2006

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CONTEXT-BASED MODELLING OF INFORMATION DEMAND: APPROACHES FROM INFORMATION LOGISTICS AND DECISION SUPPORT

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Abstract

Readily available information is a crucial basis for making decisions, solving problems, or performing knowledge intensive work. Providing such information meeting the needs of a user has to be based on an accurate, purpose-oriented and up-to-date representation of the demand in question. The paper is devoted to a study of different context-based models of user demand. The selected approaches from the fields of information logistics and decision support are based on enterprise models and object-oriented constraint networks (OOCN). Combining these approaches will allow for an orchestrated use of enterprise models and OOCN for decision support. Discussion and integration of these approaches is illustrated using an example enterprise model, a related information demand context and a corresponding decision support context.

Keywords: information demand, enterprise modelling, context, decision support, information logistics.

1 INTRODUCTION

Readily available information is a crucial basis for making decisions, solving problems, or performing knowledge intensive work. For a long time the approach to providing such information to users has been to simply make any existing information available and let the users themselves find what they want or need. More and more users perceive this way as leading to information overflow and require more sophisticated approaches in providing information, as indicated by a study among business professionals (Delphi Group 2002). Among the research activities addressing this problem are approaches from information filtering and information retrieval (Belkin and Croft 1992, Palme 1998), context-based ubiquitous computing (Dey 2000), context-based decision support and problem solving (Smirnov et al. 2005) and information logistics (Deiters et al. 2003).

The paper is devoted to a study of different context-based models of user demand. The selected approaches from the fields of information logistics and decision support are based on enterprise models and Object-Oriented Constraint Networks (OOCN). Combining these approaches will allow for an orchestrated use of enterprise models and OOCN for decision support.

The context-based approach to decision support focuses on dynamic problem modelling and solving for decision-making. Multiple domain ontologies representing relevant knowledge are integrated into context sensitive knowledge. Context sensitivity means that (a) knowledge relevant to a problem is integrated and (b) the integrated knowledge is linked to information sources providing up-to-date information. The integration of information and knowledge from heterogeneous sources is supported by the ontology model represented in the formalism of OOCN. The integrated knowledge forms a problem model treated as constraint satisfaction problem. While context-based decision support aims at providing information for problem solving, information logistics focuses on demand-oriented information supply in general, i.e. only relevant information should be provided to the users. Relevance in this context is based on such aspects as time, location, organizational role, or work activities. Development of methods, tools and techniques for the analysis of information demand (ID) is the core of the information demand based approach to information logistics.

Section 2 will introduce a definition of information demand and approaches for demand modelling from the field of information logistics. Section 3 focuses on context-based decision support and an approach based on OOCN for representing abstract and operational contexts. Section 4 investigates how information demand contexts can be used as basis for decision support context based on an example enterprise model, a related information demand context and a corresponding decision support context. Section 5 draws conclusions and discusses future work.

2 CONTEXT-BASED INFORMATION SUPPLY

In order to capture and model ID appropriately, different dimensions of demands must be considered. The starting point for any work in this area should be a clear and unambiguous definition of the term Information Demand as presented in Lundqvist & Sandkuhl (2004):

> *Information Demand is the constantly changing need for current, accurate, and integrated information to support (business) activities, when ever and where ever it is needed.*

This definition implies several aspects that have to be considered when analyzing ID:

- *changing* means that the resulting models need to be able to capture the dynamics of information demand in order to reflect changes over time;
- *current* and *accurate* requires some form of measurement of quality, relevance, and up-to-dateness;
- *integrated* as well as *(business) activities* implies a need for awareness of the context in which the demand exists as well as some mechanism for understanding when a switch in context takes place;
- *when ever* and *where ever* states the importance of timing and location aspects of ID.

2.1 Profile and Situation-based Demand Modelling

A core issue of demand oriented information supply is how to capture the needs and preferences of a user in order to get a fairly complete picture of the demand in question. This section will focus on two approaches used for this purpose: user profiles and situation-based demand models. Both approaches require active contributions from the user when defining and updating this demand information. Main criticism is the eroding quality of profiles in case they are not continuously updated.

User profiles have been subject to research and development activities in computer science since more than 20 years. Application fields include operating systems (like the MS-Windows profile), information services (like for Yahoo), or configuration of applications (e.g. ERP systems). User profiles are usually created for functionality provided by a specific application, service or system. These user profiles are based on a predefined structured set of personalization attributes and assigned default values at creation time. Adaptation of such profiles requires either an explicit adjustment of the preference values by the user (see Kotinurmi (2001) for an example), or involves deducing attribute values for a specific user through logging and interpreting of user actions (Setten et al. 2002). Recently developed approaches aim at a generalization of user profiles for a whole application domain. The objective is to enable different services to use the same profile for adapting appearance or behaviour. A frequently discussed approach is the W3Cs standardization activity for Composite Capabilities and Preference Profiles and Device Independence (Klyne et al. 2004). Instead of a fixed set of attributes, this approach aims at extensible structures for user profiles based on a common predefined vocabulary and a set of definition rules.

Applying user profiles for representing information demand requires a relatively large set of attributes, as the profile should cover all perspectives given in the information demand definition, like content, time, location or quality. Experiences from projects in information logistics indicate that user profiles are a suitable approach for applications with quite stable information demand. The WIND application is an example, providing weather information on-demand based on user profile (Jaksch et al. 2003).

A *situation-based* approach for information demand modelling was proposed in the field of information logistics for implementing demand-oriented message supply. The basic idea is to divide the daily schedule of a user into situations and to determine the optimal situation for supplying a specific message based on the information value. This approach describes a situation as an activity in a specific time interval including topics relevant for the activity and – if relevant - a location. A simplified example for a situation could be a videoconference between 10:00 and 11:00 about production planning for the product “T5” with focus on contribution from supplier “A”. Information value is a relation between a message and a situation, which is based on relevance of the topics of a message for the situation, utility of the message in specific situations and acceptance (“Does a user want to have information about a topic in a specific situation?”). More details of the situation model and examples from collaborative engineering are given in (Meissen et al. 2004, Meissen et al. 2004a).

Situation-based description of information demand allows for a more sophisticated capturing of user demands as compared to user profiles. The situation captures aspects of individual information demand like time, location and content. The information value relation adds further dimensions like acceptance and offers a way of deciding on when to supply information based on relevance and utility. However, this approach is subject to the same criticisms as user profiles: the task of defining situations and topics is requiring considerable efforts and has the danger of getting inaccurate.

2.2 Context-based Demand Modelling

In order to be able to support (business) activities and to provide integrated information as stated in the definition of information demand it is necessary to capture and evaluate information about these activities. It has been suggested that this, in conjunction with the situation-based approach described above, can be done by introducing the concept of *Information Demand Context* shown in Figure 1

(Lundqvist & Sandkuhl 2004). This is not only the largest, but also considered to be the most important aspect of ID since this defines the settings in which the users' ID exists (Lundqvist 2005). That is to say that providing the "right information at the right time and place" entails that it should be right given the demanding party's context. Context can be, and has been, defined in many different ways but for the purpose of information demand analysis, context is here simply defined as[1]:

> *An Information Demand Context is the formalized representation of information about the setting in which information demands exist and comprises the organizational role of the party having the demand, work activities related, and any resources and informal information exchange channels available, to that role.*

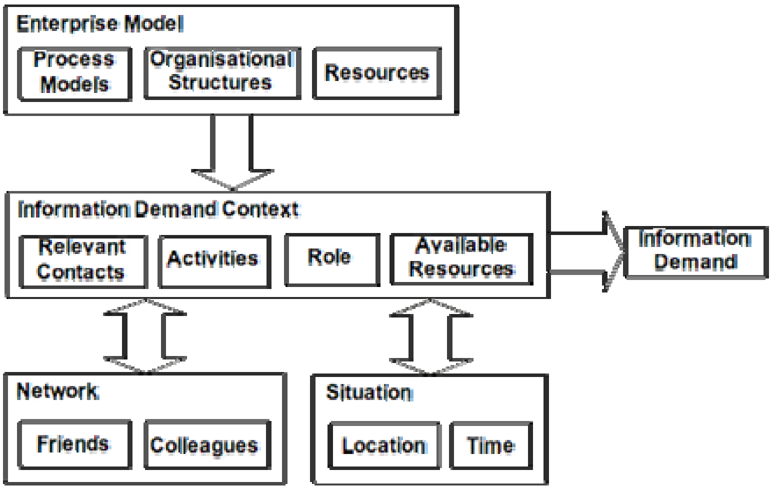

Figure 1. Information demand dimensions

The concept of *Role* mentioned in the definition can be described as a part of a larger organizational structure clearly defined by the responsibility it has within that structure. Associated with that role are a number of activities that fall within, and to some extent define, the responsibility of that role. Even though it certainly could be considered relevant to speak of ID as related to a particular activity or sub-process it is *Role* that in a natural way interconnects the other concepts depicted in Figure 1 and is therefore also considered to be the most central concept of the information demand context. Thus, when context is referred to it is considered to be the context of a specific role. Furthermore there are a number of different resources available to a specific role that can be utilised to perform activities within the responsibility of the role.

It is also proposed that an ID-context incorporates another important concept not recognised enough in most approaches today. In Figure 1 this concept is named *Network* and describes the informal information exchange channels that always, at least to some degree, seem to exist between individuals despite not being based on, or formally represented in, any organizational structures, process descriptions, or flow charts. Since such social networks are associated with individuals rather than roles they are considered to be independent of one particular context. They, or some subset of them, may however be both relevant for, and utilised, when activities are performed and are therefore introduced in the context as *Relevant Contacts*. It is also reasonable to assume that contexts creates new additional networks that the individual having the role might consider so useful that they are utilised even outside the specific context, hence the bidirectional arrow between context and network. This is equally true for the concept of situation described in section 2.1. There might exist predefined

[1] The wording of the definition was slightly updated as compared to earlier publications but the meaning remains the same.

situations so general and common that they are considered relevant to speak of in many different contexts but one specific context may also dictate new situations not predefined.

The use of the term business activities above is important for an additional reason. Even though it certainly might be relevant to speak about information demand from the perspective of individuals in such contexts as family life, various spare time activities, etc. it is reasonable to assume that the largest part of these contexts is too informal and random in nature and the information demand less critical and frequent for any information demand analysis based on the ideas presented in this paper to be meaningful or useful. As a consequence of this the focus in this paper is on information demands within a business application context in general and on support for decision making in particular. Moreover, even though not covered here either, there may be sub-contexts within a context that change everything from the role of a user to the activities to be performed (Lundqvist & Sandkuhl 2004).

2.3 Enterprise Models and Information Demand Context

The derivation of Information Demand Context can be performed in many different ways and from many different sources such as interviews with different humans (roles) within an organization, work or information flow analysis, various kinds of process modelling methodologies and so on. It is here proposed that one particular well-suited source, when available, is enterprise models. Enterprise modelling (EM) has been described as the art of externalizing enterprise knowledge and is usually done with the intention to either add some value to an enterprise or share some need by making models of the structure, behaviour and organization of that enterprise (Verndat 2002). Since such models typically include aspects of an enterprise like business processes, technical resources, information flow, and organizational structures as well as goals, objectives, and decisions, they are considered to be of great value in the derivation of roles, activities, and resources to form information demand contexts. An example of how this can be done is presented in section 4 based on a model of a fictitious enterprise.

3 CONTEXT-BASED DECISION SUPPORT

The approach to context-based decision support aims at modelling the user's (decision makers', and other participants' involved in the decision making process) problem and solving it. The concept "problem" is used for either a problem at hand to be solved or a current situation to be described. Two types of context model the problem: abstract and operational. *Abstract context* is a knowledge-based model integrating information and knowledge relevant to the problem. *Operational context* is an instantiation of the abstract context with data provided by information sources.

Decision-making is a complex process where a large number of factors can have an effect on a single problem. To naturally take into account the various factors and constraints imposed by the environment, the mechanism of OOCN (Smirnov et al. 2003) is employed. The problem is modelled by a set of to be solved by a constraint solver as CSP.

CSP model consists of three parts: a set of variables; a set of possible values for each variable (its domain); and a set of constraints restricting the values that the variables can simultaneously take. To represent the problem by a set of constraints that would be compatible on with ontology model and with internal solver representations, the formalism of OOCN is used. Typical ontology modelling primitives are classes, relations, functions, and axioms. A correspondence between primitives of ontology model and OOCN is shown in Table 1.

According to the formalism of OOCN knowledge is described by sets of classes, class attributes, attribute domains, and constraints. The set of constrains consists of constraints describing "class, attribute, domain" relation; constraints representing structural relations as hierarchical relationships "part-of" and "is-a", classes compatibility, associative relationships, attribute cardinality restrictions;

Ontology Model	OOCN	CSP
Class	Object (class)	Set of variables
Attribute	Variable	
Attribute domain (range)	Domain	Domain
Axioms and relations	Constraints	Constraints

Table 1. Correspondence between ontology model, OOCN, and CSP

and constraints describing functional dependencies. The following representation of the problem (*P*) by the formalism of OOCN is proposed:

$$P = (O, A, D, C) \qquad (1)$$

where O – a set of *object classes* ("*classes*"); A – a set of class attributes ("*attributes*"); D – a set of attribute domains ("*domains*"); C – a set of *constraints*. The set of constraints includes six types of constraints for modelling relations encountered in ontologies and constraint networks: 1) (class, attribute, domain) relation used to model triple of classes, attributes pertinent to them, and restrictions on the attribute value ranges; 2) taxonomical ("is-a") and hierarchical ("part-of") relations used to model class taxonomy and class hierarchy respectively; 3) classes compatibility used to model condition if two or more instances can be parts of the same class; 4) associative relationships used to model any relations and axioms of external ontologies neglected by the internal formalism; 5) class cardinality restriction used to define how many subclasses the class can have; 6) functional relations used to model functions and equations. Constraints of the types defined can be mapped onto solver language constructs easily.

The representation proposed is considered as the internal knowledge representation for the decision support. Ontologies used for contexts creation are supposed to be modelled by the internal representation (1).

Decision support within the approach is considered following two stages: a preliminary stage and a decision making stage (Figure 2).

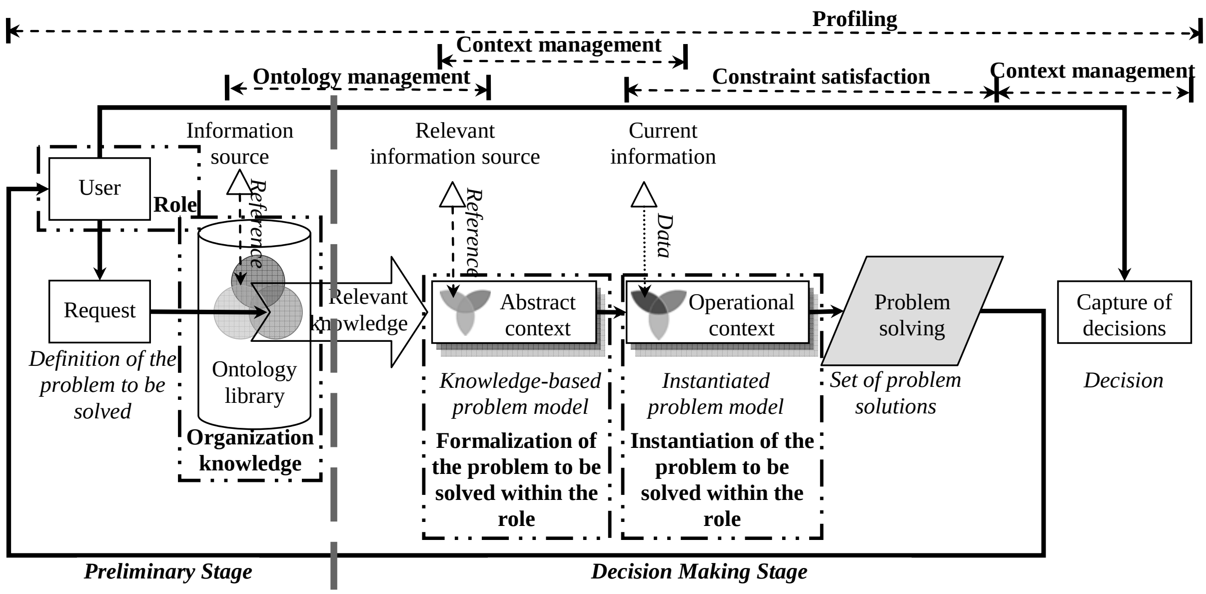

Figure 2. Technological framework for decision support

The *preliminary stage* is responsible for preparedness of a decision support system (DSS) to make decisions. Activities carried out at this stage are:

- Creation of semantic models for components of a DSS. The following components are defined: *information sources*, *domain knowledge*, and *users*. These components are modelled as follows: *domain knowledge* is modelled by ontology model; semantics of *information sources* is described by *information source capabilities* model; *users* are modelled by *user profile* model. All the components are represented by OOCN formalism;
- Accumulation of domain knowledge. The approach relies on an availability of sufficient domain knowledge represented by multiple ontologies using the internal representation. As a repository for the collected knowledge an ontology library serves. The domain knowledge is collected before it can be used in problem solving and decision-making. Knowledge collecting includes phases of knowledge representation and integration. Due to ontology model heterogeneous knowledge being collected is represented in a uniform way;
- Coupling domain knowledge with information sources. In order to obtain up-to-date information from the environment, ontologies are linked to information sources (sensors, Web-sites, databases, etc.) that keep track of environment changes. Applying the internal representation attributes of domain ontology and attributes of the representations for information sources and users are linked by associative relationships. The links mean that the attribute of the ontology class takes values provided by the information source or user.

The *decision-making stage* concerns integration of information and knowledge relevant to the problem, problem modelling and solving.

The starting point for this stage is the user request containing a formulation of the problem to be solved in a user-presented form. Based on the results of request recognition the knowledge relevant to it is searched for within the collected knowledge, extracted, and integrated. Ontology-driven knowledge integration enables methods of consistency checking for the integrated knowledge to be used. To operate on the extraction of relevant knowledge, its integration and consistency checking *ontology management* techniques are used.

The consistent knowledge is considered as an *abstract context* that is an ontology-based problem model supplied with links to information sources that will provide data needed for the given problem. The linked information sources instantiate the abstract context producing the *operational context* that is the problem model along with problem data. Changes in the environment result in changes in the operational context. Referring to problem representation (1) the context instantiation is carried out via the instantiation of attribute domains restricting them to particular values.

The operational context that is OOCN is introduced to a constraint solver to be treated as CSP. A decision is made based on feasible solutions generated by the solver. Three main forms of CSP are distinguished (Bowen 2003): 1) decision CSP when given a constraint network it is decided whether the solution set of the network is non-empty; 2) exemplification CSP when some tuple from the solution set if the solution set is non-empty, or otherwise nil is returned; and 3) enumeration CSP when the solution set is returned.

CSP is treated over attribute domains. If all the domains in an operational context have been instantiated, the operational context is considered as a situation description. This case corresponds to CSP of the 1st type. If an operational context contains non-instantiated domains, it means that a solution is expected. In that case CSP falls under the 2nd or the 3rd form. CSP of the 2nd and 3rd types return a set of satisfactory solutions for their further evaluation by the decision maker. The decision maker makes a decision based on the situation description presented in the operational context and / or on the generated set of solutions.

In order to enable capturing, monitoring, and an analysis of decisions and their effects the contexts representing problem models and respective decisions made are retained. As a result users are provided with reusable problem models and knowledge of similar situations and decisions made. For this context versioning purposed to archiving and maintaining contexts along with *profiling* (sec. 4.2) techniques are applied. Obtaining information, its organization in contexts, and context versioning are *context management* issues.

4 INFORMATION DEMAND CONTEXT AS A BASIS FOR DECISION SUPPORT

4.1 Information Demand Context: an Example

With an enterprise model as the starting point for information demand analysis much of the necessary information for context derivation is already identified and modelled. Figure 3 gives a schematic overview of an example model of selected parts of a fictitious enterprise called ABC Corporation. This model captures, and describes, central aspects of the enterprise as the organizational structure and roles in it, products and the process steps involved in producing, selling and delivering them together with the resources necessary to do so as well as the strategies and objectives the enterprise and its business is based on. As described in Figure 1, such a model can be used as the basis for deriving the ID-context for specific roles. In the case of ABC one such role is salesperson and connected with that role are a number of different activities and a number of objectives those activities should fulfil. The salesperson also has a number of resources available to support the performance of activities. Typical activities would in this case be receiving tender inquiries and orders, handling customer complaints and relations. In order to do so the salesperson can rely on such resources as CRM systems, intranets, EDMS etc. There will, most likely, also be some sort of organizational support in terms of colleagues within the sales department, a legal department, quality management and so on. In addition to this some of the objectives will be connected to activities within the salesperson's responsibilities, e.g. sales quotas, time spent on each customer, and customer satisfaction.

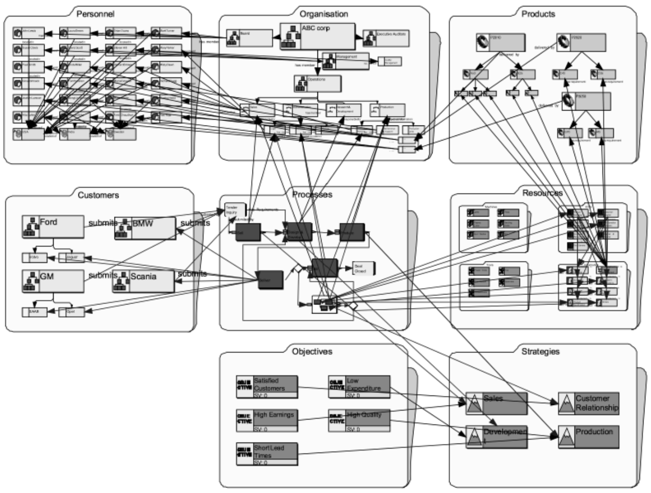

Figure 3. Model describing selected parts of the fictive enterprise ABC corp.

In order to derive information demand for the selected role that role and the activities, resources and objectives related to it must be studied in more detail. In this case the task of customer complaint management (CCM) is presented in Figure 4, expressed in Extended Enterprise Modelling Language (EEML), as an example. The CCM-task can be considered a commonly occurring situation in many manufacturing enterprises. In the model the main task falls under the responsibility of an organizational role (in this case a member of the sales department) and comprises several sub-tasks all performed or initiated by that role. In these sub-tasks several different roles, information objects, resources and decisions have a central position. The task starts with the complaint department receiving a complaint from a customer in some unspecified manner. An individual is appointed the matter, investigates and reports it to the quality manager. In order to do this access to some information and resources (information about the complaint, customer, and product) is needed. The output from the task is a detailed complaint description that can be sent to the quality management for

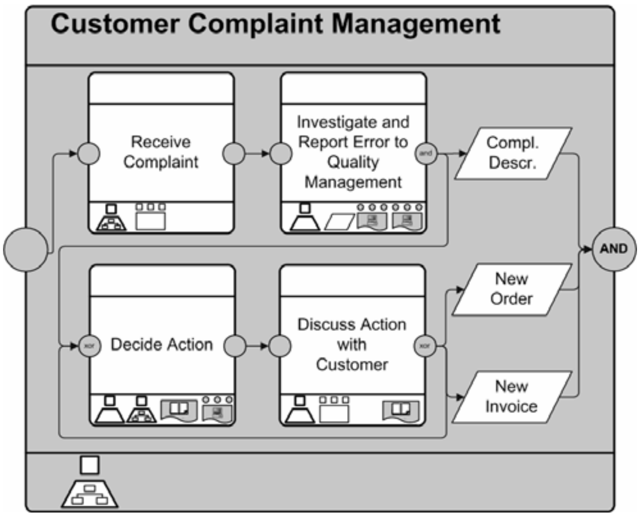

Figure 4. *Customer Complaint Management process description*

follow up, and background information necessary for deciding on what action to take. Such a decision can include discussions with the legal department about the terms of the sales contract and with the financial department about economical compensation. For this customer information and sales contract are necessary resources as the basis for decision-making. Once a decision is made this can be discussed with the customer using some ICT-tool and information about the decision. If the customer is satisfied with the decision the CCM-task will end in one of two possible ways; in a new order replacing the faulty one or with a new invoice, if not a new iteration of decision and discussion starts.

This example, even though fairly simple illustrates the concepts EM and ID-context have in common. The roles, resources, and task in the model depicted in Figure 4 correspond well to the different dimensions of ID listed in Figure 1. It is therefore possible to derive some of the IDs of the role complaint manager based on the model. However, there are some aspects not possible to derive. The model depicted above does not capture any spatial or temporal aspects at all nor any informal networks. One could imagine the complaint manager asking some colleague who earlier has had orders from the customer in question, for advice on how to best deal with the complaint. In order to identify such factors additional analysis steps are necessary together with the utilisation of the concept of situation presented in section 2.1. Nevertheless EM obviously can serve as a valuable source of ID and the context it exists in, in order to reduce the time and effort spent on analyzing.

4.2 Mapping Information Demand Context on Decision Support Context

Comparing two different viewpoints on context as both a model for uniting knowledge and information relevant to problems and as a key concept in information demand analysis, aspects common for both viewpoints have been identified, i.e. supporting decision making and knowledge acquisition through the use of information demand context (dash-dotted areas in Figure 2).

The user plays different roles depending on the activities this user carries out and other factors. For instance, within a DSS the user plays the role of a decision maker and, as well, can have several more roles within the organization. The approach to decision support defines information demand for a role using profiling technique. The core of the technique is capture, accumulation, analysis and classification of information about the user. The results of profiling are stored in the user profile, which is updated as required. Given the set of user characteristics (the results of the user profiling) the user can be uniquely identified. Some of profile structure elements, e.g. organizational belonging, activity, etc., can be adopted from enterprise models.

Within the framework for decision support, an analysis of the set of user requests together with abstract contexts describing those allows for deduction of problems typical of the given role deals with. Considering operational context related to the abstract context makes it possible to obtain what information is required for problem solving and thereby to be aware of the role's information demand. And vice versa, given abstract context (formalized problem description) allows for identification what roles deal with this kind of problem. This means that if a person faces the situation unfamiliar to him/her one can appeal to a particular role within the organization to clarify the situation and actions to be undertaken.

Enterprise and context models represent part of domain knowledge that can be applied in the creation of semantic models at the preliminary stage. This knowledge captured by the abstract and operational contexts reports what part of organization knowledge is useful in the context of a given problem.

Knowledge acquisition through ID-context is illustrated by the example of the CCM-process (Figure 4). The context of complaint management comprises concepts of customer, customer complaint, product or the product property complained on, complaints division. An organization ontology (Figure 5) specifying concepts of this context is derived from the enterprise model (Figure 3).

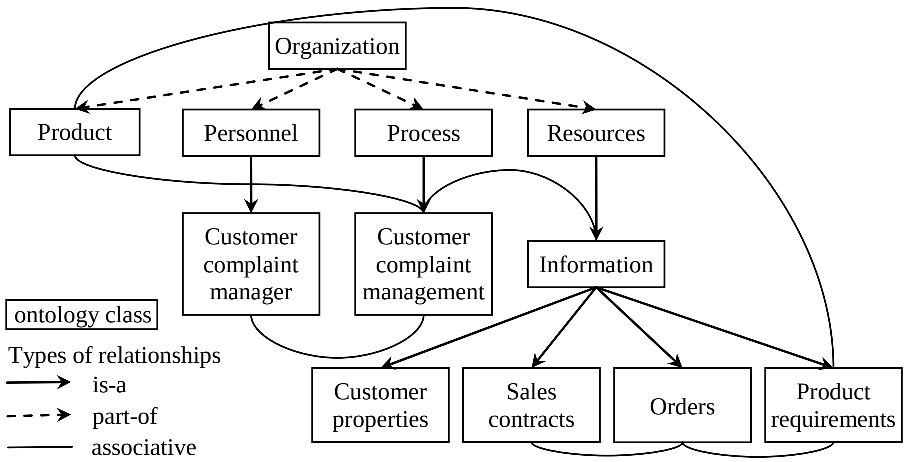

Figure 5. Domain knowledge derived from enterprise model

Figure 6 demonstrates how a customer complaint (Figure 2) is handled within the framework for decision support and how the customer complaint manager's activity that is a characteristic of the role is related to CCM. The customer sends the complaint to the complaint department where a manager has to consider it. For decision support the complaint is to be parsed and represented by means of the OOCN formalism. Usually such a request consists of the product characteristics as name, price, colour, etc. and a description of the problem they have according to the customer. The request is mapped into the OOCN formalism as the class ”product” and a set of class attributes corresponding to product characteristics as ”name, price, colour, etc.” that the customer mentioned in the request. Since domain knowledge has been derived based on the CCM-context, the derived knowledge is relevant to this context, the abstract context is identical to the organization ontology (Figure 5).

The abstract context is instantiated by the information from the resources related to the complained product and faultiness descriptions. The information from the resources includes the purchase order for this product, sales contracts, and the requirements this product has to fulfil. In order to take into account the customer complaint, domains of the attributes included in the request formalization are assigned to faultiness descriptions rather than real values. Values for customer properties are taken from the customer profile. For the situation in question location of the customer and the time zone for future discussions are considered to be relevant.

The operational context produced is a situation-based information demand description. Customer complaint manager can consider it and discuss possible actions with the customer.

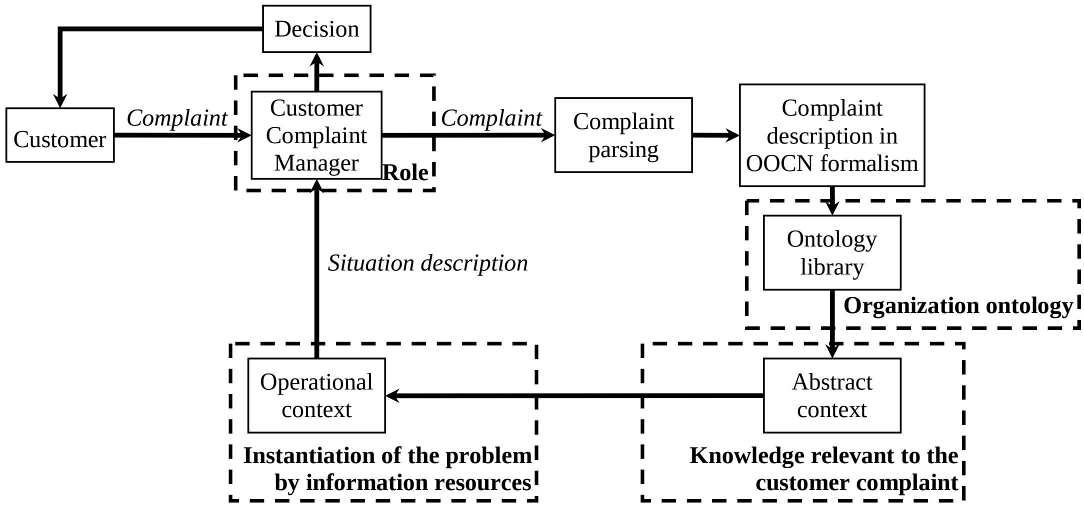

Figure 6. Customer complaint management support

5 CONCLUSIONS

Development of information technologies has resulted in a growing number of information resources providing the users with various kinds of information and knowledge. As a result the users often fail in getting the information or knowledge they need. The problem here is that the users get an enormous amount of information, most of which goes beyond their interests. The paper considers two approaches to providing the users with relevant information and knowledge: demand-oriented information supply as part of information logistics and context-based decision support.

Within the approach to demand-oriented information supply the concept of information demand with its dimensions and the derivation of information demand context from enterprise models have been discussed. The approach is applicable to the different types of organizations (large, small, small and medium enterprises) and management cultures.

Due to the orientation of DSS on the user's needs today, user-centric decision support has become important. Within the proposed framework for decision support the user personalization is achieved due to the context-based approach to problem modelling. From the information logistics point of view the approach is beneficial for definition of information demand pertinent to a role within an organization and for formalisation of situation-based information demand.

As the development of the proposed approaches to decision support progresses, the question of the best solution must be considered. The result of constraint satisfaction problem solving is a set of feasible or satisfactory solutions. In order to identify the best solution a set of evaluation criteria is intended to be adopted or defined. In decision making the user becomes aware of the problems by continuously monitoring the information required. Indicating in the operational context which variable (attributes) values the user cannot influence, would allow the user to operate with other problem parameters or factors and analyse the effects of this. Such an analysis would help to recognise critical parameters and to select a solution more suitable to the objective. Development of methods for analysis of abstract and operational contexts formalising information demand for the problems to be solved within the role will result in detection of patterns for role's information demand.

Acknowledgements

Part of this research is based on a grant from the Swedish Foundation for International Cooperation in Research and Higher Education STINT (grant no. IG 2003-2040).

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