Ontology supported competency system

Article

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Ontology Supported Competency System

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Abstract

Traditionally representation of competencies has been very difficult using computer-based techniques. This paper introduces competencies, how they are represented, and the related concept of competency frameworks and the difficulties in using traditional ontology techniques to formalise them. A “vaguely” formalised framework has been developed within the EU project TRACE and is presented. The framework can be used to represent different competencies and competency frameworks. Through a case study using an example from the IT sector, it is shown how these can be used by individuals and organisations to specify their individual competency needs. Furthermore it is described how these representations are used for comparisons between different specifications applying ontologies and ontology toolsets. The end result is a comparison that is not binary, but tertiary, providing “definite matches”, possible / partial matches, and “no matches” using a “traffic light” analogy.

Keywords: competency, competency frameworks, semi-automated comparison, ontology, competency standards, vague domain comparison, computational representation, implementation, competency mappings and relationships

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1. Introduction

Competency has grown into an important concept in many domains, especially in education and human resource. The European Union and most of the member states are also involved in competency work especially by investing in the development of competency frameworks and qualification frameworks. Traditionally these frameworks have been paper based documents or standalone documents on web pages, there is however a need to electronically manipulate and share both competencies and competency frameworks, hence the need for a computational representation is arising.

1.1 Definition of Competency

The term competency has been the root of much debate and confusion; this is probably due to the “artificial” nature of the concept of competency. The concept has even been called a “fuzzy concept” by Boon et al, and recognised as a “useful term, bridging the gap between education and job requirements.” (Boon & van der Klink, 2003) It has been created by people to represent something that is not evident in the world, and it is therefore a reification of some aspect or attribute of humans or agents, thus there is no easy way of defining the term. There is even confusion about the difference or similarity of the terms competence and competency. Mostly they are used as synonyms, but some researchers and competency practitioners apply subtle differences between the two words. Take for example the Columbia Guide to Standard American English; “Competence means both “a sufficient amount to live on, to meet one’s needs” and “having legal or practical ability to perform.” Competency means the same things but is less frequently used, except in educational argot, where competencies are the various skills pupils are to be taught and teachers are to be prepared to teach. The plural competences occur infrequently.” (The Columbia Guide to Standard American English, 1993). In this paper competency and competence will be used as synonyms.

When competency is being defined it usually includes the concepts knowledge and skills and then “something else”.

For example:

> “'competence' is defined here as a combination of knowledge, skills and attitudes appropriate to a particular situation.” (Commission of the European Communities, 2005)

> “'competence' means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in

> professional and/or personal development. In the European Qualifications Framework, competence is described in terms of responsibility and autonomy.” (Commission of the European Communities, 2006)

> “then, if intellectual capabilities are required to develop knowledge and operationalising knowledge is part of developing skills, all are prerequisites to developing competence, along with other social and attitudinal factors.” (Winterton, Delamare - Le Deist, & Stringfellow, 2005)

The techniques described below are “agnostic” of the exact definition of competency, and as such there is no need to specify an exact definition, but it is important for practitioners to know that the differences exist, as the framework allows the definition of competencies with any of these definitions, and it is the practitioners who has to create the ontological links between the different competency specifications.

Because of this fuzzy nature of the concept it is an interesting domain to model and compare by application of ontology tools, as these tools are usually more suited in domains that are well-defined, such as the domains of medicine and biology.

2. Competency Frameworks

There exists a multitude of competency frameworks. The reason for this diversity is that there are many motives for developing and using competency frameworks. For instance because they;

- enable comparisons between other competency frameworks. These are known as meta frameworks
- define different sectors in the work force
- allow users to view regional (both national and internationally) issues
- define different domains of target users (Corporate world, Education, HR, government, etc.)
- accommodate different purposes (e.g. enable easy transition between educational institutes, or between “world of education” to “world of work”
- have been developed using different methodologies (e.g. task based or functional analysis)

These frameworks are primarily used as “conceptual standards”, i.e. offers generic and theoretical solutions for comparing and harmonizing competencies, and “level standards”, i.e. defines quality levels (Stracke, 2006).

Within this section different frameworks will be presented to illustrate the vast variety that exists. The frameworks have been chosen both to show the diversity and also to illustrate the appropriateness they have for the process of comparison between different competency frameworks. The reason for this is that the competency comparison research which is presented in section 3 and 4 will be focussing on such comparisons.

2.1 EQF and ICT Skills Meta-framework

At the “highest level” of competency frameworks are the Meta frameworks, which aim at being frameworks by which other frameworks can be understood and referenced, thus made to enable comparison between different competency frameworks.

As the European Qualification Framework specifies it. The “main purpose … is to act as a translation device and neutral reference point for comparing qualifications across different education and training systems and to strengthen co-operation and mutual trust between the relevant stakeholders. This will increase transparency, facilitate the transfer and use of qualifications across different education and training systems and levels.” (Commission of the European Communities, 2006) It could be said that because the EQF is a qualification framework it does not relate to competencies. However in the EQF learning outcomes are being related to knowledge, skills and competence, which are defined as the ability to use knowledge and skill (see previous section) within the scope of EQF. In (Commission of the European Communities, 2006) it is emphasised that “learning outcomes - in the EQF understood as the statements of what a learner knows, understands and is able to do on completion of a learning process.” Furthermore it says that: “In the EQF learning outcomes are defined by a combination of knowledge, skills and competence.”

The EQF defines 8 levels of knowledges, skills and competences, which should be used as reference points by which learning outcomes from the different member states can reference the learning outcomes of their education system.

Level	Knowledge	Skills	Competence
Level 1	Basic general knowledge	basic skills required to carry out simple tasks	work or study under direct supervision in a structured context
Level 2	Basic factual knowledge of a field of work or study	basic cognitive and practical skills required to use relevant information in order to carry out tasks and to solve routine problems using simple rules and tools	work or study under supervision with some autonomy
Level 3	Knowledge of facts, principles, processes and general concepts, in a field of work or study	a range of cognitive and practical skills required to accomplish tasks and solve problems by selecting and applying basic methods, tools, materials and information	take responsibility for completion of tasks in work or study; adapt own behaviour to circumstances in solving problems
Level 4	Factual and theoretical knowledge in broad contexts within a field of work or study	a range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study	exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change; supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities
Level 5	Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge	a comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems	exercise management and supervision in contexts of work or study activities where there is unpredictable change; review and develop performance of self and others

Level 6	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study	manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts; take responsibility for managing professional development of individuals and groups
Level 7	Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research Critical awareness of knowledge issues in a field and at the interface between different fields	specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields	manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams
Level 8	Knowledge at the most advanced frontier of a field of work or study and at the interface between fields	the most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice	demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research

Figure 2.1 EQF levels Extracts (Commission of the European Communities, 2006)

A similar framework is the ICT Skills Meta framework (M-F) made by CEN/ISSS, Cedefop and CEPIS. The purpose of M-F is “to promote better understanding within the European Union about the nature and structure of the ICT Practitioner Skills required by employers.” (CEN, 2006) It is related to the EQF, as it also aims at creating further understanding of a domain (ICT practitioners both from the employers and employees viewpoint). Basically the EQF relates to the supply side of competencies with no specific target domain, whereas M-F is focussing more on the demand side (employees can also demand competencies) with a specified target domain in mind, but still developed with the same end result of being able to provide a common ground of its users.

There are several similarities and therefore symbiosis between them is possible. Figure 2.2 shows how similar the basic structure is, even though the structure of the M-F is further specified in sub-categories due to the specified nature of the domain. The M-F directly aligns their levelling system to the EQF levelling even to the point that M-F does not have level 1, 2 and because the work group behind the M-F deemed that these levels would not be needed in the domain that is covered (CEN, 2006).

ICT Skills *M-F*	**EQF**
Focus: Performance expectations that correspond to the ***application of learning outcomes*** (formal, non-formal, informal) Structure: • Cognitive competence • Functional competence • Social (incl. ethical) and meta competence	Focus: ***Learning outcomes*** Structure: • Knowledge • Skills (and know-how) • Wider Competences

Figure 2.2 Basic structures of EQF and M-F

2.2 National and Sectoral Competency Frameworks

There is an abundance of competency frameworks, and there almost exists a “Babel’s Tower” situation in the European Community, not just because of languages, but also because of the inability to communicate across borders both nationally and cross sectors. The following table is a list of frameworks, with short explanations, functioning as a validation of the variety and quantity of frameworks. The list is an extract, which was compiled to form the basis of a TRACE project report of the competency frameworks in the British Isles. The complete report (EIfEL, 2005), which was compiled, showed that the situation is consistent all over Europe.

National Vocational Qualification (NVQ)	Detailed description and levelling of vocational employment activities linked to sectors in England and Wales http://www.direct.gov.uk/en/EducationAndLearning/QualificationsExplained/DG_10039029
Scottish Vocational Qualification (SVQ)	Similar to NVQ, but for Scotland http://www.sqa.org.uk/sqa/2.html
Skills Framework for the Information Age (SFIA)	The Skills Framework for the Information Age (SFIA) provides a common reference model for the identification of the skills needed to develop effective Information Systems (IS) making use of Information & Communications Technology (ICT) in the UK http://www.sfia.org.uk
UK-Spec	UK Standard for Professional Engineering Competence http://www.engc.org.uk/UKSPEC/default.aspx
BCS Accreditation	This is the British Computer Society implementation of the Engineering Council above. They also accredit for Chartered Scientist and Chartered IT Professional http://www.bcs.org/
European Computer Driving License (ECDL)	Vocation computer user skills framework from Ireland http://www.ecdl.com
Competency Framework for Managing Change through Partnership	Framework for managing changing organisations to achieve higher performance based in Ireland http://www.ncpp.ie/inside.asp?catid=77&zoneId=1
BECTA Technical Competency Framework	Competency Framework for IT technicians in schools in the UK http://schools.becta.org.uk/index.php?section=re&catcode=ss_res_tec_man_03&rid=10033

Figure 2.3 Sample of different frameworks

The problem is that there probably is a need for each of the competency frameworks, however at the same time there is a need for a means to communicate across the communities of practice that the frameworks create. The Meta frameworks try to occupy the middle ground, but there is a perception that the Meta frameworks are good at expressing overarching high level issues and only usable for analysis by humans.

2.3 O*NET

The O*NET is not a competency framework in the traditional sense. It is an occupational database of all the occupations in the US economy defining and organising data from the “world of work”. At the core it provides a taxonomy of competency components (see next paragraph), data was then collected from actual work places specifying what levels the employees in U.S. work places in different occupations scored in each individual competency component. It is a statistic tool which can be used to explore the (vague) domain of the U.S. job market. It is open to everybody through on-line tools allowing a valuable insight into the mark-up of most U.S. jobs.

The O*NET is interesting in the context of competency frameworks because of the competency component taxonomy which organises occupation by knowledges, skills, abilities and various other categories (known as KSAO). Therefore as Ostyn suggested (Ostyn, Competency data standards resources, 2005) and Brown in TRACE project meetings elaborated upon, it could provide a large taxonomy of knowledges, skills and other kinds of information valuable in the creation of other competency frameworks. . These could be the building blocks within the competency mappings, and together with formally defined logical relationships could provide a powerful way of defining and specifying competencies.

3. Representation of Competency

When exchanging competency data between applications it is important to be able to do this in a standardised manner which enables interoperability.

3.1 Reusable Competency Definition

There exists only one agreed standard (using Lindner’s types of standards (Stracke, 2006)) to represent competencies. The Reusable Competency Definition (RCD), is an IEEE standard (IEEE, 2007), which functions as a syntactic standard, so enabling interoperability between data systems, enabling each system to establish what parts of received data is a competency and ascertain which part of the competency data is the title, description etc. The standard originates from IMS Reusable Definitions for Competencies and Educational Objectives (RDCEO) (Walker & Robson, 2003) (IMS Global Learning Consortium, Inc, 2002) Reusable Competency Definition (RCD) is used to present some of the syntactical elements of competencies.

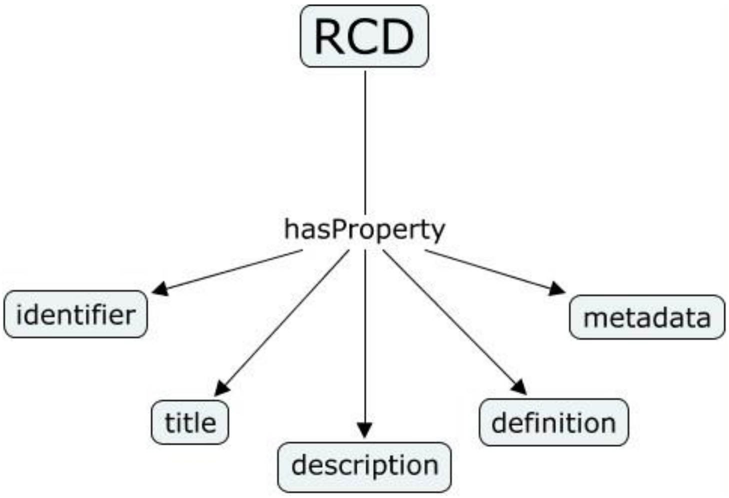

Figure 3.1 RCD

The RCD (Figure 3.1 for a specific competency should contain in natural language (IEEE, 2007):

- A unique identifier
- A title (NL)

Optionally it could also have

- A description (NL)
- A definition (a reference to another repository or definition (NL))
- Metadata; that is further information about a particular competency (this is not limited, it can be any size or format)

The main problem with this standard is that the main parts (title, description and definition) are in human readable form, so if any semantic meaning is to be made available for computers there must be additional knowledge, e.g. attached in the metadata part, connections to other RCDs with metadata or external bindings to other data structures such as ontologies. Furthermore RCDs are only a partial representation of competencies as they are only supposed to define competencies; the evidence, context, dimensions etc. are not included. Evidence is an especially important issue for many competency descriptions, and the RCD therefore needs to be “backed” up by some other material to be able to validate the competencies.

3.2 Competency Mappings

It was observed while creating a bespoke ePortfolio that inherent semantic and logical relationships between competencies are needed when creating a picture or representation of a person’s competency, and as such the RCD standard lacks the descriptive power to transfer such knowledge in the exchange processes. Ostyn has also identified this problem and proposed a standard in the IEEE draft standard “Simple Reusable Competency Mappings” (SRCM) (Ostyn, Proposed Draft Standard for Learning Technology - Simple Reusable Competency Map, 2006).

A SRCM like the RCD consists of

- A unique identifier
- A title

Optionally it can also have

- A description
- Metadata; that is further information about a particular competency (this is not limited)

But in addition the SRCM has a directed acyclic graph (DAG) of nodes with attached competencies. A DAG is a directed graph with no path that starts and ends at the same vertex. The graph must have at least one entry node (the default entry node) (Hardley, 1994). Note SRCM does not include the definition part which RCDs have, because the graph provides the equivalent (above and beyond) functionality, as the mapping enables computational representation definitions of the actual competencies, which is the whole purpose of the RCD’s definition part.

Each node can have several related properties, for instance:

- Some competency (RCD or another SRCM)

- Proficiency scores (Required or Desired)
- Relationship to other nodes within the graph (Parents and Children), where the relationship could be defined with a score or some kind of logical relationship.

When analysing the SRCM standard, it becomes evident that it is a draft standard. For instance, it is not possible to attach proficiency scores other than required and desired score. There is no way, for instance, for people to represent that they have a competency with a proficiency score. Additionally the logic relationships within the SCRMs are not based on any formal logic which, if present, could help automated understanding the actual logics behind them. The IEEE working group on standardisation of competencies has been working on developing a standard based on competency mappings[1].

4. Competency Comparison

4.1 Introduction

The competency domain is, as described in the previous section, a domain with plenty of divergent opinions, and different ways of describing the same concepts. This section discusses the approach taken to describe and compare competency and competency mappings by utilising ontologies when there is significant vagueness in the domain. This work was part of the the European Union (EU) Leonardo sponsored project TRACE, which was coordinated by the University of Reading (TRACE, 2006). The developed system was referred to as E*NET (or ENET) by the project partners. At the core of the work a competency inference engine was developed together with an application programming interface (API) and a set of tools based on this API which was referred to as the "Competency Suite". The approach to the representation of competency, competency frameworks and links between competencies, together with the ontology based inference engine and toolset go beyond what was previously available. They form the basis of a new approach to competency representation that is the subject of this paper

[1] Authors personal accounts while participating in the work group.

4.2 Initial Considerations

Early on in the project, it was realised by the partners of TRACE, that even though the domain of Competency Frameworks is vague domain, there were some similarities shared by domain experts. As described in the previous section these “universal” concepts are knowledge, skill and others (KSO), sometimes with abilities being included separately (KSA or KSAO). From this it was concluded, following Ostyn’s and Brown’s suggestions (Ostyn, Competency data standards resources, 2005), that it would be possible to develop an “upper ontology” of competency. E*NET will be able to provide the middle ground for different competency suppliers (i.e. frameworks) and demanders (i.e. ePortfolio and job descriptions) and, provided adequate inference, seamlessly make comparisons between the different domains competency usage. To get to this level of inference the semantics of the upper ontology would need to be specified, rules based on this upper ontology between different frameworks would be needed (domain and task ontology), and tools would be needed at the application level to make the links between the different kind of usages that would arise from using E*NET (i.e. evidencing and requirements). The flexibility for external users of the system would then lie in the extensions that they could make to existing statements of E*NET and other extensions, by utilising logical semantic relationships (taken from linguistic logic) such as synonymy, antonymy (opposites), meronymy (being part of), hyponymy (specialisation) etc. (Miller, Beckwith, Fellbaum, Gross, & Miller, 1990), thus allowing the creation of user specified semantic trees of bespoke knowledge. Figure 4.2 is an early example of such a tree.

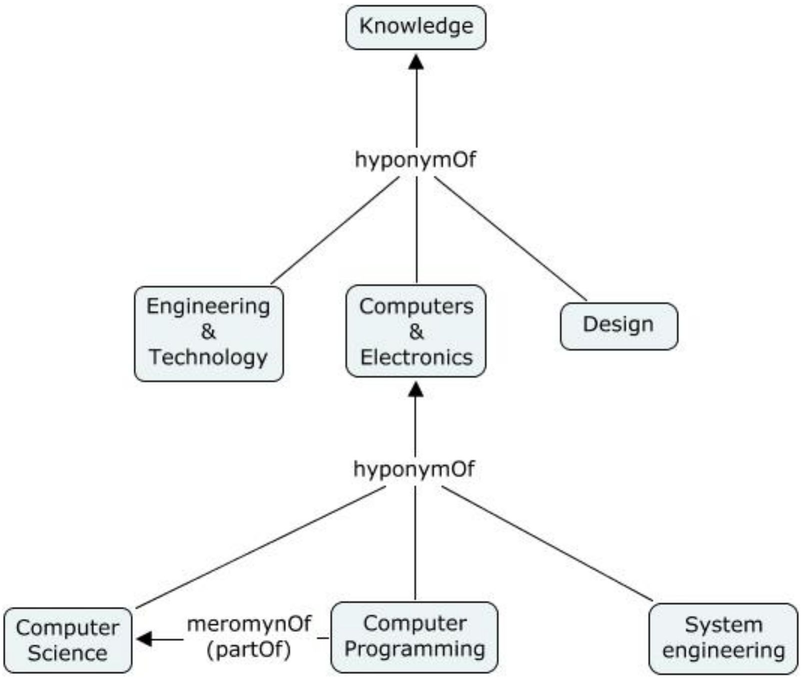

Figure 4.2: Knowledge tree

It was necessary for the TRACE project to determine whether the O*NET could be used as the basis for supplying descriptors to be used within E*NET as a starting point for a competency domain ontology. This was done by a series of feasibility tests. These tests concluded that it would be feasible as it is a comprehensive taxonomy, although appropriate changes would be needed for usage on a broader scale as parts of the O*NET are very “American”(Lundqvist, Williams, & Baker, Feasibility of the KSAO Approach in ICT Competency Frameworks, 2006) (Scienter Espana, 2006) (Scienter, 2006) (EIfEL, 2006). This approach can be criticised; the O*NET classification is not intended as a formal domain ontology of competencies, and using it as one might pose some problems. For instance the individual descriptions are written in non-formalised English, and could therefore introduce inconsistencies. Furthermore the structure of the O*NET classification is not always completely clear. However the usage of O*NET merely constituted a starting point for the research, obviously by using ontological tools this starting point could be changed once the approach is standardised, and for this research a prototype was needed to prove the concept.

Utilising the emergent competency standards the semantics defined in, and used through, the "upper ontology" would be sharable between many different applications. The development of RCDs were finalised by IEEE in the life time of the TRACE project, and thus used throughout the project in an XML, as the container for each "unit" of competency, for instance writing, driving or mathematics. The standardisation process of SRCM, however, is still ongoing at the time of writing, and we believe there are serious flaws in the standard. For instance the important aspect of being able to describe somebody having a proficiency in a competency. In the proposed standard this would be impossible, only allowing "required" and "desired" proficiency. Therefore a bespoke standard called Very Simple Reusable Competency Mapping (VSRCM) was developed based on the SCRM with a few necessary alterations. The changes are minimal, and there could definitely be made more, however these were made to make this "proof of concept" project possible, and a better, fully specified, standard would be within the remit of standardising organisations such as IEEE and IMS.

VSRCMs are defined like RCDs of having

- A unique identifier
- A title

Optionally it could also have

- A description
- Metadata; that is further information about a particular competency (this is not limited)

Note that VSRCM does not have a "definition section" like the RCD. The graph provides an improved equivalent functionality. Additionally the VSRCM has a graph of nodes with attached competencies. The graph must have at least one entry node (the default entry node). Each node has properties:

- Competency
    - RCD

      or
    - VSRCM (note this could be recursive)
- Proficiency (the actual levelling of proficiency has not been part of the TRACE project, however the tools have been designed to embrace any levelling scheme.)
    - Required
    - Desired
    - Current (has)
- Relationship to other nodes within the graph
    - All

      That is all the proficiencies of the competencies of the "sub-nodes" need to be "fulfilled" for this relationship to be successful
    - Any

      That is one or more of the proficiencies of the competencies of the "sub-nodes" need to be "fulfilled" for this relationship to be successful
    - If
        - True
        - False

      This map is used to represent alternate proficiencies of competencies, for example a taxi driver located in London is required to have specific knowledge of the area to meet licensing requirements, while a taxi driver elsewhere may only require general map reading.

Figure 4.3 is a graphical representation relating the different parts of RCD and VSRCM as described above and how they interrelate. Therefore it shows that a competency can be both an RCD or a VSRCM, and that both standards have an identifier, title, description and metadata. VSCRM additionally has the graph with nodes that are related with the different logical relationships. Used to describe a complete competency profile the graph structure of the VSRCM allows the semantic relationships between competencies to be presented in a logical syntactic way, by building up a graph of how competencies are related to each other in the competency map of the profile. Furthermore different mappings can be compared and contrasted automatically by traversing the graphs of the VSCRM using the logical rules throughout the process, however it is not truly a semantic representation of the competencies, because there is no ability to represent relationships between individual competencies within the nodes of the graph. This is achieved in this work by utilising ontologies.

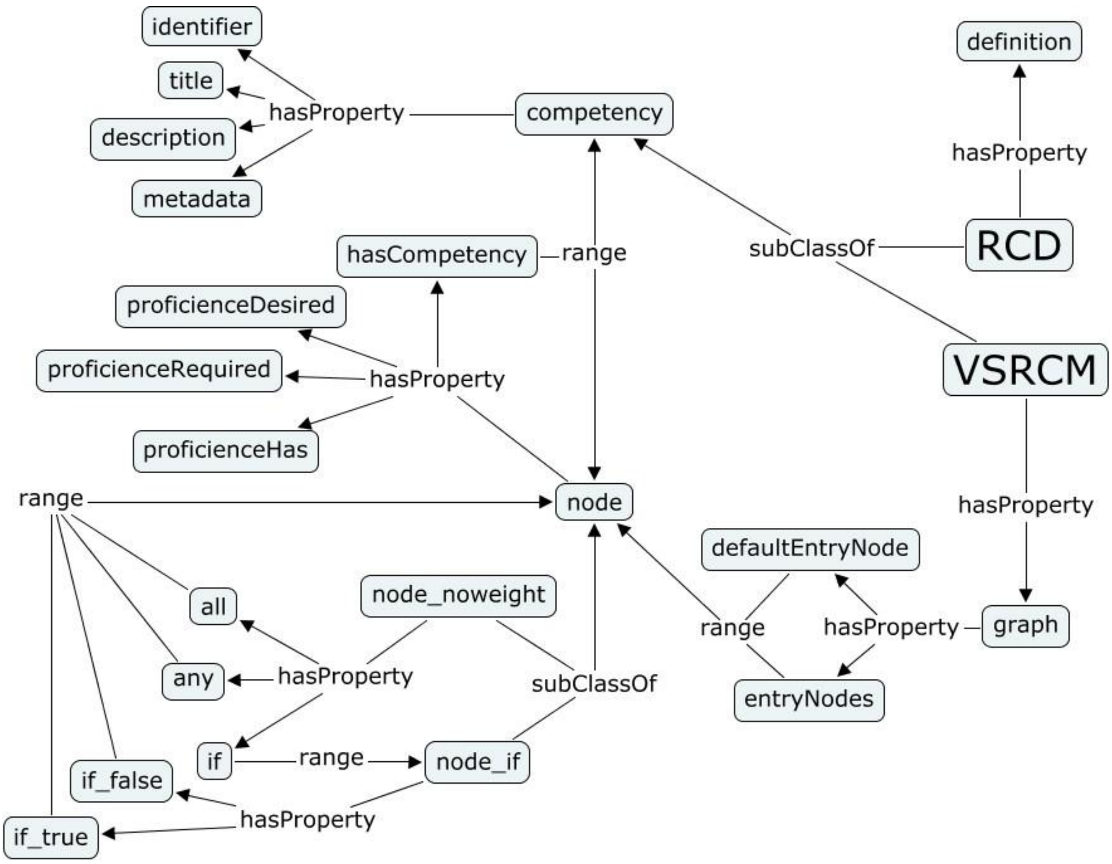

Figure 4.3: Relationship between RCD and VSRCM

4.3 The Upper Competency Ontology

It was decided to utilise ontologies as an underpinning approach to allow for and verify the increased interoperability between competency systems when performing comparisons (Lundqvist, Karstens ePortfolio: Competency Map, 2006). There are many ways to describe Ontological knowledge. OWL (McGuinness & Harmelen, 2004) was chosen as the underlying ontology language because it is used in the Semantic Web approaches, and therefore has many technologies that support its features.

The diagram in figure 4.4 represents a simplified view of the ontology underpinning the TRACE Comparison Grid.

The classes with the TRACE Comparison Grid ontology are:

- Single Competency (RCD)
- Competence Profiles (VSRCM)

RCDs are further defined in to sub-classes:

- Knowledge
- Skill
- Others

The top-left of the figure shows the different semantic relationships that are specified within the upper ontology to interrelate all the different competencies. These can be of type single competency (RCD) or competency profile (VSCRM), which incorporates a graph of logically related competencies. The single competency components can be of type skill, knowledge or "other".

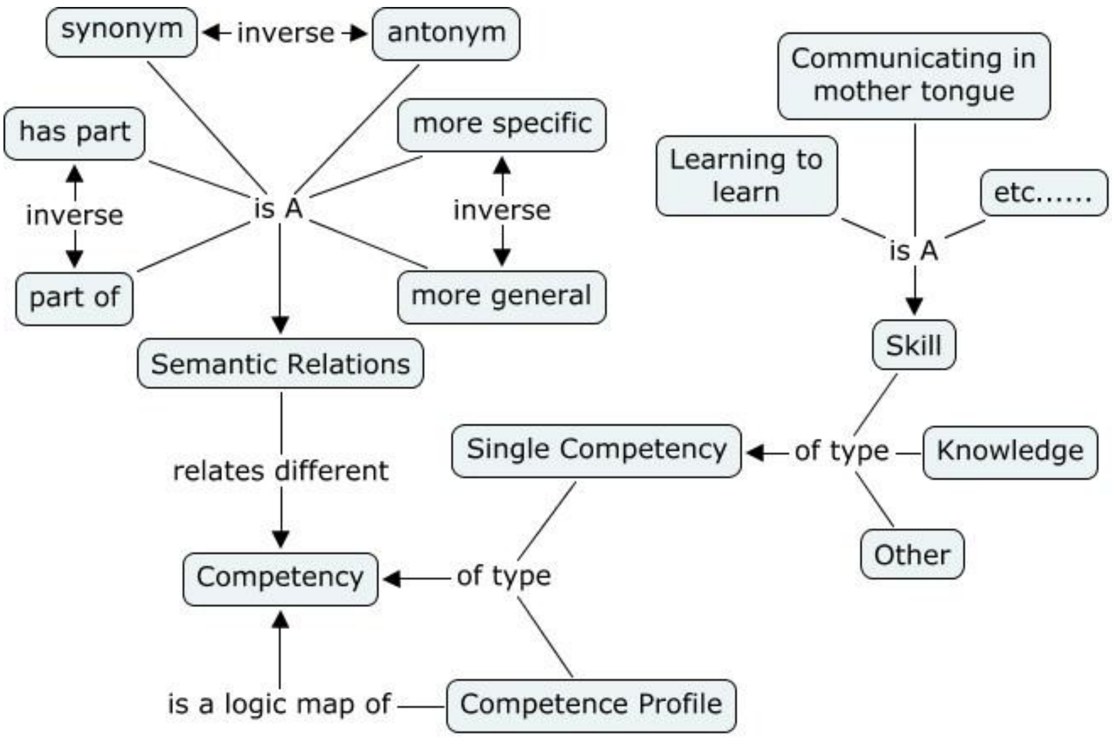

Figure 4.4: Representation of the ontology

The individual competencies used by each of the sub-classes knowledge and skills are based on the O*NET classification (O*NET, 2007) with small alterations.

Within the TRACE project the term "E*NET System" (and ENET system) was used to describe an Europeanised version of O*NET along with the ontologies, tools, techniques developed and spin off projects which uses the developed Application Programming Interface (API). The semantic relationships between competencies (both RCDs and VSRCMs) are based on semantic relationships from linguistics, that have been widely used in knowledge representations, for instance in the electronic lexical database for the English language WordNet (http://wordnet.princeton.edu/) (Miller, Beckwith, Fellbaum, Gross, & Miller, 1990). A semantic relationship is represented as a property:

- Alternates
    - Competencies which mean the same (Synonym)

      For example different terms used for the same competency across frameworks
    - Competencies which mean the opposite (Antonym)

      For example the competencies: empathy and impartial. This could be useful for inferences
- Part, either:
    - A has part B (holonym)

      That is the relationship that competency A intrinsically includes B.

      For example drive has part that is “use of brakes”;
    - A part of B (meronym)

      That is the relationship that competency A intrinsically includes B.

      For example drive is part of the competency to be taxi driver;

- Generality
    - A is more general than B (hypernym)

      A includes all the meaning of B, but B includes more detail.

      For example driving is more general than driving a lorry.
    - A is more specific than B (hyponym)

      B includes all the meaning of A, but B includes less detail.

      For example lorry driving is more specific than driving.

By using the specified knowledges and skills from O*NET and the linguistic (and loosely) defined semantic relationships it is now possible to extend the complete knowledge base in a consistent manner, which allows for further inferences on the additions across domains and applications. Figure 4.5 is an example where an ontology engineer has added knowledges and skills from a small sample of Computer Science description (dark). It is important to note that this is a practical example created by a practitioner. It is therefore not necessarily a “correct” or indeed a formalised description of the domain, but a description which can be used by this “ontology engineerer” within an organisation and the relationships could be used to make comparisons between similar representations with similar ontological commitments.

Using the semantic relationships defined by the ontology, it is possible to define relationships into the pre-defined knowledgebase (light). All these semantic additions and statements become what is known as “the model”, i.e. everything, which is known by the system at any given time. Later these additions (plus several others) can be used to make comparisons between different competency profiles contained in the model.

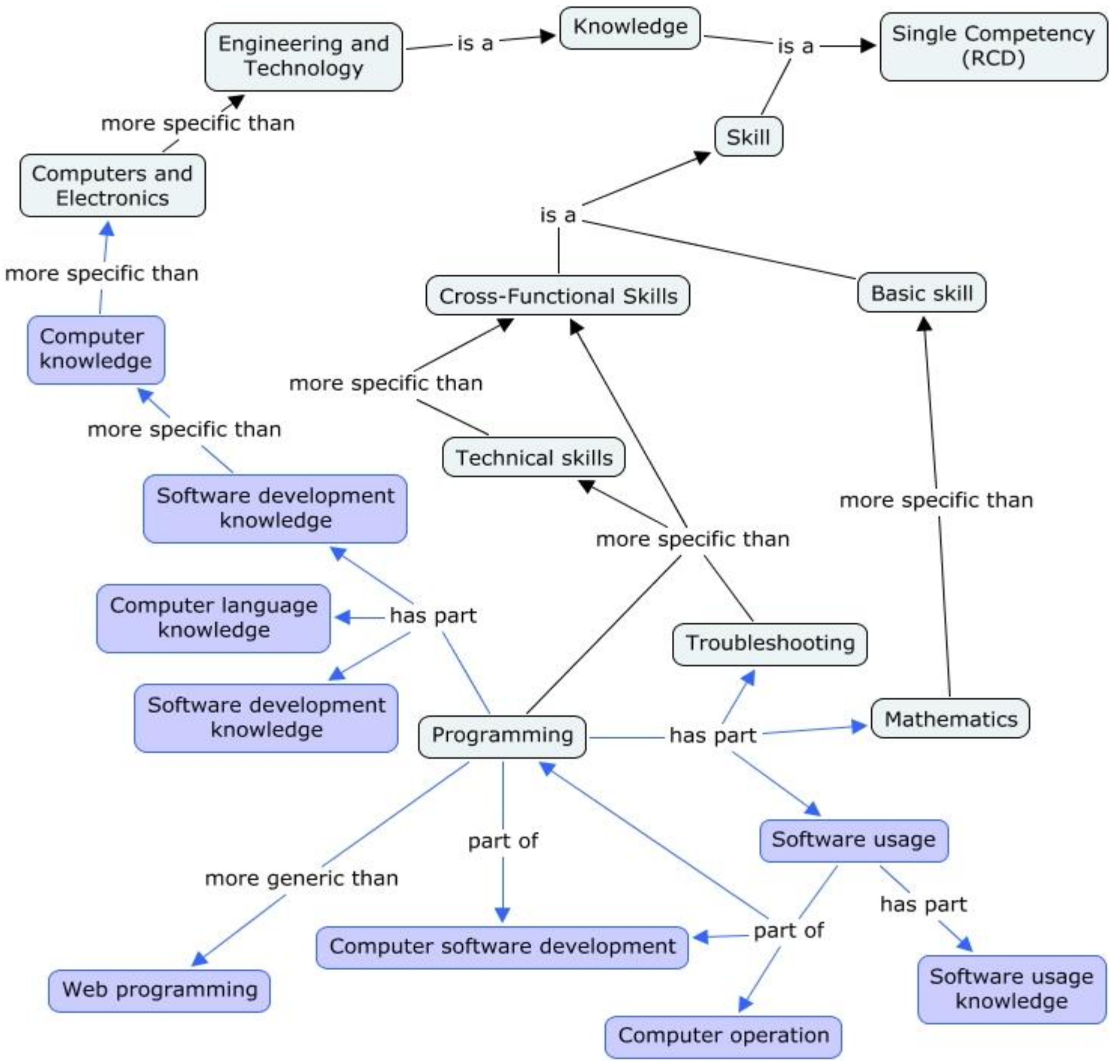

Figure 4.5 Computer Science example

Competency profiles can be created using all of the RCDs contained in "the model". Figure 4.6 is a representation of a competency profile developed from the specification of Technician A in Desktop & Application Support in the BECTA ICT Competence Framework (Becta, 2005), it is important to emphasise that the process of making the profile is a subjective engineering process, due to the vagueness of the domain.

The profile has been made by analysing the framework specifications and assessing how the words could be mapped to the competency definitions in the E*Net System. This is a non-trivial process which hardly can be performed without an understanding of the domain that the framework specifies.

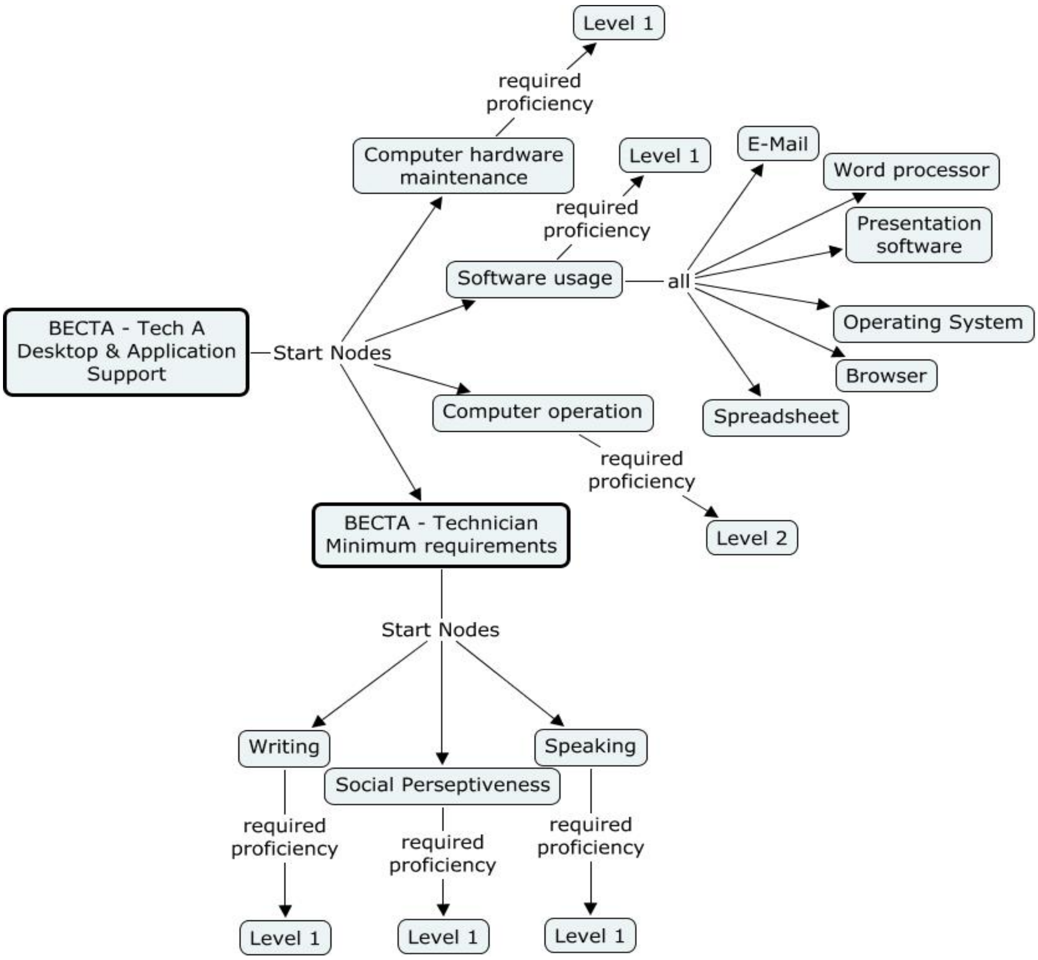

Figure 4.6 An example competency profile

The profile is made up of a graph with four start nodes ("Computer hardware maintenance", "Software usage", "Computer operation" and "BECTA – Technician Minimum requirements"). "BECTA – Technician Minimum requirements" is another competency profile which describes the assessed minimum requirements of any person working in a job described through the competency framework. This competency profile was developed as part of the competency analysis, because it was repeatedly identified within all BECTA competencies. The other starting nodes specifies the necessary levels of proficiency needed. Furthermore under software usage the contexts e-mail, word processor, presentation software, operating system, browser and spreadsheets must be satisfied, i.e. the user needs to be able to use these tools.

The E*NET system allows the users select the needed domain ontologies and load them in and out (swopped) of memory as needed. The system consists of four levels:

- The E*NET Internal Ontology level, which is always part of the system
- Userspace model, which is the model that can be modified through the API
- "Outside Userspace models", which are all models that are regarded as knowledge within the system. The system are "aware" of them, while performing inference
- Models, which are available to the system, but not in use

This system allows the users to minimise the effects of vagueness by disregarding the parts of any ontologies that they personally disagree with. The user can simply remove the parts that are disagreed with in a particular model and therefore only use the semantic knowledge they agree with.

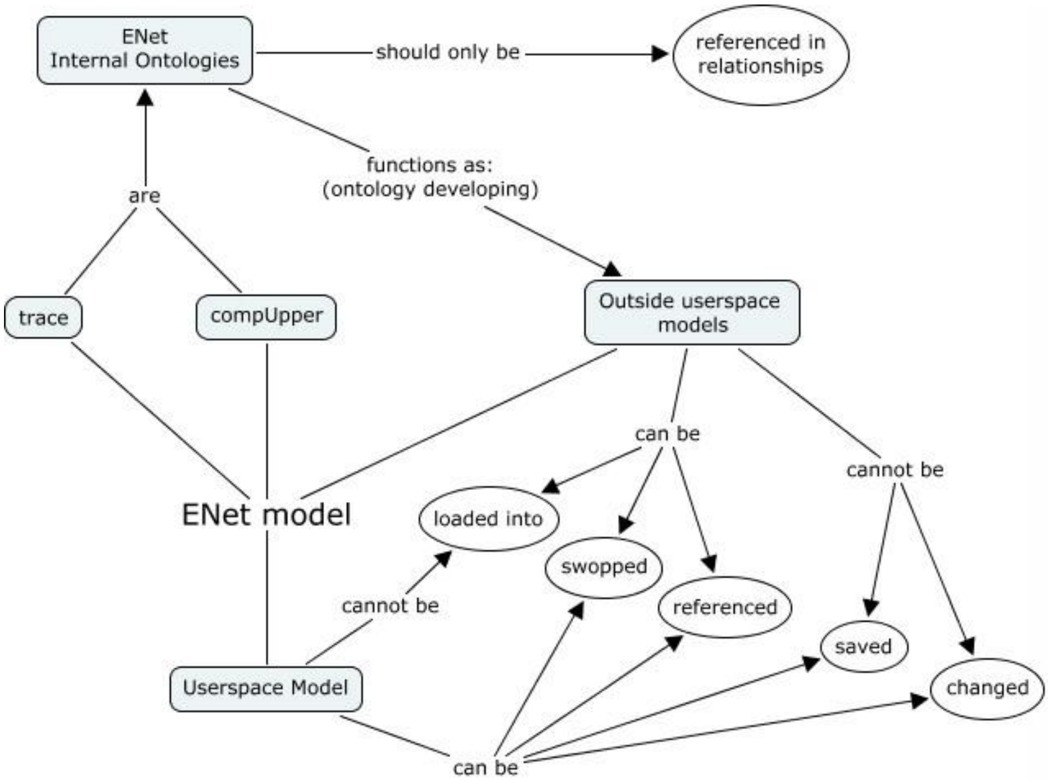

Figure 4.7 User defined Ontologies (models) can be swopped in and out of memory

4.4 Implementation of the System

In order to realize a development platform of ease utilization for developers who are not used to traditional ontology development, the system was create with a core API, using Jena (http://jena.sourceforge.net/) building upon traditional semantic web toolsets, yet distancing the ontology code from the end-developer. The intention of this was to avoid developing a monolithic system, but rather enable easy adaption and extension (Hoel, 2007). A prototype Competency Suite was developed using the API which allows the users to:

- create new and edit existing single competencies (RCD)
- create new and edit existing competency profiles (VSRCM)
- add and remove semantic relationships between single competencies and competency profiles
- perform comparisons between two existing competency profiles

The emphasis of these prototypes tools have been on demonstrating the concepts of the TRACE API, and the design of this toolset is experimental, so the focus has been on functionality rather than usability of the end users.

Another prototype was developed by the TRACE partner BitMedia (Zerdahelyi, 2007) which shows the functionality of the E*Net System in a HR (Human Resources) scenario with emphasis on usability in this area.

5. Comparison of Competency Profiles

A comparison tool was implemented to be able to compare and contrast different competency mappings, and included into E*Net System. It compares whether a competency profile A (profA) is "covered" or "matched" by competency profile B (profB By "covered" it is meant that profB is describing an agent (e.g. a person) who has (the same or higher) than the required (and possibly also desired) proficiency levels of competencies contained in the graph of profA. By "matched" it is meant that profB is describing a competency profile (e.g. a job profile or a competency framework level) which has (the same or higher) the same required (and possibly also desired) proficiency levels of competencies contained in the graph of profA. The comparison tool returns the results of the complete graph of profA, meaning that the result of each node can be examined. Such a comparison is obviously not symmetric:

$$\text{Compare(profA, profB)} \neq \text{Compare(profB, profA)}$$

For instance a very simple profile which only has one node with only ‘level 1’ required proficiency score in ‘writing’, can easily be matched by the "BECTA – Technician A Desktop & Application Support" level, because the minimum requirements of the competency profile for this job function states the requirement of ‘writing’ at ‘level 1’. On the other hand the simple profile would not match any node other than writing in the “BECTA – Technician A Desktop & Application Support” level, hence it would not match the full graph.

Without the Comparison Grid the comparison of the competency of each node would be very simplistic. It would either be the same RCD with the same identifier and match, or it would be two different RCDs and hence not match each other. This could easily lead to the situation in Figure 5.1. Two different VSCRMs (the triangles) are being compared. The arrows going out of the VSCRMs are linked to different starting nodes of the DAG, and the two VSCRM are clearly pointing at different RCDs (the circles), and therefore the two different profiles seemingly do not match, but by introducing semantic relationships through the ontological mappings (illustrated by the thick lines in the lower part of the illustration) in the ontological description a match can be inferred between the competency profiles, because there are semantic links between the different RCDs used by the two different VSCRMs.

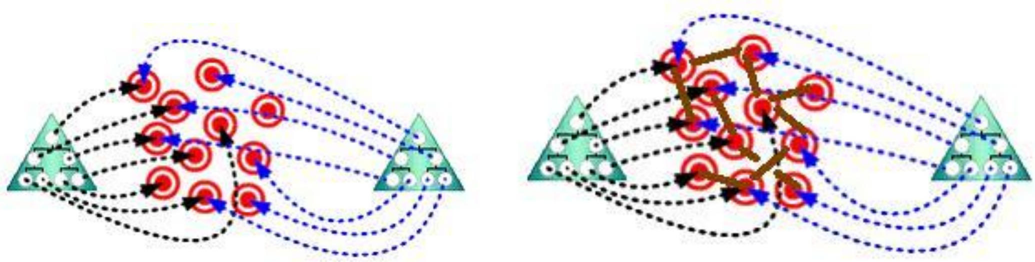

Figure 5.1: Competency profiles and the Comparison Grid

The rules for performing the ontological semantic inferences are as follow; competency A match competency B if A can find a semantic route to B using the following ontological rules:

- A equals B
- A synonymous B
- A has part B
- A is more general than B
- A has part C and C satisfies B

Furthermore competency A indicates a possible match if:

- A is more specific than B
- A is part of B
- A matches B but proficiency levels doesn’t match

Additionally, the “child” nodes of the node must be matched according to the logical relationship by which they have been related to the node. The following logic relationships are supported by the prototype:

- All: All child nodes must be satisfied (logical and)
- Any: At least one child node must be satisfied (logical or)
- If: (only partly supported) If child node is satisfied then if_true grandchild node must be satisfied. However if child node is not satisfied then if_false grandchild node must be satisfied

Automated comparison is now performed, using the above rules, by traversing the nodes of graph of the competence profile trying to find matching nodes in the graph of the other competency profile. So each node in the first competency is traversed while searching for matching or covering nodes within the secon competency profile.

Figure 5.2 shows examples of such comparisons from the Competency Suite (above). The green (monochrome) icon indicates a complete match, yellow (with black outline) a possible or close match and red (stop sign with white line) no match.

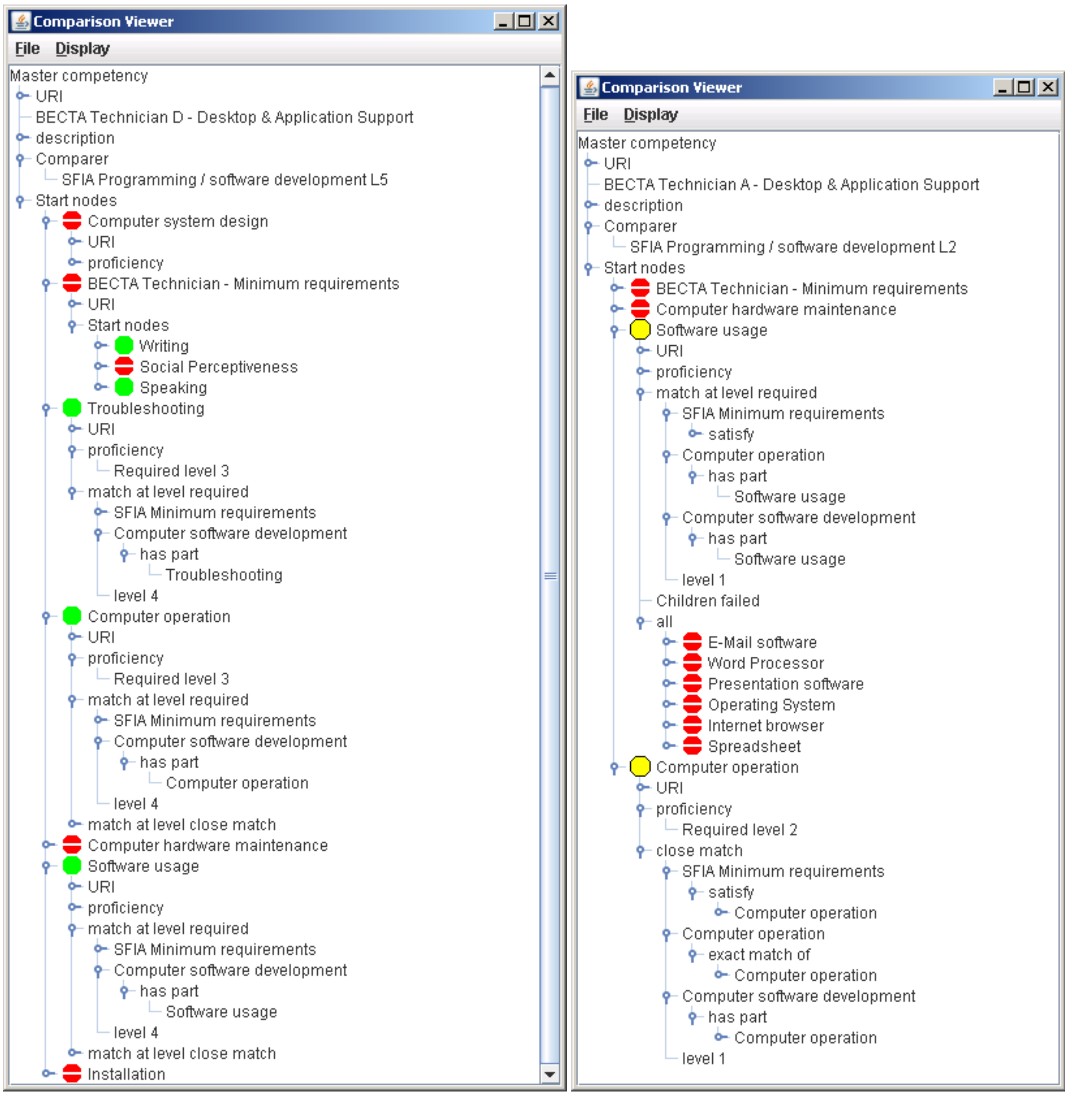

Figure 5.2: Examples of competency profile comparisons

The VSCRM “BECTA Technician D – Desktop & Application Support” has been matched with the VSRCM “SFIA Programming / software development L5”. This can be verified by looking at each individual node of the VRSCM graph (on the left). For example in the BECTA graph there is a node which has the competency “Troubleshooting” attached. This node has been matched by the SFIA node with the competency “Computer software development”, because “Computer software development” has been ontological related with the relationship “has part” to “Troubleshooting” in the comparison grid.

6. Conclusions

The area of competencies is a fuzzy vague domain which is still in need of further standardisation work, both representationally and semantically. The work presented here is a case study that shows it is possible to represent competencies by utilising and applying ontologies.

The work is based on a desk study of different European and an American (US) competency framework, which led to the conclusion, that even though there are many differences between the disparate frameworks, there are several basic similarities, for example they all rely on the concepts of Knowledge, Skills, and then other factors. The O*NET from the US was used as a basis to create an ontology to be used as "bulding blocks" in the competency maps developed. There were some issues with doing this, due to "Americanisation" of levels, but this worked well for most of the case study with only a few necessary adaptations. An "upper" ontology of inter-relationships between these "building blocks" was created using semantic relationships based on linguistic semantics. This meant that some of the formalised features of traditional ontology had to be relaxed, but this achieved a much simpler to use utility for the "normal" users, i.e. users not familiar with ontology theory, without losing the extendability of the system. All of these parts are jointly termed E*NET.

Competency Mappings were then used to create representations of specific competencies. The implemented structures were based on the proposed IEEE standard "Simple Reusable Competency Mappings". A Competency Suite was developed which comprised several tools for creating and managing competencies. An Application Programming Interface was implemented which enabled other developers to create applications utilising the competency tools and this was tested in a Web-based environment. A competency comparison engine was also developed, that generated results by traversing the graphs of the Competency Mappings. The combination of this traversal and the relaxed semantic relationships resulted in a "traffic light" based tertiary comparison indicator, indicating matches and partial matches. This matching traditionally had to be performed by people, not automated.

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