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Design of Higher Education Portfolio

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I. Overview

I.1. Introduction

Tendencies can be observed on international and domestic levels that call for restructuring of higher education according to the needs of labor market. An ontology-based system has been implemented within the frames of SAKE[1] project aiming for the support of decision preparation processes regarding these higher educational problems. OntoHR[2] project also employs an ontology-based approach in the field of education and workforce selection aiming for selecting the most competent applicants for a certain job, as well as finding a better fitting educational structure regarding that job. Both of these systems provide the comparison and matching of the demand and supply side of labor market on the basis of competences.

This thesis work is grounded in these projects and extends their results by focusing on the automated processing of labor market needs based on a wide range of documents; match them with educational outputs and integrate the results into the decision preparation of higher education. As the resources are tight, this thesis concentrates on the demonstration of feasibility of this approach. This way, the demonstrated system is implemented by using the BSc level of Business Informatics of Corvinus University of Budapest as educational outputs instead of the whole spectrum of higher education on one hand, and on the other hand, Software developer job description is used. During system development, incremental type of development process was used with the distinction of two phases. In phase one, Learning Outcome Ontology (LOO) was constructed and implemented, representing competences of the education side. Besides, a crawler algorithm was also

[1] SAKE - Semantic-enabled Agile Knowledge-based eGovernment (IST 027128) is a research co-financed from the 6th Framework Programme for Research and Technological Development. It run from 2006 to 2009. (Source: www.sake-project.org).

[2] Az OntoHR (Ontology Based Competency Matching between the Vocational Education and the WoRkplace, 504151-LLP-1-2009-1-HU-LEONARDO-LMP) is a Leonardo Da Vinci project. It run from 2009 to 2011 (Source: www.ontohr.eu).

implemented by employing Java programming language and batch files offering automated acquiring and processing of job descriptions, filtering them by relevance, extending the meta-model of Job Role Ontology (JRO) while validating and instantiating existing ontology classes. The implemented Natural Language Processing algorithms are not capable yet of fully precise processing of a data set of this size, therefore an expert revision of the constructed and validated model was necessary, that was done by Dr. András Gábor. After thoroughly studying ontology development environments, Protégé 4.1 was selected for the construction and implementation of the above described ontologies.

In the second phase of the development, an analysis of ontology matching tools and services was made that resulted in the selection of Protégé 4.2 ontology development environment for the matching of the two ontologies. By employing this toolset, differences and similarities of the class instances representing knowledge in the two ontologies were investigated. It was demonstrated this way that it is feasible to develop a system that is able to compare the two sides of the labor market on the basis of competences. In other words, an element of the higher education portfolio, Business Informatics degree program was analyzed by the compliance to the needs observed on the labor market.

This system can be implemented on any educational program, can be changed and extended based on current job offerings, but not capable of forecasting needed competences in the demand side of labor market. Openness of the system, however, can make it possible to implement this feature in the future. With some limitation, the system constructed this way can have a significant contribution to the decision preparation process of determining higher education portfolio.

Adapting labor market needs on the basis of competences can be considered as a competitive edge in the higher education, unfortunately, this approach cannot be tested in the current decision preparation processes of higher education portfolio alignment.

I.2. Scope of Research

One assumption of sustaining competitive edge of an economy is to transfer and usage of relevant knowledge to the right place and in the right time. This involves on macroeconomic level among others the mobility of workforce as well as building competitive education area.

In order to develop integration processes aiming these objectives, the European Union has set "aligned employment strategy" as target in the Amsterdam Treaty ratified in 1997. Later, Bologna Treaty signed by education ministers of Europe in 1999 determined main directives aiming a competitive Higher Education Area in Europe. Without harming national characteristics of education, fostering lifelong learning, introduction of easily comparable and understandable degrees, increasing mobility of students and graduates, introduction of European dimensions in education as well as developing a system for quality assurance was targeted among others. (European Commission, 1999).

The recent financial and economic crisis pointed out the need to train students that are able to adapt flexibly to the changing environment including the flexible application of wide range of knowledge acquired during the years of education as well as developing missing or partially attained pieces of knowledge elements individually. Competences needed by the changing labor market are assured by the student-centered education as well as increased student mobility. Besides, it is crucial that higher education institutions dispose on resources that enable „creating and maintaining a broad, advanced knowledge base and stimulating research and innovation" (European Commission, 2009).

The Hungarian government recognized that there is a mismatch between the learning outcomes of higher education qualifications and the competences required by companies. During this analysis, following signs of structural imbalance were taken into consideration:

– structural bias in favor of legal and management sciences and arts, instead of engineering and applied sciences claimed by the labor market
– excessive demand for students completed vocational education.

Therefore, one goal of the Hungarian higher education reform taking place nowadays is to rationalize qualification obtained in higher education in the light of requirements of the world of labor. (SZKTerv, 2012 pp.47)

These phenomena provide the foundation for a system investigating the ability of the Hungarian higher education to provide necessary education for its students supporting a smooth transition to the world of labor, or are there such demands on the labor market that cannot be satisfied.

I.3. Subject of Research

Processing of all kinds of degree programs would have been a very complex and time consuming task, empirical objective of this research was formulated as whether Business Informatics degree program of Corvinus University of Budapest can measure up this challenge, or in other words, is the structure of education well aligned to the changing needs of labor market. Business Informatics degree program trains students for IT job offerings, but due to the scarcity of resources, Software developer job description was selected as the base of the analysis. Aim of the research is therefore the development and testing of an ontology-based system that is suitable for investigating the compliance of higher education output competences to the aspects of the labor market needs. Based on this, a system can be constructed in the future that is able to provide suggestions for changes of certain characteristics of higher education, as financing, headcount of capacity.

I.3.1 Context of the Research

Investigation of this topic is not new, however. The SAKE project partially financed by the European Commission in 2006 aimed the analysis of common situations in public administration affected by changes of legal and other environmental factors. This work was supported by a holistic framework and toolset developed during the project (SAKE, 2006). Aim of the Hungarian pilot was to implement a decision preparation process determining the portfolio of Hungarian higher education, during which the emphasis was on creating balance between the resource usage and funding of higher education institutions. This requires the establishment of an education portfolio that enables students the smooth transition to the world of labor. In other words, development of the right higher education portfolio is needed. A fundamental element of the portfolio planning process is the matching and alignment of the three to five years forecasted demand of the labor market and the structure of educational output appearing on the supply side of the market (Kovács, 2010). The system developed during this project, however, needed further extensions in the areas of dynamic processing of labor market needs as well as in the area of improvement of matching quality.

Another project called OntoHR started in 2009 aimed to provide suggestions on educational structure more suited to certain job positions while contributing to finding the most competent applicants for these positions by applying an ontology-based selection and training system. It also suggests paths and possibilities of further education for the applicants (Kismihók-Mol, 2011) (Mol et al., 2012). While not being able for automated processing of claims, this system contains an approach and algorithm for matching the two sides of the market. Difference between the viewpoints of labor market and education, as well as cultural discrepancies, are resolved by an ontology-based approach on both sides.

Project DEHEMS[3] aim to analyze early career paths of school-leavers and foster their further career. Therefore, a knowledge-focused platform is created that aims to optimize the performance and quality assurance of various higher education institutions. After determining theoretical foundations and analyzing data, employees' claims (e.g. for balancing theoretical and practical abilities in higher education programs) were investigated by interviews in six countries querying the contents of various higher education programs (Melink-Pavlin, 2012).

CEDEFOP, the European vocational education development center has elaborated a methodological framework that aims at determining discrepancies between supply and demand sides of labor market regarding practical abilities by employing predictive models (Cedefop, 2012).

This thesis aims at developing an information system that investigates primarily the compliance of education programs and current labor market needs, but it can also be extended to analyze based on promiscuous prognoses. As the system covets the comparison of different approaches of the sides of the labor market, it follows the ontology-based concept of OntoHR and SAKE projects. Extending the results of these project, it manages the dynamic comparison of demands requiring various skills arriving from the labor market (in the followings: labor market needs or structure of occupation) as well as the structure of educational output of Business Informatics degree program (in the followings: structure of qualification). Under dynamic matching the collection of labor market needs in a certain time period and

3 Dehems project (Network for the Development of Higher Education Management System, 502890-LLP-1-2009-1-SI-ERASMUS-ENWS) is started as part of Lifelong Learning Programme.

the comparison of these to the education side is meant, by applying ontology-based methodology and evaluating the results.

The research presented in this thesis is aiming at answering the next questions:

- What kinds of documents and related processing methods facilitate the dynamic management of needs?
- Is the concept of competence really suitable for comparing the two sides?
- Is the ontology approach an appropriate methodology to present the job requirements and the structure of qualifications and to execute the matching procedure in dynamic manner?
- How the results of the matching process can be used in decision preparation processes related to the higher education?

My hypotheses corresponded to the system development phases outlined by these questions:

- Ontology development: collecting the documents and sources following the changes of the labor market, formalizing them into ontologies
- Ontology matching: examining the alignment of the two ontologies.
- System integration: evaluating the results, examining the adaptability of this system in decision making processes.

I.4. Methodology of the Research

Laying the foundation of the research methodology facilitating the justification of the hypotheses is realized by investigating at first the inductive and deductive thinking bridging the research and theories according to Babbie (1996), then by analyzing the qualitative and quantitative methodologies as suggested by Balaton and Dobák (1991). *Inductive thinking* starts from a series of observations and progresses towards connections (relationships) that reveals order among those observations. In other words, it aims at developing a general connection based on specific cases, not necessarily revealing the causes, just the existence of the relationship.

Deductive thinking, on the other hand, aims at the validation of a theoretically assumed hypothesis by observations. In other words, it progresses from the general to the specific.

Objective of *qualitative research* is to observe and explain phenomena of the world, being a naturalistic approach. Researchers investigate things in their natural forms while assigning meaning, interpreting phenomena the same way as people generally do. Qualitative research is a way of transforming phenomena of the world into case studies, interviews and personal experiences (Denzin and Lincoln, 2000).

Quantitative research, on the other hand, is built on statistical methodologies that are capable of handling large amount of data. This approach enables the testing of hypotheses via representative samples (Füstös et al., 1986).

The goal of this research was to develop a system which is capable of mapping the similarity and discrepancies between the two sides of labor market in regard of qualification. For the sake of this objective, competences of both sides are to be observed in their natural occurrences, as well as endeavors reveling relationships, which justifies the application of qualitative techniques.

The research does not want to discover rules and connections that explain interferences among people, so it doesn't fit into the world of social science research (Babbie, 2001 pp.4).

Instead, it aims to develop a system to prove the correctness of the approach. This way, the research follows the two-phased incremental software development method (Sommerville, 2007 pp. 73), where the hypotheses represented the functional requirements of the increment in every certain stage. Correctness of the hypotheses is investigated based on the output of the connected system development phase.

I.4.1. Hypotheses of the Research

H1. Structure of qualification on the supply-side of labor market can be mapped by meta-models based on the competences of educational outputs (structured geographically and periodically), while at the same time, structure of occupation can be mapped according to the competences describing advertised job offerings (also structured geographically and periodically) on the demand-side of the labor market.

As ontologies are built according to consensual agreements on a specific domain aiming the formalization of concepts of that domain, well-defined and consistent models describing structure of qualification and occupation can be created by applying ontological approach based on job offerings available on the Internet enabling automated processing; as well as documents containing description of competences of Business Informatics degree program. However, the objective of comparability requires the viewpoint of seeing these models as specializations of a general meta-model that is built in Chapter IV.1.2. Under periodical structuredness, their appearance in specific points in time (e.g. monthly or quarterly), under geographical structuredness the representation of various geographical regions (e.g. counties, countries) is meant.

Justification of this hypothesis requires a system that is able to construct the structure of occupation based on a meta-model by extracting textual information from documents in an automatic of semi-automatic manner, as well as it is able to update this model based on the changes of the documents. Besides, it has to enable the implementation of the slowly changing structure of qualification as well. Temporal and geographical structuredness is only measurable according to the ability to represent the appearance of competences in a given time and place, as well as representing temporal changes of them. Usability of the system is shown by the ability of automated accessing of documents, the dynamics of document processing, change management, in other words, what amount of human intervention is required for proper operation.

When a system is developed that is customizable for arbitrary educational programs and related job offerings, and after the necessary preparation of the created structures it is able to represent labor market needs and educational outputs appropriately, the hypothesis is accepted.

H2. An ontology-based information system can be elaborated that is able to reveal similarities and differences between the structure of occupation and qualification.

Target of the research is the investigation of matching of occupation and qualification structure. Using ontology-based approach is justified by the comprehensive literature of the matching that is built on ontologies, as well as it is a modeling tool that enables pairwise comparison of concepts that makes revealing their similarities and differences possible individually.

Justification of this hypothesis needs a specific toolset (detailed in Chapter IV.2) that compares the concepts in their specific contexts based on ontology structures while providing a report on that. This report can only be used in further development when it contains the most appropriate matches possible. Therefore, it is worth measuring here how these hits relate to the matching resulted by human-created relationships.

During the justification of these two hypotheses deductive approach is applied following the general model, moreover, the connections of ontological matching are applied in real-world situations.

H3. A system revealing similarities and differences between the structure of occupation and qualification is a useful element of the higher education decision preparation process.

Utility of the system developed during the research can be measured in its ability to integrate with the governmental decision preparation process mentioned earlier. Justification of this hypothesis can be done by applying the connections revealed by the system in a general environment requiring the application of inductive thinking.

I.5. Benefits and Importance of the Research

Governmental decisions aiming the transformation of the higher education offerings are in progress. Although directives of the European Higher Education Area call for the competence-base structuring of contents of education programs, moreover tendencies on the demand-side of the labor market can be observed that aim the description of job offerings similarly, on the basis of competences, it seems that government decisions are based on a different logic. Different decision situations are applicable on the structure of occupation and qualification, both offering certain latitude. Significance of an ontology-based system in this case can be measured most importantly in ensuring a common ground for the different viewpoints as well as tracking changes.

The system that is to be developed is only a prototype, but it will be suitable for testing whether the qualification-related differences of the supply and demand side of the labor market can be revealed. A contingent development enables on the top of this the revealing of structural differences in details according to qualifications on a certain level of certainty.

The Med-Assess project (Adaptive Medical Profession Assessor) started in October, 2012 aims the application of the dynamic learning system developed in the OntoHR project in the field of healthcare (Corvinno, 2012). Precursor of the system demonstrated in this thesis was the system realized in OntoHR that has compared the Information System Analyst job to the offerings of Dutch and Italian higher education programs (Kismihók, 2012). Developments elaborated in this thesis contribute to Med-Assess in a way that a dynamic change-tracking program can be integrated into the Med-Assess system.

Objective of the SMART (Skill MAtching for Regional developmenT) project started in October 2012 is to construct a learning system built on the education programs aiming to satisfy labor market needs. According to the plans, the system elaborated in this thesis as well as its improved successor will be part of the project's product. This project aims to contribute to the balance of the two sides of the labor market in the Andalusia region that has a high ratio of unemployment while showing signs of over-qualification. (Anon, 2012 pp.24). In other words, usefulness of the system cannot be tested currently in higher education decision preparation process, thank to the applied approaches, but can contribute to making of related decisions in other application areas. This way such education programs – even new ones – can be created that can follow changes, are more transparent, therefore more competitive.

I.6. Structure and Specialties of the Thesis

Justification of the hypotheses will be realized by the development and evaluation of a system. This should be well-grounded as it aims to support the preparation of a decision that affects a significant number of people on the long run. For this reason, Chapter II. demonstrates the applicability and advantages of comparison based on competences by presenting the usage of this concept in various approaches and viewpoints, as well as investigating currently used models in the research. In order to ensure a common ground in the usage of this concept, an ontology-based methodology is demonstrated aiming the formal, explicit, consensual and unified description of the world's objects. Concept of ontology is demonstrated in Chapter III. Chapter IV. presents the course of system development, providing an overview of the literature with regards to the available tools and methodologies and related aspects for every phase. After this overview, implementation of the chosen algorithms and application of the selected tools are presented. At the end of each phase, the product of each phase is evaluated against human processing. Chapter V. exhibits the possibilities of integration of the developed system into the higher education decision preparation process. This issue required a separate chapter since it is more an educational policy question than an issue regarding system development.

II. Competences – Theoretical Foundations

II.1. Role of Competences in Labor Market Needs

Rapidly changing business environment resulted companies facing complex business problems requiring agile reactions or even changing the organizational structure. This, on the individual level, involves the management of people's mental resources as well. Although human skills were also investigated in the taylorian times, a completely new approach has been developed in the 1970s, especially by the research of McClelland (1973). Flanagan's (1954) critical event technique – a methodology aiming to identify behavioral causes of success or failure of individuals in certain situations – demonstrated that human skills should be investigated instead of work tasks. This has led to the introduction of the importance of competence analysis by McClelland, as well as a job management approach that defines jobs through individual character, behavior and knowledge traits, or in other words, through competences, instead of task descriptions. As Lawler (1994) demonstrated in the case of companies organized according to competence-based principles, besides job planning, this approach also affects the selection process and involves changes in the system of salaries and perks as well. From this point on, detailed job descriptions are replaced by individual competence descriptions required by the organization or the organization's strategy. In the case of business process analysis, emphasis shifts from the investigation of skills necessary for execution to the revealing of individual competences necessary for the efficient execution of the business process. In this approach, motivation and self-valuation receives more emphasis as well. Formerly stable job descriptions get dysfunctional, boundaries get blurred.

During the selection process, the objective is not anymore finding the most appropriate candidate to a specific job, but finding a candidate who can integrate into the learning environment of the organization, who can learn the necessary knowledge, and besides, having the necessary competences for the specific job. In other words, filling a job offer requires indicators predicting who will provide the best performance in the future in that certain job among the existing employees and possible candidates. More researches and studies (Ghiselli (1966), Mischel (1968), Spencer(1993)) have pointed out that knowledge assessment based on tests and exams is not a sufficient predictor, instead, using of systems are needed. These systems are effective when not only the mapping of competence gaps can be done with them, but they can offer appropriate competence development, in other words, learning paths to them. This is based on the fact that employees receive their salaries and can build their career based on their competences and based on their ability to use these competences in a certain period of time. Managing individual competences contribute to the development of organizational abilities that can offer competitive edge, can make the operation of the organization more effective and can also have strategic value (Schoonover et al., 2000), moreover, it can play a significant role in succession planning (Egodigwe, 2006) as well.

II.2. Role of Competence on the Supply side of the labor market

In the last decades, focus point of education was shifted from the teacher to the student. This means that conventional content-oriented, procedural approach was replaced by a new principle focusing on the learning outcomes (Derényi, 2009). European Qualification Framework that affects current education systems defines learning outcomes as "statements related to what a student knows, what he or she can understand, what he or she can do after finishing the learning process" (Tót, 2009 pp.19). However, if the role of the concept is investigated in the educational planning processes, a more detailed picture is shown. In Gagné's theory, the planning of education programs starts with the identification of learning outcomes followed by the construction of the task analyses – or in other words, the learning hierarchy – that are responsible for execution of measurable activities. For this reason, learning outcome is interpreted as something that "makes possible the stepwise understanding of the learning process, with the help of which precise requirements can be set for the planning" (Proitz, 2010 pp. 122.).

Teaching that is built on learning outcomes as standards has the advantages of being more transparent for the stakeholders, their value and internal relationships can be demonstrated more easily. Determining the objectives and outcomes of courses and training programs is simplified greatly, and comparison of outcomes of former education is more straightforward (Derényi, 2009). Definition of learning outcomes is realized with regards to the competence principle. These are appropriate building blocks, since "they can encompass the entirety of theoretical and practical knowledge and viewpoints, can be used to decide on the level of training, can reveal strength and weaknesses of the students, can be determined the set of training programs and tasks that are able to lead the candidate to the completion of certain competences or standards” (Falus, 2006 pp.174).

First taxonomy in this area is created by Benjamin S. Bloom in 1956. His original goal was to elaborate a better way to compare results of various training programs and test methodologies. The elaborated system serves according to Bloom's ideas as:

- an appropriate communication tool regarding learning outcomes,
- guidelines for elaborating various training programs subordinated to learning outcomes,
- common ground for analysis of compliance of learning objectives, evaluation and activities on the level of training programs and courses.

His taxonomy encompassed six main categories: Knowledge, Understanding, Application, Analysis, Synthesis, Evaluation; each of which was split into sub-categories. These groups were organized from the simple to the complex, from the specific to the abstract (Kratwohl, 2002).

National qualification systems are done nowadays in the principles of learning outcomes. A qualification framework was created in 2003 for the European Higher Education Area, which aims to offer transparency and comparability of the countries' higher education systems and qualifications on the basis of competences (Bologna Working Group, 2005). The Tuning project aimed to determine reference points of general and topic-specific competences of students finishing in the first and second cycle in the fields of management sciences, pedagogy, geology, history, mathematics, physics and chemistry (Tempus, 2006). These non-compulsory reference points can be used by various higher education institutions during curricula development and evaluation. This way, a common language can be constructed while keeping institutions' independence. In the meantime, elaboration of European Qualifications Framework for Lifelong Learning (EQF) has been started in the European Union by involving experts. Goal of this process is to “encourage lifelong learning via the improvement of permeability, convertibility and portability among qualification frameworks, as well as ensuring better mobility of students and employees within the European Union” (EKKR, 2009 pp.1)..

Goal of the DeSeCo (Definition and Selection of Competences) project brought into life within OECD countries is the identification of competences that enables successful and responsible life for adults and children in a modern and democratic society, as well as supports their compliance to present and future challenges. This way, the elaboration of a common and widely used framework is aimed for identifying competences, ensuring a better and more precise measurement and understanding of competences, as well as interpretation of results (DeSeCo, 2005).

These approaches are all interrelated and all use competences for ensuring the aimed transparency, permeability and mobility.

It is not a coincidence therefore that the law of higher education (CXXXIX. in the year 2005) states that "education programs in the bachelor and masters degree can be constructed by following the qualification and learning requirements defined by the minister, while in a free manner in the area of vocational training" by the institution.

It can be stated this way that tendencies can be observed in both sides of the labor market that emphasize the importance of competence-based comparison. However, while elaborating such a system, it can easily discovered that there is no commonly agreed definition of competence that can be explained by the inconsistent application of terminology, cultural differences, different theoretical and epistemic backgrounds and the difference in the goals of application of the term competence (Falus, 2006) (Winterton et al., 2006).

II.3. Concept of Competence

Root of the term can be identified in the Latin word Compete having a meaning of being able to do something. In the English language literature, the term is divided into competence and competency. According to Rowe (1995), the first term is used for describing the satisfactory application of practical skills while putting an emphasis on the achieved performance standards; while in the second case, the behavior leading to the activities is emphasized. In other words, in the case of the word competence "What is a human capable of?", while in the case of competency "How a human is capable of doing?" is emphasized. In the European Union, the term competence is widely used, similarly to the Hungarian education area, where competence is applied in the case of key competences (Tót, 2009).

However, not only the complexity of the concept, but the different viewpoints of the authors, as well as the difference in the affected contexts results in a wide range of definitions used in the literature.

“According to the psychology approach, competence is similar to the personal, ability, motivation or knowledge characteristics, as these all can be observed in the behavior of persons. At the same time, competence encompasses these terms, being a higher order concept”. (Henczi-Zöllei 2007, pp.29).

The law on higher education No. CXXXIX, year 2005 demonstrates the background content in details as defining competence as “the total of knowledge, skills, and abilities”. According to the OECD, competence is more than knowledge and skills, it is more like “usage and application of psychosocial resources (knowledge and attitudes included) encompassing the ability of compliance to complex requirements” (DeSeCo, 2005 pp.4).

In the world of labor competences reveal themselves through an activity that is demonstrated by the following definitions.

According to Gegesi Kiss et al (2004, pp.193) “competence means performed knowledge, meaning the application of acquired personal knowledge, abilities and skills in a specific environment and situation.”

Kraiciné (Henczi-Zöllei 2007, pp.18) sees competence as a dynamic phenomenon that “means the total of knowledge acquired during education and the personal and professional experiences, this way the ability to fulfill a specific function, as well as a system of motives and abilities serving the realization.”

R.E. Quinn views competence as “knowledge and skills necessary for fulfilling a task or a role” (Szelestey 2005, pp.5).

A more comprehensive definition also listing characteristics of competence is provided by the HR-XML consortium. In their interpretation competence is “specific, identifiable, definable and measurable knowledge, skill, ability and/or another progress-type characteristic (e.g. attitude, behavior, physical ability) that is in the ownership of the human resource and is relevant or needed to the execution of a certain activity within a specific business environment” (HR-XML Consortium, 2006).

Summarized, the following elements can be distinguished: knowledge, proficiency or experience, skills-abilities and behavioral traits (patterns and characteristic), attitudes affecting motivation (viewpoints, cultural settings). As personal attitude cover the last two categories, these items are aligned with the traditional classification used in the English-language literature having the knowledge – skill – attitudes categories, as well as with the practical terms used in English-language areas of cognitive competence, functional competence and social competence.

However, content elements cannot be considered to be independent from the given context of application, which can be generated by the need of fulfilling a task or an activity, as well as of a role or a function. Besides, competences should be analyzed in a dynamic application environment as the situation, activity, function or context that needs the application of the given competence can change during time. This means that besides the interpretation of a certain situation in a given context, the ability of handling the situation by applying a range of actions is also required, within which the most relevant ones should be developed via training. In other words, fulfilling a job needs the revealing of competences related to the success and increased performance, as well as their revisions, while ensuring the necessary education programs offering the development of these competences. Competence models, as well as qualification frameworks offering education programs can serve as foundations of such complex systems.

II.4. Competence Models

Competence models are frameworks connecting the organization, individuals and jobs by offering compliance of job-related competence expectations and individual competence resources. (Henczi-Zöllei, 2007 pp.81)

According to Rowe (1995) models are applied in the area of management in the following cases:

- in the case of selection the goal is to determine “behavioral aptitudes” needed to fulfill a certain job, as well as the investigation of applicability of individual competences into these needed by the job
- in the case of skill evaluation models are used to gauge whether an individual is competent in a certain job

- in the case of development, individuals' strengths and weaknesses are collected and directions of development are appointed.

Boulter and colleagues have determined six phases for the definition of competence models to a certain job (Boulter et al, 1998):

1. Determining performance criteria: criteria needed for presenting outstanding performance in a certain role.
2. Selecting sample: taking sample among people fulfilling certain roles with the aim of data collection.
3. Data collection: discovering sample data for behavior leading to success.
4. Data analysis: constructing hypotheses related to competences explaining outstanding performance and cooperating in order to achieve the necessary performance.
5. Validation: justifying the results of data collection and data analysis.
6. Application: application of competence models in the demanded human resource activities.

Models can be distinguished that relate to a whole organization or to a specific area. It is typical however those companies do not create holistic models but focus more to a specific job or role – especially in the field of management (Henczi-Zöllei, 2007 pp.82).

Models demonstrated in the followings can be classified into two main categories: a general and a management-specific model group. Among general models, HLD-model is emphasized and presented as a widely used one on the area of competence management, as well as the ETA-model that was developed by the cooperation of business leaders and educators on the US labor market. Within the management-specific group, Spencer's competence dictionary is presented that is widely used and adopted by managers, and additionally, Management Initiative Charter model is demonstrated as the industry standard on English-language areas.

II.4.1. HLD Competence Model

HLD model emphasizes that a personal and professional competence set should be created – including knowledge, skills and personality traits. This should be dynamized by the individuals in order to realize their personal and environmental-originated goals. Competences are classified into five clusters. It distinguishes according to competences aiming at an activity – work, autonomous learning, accommodation, innovation –, or a traits necessary for practicing these competences (Henczi, 2009 pp.14-15). This way, key and cognitive competences serving as the basis of relevant activities (general competences); professional competences adequate to individual needs and tasks; social competences in relation to work and social environment; learning competences needed for continuous self-development; and finally, innovative competences necessary for improving work and social environment are included in the model (Henczi-Zöllei, 2007 pp.91-92.). Their relationships are demonstrated on Figure 1.

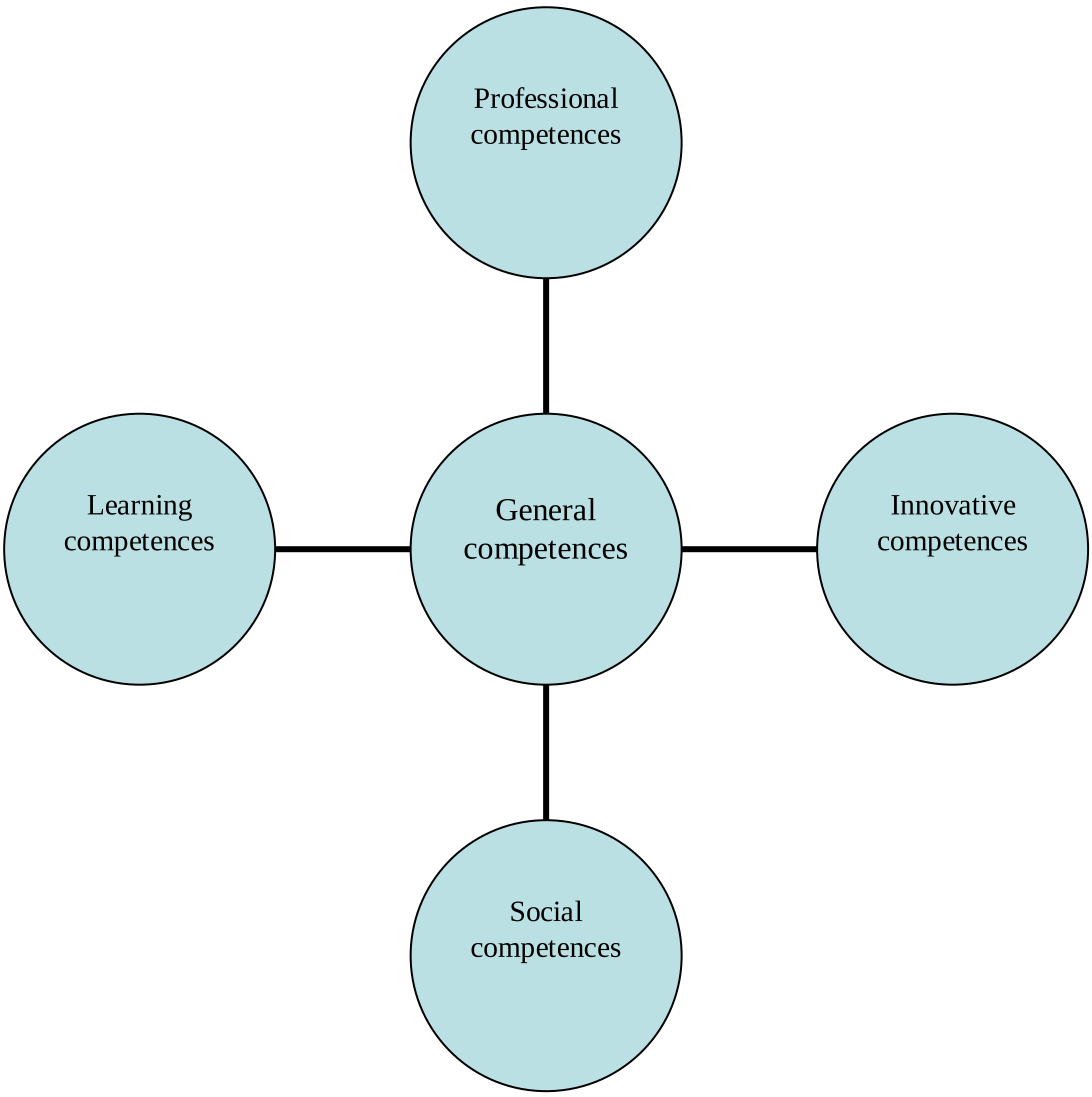

Figure 1. HLD competence model (Henczi, 2009 pp.14)

Competence groups include the triplet of knowledge-skill-attitude in an organizational context, as they are defined according to the claimed activities. It can also be observed in this model that specific competences are based on general ones.

II.4.2. ETA (Employment and Training Administration) Competence Model

During a program of the US-based ETA (Employment and Training Administration) public administration bureau such lucid and perspicuous industry competence models are created – based on the cooperation of business leaders, educators and other stakeholders – that contain the basic and technical skills and competences that are able to lead to workplace success in economically important industry sectors, while also offering resources for curricula-development, certificates and competence-evaluation tests.

General framework depicted on Figure 2 consists of 9 levels build upon each other. Basic competences on the lowest three levels – personal efficiency competences, academic competences, workplace competences – can be applied generally in any industry sector or area of employment. On the next two levels, industry-specific competences can be found that affect industry sectors of while industry branches. On the last four levels, competences related to employment, or in other words, employment-specific knowledge and requirements, technical competences and management competences are present (Ennis, 2008).

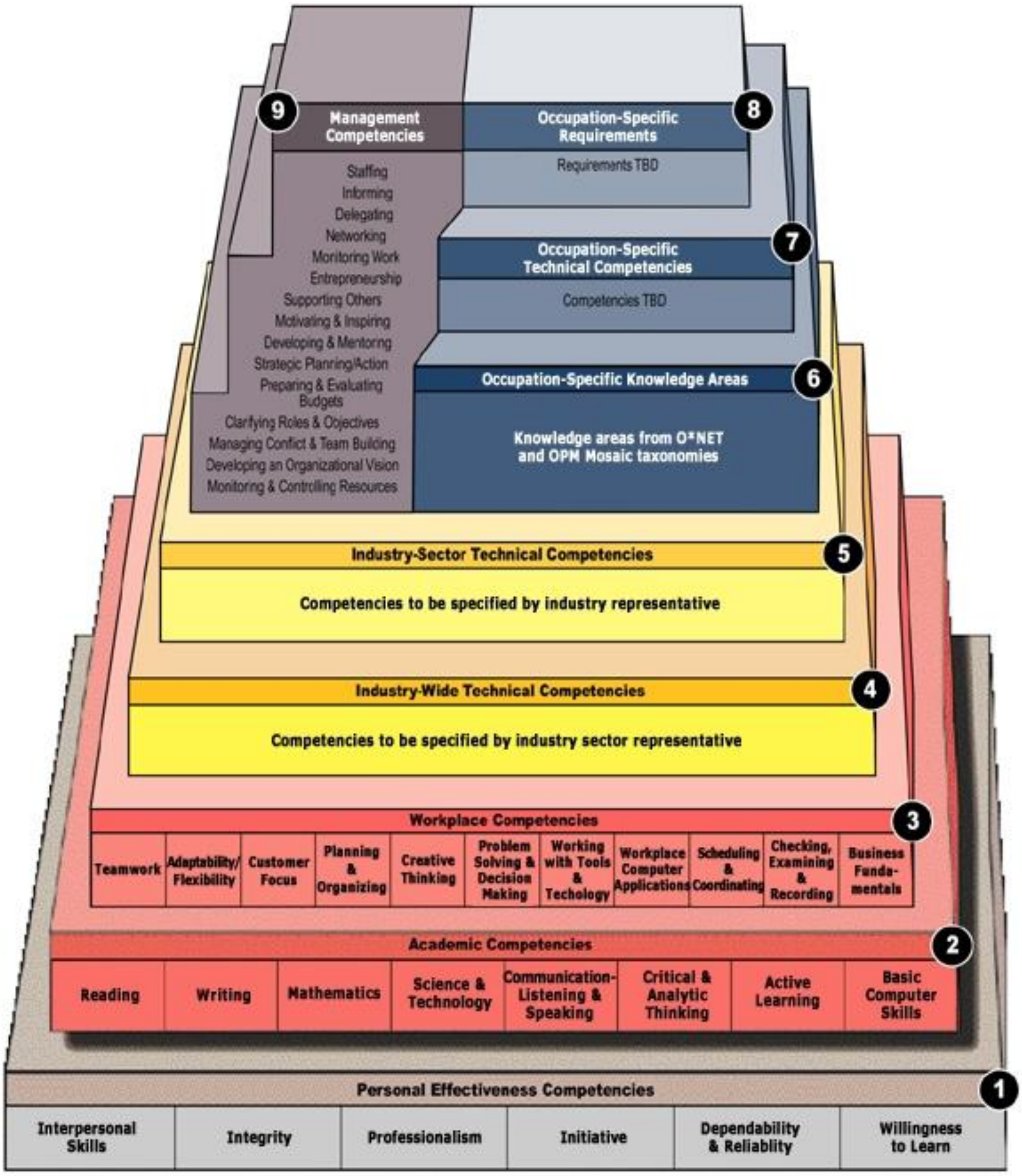

Figure 2. ETA competence model (Ennis, 2008 pp.7)

This model depicts professional and personal competences as well, but the categories have been created by more specific activities, handling this way the successive structure of competences on more levels.

II.4.3. Spencer's Competence Dictionary

Spencer's competence dictionary was elaborated based on behavior-based interviews applied in research aiming the development of corporate competence models. Every competence was defined and a number of indicators were assigned that measures its practical application (Irawan, 2011). Competences needed for fulfilling leader roles have been grouped according to the most important tasks – pursuit of performance and quality, establishing interpersonal relationships (supporting, influencing, developing, directing others), application of knowledge and self-management – that is contained in Table 1.

This dictionary is the most widely used among companied working with predefined dictionaries (Bakacsi et al., 2005 pp. 144-145.).

Competences of “performance and action”	performance-orientation shaping order pursuit of quality and preciseness initiation searching for information
Competences of “supporting and helping others”	understanding others customer-orientation
Competence of “influence”	Influencing organization-awareness building relationships
Leadership competences	developing others direction and assertiveness team work and cooperation team leading
Cognitive competences	analytic thinking thinking in concepts professional knowledge
Competences of personal efficiency	self-control confidence flexibility commitment to organization

Table 1. Spencer's competence dictionary

As fulfilling management activities is in the center of this model, competences also focus on this area. Knowledge appears only among cognitive competences, other groups contain mainly attitudes, skills and abilities.

II.4.4. Management Charter Initiative

Aim of the framework elaborated by Management Charter Initiative (MCI)[4] is to ensure standards in the field of management that are competence-based, internationally accepted, can serve as the basis of management performance measurement and are not only built on academic knowledge but on labor-market needs as well.

Its two main components are Management Standard and Personal Competence Model, as well as related knowledge and skills.

Management Standard determines what a manager needs to know, as well as determining those expected results that need to be fulfilled. Its structure is analogous to a pyramid, where the main goals of the manager – fulfilling organizational goals and continuous improvement – determine the competence units (e.g. competences used for sustaining or improving service or product operations) related to his or her key roles (e.g. managing operations). These units can be divided into smaller competence elements, e.g. those that ensure compliance of operations to quality standards. Related to these, performance criteria are defined – e.g. all supplies necessary for the operations should be available complying to the goals of the organizational unit –, as well as assumptions defining boundaries of range of application of competences – e.g. activities related to managerial level of responsibility of operations.

Evaluation is based on the performance of the manager regarding the performance criteria related to the given standard. Development is demand-oriented and guided by the manager.

Personal Competence Model is agglutinated to Management Standards that identifies personal key competences responsible for results within the area of planning, directing others, self-management and application of intellectuality (Barker, 1993).

It can be determined that every model appose competences into organizational context while having the performable activities as the range of application. It can also be seen within management-specific competence models that tasks and competences can be classified according to roles. Besides, performance criteria can

4The organization responsible for developing NVQ-type education programs on the field of management.

be agglutinated to activities enabling the measurement of competence application in specific situations. As acquisition of competences is emphasized more on the qualification side compared to their practical application, the content-related evaluation of the models will follow the presentation of the qualification frameworks.

II.5. Qualification Frameworks

"Qualification framework is a classification tool of qualification programs according to certain criteria and generally having political or strategic vision; determining relationships between qualification programs horizontally and vertically. Criteria – e.g. using of descriptors – can be applied to certain levels of learning outcomes. Regarding the classification, sectoral, national and international frameworks can be distinguished" (Temesi, 2011 pp.15).

As it was seen before, focusing on learning outcomes – or in other words, what a student knows, understands and what he or she is able to execute after finishing an education program – resulted in a paradigm shift in education in a way that definition of goals and desired outcomes of curricula and programs got easier among others. Therefore, frameworks offer a more clear description of education programs, set entry and exit points more precisely in contrast with the former content-oriented approach, depict the direction of advance between certain education programs and helping students to discover new forms of education. This way, equality of opportunity is increased and national and international mobility is facilitated.

It was first discovered in Anglo-Saxon areas (Australia, New-Zealand, United Kingdom) and in South-Africa that a qualification framework building on learning outcomes can connect vocational education to labor-market needs the best way (Temesi, 2011).

II.5.1. National Vocational Qualifications

Unemployment has been increased in the United Kingdom in the 1980's. Transformation of the education was required by the inadequate qualification of people. Therefore, the elaboration of a unified national education system built on national standards was targeted instead of the colorful educational structure that existed before (Aitken, 1993).

Since then, the former five-level qualification framework has been transformed and extended with levels affecting higher educational studies.[5]

It is hard to collect evidence on the higher level of qualification of students within education programs applying this framework, however according to the study executed among financial managers by AAT (Association of Accounting Technicians) for example, 90% of leaders found that after the introduction of NVQ qualification of accounting technicians have been improved. However, critics have been formulated against NVQ that the involvement of employers was declared but they are practically not represented in the development process (Purcell, 2001).

II.5.2. Framework of European Higher Education Area

European ministers responsible for higher education have been agreed in the adaptation of the comprehensive qualification framework of the European Higher Education Area on the Bergen conference in 2005. The system makes the national higher education frameworks and the relationships between their education programs more perspicuous, contributing this way to the realization of transparency and mobility set as objectives.

Deadline for elaborating of compatible national frameworks have been set to 2010. The framework aims to describe the primary, secondary and tertiary cycle of education programs by using learning outcomes and competences. It also provides guidelines for the elaboration and usage of the credit system of the first two cycles. The framework suggests Dublin-descriptors for describing the cycles, enabling this way general statements related to learning outcomes and output skills representing the end of each bologna-cycle (Bologna Working Group, 2005).

II.5.3. European Qualification Framework

EQF is a meta-framework that classifies qualifications acquirable within the frames of formal and informal learning according to learning outcomes into eight reference

5 http://www.tvec.gov.lk/nvq/nvq_levels.htm

levels (EKKR, 2012). It ensures this way a standard base enabling the comparison of qualifications created within the frames of national education systems to EQF, enabling this way the real comparability of education programs of different countries. This objective comparability assumes however the efficient and reliable operation of quality assurance systems on various levels of education.

The application of this framework also enables control over the education programs whether they really ensure competences defined on the given level.

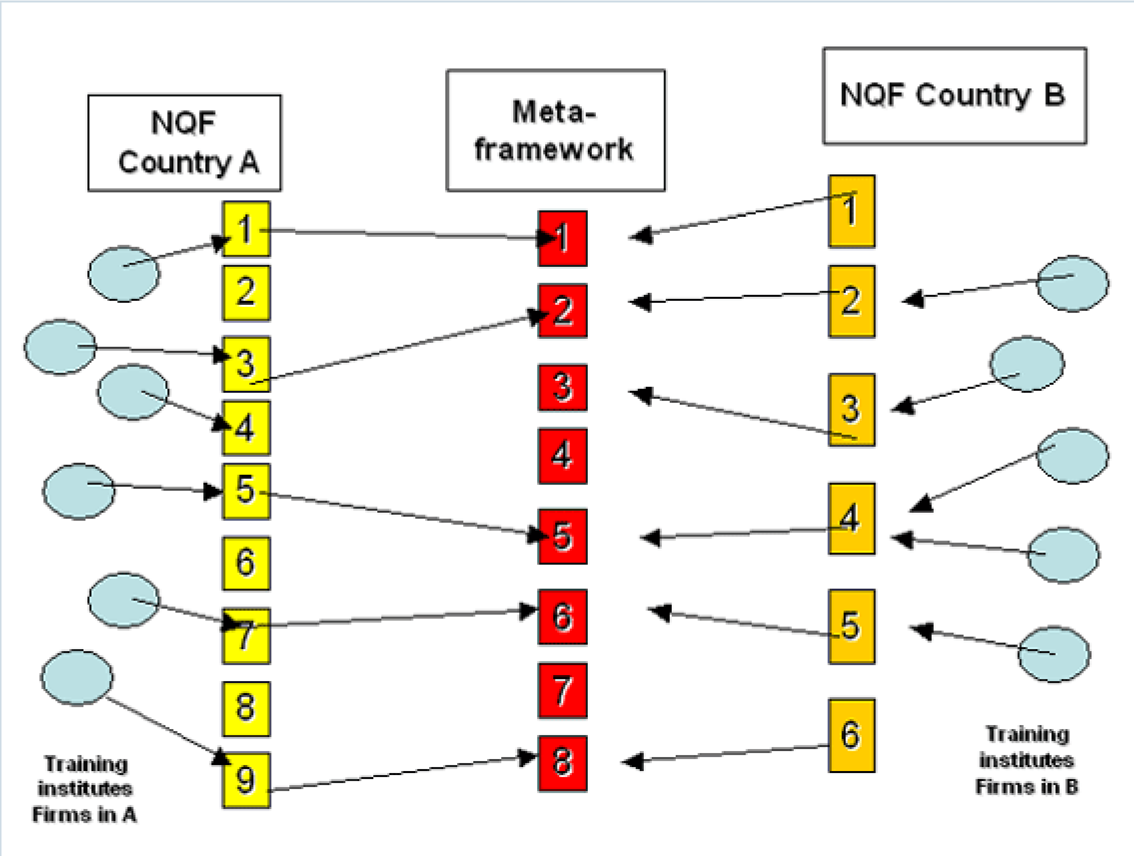

Figure 3. Comparison of different qualifications based on EQF (Anon, 2009)[6]

EQF consists of three parts: *common reference points/descriptors* assigned to the eight hierarchic levels of learning outcomes that are supported by European *toolsets* aligned to the needs of individuals (students, employees, employers) – e.g. the European credit-exchange and acceptance systems. Moreover it also contains common principles and processes that facilitate the cooperation of partners operating on various levels, e.g. in the area of quality assurance or acceptance of formal and informal qualifications (Temesi, 2011 pp. 21-27.)

[6] Source: http://www.bibb.de/en/21696.htm

In a 2008 directive of the European Parliament and Council (EuParlCoun, 2008) an examination investigating how national qualification systems can fit to EQF was prevised to 2010. The methodology of this analysis is the comparison of national qualification levels to EQF reference levels, and if it is necessary, new national qualification system has to be developed in alignment with the national law and practice.

In Hungary, the National Qualification Framework has been developed within a project number 4.1.3 of Social Renewal Operational Program called System Development of Higher Education Services (Támop, 2009).

II.5.4. National Qualification Framework

Following the directive, EQF was set as the standard by the working group elaborating this system, while taking the existing domestic practice into account. This way, a “sector-neutral” system has been developed that tries to handle individual education areas (public education, vocational training and higher education) in a unified way, as well as defining a generally applicable system for qualification criteria by using the same descriptors.

In order to be able to compare existing qualification programs to EQF, the fitting of neighbor elements needs to be investigated on the axis of EQF – national qualification system – qualification system affecting regional and certain sectors – criteria of qualification and learning outcomes of vocational training, moving from the general to the specific. As NQF is highly aligned to EQF, classification of national qualifications into the European system is easier, however the compliance of qualification levels and structure should be elaborated on sectoral level. These latter elements should be therefore an appropriately constructed bridge between the two endpoints of the axis.

Taking lifelong learning into consideration, National Qualification Framework is constructed therefore of eight levels that can be built upon each other, containing competence-based descriptions, enabling this way content-wise comparison beside credit-based one. Bridging the differences between the levels can be realized by continuous improvement; however this principle can be realized to its full extent within the category of knowledge (Temesi, 2011 pp. 99-133.)

II.6. Applicability of Competence in Research

The fact that can be discovered on the demand-side of the labor market is that a significant number of companies in the United States (e.g. 80% of the 426 companies queried by the American Company Association) have introduced some competence-base applications at the end of the 20th century (Shippmann et al., 2000), moreover competence-based job analysis have been widely spread in the European countries as well. These facts indicate that competence-based approach can provide great practical advantages to organizations.

In between on the supply-side of the labor market not only the European Qualification Framework but the framework of the European Higher Education Area initiated by the Bologna process require the existence of a competence-based Hungarian education and training system focusing on learning outcomes.

It can be seen therefore that competence-based approach is an appropriate tool for comparing the two sides. It was also demonstrated that the concept has a number of definitions, all of which agreeing on the main points, differences mainly depending on the slicing points of personal attitudes. This way, knowledge-skill-attitude (KSA) triplet will be used in the followings for the basis of comparison.

On the scene of education, Business Informatics education program is serving as the subject of investigation. Learning outcomes of this education program have not changed since 2005), it can be considered therefore as a stable base of comparison.

Regarding the investigation of applicability of competence models affecting the world of labor it was taken into consideration to what extent are competences presented in their real environments and how are these applicable to the IT job offerings being the subject of the research. Caution can be explained by the fact that content elements are not independent from the context and situation serving as the basis of the competence. The rigidity of boundaries was analyzed therefore in the sense of detailing competence elements serving as the basis of comparison, whether structure of competence elements and connection points with job offerings are depicted, moreover, whether there are relations with the education side. Results of this investigation are contained by the following table.

	HL D-model	ETA model
Competence elements	Contains KSA-triplet, however not in such a strict category	KSA-triplet appears on each levels
Structure of competences	Workplace and person-specific competences are built upon general ones	Industry-specific is built upon general, then competences related to job offerings
Relationship with job offerings	Generally applicable, there are no references to jobs	Generally applicable, there are no references to jobs except management. Originating industry sector can be observed however.
Relationship with qualification	Applied to Hungarian vocational education	Developed together with educators

	Spencer's competence dictionary	MCI
Competence elements	Knowledge is not emphasized	Contains KSA-triplet
Structure of competences	none	A hierarchy is present represented by a tree structure.
Relationship with job offerings	Management	Management
Relationship with education	On the area of leadership development	In alignment with NVQ trainings

Table 2. Analysis of competence models as the basis of comparison

It can be observed in the table that the criteria of comparing the demand and supply-side of the labor market are not completely fulfilled by any of the investigated models. Among the four models, MCI and ETA has performed the best, however MCI can only be applied in the case of IT managers, while in the case of the latter the problem is the context-dependent buildup of competences instead of a structure based on competences being preconditions of other competences.

It can be seen therefore that such a model is needed that can draft the content and application environment of competences in a general way and gets updated according to a certain job afterwards. Ontology-based approach contributed largely to the elaboration of this model. As the focus of this research is the comparison of competences defined on the occupational and professional side, the presentation of ontologies emphasizes how this tool can serve as a common ground for describing and comparing competences originated from different viewpoints. It would be out of scope of this dissertation to list and analyze all authors that are concerned with ontologies, therefore among the vast amount of literature Handbook on Ontologies (Staab, 2009) is emphasized that provides a wide-scoped overview of the topic of ontologies, as well as among the Hungarian literature the doctoral dissertation of Vas (2007) and Kő (2004) are featured beside the detailed description of the building blocks of the topic.

III. Ontology-based Approach

A number of scientific disciplines – knowledge management, health science, artificial intelligence among others – are concerned about constructing and using of ontologies. The concept itself originated from philosophy and was adapted by following a bit different aspect in the field of computer sciences. According to the difference in their meanings and following the notation introduced by Guarino and Giaretta (1995), ontology in the philosophical sense and ontology determined in the sense of computer sciences are distinguished in this research.

III.1. Concept of Ontology

The concept of ontology first appeared in 1613 in Rudolf Göckel's (Gocenius') Lexicon philosophicum and in Jacob Lorhard's (Lorhardus') Theatrum philosophicum. Roots of the concept is however even traced back to Aristotle by philosophers (Smith, 2002), who was investigating the nature and structure of reality in his work Metaphysics, in which ontology was defined as “being *qua* being”. In other words, against experience-based researches analyzing things from one given viewpoint, Aristotle wanted to investigate the nature and structure of things in their completeness, independently from viewpoints, their actual lifeforms and existence (Guarino et al., 2009).

In computer science however, as the most-quoted Gruber (1993) formulated, ontology is *"an explicit specification of conceptualization"*, where according to Genesereth and Nilsson (1987) conceptualization is meant as a *"simple and abstract approach representing the world for some reason"*, or in other words, representing hypothetically existing objects, concepts and other entities and the relationships between them in a specific domain of interest. According to Juhász and Takács (2006) during the conceptualization process of thinking common traits are extracted from the specific objects or persons of the world in order to create classes or groups, and during categorization objects are assigned to concepts.

Attributes related to one concept can be classified into two categories: prototypes provide description of the best instances (e.g. birds fly), while critical attributes (like genes) – possibly also confirmed by definitions – determining pertinence to a class establish the core of the concept. During categorization a decision on the classification realized by core attributes or by prototypes can be made. After the understanding their nature concepts can be connected and combined into statement-like thoughts following certain grammatical regularities. Embedding two statements into each other enables the formulation of highly complex thoughts. Inference is made when statements are organized into train of thoughts such a way that one statement represents a thesis or consequence, while all the other statements serve as confirmation of the thesis, or in other words, premises of the conclusion. This process takes place during propositional thinking, anent to imaginary thinking built on visual images or to motoric thinking performing thinking through movements (Atkinson et al., 1996 pp. 249-254.).

During conceptualization the viewpoint providing an approach to the world should be based on common agreements of the affected group of people, otherwise the constructed ontology will not reflect realistic enough the domain to be mapped. Studer et. al. (1998 pp. 185) has re-formulated Gruber's definition in a more precise way, defining ontology as "*a formal, explicit specification of a shared conceptualization*". This means on one hand that it needs to reflect a consensual, commonly agreed knowledge within a group of people, on the other hand that concepts and restrictions on their usage have to be defined explicitly and expressed clearly. Based on the application context of the ontology and the way of formalization, the following types can be distinguished:

"basic terms and relations comprising the vocabulary of a topic area as well as the rules for combining terms and relations to define extensions to the vocabulary" (Neches et al., 1991, p. 40.), or a *computer model representing a part of the world in the form of unique objects, concepts, relations between them, characteristics, attributes, restrictions, functions and rules* (Huhn-Singh, 1997 pp. 1). The approach of applying ontologies in their application environment is reflected by the definition of Corcho et al. (2003. p. 44.): *"ontologies aim to capture consensual knowledge in a generic and formal way, so that they may be reused and shared across applications (software) and by groups of people."*

In the process of ontology construction basically *a theory is applied to "which entities may exist in the mind of an intelligent person"* (Van Heijst et al., 1997 pp. 191) in such a way that the discovery and specification of the *"presumably existing objects, concepts, entities and relationships between them on a given domain of interest"* (Guarino et al., 2009 pp. 3) is made from the starting point of a consensual view of the world. It has to be noted here that the concept of ontology is more wide-scoped as the concept of taxonomy also responsible for organizing knowledge, as ontology also encompasses the description of concepts and objects (Sántáné-Tóth, 2006). Algebraic definitions of ontology can be found in chapter IV.2.1.1.

According to Guarino's (1995) approach, ontologies can represent general concepts independent from domains, tasks or application in the form of high-level ontologies; or, based on that, the description of the concepts of a specific activity, task or domain can be depicted; or the specialization of these both can be shown in the form of a task, domain or application ontology related to a specific area of application.

However, even when the higher education training programs are constructed with the agreement of the employment and education side (as an initiative aiming this was seen in the case of the National Vocational Qualification), originally formulated learning outcomes can change during the course of the training program – including the time needed for announcing the program and matriculation. When this situation occurs, the reconciliation between the two parties is not common at all. It can occur this way that the same competence is interpreted on the two sides in different aspects, in different context and by emphasizing different essential elements. This way, in order to realize the ontology-based comparison formulated as the goal of this research, mapping or formal specification of competence content available on both sides into two appropriate ontological structures was needed, then performing the investigation of fitting these ontologies to each other was also required. Afterwards, the analysis of the fitting of the elaborated system into the decision preparation process affecting current state of higher education was performed. Demonstration of the theory serving as the foundation of activities, as well as presenting the practical results is realized by following the development phases delineated in Chapter 1.

IV. Development of the information system

The hypotheses presented in Section 1 outline two development phases which form a sequential order and create separated system products met different requirements. This approach fits to the process of incremental system development. As Figure 4 presents, this development method states that each increment adds new functions to the preview increment (Sommerville, 2007 pp. 73).

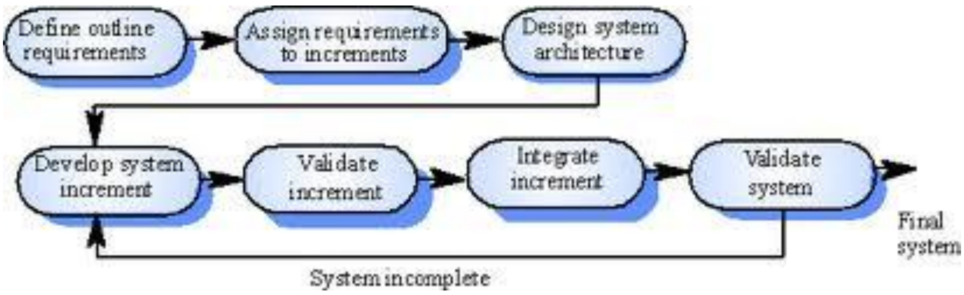

Figure 4. The process of incremental system development[7]

The Business Informatics degree program and the Software developer job role were chosen to underlie the prototype. This degree program runs at our department, so we can change its learning outcomes, if it is necessary. The developer role was needed in 25 % of the job advertisements appeared in October 2009 and October 2012[8]. It is a huge need, because only 13 roles appeared in 90% of the job advertisements. Although this degree program qualifies not developers primarily, but this role is enough needed to underlie the prototype.

The functional requirements related to the system were the next ones:

- collecting job requirements from the Profession.hu job portal in an automatic manner, extracting knowledge elements of them and forming these elements into Job Role Ontology in a self-automatic manner; formalizing the actual status into Learning Outcome Ontology;
- achieving the matching process between Competence classes or its subclasses of both ontology and evaluating the results.

[7] Source: http://www.robabdul.com/Data-Management-System-Software-Development-Cycle.asp

[8] This analysis will be appeared in a paper of the author, which will be publish by Vezetéstudomány in 2013.

IV.1. The first development phase: elaborating domain ontologies

Existing meta-models were modified to create domain ontologies. Learning Outcome Ontology was formalized based on sources representing Business Informatics degree program (like accreditation material or experiences of its lecturers). Job Role Ontology was formalized based on competences and its contexts appeared in job offers on Profession.hu, in order that the system has been capable of adapting the changes occurred in labor market.

Having designed and implemented meta-models in an appropriate ontology development tool and its ontology language, they were applied for a given domain, so instances were connected to the classes of these ontologies. Job Role Ontology was constituted from unstructured texts, so an ontology learning method, applying NLP (Natural Language Processing) techniques, served as basis to build this ontology. This ontology building process is presented in the next section.

IV.1.1 Researches to underpin the model building

The Competency Ontology (Draganidis-Mentzas, 2006 pp.4), the HR ontology (Mochol et al., 2004 pp.4), the Higher Education Ontology from SAKE project (Kő-Futó, 2008) and an extended version of Education Ontology Model from OntoHR project (Vas, 2007) (Kismihók et al., 2012) was investigated to serve as meta-models.

Draganidis and Mentzas (2006) elaborated an ontology-based competency management system to discover skill gaps of employees, or an organization in wider sense. Their system provided learning paths based on these skill gaps and supported other HR functions like succession or organization planning. Competency Ontology (Fig. 6.) consists of classes representing employees, jobs, departments, projects, skills and learning objects of an organization and classes being responsible for measuring the strengths of relationships between objects (for example <<SkillLearnObj_Lvl>> related to <<Skill>> and <<LearningObject>> classes and <<SkillRelated>> measured the gap between the skills of an employee and the organizational requirements related to his/her job profile. The ontology facilitated the interoperability of systems too.

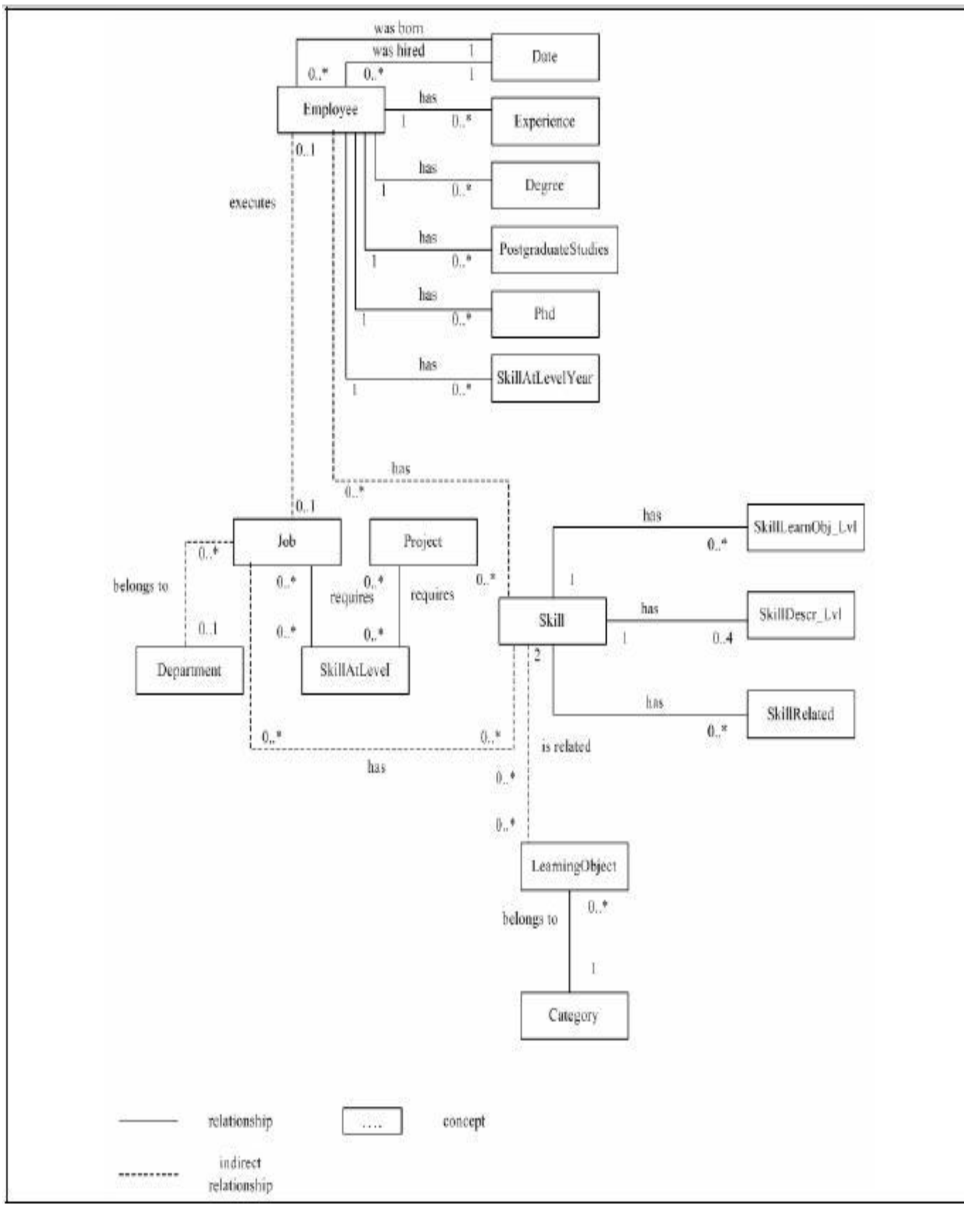

Figure 5. Competency Ontology (Draganidis és Mentzas, 2006 pp.4)

The HR Ontology created by Mochol et al. (2004) was used for matching the profile of a job seeker to a profile of job vacancy. They put competences into Competence Ontology and place them in organizational context with using <<Person>>, <<Organization>> and <<Industry>> ontologies. The competences of a person serve as building block to structure a job position or an advertisement. They calculated similarity measures between profile of a job seeker and organizational requirements to find the best match.

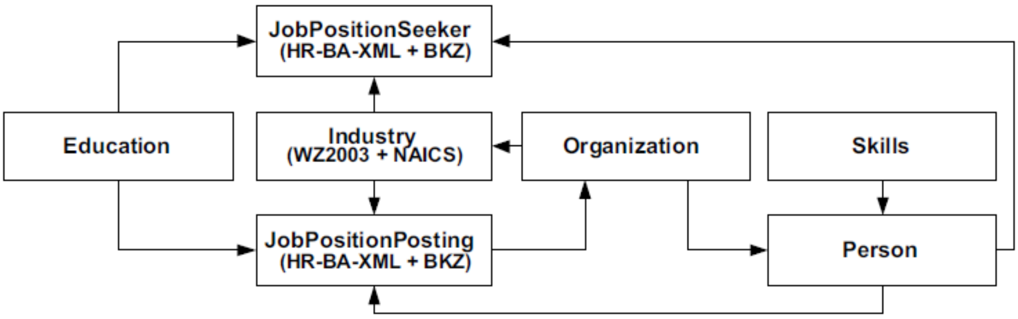

Figure 6. HR ontology (Mochol et al., 2004 pp.4)

The Higher Education Ontology was developed in SAKE project to facilitate the matching between both sides of labor market, as my research aimed this too (Kő-Futó, 2008).

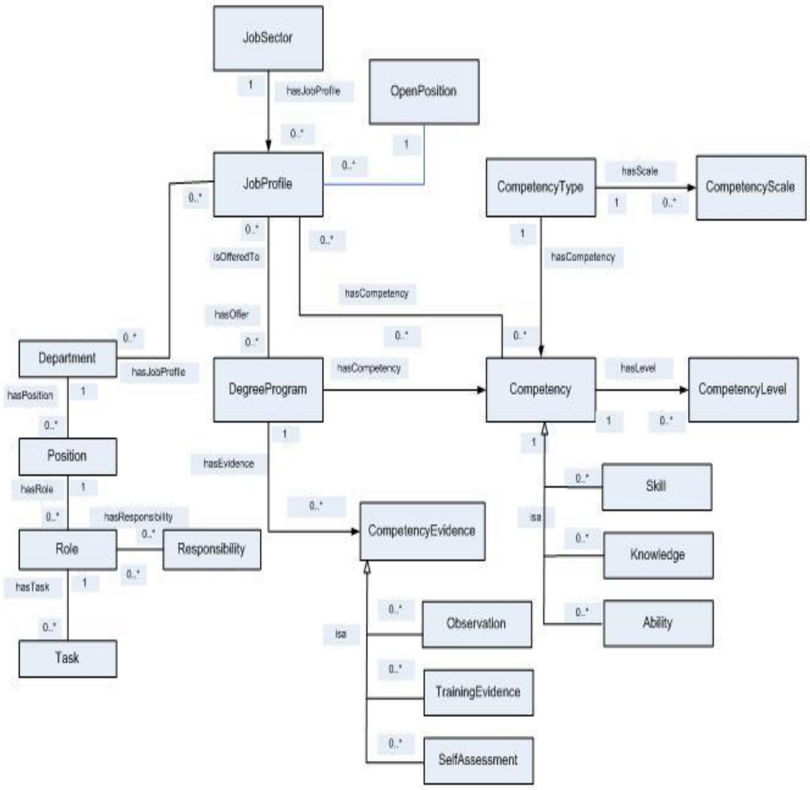

Figure 7. Higher Education Ontology

This ontology also placed competences into their context by connecting <<Competence>> to the path forming by <<Department>>, <<Position>>, <<Role>> and <<Task>>. The elements of competence were represented by <<Knowledge>>, <<Ability>> and <<Skill>> classes. The level and type of competences were showed by <<CompetencyLevel>> and <<CompetencyType>>.

One of the goals in OntoHR project was equal to mine in this research. The extended Educational Ontology (Kismihók et al., 2012) served as a basis for investing competences of both sides. Its first version (Vas, 2007) was used successfully in HEFOP-3.3.1-P.- 2004-09-0093/1.0. project (Gábor et al., 2008). This new version holds some novelty e.g. <<Mental ability>> classes representing a human psychologically.

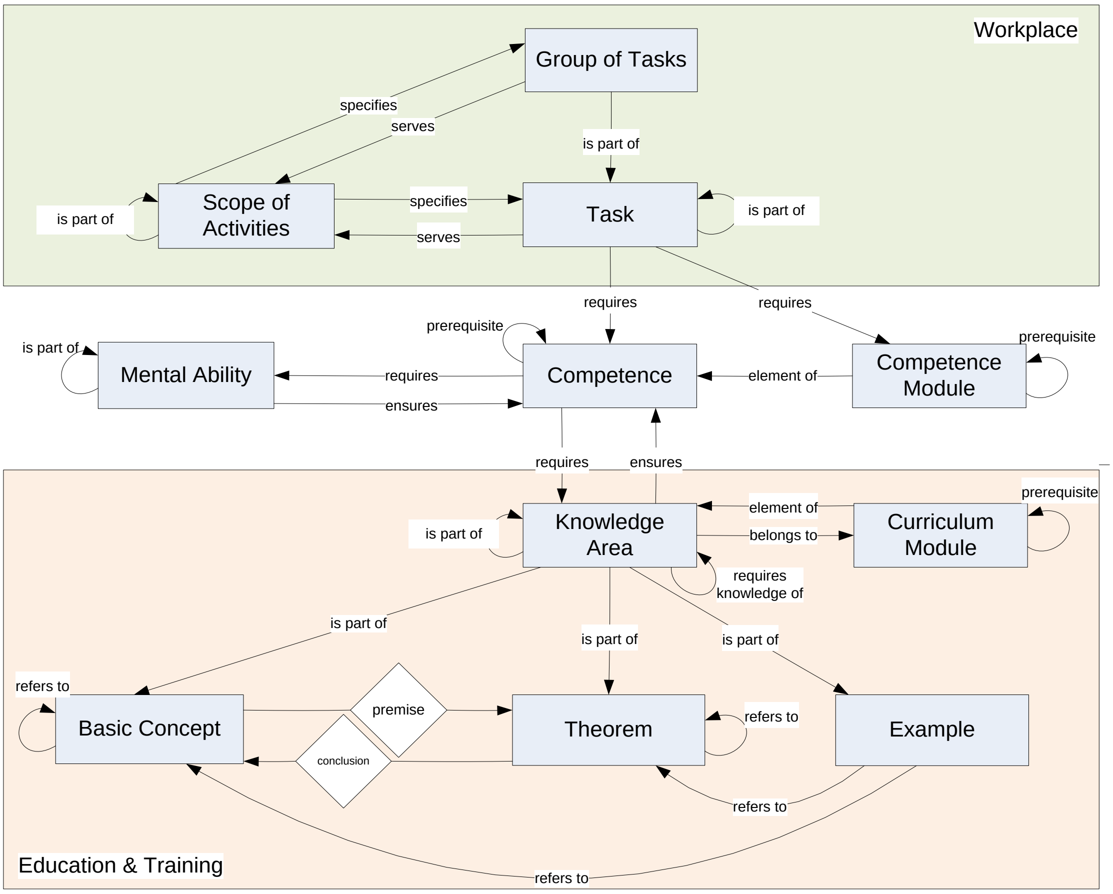

Figure 8. Extended Educational Ontology (Kismihók et al., 2012 pp.54)

The works of Draganidis and Mochol examined the competencies of employees in the light of the job requirements. This approach was extended in SAKE and OntoHR project. These projects wanted to identify the shortcomings of higher or vocational education learning outcome through matching a job role ontology based on competencies retrieved from the job role descriptions and a learning outcome ontology based on competencies extracted from the details of certain training program. SAKE concerned several ICT job profiles and Computer Economist degree program, whilst the goal of OntoHR was to build an ontology-based selection and training system based on Information System Analyst (ISA) job role whose extension dealt with the evaluation of the ICT degree programs. In these projects ontologies expressing job offers reflected a static moment of the requirements of labour market.

In SAKE, the job advertising documents were downloaded and tagged manually, in OntoHR, the ontology elements were extracted from the detailed descriptions of ISA job profile given by organizations (e.g. O*Net) or by projects concerned job analysis (e.g. EUQuaSIT). In the current research, a system was developed that was capable of formalizing job requirements d-erived from the job advertising websites into Job Role Ontology and matching this ontology to Learning Outcome Ontology which had been created from learning outcomes of Business Informatics Bachelor's degree program.

IV.1.2. Competence meta-models

In the meta-model of the Job Role Ontology, the Industry, Organization, Department and Position classes put the competences into an organizational context. Within an organization the business processes consist of tasks that roles and responsibilities belong to. In the backward direction, the Role as the parts of the Position class determines the entities of the Task and the Responsibility class. Competence(s) are required to execute a Task. The attitudes of the Competence class facilitate to execute the comparison at the appropriate Level, in the Period of Validity and in a given Region.

The meta-model of the Learning Outcome Ontology is an extended version of the OntoHR project's Educational Ontology by the Description of the Degree Program, as sources of the competences, and by the attitudes of the Competence class. The meta-models are presented by Figure 9.

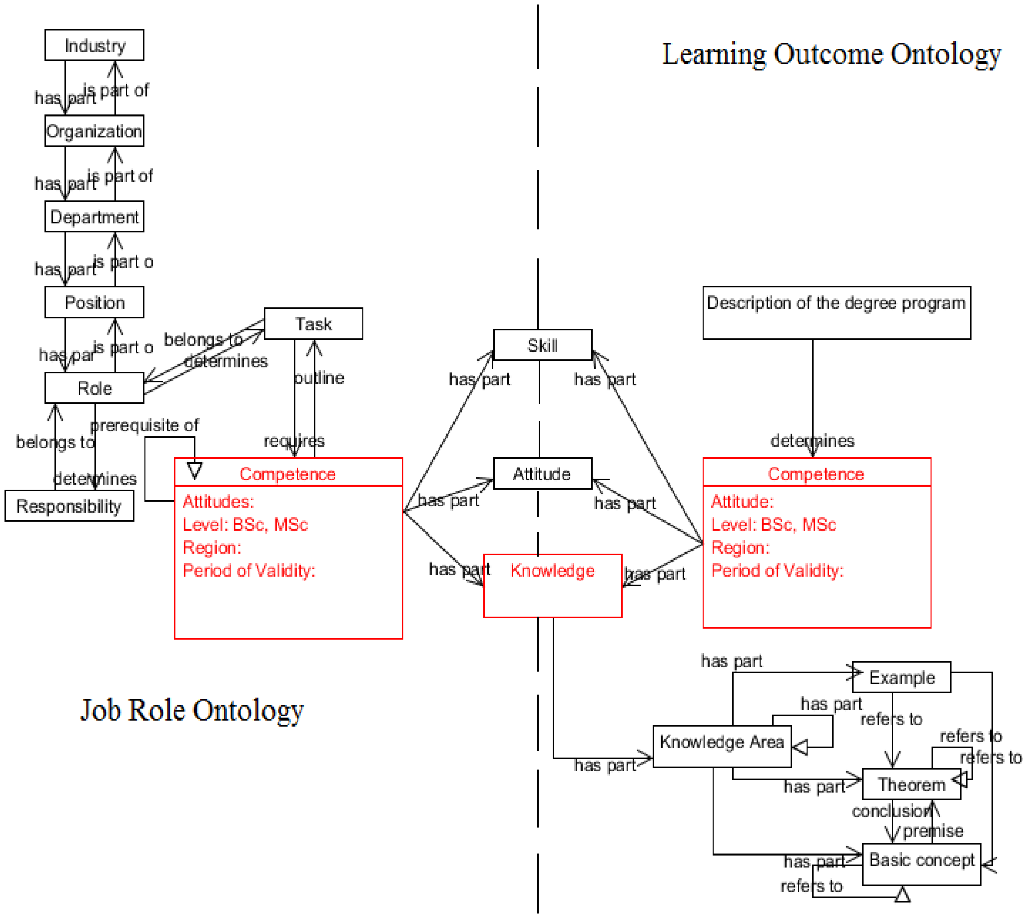

Figure 9. The meta-model of the Job Role Ontology and the Learning Outcome Ontology

The elements of competences mentioned in Chapter II (like Skill, Attitude and Knowledge) represent the basis of the comparison, but in the prototype we used only the Knowledge class as we will see in the next section.

IV.1.3. Tools for implementing the meta-model

Ontology language, ontology development tools and methods help to build ontologies. Noy (2004) stated that inference is a boosting tool for integrating ontology, so that ones were investigated, which facilitate to execute reasoning streams. The presentation of ontology development methods is not in my scope, because the meta-models were created based on merging existing ontologies.

IV.1.3.1 Knowledge representation methods and languages

It is necessary a knowledge representation method representing the above-mentioned conceptualization and a ontology language to formalize the meta-models.

Knowledge representation

This domain is a part of artificial intelligence, it means as „representing knowledge about a given domain for facilitating to solve problems related to this domain" (Futó, 1999 pp. 97). This representation is based on formalisms and inferencing on them. Formalism using knowledge representation techniques in data base management and object oriented systems is presented by Sowa (2000). In his interpretation, ontology and logic together facilitate to made a given domain understandable by computers (Shapiro, 2001). In the next section, representation methods and its ontology languages will be described for showing its role in ontology matching.

Logic based knowledge representation

First-order logic (predicate calculus) is capable of represent problems through assertions. It produces a flexible procedure to describe assertions with punctual syntax. The inference in predicate logic is exact and complete. It plays an important role in rule based inference engines or in semantic web (Fekete, 1999).

Propositional calculus uses logical operators to connect proportions with true or false value. First- order logic completes this formalism with usage of functions, predicates, constants, variables, universal or existential quantors. Second order logic already uses functions or relations as variables. Formulas reflect rather structure of assertions, instead of its semantics. The semantics of a formula can be revealed if its interpretation in all combination of true or false values added to propositional calculus is evaluated. The resolution is its theorem-proving procedure. Description logic is more expressive than first-order logic, it allows of more sophisticated inference procedures. It consists of concepts, roles and instances and its relationships. It enables to create new entities too (Sántáné-Tóth, 2006 pp.12).

KIF and Cycl ontology languages use first-order logic to represent entities. **Cycl** was developed in Cyc project to shape common sense knowledge into ontologies. It combines approx. 160 terms to interpret Cycl expressions. It uses constants, variables, formulas, predicates and microtheories. Microtheory helps to interpret the formula within its context (Su-Ilebrekke, 2006). It uses logical deductions (e.g. modus ponens) and inference mechanisms (e.g. inheritance) of AI for reasoning. It executes an optimization on a domain determined by microtheories and heuristics (Cycorp, 2011).

KIF is a formal language for exchanging information between programs. It provides declarative semantics, interpretation by predicate calculus and explicit decisions based on knowledge representation (Genesereth et al., 1992). The frame-based Ontolingua language was built on it.

These languages grounded for ontology mapping tools using ontology morphism (e.g. LOM, IF-MAP).

Rule based knowledge representation

The rule based knowledge representation follows the process of human thinking, so it plays an important role in AI. Rules serve as representing fact, relations, inferences and heuristics. They follows “If A, then B” format, where A represents the facts or logical assertions, and B means the connotation derived from them. Forward and backward chaining are the types of reasoning. These methods draw a path from starting point to end point up.

Taxonomic and non-taxonomic relations determine the structure of ontology. These relations can be formalized by rules. The comparison of two ontologies needs to apply rules. The main representatives of rule based knowledge representation – Prolog as logic programming language, Awk as text processing language and languages used in ontology reasoning (FaCT, Jess, SWRL) – will be presented in the next paragraphs.

Prolog was built on predicative logic for representing facts and rules as terms of relations. Facts expressed as predicates, whose arguments may be number or name constants. The query running against the database is either open or closed. The closed query wants to answer yes/no questions. The open query is formed as predicates, whose arguments are variables (Szeredi, 1999).

Awk is a text-processing language and scripting environment. It aims at processing text files, managing and indexing small databases, or executing other information retrieval tasks. Gawk is a version of Awk, implemented in GNU project. Gawk is to extract bits and pieces for data for processing, sort data and perform simple network communications. It matches the text lines with a given pattern appearing in /pattern/ syntax. If an appropriate pattern is found, it performs specified actions on that line, which are expressed in {actions} syntax. This algorithm ends, if it reaches the end of the input files. Actions can be formalized by functions, junctions, loops etc (Gawk, 2010).

Jess is a Java-based, rule based inference engine and scripting environment. Facts and rules can be declared, but functions can be used. Declarative rules provide to run queries, backward chaining. It is capable of creating Java objects, calling Java methods and implementing Java interface without complying Java codes. It syntax is similar to Lisp syntax (Friedman-Hill, 2008).

FaCT (Fast Classification of Terminologies) is a Description Logic (DL) classifier. It can be used for executing consistency checking on ontologies or classifying ontologies in automatic manner. It supports for reasoning with arbitrary knowledge base (e.g. ontologies structured by axioms). It is open source, Lisp-based system. It is built in ontology development environment (e.g. Protégé 4.X).

SWRL (Semantic Web Rule Language) improves the expressiveness of OWL by combining OWL DL and OWL Lite with RuleML. It models relationships of different relations. OWL axioms are extended by Horn-like rules. Rules are expressed as an implication between an antecedent and consequent (Horrocks et. al., 2004).

Ontology development environment (like Protégé 4.X) have built-in version of FaCT, SWRL or Jess. They can be used to check inconsistency on ontologies, versioning of ontologies or defining rules related ontologies etc. Awk facilitates to prepare documents for importing them into ontologies.

Semantic networks

The experiments of cognitive psychology implied that graph structure was used to store knowledge in human brains. It is a hierarchical structure, where attributes are assigned to their classes, not to their individuals.

Semantic network in knowledge representation is modeled as graphical, hierarchical graph.

“Data in semantic web is modelled in terms of directed labelled graph. Vertices of that graph represent entities and edges represent relationships between those entities”(Hassan-Quadir, 2011). Entities are defined as classes, properties or individuals. Classes are represented by sets. Relations can express is-a, instance-of relations or attributes. This representation allows classes to inherit properties and axioms from other classes. It supports reasoning by graph matching process to find correspondences between nodes and edges of the graph of facts and the graph representing the goal (Fekete, 1999).

“Some of the networks have been explicitly designed to implement hypotheses about human cognitive mechanisms, while others have been designed primarily for computer efficiency” (Sowa, 1992).

Frame-based knowledge representation

Frame-based knowledge representation gives an abstract description of semantic networks. The frames are symbolic models to describe entities. Classes are considered as prototypes of :Class meta-class, instead of sets. Individuals are created by adding values to prototype. Attributes can be shaped by relations, whose domain and range are frames, or by prototypes of :Slot meta-class, which are characterized by domain, range, constraint, default, inverse and inheritance features. Attributes can be expressed by equations.

The classes and individuals can be assigned more than one classes. The graphical hierarchical representation and the inheritance feature are inherited from semantic web based representation. Inheritance allows of representing knowledge (Fekete, 1999).

Ontology languages following frame-based knowledge representation

Ontolingua is a declarative, frame-based language, semantic and syntactical extension of KIF. It uses classes, relations, functions, objects and theories as building blocks to express statements. Ontolingua provides a mechanism “for writing ontologies in a canonical format, such that they can be easily translated into a variety of representation and reasoning systems” (Gruber, 1992). It provides high expressiveness, but no inference engine is built on it (Vas, 2007).

RDF (Resource Description Framework) was elaborated by W3C Consortium. It assignes semantics to document by standard meta-data structures, facilitating tranformation and query of documents. RDF triple (objet-attribute-property) serves as building block. RDF Schema is a vocabulary description language of RDF. It defines RDF data model by creating a vocabulary for RDF data, interpreting expressions based on it, providing modeling primitives (classes, subclasses, properties, subproperties). Properties can be ordered in hierarchy according to the definition of domain and range. It isn't capable of formalizing a data structure with different type properties etc., so more expressive languages have been evolved.

OIL (Ontology Inference Layer) provides formal semantics, effective reasoning and rich modeling primitives. It merges the advantages of XML, RDF, descriptive logic and frame-based systems. **DAML** (DARPAgent Markup Language)**+OIL** was built on RDFS (Fensel et al., 2002).

OWL Web Ontology Language is designed for processing documents, instead of just presenting them. It extends DAML+OIL by providing rich vocabulary to describe properties and classes (e.g. primitives for describing cardinality, equality, symmetry etc.).

It has three types: OWL Lite, OWL DL and OWL Full. They use the same vocabulary, but with increasing expressiveness:

- OWL Lite supports for creating classfications and simple constraints.
- OWL DL provides a reasoning mechanism with maximal expressiveness for concluding in finite time.
- OWL Full furnishes maximal expressiveness with RDF syntaxis, without aiming at computability.

OWL 2 is an extension of OWL-DL, required by researchers. It contains two new constructors (DisjointUnion, NegativeObjectPropertyAssertion or NegativeDataPropertyAssertion) to express assertions simply or to formalize user-definied data types etc (OWL Working Group, 2009).

The declaration of the two domain ontologies in abstract language had to be based on such representation methods that follow our propositional thinking (see in Section III.1) about this domain supremely. Different methods are required by the development stages. The ontology building needed to apply frame-based logic, but the ontology matching required the application of logic-based approach. So the compatibility of these methods had to be investigated. The chosen ontology development environment determined the applicable ontology languages.

IV.1.3.2. Ontology development environments

The appropriate ontology development environment allows of importing ontology elements from texts into the meta-ontologies for creating the domain ontologies and executing a matching process between them. Several environments were available, but a few envirommments with built-in inference mechanisms proposed by Vas (2007) were investigated by me.

Four ontology development tools – *PowerLOOM*[9] *including Ontosaurus*[10], *OntoStudio* [11] *instead of WebOde, Protégé 3.x/4.x*[12] *and KAON2* [13] *used in SAKE project* – were examined by general characteristics or features for importing data or executing ontology matching process automatically.

The *general features* included the name of development organization, version number and functions of the tool, and the ontology languages used by the tool.

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9 http://www.isi.edu/isd/LOOM/PowerLoom/

10 http://www.isi.edu/isd/ontosaurus.html

11 http://www.softpedia.com/get/Science-CAD/OntoStudio.shtml

12 http://protege.stanford.edu

13 http://kaon2.semanticweb.org/

	Development Organization	Version number	Functions	Language
PowerLOOM	ISI, University of Southern California	PowerLoom 4.0 beta (2012)	Logic-based representation language and development environment for intelligent and knowledge-based systems	KIF-based language
OntoStudio	Ontoprise GmBH	3.2 (2012)	Graphical rule editor, automatic data importing and mapping tool for creating and maintaining ontologies	ObjectLogic, OWL, RDF
Protégé	SMI, Stanford University	Protégé 3.4.6 (April 2011)	Tools for developping and modeling ontology-based systems, supporting its user community continually	Languages related to frame-based representatio n: OWL Lite, DL, Full, RDF(S), XML
		Protégé 4.1, 4.2 (May 2011/ July 2012)		OWL 2.0 RDF
Kaon2	FZI Research Center & AIFB Institute, University of Karlsruhe IPE Information Process Engineering	29.06.2008 (2008. június)	Ontology management infrastructure for business applications Ancestor of KAON	OWL-DL, SWRL, F-logic

Table 3. General features of ontology development environments

Automatic data import were investigated by

- open source code: this ensures the usability of the tool in long term period.

- documentation: this facilitates to transform and improve the tool.
- supported import file formats: what document format can be handled by the tool. The source documents may be transformed by using document processing tools (like gawk etc.) into the required format (e.g. XML).

	Open source code	Documentation	Import file formats
PowerLOOM	yes	user guide, tutorial, Javadoc	Flat databases
OntoStudio	three month trial version	video presentation, online help	UML 2.0 Database schemas (Oracle, MS-SQL, DB2, MySQL) Excel spreedsheets Outlook e-mails
Protégé 3.x	yes	user guide, tutorial, Javadoc	XML, RDF(S), XML Shema, JDBC/ODBC database by DataMaster plugin Excel
Protégé 4.x	yes	user guide, tutorial, Javadoc	n.a. (depending on file formats required by a new plugin)
Kaon2	for research goals	Javadoc, samples	OWL XML Presentation Syntax, OWL RDF Syntax

Table 4. Automatic data import

The process of ontology matching was studied by next features:

- modularity, extendibility: this feature is necessary for improving the original source code.
- built-in reasoner: how can this reasoner run a new algorithm?
- existence of a built-in ontology matching procedure.

	Modularity, extendibility	Built-in reasoner	Built-in ontology matching procedure
PowerLOOM	Modular with programs written in Java, but it uses own language too (Stella)	Facts and rules stored in knowledge bases serve as a basis for forward or backward chaining	n.a.
OntoStudio	extendable by plugin	Built-in F-logic inference engine and its rule editor	yes
Protégé 3.x, Protégé 4.x	Modular with programs written in Java, extendable by plugin	depending on the built-in reasoning system (Jess, FaCT or SWRL etc.)	by Prompt plugin by OWLDiff plugin or Compare Ontologies built-in function
Kaon2	Modular with programs written in Java and runable from Protégé	conjuctive quereis based on SPARQL syntax	n.a.

Table 5. Automatic matching

Although Ontostudio has built-in ontology matching procedures and it is extendable by plugins, the non available source code and the dependency on license made difficult to customize this tool – e.g. for handling the Hungarian language or importing downloaded documents in automatic manner – in change management.

The open source programs are extendable or improved by a Java program or a plugin-in to execute matching procedures or import data automatically. Protégé 3.x and 4.x have much functionality, but 4.X can handle OWL 2, so this tool and its knowledge representation method were chosen to implement the meta-models. For the creation of domain ontologies, new classes were added to the meta-models by extracting new knowledge from documents and other sources represented each side of the labor market.

IV.1.4. Structure of qualification based on Learning Outcome Ontology

The learning outcomes of the above-mentioned degree program have not been changed since 2005 and they are written too general in related documents, so **the structure of qualification as a specialization of Learning Outcome Ontology** was created by experiences of teachers. The improvement of skills is not so stressful in this degree program, so we rather focused on knowledge areas (see in Figure 11) in the process of extending the meta-model of Learning Outcome Ontology. This competence element is measurable better than the other ones.

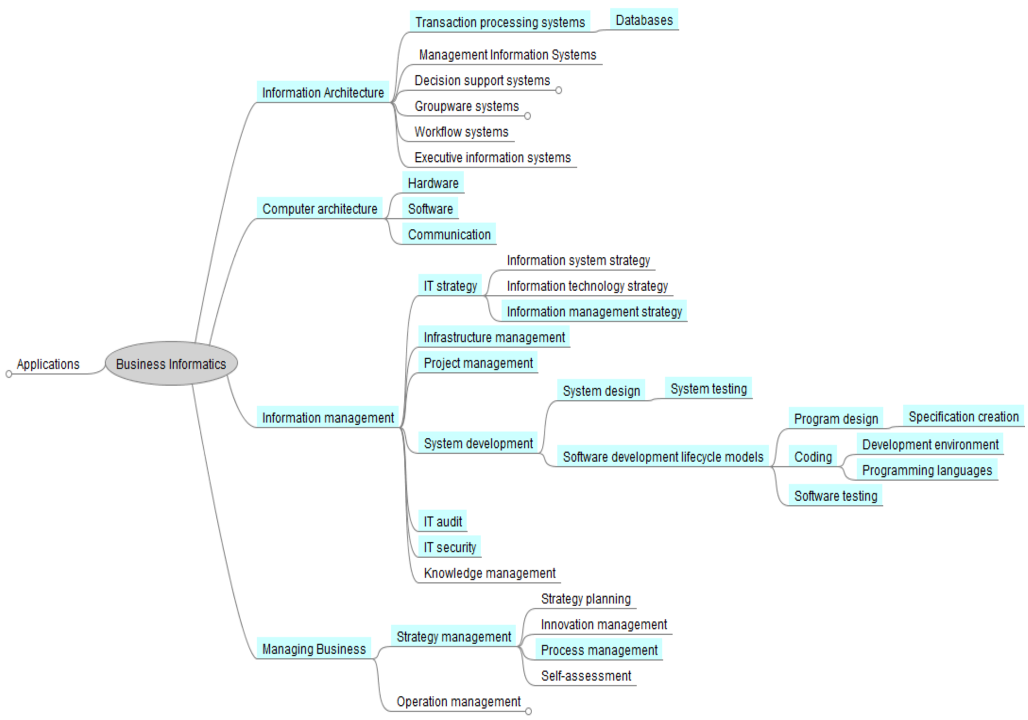

Figure 10. Knowledge areas in Business Informatics

The implementation in Protégé 4.1 and adding individuals to classes are presented in Figure 12 (See in Section IV.1.5.3).

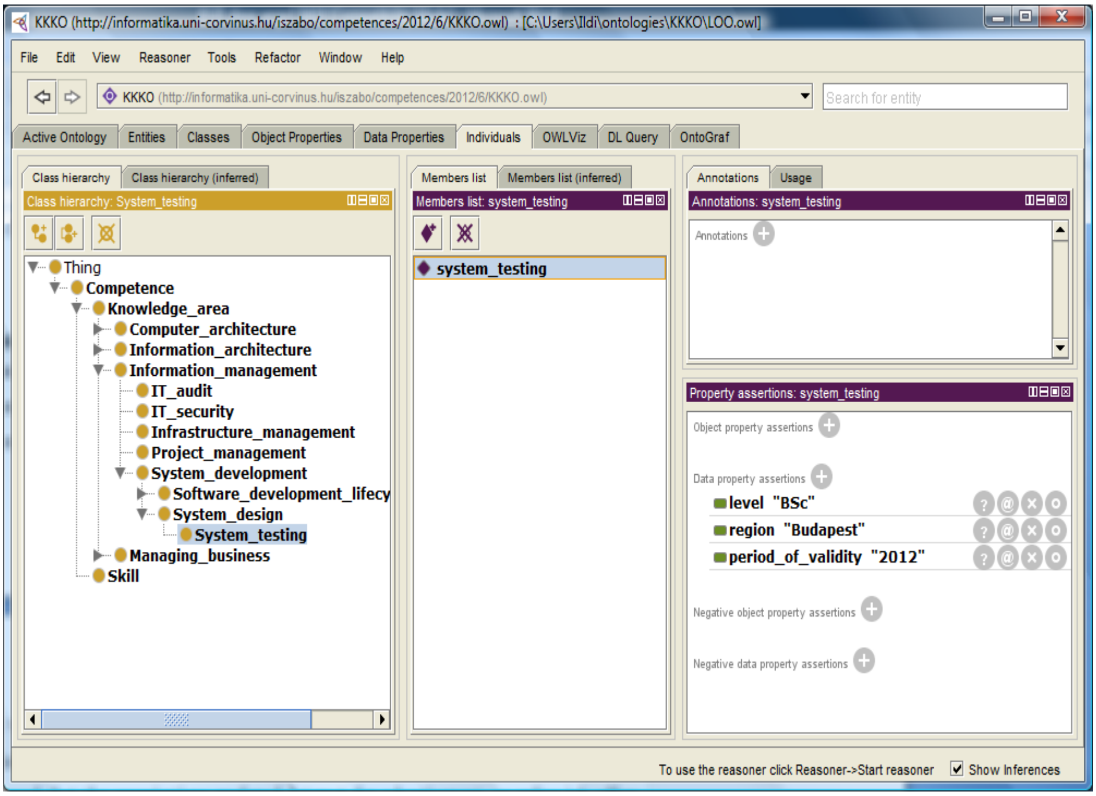

Figure 11. LOO ontology in Protégé 4.1

IV.1.5. Structure of occupation based on Job Role Ontology

The organizations need to prepare themselves to adapt successfully to a rapidly changing environment. Job roles follow these changes. The online job offers are easy accessible and contain information about job roles, so **the structure of occupation as a specialization of Job Role Ontology** was created based on them. It wasn't in the scope of this thesis to examine whether a collection of them was representative. But two researches (HRToborzás, 2011) (AllasTrend, 2009) showed that the organizations had preferred Internet for advertisement, so online job offers seemed to be a good source. From September 2009, a Java crawler was used to download job advertisements appeared on Profession.hu, as popular Hungarian job recruitment portal, in IT/Telecommunication category (IT Development/Programming category from September 2012).

Job offers contained the next information:

- position name
- company profile
- responsibilities/tasks

- necessary abilities and skills
- advantage and preferred skills
- offers by organization
- location
- position/sector
- way of application

The position names were very diverse. It would have been difficult to add them to a TEÁOR (Unified sectoral classification system of economic activities in Hungary) or an ISCO (International Standard Classification of Occupation) category. But the names contained references to roles related to the job roles.

The files downloaded in October 2009, between August 2010 and September 2010 and in October 2012 served as a basis to reveal these roles. The results are presented by the next tables and figures.

Year / Role	2009	2010	2012
administrator	30	11	43
operator	19	15	15
developer	135	182	252
manager	66	79	96
engineer	70	104	107
consultant	28	23	33
expert	41	39	75
analyst	30	39	51
system administrator	16	17	11
customer service	61	86	105
technician	4	8	9
tester	29	40	52
architect	4	25	12
otther	55	66	49
∑job offer	484	621	817
∑role	588	734	910
Developer/∑role	23.0%	24.8%	27.7%

Table 6. Frequency distributions of roles

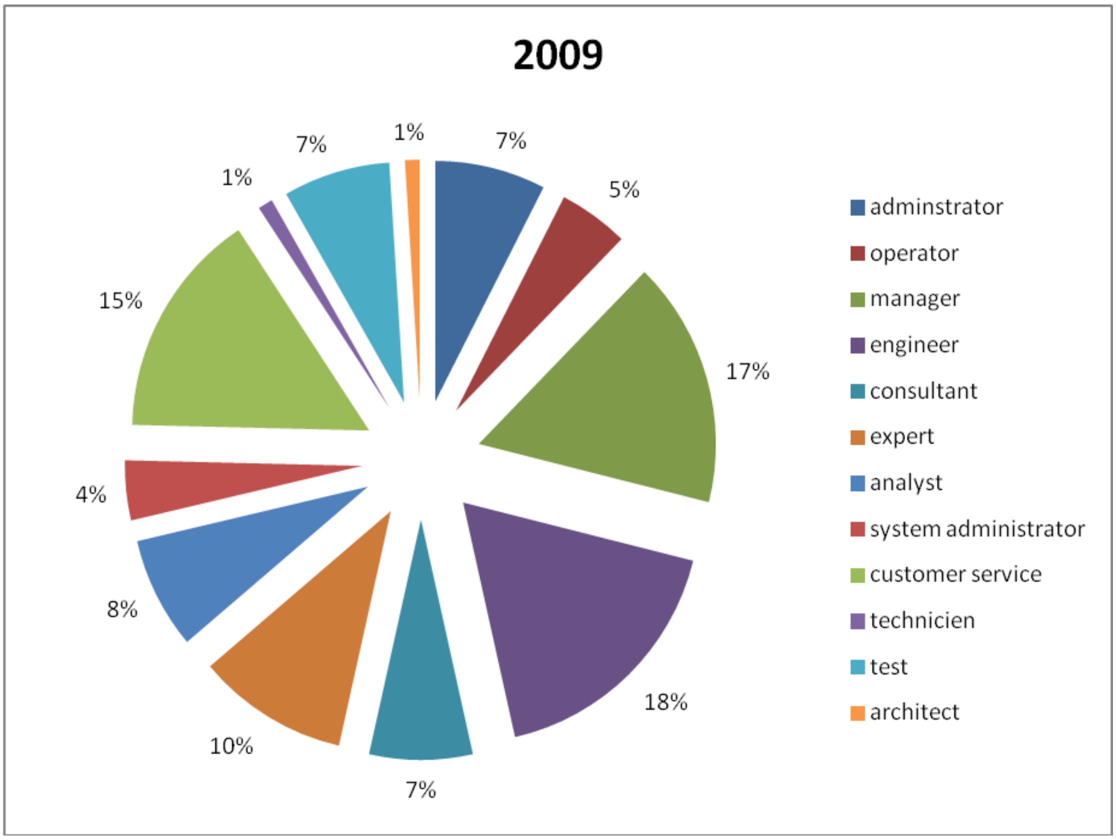

Figure 12. Required roles in October 2009

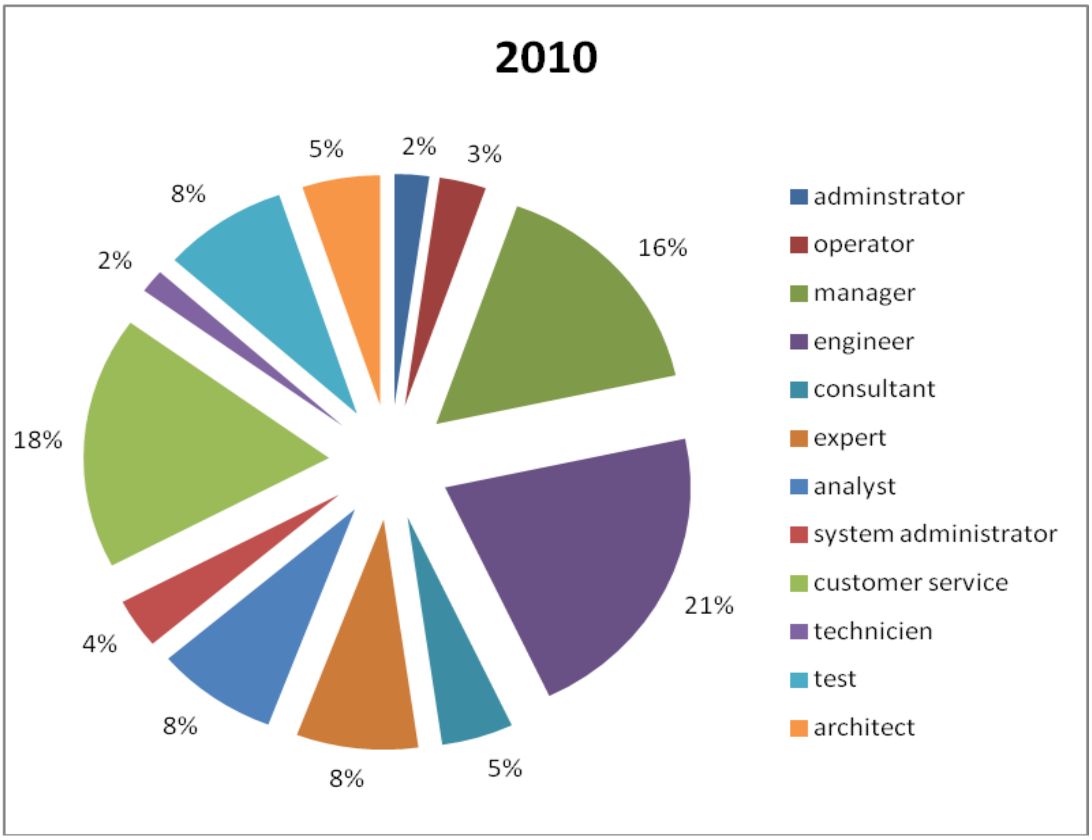

Figure 13. Required roles between August and September 2010

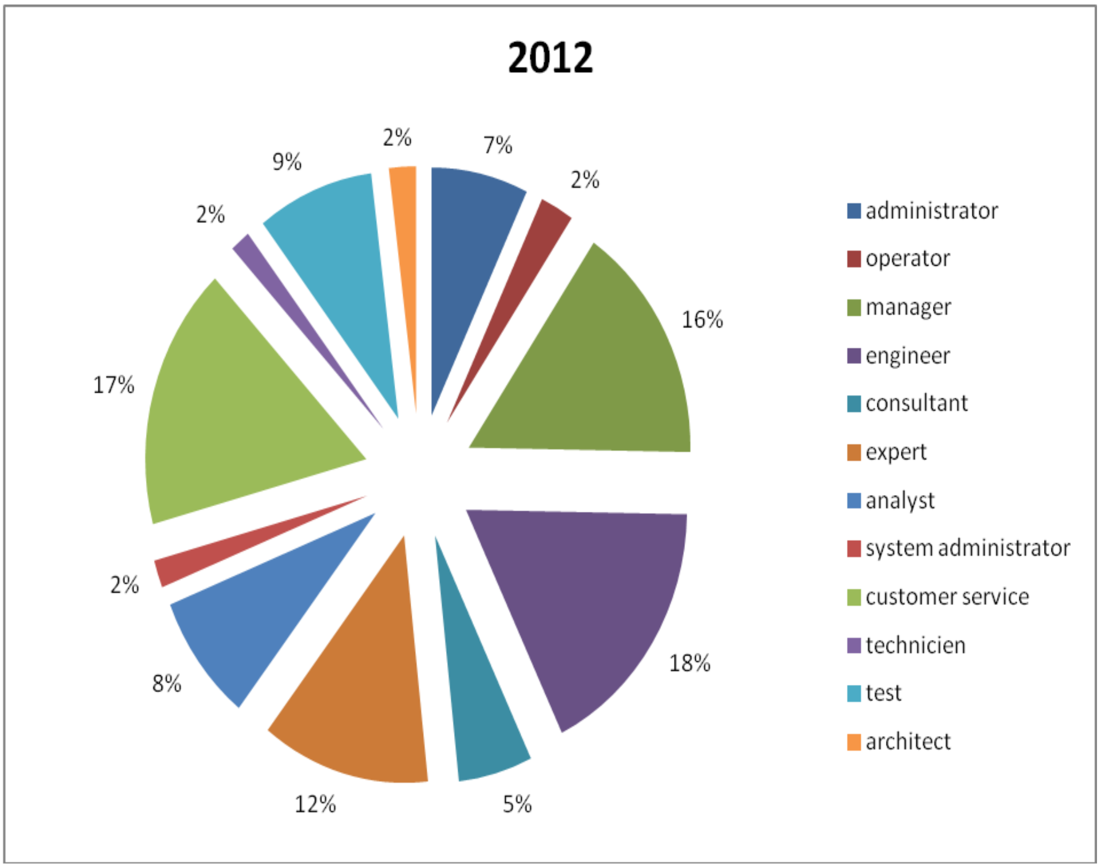

Figure 14. Required roles in October 2012

The developer roles represented the quarter of roles. The frequency distributions of other roles showed that the percentage difference were varied between 1% and 3% periodically, except of architect and administrator roles. The ratio of roles and job role were at least one, so job roles could contain at least one role. So the labor market moved less.

The appearance of knowledge elements (e.g. programming languages) and the depth of necessary experience (junior etc.) in job offers implied that job roles were shaping flexible and its boundaries would be removed (Lawler, 1994).

Not just the diversity of position names, but the file format of job offers caused a little problem in the course of implementing the meta-model of Job Role Ontology.

IV.1.5.1. The implementation of JRO meta-model

The classes related to the software developer job role served as a basis for creating the prototype that were implemented in this phase (see in Table 7 and Figure 15).

Class	Subclass
Position	Software developer
Role	Developer role
Task	Designig software development process Creating specification Program coding Program testing Creating program documentation Bug fixing Integrating systems Collaborating with people

Table 7. Classes related software developer position

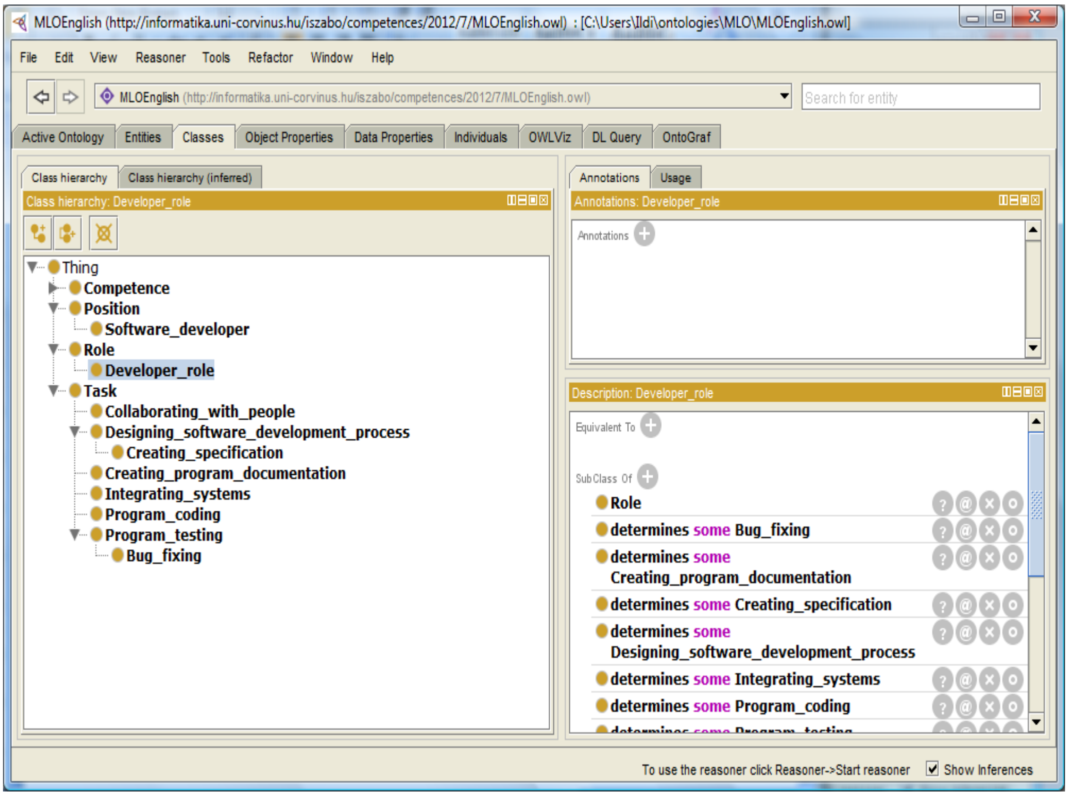

Figure 15. Extended meta-model in Protégé 4.1

IV.1.5.2 Adding new classes to this meta-model from job offers

The files downloaded by the above-mentioned crawler between 27th December 2010 and 10th April 2011 served as basis to build the first version of JRO ontology.

Two tools were taken into consideration as crawler. One of them was Google Spreadsheets' ImportXML("URL";"query") function which is capable of importing websites' texts or attributes related to a given tag. Its query is an XPath query to run on the data given at the URL. For example: =ImportXML("http://www.profession.hu/hu/allas/it-specialist-nokia-komarom-ltd-komarom-381376/sponsored";"//table/tr/td[@class='nokia_adv_szoveg']/ul/li") shows all texts which are between <table><tr><td class="nokia_adv_szoveg"> tags.

The second tool was programming in Java. Job advertising sites became downloadable in automatic manner by using some objects and functions in java.io and in java.net packages.

In summary, the usage of Google Spreadsheets function was the simplest way to retrieve data from XML, HTML, CSV, TSV file format and to import them into excel file. But it downloads all texts that satisfied queries and not only the specific ones e.g. related to the job requirements. Moreover the URL had to be given manually, so its usage lost its simplicity. And it was not able to handle Hungarian letters, whilst the enormous part of the advertisements was in Hungarian. Java program was chosen as crawler. It has been downloading job offers since 2009 and collecting their links and other information from them (company name, position name, location, publication date) in an excel file. It downloads job offers advertised in the previous month.

The XHTML format of files and the customized contents of advertisements caused some trouble (Szabó, 2012).

Problem	Solution
In one month approximately 500 advertisements usually born. Among them, there were several identical documents or documents showing few discrepancies (for example the contact person's name).	DOS Batch program found the same files, left one file of them and delete the others.
HTML tags didn't refer to its content. (For example: Requirement(s):)	Searching another patterns. For example: blocks assigned by colon.
The "requirement:" block was missing of certain job advertisements. If they existed, they contained only little information about competences.	The most job advertisements contained task description block, so competences had to be assigned to tasks (e.g. based on the knowledge elements of The Open Group Architecture Framework, an

	Open Group standard) (OpenGroup, 2009).
The useful information were between <!--hirdetes start--> and <!--hirdetes stop--> tags in 83% of files.	This information must be extracted by a text processing tool.
The documents were in XHTML formats, which were unstructured and customized by advertisers. It was ambiguous to process them.	After identifying the task: block it was necessary to create an output that can be processed by Java.

Table 8. Problems caused by file format or customization

The next figure presents the text processing process.

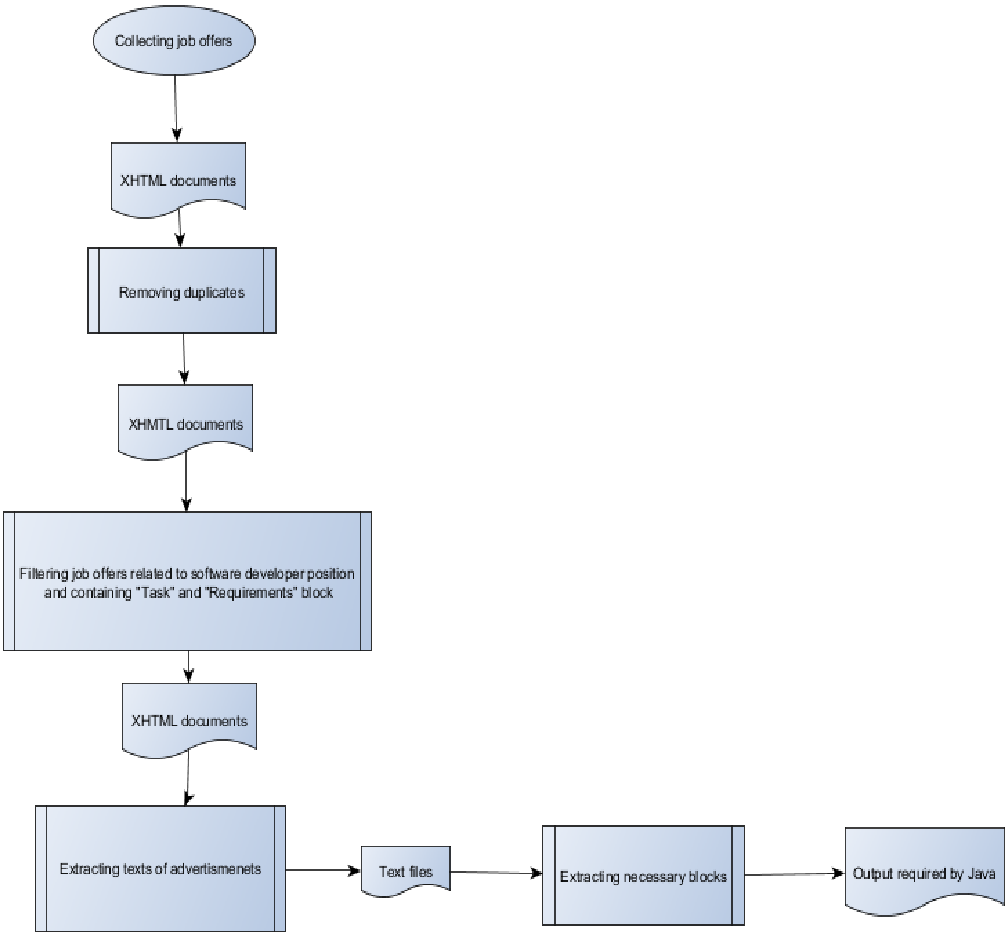

Figure 16. Process of extracting texts from XHTML files

I had to use document processing tools (DOS Batch files, gawk and gsar scripts, JAVA programs) to transform their relevant contents of documents into an appropriate format, which was Excel file format due its transparency.

Having run this process, just 10,76% of the downloaded files remained useful from 2787 files. This meant important information losing, due to unstructured file formats and unstandardized contents.

The excel file consisted of 280 rows and 1414 tasks or task group, depending on the content of a row in a job offer. This kind of output was used to extend the meta-model with new classes or to add individuals to classes in a latter development phase.

IV.1.5.2.1. Ontology learning

The objective of ontology learning is “to generate domain ontologies from various kinds of resources by applying natural language processing and machine learning techniques” (Haase-Völker, 2008). We can distinguish statistical, rule-based or hybrid ontology learning technique. The pattern-based ontology learning technique is one of them (Zhou, 2007). Having examined the downloaded job offers, it seemed that possessive cases (e.g. implementation of SAP systems) were used to express tasks mostly. So possessive cases were used as patterns for elaborating a dictionary to extract knowledge from the texts of job offers. The dictionary consisted of open queries (like queries in Prolog) and typical words (Table 9). The knowledge extraction algorithm collected the typical word and its two-word environment and discovered words by open queries in the next steps:

- To search expressions as patterns to describe a task (for example task – Collaborating with people, expression: relation with customers or task – Designing software development process, expression: design of an embedded software);
- To use these expressions like open query (for example (relation with; who) or (design of, something));
- To search the given words of open queries (e.g. relation, design) in the job advertisements and nouns forming an expression with its preposition (e.g., with or of). Depending on the position of these words in the text, these nouns were accepted or rejected as appropriate words.

Having executed this algorithm, the found expressions (e.g. relation with customers, or design of application) or the text environments of typical words were placed into Job Role Ontology as subclass of their related class. The text mined by algorithm was put into it as their comments.

Class	**Typical words and its lems**
Designing_software_development_process	design
Creating_specification	specification
Creating_specification	specify
Program_coding	develop
Program_coding	code
Program_coding	programming language
Creating_program_documentation	document
Program_testing	testing
Creating_program_documentation	documentation
Bug_fixing	bug
Integrating_systems	integrate
Integrating_systems	integration
Collaborating_with_people	connection
Collaborating_with_people	collaborate

Table 9. Dictionary used in ontology learning

Having executed this process, 18,6% of 1414 tasks appeared in the job advertisements were processed. The filtering of software developer job offers from the collection wasn't too punctual, because there were implications for other roles in the remained files.

	Summary	Found
operation	98	12
project	120	14
system administrator	11	0
maintain	63	5
sale	11	0

Table 10. Words related to other roles

SPSS Clementine text mining tool served as complementing the dictionary with new words or open queries. Its advantage was to possess built-in Hungarian dictionary, so it provided hungarian lems and their frequencies (see in Annex 1) after executing text mining process. Other tools used in education – Gate, RapidMiner, SAS Textminer – didn't produce this result. I extended the dictionary with relevant, most frequented word presented by SPSS, current programming languages and tasks related to teaching or database management. Having added new elements to the dictionary, 33% of tasks were processed. The Protégé ontology is presented by the next figure:

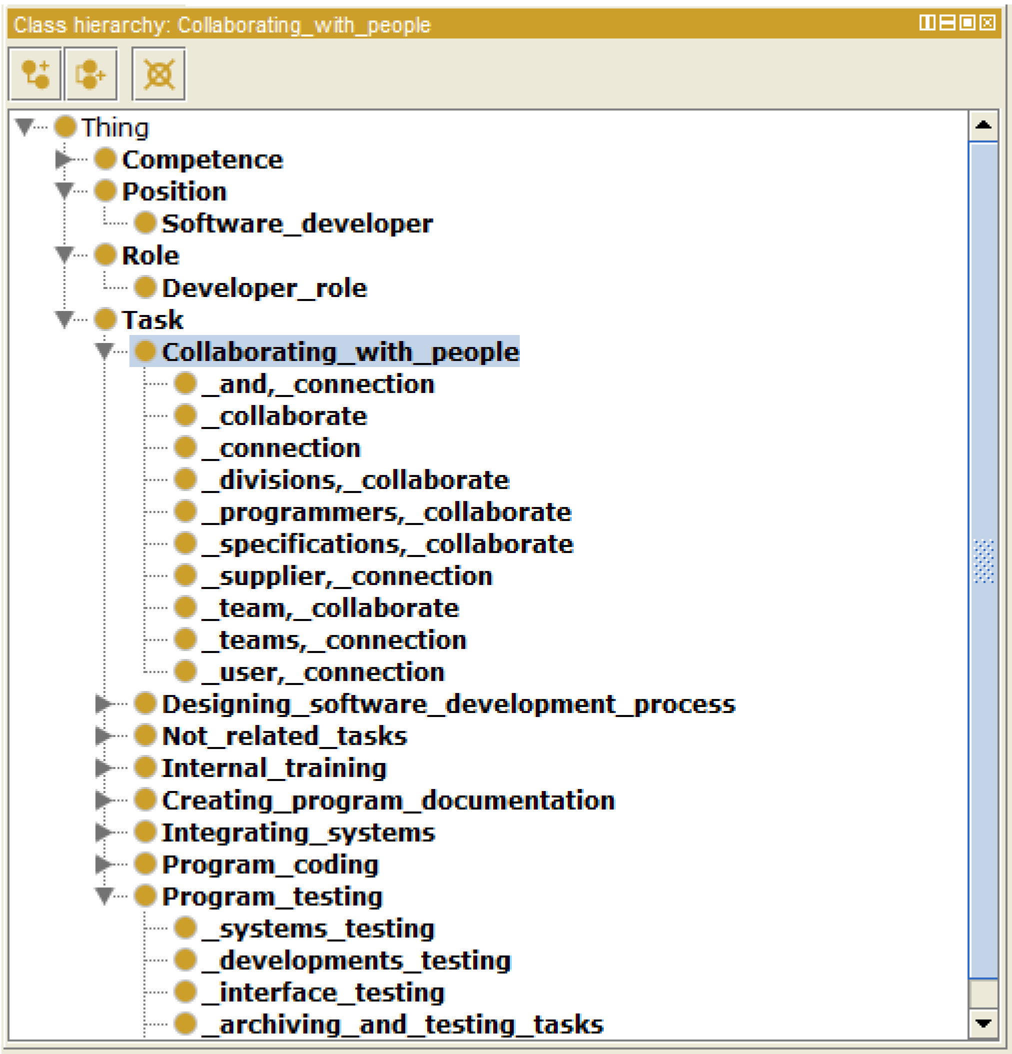

Figure 17. Extended Protégé ontology

Due to the new tasks (e.g. teaching) a new class – Internal training – was inserted into the ontology manually. Tasks not connected to the software developer role were grouped in the Not_related_task class. The algorithm added 405 new classes as subclasses to the ontology (see in Annex 2). The utility of algorithm was investigated by features in the next table:

	Number of sublasses	Belongs to other classes too	Deleted	Moved	Ratio of movement
Internal training	21	1	1	16	76.2%
Designing software development process	208	11 (1)	11	74	35.6%
Creating specification	50	4	7	5	10.0%
Program coding	36	4	6	4	11.1%
Program testing	22	2 (1)	3	1	4.5%
Creating program documentation	28	1 (1)	2	6	21.4%
Bug fixing	25	0	1	7	28.0%
Integrating systems	12	3	0	1	8.3%
Collaborating with people	18	0	7	2	11.1%
Summary	420	1 ->3;13->2	38	116	27.6%

Table 11. Evaluation of the algorithm

The expressions described 91% of new classes well, but the algorithm placed 27,6 % of new classes into wrong place. In the future new open queries, instead of new words, related to the appropriate class must be inserted into the dictionary that can improve the hit rate.

New subclasses brought new information that served as a basis for restructuring the ontology before assigning competence elements to its subclasses of Task class (Figure 18).

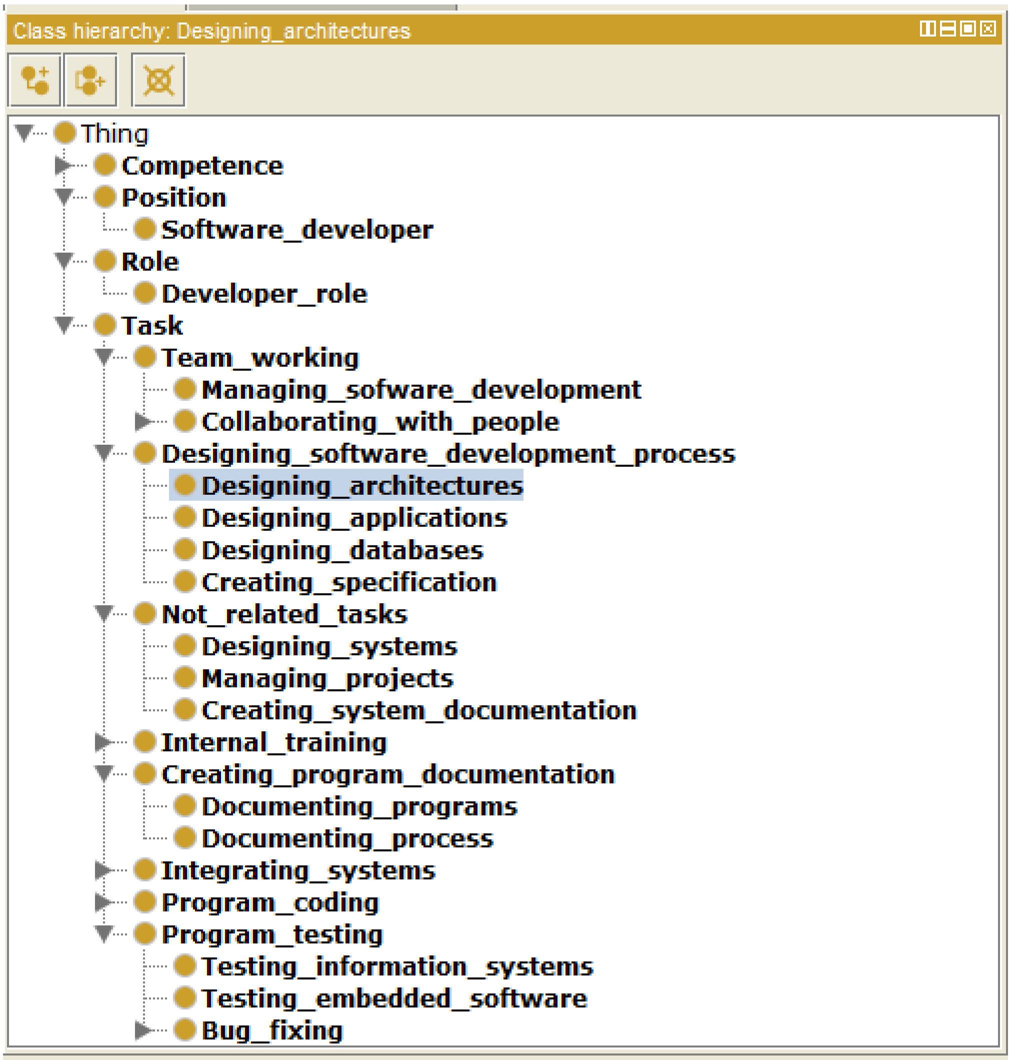

Figure 18. Hierarchy of Job Role Ontology

IV.1.5.2.2. Adding new elements to the Knowledge class

The advertisers describe the required competences slightly in many cases. Having cleaned the ontology by an expert, the competence elements (mainly the knowledge elements) of The Open Group Architecture Framework (OpenGroup, 2009:694-699) were assigned to the appropriate Task subclasses in manual or semi-automatic manner. The TOGAF is an industry standard, so it reflects the requirements of organizations for Enterprise Architecture job role including the Software Developer role too.

The program can be extendable by an algorithm, which can examine in what measure the TOGAF knowledge elements cover the actual requirements appeared in the job offers (for example Generic knowledge in Unix / Linux, AIX or Windows).

The Open Group Architecture Framework (TOGAF), is an Open Group Standard, to prove methodology and framework for creating enterprise architecture from four viewpoints like business, data, application and technology. Qualified training programs are announced by Open Group Certified Architect Program (TogafCA, 2012). The Enterprise Architecture role was the mostly related role to software development role.

The third-level and fourth-level knowledge and skills of persons playing role as Enterprise Architecture are presented in the next table.

Domain	Competence	Type of competence
Generic skills	leadership, **teamwork, inter-personal, logical analysis, oral and written communicationsd**	Skill
	stakeholder and risk management	Knowledge
Business Skills & Methods	**business case, scenarios, processes, functions, and metrics** strategic planning (visioning, strategy plans, budget management, organization)	Knowledge
Enterprise Architecture Skills	**Process management (business modeling, business process, role design, organization design)** data design systems integration **systems design (services design, solution modeling, architecture-, application design)** **building block design** **IT industry standards** **system behavior** **costs/benefits analysis**	Knowledge
Program or Project Management Skills	program-, project-, change- and value management and managing business change	Knowledge

IT general knowledge skills and technical skills	**system development(** **IT application development methodologies and tools** **programming language** **brokering applications** **Web-based services** **Information Consumer and Provider Applications** asset management **IT Operations (SLA-k, infrastructure)** **utilities** **systems** Migration Planning **Enterprise Continuums** **COTS softwares** **software engineering** **security** systems and network management **transaction processing** International Operations data interchange, data management operating system services, network services, communications infrastructure	Knowledge
Legal Environment	data protection law, fraud	Knowledge

Table 12. Competences of Enterprise Architect

Competences of software developer role determined by this table are presented by texts with blue background.

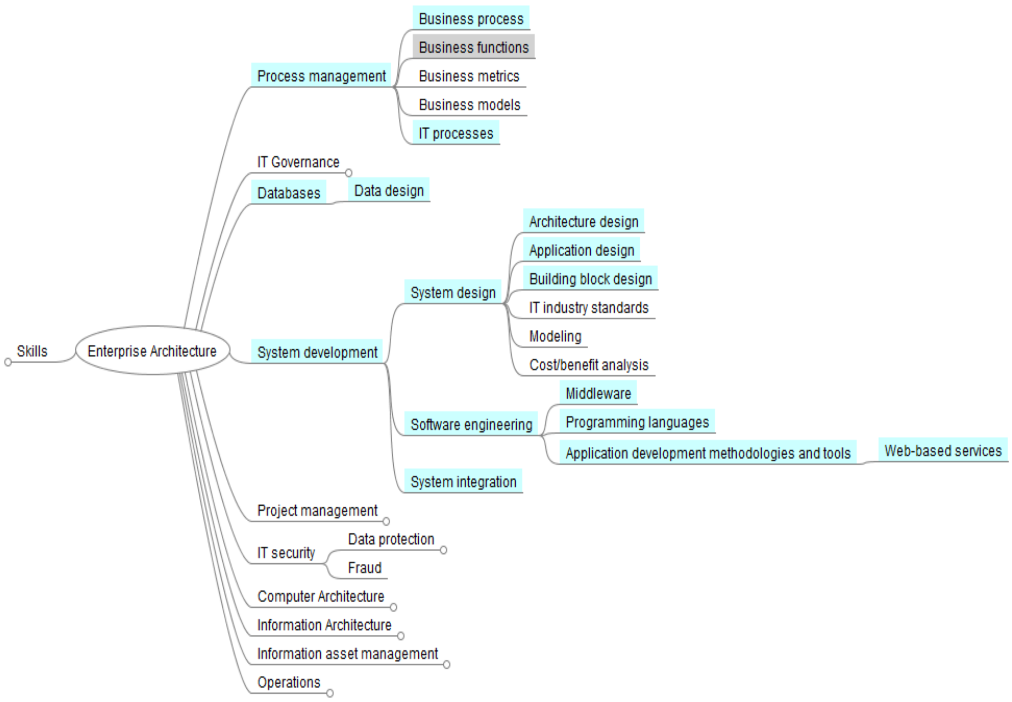

Figure 19. Required knowledge of Enterprise Architect role

We focused knowledge areas in this research (see in Section IV.1.4), so there were assigned to the Task subclasses directly, instead of the Competence classes. Having implemented these knowledge elements in Protégé, instances were inserted in the JRO and LOO ontologies.

IV.1.5.2.3. Inserting instances in the JRO and LOO ontologies

Having created the first version of Job Role Ontology and Learning Outcome Ontology, the instances of their classes were created. As I mentioned it earlier, the matching process was planned to execute through the Knowledge class. The instances of this class were represented by the level, region and period of validity attributes. The instances of LOO ontology had Budapest as Region attribute, BSc as Level attribute and 2012 as Period of validity attribute. In October 2009 and October 2012, 74% of the advertised jobs are required in Budapest. Considering the willingness of people to move, these attributes characterized the Business Informatics degree program of the prototype well.

A collection of job advertisements downloaded in October 2012 served as a basis to create instances of Competence class of JRO ontology. The algorithm extracted tasks from this collection, and searched the related Task class in the ontology using a version of the above mentioned dictionary. This algorithm processed 49,75% of the tasks advertised for bachelor students. The expressions of dictionary identified t75% of these tasks well. This led to create the instances of 7 knowledge area and 4 skills. The information appeared in the advertisements about region, level, period of validity were set as attributes of these instances.

IV.1.6. The evaluation of the first development phase

In summary, the increments of this phase are the special version of JRO and LOO meta-models. The structure of qualification was constructed manually based on the experiences of experts. The structure of occupation was created by using pattern-based ontology learning technique in semi-automatic manner and adding knowledge elements to them manually following guideline of The Open Group Architecture Framework. Dictionaries was used to place new tasks into JRO ontology, to validate these tasks and created their knowledge instances, based on actual job offers. This ontology learning technique is not punctual enough, so a human intervention is needed to review the JRO ontology and the dictionaries have to be refined in the future. But the outputs of this phase were appropriate ones as inputs of the next stage.

IV.2. Second development phase: ontology alignment

Klein (2001) gave an overview and characterization of different types of mitmatches between ontologies. Mismatches can be appeared at two levels – at language level or at ontology level. Ontology languages often use different syntaxis, logical representation, semantics of primitives or provide different expressivity (see in Section IV.1.3). If ontologies written in different languages are combined, mismatches can be appeared on these domain. The solution is to translate ontologies in the same language in the process of normalization. If ontologies describe overlapping domains, mismatches at ontology level can be derived from different conceptualization, application of paradigms or concept description, terminological discrepancies (usage of synonyms, homonyms etc.) or encoding in different formats.
The types of combining two ontologies are merging, transforming, integrating, aligning, versioning, mapping of them etc. The different approaches are distinguished by using these activities in what measure.

Ontology management deals with storing, aligning and maintaining ontologies. Fensel at al. (2002) aimed at elaborating a concept of storing systems, called ontology library systems, to handle changes occured in ontologies. Special ontologies facilitated to compare ontologies, grouped them into classes and stored them into library systems. They had to visualize connections of ontologies, check consinstency, organized itselves modulary and documented information about ontologies. Inference engine running on ontologies provided interactive searching techniques.

Ontology mediation aims at reusing ontologies throughout different heterogeneous appplications by determining and overcoming differences between ontologies. This domain consists of three areas: „ontology mapping, which is mostly concerned with the representation of correspondences between ontologis; ontology alignment, which is conerned with the (semi-)automatic discovery of correspondences between ontologies; and ontology merging, which is concerned with creating a single new ontology, based on a number of source ontologies" (Bruijn et al., 2006 pp.1).

Kalfoglou és Schorlemmer (2003) and Choi et al. (2003) considered ontology mapping broadly.

The scope of my theses was to compare ontologies so it dealt with ontology mapping or alignment.

IV.2.1. Ontology mapping

Ontology mapping defined by Su (2002 pp.3) means that „for each concept (node) in ontology A, try to find a corresponding concept (node), which has same or similar semantics, in ontology B and vice verse." So we needed to define semantic relationships between two concepts and an algorithm to reveal these correspondences and related concepts, resulting set of mapping rules.

Ehrig and Sure (2004) determined map : $O_{i1} \rightarrow O_{i2}$ ontology mapping function on ontologies defined as $O := (C,H_C,R_C,H_R, I,R_I ,A)$ tuples in the following way:

$map(e_{i1}j_1) = e_{i2}j_2$, if $sim(e_{i1}j_1 , e_{i2}j_2) > t$ threshold, then $e_{i1}j_1$ is mapped onto $e_{i2}j_2$. It means there are semantical identical. Each entitiy $e_{i1}j_1$ is mapped to at most one entity $e_{i2}j_2$. Where

- $sim(e_{i1}j_1 , e_{i2}j_2)$ measures similarity between two entities, where $i_1 \neq i_2$. and $sim(x,y)$ is a similarity function. The range of this function is [0;1]. It is a reflexive, symmetric function. The triangular inequation is valid for it, if the inequiation is true. It is the inverse of distance. If two object are identical, its value is 1.

- e_{ij} is entities of O_i with $e_{ij} \in \{C_i, R_i, I_i\}$, $j \in N$.

These ontology mapping definitions use elements of set theory. Kalfoglou and Schorlemmer defined ontology mapping based on logical theories. They considered ontologies as „a pair O=(S,A), where S is the (ontological) signature, and A is a set of (ontological) axioms – specifying the intended interpretation of the vocabulary in some domain of discourse." Ontological signature is a mathematical modeling tool to describe ontologies with a hierarchy of concept or class symbols modelled as a partial ordered set. Morphisms (structure-preserving mappings between mathematical structures) are used to define total ontology mapping from ha $O_1 = (S_1,A_1)$ to $O_2 = (S_2,A_2)$.

We could follow different way – calculating similarity measure or finding morphism – to formalize ontology mapping. Frameworks, methods, tools, case studies can help to understand this domain, and to elaborate a method to match the two sides of the labor market with each other in regard of knowledge as competence element. Kalfoglou and Schorlemmer gave an overview about this domain broadly, but other approaches can be investigated by us (Ding and Foo, 2002a) (Ding and Foo, 2002b) (Noy, 2004) (Ehrig and Sure, 2004) (Choi et al., 2006).

This research concerned on finding the semantic and/or structural correspondences between the instances of the Knowledge class of both ontologies. So ontology matching systems proposed by Choi (2006) (Glue, Mafra, Lom, Qom, Onion, Omen) and offered by Noy (2000) (Prompt, IF-Map) were investigated. As Protégé 4.x uses the OWL Diff plugin and Compare Ontologies function to achieve matching, so they were examined instead of Prompt.

IV.2.2. Ontology alignment methods and tools

GLUE system uses matching learning techniques for mapping ontologies in semi-automatic manner. It finds correspondences among the taxonomies of two given ontologies. Concepts are sets of entities, on that it run a multi-strategy learning algorithm. This algorithm in Distribution Estimator calculates

$P(A;B), P(\bar{A};B), P(A;\bar{B})$ and $P(\bar{A};\bar{B})$ joint probability distribution, where $P(A;\bar{B})$ is the probability that an instance in the domain belongs to concept A but not concept B. Similarity Estimator computes Jaccard coefficients based on this calculation to determine similarity measures. Relaxation Labeler use domain-specific constraints and heuristic knowledge on similarty matrix to search for the mapping configuration that „best satisfies the doman constraints and the common knowledge". The output of GLUE is this mapping configuration (Doan et al., 2004).

MAFRA is to provide incremental, interactive and dynamic mapping technique for handling changes occurred in ontologies. It was developed on KAON. It consists of nine components:

- modules for supporting mapping process:
    - Lift&Normalization is to express ontologies in RDF(S).
    - Similarity is to calculate similarity measures.
    - Semantic Bridging is to represent correspondence between entitities in semantic manner. It creates a bridge betwwen four entities (concepts, attributes, relations and instances.)
    - Execution is to transform ontologies into each other.
    - Post-processing is to improve the efficiency of this transformation process.
- modules for interactive connections
    - Evolution is to adapt changes into semantic bridges.
    - Cooperative Consensus Building is to make consensus in mapping process.
    - Domain Constraints and Background Knowledge is to store background knowledge for operating semantic bridge module.
    - Graphical User Interface is to faciliatate human intervention.

These components help to build semantic correspondence (bridge) between ontology elements.

LOM is a semi-automatic lexicon-based ontology mapping tool. Ontologies are built on logical theories – vocabularies and axioms. It searches for morphism between vocabularies from any two ontologies. Its algorithm contains whole term matching, word constituent matching, synset matching by exploring semantic meanings of the word constituents by using the Wordnet, and type matching (Li, 2004).

QOM is a semi-automatic tool for improving efficiency of mapping methods. It handles ontologies expressed in RDF(S). It defines equations related to logical assertions, text similarity, text equality and entity similarity. Its algorithm uses similarity function that aggregates values of these equations (Ehrig-Staab, 2004).

ONION (Ontology composition System) suggests articulations based on a library of heuristic matchers. Ontologies are represented by graphs. The matchers run on each terms of ontologies. The expert can assess the suggestions and store the appropriate or extended ones. The matchers can be non iterative e.g. matchers calculating similarity measures between terms, or iterative e.g. heuristics for comparing child nodes (Mitra-Wiederhold, 2002).

OMEN (Ontology Mapping Enhancer) is a probabilistic ontology mapping tool. Ontologies contain superclasses, subclasses, data attributes and object attributes with range or at least one domain. Bayes-net graph (BN graph) is built on ontologies. The algorithm uses a set of meta-rules "to capture the influence of the ontology structure and the semantics of ontology relations and matches nodes that are neighbors of already matched nodes in the two ontologies" (Mitra et al., 2005).

OWL DIFF is a Java-based Protégé plugin, which is capable of merging and comparing ontologies. It focuses on executing the matching process mostly structurally. It investigates axiomatic correspondences between two ontologies. It can use logical comparisons and set functions in the procedure. It shows the differences graphically in two trees, one for each ontology (OWLDiff, 2008).

Compare Ontologies is a built-in function in Protégé 4.2. It is capable of comparing ontologies with different name space, which OWL DIFF isn't. As my experiences, it searches axiomatic correspondences too, but it presents the report in table format. It distinguishes three actions: created, deleted or modified elements (including renamed elements). It groups the results based on this classification.

IF-MAP is an ontology mapping tool based on Barwise-Seligman information-flow theory. It transforms ontologies into Prolog clauses. It searches f* ontology morphism that equals to reveal $f = \langle f^*, f_* \rangle$ logical infomorphism[14] between these

[14] According to Barwise and Seligman, the basic information patterns are classifications, which is a triple of two sets and a relation between them. Infomorphism wants to connect these classficiations, so

local logics represented ontologies, where f_* suggests matching at the concept-level of infomorphism.

Evaluation of these tools

The following features served as a basis to analyze:

- ontology matching is achieved in dynamic manner:
  - automatic, semi-automatic or non automatic working: the level of human intervention
  - the handling of changes occurred in the ontology
- reusability:
  - usage of different ontology format in matching process
  - type of matching method
  - support for modularity, integration with other systems
  - adaptability in Hungarian language environment.

	GLUE	MAFRA	LOM	QOM
type of execution	semi-automatic	semi-automatic	semi-automatic	semi-automatic
change management	n.a.	through a semantic bridge	n.a.	n.a.
ontology model	ontologies formalized in language using concept-attribute-relationship triple	XML Schema, RDF/S, ontology formalized in KAON	ontologies formalized in language defined by ASCS	RDF/S ontology
method	using machine learning technique and probability distribution to count a similarity measure	building a semantic bridge based on similarity measure and the components of this bridge	machine learning technique searching morphism between glossaries	using similarity functions
modularity	not free downloadable	downloadable, runable from Command prompt	not free downloadable	not free downloadabl e
adaptability	general algorithm	general algorithm	english specific	general algorithm

it determine which facts of one classification transport information related to facts of other classification (Benthem-Israel, 1999).

	ONION	OMEN	OWL DIFF/ Compare Ontologies	IF-MAP
type of execution	semi-automatic	semi-automatic	semi-automatic	automatic
change management	n.a.	n.a.	handling through Protégé 4.X	n.a.
ontology model	ontology using IDL representation and XML-based languages	RDF(S)-type ontology model	Protégé ontologies	KIF, Ontolingua, OCML , RDF, Prológ, Protégé ontologies
method	iterative and non-iterative heuristic rules	meta-rules based on Bayesian nets	comparing axioms and patterns	searching ontology morphism
modularity	not free downloadable	not free downloadable	free downloadable	not free downloadabl e
adaptability	there is english-specific feature	general algorithm	general algorithm	general algorithm

Based on these characteristics, MAFRA (Maedche, 2002) and OWL Diff (OWLDiff, 2008) (or Compare Ontologies as its built-in version into Protégé 4.2) ontology matching tools seemed to be most suitable to achieve matching process. They are free downloadable, to execute from command prompt or a Java program automatically, to support RDF(S) or OWL languages and to handle changes occurred in the ontology through the usage of a semantic bridge or Protégé ontology editor. These are the most advantages of these programs compared to the others. However, they need human intervention as against IF-MAP. Unfortunately, MAFRA Toolkit hasn't been supported since 2009, so I opted for OWL Diff and Compare Ontologies application.

IV.2.3. Results of ontology alignment

Before executing the ontology matching procedure, I had to create two new versions of both ontologies. So I had to unify their name space and leave only Knowledge class into them. The next figures show the result of ontology matching process.

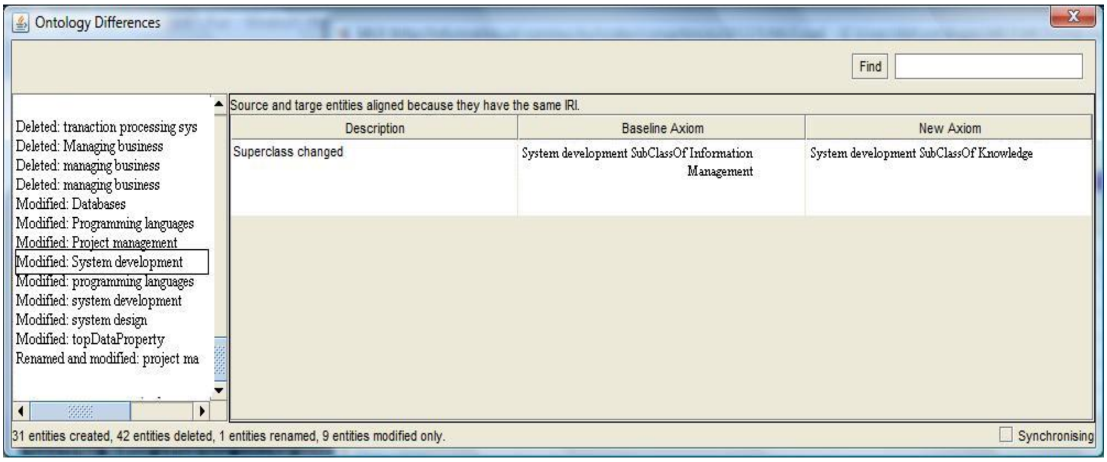

Figure 20. The results given by Compare Ontologies

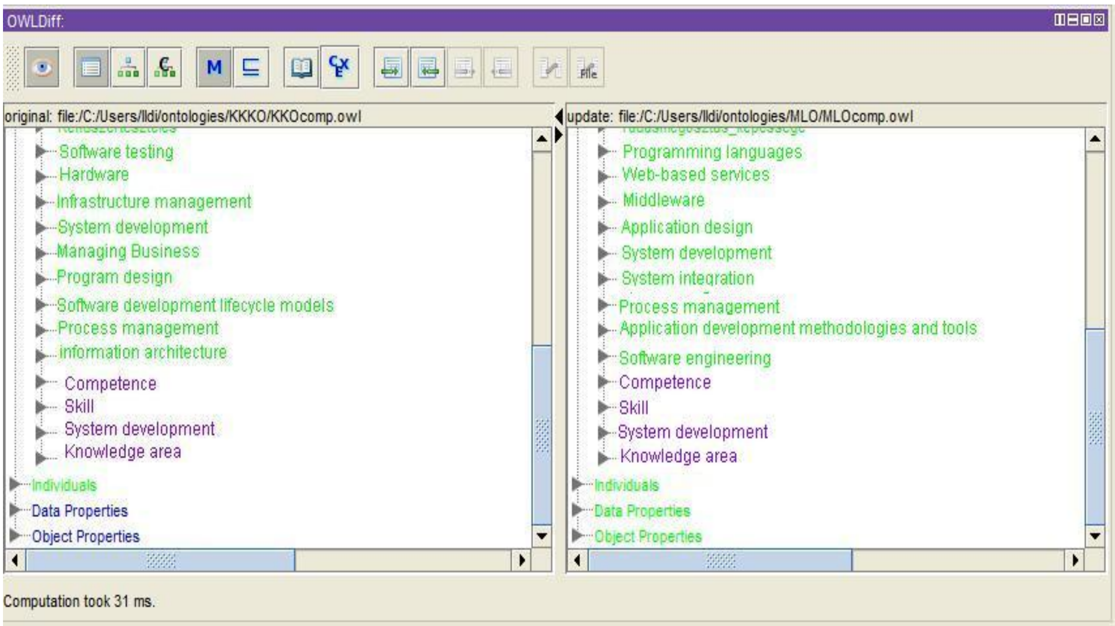

Figure 21. Comparing classes by OWL Diff

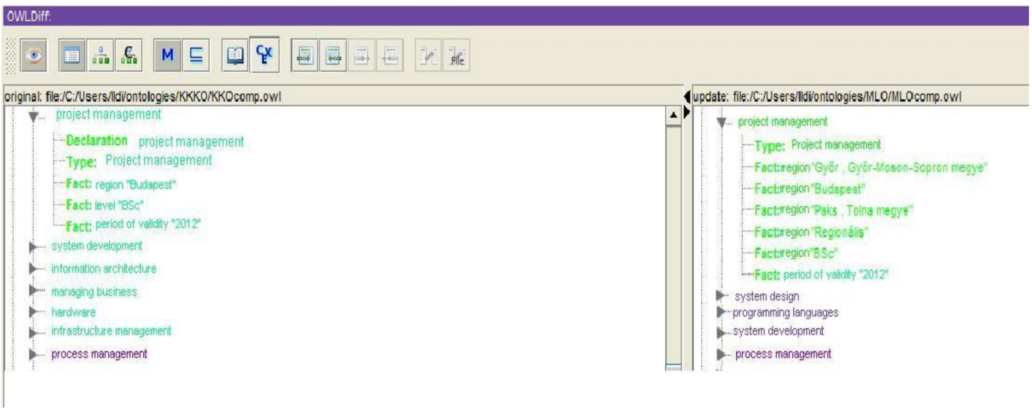

Figure 22. Comparing instances by OWL Diff

Compare ontologies function grouped the results in Deleted, Created, Renamed or Modified categories. It shows modifications for each element. The corresponding elements are in Renamed or Modified categories. The output of this tool isn't so transparent then the one of OWL Diff.

OWL Diff drew the corresponding elements with purple and different elements with green. Project management instance is green, but only its region is a difference between two concepts. It marked programming languages, system development and system design instances as matched elements in JRO ontology, but as not matched in LOO ontology. Having examined their declaration, different declaration method in JRO ontology was revealed as the cause of this symptom. JRO ontology was created manually, and LOO ontology was filled by Java API.

The next table shows the matching results.

Competences of qualification	Connection type	Competences of job role	Sublevel competences	
	Skill			
		Teamwork, interpersonal skills, logical thinking, knowledge transfer		
	Knowledge area			
Information architecture				
Transaction processing systems				
Databases	not required	**Databases**	*Data design*	
Information management				
IT-audit				
Information security				
Infrastruktúra menedzsment				
Project management	differences in region attribute	**Project management**		
System development	found	**System development**		
System design	found	*System design*		
			Application design	
			Architecture design	
			Building block design	
System testing				
Software development lifecycle models		*Software engineering*		
			Application development methodologies and tools	Web-based services
			Middleware	
Coding				
Development environment				
Programming languages	found		Programming languages	
Program design				
Specification creation				
Software testing				
Computer architecture				
Hardware				
Software				
Communication				
Managing business				
Strategy management				
Process management	found	**Process management**	*IT processes*	
			Business processes	

Table 13. Result of matching process

Both OWL Diff plugin and Compare Ontologies application assigned the instances with same name pertfectly, but they weren't capable of handling synonyms and set operations between attributes with the same name. But these are open source tools, so their algorithm can be improved by any other algorithm of the above-mentioned tools (e.g. LOM and QOM). OWL Diff presented more transparent riport than the other tool.

IV.2.4. The evaluation of the second development phase

The ontologies developed in the previous phase were matched used by two built-in tools – OWL Diff and Compare Ontologies – of Protégé 4.2 ontology development environment. These tools were chosen among eight tools proposed by experts, according to its usage in this phase. OWL Diff presented the output in more transparent manner, than the other tool did. The prototype had 11 elements, which could be compared manually in easy way, but the tool executed the process in 31 seconds, so faster than a human did. So the tool has great advantages in the case of more complex ontologies.

In summary, the developed system satisfied the requirements related to the system development phases, so the hypotheses were accepted. But the system has boundaries that may be eliminated in the future.

V. The possibility of system integration

H.3 hypothesis dealt with integrating this system into HE decision maker processes. This hypothesis couldn't be proved in the current circumstances, because the national politics follows economic guidelines, instead of guidelines of labour market, to determine structure of qualification. (SZKTerv, 2012:199). Hungarian Higher Education institutions struggle with financial problems in nowadays. The financial guidelines and number of students seem to be determined in ad-hoc manner, instead of investigating the needs of labour market. The national HE information systems can serve data for preparing decisions, but learning outcomes of training program are too broad for comparing them with those data.

The Med-Assess project (Adaptive Medical Profession Assessor) started in October, 2012 aims the application of the dynamic learning system developed in the OntoHR project in the field of healthcare (Corvinno, 2012). Precursor of the system demonstrated in this thesis was the system realized in OntoHR that has compared the Information System Analyst job to the offerings of Dutch and Italian higher education programs (Kismihók, 2012). Developments elaborated in this thesis may contribute to Med-Assess in a way that a dynamic change-tracking program can be integrated into the Studio system.

Objective of the SMART (Skill MAtching for Regional developmenT) project started in October 2012 is to construct a learning system built on the education programs aiming to satisfy labor market needs. According to the plans, the system elaborated in this thesis as well as its improved successor will be part of the project's product. This project aims to contribute to the balance of the two sides of the labor market in the Andalusia region featured by unemployment and overqualification (Anon, 2012 pp.24). In other words, usefulness of the system cannot be tested currently in higher education decision preparation process, thank to the applied approaches, but can contribute to making of related decisions in other application areas. This way such education programs – even new ones – can be created that can follow changes, are more transparent, therefore more competitive.

VI. Conclusion and outlook

The developed system had lighted a solution for checking the compliance of Higher Education portfolio to job market needs that is an actual problem in the public administration.

Competences models and qualification frameworks make organizational activities and educational programs transparent, so the competence concept served as suitable basis for matching both sides of labor market with each other, aligning structure of qualification to structure of occupation. The competence concept hasn’t universal definition in the literature, due to contextual discrepancies derived from its usage. So their content elements (skills, knowledge and attitudes) were used in this research.

The ontology approach served as an appropriate method for underlying the development by providing an explicit, formal specification about this domain and comparing the competences semantically and structurally. The ontology learning approach was responsible for building ontology dynamically and the ontology matching was used to execute the comparison.

As a result of the research, a prototype has been developed to match the competencies of Business Informatics Bachelor's degree program at Corvinus University of Budapest to the requirements given by Software developer job role. Software developer job role was chosen as an appropriate job role, because the developer role was needed in 25 % of the job offers appeared in October 2009 and October 2012 too. It was a huge need, because only 13 roles appeared in 90% of the job offers. Although this degree program qualifies not developers primarily, but this role is enough needed to underlie the prototype.

The system development method followed two-phased incremental system development methodology. Hypotheses were considered as the requirements of each development phases. At the end of the phases the developed subsystems had been analyzed that underlie the step into the next phase. The utility of final version of the developed system was examined as the useful element in higher education decision preparation process.

As **H1 hypothesis** stated, structure of qualification on the supply-side of labor market could be mapped by meta-models based on the competences of educational outputs (structured geographically and periodically), while at the same time, structure of occupation could be mapped according to the competences describing advertised job offerings (also structured geographically and periodically) on the demand-side of the labor market.

The structure of qualification was created as a special version of Learning Outcome Ontology, the structure of occupation was elaborated as a special version of Job Role Ontology too. The meta-models of these ontologies were developed by extending and merging existing meta-models.

The structure of qualification was built by the experiences of lecturers teaching in Business Informatics degree program. The structure of occupation was built by using an ontology learning method. The input of its algorithm was a collection of job requirements downloaded from Profession.hu portal, in the first quarter of 2011. A crawler written in Java was to be responsible for ensuring this input - at given intervals. Having shaped these documents into an appropriate format, a pattern-based ontology learning algorithm, in a form of Java API, mined new classes from these files and inserted them into the meta-model of Job Role Ontology. Having reviewed and restructured this model, knowledge elements from TOGAF were inserted to it and connected to the appropriate classes. The creation of knowledge area instances followed this ontology learning method too. A collection of job offers from October 2012 served as a basis for this task.

The structure of qualification and occupation were implemented in Protégé 4.1. The construction of these ontologies meant the verification of the **H1 hypothesis.**

As **H2 hypothesis** stated, an ontology-based information system could be elaborated that was able to reveal similarities and differences between the structure of occupation and qualification.

In the prototype, the comparison between both sides has been executed through the Knowledge class, because the knowledge elements could be measured and assigned to the tasks more unambiguously than the other elements. This research concerned on finding the semantic and/or structural correspondences between the individuals of the Knowledge class of both ontologies.

OWL Diff and Compare Ontologies tools had been chosen to execute the matching process among eight tools proposed by experts. The similarity and differences between both structures had been revealed due to these tools, so H2 hypothesis were accepted. There were differences between the transparability of outputs of these tools. The great advantage of these tools is to compare ontologies faster than a human does. In the future, it is necessary to improve them for semantic comparison too.

In summary, the developed system satisfied the requirements related to the system development stages, so the hypotheses were accepted. But the system has boundaries that may be eliminated in the future. The strengths and weaknesses of this system are summarized in the next table.

<table>
<tr><th colspan="2">The strengths of the system</th></tr>
<tr><td colspan="2">The meta-models reflect reality and contexts.</td></tr>
<tr><td colspan="2">The expressions in the dictionary describe the ontology elements in high precision manner.</td></tr>
<tr><td colspan="2">The matching tool assigns the ontology elements with same name and attributes with each other in 100%.</td></tr>
<tr><th>The weaknesses of the system</th><th>Development ways</th></tr>
<tr><td>Just one part of job offers is usable due to their semi-structured format (e.g. XHTML format).</td><td>To stand for filtering more relevant text blocks (not only Task: and Requirement: blocks)</td></tr>
<tr><td>Less than 50% of the tasks can be processed in the ontology development.</td><td>To extend the dictionary with new expressions
To eliminate the tasks related to not the given role.</td></tr>
<tr><td>The algorithm places tasks into wrong classes.</td><td>To extend the dictionary with open queries instead of verbs.</td></tr>
<tr><td>The matching tool doesn’t handle synonyms generally and set operations between the attributes with same name.</td><td>To improve its algorithm.</td></tr>
<tr><td>The whole process stops, if one application (e.g. OWL Diff) requires different input format as provided by the other application (e.g. Protégé API).</td><td>An algorithm is needed to convert these formats into each other.</td></tr>
</table>

Table 14. The strengths and weaknesses of the system

Among these boundaries the system is usable and customizable by other Profession.hu job advertisements and higher education qualifications. So this prototype proved the thesis given by András Gábor, i.e. the qualifications can be verified in the function of job requirements using competence based approach and information technology tools.

To put forecasting models into the system may provide more information to underlie the decision making process in higher education. Finally, a competitive higher education portfolio may be created.

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ANNEX 1. The top 20 of Hungarian frequent words appeared in job offers downloaded between 27/12/2010 and 10/4/2011

words	occurrence	number of docs
felad	2590	2371
keres	2090	2057
megold	742	613
tesztel	699	611
megbíz	592	564
kínál	526	526
üzemeltet	557	404
karbantart	437	376
ellát	362	332
kapcsolódik	352	318
együttműködik	331	302
dokumentál	319	295
jelent	299	260
kiválik	265	250
bevezet	285	233
fejleszt	199	195
koordinál	188	179
megfelel	180	177
szeret	209	164
bővül	163	163

ANNEX 2. Ontology metrics after using ontology learning based on the improved dictionary