A Framework for the Social Description of Resources in Open Environments*

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Abstract. The description of public resources such as web site contents, web services or data files in open peer-to-peer networks using some formal framework like RDF usually reflects solely the subjective requirements, opinion and preferences of the resource provider. In some sense, such resource descriptions appear "antisocial" as they do not reflect the social impact of the respective resource and therefore might not provide impartial, reliable assessments. E.g., commercial web sites do not contain any relationship to the information, service and product offers of competing sites, and the assessment of the site by customers, experts or competitors is unknown to users and information agents also. We introduce an open multiagent system framework which derives multidimensional resource descriptions from the possibly conflicting opinions of interacting description agents, which act as representatives for individual, organizational or institutional clients, and compete in the assertion of individual opinions against others to provide a "socially enhanced" solution for this problem. In contrast to the results of majority voting based recommendation systems, the obtained social resource descriptions reflect social structures such as norms and roles which emerge from communication processes.

Keywords: Semantic Web, Information Agents, Web Ontologies, Recommender Systems, Multidimensional Ratings

1 Introduction

In the context of the World Wide Web and large, open and heterogenous peer-to-peer networks like Gnutella [21], FastTrack [22] or eDonkey [20], a well-known problem is constituted through the notorious lack of reliable, impartial descriptions of publicly accessible resources such as web sites (or the content they provide, respectively), shared files or web services. If a resource description (RD) is available, in most cases the description is provided by the original resource provider, which makes it in general as useless as any other kind of advertisement. In contrast, recommendation systems [3] based on the evaluation of access statistics, voting or resource content analysis try to ascertain the "objective" value of resources. E.g., collaborative filtering recommendation systems provide filter criteria for site classification, that classify the rated site in terms of "appropriate/inappropriate" or "interesting/uninteresting", based on the surfing behavior of a more or less homogenous group of users with a common interest

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profile (user community) or implicit majority voting processes like Google's *PageRank* technology [18], which count the number of hyperlinks referring to the rated site. As a supplement or as a competing approach, content-based filtering recommendation systems try to analyze the content of web resources (usually by means of keyword counting) and compare the results with the interest profiles of the web surfers [2]. The main drawback of such filtering systems is their limitation to one-dimensional descriptions (amounting to "$like/dislike$") based on the presumed predilections of predefined or computationally obtained social groups. This approach does not provide much help for the process of interest forming, which should precede any recommendation and filtering. Likewise, systems based upon trust networks like PeopleNet [12] can't do much if there is no trust yet related to a specific rater, topic or object, or the potential truster is anonymous. Another problem is the apparent black-box character of many (commercial) recommendation systems, which on the one hand provides some protection against manipulation, but on the other hand seriously restricts their trustability. For these reasons, transparent, balanced descriptions which are in addition reliable and semantically rich can currently only be provided by humans, for example journalists and experts, or through discussion forums (e.g., newsgroups and threaded message boards like *Slashdot* [19]), which makes this solution inappropriate for huge networks. Another disadvantage of this kind of approach is of course the absence of a machine readable encoding of the results, which makes it almost impossible for information agents like web spiders to analyze such descriptions. Although the Semantic Web effort addresses the problem of missing machine-understandability of web site descriptions, it currently focusses primarily on the specification of languages and tools for the representation of consistent semantics and ontologies, not on the process of information gathering and rating itself, and it is just beginning to take into consideration phenomena like social RD impact [14], conflicting opinions, information biasing by commercial interests, and inconsistent or intentionally incorrect information. In contrast to traditional approaches, our goal is to provide so-called *social descriptions*, which are obtained from the contribution of multiple, conflicting opinions represented by interacting information agents (so-called *(resource) description agents*), and which are *rich* (i.e., with unrestricted multidimensional description criteria [1], multiple levels of generalization and unveiled information about the social relationship of their contributors) - somewhat comparable to a computational résumé of a human discussion. Aiming at this, this work proposes a framework for the derivation of formal *social expectation structures* from observed agent communications [7, 8], and describes how the social description of web resources can be seen as a special case of such structures. To allow for the embedding of our framework into open environments like the Semantic Web, its architecture is *open*, i.e., it assumes a heterogeneous, unrestricted and fluctuating set of agents, and does make almost no assumptions about special agent capabilities and agent architectures, except their rationality, autonomy and ability to communicate.

The reminder of this paper is structured as follows: The next section specifies the general objectives and requirements for a multiagent system for social descriptions. In section 3, we introduce the overall architecture of the framework. Section 4 describes how social structures can be represented and generated from observed communications. Section 5 outlines how social descriptions can be obtained from social structures. With a short discussion of open problems and directions for further research in section 6 the paper concludes.

2 Terms and requirements

In terms of the RDF standard (the XML-based *Resource Description Framework* [10], a successor of the internet description language PICS [16]), the description of a certain (web) resource is a finite set of statements (*elementary (resource) descriptions*) together with a description vocabulary. Each statement describes the properties of the respective resource (which can be virtually any kind of object like web site attributes, documents or web services, but also other statements) by means of meta data, according to a vocabulary of property types or classes (sometimes called an "ontology" or "schema"). Technically, such an elementary description is defined as a proposition of the form $(resource, propertyType, value)$, in which $resource$ denotes an object with an unique identifier (i.e., a Uniform Resource Identifier (URI) or a P2P-resource locator like `ed2k://|file|filename.mp3`). $propertyType$ is the described attribute of the resource (an element of the given description vocabulary), and $value$ is its assigned value. $value$ can be a resource by itself, and thus the description vocabulary can form a hierarchy of property types (e.g., $Author$ and $Credibility$ in ($\texttt{www.somesite.com}, Author, John), (John, Credibility, high)$) Elementary descriptions can be expressed through a formal description language, for example RDF or DAML [15]. An example for a description with boolean property type is ($\texttt{www.SomeCompany.com}, MinorOrientation, True$). Beside such simple statements, description languages like RDF can of course express more complex RDs, but their basics are always as described, so we don't deal with technically more complicated cases. We talk about a *competitive (resource) description* if the elementary description is pro-actively supported by a description agent in competition with inconsistent descriptions represented by other agents, with his goal to make some supra-individual social description (e.g., the public opinion) consistent with his individual descriptions. A *social (resource) description* is a probably inconsistent RD together with a social weighing of each of its elements, i.e., a more or less abstract description of the degree of social assent and of the supporters or opponents of the respective elementary description. A well known example for such a social description would be the result of an opinion poll: "10% of the questioned individuals do support opinion A, 90% do support opinion B". The percentages here are supposed to describe the social acceptance of each opinion by means of a majority voting, which also underlies most web site recommendation systems, although these systems usually unveil only the winner of the poll. Additionally, usual recommendation systems are limited to the single property type appropriateness with regard to the presumed needs of certain users. While our approach can lead to similar results given certain circumstances, our descriptions are derived from an active competition process among description agents, they are multi-dimensional, allowing to asses multiple criteria at the same time, and, most important, they are able to reflect social structures and conditions. Therefore, our approach is settled on the knowledge-gathering and inference layer of the Semantic Web, preceding recommendation and filtering. For the human part of the web there already exist social structures with a strong influence on the provision of shared content. In our opinion, a long-term objective should be to make these latent structures explicit to web users and information gathering agents by means of a formal, socially rich description which rates a site not only in terms of "interesting" or "appropriate", but unveils primarily *who* says so and by which criteria. In a larger scenario, the social descriptions for a significant part of the internet could be a step towards a "Social Semantic Web". The characteristics and objectives for an approach towards this goal can be summarized as follows:

Recognition of controversies A high amount of RDs are subjectively biased quality judgements with a high conflict potential. Competitive descriptions, represented by software agents, shall *enable* such controversies, and social descriptions shall make them *explicit* and available to information agents. In general, it is unavoidable that the contributors of the Semantic Web or other hybrid open systems (i.e., open systems where humans interact with machines) will generate intentionally inconsistent information. In absence of a omniscient, normative instance, knowledge inference mechanisms for the Semantic Web will have to acknowledge inconsistencies.

Pro-active opinion representation The competitive descriptions which contribute to social descriptions are no single "passive" statements like votes for an opinion poll, but shall instead continuously be represented by intelligent, social agents which support them actively in a dynamic social process, e.g. by means of argumentation, reasoning and conflicting behavior.

Complexity and hybridity Due to the size, the heterogeneity and the openness of the world wide web and public peer-to-peer networks, the agent-supported description of resources is a highly complex task. Social descriptions increase the complexity of hybrid information-rich environments because they make human sociality "behind" the technical infrastructure visible. Nevertheless, to overcome the idea of a semantic web consisting of unrelated (or only syntactically related) information pieces, the enabling of computational social structures is inalienable in our opinion.

Unveiling of social relations Even an individual description does not only assert the rated resource, but makes an implicit statement about the actor that is responsible for the description [14]. The presence of competing competitive descriptions is supposed to strengthen this exhibition of personal preferences and opinions.

3 Architecture

As an approach to the described issues, we outline a multiagent system that consists of the following components:

1. Formal languages for competitive descriptions and the (presumably indefinite) social descriptions to enable the utterance of individual descriptions by agents and

the representation of inconsistent contributions from different opinion sources. The emphasis should be on opinion announcement rather than on usual objectives like cooperation and consensus finding, and these languages should be compatible with current standards for agent communication languages (ACLs) like FIPA-ACL [9] and WWW-oriented description languages like RDF or DAML [15].

2. Intelligent *resource description agents* which are able to deliberatively rate resources in accordance with the opinions, criteria and interests of their private/public/ commercial etc. clients, and to represent their individual descriptions in a social discourse with other description agents.

3. A technical instance (*social resource description system*) for the technical facilitation of description agents communication and for the derivation of social descriptions from these communication.

Description agents act either as representatives for existing RDs (therefore in some sense the pro-active "incarnations" of RDF documents), peers, user communities, source creators (e.g., web sites owners or multimedia providers), or private and public organizations. Every description agent supports a certain opinion and announces, asserts and defends it in an open discussion forum which is assigned to the rated resource (usually a web site) or a peer-to-peer client (e.g., a file sharing application). Every forum is part of the Social Resource Description System (SRDS), a software application (within the Semantic Web knowledge inference infrastructure) which observes the forums and continuously derives from the forum communication so-called *social expectation structures* [7, 8]. These structures are distilled to social descriptions. Together with the rated web site, the social descriptions are presented to the user (e.g. to the web surfer through a special HTML frame within the browser window or via some user agent), and to information agents, for example the web spiders of internet search machines like Google or Altavista. The description agents will of course also obtain these information, as social knowledge is considered to be very important for the agents to let them intentionally avoid or achieve oppositional or conformist behavior in respect to other agents and social norms, and to find appropriate allies and opponents.

Figure 1 shows the proposed framework. For simplicity, the figure consists only of a few description agents, a single web site and the central rating system, and an attached recommender system (cf. below).

3.1 Resource description agents

In figure 1, the ovals in the top left part symbolize description agents (gray color) and their clients (white color) - users, organizations and institutions (i.e., governmental organizations). Every description agent should be able to obtain individual descriptions conforming to the preferences of his client, to keep these descriptions up-to-date with respect to changes of the resource content and the opinion and needs of his client, and to represent the descriptions in the forum. The latter means, that the agent tries to

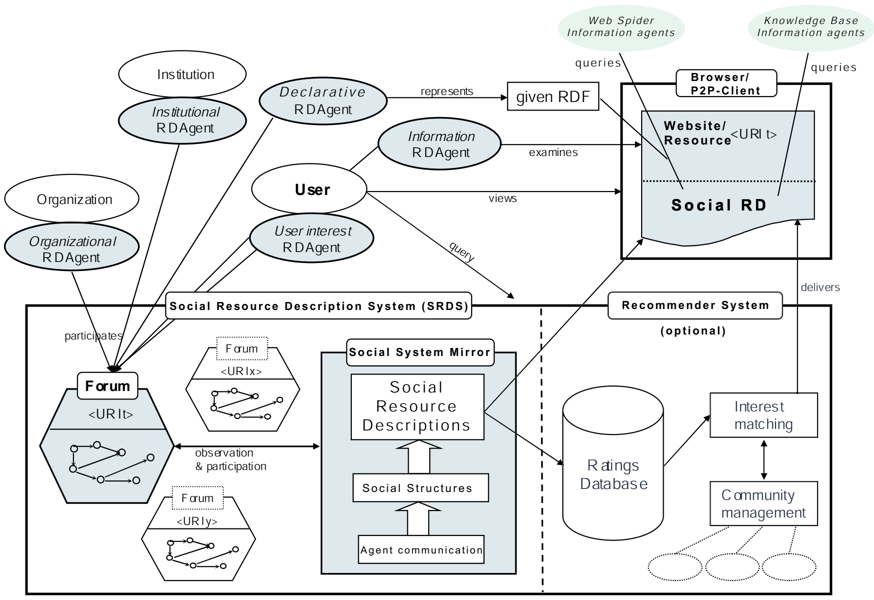

Fig. 1. Architecture of the framework

influence the social descriptions with the goal to make them *consistent* with his subjective descriptions. To achieve this goal (which induces a goal conflict with competing description agents), the agent must have adequate technical, mental and social capabilities (for example the capability to cooperate with other agents in the assertion of some common opinion). Since social descriptions are derived solely from the forum communications, the agent must be able to participate in the forum (e.g., as a mobile agent which is executable on the forum server), know the description communication language and the algorithms the SRDS uses to derive social descriptions to obtain a reasonable argumentation strategy. In addition, description agents should idealistically not only be able to propagate some predefined description, but also to gather new information about the respective resource, other comparable resources, and in particular the descriptions, knowledge and strategies of other description agents.

The following set of description agent types is presumably useful for large, information rich environments like the world wide web:

– *Organizational description agents* represent private or public organizations (including companies). Their purpose is to propagate interests and evaluation criteria of almost any kind (commercial, legal, scientific, ethical, political...).

– *Institutional description agents* are supposed to have a strong influence on other agents and the social descriptions, because as a particular sort of organizational agents they represent governmental authorities. Their description criteria and opinions are thus supposed to be base on law. Such description agents can participate in the SRDS to inform the web surfers (as far as they are able to influence the social descriptions) and other agents about the legal assessment of the respective resource, or to label the rated resource, e.g. for a minor-protecting filtering software.

- *User-interest description agents* rate resources regarding the preferences of individual web surfers, peers and communities with a similar interest profile. The finding of an interest profile could be achieved either using the classical approaches of content- or collaborative-based recommendation systems, or alternatively in a combined process of simultaneous description obtainment (e.g., through the evaluation of social descriptions and observation of other agents) and description announcements. It would also be conceivable to evaluate parts of the content of user home pages to derive their opinions and predilections, if this information is publicly accessible and encoded using a formal language. Like all description agents, user description agents are supposed to act deliberatively and intelligent, but they could just as well be implemented as simple machinery which translates user intentions into a machine readable format.

- *Declarative description agents* represent an existing RD. Such agents could act as advertisers, or they compare their descriptions with another description and calculates their difference (e.g., “This web site is better/worse/... than ...”).

- *Content analyzing description agents* analyze resources and feed the obtained information into the forum as asserted descriptions. The information acquisition could be done via statistical keyword analysis, for example. Therefore, content analyzing description agents act as service agents which help other agents to complete their own descriptions. Obviously, the purpose of this type of agent might overlap with the objectives of other description agent, for example user-interest description agents which form a description by means of a comparison of the results of content analysis and interest profiles of their clients.

Figure 2 shows an description agent in the context of our framework.

3.2 Social resource description system

For each web site, the description system accommodates a *forum* which has the respective resource as its communication topic (corresponding to a certain ontology that can be used with the RD language). The forum serves as a public whiteboard, on which the agents put their messages addressed to other agents and receive responses - very much like people do in Usenet newsgroups and web-based message boards. Every forum has its own description vocabulary which could be assembled by the agents themselves via some ontology negotiation technique. Besides the syntax of the RD language and the communication protocols that may accompanying this language, the common vocabulary causes the only constraint for the agent’s social behavior. Forums are *open* - every agent which is able to communicate using the RD language can participate at any time (even in multiple forums simultaneously), as long as he identifies himself and his

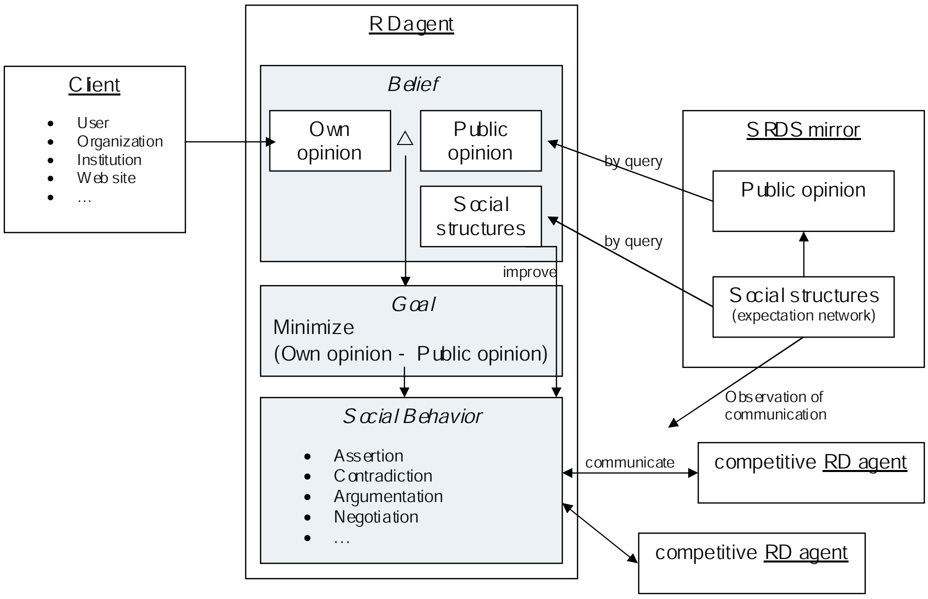

Fig. 2. Resource description agent

clients to the SRDS and therefore to the system users[1]. As the central part of the SRDS, a so called Social System *Mirror* (or "Mirror" for short) [7, 6] continuously observes each forum, analyzes observed communications and derives the social structures which emerge from the communications. In a second step, for each forum (and therefore each resource) the Mirror generates social RDs corresponding to the obtained social structures. The generation of social RDs is carried out either continuously for each newly observed communication (similar to the examination and moderation of a newsgroup or a message board), or on request.

Social descriptions are not only communicated to the description agents, but primarily to the users and to information gathering agents. Doing so, the SRDS act very similar to a newspaper. Because of this, it is of course recommended to place the SRDS on "neutral ground", e.g. as a service of a web search engine which returns social descriptions for web sites, or through a web service or a proxy server that delivers social descriptions to the browser or peer clients together or prior with/to the requested resources[2].

A straightforward extension of our framework would be to implement a recommendation system as part of the SRDS, which stores the social descriptions generated from the SRDS Mirror in a descriptions database. Instead of requesting directly the social

[1] For obvious reasons, the identity of the client should be authenticated by means of a trusted security certificate.

[2] Instead of just publishing the descriptions, it would of course be feasible to use them for filtering mechanisms which hide resources with a someway "bad rating" to the user, although this would be very much in contrast to the intention behind our approach.

descriptions, the user in this scenario forwards a personal interest profile to the recommendation system (e.g. in form of a desired social description). The recommendation system then compares this profile with each of the collected social descriptions and returns a list of matching resource indemnificators back to the user.

3.3 The Social System Mirror

The Mirror as the core component of the SRDS is a middle agent which models the social system of the focussed forum(s)[3]. Technically, it can be thought as an intelligent knowledge base which derives social structures from observed communications and makes them available for the participating agents and human users. The Mirror has two major purposes: First, the monitoring of communication processes and the continuous derivation of emergent social structures and social RDs from these observations (to inform the users of the SRDS), and second, the announcement of social structures and social RDs to the agents (the so-called *reflection* effect of the Mirror). The agents can query the Mirror very much like a database and deliberatively use the social structures which are made explicit to them as a guideline for their decision making and their interaction behavior, i.e., to assess their own social status and the status of other agents, to prevent (or intentionally not to prevent) the violation of social norms, and to influence the current social RDs. If the agents deliberatively adopt to the reflected structures, these structures become "stronger", otherwise "weaker" (cf. next section). By means of this the Mirror reflects a realistic model of a social system to the agents and thus influences them (similar to mass media in human societies). Doing so, it never restricts agent autonomy - its influence is solely by means of information and not through the imposition of constraints.

4 Social expectation structures

To derive social descriptions from competitive RDs, we need a means for the derivation and representation of social structures, in particular the relationships among competitive RDs. In our framework, this is achieved by the Mirror component within the SRDS, which models each forum as a *communication system* [8] consisting of communications (with competitive RDs as messages content) and their relationships. The assumption underlying this approach (influenced by sociological *Systems Theory* [5]) is that all relevant aspects of sociality are eventually revealed through communication, and that empirically obtained expectations regarding communications are the most general way to model sociality if no a-priory assumptions about agent behavior or mental properties of agents can be made, as it is surely the case in an open environment like the internet.

The data structure a Mirror operates on to represent social structures is called *expectation network* [7, 8]. An expectation network is a graphical data structure (not necessar-

[3] The Mirror is a general design concept and a coordination medium for open multiagent systems and therefore not restricted to our kind of application.

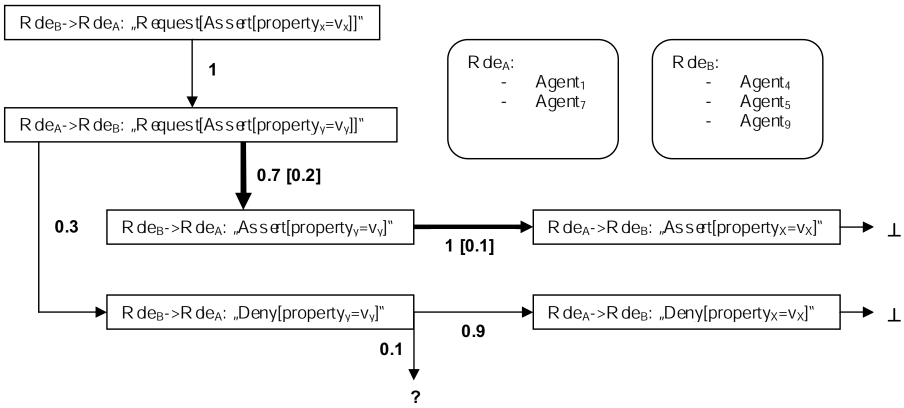

Fig. 3. An expectation network

ily coherent), which consists of *elementary expectations* regarding the future communicational behavior of a set of observed agents (obtained from a temporal generalization of observed communication trajectories)[4]. Its basic constituents are *event nodes* which represent expected utterances, and probabilistically weighted *edges* connecting event nodes, which represent significant correlations of the respective utterances. Expectation networks always represent dynamic belief, i.e., belief that is constantly under revision according to the evolution of social structures as they show up in each forum. For lack of space, we cannot introduce the formal framework and the stochastic approach behind communication systems and expectation networks here (cf. [8, 6]). Instead, with figure 3 we provide an example of an expectation network that represents the structure of a discourse among description agents[5]. Presumably, it might be possible to use other formal structures to model the social expectation structures of an SRDS (e.g., belief networks or stochastic automata).

Nodes (squares) are labelled with message templates (in a formal RD agent communication language) and the special symbols "⊥" (denoting the end of a conversation) and "?" (denoting an unknown continuation). Nodes are connected by edges (arrows) labelled with numerical *expectabilities*, which denote the probability that the respective message(s) occur subsequently. These probabilities are derived from observed frequencies of the respective message sequences in the past. The thickness of edges represents the *normativity* of the respective expectability and the numerical value in square brackets denotes its *deviancy*. An edge with high normativeness (thick arrow) represents an expectation which has proved itself as empirically stable in the long term, which is a typical property of expectations obtained from laws and other social norms. The deviancy is the difference of long-term and short-term expectability, corresponding to the expectability of agent behavior which deviates from a social norm. Substitution lists

[4] *Trust*, which is used by e.g. [12] to achieve reliability, is a special case of expectation.

[5] For simplicity, we use a graphical notation that is slightly different than the notation introduced in [7, 8, 6].

appear in rounded boxes. A substitution list denotes a social *role* the listed agents can impersonate. For this purpose, the message templates contain role variables ($Role_A$ and $Role_B$) that can be bounded to each of the list entries, provided this bounding is done in a consistent way along the respective path. An expectation network can be *generalized* in two ways: First, a single expectation network might describe the expectations regarding multiple message sequences due to different instantiations of role variables (the MAS Mirror obtains these roles automatically from the unification of syntactically matching message sequences observed for different agents) and variables for external objects, in our case resource descriptions and their values. Second, each message sequence is expected to be repeatable without precondition if the root of the corresponding path does not have incoming edges. The numerical expectabilities correspond to the frequency of observed message trajectories that unify syntactically with the respective paths. Theoretically, an expectation network contains paths for every possible sequence of messages, but in practice, edges with a very low (or unknown) probability are omitted.

The message templates attached to the nodes do only serve as examples, formalized in a pseudo speech-act notation ("Sender⤚→Addressee:Performative[Content]"). Generally, any speech-act based ACL which supports the assertion of logical propositions (corresponding to elementary RDs) like FIPA-ACL or KQML/KIF could be used. In addition, the description agents shall be able to query the current social descriptions (cf. next section) and the current expectation network (or parts of it) to improve their social behavior.

5 Social resource descriptions

Now that we've introduced social expectation structures derived from observed communications, it is straightforward to derive social descriptions: Social descriptions based on the underlying model of social expectations are sets of social expectations regarding the utterance of elementary RDs. Each element of a social description is therefore the expectation of a *reply* to a question regarding the *agreement* with an elementary description, directed to agents (or social roles) which currently participate in the observed forum. The calculation of social descriptions regarding resource properties from expectations regarding communications makes use of the fact that an elementary RD is equivalent to a set of meta descriptions, i.e. descriptions of descriptions with a common property type "$Assent$": From a multi-dimensional description $(resource, propertyType, value)$ as in RDF we can generate meta-descriptions in the form of

$(propertyType = value, Assent, degree\ of\ assent)$,

where the first element of this tuple is the content (logical proposition) of an assertive ACL message, the second element denotes the property type corresponding to the ACL message performative "$Assert$"[6]. The omitted resource $resource$ is provided implicitly through the forum topic. The social amount of agreement or dissent, respectively, can then simply be measured as the probability that a certain agent or a role subsuming

[6] or what ever performative the ACL provides to signal consent.

a set of agents utters the message
"$Actor_1 \rightarrowtail Actor_2 :' Assert[propertyType = value]'$".
For example, a query regarding the assessment of the SomeCompany web site directed to a set of agents A would look like
$(\texttt{www.SomeCompany.com}, MinorOrientation, ?x)$
(where $?x$ is an existentially quantified variable with instances v_i), which could for example be transformed into the speech-acts
"$B \rightarrowtail A :' Query[MinorOrientation =?v]'$ or
"$B \rightarrowtail A :' Request[Assert[MinorOrientation = v_i]]'$.
The social description is then a set of expectabilities of the potential reactions to such a request, together with the respective values for expectation normativity and deviancy. For example, the resulting values for answers asserting
$(\texttt{www.SomeCompany.com}, MinorOrientation, True(= v_1))$ could be
$strength = 0.9$, $normativity = 0.7$, $deviancy = 0.01$
and
$strength = 0.1$, $normativity = 0.7$, $deviancy = 0.01$ for
$(\texttt{www.SomeCompany.com}, MinorOrientation, False(= v_2))$[7] (i.e., these agents believe in a quite normative way that SomeCompany is highly minor-oriented). This result could have been obtained from expectation network Fig. 3, on condition that $MinorOrientation$ is a valid instance of variable $property_x$, and $True$ and $False$ are instances of v_x, because according to this graph, the probability that $Agent_1$ or $Agent_7$ asserts that $MinorOrientation = True$ is 0.7, and the probability that $Agent_4$, $Agent_5$ or $Agent_9$ would assert this is 1, so the average probability that any agent asserts $MinorOrientation = True$ is approximately 0.9.
Of course, this particular result would not provide much more value than the result obtained from a filtering recommender system, as it likewise aggregates the opinions of multiple agents to a single "vote", but our example network would (with more detailed queries, see below) not only reveal collaborating sets of agents or roles, but also that $Agent_1$ and $Agent_7$ support opinion $MinorOrientation = True$ just because they want to reward other agents ($Role_B$) for their support of $property_y = v_y$, i.e. for "commercial reasons" and not because of the strong conviction that SomeCompany is indeed suited for children.

We denote (unconditioned) social descriptions as sets of terms having the form
$Actor : (resource, propertyType, (value, expectability, normativity, deviancy))$, where $Actor$ can denote an agent or a social role.
The query results are obtained from the expectation network, either directly if the expectation network already contains paths which correspond to the focussed
$Query/Request[...] \rightarrow Assert/Agree/Deny[...]$ sequences, or by means of an SRDS query on the forum directed to the agents. In the latter case, the SRDS communication introduces the required expectation network paths, and then it observes the subsequent agent communications to obtain significant expectabilities which reflect the agent opin-

[7] Uttered using a "$Deny$" performative, for example.

ions along this paths[8]. Besides this example, expectation networks allow for the obtainment of a large variety of other kinds of social descriptions. The usefulness of the following patterns for social RD of course depends on the particular interests of the SRDS user.

– *Single agent RD*, obtained from
  "$B \rightarrowtail SingleAgent :' Query[PropertyType = ?v]'$" $\rightarrow$
  "$SingleAgent \rightarrowtail B :' Assert[PropertyType = v_i]'$"

– *Social role RD*[9], obtained from
  "$B \rightarrowtail Role :' Query[PropertyType = ?v]'$" $\rightarrow$
  "$Role \rightarrowtail B :' Assert[PropertyType = v_i]'$"

– *Public RD* (provided that the substitution list for role All contains every agent within the forum), obtained from
  "$B \rightarrowtail All :' Query[PropertyType = ?v]'$" $\rightarrow$
  "$All \rightarrowtail B :' Assert[PropertyType = v_i]'$"

– *Conditioned social RD*, obtained from
  Prefix $\rightsquigarrow$ "$B \rightarrowtail A :' Query[PropertyType = ?v]'$" $\rightarrow$
  "$A \rightarrowtail B :' Assert[PropertyType = v_i]'$"
  Here, "*Prefix* $\rightsquigarrow$" denotes a sequence of messages (or message templates) which has to precede the Query/Answer pattern. For example, an agent might commit himself to a certain RD that has been requested from another agent only if the other agent agrees with a certain RD by himself (as in figure 3).
  Since an expectation network can model virtually any kind of interaction pattern, *Prefix* could denote highly complex conditions, e.g. auctions for the selling of web site ratings for the purpose of commercial advertising (i.e., the agents commit themselves to agree with the opinion of the auction winner).

5.1 Embedding social descriptions within RDF documents

Social RDs have to be communicated to information gathering agents in some standard language. In addition, it is expected to be useful to store a set of often-requested social RDs with the respective resource (very much like RDF is used) instead of calculating them on demand.
To provide a machine-readable format for (simple) social descriptions taking the form $\{Actor : (resource, propertyType, (value, expectability, normativity, deviancy))\}$, it seems reasonable to extend a well-established XML-based RD language like the RDF. This can basically be done by means of a replacement of the description parts of statements with lists of probabilistically annotated propositions. The description vocabulary

[8] In the case that A is a singleton (and therefore the SRDS does not need to generalize upon multiple agents by means of social roles), the SRDS could simply ask agent A for his opinion regarding SomeCompany.

[9] Although social roles usually group similarly behaving agents, in our formal framework [8], a single role can generalize different inconsistent opinions.

for the following example is implicitly given as an XML namespace “V” , provided by some organization “description.org”, and through a “Social Resource Description Rating Meta Language“ namespace called SRDML.

```
    <rdf:Description about='http://www.SomeCompany.com'
     xmlns:s='http://description.org/schema'>
         <V:MinorOrientation>
                 <SRDML:disjunctive>
                         <SRDML:boolean strength=0.9 normativity=0.7 deviancy=0
                                 agent='Entertainment industry'>True</SRDML:boolean>
                         <SRDML:boolean strength=0.1 normativity=0.7 deviancy=0
                                 agent='Entertainment industry'>False</SRDML:boolean>
                         <SRDML:boolean strength=0.3 normativity=0.7 deviancy=0.6
                                 agent='User community 6'>True</SRDML:boolean>
                         <SRDML:boolean strength=0.7 normativity=0.7 deviancy=0.6
                                 agent='User community 6'>False</SRDML:boolean>
                 </SRDML:disjunctive>
         </V:MinorOrientation>
</rdf:Description>
```

An alternative approach would be the usage of higher-order statements (i.e. statements about statements) already provided by RDF. Here, we treat the elementary descriptions as subjective statements, as in:

```
    <rdf:Description>>
         <rdf:subject resource'http://www.SomeCompany.com'/>
         <rdf:predicate resource='http://description.org/schemaMinorOrientation'/>
         <rdf:object>True</rdf:object>
         <rdf:type resource='http://w3.org/TR/1999/PR-rdf-syntax-19990105Statement'/>
         <a:attributedTo>Entertainment industry
                 <SRDML:expectationAttr strength=0.9 normativity=0.7 deviancy=0/>
         </a:attributedTo>
</rdf:Description>
```

6 Conclusions

We have introduced a framework for social RDs as a contribution to the emerging Semantic Web, and to provide a novel approach to collaborative resource rating. In contrast to traditional approaches, we’ve focussed on the unveiling of social structures obtained from communications and on multidimensional descriptions instead of interest-driven filtering criteria. To achieve this, we’ve used social expectation structures emerging from observed communication trajectories and have outlined how social RDs can be derived from social expectations. Currently, we are implementing a prototypical version of a SRDS for website ratings to evaluate the framework. For future research, we consider it as a very important objective to extend our approach towards the social semantics of large net societies ("Social Semantic Web"), whereas this paper only focussed on small agent interaction systems (forums). In addition, to enable complex communication processes like *trading with RDs*, we are investigating a RD communication language that is enhanced with interaction protocols for scenarios like information trading platforms and auctions, and language performatives corresponding to so-called Symbolically Generalized Communication Media [5] like "Money"[10]. Since social RDs are calculated from expectation networks which consist of expected action event sequences, virtually any kind of protocol can be used as a pattern for social RDs, but it would be necessary to create an RDF extension with support for complex social RDs beyond the examples in section 5.1. Another issue which deserves attention is the fact that search engines like Google or Altavista are flooded with fake web sites and linkages for the purpose to increase the ranking of some advertised content. Because the SRDS Mirror calculates expectation structures on the basis of stochastical frequency analysis, it will probably be affected by this problem too.

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[10] This would enable utterances like "If you pay me ..., then I'll rate your web site...").

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