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Interoperability of Knowledge Units in Plant Protection: Case Studies

M. Beránková, M. Houška, R. Kvasnička

Czech University of Life Sciences Prague

Abstract

In this work, we provide two case studies on interoperability and transfer of knowledge in the environment of a company dealing with plant protection. We find that the area of plant protection is highly oriented on working with knowledge. In this case interoperability of knowledge can play an important role in acquiring knowledge from different environments to solve specific problem in companies dealing with plant protection. Nevertheless, the concept of interoperability is well-developed on the level of data and information only.

We stem from our previous works, where we defined a logical concept for the interoperability of knowledge on the level of knowledge units. The objective of this work is to show how to apply our process model of knowledge interoperability in a particular plant protection company. Two case studies are provided in order to demonstrate distinguishing between simple knowledge transfer and knowledge interoperability.

Key words

Interoperability, knowledge transfer, plant protection, knowledge unit, process model.

Anotace

Tato práce obsahuje dvě případové studie interoperability a transferu znalostí v prostředí firmy zabývající se ochranou rostlin. V této oblasti je práce se znalostmi velmi důležitá, neboť se zde vyskytuje mnoho problémů, pro jejichž řešení jsou potřeba vysoce odborné znalosti. V tom případě může být aplikace principů interoperability znalostí velmi přínosné pro vyhledávání znalostí v různých prostředích. Koncept interoperability je však dobře rozpracován pouze pro úroveň dat a informací, nikoliv pro úroveň znalostí.

Na základě našich předchozích prací, kde jsme navrhli koncept na úrovni procesních modelů pro interoperabilitu znalostí, v této práci ukazujeme, jak je možné tento koncept využít v praxi, v prostředí ochrany rostlin. V práci rovněž ukazujeme rozdíl mezi prostým transferem znalostí a jejich interoperabilitou.

Klíčová slova

Interoperability, knowledge transfer, plant protection, knowledge unit, process model.

Introduction

Interoperability and interoperability of knowledge, respectively, is a process. Process modelling techniques are often used for the description and formalization of knowledge processes. Raamesh and Uma [1] deal with the issue of knowledge discovery in databases; in particular, they generate optimal test cases from Unified Modelling Language diagrams using Intelligent Software Agents for highly reliable systems in order to improve the efficiency of software testing.

In general, a standard definition of interoperability is provided by IEEE [2] as "... the ability of two or more systems or components to exchange information and to use the information that has been exchanged." The definition covers mainly the interoperability of data and information. On that level, a lot of applications based on international standards for interoperability have been developed. According to Ibrahim et al. [3], WiMAX (Worldwide Interoperability for Microwave Access) IEEE 802.16 is the most promising wireless technology for providing broadband access. In their study, the authors deal with providing quality-of-service (QoS) across the

WiMAX to the applications considering the point-to-multipoint (PMP) mode and propose the QoS model for the WiMAX. It allows them to obtain data for traffic analysis and control, as well as to study various scheduling algorithms for different types of traffic.

Urrego-Giraldo and Giraldo [4] study enterprise interoperability. They mention that the concepts involved in the current frameworks, enterprise models and languages offering a standard guide to the enterprise modelling do not support a dynamic adaptation of the models aiming to the interoperability. Thus, they provide a multi-system multidimensional framework to be able to manage the complex and dynamic organizational knowledge. They see the key role of ontologies; according to them, the ontology supports the integration and interoperability of different enterprise models.

Ontology and ontological modelling can also be used to enhance efficiency of supply chain management, especially if impaired by inconsistent exchange and sharing of knowledge semantics among supply chain partners [5]. In this case, a schematic language should be used to ensure a correct communication between domain experts and users. Ye et al. [5] also provide a case study from the area of heterogeneous supply chains and show how to define formal semantics of ontologies of supply chain management (Onto-SCM) for effective knowledge interoperability.

It is a common issue to work with knowledge in the area of plant protection. Gonzalez-Diaz et al. [6] used both literary sources and experts to acquire knowledge for their expert system on plant protection in pepper (*Capsicum annuum* L.). Based on production rules they are able to recognize 11 weeds, 20 insects, 14 diseases and 3 biotic factors and control measures. The authors present very satisfactory results from experts' and non-experts' evaluations.

Gonzalez-Andujar et al. [7] present expert system for seedling weeds identification in cereals that helps farmers and extension workers to identify weed species. The expert system uses a hierarchical classification and a mix of the text description, photographs and artistic pictures in order to help non-expert users to be able to make identification of

the weeds. The authors also mention educational impacts of their system.

Based on the above-mentioned theses we deduce that the area of plant protection is highly oriented on working with knowledge. In this case interoperability of knowledge can play an important role in acquiring knowledge from different environments to solve specific problem in companies dealing with plant protection. Nevertheless, the concept of interoperability is well-developed on the level of data and information only.

In this work we stem from our previous works, where we defined a logical concept for the interoperability of knowledge on the level of knowledge units – a specific atomic form of knowledge representation. The objective of this work is to show how to apply our process model of knowledge interoperability in a particular plant protection company. Two case studies are provided in order to demonstrate distinguishing between simple knowledge transfer and knowledge interoperability.

Material and methods

Knowledge Units

In their work Dömeová et al. [8] suggested to define "knowledge unit" as a special, well-structured type of knowledge unit (KU), as contents of one production rule related to the successful solving of an elementary problem. Formally, knowledge unit can be recorded as

$$KU = \{X, Y, Z, Q\}$$

where

X stands for a problem situation,

Y stands for the elementary problem being solved in the framework of the X problem situation,

Z stands for the objective of solving the elementary problem,

Q stands for a successful solution of the elementary problem (result).

The elementariness of knowledge is predetermined by the elementariness of the problem. The elementary problem is a problem or a part of a

complex problem which is impractical to be further divided into more simple subproblems. Criteria for assessing the degree of elementariness are defined by the knowledge user, because they depend on his or her ability to understand and apply the rules included in knowledge unit. This is in conformity with Zack's definition of knowledge units [9].

Knowledge unit may be expressed as a whole in natural language. As mentioned above, there is no exclusivity; each part of elementary knowledge has several facultative ways of expression and almost all of their combinations are feasible.

Knowledge unit can also be expressed by natural language as follows:

“IF you want to solve the elementary problem Y in the problem situation X to reach the objective Z, THEN apply the solution Q.”

Operations with Knowledge Units

Drill-down operation with knowledge units [10] allows switching hierarchical levels of details from more general to more specific, i. e. transition from complex problem to elementary problem (or just problem). The drill-down operation can be formalized as follows:

$$KU^{(i+1)}_j = f(KU_{ij}),$$

where

KU_{ij} is the j -th knowledge unit on the i -th hierarchical level and

$KU^{(i+1)}_j$ is the j -th elementary knowledge on the next hierarchical level of detail.

Formally, “dd” operation will be hereafter used for specification of drill-down operation, so the equivalent form of the statement is:

$$KU^{(i+1)}_j = dd(KU_{ij}).$$

It means to execute the following assignment:

$$X_{ij} \rightarrow \emptyset \text{ (omitted);}$$

$$Y_{ij} \rightarrow X^{(i+1)}_j;$$

$$Z_{ij} \rightarrow Y^{(i+1)}_j;$$

$Q_{ij} \rightarrow Z^{(i+1)}_j$ has to be and “manually” added into the hierarchical structure, because it is a completely

new element that has no pattern on the i -th hierarchical level.

Equivalency operation with knowledge unit is a formal operation that allows declaring two knowledge units as equivalent. Let KU_i and KU_j knowledge units. Then they are equivalent, i.e.

$$KU_i \cong KU_j,$$

if and only if

$$X_i = X_j;$$

$$Y_i \cong Y_j;$$

$$Z_i \cong Z_j;$$

$$Q_i \cong Q_j.$$

The symbol “ \cong ” means a semantic equivalency of each pair of text variables Y_i and Y_j , Z_i and Z_j , and Q_i and Q_j .

Interoperability Process of Knowledge Units

Process of knowledge interoperability is basically a demand-driven process; however, the supply side could also initiate that process. If it has some unique knowledge units available, it will be interested in their exploitation in a different environment in order to produce some benefits.

For the formalization of the knowledge interoperability process, we use the methodology “Architecture of Integrated Information Systems” developed by Scheer [11]. In particular, we use two kinds of the ARIS models [12]:

- Process-oriented function tree model that describes relationships between processes on the highest hierarchical level;

- Extended Event Driven Process Chain (eEPC model) that represents each process flow in detail. “Extension” means that some auxiliary elements (such as data clusters or organizational units) are used there and linked to individual functions.

We start with modelling on the most general level to express these relationships between the whole processes. For this purpose, we use a process oriented function tree; see figure 1.

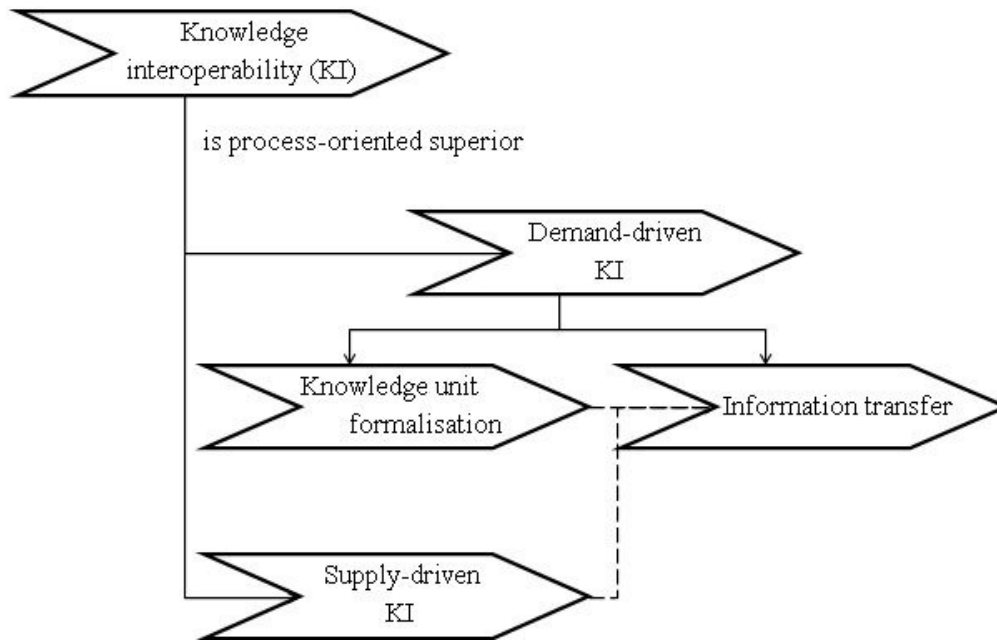


Figure 1: Process-oriented function tree for interoperability of knowledge.

Now, we will concentrate to the demand-driven process and formalize it by eEPC models. Formally, we decided to split the demand-driven process into two phases. The first one is in the demand side; it is an auxiliary phase that allows peer communication with different environments. The second phase covers the exchange of information between environments in order that the demand side is able to complete the knowledge unit.

For the demand side, the process is run by an event elicited by some independent decision-making; someone (a user) has to feel that a new knowledge unit is necessary for the specific problem solving and decide on the acquisition of the unit by the knowledge interoperability process.

Naturally, the user always tries to acquire a missing part(s) of the knowledge unit in his environment; asks his colleagues, searches the internet, books or other sources that are familiar to him. This effort may be successful; in this case, the process can finish, because the user has achieved his objective.

If the user was not successful, he has to create a communication interface in order to be able to search for the knowledge unit in another environment and exchange messages correctly with it. Ontology represents such an interface; but firstly, the user has to express and formalize the subject of his aim, the knowledge unit or its parts,

respectively. The problem situation “X” stems from user’s environment, so it should be always known. Furthermore, the user could know some subset of “Y” and “Z”; all of them, none of them or one of them. On the other hand, the solution “Q” is always unknown and the user at least searches for it. A formal expression of the knowledge unit is produced by this function.

After the knowledge unit has been formalized, the user usually needs to cooperate with an expert from the branch of knowledge/ontology engineering. He should create ontology to be able to communicate with other environments and search for similar term structures. This is the end of the knowledge unit formalization process, which runs the connective process “Information transfer”.

For a formal model of the knowledge unit formalization process see figure 2.

Unlike them, we are able to specify exactly how to work with information to obtain knowledge or knowledge unit. First we have to explain why we decided to denote this process as “Information transfer”, when we are dealing with the interoperability of knowledge. As we mentioned above, the demand side never calls for the whole knowledge unit; it always knows at least a problem situation “X”. In this case, it is enough to add the missing parts of the knowledge unit to make it complete; it means to acquire the solution “Q” and

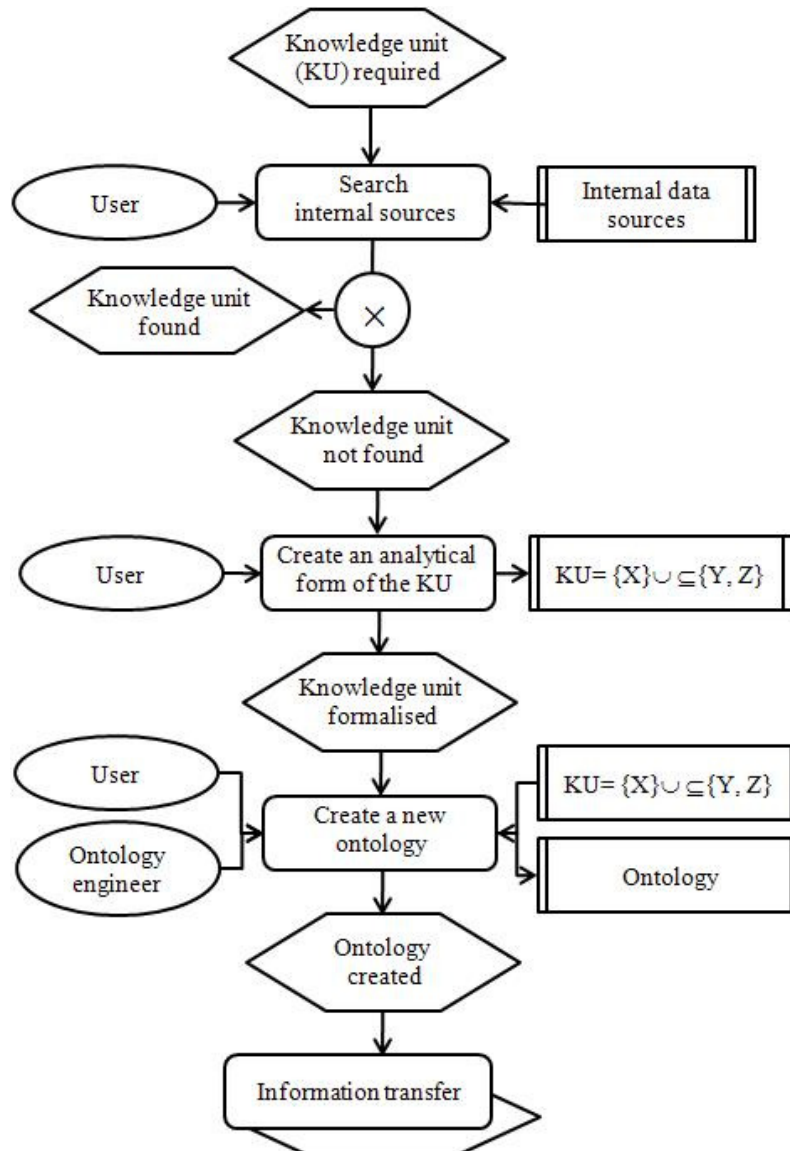


Figure 2: Knowledge unit formalisation process.

sometimes the objective “Z” and/or the elementary problem “Y”. As individuals, all of them “Y”, “Z” and “Q” have the quality of information, so we can say:

“Knowledge interoperability (or knowledge transfer, respectively) is realized by the acquisition of information.”

This thesis is in concordance with one way of view of knowledge that is generally accepted in the community of knowledge sciences. More authors, e.g. [13], [14] or [15], declare that knowledge is some kind of enriched information.

A complete ontology is the necessary condition for the activation of the information exchange process. In the ontology, there are all the relevant terms

from the incomplete knowledge unit, as well as relationships among these terms.

The call for the missing information follows. The ontology is the input for this function that is executed by the ontology engineer. He systematically explores other environments and searches for structures similar to his ontology. His effort could sometimes fail; in this case, the process finishes and knowledge interoperability cannot be successfully achieved.

As soon as the missing information is found, cooperation between the ontology engineer and a supply side member is required. They should work together and enhance the original ontology with new information; make it complete in order for the

user from the demand side to also complete his knowledge unit.

For a formal model of the information transfer process see figure 3.

Results and Discussion

In this section, we provide two real case studies from the environment of a plant protection company in order to show differences between the transfer and interoperability of knowledge. First let us briefly introduce the company. Since 1992, Agro Žamberk, a.s. has provided different services for farmers [16]; in particular, storing and supplying the farmers by industrial fertilizers and plant protection preparations. Throughout the years, it also has started its business in the area of trading with fuels, agro-chemistry products, oils, tyres and other commodities. Both case studies are connected with the agenda of the department of fertilizers, chemistry and coal managed by Mr. Miroslav Mikulecký.

According to him, knowledge transfer is the most common way of problem solving in the company and in his department, respectively. Frequently, an employee solves such problems when he provides advisory services to a client. In this case he puts effort to find appropriate knowledge and provide it to the client to solve his problem. The advisory service is usually for free, but as a part of a marketing strategy of the company, it contributes to the increase of revenues from trading with plant protection products.

Case 1: Weeds problem of a private farmer (transfer of knowledge)

A private farmer observed that some weeds grew up in his field of winter wheat. He was able neither to identify the weeds nor select an appropriate preparation to eliminate it. He visited the company with the sample of weeds to identify it and buy the right plant protection preparation.

In this case the company (and its consultant, respectively) should provide knowledge. Apparently, it plays the role of knowledge supply side; nevertheless, the consultant has to find the answer to the client's problem first. The equivalent event that starts the process is "Knowledge required" and "Knowledge unit required",

respectively; this is an initial event for the process "Knowledge unit formalization", which is primarily assigned to the demand side of the interoperability process (see figure 2).

Obviously, the process should be executed by the consultant. He cannot suppose that his client (a farmer) is able to express and represent his knowledge in a specific form of knowledge unit or in another type of knowledge representation. Thus, the consultant should follow the process and manage his dialog with the client.

Step 1: Search internal sources

First the consultant tries to identify the species of the weeds. For this purpose he uses internal data sources – a herbarium with typical weeds for the specific location and main crop. He is successful; according to main characteristics of the weeds he is able to specify it – Silky Bent Grass (*Apera spica-venti*). But the problem is more complex; he also should recommend a preparation to eliminate it. He has never faced this problem and so he has no record in internal sources how to proceed, what an appropriate solution is. Therefore, the process has to continue.

Step 2: Create an analytical form of knowledge unit

The consultant is now able to specify his problem exactly and determine knowledge unit KU11 as follows:

$$KU11 = \{X11, Y11, Z11, Q11\},$$

where

$$X11 = \text{"winter wheat growing"};$$

$$Y11 = \text{"Silky Bent Grass in the field"};$$

$$Z11 = \text{"to eliminate the weeds"};$$

$$Q11 = \text{"to choose an appropriate preparation"}.$$

The consultant sees the above-mention knowledge unit as too general. It provides him the solution of his problem, but he is not able to execute it. Thus, he should make the knowledge unit KU11 more specific through the application of the operation "drill-down". So,

$$KU21 = \text{dd}(KU11),$$

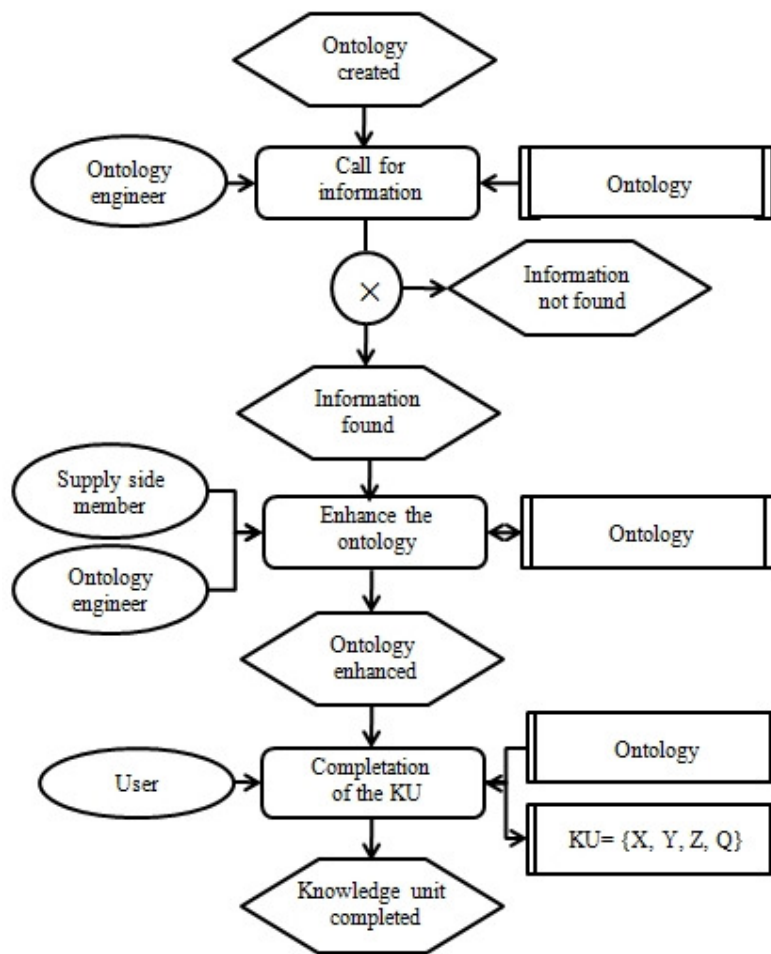


Figure 3: Information transfer process.

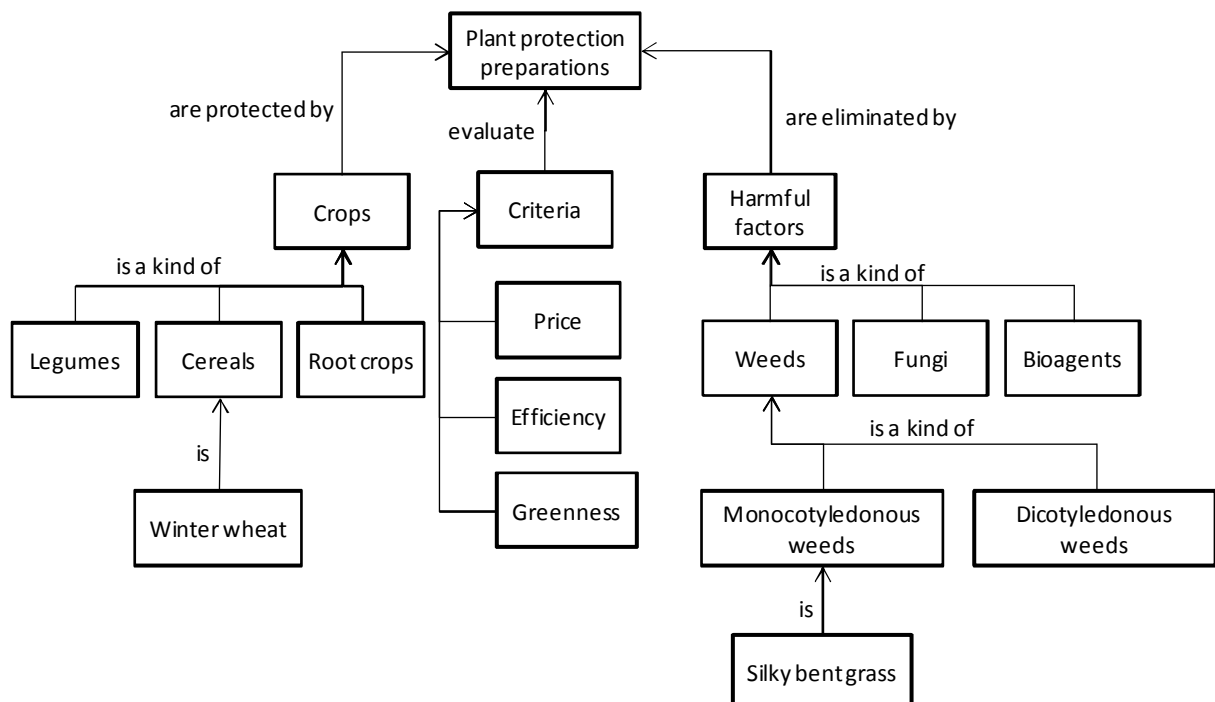


Figure 4: Ontology for the weeds problem.

where

X21 = "Silky Bent Grass in the field";

Y21 = "to eliminate the weeds";

Z21 = "to choose an appropriate preparation".

Q21 = unknown.

Step 3: Create a new ontology

The consultant is not able to continue without exact specification what "an appropriate preparation" is. He should create an ontology that helps him to express relevant terminology and relationships among individual terms, respectively. The ontology (here represented by a semantic network) also helps him to ask the client for additional information. See figure 4.

Now the consultant can specify what "the appropriate" means. The plant protection preparation has to

- cause no damage on the field of winter wheat, so the farmer must avoid using ones with contraindication of cereals;
- eliminate monocotyledonous weeds in general and silky bent grass, ideally;
- be the cheapest, the most efficient, or the most greenness.

The knowledge unit provided by the consultant to the client has to be unambiguous. Thus the client has to specify the criterion for the final recommendation. He prefers the criterion "price per unit". So the consultant can apply the following equivalency of knowledge units:

$KU21 \cong KU22$,

where

X22 = X21 = "Silky Bent Grass in the field";

Y22 = Y21 = "to eliminate the weeds";

Z22 \cong Z22 = "to choose the cheapest preparation"
(\cong "to choose an appropriate preparation");

Q22 = unknown.

The further procedure is not complex. The consultant makes a list of available preparations those are registered and approved to be applied in the Czech Republic using the National Registry of State Phytosanitary Administration and catalogues of suppliers of individual preparations. His final recommendation stems from the following table:

The knowledge unit KU22 is completed now:

X22 = "Silky Bent Grass in the field";

Y22 = "to eliminate the weeds";

Z22 = "to choose the cheapest preparation";

Q22 = "to apply Herbaflex, 2 l/ha for 112 CZK/ha";

and due to the above-defined equivalency

$KU21 \cong KU22$

also

X21 = "Silky Bent Grass in the field";

Y21 = "to eliminate the weeds";

Z21 = "to choose an appropriate preparation";

Q21 = "to apply Herbaflex, 2 l/ha for 112 CZK/ha".

The final recommendation to the client is as follows:

"IF you want to eliminate the weeds in case of Silky Bent Grass in the field by an appropriate preparation, THEN you should apply Herbaflex, 2 l/ha for 112 CZK/ha."

Now the knowledge transfer process is over and the whole business process can continue, probably by negotiation about the conditions of the contract.

Case 2: Interpersonal conflict in plant protection department (interoperability of knowledge)

The head of the plant protection department face the following problem. Two of highly-qualified experts are not able to cooperate because of interpersonal antipathy. It leads to the decrease of performance of the whole department. The head is an expert in the area of plant protection but he has never faced such a problem. His current knowledge is insufficient to solve the problem.

Preparation name	Price (CZK/package)	Package (kg, l)	Application (per 1 ha)	Costs (CZK/1ha)
Attribut SG 70	4 067	0.3 kg	0.06 kg	813
Calipuron	247	5 l	2 l	247
Grodyl Plus	11 065	0.5 kg	0.03 kg	664
Herbaflex	559	10 l	2 l	112
Hurricane	5 309	1 kg	0.2 kg	1 062
Sumimax	2 473	0.3 kg	0.06 kg	495
Tolian Flo	1 591	5 l	1.5 l	477
Zeus	3 348	1.5 kg	0.3 kg	670

Table 1: Comparison of individual preparations.

Subject to the knowledge interoperability process, the head is definitely in the position of a demand side. He calls for knowledge to solve the above-mentioned problem. The initial phase of the process is the same like in Case 1; first a knowledge unit should be formalised.

Step 1: Search internal sources

No idea, no internal sources on the problem are available.

Step 2: Create an analytical form of knowledge unit

The head orders information about the problem into analytical form of the knowledge unit KU11,

where

X11 = “management of the department”;

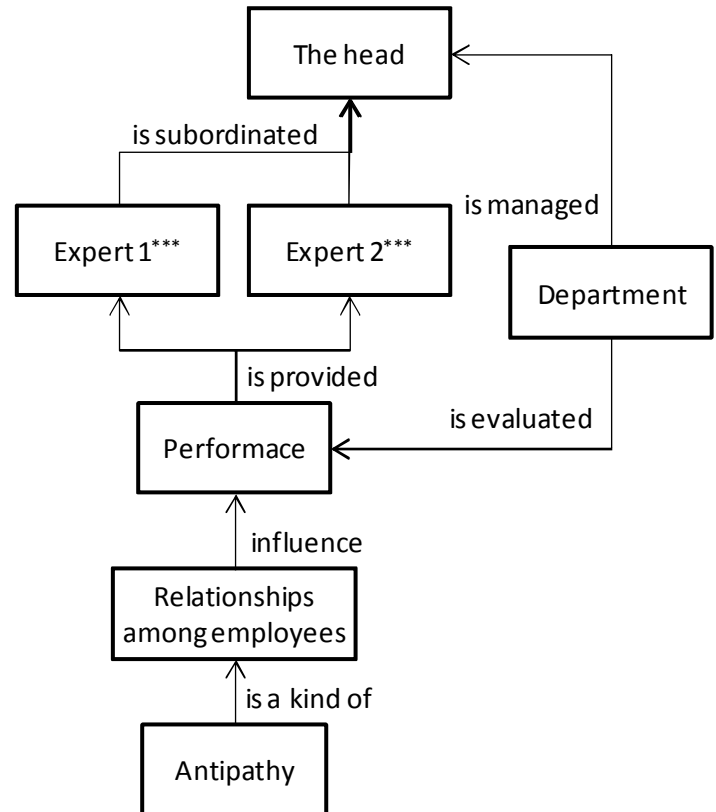
Y11 = “to normalize relationships between experts”;

Z11 = “to increase the performance of the department”;

Q11 = unknown.

Step 3: Create a new ontology

According to [17], this is a well-structured problem; the head knows all parts of the knowledge unit except the solution. He has no opportunity to find the solution in his environment, thus he has to create ontology for his problem and the problem situation, respectively. See figure 5.



***Note: The authors of the paper know the names of both experts, but they have no permission to quote them in the paper.

Figure 5: Ontology for the problem of interpersonal conflict. After the ontology has been created, Information Exchange process can start.

Step 1: Call for information

The head should call for information in other environments. In this case he finds the information in the area of personal management. He asks his colleague dealing with personal management and its psychological aspects for an advice. The head

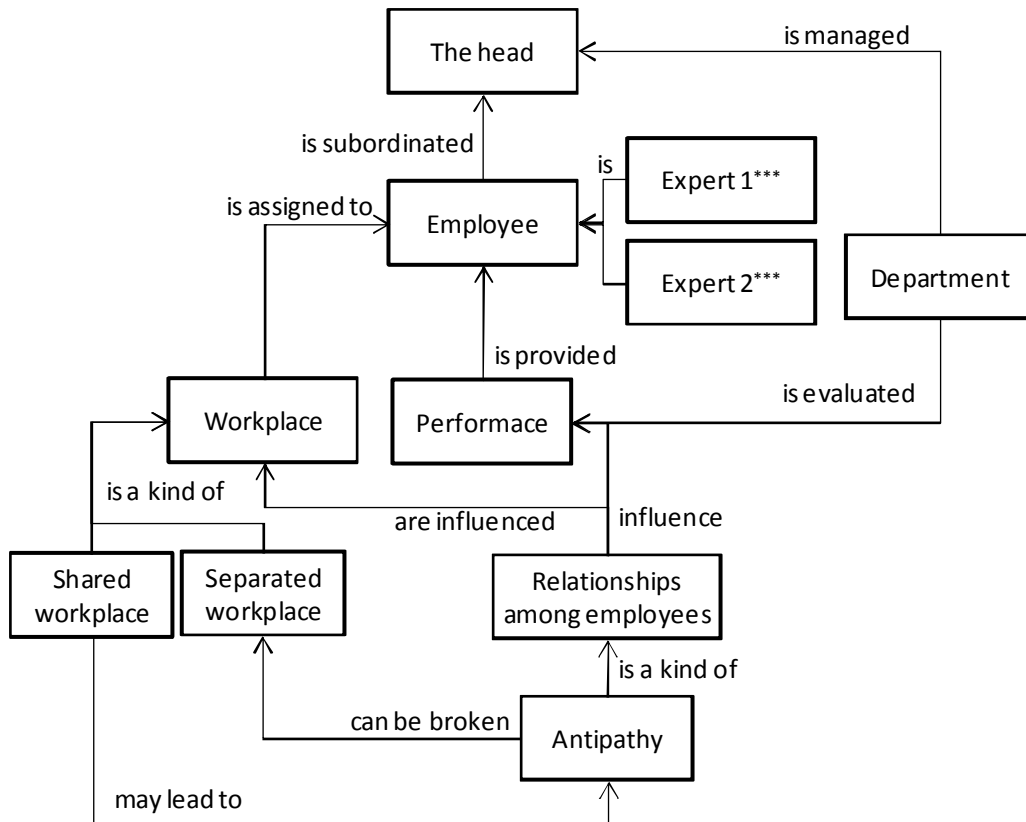


Figure 6: Enhanced ontology for the problem of interpersonal conflict

describes him the problem and forward him the above-mentioned ontology to complete it.

Step 2: Enhance the ontology

According to his knowledge and experience, the personal management expert enhances the ontology. He adds there other important terms, aspects and categories to find the required information. The enhanced ontology is as follows (see figure 6).

Based on figure 6, the required information can be provided to the head. Obviously, the personal management expert aims at the aspect of the problem that has been omitted by the head: the impact of workplace on relationships among employees as well as the impact of shared and separated workplaces on interpersonal antipathies.

Step 3: Complete the knowledge unit

New information provided by the personal management expert completes the knowledge unit KU11 as

X11 = “management of the department”;

Y11 = “to normalize relationships between experts”;

Z11 = “to increase the performance of the department”;

Q11 = “to provide separate workplaces to both experts”.

Expressed in natural language, the knowledge unit sounds as

“IF you want to normalize relationships between experts in management of the department in order to increase the performance of the department, THEN you should provide separate workplaces to both experts.”

The knowledge unit is complete and the process of knowledge interoperability is over.

Technical remark: In above-introduced story, the authors of the paper played the role of ontology engineers; they helped to the head of the department to express and formalise his problem as well as to the personal management expert to enhance the ontology to be both formally correct and understandable for the head. Now we also

know the real end of the story; the problem was successfully solved, antipathy between the experts is broken and the department provides its standard performance.

Conclusion

Interoperability is a specific type of knowledge transfer. The difference between knowledge interoperability and knowledge transfer lies in environments; knowledge transfer is realized in homogenous environment, knowledge interoperability in heterogeneous environment. Both of them are demonstrated in our cases; first one deals with knowledge transfer, responsible employee solved his problem by use of another weeds and preparations database. Second one deals with knowledge interoperability, the consultant had to solve his problem through the assistance of the human resources manager.

We also showed that process of knowledge transfer (including knowledge interoperability) and tools for it are easy to use. There are no other additional costs, except time of responsible employee, mostly manager, who has to solve the particular problem.

Corresponding author:
Ing. Milan Houška, Ph.D.
Department of Systems Engineering
Czech University of Life Sciences Prague
Kamýcká 12, 165 21, Prague 6
Phone: +420 224 382 35
Email: houska@pef.czu.cz

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However, problem solving is his daily work and our approach can help him make it easier.

In the second case, the manager used knowledge from different environment, but it is environment he knows quite a good. In our further work, we are going to enrich our approach about such a tool, which could be used for knowledge interoperability also in heterogeneous environments he does not know much or anything, at all.

Ontology is the theme, which is enhanced nowadays, many universities, institutions deal with semantic networks and use them for knowledge storage. Such networks also could help other users as a new knowledge sources and our tools can help users to work with them.

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