December 2002

APPOINTMENT SCHEDULING AMONG AGENTS: A CASE STUDY IN DESIGNING SUITABLE INTERACTION PROTOCOLS

Rainer Herrler
University of Würzburg

Christian Heine
Technical University of Ilmenau

Franziska Kluegl
University of Würzburg

Follow this and additional works at: http://aisel.aisnet.org/amcis2002

APPOINTMENT SCHEDULING AMONG AGENTS: A CASE STUDY IN DESIGNING SUITABLE INTERACTION PROTOCOLS

Rainer Herrler
University of Würzburg
Information Systems 6
herrler@informatik.uni-wuerzburg.de

Christian Heine
Technical University of Ilmenau
Information Systems 2
christian.heine@tu-ilmenau.de

Franziska Klügl
University of Würzburg
Information Systems 6
kluegl@informatik.uni-wuerzburg.de

Abstract

This article presents a case study in the design of suitable communication protocols for software agents. A process to derive a formal language from example stories is proposed and presented for the case of appointment scheduling among agents. Such a formal language that consists of language primitives and protocols is prerequisite for coordination and mutual understanding in agent systems. It can either be used among software agents or for the communication between software agents and real agents (human principals, software users). Important requirements are intuitivity, consistency, extensibility and a clear separation between invariant protocol structures and variant reasoning elements. The proposed story-driven design-process is analyzed and evaluated according to these requirements. It is illustrated using an example story for hospital patient scheduling.

Introduction

Everyone knows examples of appointment negotiations from daily life. Possible forms reach from simply making appointments for hairdressing or booking a flight to complex negotiations like the joint search for a suitable meeting-date (Buseman et al. 94). Another interesting example is the distributed planning and scheduling of treatment and examination tasks in hospitals (Miksch 99, Decker 98). This is also our main application domain. Our mission is preliminarily to identify and evaluate potential optimizations in hospitals with the instrument of multi-agent simulation.

The scheduling of tasks in natural multi-agent systems is usually distributed. An organizational unit just has control over its own time table. Although this leads to a reduction of the problem complexity, it enlarges the necessity for coordination and thus for negotiation. Existing authority structures and non-standard individual goals have to be taken into account. Existing artificial scheduling systems on the other side frequently use a central solution method. Therefore they are more apt for representing and considering global goals on the hospital level. However, in some cases – e.g. when a scheduling system has to be integrated into a distributed environment, or real-world scheduling processes have to be reproduced in a simulation model, distributed scheduling is essential. An important prerequisite for distributed scheduling is that the agents have the ability to arrange dates and negotiate about them. The latter includes four aspects: the availability of communication tools (transmission-channel, perception,..), a common language, common knowledge about negotiation policies, and finally negotiation strategies, that help reaching the own goals. After a short overview over related work, we present different requirements for negotiation protocols and propose a story-driven method for designing a suitable formal negotiation language that is illustrated using examples from the hospital domain.

Related Work

Negotiation in general has been an important research area in Distributed Artificial Intelligence for years. Thus there is a variety of work related to the issues tackled in this paper. General considerations may be for example found in (Müller 1996) or (Jennings et al. 2001). In the following we will concentrate on considerations on designing negotiations. Besides game-theoretic approaches (Sandholm 1999) most negotiation protocols are based on speech act theory (Searle 1969, Austin 1962). A speech act can be seen as an utterance with effects in the environment of the speaker. Examples of speech acts are "tell", "declare", "deny", etc. Appropriate speech acts are used in agent communication languages like KQML or FIPA-ACL. All higher level negotiation protocols may be described as coordinated (possible) sequences of speech acts. The most famous negotiation protocol is the contract-net protocol (Smith and Davis, 1981). Inspired by contracting processes in human organizations, it – or one of its variants – is now used in various domains (e.g. (Moreno et al. 2001), FIPA-Contract-Net-Protocol). However, it is not a proper instrument for the purposes of flexible appointment negotiation including concession and joint search for new alternatives (Pruitt 1981).

Thus new negotiation protocols have to be designed for appointment scheduling in hospitals. These protocols and their result will rely heavily on task structures, like clinical guidelines or treatment plans. These play an important role in deducing restrictions of specific appointments. (Decker 1995, Miksch 1997) present description languages, that allow not only a formal task description including its environmental demands, but an execution of specified tasks. In (Decker 1998) and (Miksch 1999) these concepts are applied to the medical domain.

Scheduling and Task Structures: The Special Case of Medical Treatment Plans

Before introducing our method for designing negotiation protocols for appointment scheduling, some specifics of the domain will be described. Appointment scheduling is basically the assignment of tasks to dates. In hospitals there is a huge amount of negotiations for fixing such appointments when treatments or examinations should be executed. However there are many constraints that make the appointment of a date rather sophisticated:

Treatment or examinations are tasks that mostly have to be done with a present patient. This leads often to an associated transportation problem. Single tasks are normally parts of a treatment plan (see figure 1) which is specific for one patient. Due to the state of health of the patient or to task specific requirements the resulting schedule has to satisfy several temporal restrictions. Examples are predefined sequences of execution (remove plaster cast before x-ray) and necessary delays between investigations and other tasks (e.g. no meal before gastroscopy).
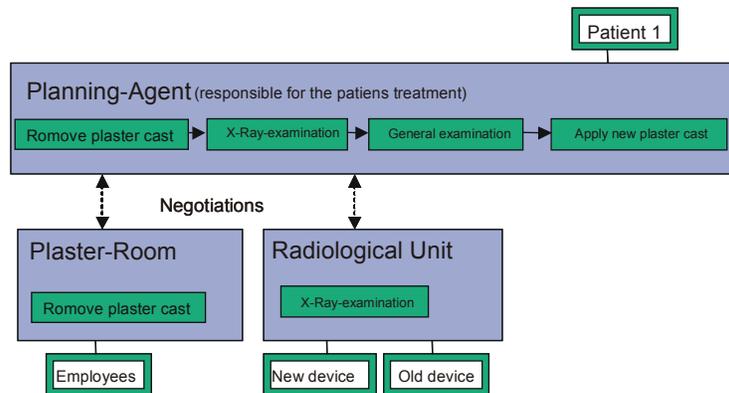
Figure 1. Example of a Treatment Plan in an Orthopedic Hospital
(Temporal restrictions exist between the specific tasks, which are assigned by different
organisational entities to their limited ressources.)

Not only the amount of constraints for appointment scheduling makes it a complicated task, the organizational structure makes it worse. Many of treatments of examinations are performed by different organizational entities that autonomously manage their time plans. Additionally, the execution of tasks often requires the work of several agents, e.g. medical personnel. The involved agents (from different organizational entities) negotiate and agree upon appointments; every agent considers his own restrictions and preferences and integrates the appointment into a special time table for ward or functional unit.

Requirements for a Language for Appointment Scheduling

The basis for negotiation forms a language that can be used for specifying the proposals that negotiation is about. We derive some requirements for a language that is expressive enough for specifying negotiations about appointments in the context sketched in the last section.

General Requirements

Intuitivity: The language should be derived from human communication and intuitively understandable. Reproduction of negotiations by simulated agents is facilitated, as well as the implementation of negotiating software agents by a human programmer. In hybrid organizations negotiations performed in a human centered way which may improve human-agent-interaction.

Consistency: The protocols of the sending and the receiving agent have to be consistent without deadlocks, lifelocks or undefined reactions. Each speech act triggers a corresponding well defined reaction.

Extensibility: In complex scenarios it is necessary to construct and validate them iteratively. Thus negotiation protocols and content language should be extensible.

Separation of protocol structures and reasoning elements: A separation of *invariant* protocol structures from *variant* strategic reasoning elements is an important requirement for specifying different strategies in an efficient way.

Scenario-Specific Requirements

Ability to express priorities and preferences: An agent may use priorities in its private reasoning process. As a consequence the agents must be able to talk about task or date priorities. Related to this, the language should provide a mean to communicate about preferred time and task assignments.

Ability to Reserve fixed dates: In real-world scenarios sometimes a short-time reservation precedes the actual appointment.

Expressability of Uncertainties: If the duration to task performance is not fixed, appointments with estimated durations might be necessary. Another source of uncertainty may be a probability for cancellation.

These requirements may have to be extended when more sophisticated scenarios are tackled. But as we focus on developing negotiation protocols, a reasonable, but not a complete language is sufficient for our aim.

Stories as the Basis of Protocol Design

Our method of designing negotiation protocols was inspired by *extreme programming* (Beck 2000). Similarly to "user stories" used for specification and analysis of software requirements, we use real episodes of negotiation for appointment scheduling in hospitals. Such a story is used for identifying a suitable scheme for negotiation protocols and the negotiation primitives that it consists of. Other principles that are adopted from extreme programming are simplicity and refactoring.

To illustrate this method an example story is used. The complete set of stories can be found in (Herrler et al. 2001). Each speech act of the story dialogues is classified and its semantics and pragmatics are described. A complete story consists of several admissible sequences of speech acts. Such a story can be used for a prototype design of interaction protocols.

Example Story

A patient, who should be examined with a computer tomography device within two days, is assigned to a ward. The examination was ordered by a medical director during the ward round. The negotiating parties are the ward (in the roles of service demander and initiator of the negotiation) and the radiology unit (in the roles of service provider and reacting agent in the negotiation).

"I would like to have an appointment for a CT on Monday or Tuesday."
    Speech act: Appointment request with task-specification and restrictions
    Semantics: The speaker needs a date for an appointment respecting the mentioned restrictions, which are a subset of the restrictions that he has to respect.
    Pragmatics: The speaker wants to get a proposal for an appointment. He intends to evaluate this and then to decide, weather to reject or agree to the proposed date.

"Tuesday at 14:00 o' clock ?"
    Speech act: Appointment proposal with specified task (given by the context) and date
    Semantics: The speaker can provide the desired service at the proposed date.
    Pragmatics: Information. The speaker waits for agreement to or denial of the proposal.
    Strategy: either reserve the proposed date temporally for the demander, or not. Deprive possible dates (e.g. for emergencies).

"No, that's not possible for me, another please."
    Speech acts: Denial, Appointment request with stronger restrictions
    Semantics: The date is not suitable.
    Pragmatics: existing temporal reservations can be retreated. The speaker wants to get further proposals.

"We don't have further dates on monday and tuesday, but how about wednesday at 15:00."
    *Speech act:*Appointment proposal with specified task (given by the context) and date
    Semantics, Pragmatics und Strategy: compare with above.

"Yes, I would like to have this, could you reserve it?"
    Speech act: Agreement to a proposal, including specified task and date
    Semantics: The service demander is content with proposal and agrees to an appointment.
    Pragmatics: He desires the service provider to note the appointment and waits for an acknowledgement.
    Strategy: Probably the demander might agree, but keep in mind to negotiate again in future.

"Okay"
    Speech act: Acknowledgement
    Semantics: The Service provider also agrees with the appointment. Now both sides have made mandatory statements.
    Pragmatics: Information about agreement.

In this story (as well as in the others we analyzed) only five types of speech acts are used: *(Appointment) Request*, *Proposal*, *Agreement*, *Acknowledgement* and *Denial*. Based on such stories one can also derive valid interaction paths in negotiation protocols.

Categories of Negotiation Contents

Depending on the domain further stories can be found. In the hospital domain one can identify the following three *negotiation cases* that form categories for episodic stories.

New Appointment: The example story depicted above belongs to this category. It contains all stories in that appointments for previously unscheduled tasks are made. The basic new appointment negotiation can be extended in various directions: Service demanders may temporally reserve dates and go on negotiating about subsequent tasks, agents may interrupt the negotiation process for modifying appointments with other agents.

Modification of an existing appointment: Due to the dynamics of the hospital domain a need for changing an already fixed appointment may emerge.

Cancellation of an appointment: Unexpected events may make existing plans and appointments obsolete. On the side of a functional unit this may be caused by a breakdown of a machine or the arrival of an emergency. A change in the patients state of health may also result in the cancellation of an appointment.

For each of the three negotiation cases a general negotiation protocol can be defined based on analyzing the relevant stories. Before describing the protocols and their representations in more detail, the next section clarifies the atomic primitives of a protocol, namely the speech acts.

Speech Acts

As mentioned above the set of speech acts that is sufficient for all scenarios that we considered, is quite small. Figure 2 shows a class diagram of these speech acts together with a representation of relevant constraints. We consider a speech act as a basic message object, which is transported from a sender to a recipient. It is tagged with an identification number for the context of the discussion, i.e. the current position in the protocol. Depending on the actual type it has further attributes, describing its effects more precisely.

As done in the example story we analyze the utterances in an appointment negotiation for identifying the relevant speech act concisely. First the type of the speech act is given with all necessary information concerning the content. Afterwards a description of semantics and pragmatics follows. This basic analysis is presented in more detail for an *Appointment request*: A request may need a specification of four attributes, the type of the task, a set of temporal constraints, a maximal response time and the expected number of desired proposals. Temporal constraints can be derived from the complete set of local restrictions of the service demander that are especially based on treatment plans for the particular patient. A suggestion for a representation of these restrictions in a very basic form could be pairs of time intervals with priorities. More complex temporal relations to other tasks, even preferences for special times can be reduced to this representation. To avoid communicational overhead and to simulate the typical behavior of real-world agents the service demander may also decide to disclose some of his restrictions. The attribute "maximum response time" stores the time the speaker is willing to wait for a response. If this time is exceeded, he will use a backup strategy, e.g. asking other service providers. A requesting agent may expect one or more proposals. Therefore the attribute "desired proposals" can be set to represent two different strategies: "Give me the best proposal, and I tell you if this is viable for me" and "Give me (all) possible proposals, and I'll choose the best for me.".


**Figure 2. Outline of a Set of the Speech Acts, Containing Several Attributes,
Together with a Definition of Additionally Necessary Terms as Part of an Negotiation Ontology**

The semantics and pragmatics of *Appointment request* are quite intuitive: The speaker needs an appointment respecting given constraints, which are a subset of his individual restrictions. He expects to receive a proposal or information, that the request could not be granted (denial). He may agree to a proposed appointment or deny it after evaluation. Objects and terms referenced in the attributes of the speech acts – such like *task* or *temporal constraint* also have to be defined. They are part of a additional negotiation ontology, the definition of term used in the example is also shown in Figure 2.

Protocol Diagrams

Following (Jennings et al. 2001), a negotiation protocol is a set of rules that govern the interaction. A fixed framework for a directed interaction is already given by the description of the speech acts' pragmatics. Based on these definitions one can develop SDL diagrams for the initiator and the reactor to specify a negotiation protocol. Two of such diagrams are shown in Figure 3 and Figure 4: In the first diagram a protocol for the service demander of a negotiation is sketched. The *input-* and *output-nodes* correspond to speech acts described above. The permitted transitions between the nodes reflect the pragmatics of the speech acts (expected next action or speech act). The centerline of the diagram represents the negotiation path, when there are no conflicts. It shows the shortest possible sequence consisting of "request" - "proposal" - "agreement" - "acknowledgement". Each of these four steps always must be passed, whereas some detours and cycles may be passed before the negotiation terminates. The space for modeling negotiation strategies can be found in predicates of the *decision nodes* (the rhombs) and in actions of the *task nodes* (the rectangles). The decision nodes specify, what speech act the agent chooses next, whereas the task nodes substantially specify the parameters for the following speech act. Timeouts after exceeding the maximal response time are not depicted in the diagram for reasons of clarity. They lead to a termination of the negotiation, if the communication fails. The second diagram (see Figure 4) shows the negotiation behavior in reaction to the protocol described before. Mutual understanding of the agents requires that both diagrams "fit" to each other. "Fitting" means that each outgoing speech act has a corresponding incoming speech act in the response diagram. The centerline indicates again the shortest possible negotiation process without problems.

Another important aspect regarding communication protocols is the context of a communication. The context can formally be seen as the history of received speech acts that have been transmitted so far (including their parameters). In natural multi-agent systems the agent usually just remembers the relevant data. For example he might think of a reserved date, but not all previously proposed dates. This context of the current negotiation is stored, as long as a protocol is active. This reduces communicational overhead between the agents, since both parties know the past negotiation and are able to suppose that the interlocutor has the same knowledge.
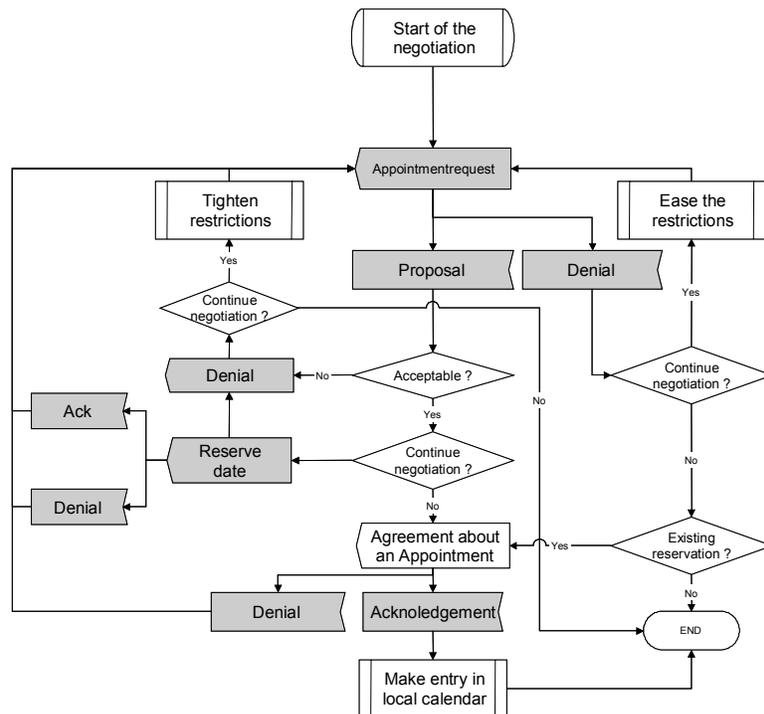
Figure 3. Protocol of the Initiator (Service Demander) During a Negotiation about a New Appointment
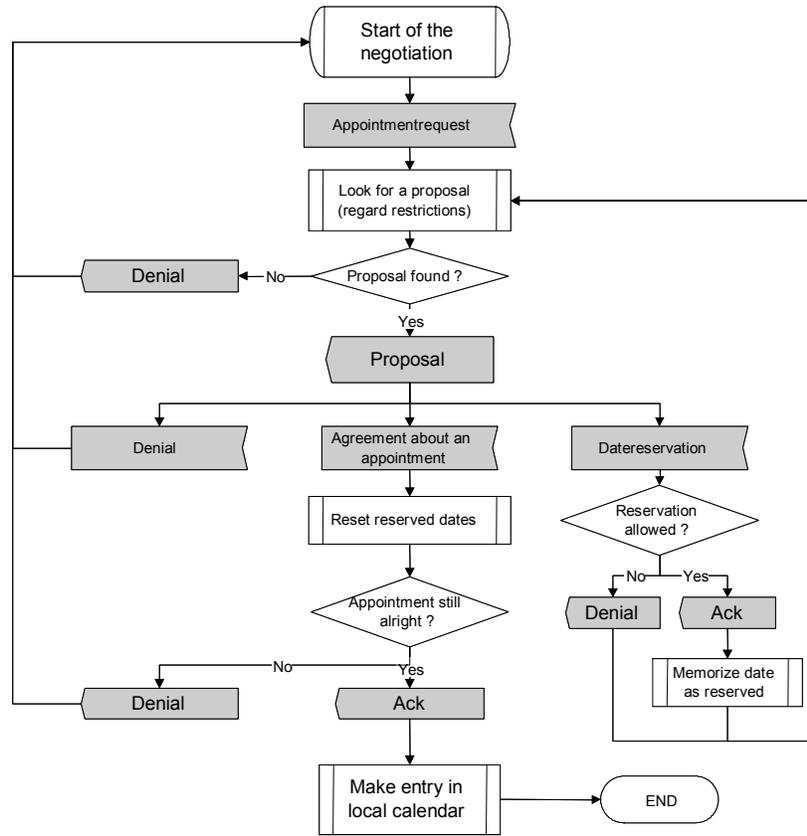(The colored boxes represent the speech acts.)

Figure 4. Reaction Protocol for the Service Provider During a Negotiation

Summary and Conclusion

Formal protocols for negotiation processes form a good basis for the implementation of intelligent distributed information systems. They can be seen as a framework, that determines the substantial structures of a communicational interaction. Nevertheless, it is necessary to model the different strategies that individual agents apply. These strategies not only determine the actual content of a speech act, but also when to use what speech act. Protocols like depicted in figures 3 and 4 provide enough possibilities for parameterization and thus for implementing different strategies.

A common language and mutual understanding are prerequisites for successful negotiation. Classification of messages into categories of speech acts is an intuitive way to define semantics and pragmatics of agent communication language. It forms the basis for creating formal negotiation protocols, since possible speech act transitions are directly derived from the pragmatics definition. Protocols may be validated by analyzing the sequence of the speech acts and – on the other side – the completeness of the set of speech act may be shown in a given domain like distributed negotiation-based appointment scheduling.

Currently we are implementing the protocols developed in this case study. They are integrated as templates into a multi-agent simulation system. Instantiating and filling in particular strategic information we hope to be able to reproduce negotiation about appointment scheduling in a real world hospital in order to evaluate different strategies in this sophisticated coordination domain.

References

Austin J. L.: How to do Things with Words, Clarendon, Oxford.1962.
Beer M., d'Inverno M., Jennings N., Luck M., Preist C. and Schroeder M.: Negotiation in Multi-Agent Systems, *Knowledge Engineering Review*, 14(3), 285-289, 1999.
Beck, K.: Extreme Programming. Addison-Wesley, Munich, 2000.

Busemann, S., Oepen, S., Hinkelman, E., Neumann, G. and H. Uszkoreit.: COSMA – Multi-Participant NL Interaction for Appointment Scheduling. Technical Report RR-94-34, DFKI, Saarbrücken, Germany, 1994.

Decker, K. and L. Jinjiang: Coordinated hospital patient scheduling. *Artificial Intelligence*, 49,104–111,1998.

Decker, K.: "TÆMS: A framework for analysis and design of coordination mechanisms" In G. O'Hare and N. Jennings (eds), Foundations of Distributed Artificial Intelligence. (= Chapter 16) Wiley Inter-Science, New York. 1995.

Davis D. and Smith R.G.: Negotiation as a Metaphor for Distributed Problem Solving, *Artificial Intelligence*, 20: 63-109. 1983.

FIPA Contract Net Protocol Specification: http://www.fipa.org/specs/fipa00029/XC00029E.pdf

Herrler R., Puppe F. and F. Klügl : Speech Acts, Protocols And Strategies Among Agents (in german). In. Proceedings of the 3rd Colloquium of the German Priority Research Program: *Intelligent Agents and realistic Commercial Application Scenarios*, Bremen, 2001.

Jennings, N. R., Faratin P., Lomuscio A. R., Parsons S., Sierra C. und Wooldridge M.: Automated Negotiation: Prospects, Methods and Challenges. *Journal of Group Decision and Negotiation*, 10(2):199-215, 2001.

Miksch, S., Shahar, Y., and P. Johnson: Asbru: A task-specific, intention-based, and time-oriented language for representing skeletal plans, In: Proceedings of the Seventh Workshop on Knowledge Engineering Methods and Languages (KEML-97), Milton Keynes, UK, 1997.

Miksch, S. Plan Management in the Medical Domain, *AI Communications,* 12(4):209–235, 1999.

Moreno, A., Valls, A. and J. Bocio. Management of Hospital Teams for Organ Transplants using Multi-Agent Systems, In. Quaglini, S., Barahona, P., Andreassen, S. (eds.): Artificial Intelligence in Medicine, Lecture Notes in Computer Science 2101, pp.374-383, Springer, Munich, 2001.

Müller H. J.: Negotiation principles, Sixth-Generation Computer Technology, pp 211–229, New York, 1996.

Pruitt, D. G. Negotiation Behavior, Academic Press, London, 1981.

Sandholm, T.W.: Distributed Rational Decision Making, in: Weiss, G. (ed) Distributed Artificial Intelligence, MIT Press, pp 201-258, 1999.

Searle J. R.: Speech Acts: An Essay in the Philosophy of Language, Cambridge University Press, Cambridge, 1969.

Smith, R. G. and Davis, R., Frameworks for Cooperation in Distributed Problem Solving, IEEE Transactions on Systems, Man and Cybernetics, 11(1): 61-70, 1981

Smith S. and Becker M.: "An ontology for constructing scheduling systems", Working Notes of 1997 AAAI Symposium on Ontological Engineering, AAAI Press, March, 1997.