Argumentation-based agents for eProcurement

(Short Paper)

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ABSTRACT

Procurement is the complete process of obtaining goods and services – from preparation and processing of a requisition through to receipt and approval of the invoice for payment. The support for eProcurement is important for realising agent-based eBusiness applications. This paper proposes the use of argumentation-based agents to support the selection of suppliers for goods and services within the negotiation phase of procurement. Argumentation is used to compare candidate suppliers and identify the one that best meets the buyer's business-specific needs. The use of argumentation-based technology presents important advantages over traditional procurement methods such as competitive bidding, direct negotiation or single-source acquisition in that it can cope with qualitative uncertainty and preferences as well as the construction of contracts. We apply the method to the industrial procurement of an eOrdering system.

1. INTRODUCTION

The Online Business Dictionary defines procurement as the complete process of obtaining goods and services – from preparation and processing of a requisition through to receipt and approval of the invoice for payment. Also called sourcing, procurement commonly involves purchase planning, standards determination, specifications development, supplier research and selection, value analysis, financing, price negotiation, making the purchase, supply contract administration, inventory control and stores, and disposals and other related functions. A method of procurement is defined as a procedure used in converting requirements into purchase orders or contracts. Three common methods of procurement are competitive bidding, direct negotiations, and single-source acquisition. Procurement is one of the central applications in eBusiness. As a consequence, companies such as Cisco, Chevron and Eastman Chemicals are developing eProcurement systems [2] to improve their suppliers relationships, enhance the speed, accuracy and effectiveness of their procurement process, achieve higher service levels, reduce prices from key suppliers and reduce inventory costs [11]. The use of agents to support eProcurement has already been advocated (e.g. in [7]). In this paper, we show how *argumentative agents* can fruitfully support (part of) the procurement process. Here, argumentative agents are agents using argumentation technology to make decisions, e.g. as in [10; 1; 14].

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Wikipedia's article[1] divides procurement into seven steps:

Information Gathering: If the potential customer does not already have an established relationship with sales/marketing functions of suppliers of needed products and services, it is necessary to search for suppliers who can satisfy the requirements.

Supplier Contact: When one or more suitable suppliers have been identified, Requests for Quotation, Requests for Proposals, Requests for Information or Requests for Tender may be advertised, or direct contact may be made with the suppliers.

Background Review: References for product or service quality are consulted, and any requirements for follow-up services including installation, maintenance, and warranty, are investigated. Samples of the product or service being considered may be examined, or trials undertaken.

Negotiation: Negotiations are undertaken, and price, availability, and customisation possibilities are established. Delivery schedules are negotiated. The candidate suppliers are evaluated and a supplier is selected. A contract to acquire the product or service from the chosen supplier is completed.

Fulfilment: Supplier preparation, shipment, delivery, and payment for the product or service are completed, based on contract terms. Installation and training may also be included.

Consumption, Maintenance and Disposal: The company evaluates the performance of the product or service and any accompanying service support, as they are consumed.

Renewal: When the product or service has been consumed and/or disposed of, the contract expires, or needs to be re-ordered, and the company experience with it is reviewed. If it is to be re-ordered, the company determines whether to consider other suppliers or to continue with the same supplier.

This paper explores the potential of argumentation-based techniques for supporting and automatising the evaluation of offers, the selection of a best supplier and the composition of a contract as required for the negotiation step. It is thus assumed that information gathering, supplier contact and background review have been established prior to this. We also assume that the buyer has already formed a short-list of four or five suppliers [12]. The buyer may then compare their offers using his own (qualitative) criteria and select the one that best meets his business strategy. A structured, planned and well-informed approach is required for procurement negotiation as the choice of a supplier is likely to be a critical factor in the buyer's ability to deliver business benefits. Our study is illustrated by the procurement problem of an eOrdering system, as described by the eBusiness specialist *cosmoONE*[2] for the EC-funded ArguGrid[3] project.

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[1] http://en.wikipedia.org/wiki/Procurement
[2] http://www.cosmo-one.gr
[3] http://www.argugrid.eu

2. INDUSTRIAL USE CASE

Industrial procurement is a complex problem that requires expertise in the domain of the product or service to be purchased. Experts are not only required for understanding the various features of offers made by suppliers but may also help the buyer identify and formulate his business-specific needs. Once a clear representation of the procurement problem has been obtained, features and expected benefits can conveniently be modelled in a qualitative way, as illustrated by the following industrial use case. Let us consider the problem – originally described in [13] – of a company (the buyer) that wishes to acquire an electronic ordering system to support its purchasing department. With this purchase, the buyer expects to achieve three goals: i) to decrease his direct or indirect purchasing and inventory costs, ii) to achieve better control on its spending and iii) to enhance the standardisation and automation of buyer-supplier communications. Informally, the most advantageous offer for the buyer shall be the one for which these benefits are achieved with highest degree.

ref.	description
f_1	the system provides self-service supplier catalogue processing
f_2	the system provides catalogue changes tracking and authorisation mechanisms
f_3	the system supports shopping cart aggregation
f_4	the offer includes integration of the e-Ordering system with the company's enterprise resource planning system (ERP)
f_5	the system supports out-of-catalogue requests
f_6	the system supports "round-trip" / "punch-out" requests
f_7	the system supports framework agreements
f_8	the system supports multiple and concurrent product categorisations
f_9	the system supports multiple workflow types (serial, parallel, per category, etc)
f_{10}	the offer is based on a 3-year flat contract cost
f_{11}	the system supports electronic auctions

Figure 1: Features describing eOrdering systems.

Offers on eOrdering systems can be described using the features listed in figure 1. Each feature has an impact on the degree of achievement of the benefits i)–iii). The more insights the buyer has on the features and benefits expected, the simpler the evaluation and selection problem. Experts in eOrdering systems [13] consider that any feature in the category $C_1 = \{f_3, f_6, f_{11}\}$ decreases direct purchasing costs. Also, any feature in $C_2 = \{f_1, f_2, ..., f_9\}$ decreases indirect purchasing costs. All features in $C_3 = \{f_1, f_2, ..., f_5, f_7, f_8, f_9\}$ decrease inventory costs. Finally, a low contract cost (the only feature in $C_4 = \{f_{10}\}$) helps decrease eOrdering costs and avoid hidden costs[4]. Therefore, maximal cost reduction is attained when all four types of costs are reduced. A simple way of assessing the degree of achievement of benefit i) (cost reduction) by an offer is to count the number of categories amongst $C_1 - C_4$ covered by its features. Since only four categories are used, four levels of achievement will be sufficient. We may call these degrees *poor*, *fair*, *average* and *high*. We say for instance that an offer decreasing the four types of costs highly decreases the buyer's costs.

[4]Note that features for additional payments schemes such as pay per use/software as service model or open-source + consultancy can be introduced if necessary.

Benefits ii) and iii) are simpler to analyse. In fact, we can consider that all features amongst $A = \{f_2, f_3, ..., f_9\}$ allow the buyer to achieve a better spending control and all features amongst $B = \{f_1, f_2, f_5, f_6, f_7, f_8\}$ enhance buyer-supplier communications. We assume that features additively contribute to the degree of achievement of those benefits (so, for example, the higher the number of features in A, the higher the degree of achievement of benefit ii)). Figure 2 summarises the correspondence between features and benefits as described by eProcurement specialists.

	decrease costs	**better spending control**	**enhance communication**
high	4 categories	$\geq$ 4 features	4 features
average	3 categories	3 features	3 features
fair	2 categories	2 features	2 features
poor	1 category of C_1-C_4	1 feature of A	1 feature of B

Figure 2: Structure of the buyer's preferences.

Figure 3 describes four fictitious offers. Cells with yes (respectively no) represent features that are (respectively are not) part of the offers. The other cells indicate the buyer's uncertainty regarding the presence of advertised features. Buyers may indeed have doubts regarding the details of offers. Here, the buyer may wonder whether supplier s_4 has the required level of expertise to integrate its product within the buyer's Enterprise Resource Planning system (f_4). The buyer may also have asked the least trusted short-list suppliers to exhibit the key features of their product and thus have spotted an important default concerning s_1's catalogue interface (f_2). Finally, he may discover that supplier s_2 (respectively s_3) could add f_5 (respectively f_6) as an option and for no extra fee. In fact, such uncertainties can be resolved via supplier-specific contract clauses. Contracts – defined here as sets of clauses that the buyer wants a supplier to guarantee – offer a sound basis for comparing offers in a formal way. We propose in section 3 a method for comparing offers whereby contract clauses are treated as assumptions and used to derive arguments concerning the benefits they provide.

	s_1	s_2	s_3	s_4
f_1	no	no	yes	yes
f_2	interface !	no	no	no
f_3	no	no	no	no
f_4	no	yes	no	expertise ?
f_5	yes	optional	yes	yes
f_6	no	no	optional	yes
f_7	no	no	no	no
f_8	no	yes	yes	no
f_9	yes	no	yes	no
f_{10}	no	yes	no	no
f_{11}	yes	no	no	yes

Figure 3: Offers made by the short-list suppliers.

Existing evaluation methods suggest to compute a technical score, defined as a weighted sum of the features value/utility. Weights and utilities are unfortunately difficult to choose in practise. More importantly, technical scores are not affected by the buyer's uncertainties. Decision-theoretic approaches [4] address the latter issue by using probabilities, but probabilities are difficult to obtain and unlike contracts, do not resolve uncertainties. Assumption-based argumentation allows to select the best suppliers and at the same time determine optimal contracts to resolve existing uncertainties.

3. ARGUMENTATION & PROCUREMENT

Argumentation is a logic-based mechanism where truth is not absolute but rather stems from competitive debate about contradictory outcomes. As anyone can easily imagine, argumentation naturally takes place everyday in business decisions and negotiations. The argumentation paradigm introduced in this section allows to model and simulate the type of competition that occurs between candidate suppliers in procurement. Intuitively, in this competitive setting, suppliers would attack (contradict) each other by proving various claims regarding the quality of their offers and the buyer would play the role of arbiter. In the kind of argumentation we adopt (that of assumption-based argumentation) arguments can be supported by assumptions that include issues which the buyer is uncertain about, but that can be resolved via contracting (as discussed earlier).

Assumption-based argumentation.

An *assumption-based argumentation framework* (ABAF) [3; 5] is a tuple $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \mathcal{C} \rangle$ where $\mathcal{L}$ is a set of sentences referred to as the underlying *language*; $\mathcal{R}$ is a set of *inference rules* of the form $\frac{p_1,\ldots,p_n}{q}$ for $n \geq 0$ where $p_1, \ldots, p_n \in \mathcal{L}$ are called the *premises* and $q \in \mathcal{L}$ the *conclusion* of the rule; $\mathcal{A} \subseteq \mathcal{L}$ is a set of *assumptions*; $\mathcal{C} : \mathcal{A} \to \mathcal{L}$ is a total mapping giving the *contrary* of each assumption.

In ABA, arguments are deductions of conclusions, based on assumptions and built using inference rules. Formally, an *argument* $\Delta \vdash p$ with conclusion $p \in \mathcal{L}$ and based on set of assumptions $\Delta \subseteq \mathcal{A}$ is a finite sequence of sets of sentences $\beta_1, ..., \beta_m$ (each $\beta_i \subseteq \mathcal{L}$), such that $m > 0$, $\beta_1 = \{p\}$, $\beta_m = \Delta$ and, for each β_i, $1 \leq i < m$, $\beta_{i+1} = \beta_i - \{s\} \cup \{p_1, \ldots, p_n\}$ for some $s \in \beta_i - \mathcal{A}$ selected in β_i and inference rule $\frac{p_1,\ldots,p_n}{s} \in \mathcal{R}$.

Given any two sets of assumptions Δ_1 and Δ_2, we say that Δ_1 *attacks* Δ_2 if and only if there exists an argument $\Delta_1 \vdash p$ with p the contrary of an assumption $q \in \Delta_2$, i.e. $p = \mathcal{C}(q)$. Finally, a set of assumptions Δ is said to be *admissible* if and only if Δ does not attack itself and Δ (counter-)attacks every set Δ' attacking it. Intuitively, admissibility is meant to characterise the rationally acceptable assumptions (and arguments based on these assumptions) that can be held given some knowledge ($\mathcal{R}$). In general, there may be multiple admissible sets of assumptions, namely admissibility is a *credulous* approach to argumentation. [5] A sentence α is admissible when there exists an admissible set of assumptions Δ such that there exists an argument $\Delta' \vdash \alpha$ and $\Delta' \subseteq \Delta$. Any such Δ is often referred to as a *defence set* of α.

ABA for eProcurement.

We now introduce an ABAF $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \mathcal{C} \rangle$ that models the procurement problem discussed in section 2. Given this ABAF, *only sentences representing the best suppliers are admissible*. Furthermore, their corresponding *defence sets represent optimal contracts*.

Let $S = \{s_1, \ldots, s_N\}$ denote the set of suppliers, $F = \{f_1, \ldots, f_M\}$ the features describing their offers, $B = \{b_1, \ldots, b_K\}$ the set of benefits the buyer wants to achieve, $D = \{d_1, \ldots, d_L\}$ the possible qualitative degrees of achievement of benefits and $Q = \{q_1, \ldots, q_R\}$ a set of contract clauses. In the case of section 2, $N = 4$, $M = 11$, $K = 3$ (as the benefits are i)–iii)), $D = \{high, average, fair, poor\}$ (thus $L = 4$), and $R = 4$ (as four doubts appear in figure 3). The argumentation language $\mathcal{L}$ is formally defined as

$$\begin{aligned}\mathcal{L} = {} & S \cup \{f_m(s_n) \mid 1 \leq m \leq M, 1 \leq n \leq N\} \cup \\ & \{q_r(s_n) \mid 1 \leq r \leq R, 1 \leq n \leq N\} \cup \\ & \{\text{benefits}(s_n, b_k, d_l) \mid 1 \leq n \leq N, 1 \leq k \leq K, 1 \leq l \leq L\} \cup \\ & \{\neg\text{benefit}(s_n, b_k, d_l) \mid 1 \leq n \leq N, 1 \leq k \leq K, 1 \leq l \leq L\} \cup \\ & \{c_n \mid 1 \leq n \leq N\} \cup \{\neg q_r \mid 1 \leq r \leq R\}\end{aligned}$$

where c_n and $\neg q_r$ are sentences, different from all other sentences in $\mathcal{L}$, standing for the reasons for not choosing supplier s_n and the absence of clause q_r in a contract, respectively. The assumptions $\mathcal{A}$ are given by

$$\begin{aligned}\mathcal{A} = {} & S \cup \{q_r(s_n) \mid 1 \leq r \leq R, 1 \leq n \leq N\} \cup \\ & \{\neg\text{benefit}(s_n, b_k, d_l) \mid 1 \leq n \leq N, 1 \leq k \leq K, 1 \leq l \leq L\}\end{aligned}$$

The contrary relation is given by the total mapping

$$\mathcal{C} = \begin{cases} s_n \mapsto c_n \\ \neg\text{benefit}(s_n, b_k, d_l) \mapsto \text{benefits}(s_n, b_k, d_l) \\ q_r \mapsto \neg q_r \end{cases}$$

Finally, the inference rules of $\mathcal{R}$ are all rules of the form

1. $\frac{f_{i_1}(s_n),\ldots,f_{i_m}(s_n)}{\text{benefits}(s_n,b_k,d_l)}$ if the features $f_{i_1}, ..., f_{i_m}$ of offer s_n fulfil benefit b_k at degree d_l, with $\{i_1, \ldots, i_m\} \subseteq \{1, \ldots, M\}$
2. $\frac{}{f_m(s_n)}$ if s_n's offer has feature f_m or $\frac{q_{i_1}(s_n),\ldots,q_{i_r}(s_n)}{f_m(s_n)}$ if clauses $q_{i_1}, ..., q_{i_r}$ need to be added to a contract for s_n to provide f_m with quasi-certainty, with $\{i_1, \ldots, i_r\} \subseteq \{1, \ldots, R\}$
3. $\frac{\neg\text{benefit}(s_n,b_k,d_l),\text{benefits}(s_{n'},b_k,d_l)}{c_n}$ for every $1 \leq n, n' \leq N$ such that $n \neq n'$, $1 \leq k \leq K$ and $1 \leq l \leq L$
4. $\frac{s_n, s_{n'}}{c_n}$ for every $1 \leq n, n' \leq N$ such that $n \neq n'$.

Rules of the first two kinds are case-dependent (cf. figures 2 and 3).

In this framework for procurement, arguments may be constructed as follows:

- $\{s_n, s_{n'}\} \vdash c_n$ which may be read as 's_n cannot be selected (represented by c_n) since $s_{n'}$ has already been selected'
- $\{\neg\text{benefits}(s_n, b_k, d_l), q_{i_1}(s_{n'}), ..., q_{i_p}(s_{n'})\} \vdash c_n$ which may be read as 'My offer s_n' based on contract clauses $q_{i_1}, ..., q_{i_p}$ fulfils benefit b_k at degree d_l, but I presume that yours (s_n) doesn't !' and representing a criticism from $s_{n'}$ against s_n
- $\{q_{j_1}(s_n), ..., q_{j'_p}(s_n)\} \vdash \text{benefits}(s_n, b_k, d_l)$ which may be read as 'I can provide benefit b_k at degree d_l using contract clauses $q_{j_1}, ..., q_{j'_p}$, so what you presume is wrong !' which constitutes a counter-argument given by s_n against $s_{n'}$.

Arguments of the first kind are attacked by arguments of the second kind, that in turn are attacked by arguments of the third kind. Thus, this argumentation framework emulates the construction and exchange of arguments between suppliers, as would take place if the suppliers were directly competing under supervision of the buyer. When a supplier s_n can resist all attacks from the other competitors, it finds itself in a dominant position. This happens exactly when s_n is an admissible sentence in the framework. This justifies why the notion of admissibility is suitable for identifying the best suppliers. When s_n is admissible, its defence sets contain all the

[5] Sceptical approaches also exist, see [6], but would not be suitable for the problem in this paper, as they would rule out the possibility that two suppliers have made equally good offers and the choice between them is somewhat arbitrary. In the case of equally good offers, a sceptical approach would prevent any choice to be made.

contract clauses that supplier s_n needs to prove to be a best supplier. It is however important to note that the best supplier may not be unique and that there may not always exist a best supplier. When a best supplier does not exist, the "best" supplier could be taken as one with defence set of "maximal degree of admissibility", i.e. a defence set such that the fraction of attacks that can be counter-attacked is maximal. This topic – although left at the moment for future research – would interestingly allow us to compare offers without having to map sets of offered features onto a common monetary scale, as usually done in practise.

4. IMPLEMENTATION

We have used the argumentation system CaSAPI [6] to check the admissibility of sentences representing the suppliers and finds their corresponding defence sets, i.e. the required contracts. The framework to be processed needs to be represented within a Prolog file as follows (for CaSAPI 4): rules $\frac{p_1,\ldots,p_n}{q}$ are represented as Prolog facts `myRule(q,[p_1,...,p_n]).`; assumptions a are represented as facts `myAsm(a).`; contraries c of assumptions a are represented as facts `contrary(a,c).`; and each sentence s to be checked for admissibility is represented as a fact

`toBeProved([s]).`

In the procurement setting, CaSAPI must separately check the admissibility of the assumptions s_n. Each check answers the question: 'Is there a contract with supplier s_n that would guarantee his offer is the best ?'. If there is no such contract, CaSAPI simply answers no, but if such contracts exist, then CaSAPI answers yes and can be used to list them all.

In the eOrdering system procurement problem of section 2, the best supplier is s_3 and the associated contract contains a clause specifying that the round-trip / punch-out requests option (f_6) is required. This contract guarantees the buyer that the system offered by s_3 will provide all expected benefits i)–iii) to an average, high and average degree, respectively. These are the maximal degrees of achievement that can be reached given the offers made to the buyer.

Our approach can be used directly by argumentative agents, e.g. as given in [10; 14], acting on behalf of buyers. These agents could gather all required information in the form of tables (such as in figures 1-3), e.g. via a simple web-based GUI that could translate them automatically into an equivalent ABAF. The framework can then be processed by a general-purpose engine for ABA such as CaSAPI, returning to the buyer, via a GUI, the solution of the procurement problem.

5. EVALUATION AND CONCLUSION

The application studied in this paper is a genuine industrial problem and CaSAPI encounters no computational problem with it. Few minutes suffice to select the best supplier and compose a contract. A more thorough experimentation with larger problems and a GUI are ongoing work.

The procurement technique presented in this paper requires the buyer to express and structure his needs and preferences, identify the goals he wants to achieve and how the features of offers contribute to their achievement. The method presented can accommodate a rich family of needs and preference structures that goes well beyond the simple structures used in the given case. Indeed, benefits can be arbitrarily decomposed into hierarchical synergy structures involving goals, sub-goals and features.

Composing a feature-to-benefit summary table and issuing it to the candidate suppliers may efficiently guide the suppliers in the elaboration of their offers. The buyer may then test the products or services and have them demonstrated so as to spot their defaults or weaknesses. Any uncertainty can then be expressed and added to the underlying argumentation system. The latter then compares automatically all the possible contracts that can be formed from these offers by adding optional features, reducing some uncertainties or via product customisation. This comparison is made in a fair, traceable, transparent and auditable way. The comparison and selection of suppliers is made by automatic simulation of multilateral debates which would naturally take place between the competing suppliers. Argumentation technology, by automatising this process, renders negotiations simpler and more rational. It can be proved that the best suppliers, if at least one exists, are always found using the notion of admissibility.

Overall, this argumentation-based method of procurement enhances the level of competition between the suppliers, unlike methods based on direct negotiation. The method also allows the buyer to really focus on the accomplishment of benefits that define his business strategy contrary to competitive bidding methods which only focus on price.

[6]The name CaSAPI stands for 'Credulous and Sceptical Argumentation - Prolog Implementation' [8; 9]. CaSAPI is developed in the context of the ArguGrid project and is open-source. It can be downloaded from `http://www.doc.ic.ac.uk/~dg00/`. The full code used for the use case of section 2 is also available for download as an application example for the CaSAPI engine.

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