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Context Modelling In Process of Developing Employment Solutions

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Abstract. The intelligent decision making requires the consideration of current contextual information. The article is devoted to construction of formal models for the presentation and usage of contextual information for decision-making in the field of employment. The paper analyses existing approaches to the definition of the concept of context at the conceptual level. The results of comparison of formal context models taking into consideration the requirements for employment business processes are presented. The ontological approach is selected as a basis for contextual models specification. The paper presents the formal representation of the context models for business operations of the employment sector. The model of contextual graphs for the solution of the problem of employment business operations context refinement was developed.

Keywords: models, context, knowledge, contextual model, employment.

INTRODUCTION

One of the prevalent trends in the development of enterprise information systems today is the growing demand for quality management solutions. This problem is addressed by the intellectualization of information systems [1], which recently is seen as the transition to the concept of a cognitive enterprise. One of the main requirements [2, 3] for such an enterprise is the usage of contextual information in decision-making processes, that is, the definition and understanding of such contextual elements as syntax and semantics of information, time, and location, peculiarities of the subject area, user profile, business process, current task and goals.

The concept of context is used and researched in many branches of science. The first attempts to understand and use of this concept were made in linguistics to execute the tasks of automated translation. Later, with the advent of knowledge-based intelligence, it became clear that all knowledge is context-dependent, that is, relevant only within certain, often implicitly given conditions. The lack of accounting for contextual dependences or knowledge was the cause of failure in many intellectual systems projects [4].

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Achieving a common understanding of the concept of context is a prerequisite for the possibility of using contextual models and methods developed by researchers to solve various problems. At the same time, today there are different definitions and understandings of this notion.

Thus, the dictionaries define the context as "interconnected conditions in which something exists or occurs" [5]. Many researchers associate the notion of context with the concept of the situation. In particular, in [6] the context is defined as the information necessary to describe a situation: 'context is an arbitrary information that can be used to characterize a situation of a certain nature'. Some works [7] consider the concept of context and situation as synonymous. This does not take into account that the context often reflects implicit knowledge of the situation. Instead, in [4], a definition is given that takes into account the implicit nature of the context: "context is what constrains a problem solving without intervening in it explicitly".

Often, the researchers specify the concept of context, adding to its definition characteristics, which are the properties or parts of a particular task, or class of tasks. Thus, in [8] the context is defined as knowledge about the current state of users and devices, including their environment. In this work, the context is specified as the location of the object, its identification and what it is doing, and time.

At the same time, it was emphasized in [6] that the existing context definition are too general and intuitive (and thus cannot be used for practical purposes), or too specific (and thus suitable only for solving specific problems)

In the study [9], context definitions were collected and analysed from 66 different scientific sources, from the areas of artificial intelligence (39), document science (27), cognitive ergonomics (9), cognitive psychology (6), business analysis (4), philosophy (2) and linguistics (4). The application of the cluster analysis made it possible to arrange the definitions into several groups. The first group includes the understanding of context as the information necessary to eliminate ambiguities and incompleteness in data. A large number of works understands context as the characteristics of a particular object in its environment. The third group includes a definition of context developed in linguistics. In [9] it is concluded that the diversity of definitions complicates the solution of the problem of a common understanding of the concept of context.

For the proper understanding of concept of context, it is important to determine where it is used. In particular, as a result of our analysis of contextual information usage in

the domain of intelligent decision support systems, following context use-cases have been identified:

- the support of decision-making when the information is incomplete or ambiguous and additional research needs to be done in the context of the situation;
- an analysis of the context is carried out for a deeper understanding of the situation and taking into account a wider set of facts. Thus, it is possible to get better solutions, for example, based on the individual characteristics of a person or his or her location;
- to facilitate communication between two agents, a common corpus of knowledge is used as a context. Agents themselves choose the relevant knowledge from this corpus, depending on the situation;

Works [10,11,12] describe the classification of different types of context, including the static and dynamic contexts, contextual knowledge and procedural context.

In many cases, when working with context, the authors emphasize the central role of "focus of attention" in defining contextual data [9]. Therefore, we consider the main thing that defines the context being an element - a "focal object" (fig. 1). The procedural context is the information needed to complete the task by the agent at a given time. The focal object is part of the procedural context, since its parameters (for example, the agent's purpose, or the characteristic of the problem that it solves) determine the task. Contextual knowledge is knowledge, even though not relevant for the current context, but can be included in the context when context refinement is needed. The presence in the figure of the outside world reflects the fact that there are knowledge and information that the agent does not possess.

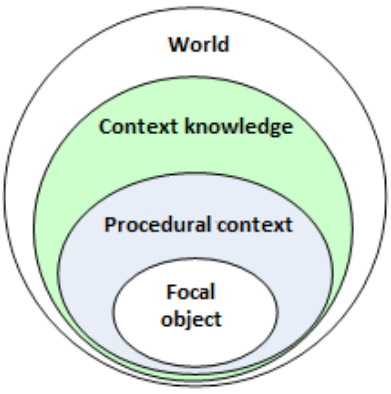

Fig. 1. The conceptual context model

THE REQUIREMENTS FOR FORMAL CONTEXT MODELS IN EMPLOYMENT AREA

Context models are used to access contextual data and knowledge when solving practical problems. The relevance and completeness of the received information for decision-making depends on the right choice of the context model, which, in turn, determines the quality of the decisions made.

Formal context models use a variety of symbolic or graphical representations of contextual information and are based on the chosen mathematical formalism. The most well-known formal context models are [12,13]:

- "key-value" models;
- markup languages;
- graphic patterns (graphs);
- object-oriented models;
- logical models;
- model based on rules;
- models based on ontology.

When comparing context models, one must take into account:

- features of the subject area and the problem solved in it;
- types of context (static or dynamic, procedural or context knowledge);
- purpose for using the context (decision making, personalization, ease of communication);
- need to support reasoning and use a multilevel context.

A comparison of formal context models is presented in many papers devoted to the study of context modelling [13-15]. Thus, [13] compares the context models for Internet systems of things and ubiquitous computing. The author defines the following requirements for the context models derived from the chosen subject area:

- support for distributed storage and processing of data;
- partial validation of data, rejection of incorrect options;
- work with large real datasets, supporting multi-variant solutions;
- processing of incomplete and fuzzy data;
- processing information at different levels of abstraction;
- the possibility of using existing technological solutions, compatibility with them;

On the basis of those requirements, the author [13] compares formal contextual models, defines their advantages and disadvantages for applications in the Internet of things.

In [12], the above-mentioned context models are compared in the regarding the possibility of using logical reasoning in the process of contextual information processing. The author defines the criteria for model comparison, which partially overlap with the criteria from [13]:

- support for heterogeneity of systems and mobility;
- using dependencies and relationships;
- taking into account the history of changes;
- support for fuzzy and incomplete information;
- support for reasoning;
- data integrity checking;
- support for different levels of context processing

The paper [11] is devoted to context modelling for decision support systems. It describes and compares contextual models for solving contextual model management problems. Article [13] considers context models based on the ontologies for the Internet of things.

At the same time, existing comparisons of context models take into account only the features of the subject area. In our opinion, it is more useful to include in comparison more parameters taking into account the

mathematical apparatus, the universality / specificity of the models, the use of the context as generalized task groups.

In our approach to context models comparison greater number of factors is taken into account. As a result of the analysis of the processes and tasks of the employment domain [15], the following requirements for context models in employment area were defined (table I):

Table 1. Rationale of requirements for contextual models

Requirement	Rationale
The focal object is a client - a person who is in search of employment	The main purpose of the employment service is to employ a client
Support for both static and dynamic contexts	Determined by the variability of the situation in the labor market,
Using the knowledge of experts	Allows you to discard false and subjective information
Processing inaccurate and incomplete information	The information provided by the search provider or the employer is often incomplete and inaccurate
Supporting reasoning and resolution of conflicts	The conflict of interest between the client and the employer is possible.
Using variety of sources of information and data formats	Employers provide information in various formats
Taking into account the history of changes	The history of the applicant's recruitment influences solutions
Ability to offer and choose alternative solutions	Client satisfaction is greater when he can choose

In addition to the requirements arising from the features of the domain, the contextual model must support the general requirements that affect the system's performance. These requirements include the ability to verify the integrity of information and its validation, supporting different levels of processing the context, supporting various mechanisms of reasoning.

The results of comparing the contextual models are shown in the table 2.

When choosing the type of context model for building an employment information system, it is impractical to restrict the use to only one type of model, since various types of contextual models are used in practice to execute tasks in the employment field. However, models based on ontologies occupy a special place among the contextual models, because they provide a basic structure of common concepts and relations upon which all other types of models can be built. The main advantages of using an ontological approach are:

- ontologies make it possible to formally define the concepts of the subject area and the relationships between them. This knowledge reflects the properties of the subject area and can be reused.
- on the basis of concepts, relationships, and axioms of ontology, one can build models for displaying different types of context (historical, person, location, etc.).
- for the ontological presentation of knowledge, tools for logical reasoning and integrity verification have been developed.

Based on a common ontology, models that support different forms of reasoning can be built.

Table 2. The context models comparison and suitability for employment area systems

Context model	Used apparatus	The type the problems resolved	Suitability for employment area
Key-value	Cortege of values	The key allows to interpret a particular value	Not suitable. Insufficient ability to represent context data
Markup languages	Formal languages	Used for structured and semi-structured formats	Do not use contextual knowledge.
Graph models	Graph theory	Historical context, process context represen-tation	Do not support reasoning
Object - Oriented	Object-Oriented Modeling	Used to detect contextual dependencies in a subject area	Suitable for of processes. There is no verification of the data integrity
Logical	Mathematic al logic	Defining logical statements which are contextually valid	Logical reasoning is limited.
Based on rules	Associative rules	Rules that are relevant in a specific context	Cannot organize contextual information.
Based on ontology	Ontology	Representing an integral formal model of the domain	Formal representation of domain and a basis for other models

GRAPH-ORIENTED MODELS FOR CONTEXT REPRESENTATION AND PROCESSING

In [16], the method for constructing employment ontology on the basis of the analysis of business operations context was proposed, and an example of such an ontology for the employment area is provided.

The process of the ontology construction is based on the analysis of operational contexts. It begins with the creation of a business process model using one of the process modelling languages. As a result, the structure of the process, its component business operations and the

connections between them are elucidated. In the second step the context of each business operation is analyzed. We determine:

a) the entities and their attributes which participate in the operation. If possible, they are referred to types that are already defined in the general ontology *On*. If objects of these types are not present in the ontology, new types of objects or attributes are added.

b) the relations and their attributes which are relevant to the operation. Similarly, we refers them to known types of relationships, or create new types of relationships.

As a result of the analysis of business operation, the ontology of this operation is constructed: $On_{op} \subseteq On$.

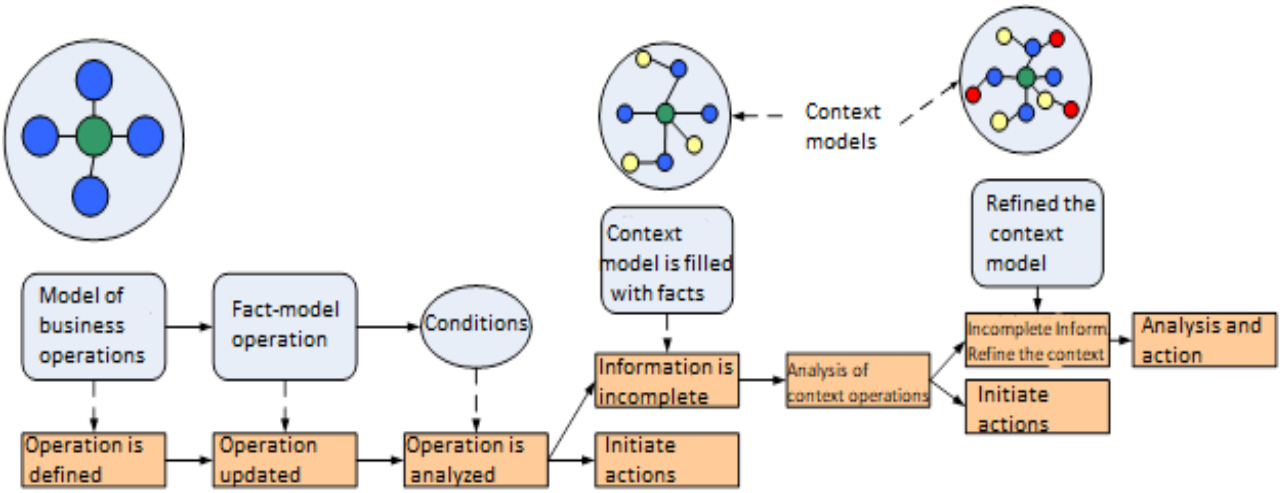

Fig. 2. The conceptual context model

In [4], the presentation of business processes by context graphs was proposed. The authors note that the structure of such a graph, which corresponds to the structure of decision-making in the business process, is well defined and is often standardized in normative documents. But in practice, the selection of a specific solution depends on the context of the business operation, must take into account the nuances of the situation, and occurs as a result of an analysis of this context. At the same time, [4] does not specify how to formalize the process of analyzing business operation context and how to choose the specific solutions.

The ontological model of business operation contains the ontology of operation On_{op} and the set *SSt* of situations specifications, which are defined in the context of this operation. Each situation is defined by the conditions specified using the values of the objects included in the ontological model of the operation:

$$Md_{op} = (On_{op}, SSt) \qquad (1)$$

The set of situations is determined by the expert in the form of ontological model. Each situation is a tuple:

$$Sit = (Sig_{st}, SAc_{st}), \qquad (2)$$

where Sig_{st}, - the signature of the situation, SAc_{st} - a set of actions. The signature of a situation is a condition defined on the values of the ontology entities from operation's model. If this condition is fulfilled, then it is assumed that the situation is taking place, and actions from SAc_{st} should be executed.

The process of analyzing the context of a business operation is shown on figure 2. First, the current business operation and the corresponding ontological model are determined. The entity and relations from the model are instantiated by corresponding facts. Next, an analysis of the conditions included in the signatures of model situations is performed in order to identify current situations. Depending on which situation is detected, appropriate actions are initiated.

In practice, current combination of facts values can be not sufficient to make a decision and it is necessary to obtain additional information from the context of the objects included in the ontological model of the business operation. The contextual model of business operation model is enhanced adding some entities and relationships from the context of existing objects. In [14], it is proposed to use the chains of ontology elements for the formal specification of path leading to such contextual objects. This allows starting with the particular element of the operation ontology model to determine the contextual element, taking into account all intermediate chain elements. The context model is initiated by the facts of the subject area. The subsequent analysis of this enhanced model determines the necessary actions. One possible action is to further refine the context by obtaining additional information necessary for decision-making.

DISCUSSION AND CONCLUSIONS

Let us consider an example of a context analysis for the employment process. Processing the client's request is a starting point in the business process of employment agency (fig.3) [15,16]. Upon the availability of request, the personal consultant is assigned for following up this request execution. The request is analyzed and entered into the Unified Information and Analytical System (EIAAS), along with consultant's information and the date of submission. During the analysis, it is necessary to investigate the client's context. For example, whether the client asks for this position for the first time. If the request

is not submitted for the first time, then it is advisable to expand the search context, in particular, to consider the history of previous requests and the results of the implementation of job placement recommendations. With this purpose, an excerpt from the history of previous requests for a consultant will be formed. The system can also direct the client to a consultant with a bigger experience in a particular employment field that can analyze the causes of past job problems.

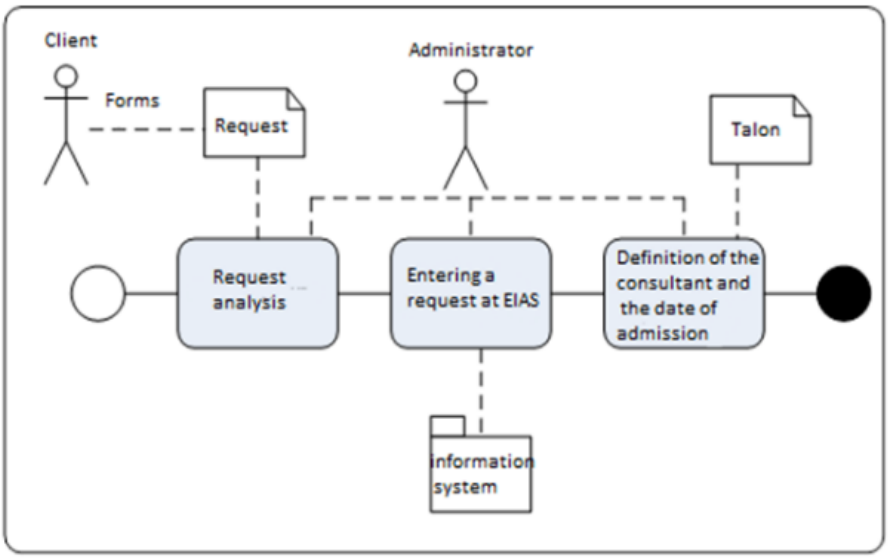

Fig. 3. Business operation model of employment application submission

Additionally, information from social networks about client and his previous employers can be useful to make well- informed job recommendation.

Similarly, the system verifies the client's context in order to identify the client's level of qualification, his health and other information that can be used to improve the quality of service.

The refinement and elaboration of contextual information using ontological context models allows to form better decisions, because more real life situations and corresponding solutions are considered and applied.

The use of ontological modelling to represent and analyse the context of employment business processes provides additional knowledge about rules and relationships in this area which can be used to build different types of decision support models.

The model used in this article to represent employment business process is contextual graph. In such a graph the vertices correspond to the operations of the analysis of the context or actions, and the arcs determine the main directions of in-depth analysis of the context and the transitions between business operations.

Today's employment information systems are mainly used for registering and storing data about customer requests and available vacancies, while all decisions are made by consultants at employment centers based on their experience. The introduction of the analysis of business operations contexts will make it possible to formalize expert knowledge for typical situations and automatically identify such situations, conduct a detailed analysis of the context of the client, employer and job offerings in order to avoid mistakes and improve service quality.

The developed methods of context analysis are implemented in the form of a web application that uses a central knowledge base for keeping knowledge about the employment business processes, along with the information about clients and employers. The web application will support the work of the employment agency for query processing, providing additional information and decision guidance for all business operations.

At the same time, theoretical research will be aimed at developing methods for choosing context models taking in consideration a larger set of criteria, as well as in the conditions of incomplete or inaccurate information. The valuable input information for decision making in this case can be provided by building and analysing datasets for employment agencies using machine learning and data analysis methods.

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