A semantic-based integrated solution to personnel and learning needs

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Abstract: In knowledge intensive companies intellectual capital assumes a crucial role in the organizational strategy and, as any other strategical asset, it needs to be scheduled to achieve sustainable competitive advantage. When the required knowledge is a resource available inside the company, its assignment represents a key success factor, which many research efforts are devoted to. On the other side, when the needed competence is unavailable within the company, training programs may be seen as methods to strengthen such a strategic asset. In this paper we show a semantic-based integrated system aimed at supporting both the assignment of available intellectual resources in three different multiplicity scenarios and the search for training programs ad-hoc composed to fill possible knowledge gaps.

1 Introduction

The vision of knowledge intensive companies intuitively focuses on competencies human resources are endowed with. Any organization aiming at sustainable competitive advantage needs then to schedule and acquire competencies as any other asset. In such a manufacturing metaphor, internal personnel may be seen as the knowledge warehouse a company holds; when such a warehouse runs out

of stock, management may revert to outsourcing, which means hiring external personnel, or to a further supplying, which consists in making new competencies available in the knowledge warehouse. In both such solutions, the company needs to search for a knowledge provider able to fulfill the arising competency need. Even though it is straightforward thinking of knowledge providers in terms of workers, also resources like e-learning modules (learning objects) may be considered available to fit the need. In this paper we propose an integrated system implementing the approach designed in [Colucci et al., 2007] for the solution of knowledge needs, either in terms of search for professional profiles or for personalized training programs. In order for the search and the composition process to be automated, the descriptions of the knowledge need, the available professional profiles and the learning objects to be composed are modeled according to the formalism of Description Logics(DLs)[Baader et al., 2002] in order to take advantage from some provided reasoning services useful in the processes our system supports. In particular, together with standard DLs services, non standard explanation services have been exploited to investigate on missing and conflicting competencies in knowledge provider descriptions w.r.t. formalized knowledge needs. An overview of DLs formalism and needed reasoning services is given in [Colucci et al., 2007]. The use of DLs ensures also the full interoperability with Semantic Web [Berners-Lee et al., 2001] languages, as witnessed by the existence of a subset of OWL language[1], OWL-DL, developed to map DLs constructs in OWL.
The paper is organized according to the following outline: in next section the proposed system is detailed in all its components; in Section 3 system working mode is explained with the aid of an extended example. Related work on the subject and conclusions close the paper.

2 The Integrated System

The integrated solution we propose to solve personnel and learning needs implements the framework designed in [Colucci et al., 2007] and grounds on the architecture shown in Figure 1. In the initial step, the user chooses the matching scenario (Arrow 1) and models according to a reference ontology the tasks to be satisfied by knowledge provider profiles available within the system repository. The following three multiplicity cases are allowed:
1. *Single one to one matching*: one knowledge need at a time is taken into account and assigned to only one knowledge provider through the algorithm *Assign* proposed in [Colucci et al., 2006].
2. *Multiple one to one matching*: more than one knowledge need at a time is considered and each of them is assigned to only one knowledge provider among

[1] OWL. www.w3.org/TR/owl-features

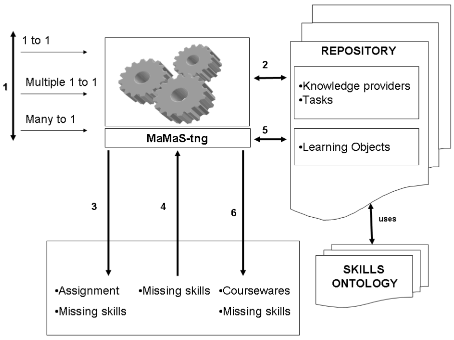

Figure 1: System architecture

the set of available ones, according to the algorithm $MultipleAssign$ proposed in [Colucci et al., 2007].
3.*Many to one matching*: one knowledge need at a time is taken into account and assigned to an ad-hoc created team of knowledge providers by applying the algorithm *TeamComposer* proposed in [Colucci et al., 2006].

In all of the three multiplicity cases, the assignment is performed on the basis of the suitability of the knowledge provider descriptions to the task descriptions. Such a suitability is evaluated through a function U outlined in [Colucci et al., 2007]. In a nutshell, U evaluates a numerical score for the similarity of knowledge provider to task descriptions by taking into account:
– the part H of knowledge need not explicitly provided by the analyzed knowledge provider. Such an explanation is provided by solving a Concept Abduction Problem [Colucci et al., 2006], a non standard DL reasoning service
– the part G of the knowledge need to be given for the selection of the analyzed knowledge provider. Such an explanation is the result of a non standard problem by Dl: Concept Contraction [Colucci et al., 2006].

All the required tasks, $T_i \in D$ with $i = 1 \ldots n$ and the knowledge provider profiles $P_j \in S$ with $j = 1 \ldots m$ have to be formalized in a subset language of DLs, $\mathcal{ALN}$ [Baader et al., 2002], by using the terminology of the skills ontology, independently on the chosen matching scenario. This requirement, related only to the current system implementation, is determined by the use of MaMaS-tng[2] as reasoning engine. To the best of our knowledge, MaMaS-tng is the only reasoning engine able to solve Concept Abduction and Concept Contraction problems. The system queries MaMaS-tng in order to search in the repository for knowledge providers able to satisfy the formalized tasks (Arrow 2) and returns an assignment proposal, together with the explanation about skills still missing in

[2] **MA**tch**MA**ker**S**ervice is available at http://dee227.poliba.it:8080/MAMAS-tng.

the assignee profile (Arrow 3). Such lacking knowledge represents the learning need to be covered (Arrow 4) by a learning path automatically returned (Arrow 6) by composing the learning objects advertised in the repository as $\mathcal{ALN}$ descriptions(Arrow 5). An explanation about skills still missing after learning path fruition is also returned to the system user.

A framework for the automatic composition of learning objects into learning paths, denoted as coursewares, was proposed in [Colucci et al., 2005b]. Such a framework implements an algorithm, *teacher*, automatically computing personalized coursewares and the part of learning need still uncovered after courseware fruition. Also in the composition process, Concept Abduction is exploited to get the explanation about lacking knowledge. On the contrary, we do not need here to solve any Concept Contraction Problem, because the situation in which the learning need is incompatible with a learning object description and needs to be contracted may not ensue because of the nature of knowledge itself: knowledge about a given skill is always compatible with any other sort of knowledge. Both the learning objects and the learning need are formalized in a *description*(pedex D) and a *background knowledge*(pedex BK) component: each learning object λ teaches the knowledge described by λ_D and requires the knowledge described by λ_{BK}; the learning need ρ is a request for the knowledge described by ρ_D, starting from a knowledge background expressed by ρ_{BK}. Such a formalization causes the proposed courseware to be personalized: only the providers holding the required background knowledge may be asked to learn the competences detailed in the learning object description.

Our system supports user's decision also in choosing the learning process which requires the least effort for covering the learning need, given that different personalized processes are possible. In our opinion a completely automatic selection is not the most suitable solution in this phase, because several highly subjective choice factors have to be taken into account. Courseware complexity, evaluation of missing skills and of knowledge bonus learned after courseware fruition are possible choice factors. In particular the knowledge bonus is computed by solving a Concept Abduction Problem returning the part of the courseware description not explicitly formalized in the knowledge need. Instead of proposing an automatic learner selection our system presents an explanation facility for these three factors to the system user, so making available the whole information relevant for her decision. The final selection of the candidate is then up to the system user.

3 Working example

Imagine the scenario in which an user needs to solve a set of tasks, by assigning each of them to only one knowledge provider. She can ask the system for a multiple one to one assignment process. Imagine skill domain is described in the ontology shown in the following in its DL formalization:

$\texttt{ComputerScience} \sqsubseteq \texttt{Skill}$
$\texttt{InternetUse} \sqsubseteq \texttt{ComputerScience}$
$\texttt{InternetTechnologies} \sqsubseteq \texttt{ComputerScience}$
$\texttt{CGI} \sqsubseteq \texttt{ComputerScience}$
$\texttt{TCP/IP} \sqsubseteq \texttt{ComputerScience}$
$\texttt{C++} \sqsubseteq \texttt{OOP}$
$\texttt{Java} \sqsubseteq \texttt{OOP}$
$\texttt{HTML} \sqsubseteq \texttt{MarkupLanguages}$
$\texttt{MarkupLanguages} \sqsubseteq \texttt{ComputerScience}$
$\texttt{ClientServerProtocol} \sqsubseteq \texttt{ComputerScience}$
$\texttt{InternetDevelopment} \sqsubseteq \texttt{ComputerScience}$
$\texttt{WebDesigning} \sqsubseteq \texttt{InternetDevelopment}$
$\texttt{TotalQualityManagement} \sqsubseteq \texttt{Skill}$
$\texttt{VBScript} \sqsubseteq \texttt{ComputerScience}$
$\texttt{Design} \sqsubseteq \texttt{Skill}$
$\texttt{ComputerGraphics} \sqsubseteq \texttt{ComputerScience}$
$\texttt{Engineering} \sqsubseteq \texttt{degree}$

$\texttt{Engineer} \equiv \exists\texttt{hasMasterDegree} \sqcap \forall\texttt{hasMasterDegree.Engineering} \sqcap \exists\texttt{advancedKnowledge} \sqcap \forall\texttt{advancedKnowledge.Design} \sqcap \exists\texttt{basicKnowledge} \sqcap \forall\texttt{basicKnowledge.(Mathematics} \sqcap \texttt{Physics)}$

$\texttt{ManagerialEngineer} \equiv \texttt{Engineer} \sqcap \exists\texttt{advancedKnowledge} \sqcap \forall\texttt{advancedKnowledge.ProcessManagement}$

$\texttt{LearningObject} \equiv \exists\texttt{BackgroundKnowledge} \sqcap \exists\texttt{Description}$

Let D be the set of knowledge requests composed by the tasks shown in the following together with their DL descriptions:

– *Workers with basic knowledge of Internet Use and Markup Languages*

$T_1 = \exists\texttt{basicKnowledge} \sqcap \forall\texttt{basicKnowledge.(InternetUse} \sqcap \texttt{MarkupLanguages)}$

– *Workers with advanced knowledge about Client Server Protocol and Process Management, expert in tools for Internet Development*

$T_2 = \exists\texttt{advancedKnowledge} \sqcap \forall\texttt{advancedKnowledge.(ClientServerProtocol} \sqcap \texttt{ProcessManagement)} \sqcap$
$\exists\texttt{toolsKnowledge} \sqcap \forall\texttt{toolsKnowledge.InternetDevelopment}$

– *Graduated workers with more than three years of working experience and advanced knowledge about Total Quality Management, C++ and TCP/IP protocol*

$T_3 = \exists\texttt{advancedKnowledge} \sqcap \forall\texttt{advancedKnowledge.(TotalQualityManagement} \sqcap \texttt{C++} \sqcap \texttt{TCP/IP)} \sqcap$
$\exists\texttt{hasMasterDegree} \sqcap \exists\texttt{hasExperience} \sqcap \forall\texttt{hasExperience.(}\geq \texttt{ 3 years)}$

Let now P be the set of available assignees composed by the following descriptions:

– *Graduate, with less than 2 years of working experience and basic knowledge of Internet Use, Computer Graphics and HTML*

$P_1 = \exists\texttt{basicKnowledge} \sqcap \forall\texttt{basicKnowledge.(InternetUse} \sqcap \texttt{ComputerGraphics} \sqcap \texttt{HTML)}$
$\sqcap \exists\texttt{hasMasterDegree} \sqcap \exists\texttt{hasExperience} \sqcap \forall\texttt{hasExperience.(}\leq \texttt{ 2 years)}$

– *Managerial Engineer, with advanced knowledge about Internet Technologies and knowledge about Web Designing Tools*

$P_2 = \texttt{ManagerialEngineer} \sqcap \exists\texttt{advancedKnowledge} \sqcap \forall\texttt{advancedKnowledge.InternetTechnologies}$
$\sqcap \exists\texttt{toolsKnowledge} \sqcap \forall\texttt{toolsKnowledge.WebDesigning}$

– *Engineer, with advanced knowledge about Total Quality Management, Client Server Protocol, VBScript and Object Oriented Programming*

$P_3 = \texttt{Engineer} \sqcap \exists\texttt{advancedKnowledge} \sqcap \forall\texttt{advancedKnowledge.}$
$\texttt{(TotalQualityManagement} \sqcap \texttt{ClientServerProtocol} \sqcap \texttt{VBScript} \sqcap \texttt{OOP)}$

The matching process implements *MultipleAssign* [Colucci et al., 2007] which performs an assignment problem [Cormen et al., 1990] to minimize the objective function

$$Z = \sum_{i=1}^{n} \sum_{j=1}^{n} u_{ij} x_{ij}$$

where u_{ij} are the values of function U filling the suitability matrix in the following, if computed according to the close form proposed in [Colucci et al., 2007]:

	T_1	T_2	T_3
P_1	0	1	0.88
P_2	0.6	0.11	0.6
P_3	0.6	0.56	0.4

Notice that x_{ij} are the decision variables such that in the solution $x_{ij} = 1$ if assignee i performs task j and $x_{ij} = 0$ otherwise. The algorithm returns the following assignment solution:

1. $x_{11} = 1 \quad (T_1, P_1, H_{11} = \top, G_{11} = \top)$

P_1 represent a full match for T_1 according to the skills ontology ($H_{11} = \top$ means that no hypothesis is needed about knowledge not elicited in P_1 but required by T_1): even `MarkupLanguages` knowledge , apparently lacking, is in fact embedded in `HTML`. Moreover P_1 does not contradict T_1, as shown by the result $G_{11} = \top$.

2. $x_{22} = 1 \quad (T_2, P_2, H_{22} = \forall \texttt{advancedKnowledge.ClientServerProtocol}, G_{22} = \top)$

P_2 is compatible with T_2 according to the skills ontology: hypotheses H_{22} is anyway needed on the advanced knowledge about `ClientServerProtocol` while `InternetDevelopment` knowledge is embedded in `WebDesigning`. Moreover P_2 does not contradict T_2, as shown by the result $G_{22} = \top$.

3. $x_{33} = 1 \quad (T_3, P_3, H_{33} = \exists \texttt{hasExperience} \sqcap \forall \texttt{hasExperience.}(\geq \texttt{ 3 years}) \sqcap$
$\forall \texttt{advancedKnowledge.}(\texttt{C++} \sqcap \texttt{TCP/IP}), G_{33} = \top)$

P_3 is compatible with T_3 according to the skills ontology: hypotheses H_{33} have to be formulated on the work experience requirements and on advanced knowledge about `C++` and `TCP/IP`: in particular even if P_3 knows about `OOP`, her knowledge about `C++` can only be hypothesized because the second one is more specific than the first one. Moreover P_3 does not contradict T_3, as shown by the result $G_{33} = \top$.

Both the second and the third solutions lead to a knowledge need which can be solved by the fruition of ad-hoc created coursewares. Respectively, such knowledge needs are represented as follows:

– $\rho_2 = \exists \texttt{BackgroundKnowledge} \sqcap \forall \texttt{BackgroundKnowledge.} P_2 \sqcap \exists \texttt{Description} \sqcap \forall \texttt{Description.} H_{22}$

– $\rho_3 = \exists \texttt{BackgroundKnowledge} \sqcap \forall \texttt{BackgroundKnowledge.} P_3 \sqcap \exists \texttt{Description} \sqcap \forall \texttt{Description.} H_{33}$

Suppose the following learning objects are available as knowledge providers in the system repository:

– *Java and C++ course. Requirements: Object Oriented Programming knowledge*

$\lambda^1 = \texttt{LearningObject} \sqcap \forall \texttt{BackgroundKnowledge.}(\forall \texttt{advancedKnowledge.OOP})$
$\sqcap \forall \texttt{Description.}(\forall \texttt{advancedKnowledge.}(\texttt{C++} \sqcap \texttt{Java}))$

– *Client Server protocol course. Requirements: CGI knowledge*

$\lambda^2 = \texttt{LearningObject} \sqcap \forall \texttt{BackgroundKnowledge.}(\forall \texttt{advancedKnowledge.CGI})$
$\sqcap \forall \texttt{Description.}(\forall \texttt{advancedKnowledge.ClientServerProtocol})$

– *CGI Course. Requirements: Internet Technologies Knowledge*

$\lambda^3 = \texttt{LearningObject} \sqcap \forall \texttt{BackgroundKnowledge.}(\forall \texttt{advancedKnowledge.InternetTechnologies})$

$\sqcap\forall$`Description.(`$\forall$`advancedKnowledge.CGI)`

By applying *teacher* the two learning solutions in the following are proposed.

Assignee	Λ	**UncoveredKnowledge**	**KnowledgeBonus**
P_2	$\{\lambda^3, \lambda^2\}$	$\top$	$\top$
P_3	$\{\lambda^1\}$	`TCP/IP`	`Java`

Assignee P_2 needs the courseware $\Lambda = \{\lambda^3, \lambda^2\}$ to fully cover her knowledge need ($UncoveredKnoweldge = \top$); in particular the fruition of λ^3 makes the background knowledge needed to learn λ^2 available . No additional knowledge is gained by courseware fruition ($KnoweldgeBonus = \top$).Assignee P_3 can only partially cover her knowledge need by learning λ^1: knowledge about `TCP/IP` continues to be uncovered after the fruition, but on the other side a knowledge bonus about `Java` is gained.

By subjectively analyzing the two proposed learning solutions, a company management adopting the system we present may evaluate the opportunity of initiating one or both of the suggested learning paths.

4 Related Work

In recent years competence based management has been investigated under a variety of perspectives and several systems and approaches have been presented in literature to cope with both knowledge and learning management [Draganidis and Mentzas, 2006], even though the number of approaches integrating the two research field is small if compared with that of proposals about each one of them [Draganidis and Mentzas, 2007]. Among system for competence management, ontology based solutions to task assignment and team composition are proposed in [Colucci et al., 2003, Colucci et al., 2004, Colucci et al., 2005a, Hefke and Stojanovic, 2004]. By reverting to learning management, an ontology based solution to learning paths composition grounding on non standard inference services provided by $\mathcal{ALN}$ has been proposed in [Colucci et al., 2005b]. A surprisingly similar approach, exploiting a less expressive DL was proposed in [N. Karam and Meinel, 2007].

In [Draganidis et al., 2006] and [Colucci et al., 2006] two ontology based systems integrating competence management and e-learning are proosed.

5 Conclusions

We presented a semantic based system to support personnel and learning needs in an organizational context. The system performs the assignment of professional profiles to tasks in three different multiplicity cases and exploits non standard inference services by DLs to investigate on possible knowledge gaps to be solved by the fruition of ad-hoc learning paths automatically composed. In order to keep its decisional support nature, the system is not fully automated but it leaves to the user the possibility of a manual choice in each selection process involving subjective factors.

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