OIL Ontologies for Collaborative task Performance in Coalitions of Self-Interested Actors

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Abstract: Presented are the Task Model and the ontologies for arranging co-operative work in an open organization of intelligent agents-executives. These agents dynamically form the coalitions for collaborative task performance. Coalition formation is guided by contracting negotiation in frame of the Arrangement Phase. The role of the Task and Negotiation Ontologies is to provide the shared conceptualisation of the terms, the structures and the procedures used by agents in the processes of activity analysis, decomposition, performance and delegation. The ontologies are formalized in OIL and are translated to DAML (RDF), RDFS, SHIQ notations, thus providing the concepts in the forms of emerging service mark-up standards.

1 Introduction

The development of the means for semantic interoperation among intelligent service providing agents is one of the mainstreams of the Semantic Web [1] implementation activities. As it was mentioned in [2], "The Web once solely a repository for text and images is evolving into a provider of services. … we are seeing increased automation of Web Service interoperation primarily in B2B and E-Commerce applications. … Fundamental to reliable, large-scale interoperation of Web services by computer programs or agents is the need to make Web Services directly understandable – to create a Semantic Web of services whose properties, capabilities, interfaces and effects are encoded in an unambiguous, machine-interpretable form." Clearly, these services may be formally seen as distributed flows of activities among intelligent, self-motivated and benevolent actors. These actors are both humans and software agents.

Distributed processes, dynamic changes in process flow, self-interested behaviours and collaborative performance are obviously the intrinsic features of the E-Commerce world. Contemporary requirements to software implementations in the domain are, thus, the kind of the intelligent equilibrium on these, sometimes contradictory, features. Economically rational [3] artificial actors performing intelligent activities and tasks are often implemented as software agents. Distributed interoperable implementations are based on sharing knowledge among the open organization [4] of the actors on how to perform an activity or a cluster of activities in rational collaboration with each other. The ontologies providing conceptualisations for knowledge sharing among the agents and for rational activity arrangements are the focus of this paper. These ontologies are used in the process of co-ordination of collaborative performance in dynamic coalitions [5] of self-interested agents-executives.

An important aspect is that co-ordination patterns in the domain should be as real-life as possible taking into account the balance of the actors' features of rationality, self-interest and benevolence (in the sense of being rationally ready to collaborative performance). In frame of the presented research in progress this goal is approached by the ability of the actors to dynamically form the coalitions for optimal task execution. Coalition formation is co-ordinated by negotiation.

An actor may either be not able or not really interested to perform the whole task itself due to various reasons: lack of capability, overload, self-interest. One of the democratic and the rational ways for an actor to find collaborators for performing parts of the task is to negotiate with its fellow actors and to choose the optimal bid presented by an optimal trade-off. Negotiation pattern used in the presented approach is based on the introduction of the so-called Arrangement Phase for negotiation on activity placement. Negotiated are trade-off functions providing the dependencies of the proposed incentive over time.

The remainder of the paper is organised as follows: Section 2 is devoted to related work; Section 3 introduces the motivations of the research by presenting an example of a perspective B2B investment consulting electronic marketplace; Section 4 briefly outlines the Task Model for a community of self-interested actors; Section 5 sketches out the framework for negotiation on activity placement within the Arrangement Phase; Section 6 presents the Task Ontology and the Negotiation Ontology; Section 7 presents the conclusions and the plans for future work.

2 Related Work

To weave shared semantics into the Web with its intrinsic aspiration for distributedness, autonomy democracy and privacy is quite a hard issue. As Makiavelli mentioned in 1513, there is no cause more difficult in conception, more dubious in success, more dangerous in implementation than introducing a new order. Substantial effort is applied to resolve the problem by various research communities as well as by standartization bodies trying to unify the means for concept sharing and semantic interoperability, co-ordination patterns, process description and service provision facilities. In distributed process management and service provision domains the activities in these 3 streams may be presented as follows.

The major standartization effort in process, workflow modeling and management belongs to WfMC[1]. The major accomplishments of WfMC in the field are: the Process Model – workflow and activity representation, XPDL – XML binding of PDL. Semantic interoperability solution is generally seen by WfMC as Workflow-XML binding.

As it was mentioned in [6], "...cooperation and coordination of the planning, monitoring and workflow of the organizations can be assisted by having a clear shared model of what comprises plans, processes and activities...". Known are the efforts aiming to define the basic shared concepts: SPAR [6] ontology, the Enterprise Ontology [7], Process Specification Language [8] (ordered hierarchies of activities), ToVE [9] (shared terminology for a virtual enterprise), aggregation of activities at multiply levels [10], O-Plan research [11] (manipulating plans of task execution) and others.

A comprehensive survey of negotiation approaches to distributed service provision may be found, for example, in [12]. In E-Commerce, for instance, the models for

[1] Workfolow Management Coalition. http://www.wfmc.org/. Last accessed on Nov. 4, 2001

coalition formation based on pre- and post- negotiation patterns are proposed in [13] having COALA[2] as the general-purpose testbed for studying co-operative behaviours in agent coalitions. The approach of the presented research is close to that of service oriented negotiation [14], which involves determining a contract under certain terms and conditions. The mechanisms of service provision via negotiation discussed in this paper are more close to that of ADEPT [15], though, more authoritarian algorithms are investigated as well [16]. Alternatively, the capability based approach to service matchmaking (Eg., [17]) is proposed to determine the proper candidate to become the service provider.

Substantial results are appearing in the development of the languages for service mark-up. DAML+OIL [2] initiative promises probably the best perspectives as both languages are built on top of RDF(S) – W3C[3] metadata standard.

3 Motivating Example

Authors' earlier publications addressed several modelling cases of project planning [18], personnel (PhD) recruiting [19], production management [20] processes. These case studies used simplified modelling methodology. The enhancement of the modelling framework was primarily motivated by the desire to model more sophisticated collaborative interrelationships and behaviours, than 100 per cent altruistic commitment to gain the organizational goal [20]. The following example of a possible B2B Consulting E-Market application may be convincing in the necessity for the actor agents to be more economically rational as well as to simultaneously possess substantial willingness to collaborative performance.

Suppose ABC is a successful consulting company working in the field of Capital Construction Investment (Fig. 1). Assume ABC organization comprises the following staff of actors: Project Managers, Construction companies' representatives, Construction materials supply companies' representatives, Transportation companies' representatives, Community officials' representatives. Each of the actors presents the capabilities and the interests of the "wrapped" organizations. From the other hand, it is ABC fellow member and should be concerned about company's success and revenues. The environment, ABC works within, is inhabited by the perspective investors. The investors seek for effective investments in the field.

To be successful on the market ABC needs to provide attractive investment plans with minimal risks. These investment plans should balance on the mutual interests of both the investors and the represented companies from one hand as well as upon the constraints on the resources and on the executives involved. The investors and the wrapped executives may also have overlapping, conflicting and/or coherent interests, commitments and intentions (Fig. 1).

To provide credible investment proposals in response to the investors' queries ABC should be capable to model (simulate and evaluate) the processes of corresponding projects' implementation, reason about the possible behaviour of the executive organizations participating in the project and reason about the risks as well as about the possible overall project success or failure. It should also provide reasonable recommendations on corrective influences for the critical project steps.

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[2] http://www.cs.cmu.edu/~softagents/coala.html. Last accessed on Apr. 10, 2001.

[3] World Wide Web Consortium. http://www.w3c.org. Last accessed on Nov. 4, 2001.

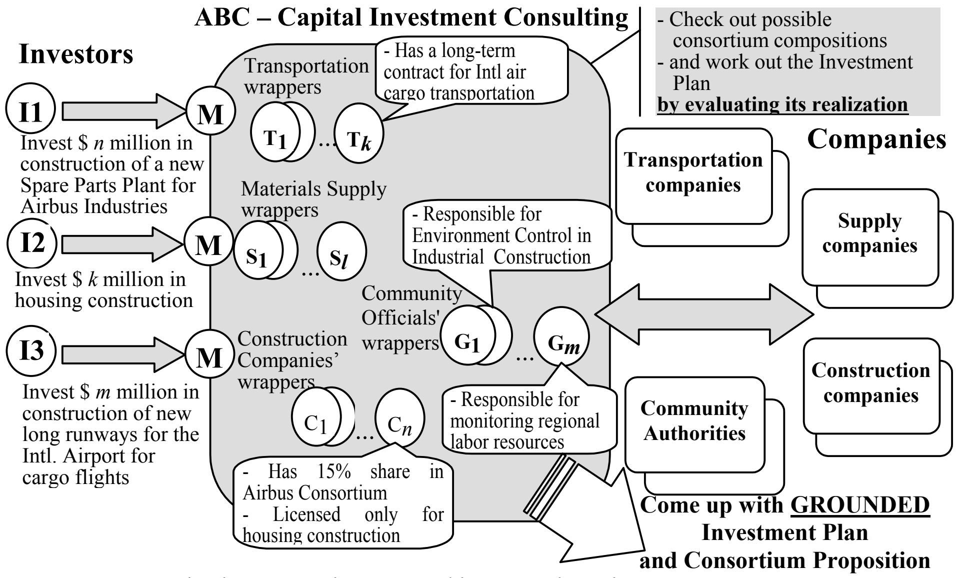

Fig. 1. ABC organization, actors' interests and investors' intentions.

Human investors and their assistant agents **I1**, **I2**, **I3** provide external influences in the form of tasks "Work out investment proposal ...". ABC organization is modelled by Multi-Agent System (MAS), comprising executive agents with specialisations: **M**, **T**, **S**, **G**, **C**. The combination of their commitments, goals and intentions forms the degree of uncertainty, that affects the execution of the tasks provided by the investors and may result in success or failure of the task execution. Actor instances are modelled by software agents designed in frame of the generic formal approach [20]. Individual behaviours of the certain actors T_1, ..., T_k, ..., C_n are generally the functions of the four parameters: ***capability***, ***capacity***, results ***desirability***, ***credibility*** (see Section 4).

The following simple example will further on be used to illustrate the use of Task and Negotiation Ontologies in the process of Investment Plan Evaluation.

Suppose a perspective human investor coming up to a User Assistant agent **I3** to generate the proposition "Work out the investment proposal for the investment of USD 300 million in construction of new long runways for the Intl. Airport to enhance cargo flight reception capacities. The result is required within 1 week starting from now." The formulation of the request is guided by **I3**'s Investment Domain Ontology (not discussed in this paper) as shown on Fig. 2.

ABC Project Manager agent (**M**) receives this proposition from **I3** as a task in a formalized way as shown on Fig. 3. This task is further analyzed, decomposed and collaboratively executed by the dynamic coalition of ABC member actors. The guidance on how to decompose the task and who are capable to perform its parts is distributed among the knowledge bases of the participant agents and is formalized by *Task Model* (Section 4) and *Task Ontology* (Section 6). Agents join this task coalition by participating in Negotiation on Activity Placement. The pattern for these negotiations is provided in the frame of the Arrangement Phase (Section 5). The semantics of the knowledge the agents are exchanging with each other within the Arrangement Phase is formalized by *Negotiation Ontology* (Section 6).

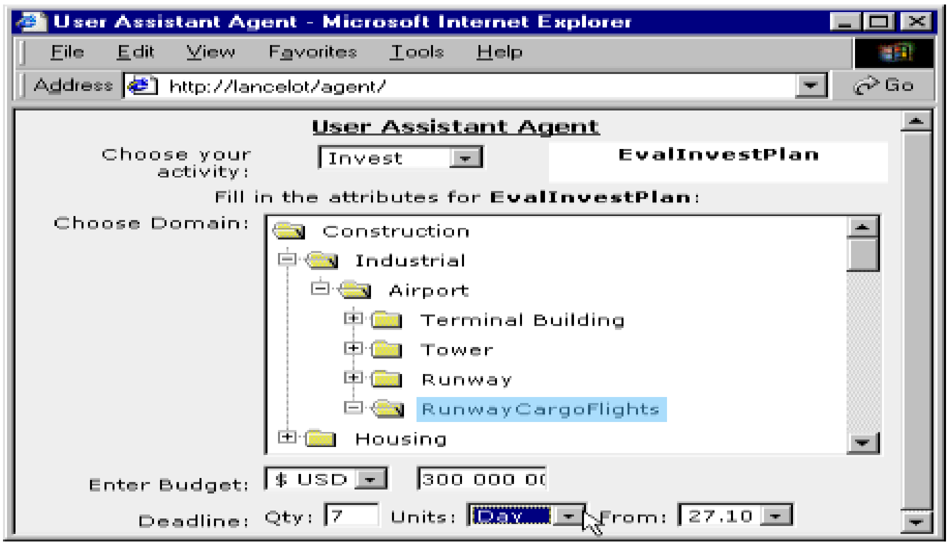

Fig. 2. I3 assisting in the formulation of "Work out investment proposal ..." task

4 Task Model

It is assumed that a *task* $\mathrm{T} = \{w^1, w^2, ..., w^k\}$ is the set of one or more *activities* (Ref. Eg. [7]). Each activity w^k, being atomic for a given actor, may be recognised as a task by another actors according to their knowledge about the incoming influence. `EvalInvestPlan` activity **I3** passes to **M** in our example is decomposed by **M** into the task[4]:

```
T = { w¹ = (PerformArchitecturalDesign, …),
      w² = (GetAirTrafficControlPermission, …),
      w³ = (CheckEnvironmentalRegulations, …),
      w⁴ = (BuildRunway, …),
         …,
      wᵏ = (AssembleInvestPlan, …),}.
```

Actors are also capable to generate activities without any external influence in response to some events or in the course of activity performance. The semantics of a task is structured according to the *Task Ontology*. The ontology is used for:

– Checking if the incoming task contains activities known to the actor
– Decomposing the activities which are recognized as being non-atomic
– Reasoning if the parameters and the results' templates ([20]) match to the actor's knowledge about the activity
– Reasoning on whether to perform this activity itself or to negotiate on its delegation to its fellow actors

[4] The details are omitted for brevity.

```
(ask-one
:sender            "I3"
:receiver          "M"
:in-reply-to        Null
:reply-with        Null
:language           (XML)
:ontology           (Task)
:contents           (
<task>
 <activity>
  <name>EvalInvestPlan</name>
  <descr>Work out investment proposal: USD 3 000 million,
         construction of a long runway for cargo flights.
         Deadline: 1 week from today.</descr>
  <budget>   <value>USD, 300 000 000</value>
             <format>money</format> </budget>
  <deadline> <value>day, 7, today</value>
             <format>deadline</format> </deadline>
  <param>    <name>Domain</name><value>RunwayCargoFlights</value>
             <format>Category</format> </param>
  <result-template> <name>InvestPlan</name>
                    <spec>Investplan.dot</spec>
                    <format>MSWordDotFile</format>
  </result-template>
  <result-template> <name>ConsortProp</name>
                    <spec>ConsortProp.dot</spec>
                    <format>MSWordDotFile</format>
  </result-template>
 </activity>
</task>             )  )
```

Fig. 3. KQML [21] message containing `EvalInvestPlan` *activity specification* in XML

Each of the actors involved in task execution has its own beliefs on how, in what sequence, to perform atomic activities and how much effort should be spent to accomplish the activity, provided that it possesses certain working ***capacity*** related to this certain atomic activity. These beliefs form their subjective Partial Local Plans (PLP) [5]. PLPs are formalised by the Task Ontology and are used by actor's macromodel programs [20] in the course of activity performance. PLP differ from, say, GPGP [22] by the fact they do not contain the subjective beliefs on what would be the actions of the fellow actors. Alternatively, an actor uses its Fellows' ***Capabilities*** Matrix [23] and Fellows' ***Credibility*** Matrix [5] to reason if one or another fellow actor is possibly capable to perform the activity or is trustworthy, respectively.

In case the overall task is thought in the form of a graph (see for instance [24]) the final shape of this graph may alter depending on the sequence of actors' involvement. The actors are involved into the task execution by the results of negotiation on placing of one or another activity. This negotiation occurs within the Arrangement Phase each time before the activity is delegated to the executive. As far as the actors are allowed to generate activities, a task graph may evidently contain cycles, since a node (an actor) may generate a subtask containing or leading to the performance of the activity, which may finally be assigned to this very node.

After a task is perceived by an actor and possibly decomposed according to its knowledge the actor may:

– Accept and perform some of the atomic activities contained within the task
– Decline some of the activities

– Decide to delegate some of the atomic activities to one its fellows
– Require the performance of some new atomic activities, the execution of which is essential to successful completion of the overall task

Since the actor has not declined one or more of the atomic activities it becomes linked to the process of the task execution and joins the task ***coalition***. Task coalition is thus a dynamic open system pending Scott's definition [4].

By joining the coalition an actor pledges to follow some system rules, which regulate the proportion of its benevolence and self-interest. These rules may be classified, following Jennings Commitment-Convention hypothesis [24] as actor's Individual and Joint Commitments and Coalition Conventions:

Rule 1: **Relative co-operation commitment**. Coalition members are **relatively** committed to co-operatively achieve the overall goal: to accomplish the task with maximally achievable effectiveness (maximal quality, balanced load, minimal time, ...). The ratio of this commitment depends upon the discrepancy between the actor's autonomous intentions and the overall goal of the task coalition.

Rule 2: **Activity arrangement convention**. Within the Arrangement Phase the coalition member proposing the activity (the Initiator) pledges to truthfully advertise ***desirability*** function related to the proposed activity. In response, perspective contractors (the Participants) are committed to truthfully report about their readiness to perform the activity providing the information about their ***capacity*** share by replying with the duration of activity execution in the form of parametric feedback [20].

Rule 3: **Results delivery commitment.** Since an activity is accepted by the actor for the performance the actor pledges to unconditionally accomplish this activity and to bring up the results to public immediately after the work is done.

It is assumed that the actor A is characterized by its ***capacity*** $N_A(w^j)$ with respect to the certain activity w^j in a discrete time space. Capacity is understood as actor's ability to accomplish the activity per unit time interval τ. If, for instance, A is delivering construction materials to the cite, than $N_A(w^j = (\text{"}deliver\_1\_tone\_of\_concrete\text{"},...)) = 4$ in case A has 1 ready-mix truck able to deliver up to 4 tones of concrete per τ and will be doubled if A gets one more carrier of the same type. Actor's capacity may be considered **unlimited —** as if at any time it is able to deliver as much concrete as needed. Note that in this case w^j accomplishment duration will still be exactly $1\times\tau$ as far as the actor operates with the certain type of trucks and minimal duration may not be less than one unit time interval. This ideal case is the case with no activities waiting in line. In case the actors' capacity is **limited** (as if it has the fixed number of ready-mix trucks at its disposal) $N_A(w^j)$ may be evenly, or not really evenly, say, according to the priority the customer has, distributed over the activities to be performed.

Activity w^j may be constrained by the ***deadline*** d_{w^j}. The deadline is the point in time after which w^j results are not needed anymore by the customer agent. For example, the construction company will not need any concrete on Sunday instead of Friday. This means that w^j results ***desirability*** function value (see *TÆMS* quality property [22] for the kind of an indirect analogy):

```
<Desirability>
  <Activity> <Name>DeliverConcrete</Name> </Activity>
  <Deadline> <Value>27.10.2001/20.00</Value>
             <Format>datetime</Format> </Deadline>
 <Time> <ZeroPoint>  <Value>27.10.2001/08.00</Value>
                     <Format>datetime</Format></ZeroPoint>
        <Granularity><Value>2</Value>
                     <Format>hours</Format></Granularity>
 </Time>
 <PointsNo>6</PointsNo>
 <TdfPoint> <TimeIncr>0</TimeIncr> <Incentive><Value>300</Value>
                    <Format>Money</Format></Incentive> </TdfPoint>
 …
 <TdfPoint> <TimeIncr>5</TimeIncr> <Incentive><Value>0</Value>
                    <Format>Money</Format></Incentive> </TdfPoint>
</Desirability>
```


Fig. 4. Desirability function (XML) for `DeliverConcrete` activity results

$$des_{w^j}(t, d_{w^j}) = \begin{cases} tdf(t), t \le d_{w^i} \\ 0, t > d_{w^i} \end{cases} \qquad \textbf{(1)}$$

falls down to zero after the deadline has passed and promises changing incentive $tdf(t)$ as a kind of a trade-off over time. For the concrete delivery example this desirability may be as shown on Fig. 4.

5 Arrangement Phase

The role of the Arrangement Phase is to seek for the executor of the certain activity, which is decided (according to PLP or because of the overload) to be delegated to another actor. Arrangement is performed via negotiation between the Initiator and the group of Participant actors. Initiator's goal is to perform the activity in the most optimal way. It is assumed that in the course of negotiation on activity placement Initiator actor attempts to solve two-criteria optimisation problem. First criterium is related to the believed optimal time of the activity accomplishment. Second one is the optimal incentive to be paid to the fellows. The proposed incentive values are derived from the activity budget (Task Ontology). The protocol used for peer-to-peer communication is a kind of FIPA CNP [25] (Fig. 5a) Initiator multicasts activity results' desirability function (1) to negotiation Participants. The Participants reply with their 2-point trade-off assessment feedbacks indicating their readiness to perform the proposed activity (Fig.5b). The participant is ready to perform the activity in case it's feedback contains intersections with the desirability function declared by the Initiator. Otherwise, it rejects the proposition. Initiator than chooses the best bid from the set of received intersections. The participant, which feedback has been chosen as the optimal bid, becomes the contractor. It thus joins the task coalition (Fig. 5c) and proceeds with delegated activity performance. More details on the behaviour models of the parties within the Arrangement Phase may be found in [23, 26].

Let's observe which shared concepts (marked bold) are used by ABC actors while arranging the performance of `DeliverConcrete` activity. $\mathbf{C}_i$ becomes the Initiator of the Arrangement Phase after it has generated `DeliverConcrete` **activity** in the course of `BuildRunway` **task** decomposition, has realised (**PLP**) that it is not capable

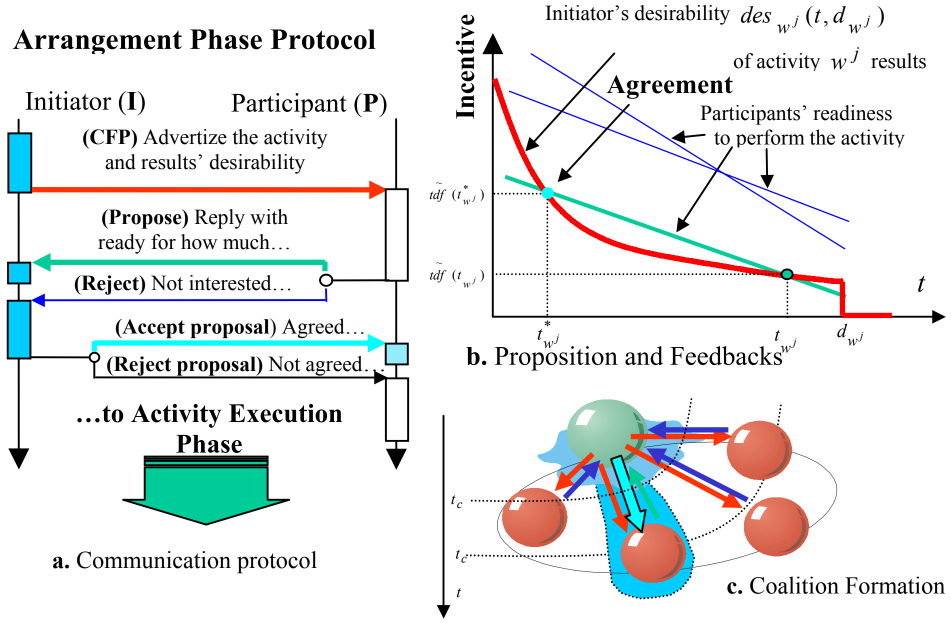

Fig. 5. Arrangement phase. Negotiation on delegating the activity and joining the coalition

to perform this activity itself and has detected that $\mathbf{T}_1,\ldots\mathbf{T}_n$ are the proper candidates for the job according to it's Fellows' Capabilities Matrix. $\mathbf{C}_i$ multicasts `DeliverConcrete` activity **specification** and results **desirability** function to $\mathbf{T}_1,\ldots\mathbf{T}_n$. $\mathbf{T}_1,\ldots\mathbf{T}_n$ in turn benevolently become the Participants after perceiving this influence from $\mathbf{C}_i$ and report their attitudes to the proposition in the form of 2-point trade-off assessment feedbacks (Fig. 6). These feedbacks are based on the assessment of the capacity share or the **effort** the participant is ready to spend to the activity performance.

6 Task and Negotiation Ontologies

Task and Negotiation ontologies were designed and formalized in Standard OIL [27] to serve as shared conceptualisations in frame of the reported approach to model collaborative task execution by coalitions of service providing agents. The framework and the design of these ontologies was primarily motivated by B2B E-Commerce features of uncertainty and the need of the proper balance between self-interest, rationality and benevolence. The role of the Task Ontology is to provide shared concepts of a task, an activity, a parameter, a result template an effort, a priority, a deadline, a budget as well as a Partial Local Plan for activity performance. These concepts are used by service providing agents to determine: if the incoming activity is atomic; if they are capable to perform the activity; if the parameters and the expected results match to their knowledge about the activity; if they need their fellows' assistance to perform the activity. ER-style diagram of the Task Ontology is given on Fig. 7.

```
<TdfFeedback>
 <activity> <name>DeliverConcrete</name> </activity>
 <PointsNo>2</PointsNo>
 <TdfPoint>
   <TimeIncr>$t^*_{w^j}$</TimeIncr> <Incentive><value>$\widetilde{tdf}(t^*_{w^j})$</value>
                                    <format>Money</format></Incentive>
 </TdfPoint>
 <TdfPoint>
   <TimeIncr>$t_{w^j}$</TimeIncr> <Incentive><value>$\widetilde{tdf}(t_{w^j})$</value>
                                    <format>Money</format></Incentive>
 </TdfPoint>
</TdfFeedback>
```

Fig. 6. Example of Trade-off Assessment Feedback (XML) for `DeliverConcrete` activity

Negotiation Ontology provides shared conceptualization of the terms used by agents while they participate in negotiations on activity placement. Negotiation type for the Arrangement Phase is Contracting. The difference of the negotiation approach used in the reported research from another contracting frameworks is the use of parametric trade-off assessment feedbacks. This parametrization provides more flexibility to agents' behaviour and allows to avoid negotiation iterations. The shared concepts of Negotiation Ontology are: activity, results' desirability, proposed deadline, time and its granularity, incentive, trade-off point, trade-off feedback. ER-style diagram of the Negotiation Ontology is presented on Fig. 8.

OilEd 2.2a[5] and FACT[6] reasoner were used for ontologies design and expressiveness check respectively. OIL, RDFS, DAML and SHIQ versions of the reported Task and Negotiation Ontologies are available at http://eva.zsu.zp.ua/eva_personal/ontologies/.

5 Conclusions and Future Work

Co-ordination patterns for distributed activity performance in E-Commerce domain should take into account the balance of the actors' features of rationality, self-interest and benevolence. In frame of the presented research in progress this goal is approached by the ability of the actors to dynamically form the coalitions for optimal task execution. Coalition formation is co-ordinated by contracting negotiation on one or another activity placement. The role of the Task and Negotiation Ontologies presented in the paper is to provide the shared conceptualisation of the terms, the structures and the procedures used by agents in the processes of activity analysis, decomposition, performance and delegation. The ontologies are formalized in OIL and are translated to DAML (RDF), RDFS, SHIQ notations, thus providing the concepts in the forms of emerging service mark-up standards in frame of, eg., W3C activities.

The bulk of the planned future work contains: modelling and conceptualisations of alternative negotiation patterns (iterative bargaining, auction, …); further enhancement of the Task Ontology by providing means for Problem Solving Method and Macromodel Procedure description (this may require the development of OIL extensions);

[5] Freely downloadable from http://img.cs.man.ac.uk/oil/. Last accessed on Nov. 3, 2001.
[6] http://www.cs.man.ac.uk/~horrocks/FaCT/. Last accessed on Nov. 3, 2001.

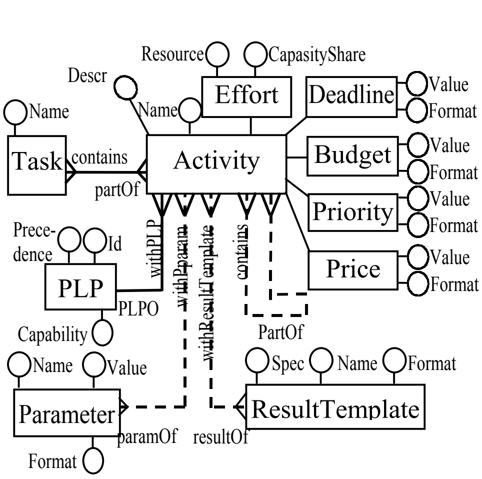

Fig. 7. ER-style diagram of Task Ontology

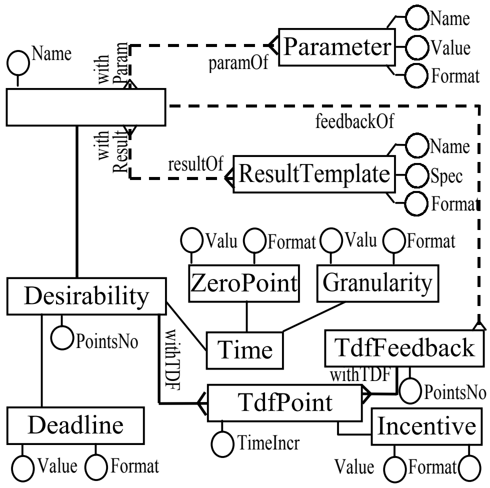

Fig. 8. ER-style diagram of Negotiation Ontology

development of a prototype agent-based application for B2B Investment Consulting Marketplace.

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References

1. Berners-Lee, T., Fischetti, M.: Weaving the Web: The original Design and Ultimate Destiny of the World Wide Web by its Inventor. Harper, San Francisco (1999)
2. Mcllraith, S. A., Son, T.C., Zeng, H.: Mobilizing the Semantic Web with DAML-Enabled Web Services. In: Proc. Of the Second Intl. Workshop on the Semantic Web – SemWeb'2001, Honkong, China, May 1, 2001 (2001) 82–87
3. Nwana, H. S.: Software Agents: an Overview. Knowledge Engineering Review 11(3) (1996) 205–244
4. Richard Scott, W.: Organizations: Rational, Natural and Open Systems. Prentice-Hall, Inc. Englewood Cliffs, NJ (1987)
5. Ermolayev, V. A., Borue, S. U., Tolok, V. A., Keberle, N. G., Plaksin, S. L.: Arranging Co-operative Activities in Dynamic Coalitions of Self-Interested Actors. Technical Report. Dept. of Math. Modelling and IT, Zaporozhye State University (2001)
6. Tate, A.: Roots of SPAR - Shared Planning and Activity Representation. Knowledge Engineering Review 13(1) (1998) 121-128
7. Uschold, M., King, M., Moralee, S., Zorgios, Y.: The Enterprise Ontology, Knowledge Engineering Review 13(1) (1998)

8. Schlenoff, C.; Ciocoiu, M.; Libes, D.; Gruninger, M.: Process Specification Language: Results of the First Pilot Implementation. In: Proc. of the Int. Mechanical Engineering Congress and Exposition, Nashville (1999)
9. Fox, M.C.; Gruninger, M.: Enterprise Modelling. AI Magazine 19(3) (1998) 109–121
10. Gruninger, M., Fox M. C.: An Activity Ontology for Enterprise Modelling. Workshop on Enabling Technologies – Infrastructures for Collaborative Enterprises, West Virginia Univ. (1994)
11. Tate, A.: <I-N-OVA> and <I-N-CA> - Representing Plans and other Synthesized Artifacts as a Set of Constraints. In: Proc. of the AAAI-2000 Workshop on Representational Issues for Real-World Planning Systems, Austin (2000)
12. Faratin, P.: Automated Service Negotiation Between Autonomous Computational Agents. PhD Thesis, Univ. of London (2000)
13. Tsvetovat, M., Sycara, K., Chen, Y., Ying, J.: Customer Coalitions in the Electronic Marketplace. In: Proc. of Agents 2000 Conference, Barcelona, Spain (2000)
14. Faratin, P., Jennings, N. R., Buckle, P., Sierra, C.: Automated Negotiation for Provisioning Virtual Private Networks Using FIPA-Compliant Agents. In: Proc. 5th Int. Conf. on the Pratcical Application of Intelligent Agents and Multi-Agent Systems (PAAM-2000), Manchester, UK (2000) 185–202
15. Jennings, N. R., Faratin, P., Norman, T. J., O'Brien, P., Odgers, B. Alty, J. L.: Implementing a Business Process Management System using ADEPT: A Real-World Case Study. Int. Journal of Applied Artificial Intelligence 14 (5) (2000) 421-465
16. Barbuceanu, M.; Fox, M.S.: The Architecture of an Agent Building Shell. In: (Wooldridge, M.; Mueller, J.P.; Tambe, M. Eds): Intelligent Agents II: Agent Theories, Architectures and Languages. Lecture Notes in Artificial Intelligence, Vol. 1037, Springer-Verlag, Berlin Heidelberg New York (1996)
17. Sycara, K., Klusch, M., Widoff, S., Lu, J.: Dynamic Service Matchmaking Among Agents in Open Information Environments. ACM SIGMOD Record 28(1) Special Issue on Semantic Interoperability in Global Information Systems (1999) 47–53
18. Borue, S. U., Ermolayev, V. A., Tolok, V. A.: Application of Diakoptical MAS Framework to Planning Process Modelling. Problems of Programming. The Scientific Journal 1-2, 2000. Special Issue: Proc. of the 2-nd Int. Scientific - Practical Conference on Programming (UkrPROG'2000), Kiev, 23-26 May 2000 (2000) 488–500
19. Ermolayev, V., Dynamic Agent Communities Facilitating to Distant Learning in a Virtual University Information Space. In: Proc. of Intl. Conf. IS2000, Special Session on Virtual Universities and Distance Education, Japan, November 5-8, 2000 (2000) 488–495
20. Ermolayev, V. A.; Borue, S. U.; Tolok, V. A.; Keberle, N. G.: Use of Diakoptics and Finite Automata for Modelling Virtual Information Space Agent Societies. Lecture Notes of Zaporozhye State University, 3(1) (2000) 34–44
21. Labrou, Y., Finin, T. A Proposal for a New KQML Specification. TR CS-97-03, Univ. of Maryland Baltimore County, Feb. 1997 (1997)
22. Decker, K.S.: Environment Centered Analysis and Design of Coordination Mechanisms. Umass CMPSCI Tech. Rep. 95-69, (1995)
23. Ermolayev, V. A, Tolok, V. A.: Modelling Distant Learning Activities by Dynamic Agent Task Coalitions. To appeare In: (Noguchi, S., Yu, C. Eds.): Enabling Society with Information Technology. Springer-Verlag, Tokyo (2001)
24. Jennings, N. R.: Coordination Techniques for Distributed Artificial Intelligence. In: (O'Hare, G. M. P., Jennings, N. R. Eds.) Foundations of Distributed Artificial Intelligence. Wiley (1996)
25. Foundation for Intelligent Physical Agents. FIPA Contract Net Interaction Protocol Specification. Version E. Ref. No XC00029E. (2001
26. Ermolayev, V. A., Plaksin, S. L.: Co-ordination of Work Placement in Agents' Task Coalitions. Lecture Notes of Zaporozhye State University, 4(2), to appear (2001)
27. Horrocks, I., Fensel, D., Broekstra, J., Decker, S., Erdmann, M., Goble, C., Van Harmelen, F., Klein, M., Staab, S., Studer, R.: OIL: The Ontology Inference Layer, Tech.Rep. IR-479, Vrije Universiteit Amsterdam, Sept., 2000 (2000)