Web Service-based Applications for Electronic Labor Markets: A Multi-dimensional Price VCG Auction with Individual Utilities

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***Abstract*—We design an efficient and transaction cost reducing Vickrey-Clarke-Groves auction as part of a web service for the work allocation problem in temporary employment agencies. In this auction bids are work contracts with multi-dimensional salaries. To compute the allocation we assume that every temporary employment worker conveys a utility function specifying the utility gained from working a given job for a salary consisting of multiple components. We then embed the designed mechanism in an updated transaction phase model describing the repeated allocation of temporary agency workers to work assignments. We prove that the designed auction mechanism at the heart of the web service satisfies Incentive Compatibility and Pareto Efficiency.**

***Keywords*-Vickrey-Clarke-Groves auction; web service; electronic human resource management; mechanism design; multi-dimensional price**

I. Introduction

The last decades saw a swift and fundamental change of work and working environments. The number of blue-collar workers has dramatically fallen while the number of white-collar workers has simultaneously increased. This change was driven by the so-called “3-sector-hypothesis” or “Petty’s law” [1]. As a result, many aspects of the working environment became less rigid and numerous employment models have evolved. One of the most successful novel models is that of temporal employment with about 9.5 million employees and a market of more than US$ 340 billion worldwide [2, pp. 11].

Competition pressure creates a sustained impetus for businesses to lower labor costs, which can be achieved in two ways. These costs can be lowered by paying lower wages and salaries or by reducing superfluous transaction costs [3]–[5]. Taking the first route leads to disappointed and unmotivated employees [6]–[8]; thus, we will here focus on the second way instead. Electronic markets are an adequate and a well-established option to reduce transaction costs [9]. During the last two decades electronic markets for commodities were thoroughly investigated and practical business applications (e.g., eBay and Amazon) flourished. Today such electronic markets often incorporate web services [10]–[13], which have also attracted scientific interest on a fundamental level [14].

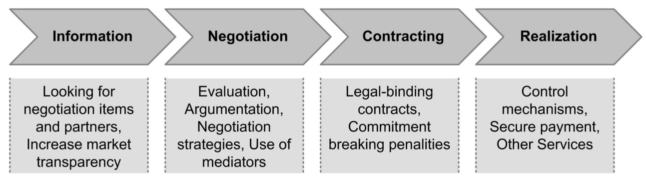

Figure 1. Transaction phases according to [18]

By contrast, widespread highly automated electronic labor markets failed so far to materialize. First, unlike well standardized commodities, labor can only imperfectly be described [15, pp. 365]. This imperfect description refers to the description of job demands, to employee characteristics and to job performance. The difficulty in describing job performance due to the complexity of the person-situation interaction has been thoroughly investigated; cf. [16], [17]. Electronic markets for only imperfectly describable goods and services are scarce in the real world; possibly partly due to the little scientific interest they received [18]. Thus e-business applications and web services for such markets have received little attention in the literature.

Second, the utility (function) of work is very complex [19, p. 85] and varies individually. An automated labor market would require market players to specify a priori utility functions (or a similar encoding of personal preferences) specifying preferences for an overwhelming number of possibilities enabling agents to act (search and negotiate) on their behalf.

As a result, today we either find well described theoretical formal models, which are not quite applicable to real world situations, see further Section II, or we find matching algorithms aiding the search for a new job or a new employee [20]. These matching algorithms all address the information phase of a transaction, further transaction phases cannot be supported by such algorithms, see Figure 1. A further automation of electronic labor markets should also address other transaction phases. One such important step would be the development of an efficient allocation algorithm that also computes salaries based on individual and private preferences of market players.

The main contribution of this paper is a web service based application running a novel algorithm (based on a Vickrey Clarke Groves auction [21]–[23]) that matches workers and employers efficiently and that computes salaries consisting of multiple components. In more detail, we consider a Temporary Employment Agency (TEA) that employs Temporary Agency Workers (TAWs) and in turn lends them to businesses for a period of time. We develop a Vickrey Clarke and Groves (VCG) mechanism that allows every TAW and every business representative to specify multi-dimensional utility functions. So, in this auction bids and payments are multi-dimensional. To the best of the authors knowledge such a mechanism has never been described in the literature before.

A. Extended Goal Statement

Summing up we want to develop a web service based application, which uses a novel allocation mechanism, thereby covering at least the first two transaction phases. The aim is that this system satisfies several objectives:

1) Reduce transaction costs.
2) Allocate TAWs to businesses in a Pareto Efficient way, i.e., there is no other way to make no bidder worse off and one better off.
3) Ensure bidders bid their true valuations, i.e., the auction is Incentive Compatible.
4) Enable TAWs to influence their work environment, thereby increasing job engagement and job satisfaction and as a result create added value for businesses [24].
5) Create a work environment that is perceived to be fairer by stakeholders and the general public. Thus improving the social standing of temporary agency workers and temporary work as a whole.

The rest of the paper is organized as follows: Next, we consider related work and the real-world economic background. Then, we present the auction model, followed by an evaluation via mathematical proofs for Incentive Compatibility and Pareto Efficiency of the auction and we give a simple example. Finally, we conclude with a discussion of the model, its limitations and an outlook concerning future work.

II. Real-World Economic Background and Related Work

We now turn to discussing related work.

A. State of the Art in Electronic Negotiations and E-HRM

Being forecast about three decades ago in [25], electronic negotiations have been a hot topic in computer science, so much so that now many well researched overviews exist [26]–[30]. However, the maximal level of automation attainable is controversial. We here exhibit the classification of approaches given in [31].

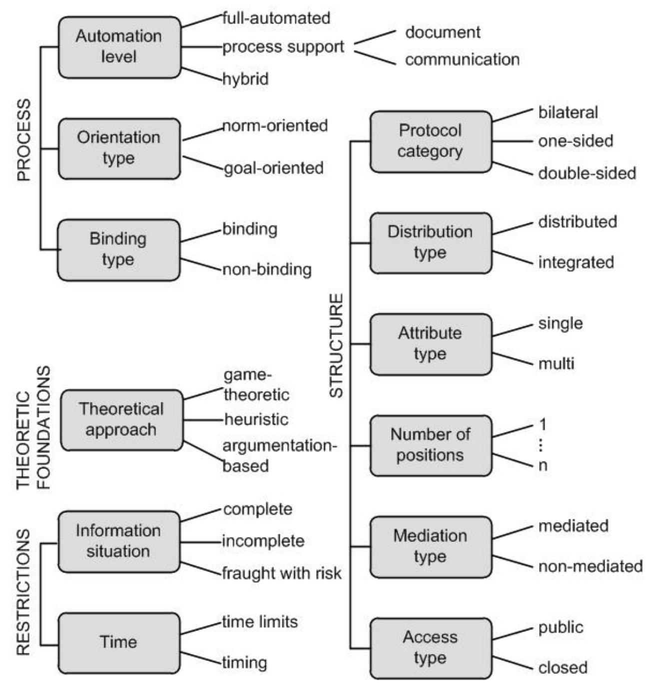

Figure 2. Classification of electronic negotiations [31]

The landscape of scientific research on electronic negotiations is mainly populated by studies of the process and the structure of negotiations whereas issues located in the lower left in Figure 2 have received considerably less attention [31].

The models of electronic negotiations can be classified as game-theoretic, heuristic or argumentation-based [32]. The game-theoretic approach investigates optimal strategies via the analysis of the equilibrium conditions dating back to the seminal work of Nash [33]. Game-theoretic models are well studied, often allowing mathematically elegant investigations, but their potential in practical applications suffers from the assumptions of perfect rationality, unlimited resources and perfect information [32], [34]. Heuristic approaches reject the assumption of unlimited (computing) resources and/or perfect rationality and rather employ thumb rules, see for example [35]. Automated negotiation models based on heuristic approaches have to be intensively evaluated, normally via simulations and/or empirical analysis [32, p. 210]. In argumentation-based negotiations (ABN), agents have the ability to reason their positions. When the negotiation partner is persuaded, who will change her negotiation position, exemplary we mention the system PERSUADER [36].

Related, but not directly relevant, are ongoing developments in e-recruiting and e-HRM, which have been recently surveyed respectively in [37, pp. 231-232] and [38]–[41].

B. Imperfect Information about the Negotiation Item

In [18], 96 electronic negotiation models were studied. Almost all negotiation models (94 percent) assumed imperfect information about the negotiation partner(s). Research on imperfectly described environments and/or negotiation items is considerably less frequent. Only 8 percent of models studied considered the problem of imperfect information concerning the negotiation item, e.g., [42], [43]. Interestingly, one of these models was developed for eHRM [44] and later extended to FuzzyMAN in [45]. In FuzzyMAN and the model implemented therein [43] agents' preferences regarding the negotiation item are expressed in fuzzy [46] terms.

Further work dealing with imperfect information about the negotiation item exists. Different approaches have based their models on different formalisms: probability [47], [48], conjoint scheme [48], genetic algorithms [47] and bandwidths [49].

Overall, we want to develop a game-theoretic model allowing a well-founded evaluation via mathematical proofs. Any successful real-world implementation of such a model has to be comprehensible to all stakeholders [50]. Due to the complex challenges posed by negotiation items that can only imperfectly be described, we use a well-established negotiation model of low complexity, i.e., an auction.

C. Auctions

Auctions are one of the oldest (according to ancient Greek Herodotus, auctions date back to the Babylonians around 500 B.C.) and on the surface simplest form of negotiation. Today, auctions are the main mean to sell expensive antiques, U.S. treasury bonds and rights to use the electromagnetic spectrum for telecommunication purposes. Furthermore, numerous commodity markets rely on auctions [Tsukiji fish market (Tokyo, Japan), the Bloemenveiling flower auction (Aalsmeer, The Netherlands)].

Over the centuries, many auction formats have evolved (first price, second price, open, sealed-bid, with deadline, without fixed deadline, etc.). Different formats were designed to satisfy a variety of properties such as revenue maximization, incentive compatibility and efficiency maximization. Further auction formats were developed, which allow the sale of multiple items at the same time, while other formats discourage collusion and snapping.

More generally, an auction can be understood as a mechanism, which takes as input a set of preferences and outputs an allocation of resources. The art of ensuring that the outcome has desirable properties is known as Mechanism Design (MD) [34]. One branch of MD investigates the design of auctions [51]–[53] to allocate resources to bidders in exchange for a payment.

A Vickrey auction is a sealed-bid second price auction. That is, the auction item is allocated to the highest bidder, who pays the second highest bid submitted. Such an auction satisfies Individual Rationality, Pareto Efficiency and Incentive Compatibility. A Vickrey Clarke Groves (VCG) auction [21]–[23] extends a Vickrey auction allowing multiple items to be auctioned off simultaneously by a single bid taker. Crucially, a VCG auction also satisfies these three properties. Even so, VCG auctions are not always an appropriate mechanism, see for instance [54], [55] and for an overview [56].

Multi-dimensional extensions of classical auctions have been studied. This multi-dimensionality either refers to private valuations (or signals thereof) [57] or to the auction item [58]–[62]. It is well known that in case a public multi-attribute function is used by all participants of an English auction, then such a multi-dimensional auction is equivalent to a one-dimensional auction.

A VCG auction with multi-dimensional bids was developed in [63] by the authors of this paper. In [63] we assumed that all bids were evaluated with respect to the multi-dimensional utility function of the center (TEA). We here build on this work by designing a VCG auction with multiple bidders and multiple bid takers, which all have their own multi-dimensional utility function. The allocation and the payment rule only depend on these functions, in particular they are independent of the TEA's utility function. Results reported in [27] suggest that multi-dimensional auctions yield more utility for the bid taker.

How far, or even if, game theoretic results regarding multi-dimensional prices, respectively multi-dimensional auctions, are transferable to the real world has been investigated in [64], [65].

D. The Business Model of Temporary Employment Agencies

Temporary employment agencies have become a large-scale form of labor market intermediary, acquiring the status of a broker of flexibility at both the micro- and the macro-level [66]. They meet the needs of enterprises to flexibly increase or decrease the size of their workforce, while ensuring for their workers considerable security in terms of job opportunities and employment standards, including pay, working time and training [2, pp. 7, pp. 26]. The business model can be characterized by a triangle. In one corner is the TEA, which has a labor contract with a TAW. Crucially this contract contains a clause granting the TEA the managerial authority to order a TAW to work at (and under the supervision) of one of its clients.

Furthermore, the TEA has business to business (b2b) contracts with customers specifying commercial details of the temporal assignment of TAWs. In general, a TAW working at (and under the supervision of) a client of a TEA and this client do not enter a contract. For the above auction we can hence assume that every participating TAW has a valid work contract with the TEA. Applying the transaction phase model displayed in Figure 1 to the model we developed here, we now adapt the realization phase, see Figure 3. Overall, this yields an adapted model of transaction phases depicted in Figure 4.

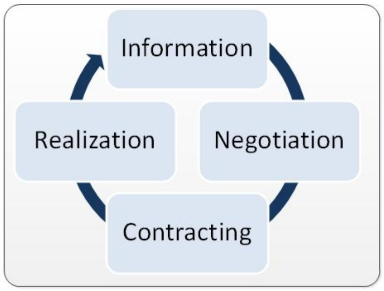

Figure 3. The adapted realization phase

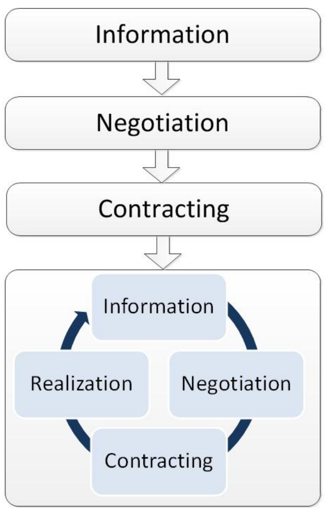

Figure 4. The new model of transaction phases

One important reason for businesses to use a TEA as an intermediary is that the assignment of TAWs may be of limited or unspecified duration with no guarantee of continuation allowing a flexible management of the workforce to adapt to quickly changing market conditions.

Providing a service the TEA charges a fee, ultimately paid by its customers and/or the TAWs. This fee (normally a fixed percentage of the salary) can amount up to 80% of the net salary (depending on circumstances and national laws, e.g., taxes and social security contributions) of a TAW. A considerable part of the operating costs of a TEA are generated by the labor intensive (and hence costly) process of matching TAWs to requests for labor. A further disadvantage shared by TAWs and customers of a TEA is that the matching of TAWs and requests for labor is done to best suit the TEAs' needs. Having no influence over their work environment (including salary) TAWs have in general a lower job engagement, which correlates strongly with productivity [24], [67]. Furthermore TAWs are typically paid less than permanent workers doing the same job violating the principle of same pay for same work causing tensions in the workforce of the client of the TEA [68].

III. The Auction

We now introduce the auction mechanism.

A. Participants

There are two types of participants. First, any business that seeks to hire temporary staff from the TEA can take part. Second, all currently idle TAWs that have a work contract with the TEA may take part. Unless otherwise stated, we mean from now by TAW a participating TAW. A representative of a participating business is from now simply called *employer*. Do note that the TAWs are employed by the TEA. The term employer is chosen here to ease the understanding and the write-up; see further Section II-D. To ease the notation, we make the convention that every employer is looking to fill exactly one full time vacancy (multiple vacancies at a company are modeled by multiple employers).

B. Information Phase

During the information phase participants search for potential matches, read background information stored at the TEA or on the Internet on potential employers (policies, corporate philosophy and identity) or on TAWs (CV, references and possibly a sample of previous work). To predict future potential job performance of job candidates (TAWs), employers may carry out e-assessments [69], [70] enhanced by exchanged emails, interviews conducted via text-based chat applications and/or (video) calls. Similarly, TAWs may pick up information crucial for their valuation of future job assignments. From a formal perspective, the sending and exchanging of signals, indices and arguments can be seen to take place to combat the infamous adverse selection problem [15], [71].

To enhance quality and speed of the search in large databases, a recommender system [72], [73] and/or a reputation system [74], [75] may be used.

C. Bidding

Let $E := \{E_1, \ldots, E_e\}$ be the set of employers seeking to secure the services of a TAW and let $W := \{w_1, \ldots, w_t\}$ be the set of TAWs looking for work. For $1 \leq i \leq n$ let M_i be a salary component, such as wage per hour, benefits, sick pay or overtime premiums. Let $M = M_1 \times \ldots \times M_n$ be the set of all contracts consisting of these components. We define an additive structure on M by $\oplus M \times M \to M$ via addition by component $(m_1, \ldots, m_n) \oplus (k_1, \ldots, k_n) := (m_1 + k_1, \ldots, m_n + k_n)$.

For $1 \leq i \leq t$ let $\{E_{i_1}, \ldots, E_{i_{k(i)}}\}$ be the set of employers interested in acquiring the services of TAW w_i. Now every $w_i \in W$ sends a utility function $u^i_{i_r} : M \to \mathbb{R}$ to employer E_{i_r} detailing how much s/he (dis-)likes to work for E_{i_r}, if the TAW is sufficiently qualified to perform these jobs. These utility functions are also communicated to the TEA and to all other employers. In case TAW w_i does not send a utility function to an employer E_{i_r}, the utility function $u^i_{i_r}$ is set to be the zero function. We can hence assume that the TAWs' utility functions are functions mapping $M \times E \to \mathbb{R}$.

A significant proportion of TAWs is low-skilled [2, table 3.6 page 19] and might hence require training and/or decision support tools to construct these utility functions; see further [76] for one such tool designed for an electronic labor market. These tools normally use preference elicitation techniques [77]. Such techniques can go a long way to aid the understanding and thus acceptance of designed applications and computer systems [50], [78].

We assume that every employer E_d is risk neutral, fully rational and the valuation of TAWs and contracts is independent of the valuation of other employers. We hence assume that E_d has a utility function $UU_d : M \times W \to \mathbb{R}$ specifying how much value a TAW working a certain job for a given contract brings to employer E_d. We assume furthermore that these functions are *additive*, that is UU_d is given as a sum of utility functions, i.e., $UU_d(m, w) = U_d(m) + V_d(w)$. This notion of an additive utility function generalizes the notion of a quasi-linear utility function to multi-dimensional prices. Furthermore, we assume that U_d commutes with the additional structure $\oplus$.

At this point, every employer has a choice to make based on the utility functions $u^i_{i_r}$ communicated, either to take part in the following auction and accept the binding outcome or to drop out and not take part in the auction. For the time being, we assume, for the sake of a simpler notation, that no employer drops out. Why an employer might drop out will be investigated in the section Incentives.

Every employer now makes one sealed bid for each TAW, from which a not vanishing utility function was received. That is for $1 \leq d \leq e$ a, in general partial, function $bid_d : W \to M$ is communicated to the TEA. These functions are in general partial because not every $w \in W$ communicates a utility function to all employers.

To ease the notation we make the following convention. Every partial function bid_d is extended to a total function by setting bid_d to zero wherever it was not defined. Furthermore $u^i_{\emptyset}$ and $bid_{\emptyset}$ are set to vanish everywhere.

D. The Allocation

Definition 1 A function $f : \{1, \ldots, t\} \to \{1, \ldots, e\} \cup \{\emptyset\}$ is called an *allocation* if and only if $f(i) = f(k)$ implies that $f(i) = f(k) = \{\emptyset\}$. Thus an allocation allocates every employer (representing a single vacancy) at most one TAW.

The TEA then calculates the allocation f that maximizes

$$\sum_{1 \leq l \leq t} u^l_{f(l)}(bid_{f(l)}(l)) \tag{1}$$

under the constraint that for $f(l) \neq \emptyset$ employer $E_{f(l)}$ has put in a non-zero bid for TAW w_l. The constraint implies that an employer will never be allocated a TAW w_l, for which this employer has not put in a bid.

For $1 \leq d \leq e$ let f_d be the allocation, which maximizes the sum in Equation 1 and which satisfies the constraint in case that E_d does not enter a single bid (or equivalently E_d does not take part in the auction).

All participants are then informed of the outcome of the allocation concerning themselves. So every employer E_d learns, which TAW (if any) has been allocated to work for E_d, vice versa for the TAWs. To calculate the salary (in auction terminology: payment rule) we need to introduce some notation.

E. Salaries

Definition 2 For $t \in \mathbb{N}$ let $[t] := \{1, \ldots, t\}$ and for $1 \leq l \leq t$ put $[t - l] := \{1, \ldots, t\} \setminus \{l\}$ and $[t - \emptyset] := [t]$. Let $g : X \to Y$ be a function, then the *level set of g at level y* is defined as $\{x \in X | g(x) = y\}$.

For $l \in [t], x_l \in \mathbb{R}$ and a utility function $U_d : M \to \mathbb{R}$ let $\langle \sum_{l \in [t]} x_l \rangle_d$ be an element in M that minimizes $U_d(\oplus_{l \in [t]} m_l) = \sum_{l \in [t]} U_d(m_l)$ under the condition that for every $l \in [t]$ m_l is an element of the level set of $u^l_{f_d(l)}$ at level x_l. That is employer E_d gets to pick an element in all those level sets. Since this expression will later be part of a salary paid, the employer makes choices suiting best his/her needs. For $x \in \mathbb{R}, m \in M$ and a utility function $U_d : M \to \mathbb{R}$ let $x - U_d(m)$ be an element of the level set of U_d at level $x - U_d(m)$.

Employer E_d then pays TAW $w_{f^{-1}(d)}$

$$\begin{aligned} Salary(E_d) := - \sum_{l \in [t - f^{-1}(d)]} u_f(l)^l (bid_{f(l)}(l)) \\ + \langle \sum_{l \in [t]} u^l_{f_d(l)}(bid_{f_d(l)}(l)) \rangle_d. \end{aligned} \tag{2}$$

Do note that the second term in Equation 2 cannot be influenced by any bids made by employer E_d, since it only contains terms that are calculated for an auction, in which she did not participate. To ease the reading we set $U_d(C_d)$ to be the utility received from this term.

Note that employer E_d wants to maximize the overall utility received, which equals

$$V_d(f^{-1}(d)) + \sum_{l \in [w - f^{-1}(d)]} u^l_{f(l)}(bid_{f(l)}(l)) - U_d(C_d). \tag{3}$$

Any fully rational bidding strategy an employer pursues will hence only depend on the first term in 2 and the TAW allocated due to our assumptions about UU_d (additive and commuting with addition).

F. Incentives

Theorem 1 The above auction satisfies Incentive Compatibility and Pareto Efficiency.

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Proof: The main idea in the following proof is to show the fact that it is in every employers best own interest to maximize the utility to be distributed. That is, a rational selfish employer seeks to pursue the common good.

Firstly, we have to prove, that bidding their true valuation is an ex-post Nash equilibrium for all bidders. That is, even knowing all other bids, it is for every bidder an optimal strategy to bid true values. We here mean by true valuation that bid_d satisfies $V_d(l) = u_d^l(bid_d(l))$ for all $l \in [t]$. So the employer obtains as much utility from being allocated w_l as the bid for w_l by this employer is worth to w_l.

Recall that f maximizes the sum in Equation 1. Now if $V_d(l) = u_d^l(bid_d(l))$ for all $l \in [t]$, then Equation 1 and Equation 3 only differ by a constant. So f also maximizes 3 in this case. There is hence no better strategy for employer E_d than to bid the private true valuations for all TAWs.

Let us now assume for the second part of the proof that all bidders bid their true valuations (i.e., they all follow an optimal strategy). Then f maximizes the overall utility distributed. Hence, allocating more utility to one bidder will at least make one other bidder lose utility. ■

In case there is less than full confidence in the TEA to properly execute the auction and/or to keep information entered into the system private, an auction issuer [79] can be used to ensure the proper handling of sensitive information and to ensure the correct computation of the allocation and payments.

Example 1 Consider an auction with three employers $\{E_1, E_2, E_3\}$, which have decided to bid for a TAW w_1. Assume furthermore that for the three utility functions communicated to the employers it holds that $u_i = u$. If $u_1(bid_1(1)) > u_2(bid_2(1)) > u_3(bid_3(1))$, then w_1 will work for employer E_1 for a salary in the level set of u at level $u(bid_2(1))$ to be specified by E_1.

From this example, the following observation can be inferred. If there is only one auction item (i.e., one TAW) and the TAW is only interested in the salary (i.e., not in the jobs to do), then the winning bidders bid is of lower utility (to the bidder and the TAW) than the salary paid.

Do note that the above calculations were all done without the explicit knowledge of U_d, that is the private valuation of E_d of multi-dimensional salaries. To actually calculate the figure in Equation 2 one needs to know U_d. In one-dimensional price VCG-auctions all U_d are simply assumed to be the identity function $id : \mathbb{R} \to \mathbb{R}$ and furthermore it is assumed that this is *public* knowledge. It is hence not surprising, alas not ideal, that the here presented mechanism cannot do without any knowledge of the U_d. Assuming that the U_d are known to the TEA or assuming a certain knowledge of the level sets of the U_d are two ways of solving this problem (it suffices to know one element in every level set of the U_d and the level sets containing the C_d).

Observe that in the one-dimensional case the level sets completely determine the function. Counterintuitively, this multi-dimensional price auction requires less information about utility functions on prices than the one-dimensional counterpart.

By contrast, note that the bidder's utility from obtaining an auction item (i.e., a TAW) is revealed through the design of the mechanism, if the bidder acts rationally.

Finally we have to consider the case of an employer E_d that is not allocated a TAW. To keep the attractive properties of Incentive Compatibility and Pareto Efficiency, the payment rule also has to be applied to such an employer. A payment goes to or comes from the center (i.e., the TEA), as there was no worker allocated to this employer. The payment can be calculated and subsequently paid in case one of the above two conditions on the knowledge of the U_d is satisfied. Note that in case every employer is allocated a TAW, this issue concerning the payment rule does not surface.

As we have seen above it makes sense for bidders to be honest but what about the TAWs? Recall that they also submitted utility functions; can they obtain an advantage by not reporting their true valuations? We have already seen in the above example that misreporting the shape of the utility functions $u^i_{i_r}$ is in general not advantageous.

Recall that for bidders it is rational to bid such that $V_d(l) = u_d^l(bid_d(l))$. So a TAW stands to gain by making extraordinary high demands. To discourage such behavior the $u^i_{i_r}$ are communicated to all bidders, which have subsequently the option to abstain from the auction in case salary demands are perceived to be too high. An employer not participating in the auction will look elsewhere for workers.

G. The Algorithmic Complexity of Calculating the Allocation

The number of complete matchings in a connected complete bipartite graph with independent sets of sizes $x \geq y$ is $\frac{x!}{(x-y)!}$. So the number of possible allocations with $e \geq t$ is $\frac{e!}{(e-t)!}$. Hence calculating the allocation f that maximizes the utility is of high algorithmic complexity [80].

Observe that the problem of calculating this allocation simplifies significantly in case the bipartite graph consists of several disconnected components. Connected components of a bipartite graph can be found in linear time. From a practical point of view, reducing the problem to connected components of the graph is hence highly desirable. If the computational complexity of calculating the allocation after the decomposition into connected components is still too high for practical purposes, then approximation algorithms [81], [82] can be used to calculate an allocation that is close to the efficient allocation.

H. The Aftermath

Consider a TAW allocated to a given employer and recall that the VCG-mechanism outputs work contracts consisting of multiple salary components. Possibly there is a contract, which both the TAW and the employer prefer to the one generated by the mechanism. This is in stark contrast to the one-dimensional case with only one salary component. There an employer prefers a lower and a TAW a higher salary. Allowing renegotiations of multi-dimensional salaries may yield gains for the TAW and the employer (and possibly the TEA); however, it renders the above mechanism Incentive Incompatible.

IV. Possible Extensions and Further Applications

Do note that we assumed above that every TAW can only have one job at the same time. This is surely a sensible assumption if all jobs are full time jobs. Extending the above auction to also include part time jobs is possible; one then has to use multivalued allocations f (instead of functions) that assign TAWs to (possibly) multiple employers. Again, this new mechanism does satisfy Incentive Compatibility and Pareto Efficiency. Due to space constraints and our wish not to overload this paper with notation we will refrain here from doing so.

Furthermore, it is possible to include externalities in the mechanism by allowing for the possibility that the utility functions u_l^d depend not only on the job w_l will be working but on the whole allocation f. For example this enables a TAW to express that s/he prefers to work at the same place as her/his husband/wife, yielding monetary gains (lower transportation costs by using the same car) and non-monetary gains (joint lunch). From a formal point of view, extending the framework in this way does not yield; in our opinion; valuable insights and we will hence not present it here.

Conversely the framework can be extended to allow bidders to bid for multiple TAWs simultaneously instead of single TAWs. So the operator of a restaurant can put in a combined bid for a cook and a waiter, which have previously successfully worked together, which may be higher than the sum of bids for the cook and waiter individually.

The here presented mechanism can of course be also used to allocate tasks in other circumstances, for instance in grid and cloud computing similar allocation problems need to be solved. The tasks to be allocated are computing tasks. One further area of application is the wide field of social choice dealing with the multi-faceted problem of how to increase social welfare [83].

V. Conclusion and Future Work

We have presented a web service based application running an algorithm matching TAWs and business, which uses a multi-dimensional price VCG auction. In this auction, the TAWs can individually express salary demands, depending on the job to be done and the employer. We showed that the best a bidder can do is to bid true valuations. Furthermore, we have seen that there are also incentives for the TAWs to honestly report preferences. We have hence designed a mechanism encouraging proper behavior creating an environment that hopefully contributes to a rise in the social standing of temporary workers and temporary work in general.

Formally, we have applied a model of transaction phases to our approach and subsequently extended this model, see Figure 4. This new model allows us to state that our approach addresses the online information and negotiation transaction phase inside the realization phase thus allowing a further automation of a particular labor market. We are optimistic that electronic auctions are a suitable mean to reduce transaction costs for trading goods and services that cannot perfectly be described, in particular labor. Enabling market players (here TAWs and employers) to specify their own multi-dimensional utility functions is in our view a key ingredient for a successful implementation.

Overall, we have reached the goal we set out [see Section I-A] and alleviated in the last section highlighted drawbacks of the business model of a TEA.

A. Limitations

The here presented approach is limited by the assumption that all salary components can be added in a natural way, furthermore we assumed that the employers utility functions are additive and commute with addition. A restriction to the numbers of participants taking part in the auction arises from the complexity of calculating the allocation f. Furthermore, the assumptions of full rationality and risk neutrality are in general not always satisfied in the real world.

One limiting factor in electronic labor markets is the human aversion to new technologies. However, an easy-to-use, understandable and benefiting system stands good chances to mostly overcome such aversions [78].

B. Future Research

In our view, it is desirable to design a mechanism similar to the above that can handle salary components, which cannot be added canonically (such as: job title, job location, work task). We consider the long-term goal of a development and an implementation of a multi agent system (with agents acting for and on behalf of market players) for electronic labor markets worthy of future attention from the scientific community as well as from business communities.

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