p$ Bid evaluation $V_0(AT^u AT^v AT^p)$
Payment Rule	compute payment using: AT^u AT^v	compute payment using: AT^u AT^v AT^p
Attribute Information Update	-	Collects information of the auction: $Update(AT^p)$

Auctioneer provided attributes in FMAAC

- Auctioneer provided attributes will modify multi-attribute auction allocation



Multi-dimensional Fairness for Multi-attribute Resource Allocation

Challenges vs. Contributions

- Multi-attribute IC
- Workflow related issues
- Recurrent auctions' issues

- PUMAA
  - Design of a multi-attribute auction for task allocation
  - Multi-criteria requirements study
- FMAAC
  - Study attribute types in auctions
  - Develope a framework for customizing multi-attribute auctions
- Multi-dimensional fairness
  - Multidimensional fairness mechanism for MARA
  - Fair version of PUMAA
  - Minimize the bidder drop problem

Multi-dimensional fairness

- Existing fairness methods are **uni-dimensional.**
- **Multi-dimensiona**l fairness: take into account all bidder-provided attributes.
  - Keep track of the auction victories and results
- Use a priority auctioneer-provided attribute w_i according to the bidders' auction history:
  - A high w_i means the agent might leave the market soon.
  - w_i should consider all the attributes
  - $w_i \in [0,1]$

[8] Multidimensional Fairness for Auction-based Resource Allocation. A. Pla, B. López, J. Murillo Knowledge-based Systems. (Submitted on November, 2013).

Quantitative methods

- Based on the number of victories or defeats.

- Won auction coefficient (WOC)
  - Relation between auctions won and auctions participated.
  - Proportional measure.

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

- Loosing streak (LS)
  - Number of consecutives defeats
  - Include cognitive distortions such as “bad luck sense”
  - Defines a maximum loosing streak in which the player will not increase its priority.

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

Qualitative methods

- Evaluating the quality of a bid respect to the winner bid:
  - Avoids dummy bids to increase quality
  - Favors high-quality bidders
  - Fitness function to evaluate the bids:

$$q_i = \frac{V_0(B_i')}{V_0(B_1')}$$

- Bid-based WOC
  - Relation between the auctions won and the bid quality.

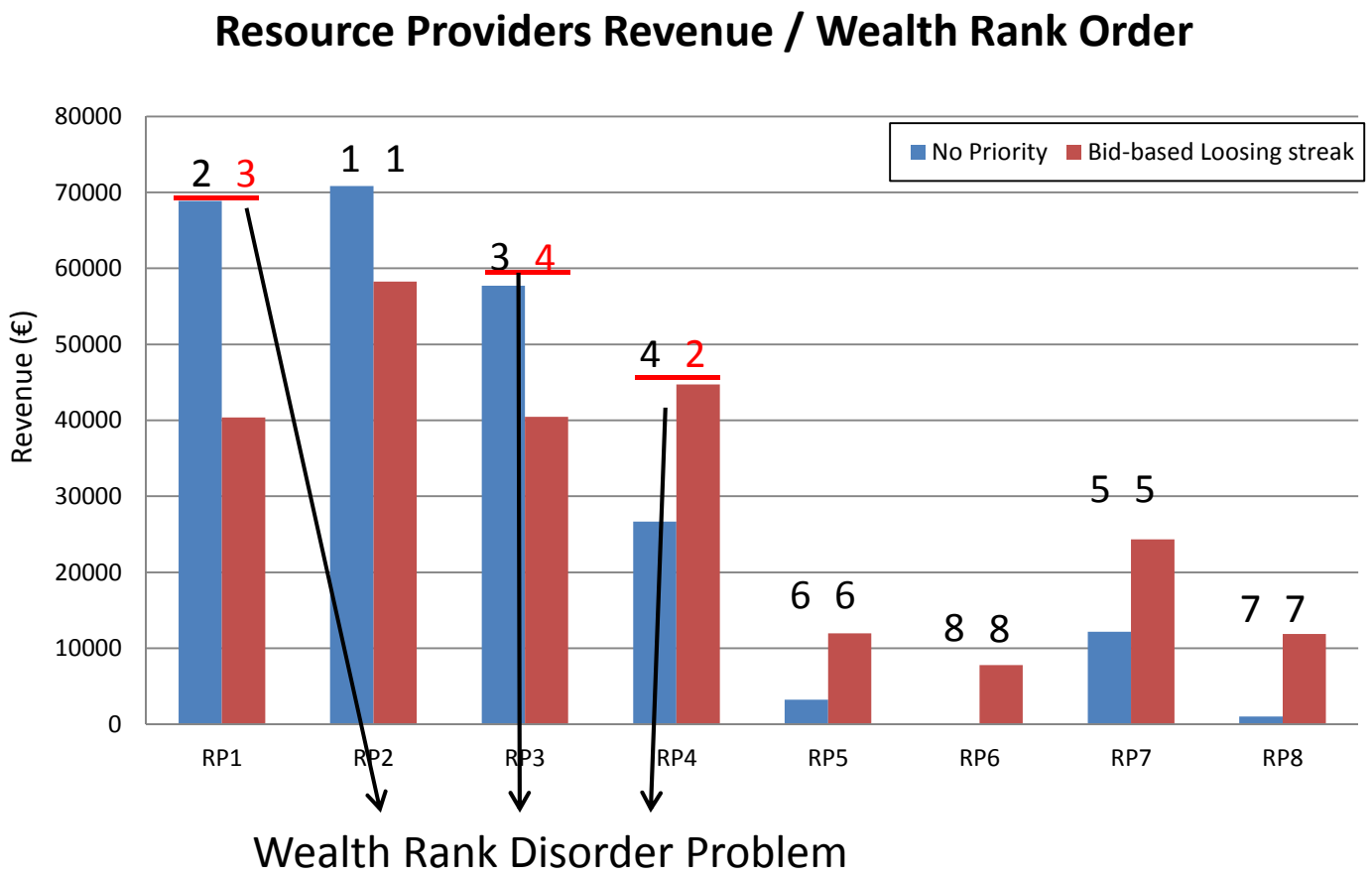
$$w_i = 1 - \frac{1 + won(a_i)}{1 + \sum_{j=0}^{c-1} q_i^j}$$

- Bid-based LS
  - Quality of the bids during the loosing streak.

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

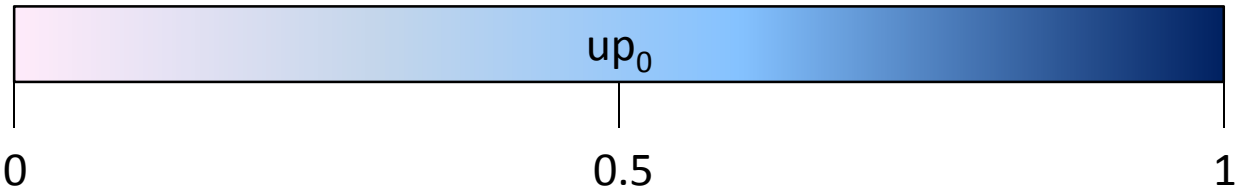
Probabilistic methods

- Priorities can affect the wealth rank of resource providers



Probabilistic methods

- Probabilistic version of the previous methods
  - w_i is only update at certain auctions according to an update probability up_0
  - up_0 will condition the influence of the priority
  - Reduce the chances of a bidder learning its own priority

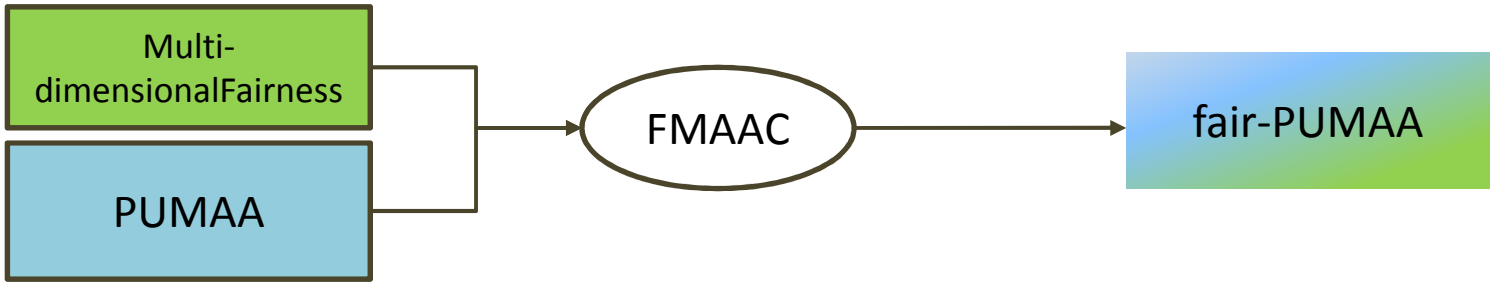


- Priority never updated
- Equivalent to not using priorities

- Priority always updated
- Equivalent to the previous methods

- prob-WOC
- prob-BBWOC
- prob-LS
- prob-BBLS

fair-PUMAA properties



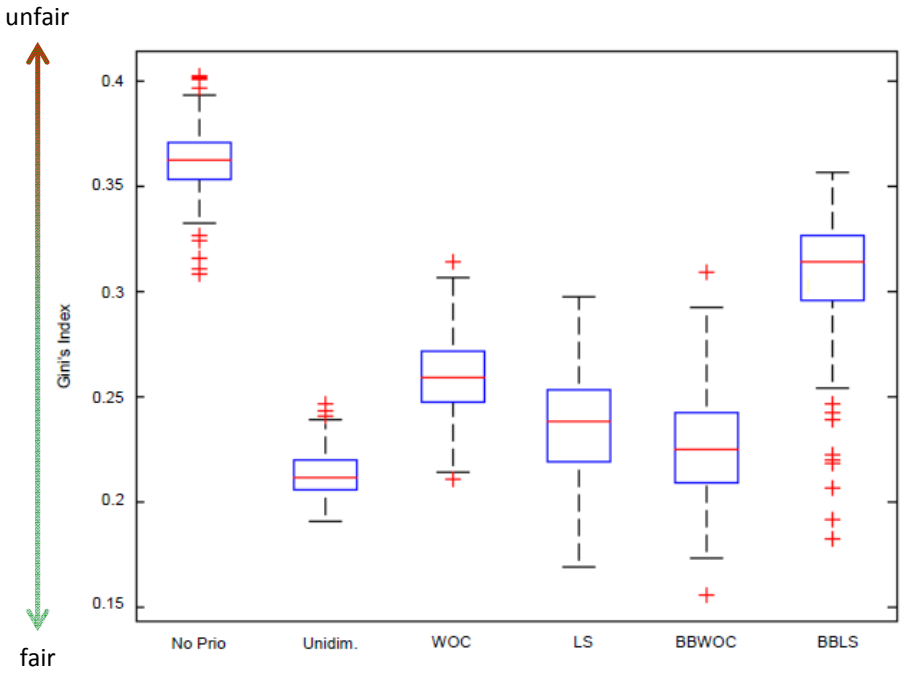
	PUMAA	fair-PUMAA
Incentive-compatibility	✓	✓ (single auction)
Efficiency	✓	✓ (long run)
Buyer optimality	✗	✗
Budget-balance	✓	✓
Social welfare	Utilitarian	Egalitarian
Robustness	✓	✓
Reliability	≈	≈

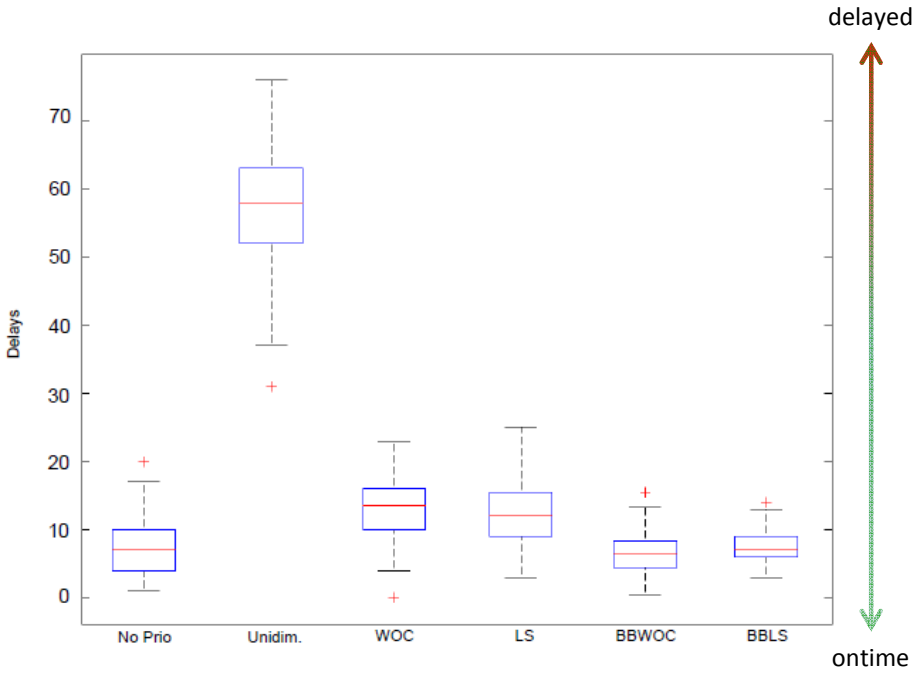
fair-PUMAA Results: Experiments

Experiment	Goal	Scenarios	Methods evaluated	Metrics
1	**Uni-dimensional vs Multi-dimensional**	**Real data**	**1. PUMAA** **2. Uni-dimensional priority** **3. fair-Pumaa**	• Incomes • Expenses • **Fairness (Gini's)** • **Delays**
2	Probabilistic Methods	Stochastic Methods	1. PUMAA - probWOC - probLS - probBBWOC - probBBLS	• Wealth Rank Disorder (Spearman's footrule) • Fairness (Gini's)
3	**Bidder Drop Problem**	**Real Data**	**1. PUMAA** **2. fair-PUMAA** - WOC - LS - **BBWOC** - BBLS - probBWOC	• **Active bidders** • **Mean task cost**

fair-PUMAA results – Uni-dim. vs Multi-dim.

- Gini's index for the resource providers income's
- Delays per simulation





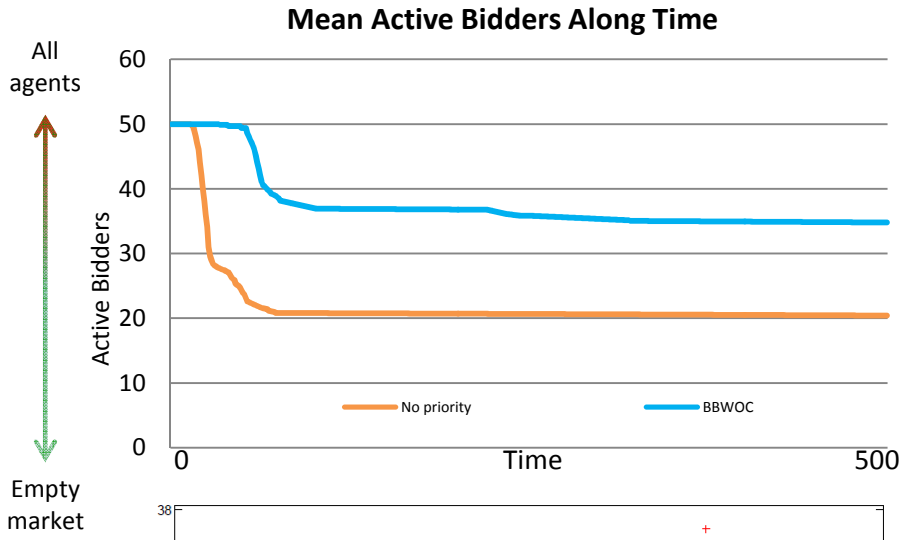
fair-PUMAA Results: Experiments

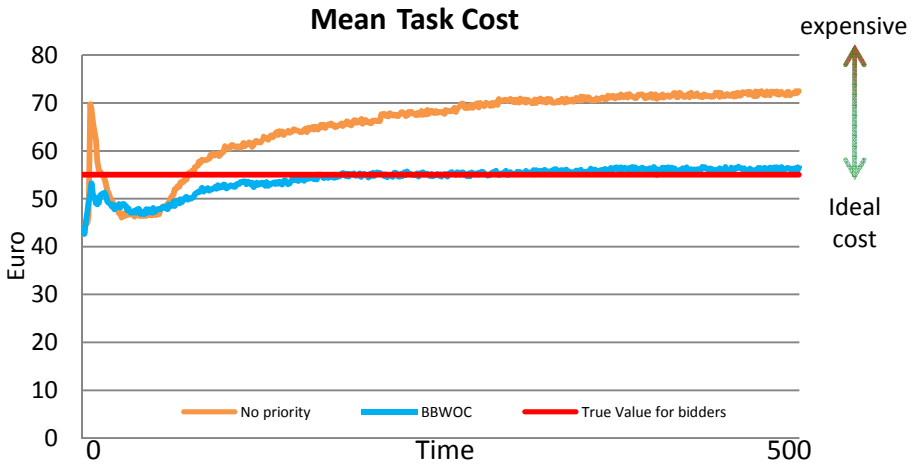
50 Resource providers with the same skills:

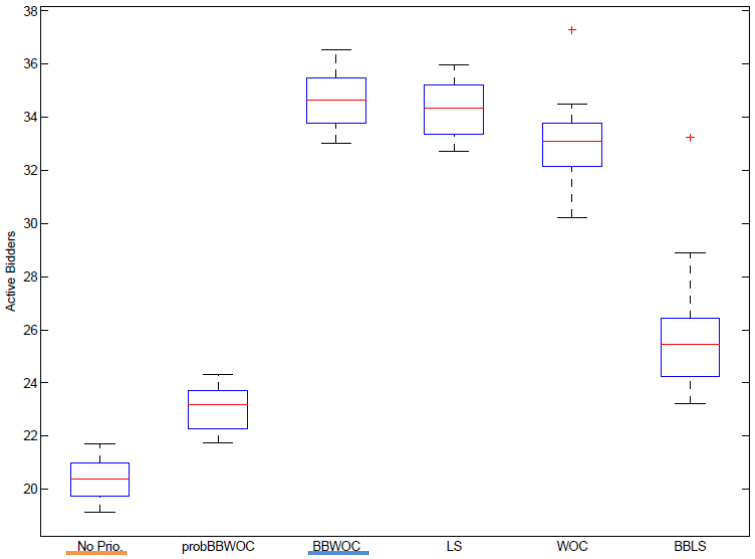
- 25 follow honest bidding
  - Leave the market if after 50 auctions they don't have benefits
- 25 follow oligopolistic strategy
  - Start working under cost to kick out competence
  - Try to rise the market prices
  - Leave the market if after 100 auctions they don't have benefits

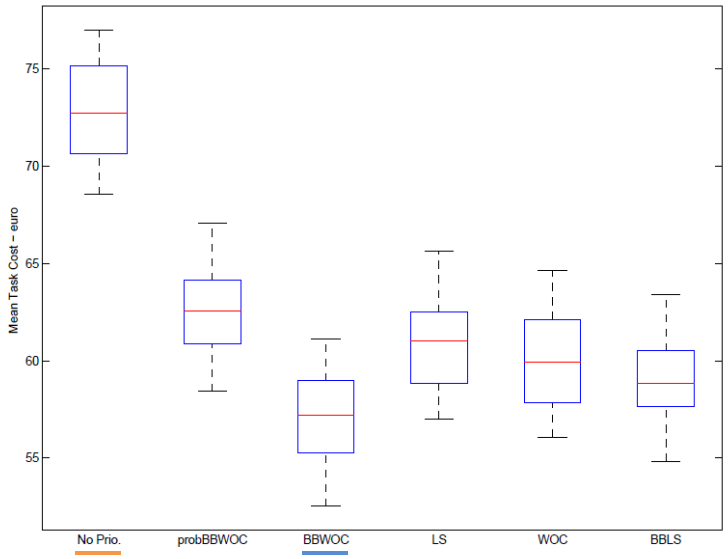
Experiment				
3	**Bidder Drop Problem**	**Real data based**	**1. PUMAA** **2. fair-PUMAA** • WOC • LS • **BBWOC** • BBLS • probBWOC	**•Active bidders** **•Mean task cost**

fair-PUMAA results – Bidder Drop Problem









Conclusions

Challenges vs. Contributions

1. Multi-attribute IC
2. Workflow related issues
3. Recurrent auctions' issues

- PUMAA
  - Design of a multi-attribute auction for task allocation
  - Multi-criteria requirements study
- FMAAC
  - Develop a framework for extending and customizing PUMAA
  - Study attribute types in auctions
- Multi-dimensional fairness
  - Multidimensional-fairness mechanism for MARA.
  - Fair version of PUMAA
  - Minimize the bidder drop problem

Conclusions: PUMAA

- Design auction mechanism for allocating multi-attribute resources in uncertain and dynamic workflow environments.

- PUMAA:
  - Suitable for uncertain domains
  - Attributes considered along the whole mechanism
  - Utility preservation
  - Incentive compatible
- Evaluation function requirements
  - Monotonic, real-valued and bijective function
- Tested with a real data-based MAS simulator

Published in:

PRIMA 2011 / AILOG 2010

STAIRS@ECAI 2012

CCIA 2013

MDAI 2012

Journal of Intelligent Manufacturing (*in press*)

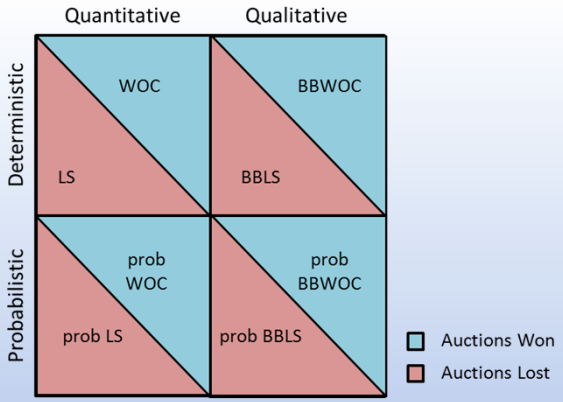
Conclusions: FMAAC

- Classification of the attributes which can appear on multi-attribute auctions
  - Unverifiable bidder-provided
  - Verifiable bidder-provided
  - Auctioneer-provided
- Framework for multi-attribute auction customization
  - Generalization of PUMAA
  - Adaptation of the allocation to domain requirements
  - For instance: egalitarian allocations, trust-inclusion, etc.

Published in: Expert Systems with Applications Journal 41(10), August 2014

Conclusions: Multi-dimensional fairness

- Fairness in multi-attribute auctions must consider all the involved attributes.
- Definition of a fairness mechanism for multi-attribute auctions based on priorities.
  - Quantitative, Qualitative
  - Auctions won, Auctions lost
  - Deterministic, Probabilistic



- Experimentation showed that the use of priorities can minimize the bidder drop problem

Submitted to: Knowledge-based Systems Journal (November 2013)

Future works

- Generalize PUMAA for combinatorial auctions*.
- Allow PUMAA to distinguish between “lies” and “estimation errors”.
- Use similarity measures to allow “Unstructured bids”.
- Add a trust-model to PUMAA using FMAAC*.
- Adapt PUMAA to other domains such as the electricity smart grid or health-care management.
- Study how false-name bidding can affect the fairness mechanism.

* [9]*Using multi-attribute combinatorial auctions for sustainable workflow scheduling.* F. Torrent, A. Pla, B. López. 12th Conference on Multiagent System Technologies (MATES 14). (To be submitted).

Publications

- Journals
  - **Albert Pla**, Pablo Gay, Joaquim Meléndez, Beatriz López *Petri net-based process monitoring: a workflow management system for process modelling and monitoring* In: Journal of Intelligent Manufacturing. 2012. pages 1-16 (pre-print).
  - **Albert Pla**, Beatriz López, Javier Murillo, Nicolas Maudet *Multi-Attribute Auctions with Different Types of Attributes: Enacting Properties in Multi-Attribute Auctions* In: Expert Systems with Applications 41-10, August 2014, Pages 4829–4843
  - **Albert Pla**, Beatriz López and Javier Murillo. Multidimensional *Fairness for Auction-based Resource Allocation*. Knowledge-based Systems. (Submitted on November, 2013).
- Conferences
  - B. Lopez, **Albert Pla**, D. Daroca, L. Collantes, S. Lozano, J. Meléndez. *Medical equipment maintenance support with service-oriented multi-agent services.* PRIMA workshop on Services and Agents (ServAgents), Kolkata, India, November 12th-15th, 2010. To be published by Springer.
  - **Albert Pla**, Beatriz López, Javier Murillo. *Multi-Attribute Auction Mechanism for Supporting Resource Allocation in Business Process Enactment,* In: Proceedings of the Sixth Starting AI Researchers' Symposium (STAIRS 2012) at ECAI 2012. ISBN: 978-1-61499-095-6 pages: 228-239 Montpellier, France, August 2012

Publications

- Conferences
  - **Albert Pla**, Beatriz López, Javier Murillo. *Multi Criteria Operators for Multi-attribute Auctions*. In The 9th International Conference on Modeling Decisions for Artificial Intelligence (MDAI 2012), Girona, Spain. November 2012. LNCS 7647, pp 318-328
  - **Albert Pla**, Beatriz López, Javier Murillo *How to Demonstrate Incentive Compatibility in Multi-Attribute Auctions* In: Proc. 16th International Conference of the Catalan Association for Artificial Intelligence. Frontiers in Artificial Intelligence and Applications (vol 256). Pages: 303-306. October 2013, Vic, Catalonia
  - Ferran Torrent, **Albert Pla** and Beatriz López. *Using multi-attribute combinatorial auctions for sustainable workflow scheduling*. 12th Conference on Multiagent System Technologies (MATES 14). (To be submitted).

- Workshops
  - **Albert Pla**, Beatriz López and Javier Murillo. *Workflow Resource Allocation through Auctions*. 2nd Workshop on Artificial Intelligence and Logistics IJCAI, pp 55-60, Barcelona 2011.

Grants & projects

- Scholarship
  - BR-UDG 12/2010
- Projects
  - AIMES: Advanced Infrastructure for Medical Equipment Management and Services
  - SUROS: Subastas Robustas mediante la incorporación de técnicas SMT
  - MoSHCA: My Mobile and Smart Health Care Assistant
- Journals
  - **Albert Pla**, Beatriz López, Pablo Gay, Carles Pous *eXiT*CBR.v2: Distributed case-based reasoning tool for medical prognosis* In: Decision Support Systems 54 (3), 1499-1510. DOI:10.1016/j.dss.2012.12.033. ISSN: 0167-9236
  - Pablo Gay, Beatriz López, **Albert Plà**, Jordi Saperas, Carles Pous *Enabling the Use of Hereditary Information from Pedigree Tools in Medical Knowledge-based Systems*, Journal of Biomedical Informatics, Available online 15 June 2013, DOI:0.1016/j.jbi.2013.06.003. ISSN 1532-046

Multi-Attribute Auctions: Application to Workflow Management Systems

Albert Pla Planas

Supervisors:
Dra. Beatriz López and Dr. Javier Murillo
Departament EEEA

Universitat de Girona

eXiT
Control Engineering and Intelligent Systems