Knowledge Fusion Patterns for Context Aware Decision Support

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INTRODUCTION

Decision support systems heavily rely upon large volumes of data, information, and knowledge available in different sources. Whereas several years ago the main technology used to integrate data and information from multiple sources within a decision support system (DSS) was data fusion, today the focus of data fusion has naturally changed to knowledge fusion. Knowledge fusion problem refers to integration of information/knowledge from different sources to obtain new knowledge. The main result of knowledge fusion is synergetic effect from the integration.

Information and knowledge become interpretable in context. The DSSs that use context to provide the decision maker with a set of decisions that can be made in the current situation are referred to as context-aware.

This article investigates knowledge fusion processes in a context-aware DSS. Such processes occur at different stages of DSSs exploitation. The objectives of the article are discovery of knowledge fusion processes which take place in the DSSs, investigation of effects these processes produce, and retrieval of patterns for the discovered knowledge fusion processes.

BACKGROUND

Based on the analysis of knowledge fusion studies, a number of knowledge fusion processes can be distinguished:

1. Intelligent fusion of massive amounts of heterogeneous data/information from a wide range of distributed sources into a form which may be used by systems and humans as the foundation for problem solving and decision making (Scherl & Ulery, 2004; Alun et al., 2001).
2. Integration of knowledge from various knowledge sources (KSs) resulting in a completely different type of knowledge or new idea how to solve the problem (Lee, 2007; Grebla, Cenan & Stanca, 2010). Integration of different types of knowledge (domain, procedural, derived, presentation, etc.) resulting in a new knowledge type (Holsapple & Whinston, 1986) and integration of multiple KSs into a new knowledge object (Kuo, Tseng, & Lin, 2003; Gou, Yang, & Chen, 2005) belong to this type of knowledge fusion.
3. Combining knowledge from different autonomous KSs in different ways in different scenarios, which results in discovery of new relations between the knowledge from different sources or/and between the entities this knowledge represents (Laskey, Costa & Janssen, 2008; Jonquet et al., 2011).
4. Re-configuration of KSs to achieve a new configuration with new capabilities or competencies (Lin & Lo, 2010).
5. Knowledge exchange to improve capabilities or competencies through learning, interactions, discussions, and practices (Lin & Lo, 2010).
6. Involvement of knowledge from various sources in problem solving, which results in a new knowledge product (Smirnov et al., 2003).

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The processes above can produce the following possible knowledge fusion results:

- A new knowledge object created from data/information (the result of the process 1);
- A new knowledge type or knowledge product (service, process, technology, etc.) (the result of the process 2);
- New relations between knowledge objects (the result of the process 3);
- New capabilities/competencies of a knowledge object (the result of the processes 4 and 5);
- A new idea how to solve the problem (the result of the process 2); in the informatics terms this result corresponds to a new problem solving method;
- A solution for the problem (the result of the process 6).

Discovery of knowledge fusion patterns has not been a hot research topic. Up to now, some general patterns like unstructured fusion (Chen & McQueen, 2010), convergence (Lee, 2007), fractal fusion (Lee, 2007), knowledge recombination (includes two patterns: knowledge fusion and knowledge reconfiguration) (Lin & Lo, 2010) were mentioned in a few research works. These patterns were discovered as a generalization of processes of knowledge interchange and combination (integration) in different distributed organizations and as a specialization of technology fusion patterns.

The present article tries to discover knowledge fusion patterns as a generalization of knowledge fusion processes occurring in the context-aware DSSs. For this, knowledge fusion processes are identified in a real context-aware DSS and their effects are investigated. Knowledge fusion patterns propose a generalization of the identified processes with regard to preservation of structures and autonomies of multiple sources involved in the knowledge fusion and to the effects these processes produce.

By source structure, the structure used in the representation of this source is meant. Source's autonomy depends on how this source is related to other sources. Autonomous KS is an independent source, which does not have any relationships with other KSs. Non-autonomous KS has relationships with other (non-autonomous) sources.

KNOWLEDGE FUSION PROCESSES AND KNOWLEDGE FUSION PATTERNS

For the investigation and demonstration of the knowledge fusion processes the context-aware DSS for the emergency management domain is used. Some examples from the fire response scenario accompany the descriptions of the processes taking place in this DSS.

The processes producing the knowledge fusion effects are specified in terms of patterns. The patterns measure knowledge fusion outcomes in terms of preservation/change of the structures and autonomies of the initial and eventual KSs. Any sources of data, information, or knowledge are considered as KSs. The sources, integration or fusion of knowledge from which produces a knowledge fusion effect are referred to as initial KSs. The source(s) organized as a result of knowledge fusion or enclose(s) such a result is referred to as eventual KS(s). Additionally, the patterns formulate the knowledge fusion outcomes in terms of the results the knowledge fusion processes produce in the DSS (the possible results are summarized in the background Section) and map these results in the ontology paradigm. Classes, properties, and instances are considered as the fundamental ontology representation items.

Each pattern is specified using the following constructs:

- **Name:** A name to refer to the pattern.
- **Problem:** a problem the knowledge fusion process solves.
- **Solution:** a description of the knowledge fusion process.
- **Autonomy Pre-States:** a degree of autonomy of KSs before the knowledge fusion process. Three degrees are provided for: autonomous, non-autonomous, and n/a (for a non-existing KS).