An Introduction to the Pocket Negotiator: A General Purpose Negotiation Support System

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Abstract. The Pocket Negotiator (PN) is a negotiation support system developed at TU Delft as a tool for supporting people in bilateral negotiations over multi-issue negotiation problems in arbitrary domains. Users are supported in setting their preferences, estimating those of their opponent, during the bidding phase and sealing the deal. We describe the overall architecture, the essentials of the underlying techniques, the form that support takes during the negotiation phases, and we share evidence of the effectiveness of the Pocket Negotiator.

1 Introduction

Negotiation is a complex emotional decision-making process aiming to reach an agreement to exchange goods or services. Although a daily activity, few people are effective negotiators [38]. Fisher and Ury, Raiffa and Thompson, and others, emphasize that negotiation is not just about money. Good relationships, awareness of all issues (domain model), personal preferences (user and opponent model), and knowledge of your alternatives (if no deal is reached), are all important, see e.g., [20,21,36,38]. In negotiation four major stages can be discerned: private preparation, joint exploration, bidding, and closing (see the upper bar of Fig. 1).

Existing automated negotiating agents could make a significant improvement if the negotiation space is well-understood, because computers can better cope with the computational complexity. However, the negotiation space can only

Author ordering: Jonker as overall initiator and coordinator as first author, other authors in alphabetical ordering as their contribution is hard to quantify.

N. Criado Pacheco et al. (Eds.): EUMAS 2016/AT 2016, LNAI 10207, pp. 13–27, 2017.
DOI: 10.1007/978-3-319-59294-7_2

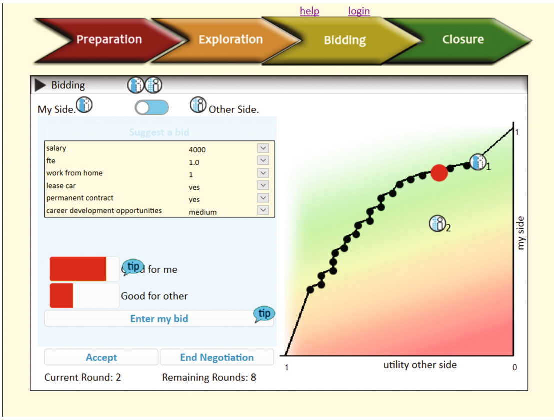

Fig. 1. The Pocket Negotiator can suggest possible bids to the user and preview their placement in the estimated outcome space. Support for the four negotiation phases can be reached by clicking on the phase intended. (Color figure online)

be properly developed if the human parties jointly explore their interests. The inherent semantic problem and the emotional issues involved make that negotiation cannot be handled by artificial intelligence alone, and a human-machine collaborative system is required.

Based on our long-standing experience in automated negotiation, see e.g., [9,10,14–16,27,31], we decided to use our knowledge of negotiation strategies to offer negotiation support to human users. For this purpose we developed a prototype system called the Pocket Negotiator. It offers a qualitative preference elicitation tool that is inspired by Harvard's approach for addressing underlying concerns, often called interest-based negotiation. As almost all bidding strategies are utility-based we decided to map the qualitative profiles of the user and the opponent to additive linear utility functions. Furthermore, the user receives bidding advice and an advice of when to accept a bid of the other party.

The organization of the paper is as follows. Section 2 describes the architecture. The interests underlying the negotiation and all other profiling tools are the topic of Sect. 3. The bidding phase is detailed in Sect. 4. Before we implemented the Pocket Negotiator we investigated the acceptability and possible usability of such a device, see Sect. 5. Once the Pocket Negotiator was on its feet we started experimenting, and here we present some of our results in Sect. 6. Our is not the only effort to develop negotiation support systems. A brief review of related work can be found in Sect. 7. In Sect. 8 we discuss the current state of the Pocket Negotiator and draw conclusions about its future use.

2 Architecture and Negotiation Phases

The Pocket Negotiator is set up as a modular system to allow an efficient connection to the repositories of the GENIUS framework [31], which is an automated negotiation simulation framework that supports a variety of agents, scenarios, and protocols. A simplified picture of the architecture is presented in Fig. 2. It has two repositories; one for domains that also includes preference profiles for the roles mentioned in the domains, and a repository for the strategies used to provide advice to the user.

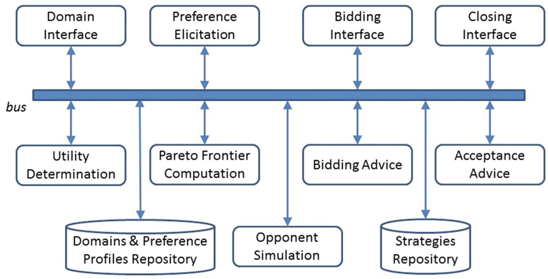

Fig. 2. The architecture of the Pocket Negotiator

Through the domain interface, the user obtains information about the available domains, and picks the appropriate one. Furthermore, this interface allows the user to inform the PN about his experience in negotiation, how badly a deal is needed, and what kind of negotiation personality he has. The same is asked about the opponent (in as far as the user knows about this). In the preference elicitation interface the user sets all his preferences: domain related, strategic, and procedural. The specifications of domains and preference profiles are stored in a dedicated repository.

For the strategies, all bilateral bidding strategies, the opponent modeling strategies and the strategies for when to accept bids as available in the GENIUS strategies repository can, with small moderations, be used in the PN, see [3]). More information on each of these aspects can be found in the next sections.

The Pareto Frontier Computation component approximates the Pareto Optimal Frontier for the preference profile of the user and the estimated profile of the opponent.

The Utility Determination component determines a utility function for both negotiation participants based on the information gathered in the preference elicitation interface. Furthermore, it keeps a tab on all bids exchanged between the parties, and, if appropriate, updates the profile of the opponent. The automated opponent modeling strategy uses a frequency analysis approach as described in, e.g., [7].

The Opponent Simulation is a component that is active in the variants of PN designed for experiments and training. In these variants human participants negotiate against a bot.

The Pocket Negotiator distinguishes and emphasizes the four phases of negotiation identified in Sect. 1 by design: the Preparation, Exploration, Bidding and

Closing phases. Each of theses phases is supported through a set of dedicated interfaces. The list of phases is always available at the top of all PN interfaces, see e.g., Fig. 1.

The Preparation phase supports the choice of domain and strategic choices and information, as described in Sect. 3. For reasons of security, the domain editor is not directly linked to the Pocket Negotiator. It is provided as an independent program, the output of which is uploaded by our server administrators upon request. Both the Preparation phase and the Exploration phase give access to the interests and other preference profile information for both roles.

The Exploration phase is the phase in which the negotiators get to know each other, feel out the playing field, and thus spend time to deepen and adapt their profiles. The Pocket Negotiator specifically urges users to not only model their own preferences profiles, but also those of their opponent. As preferences are constructive in nature, both parties need those conversations and private contemplations to form these profiles. The literature of human negotiation shows that the quality of the outcome of the negotiation depends largely on the quality of the preparation and exploration phase, see e.g., [20,21,37,38].

The Bidding phase is supported by the bidding interface which presents the Pareto Optimal Frontier as provided by the Pareto Frontier Computation component, and specific interface elements to let the user enter his bid and see how good that is for himself and for the opponent. It presents an overview of the bidding history. It gives access to the bidding support agent to suggest bids, and offers advice on whether to accept the bid of the opponent. More information can be found in Sect. 4.

The Closing interface supports the closing phase by summarizing the agreement, and offering to either print or email the outcome for further processing.

The next sections provide more information on the essential components and technology that underly the Pocket Negotiator. No further information is provided on the Closing interface.

3 Profiling

This section discusses the essentials of the tools and techniques used in the Pocket Negotiator for profiling the domain, the user and the opponent. Next to domain preferences that explain which negotiation outcomes are to be preferred as described in Sect. 3.3, the profiling also addresses strategic preferences and background information for the negotiation, see Sect. 3.2.

3.1 Domain Editor

With respect to domains a small number of domains is standardly made available, and new domains can easily be loaded or designed using a dedicated domain editor. The domain editor enables the specification of the domain in terms of the roles in negotiation typically taken (e.g., seller vs buyer, or consumer vs provider), the interests, the most commonly negotiated issues with their value ranges, example outcomes, and initial profiles for each of the roles. The domain editor requires a good understanding of modeling domains, preference profiles and utility functions. For security reasons it is disconnected from the PN.

By now there are a number of negotiation domains available in the PN. Most elaborated are the *Jobs* scenario and real estate, where also the link between the interests-based profile and the utility-based profile has been validated. Other available domains are: Energy contracts and Water management.

3.2 Strategic Preferences and Background Information

In terms of strategic information and choices, the user can choose which agent will offer support and how many rounds he expects to negotiate. He enters information about the expertise in negotiation for both parties, see Fig. 3.

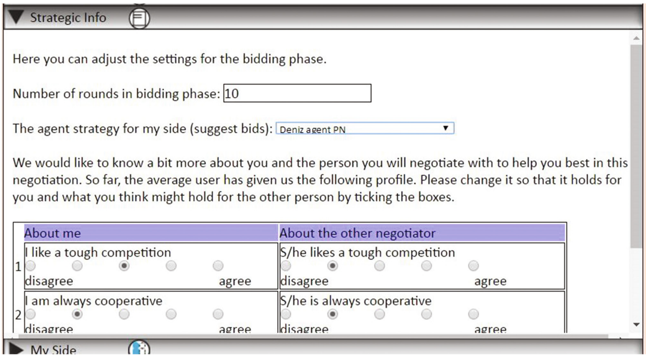

Fig. 3. The domain interface of the Pocket Negotiator

The expertise and expectation questions are about the user and what user beliefs about his opponent. The questions are about how competitive they are, how cooperative, how much they need a deal, and how experienced they are in negotiation. The answers to each of these questions can be used to fine tune the strategies for bidding and accepting offers. More information on cooperative vs competitive negotiation strategies can be found in, e.g., [5].

3.3 Interest-Based Preference Elicitation

As the way people prepare for a negotiation determines to a large extent the quality of the outcome of the negotiation, preference elicitation is of fundamental importance to a negotiation support systems. For that purpose we investigated various ways of elicitation, see e.g., [33,35]. In the first paper, we set up a compositional design approach for the creation of preference elicitation interfaces that takes into account that preference elicitation requires the user to undergo a constructive process. The constructive nature of preferences refers to the fact that humans typically don't know their preferences; they have to figure these out by engaging with the topic. In the second paper, we applied the method of the first paper, to study the effectiveness of elicitation methods in relation to the cognitive effort required and preference detail. Based on our results and given recommendations to use interest-based negotiation, we decided to use the Value-Sensitive Design approach, see e.g., [22], to develop the preference elicitation tools for the PN. This led to a system in which the user is first asked to reflect on the interests that for him underly the negotiation, see Fig. 4.

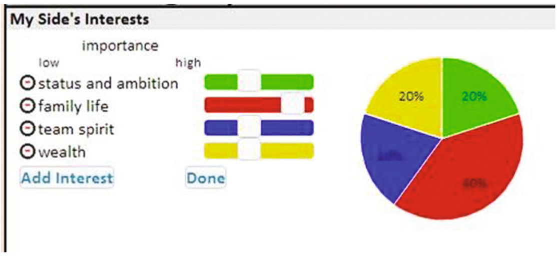

Fig. 4. The interests underlying the negotiation

By manipulating the sliders the user indicates the relative importance of the interests for him. More interests can be added, existing ones be removed. By clicking on the name of an interest a new interface pops up that allows the user to indicate which negotiable issues are influenced by that interest, see Fig. 5. The examples presented come from a negotiation about job conditions, and are discussed from the point of view of the new employee. By doing a user study amongst young ICT specialists, we found that these were the most commonly encountered interests.

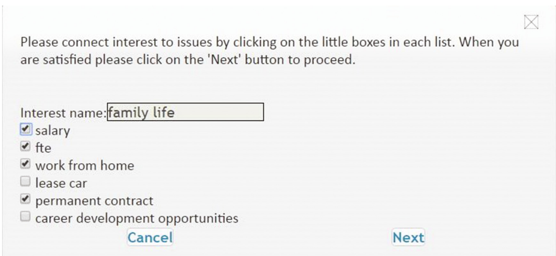

Fig. 5. How an interest links to negotiable issues

In this interface the check-boxes indicate which of the issues are influenced by the interest. The link is made from the interest in family life to salary (as that is necessary to pay for e.g., children), fte (which stands for "full time equivalent", and is relevant for being able to care for children yourselves), work from home (as that makes you more flexible with respect to e.g., children and school), and a permanent contract (as that gives security). By clicking on the "next" button, the user is presented with a new interface, see Fig. 6.

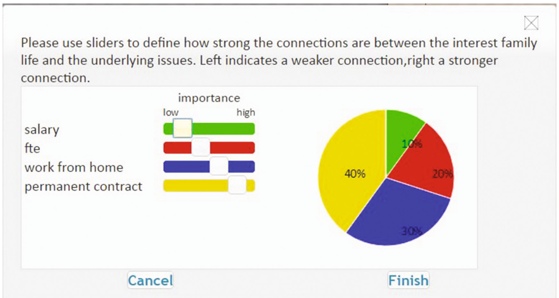

Fig. 6. The impact of an interest on the weights of negotiable issues

We chose as much as possible the same interface type so as to make them easy to understand for the user. As in Fig. 6 we are again asking for a relative impact, we chose the same format as for the interests. In this case we are asking for the relative influence of the interest in family life on the importance (called weight) of the issues.

3.4 Utility Functions

The preference elicitation method of the PN as described above, defines a qualitative preference structure. To be able to use the state-of-the-art negotiation strategies from automated negotiation research, we need to transform this to a linear additive utility function. We do this in two steps. We first define a utility function U by taking the settings of the sliders from the preference elicitation tools as numbers. Even though the user only entered this as relative notions and not concrete values, this direct translation certainly respects the rankings make by the user. Then we define a our target linear additive utility function U'. The final step is to prove that these two functions give the same utility for any bid. This requires the introduction of some notation:

IN is the collection of interest items; e.g., $\{sparetime, wealth, status\}$
IS is the collection of negotiable issues; e.g., $\{salary, fte, leasecar\}$
V_i is the collection of value items for issue $i \in IS$; e.g., $V_{fte} = \{0.6, 0.8, 1.0\}$
$B : \Pi_{i \in IS}(V_i)$ is the set of all possible bids. For any $b \in B$, let b_i denote the projection of b on V_i, i.e., the value for issue i in the bid.

Definition 1. *Weights of an Interest-based Utility function*
Let $w_n \in \langle 0,1]$ denote the weight of interest $n \in IN$. Let $w : IN \times IS \rightarrow [0,1]$ denotes the weight of an issue as part of an interest in the profile.
The weights w_n and $w(n,i)$ are defined by what the user entered in the corresponding interfaces, see Figs. 4 and 6 respectively.

The elicitation method ensures that sum of all interest weights is 1.

Definition 2. *Partial Interest-based Utility functions*
For any $i \in IS$, $n \in IN$, and $v \in V_i$, $u_i(n,v)$ denotes the utility of v. Each partial utility function u_i is defined by the domain model in the repository[1].

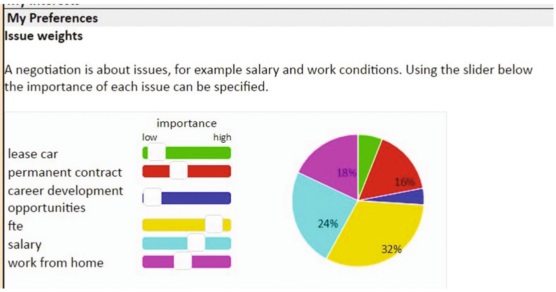

Fig. 7. The weights of negotiable issues

Definition 3. *Interest-based Utility*
We define the interest-based utility function $U : B \rightarrow [0,1]$ as follows:

$$U(b) = \sum_{n \in IN} w_n \sum_{i \in IS} w(n,i) u_i(n,b_i) \tag{1}$$

Definition 4. *Intended utility function*
The intended linear additive utility function $U' : B \rightarrow [0,1]$ is defined by

$$w'_i = \sum_{n \in IN} w_n w(n,i) \tag{2}$$

$$u'_i(b_i) = \sum_{n \in IN} \frac{w_n w(n,i)}{w'_i} u_i(n,b_i) \tag{3}$$

$$U'(b) = \sum_{i \in IS} w'(i) u'_i(b_i) \tag{4}$$

where U' refers to the overall utility function, $w'(i)$ to the weight of issue i, and $u'_i : V_i \rightarrow [0,1]$ refers to the partial utility function of issue i. The deeper part of the preference elicitation interfaces present these weights w'_i and functions u'_i to the user. For the weights the format of relative importance is used, see Fig. 7. The pictures for u'_i are left out for reasons of space.

[1] Functions are not visible in the interfaces of PN.

Theorem 1. *The interest-based utility function U and the intended utility function U' give the same results for all bids in B:*

$$\forall b \in B : U(b) = U'(b) \tag{5}$$

4 Bidding Phase

The PN offers support for making the right proposals during the bidding phase (see Fig. 1). To make the PN aware of bids that have been offered by the opponent (in real-life), the user can enter their bid into the system. By clicking *Suggest a bid*, the PN can recommend a counter-proposal and highlight a preview of this bid in the outcome space (i.e. the red dot in Fig. 1). The user has the opportunity to refine the suggestion by tweaking the desired values for each individual issue. Finally, the user can choose to send out the offer to the opponent (in real-life) and signal this to the PN by pressing *Enter my bid*.

For every contemplated offer, the PN also provides an estimate of the utility for the user and for the opponent, which, at the start of the bidding phase, is determined by the information provided during the preparation and exploration phase. Similarly, it shows the estimated outcome space, in which the red area signifies lose-lose outcomes that are to be avoided, while the green area indicates the win-win outcomes, including, in particular, the estimated Pareto optimal offers, which the PN will aim for.

The bid recommendations by the PN are performed by a negotiation agent, which is designed as a modular component of the system. The negotiation model of the Pocket Negotiator is in principle compatible with all repository items from Genius [31]. This means the bidding strategies (including the ability to accept [13]) contained in Genius can all be integrated into the Pocket Negotiator with only minor adjustments; examples include [1,17,18,25,28,40].

During the bidding phase, the agent has the opportunity to learn more about the opponent through the exchanged bids [2,7,8], which involves three different aspects: the opponent's *type*, *preference*, and *strategy* [9]. The agent that is used in conjunction with the PN determines which type of learning method is employed. The PN supports a separate bidding, opponent modeling, and accepting architecture [4,12], whereby any established concession strategy (e.g. time-dependent tactics [19]) can be recombined with established components for learning (e.g. Bayesian learning [18,26]) and acceptance (e.g. optimal stopping [11]).

Currently the (type of) bidding strategies that are available are the Bayesian agent [26], the Conceder Agents [19], the Simple Agent, and the Simple Tit for Tat Agent, see [5,10] for their descriptions. The default bidding strategy is the Deniz agent, which is an extension of the optimal bidding strategy as described in [6]. In the practice versions of the Pocket Negotiator, where an agent plays the user's opponent, Deniz is also the strategy for the opponent.

5 Acceptability

Before implementing the Pocket Negotiator, we decided to first to perform some acceptability studies to make sure we would be making something that would be to the interest of people. This study is reported in [34], where we asked people to reflect on the possible use of negotiation support systems (NSS) in different social contexts and the consequences for their design. We conducted focus groups sessions separately with negotiation experts and potential users. This resulted in the idea that we should design a mobile NSS, and some design guidelines.

We used an online survey to establish the following. Our first goal was to find out in which situations people consider a NSS socially acceptable. The second goal was to find the factors and relationships that influence this acceptance in the different situations and social contexts. The last goal was to investigate the consequences of people's attitudes toward NSS for the system's design.

The data showed that subjective norm is an important factor influencing the intention to use the system and that the acceptance of NSS depends on the use context. We concluded that our NSS should be designed not only merely as a tool for actual negotiations, but also as a social device harnessing social networks to provide support in all negotiation phases. These were promising results, that motivated us to implement our ideas for the Pocket Negotiator.

6 Experiments

In order to assess to what extent the Pocket Negotiator successfully supports people in their negotiation, we conducted a user experiment. We prepared two variations of the Pocket Negotiator: *No-support* and *PN-support*. In both versions, the opponent of the human participant is played by the Deniz agent. In all experiments exactly the same domains and preference profiles are used in the two variants. The only difference between the variants is that the PN-support version provides all the support as presented in the previous sections, while the No-support version does not provide any of them.

We asked half of the participants to negotiate with the PN-support and the other half to negotiate with the No-support version. During their negotiation, we logged their actions and the negotiation outcome they reached. The results show that the participants with the PN-support gained higher utilities/or at least high utility as the participants with the No-support version received in most of the cases. According to the questionnaire filled in by the participants after their negotiation, it can be said that most of the participants found the Pocket Negotiator useful in their negotiation.

7 Related Work

This section discusses research reports of other Negotiation Support Systems, but also a bit about research into human-agent negotiations. The last category is where we see a possible line of future research work.

According to the classification of negotiation support systems in [23] into (1) real-life applications, (2) systems used in business, research and training, and (3) research results, the Pocket Negotiator is intended for real-life applications, but needs to specialize to business systems. The variants we initially created for our research in which you can play against an bot-opponent are actually already used for training students (psychology students of Leiden University, business and computer science students of TU Delft and Erasmus University, and computer science students of Özyeğin University. Similarly, their listing of key constructs in Negotiation Support Systems is still useful and has also helped us in determining what we wanted to focus on in developing the PN. Their discussion of successful and unsuccessful cases makes it clear to us that our PN still has to pass this test. The Aspire system [30] has been an inspiration from the start. We decided to focus on complete bids, and avoid free text interaction.

The work of Vahidov and co-authors, see [39], studies the prospects of agent-to-human negotiations using experiments with human subjects. In particular, they studied how humans use analytical support tools in making their decisions. The strategies used in the agents that played their opponents show the same types of strategies we offer to the user: conceder, individualistic, and tit-for-tat. Their findings confirm those of similar experiments of the past, see e.g., [14]: Overall, the findings speak in favor of agent-managed negotiations.

The Shaman systems as introduced in [29] is a framework for the construction and operation of heterogeneous systems enabling business interactions such as auctions and negotiations between software and human agents across those systems. The Pocket Negotiator could be linked to Shaman to support humans in their negotiations. It would be interesting to see how the PN could largely do the negotiations on behalf of the human and every now and then discuss the progress with the human user before concluding the negotiations. As automated negotiating agents can easily exchange some 3000 bids for normal-sized domains, such a bounded interaction with human users could improve the overall outcomes over agent-agent negotiations and agent-human negotiations.

Gratch *et al.* studied how virtual agents can be used in practicing negotiation skills [24]. They observed that the participants in their experiments were more comfortable to negotiate with a tough computer agent rather than a tough human opponent. Mell and Gratch developed a human-agent negotiation environment namely IAGO, which studies of human-agent negotiations with the aim to improve the negotiation skills of humans by teaching and practicing with IAGO, see [32]. Future research is to see what difference a NSS, in particular, the PN can make for these negotiations.

8 Discussion and Conclusion

The Pocket Negotiator is a negotiation support system that provides support for negotiations in all negotiation phases. It's key contributions are the unique way of eliciting preference profiles over interests and automatically translating the profiles to linear additive utility functions.

The second key contribution is that the PN encourages the user to also model a preference profile for the opponent. This further improves the preparation of the user for the negotiation, and furthermore enables the PN to support the user with tools developed for automated negotiations and their performance analysis. The bidding support is therefore equiped with a picture of the bidding space that includes an estimation of the Pareto Optimal Frontier, depicts the bidding history and allows the user to pick elements of the Pareto Optimal Frontier for reaching efficient outcomes.

The last key contribution is the access to the richness of the state-of-the-art in bidding-, opponent modeling, and acceptance strategies for bilateral negotiations for arbitrary domains.

To prepare for a negotiation you start it with the domain you need and a strategy that fits the needs and wishes of a stakeholder. It encourages the user to also consider the position and preferences of the party he will negotiate with. For professional negotiators this is easier than for the layperson, but if the domain model has been well researched, also the layperson can take advantage of studying the profile that comes with the domain description. However, we feel that for a commercialization of the PN, it would be better to specialize this part further and connect it to the Internet to automatically update and enhance the domain model. Domains that might lend themselves well for the PN are conflict resolution, customer retainment, and contract renewal for e.g., energy providers, Internet providers and so on.

The preference elicitation strategy is based on the interest-based negotiation approach. It is unique in deriving a standard utility function automatically from the user's reflection on the relative importance of typical interests underlying negotiations in the given domain. The user can iteratively deepen his investigation of his preferences, by linking the interests to the negotiable issues and indicating the relative impact of an interest to those issues. When continuing the reflection of his preferences brings the user to the more often seen of ranking the possible outcome elements per issue. More research is needed to add explanation of these matter to the system.

In case the domain of negotiation needed is not included in the Pocket Negotiator, a domain editor is available to create a new domain description. However, improvements to this domain editor would be necessary to make it suitable for a layperson. Due to its modular architecture plug-ins can be added that automatically extract domain knowledge from the Internet. For example, for a second hand car dealer, current prices for a car model and mileage can be easily added. The car dealer can update the domain model with all accessories, and services that are negotiable.

Acknowledgement. This research was supported by the Dutch Technology Foundation STW, applied science division of NWO and the Technology Program of the Ministry of Economic Affairs. It is part of the Pocket Negotiator project with grant number VIVI-project 08075.

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Multi-Agent Systems and Agreement Technologies
14th European Conference, EUMAS 2016, and 4th International Conference, AT 2016, Valencia, Spain, December 15-16, 2016, Revised Selected Papers
Criado Pacheco, N.; Carrascosa, C.; Osman, N.; Julian, V. (Eds.)
2017, XIV, 582 p. 147 illus., Softcover
ISBN: 978-3-319-59293-0