An Agent Model in BI Knowledge Intensive Environment

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Abstract. The Business Intelligence (BI) traditional goals still stay: provide the right information users in organization with right information at the right time and place. The BI systems by their nature demonstrate as heterogeneous, while all plans to unify them eventually fail. Moreover the expectations of R&D of proactive BI let us conclude, the heterogeneity may become chaotic. We claim that, for mastering such a heterogeneous and dynamic system, a programmatically accessible and self managed knowledge management system, capable of storing and representing the whole content of a BI system is required. The properties of Knowledge Management Structures (KMS), combined with intelligent agents (IA) and Multi-agent systems (MAS) show great capabilities, and have, in limited scope, proved their strengths, acting in heterogeneous systems. In the following paper we synthesized the state of the art research in the fields of BI, KMS, IA and tried to fill a gap disabling successful application of IA for management of KMS in a dynamical environment. To do so, a model of an IA, capable of reasoning and acting in a dynamic KMS environment and sharing its knowledge is presented.

Keywords: Business intelligence, Intelligent Agents, MAS, BDI, Knowledge management, Ontologies.

1. Introduction

Typically BI systems include a wide variety of data structures, processes, tools, and KMS. The diversity of technologies in proactive BI, combined with increased complexity of company data indicates an explosion of heterogeneousness in BI systems.
BI systems pull information from other systems, convert data into information and, through user analysis into knowledge. BI systems consist, as presented in Figure 1, of three main parts: Data acquisition, data analysis environment, and information delivery. Evolved BI systems can consist of multiple, lightly connected instances of these three elements.

![Figure 1: BI data framework](image)

The core of BI system; data analysis environment consists of three major elements: Data warehouses, Analysis methods and Meta data repositories. Multiple and often inconsistent, data warehouses are built since they differ by purpose, location and data source. Analysis methods differ mostly due to requirements, set by users, the capabilities of used methods, used analytical tools, level of data aggregation and others. Level and quality of information, extracted from available data still doesn’t reach BI expectations, therefore methods and tools of data analysis are constantly evolving.

BI systems possess knowledge representing structures in form of Meta data. These structures hold the knowledge about data structures, data contents, used analytical methods, statistics and other information, needed to perform data analysis. Meta data, used in BI applications is focused to support partial analysis processes, acting on underlying data and is adapt to local formal structures and standards. There are several issues disallowing systematic use of Meta data, among them: fragmentation of Meta data structures, and lack of compliance to structural standards disabling automatic program recognition and reasoning.

The BI information converges in the phase of information delivery, where there information is unified before it is presented to the users. Usually unification of content and visualization standardization is accomplished with use of web resources, for instance web portals as the universal unifying platform.

Range of available BI technologies and methods, vast amount and heterogeneity of data and extracted information create a dynamic environment, hard to organize and even harder to manage. While often proved impossible to uniform BI systems; MAS, KMS based systems show potentials in managing and coordinating the processes in such systems. This could get us one step toward newer reached goal: providing the right decision takers with the right information in the right form and the right time.

3. Agents and Knowledge Management

The modeling of intelligent agents and MAS goes to the 80-es and 90-es when some fundamental models were constructed. For instance AOP, 3APL, SOAR and BDI [3; 20]. These models rely on presumption that the agent’s architecture and the reasoning capabilities of the agents are based on the recognizable behavior patterns. Some models evolved to specialized agent languages, as for instance 3APL and AgentSpeak(L), other, such as BDI, define the agent’s structure. In Java, some platforms are created, as for instance JACK [16] and JADE [1]. Although JADE doesn’t comply fully with BDI model, JADEX [18], built on a JADE framework, does.

The Knowledge management R&D community is active for the last 20 years and it shows great potentials in knowledge representation and reasoning technologies. The current R&D directions are presented by Frappaolo [6].

The presentation of knowledge uses ontologies: XML-based structure languages, such as RDF and OWL. These languages contain structures, enabled for machine recognition and reasoning based on the data content. They therefore provide the adequate means for the automated computer communication and reasoning [10].

The standard agent’s models presume all the BDI resources are stored inside the agent. When acting in information supported environments, the need for using external KMS arises. The attempts of connecting agents with external KMS have already been presented [15]. They are based on the creation of static agent structures, resembling the KMS from their environment. Although the attempts to picture the KMS into agent’s memory were presented [9], [7] the
formal specification of an knowledge aware IA still isn’t provided

4. BIMAS Framework

BIMAS (Business Intelligence Multi-Agent System) framework is based on BI system, compliant to Model-driven DSS [19], using algebraic, decision analytic, financial, simulation, and optimization models to provide decision support with trend in development to acquire proactiveness and ubiquitousness.

The main task of BIMAS is the active management of BI analytic tools and used methods, to raise the quality level of BI system performance, of the information delivered and to lower the maintenance and change costs of the system, using existing local KMS.

According to the properties of BI systems, the role of MAS and it’s agents in BI surrounding, change exceedingly, comparing to non-information supported environment:

Agents in the BI system act according to the rules, deployed in external KMS. They are capable of accessing, understanding and complying with local rules and using local methods. Therefore they must adapt accordingly to the changes in BI environment. Their main task is to successfully encapsulate the complexity of local processes and present their capabilities to the MAS.

A MAS is a communication and presentation platform for the capabilities of its agents, providing the means for integral management of incomplete, distributed and heterogeneous BI resources.

This structure could prove applicable to solve the problem of managing BI distributed, semi knowledge based system by encapsulating distributed KMS and standardizing their content on a higher level.

4.1. Agent model

The presented agent structure is based on BDI structure originally presented by Rao and Georgeff [4; 20]. It embodies agent’s capabilities: believes, intentions, desires, goals plans, sensors and executors, driven by internal reasoning engine and is often used as a model of intelligent agents. We argue the presumptions, delivered in the original BDI model are not suitable when agent is acting in an information supported environment since it lacks the ability to handle with external dynamic KMS [9; 14].

Therefore we expand the standard BDI model by dividing Agent’s capabilities into inner (basic) and external (dynamic) capabilities.

Inner capabilities can be further divided in capabilities to function as an individual agent and abilities to use agency resources. Both share the attribute of being formed at agent’s creation, are generally static and where presented in original BDI model.

- Functional capabilities include the reasoner, desires, intentions and inner believes. They are generally pre-designed and generic for all agents, functioning in the MAS.
- Abilities to function in a MAS [5] are communication abilities and abilities to use agencies shared resources as for instance Directory Facilitator.

The external capabilities of are used to exploit the system’s information resources.

- Agent uses external KMS, holding information about the potential means for the agent and environment rules, he must comply. Agent responds to the dynamic changes in external KMS.

Therefore the reasoning process involves both: agent’s basic and dynamic capabilities. In the case of existence of reasoning engines in the BI environment...
environment, the agent can decide whether to use its own reasoning engine or to outsource the part of reasoning process to the environment’s reasoning engine.

Agent’s internal structure, presented in Figure 2 contains basic and dynamic capabilities, and the processor of a BDI agent, linked with key elements of BI environment to where agent activities are focused. The figure also contains main processes in an agent’s execution cycle.

4.1.1. Structure

Agent capabilities are, according to BDI model, formed as tuples of believes, desires, and intentions.

Desires are tightly interlinked with requests of potential principals. Desires contain potential states, which agent is willing to acquire and are generally not essentially modified during agent’s existence. Desires can be focused on existence of the agent, communication with other agents and active participation in its environment. Desires must be applicable, where intentions provide the means for their appliance, with the conditions for their execution fulfilled. The desires scheme is usually complex, including hierarchies, sequences and other structures.

Intentions contain means, potentially capable of fulfilling agent’s desires. They act as a register of methods and conditions, required to engage a method, calculating operational costs and validating success and failure conditions. Intentions, as desires, are stored in complex structures where level of hierarchy is connected with the level of appropriate desire.

Believes contain active and passive data, where passive data is required only for validation purposes of desires and intentions in the process of reasoning, while active believes have the ability to post a request that triggers the processor cycle. Believes can be typically denoted in a key-value form.

For agent to function in its environment two basic groups of capabilities (tuples ob Desires, Intentions and Believes) are required: Basic and Dynamic capabilities, each with its rationale and depending structure.

The basic capabilities contain functional, communicational and environment capabilities, deployed in an agent structure. These capabilities tend not to change during agent’s existence.

Dynamic capabilities represent the rules, originally stored in environment KMS. The content of those can change according to changes in KMS.

The communication between processor and dynamic capabilities demands for a clear modular design of an agent [14], invoking standard Q/U abilities.

The agent’s basic and dynamic capabilities are delivered to agency and reasoner in a uniform way, although the reasoner should be aware about the origin of desires.

Agent’s processor encloses structures, supporting the execution cycle consisting of scheduler, reasoner, goals and plans.

Scheduler accepts the incoming requests and manages queues and timing of execution cycle. It allocates the resources for selected tasks.

The reasoner conducts the decision process. The decision process runs in two major steps: in first step appropriate desires, compliant with the received requests, are selected. In step two, for selected desires, the applicability of appropriate intentions is validated with use of agent’s believes. If the reasoning is successful, goals, representing selected desires and plans, representing applicable intentions are created.

The reasoner can use fixed, hard-coded decision taking algorithms or use open algorithms, based on dynamic ontologies where not only data, but also the ontology structure can change. For achieving the required level of agent’s adaptivity, reasoner can delegate the reasoning process to external reasoners, residing in agent’s KMS environment (in case of their existence).

Goals represent achievable desires, selected in the decision process. Goal achievability is determined by comparing the pre-conditions of intentions with the believes current states.

Plans represent the applicable intentions, used for achieving selected goals. Plans must conclude the series of tasks, leading to accomplishment of selected goals and report of their failure or success.

Plans can be executed by agent’s methods for changing basic capabilities, by using methods, residing in agent’s environment, or passing the execution to another agent.

Environment is the raison d’être of an agent. Agent’s purpose is to perform assigned tasks in the environment, according to the mandate and capabilities it possess, while data represents the working material of an agent, using it’s methods as the tools to work with.

External KMS encompass state of affairs in the external systems. Distributed environments
hold separated KMS, built in compliance with diverse standards and languages, usually holding only partial information about the methodologies and rules. If KMS are compliant to standards, such as OWL or RDF, plug-ins can be used for dynamic representation of agent’s dynamic capabilities and external reasoners can be used, if they are expected to deliver better decisions than the built in reasoning engine.

The external reasoning engines could prove useful in the second step of the decision process: the reasoning about the properties of intentions for the selected desires.

The structures in a BIMAS agent model display only static view of the agent. To clarify the picture we will try to present the main steps in an execution cycle of a BIMAS agent.

4.1.2. Processes

The agent’s processes in BI environment expand the standard executing cycle with some additional steps and options. In the following the formal steps are presented. Some sub-steps can be processed parallel or optional.

1. A request to processor: a request can originate from multiple sources
   • Time or state conditional trigger, stored in agents believes. The state or dynamic believes is altered by changes in environment, a change in basic believes represents change of the agent’s state or
   • A request, origins from another agent or
   • Execution of a sub-goal in completing of a complex goal.

Requests are handled by scheduler, which involves the reasoner to select the appropriate goals.

2. The decision process is handled by a reasoner. It handles received requests and uses desires, intentions and believes to propose appropriate goals and plans. The decision process consists of some sub-steps:
   • Selecting the desires, fitting to the request,
   • Selecting appropriate intentions,
   • Testing the intentions pre-conditions: By using agent’s believes or by passing the testing problem to a external reasoner,
   • Forming the appropriate goals and execution plans,

3. Using the methods for agent’s inner actions or actions in environment data and KMS, or passing requests to other agents.

4. The reports of success or failure of agent’s actions, needed for the principal or, in the case of execution of sub-goals, to start the next cycle of execution, are delivered to agent reasoner.

4.2. Using BI KMS and reasoning engines

In the presented model two segments need focusing: the synchronization of agent’s dynamic capabilities with BI KMS and communication between agent’s and external reasoning engines.

The uniform presentation of desires and intentions is crucial for the agent’s reasoner but also for the presentation of the agent’s capabilities in the hiring community.

Built in reasoner accepts decisions, needed for the agent to function (inner decisions), decisions for function in agency (agency decisions) and in its environment. The inner and agency decision capabilities are burned in agent’s structure and are not expected to change. The built in reasoner is optimized to work with these structures, while the structure of dynamic capabilities is built using KMS and is not optimized to function with the agent’s built in reasoner. The presented structure enables the outsourcing of the reasoning process to the reasoner, optimized for the KMS, used in BI.

The agent’s reasoner is aware of external reasoner and recognizes its authorization, based on its dynamic capabilities.

The communication between the agent’s and the external reasoner is as simple as possible. Agent only uses standard methods of posting a request and getting a response of external reasoner. If the external reasoner includes no standard communication capabilities, an agent can be created to envelope the KMS reasoners communication.

The external reasoner decides upon data, stored directly in external KMS. This enables agent to act not only on its own believes, but also on believes stored in its environment.

Since single agent can not perceive the complexity of the BI environment, coordinated functioning of the agency is considered necessary, where special agents, managing local areas, are coordinated.

5. Summary

BI and intelligent agents have emerged as diverse research areas; though they both share some results of recent research issues, they diverse in their ambitions. In this paper we
investigated the possibilities of merging these fields of the research. First we explored the properties of BI systems to discover prospective fields for using agent technologies with focus on management of analysis methods.

After illustrating the state of the R&D in the field of agent, MAS and KM, a framework BIMAS was presented. The BDI based model of an agent, capable of exploiting the existing KMS was constructed. The model reveals modifications in the design of the BDI structure enabling optional usage of external KMS and reasoning engines, making the agent adaptable to the changes in the knowledge structures, stored in the environment.

In the future we intend to test the applicability of the model, using a java based agent development environment. We intend to build prototypes, supporting the management of data mining processes for detecting the probability of default.

6. References