Toward an Integrated Competence-based System Supporting Lifelong Learning and Employability: Concepts, Model, and Challenges

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Abstract. Efficient and effective lifelong learning requires that people can make informed decisions about their continuous personal development in the different stages of their life. In this paper we state that lifelong learners need to be characterized as decision-makers. In order to improve the quality of their decisions, we propose the development of an integrated lifelong learning and employment support system, which traces learners' competence development and provides a decision support environment. An abstract conceptual model has been developed and the main design ideas have been documented using Z notation. Moreover, we analyzed the main technical challenges for the realization of the target system: competence information fusion, decision analysis models, spatial indexing structures and browsing structures and visualization of competence-related information objects.

1 Introduction

At the moment we are experiencing the effects of the transition from the industrial to the knowledge economy which is characterized by a dynamic market, severe changing occupations, and insecurity of jobs [13]. Some qualifications are becoming obsolete but emerging new competences require continuous, lifelong learning and development of large categories of employees. Policy makers in OECD countries are concerned about the possible negative consequences of this transition to the knowledge economy because it may lead to a decrease in employability and job security over the career [3]. Remaining attractive and employable in the 21st century implies that employees become more accountable for investments in their own human capital and hence in their own job security, learning and career development [8]; this presupposes a high level of self-directedness in career and learning processes. Research, however, indicates that for large groups of employees self-directedness is not a natural habit. They lack the meta-cognitive skills to steer their own career and learning process and can not pro-actively recognize and utilize opportunities [12, 18]. For large groups of employees their learning is mainly restricted to responding to changes in work tasks, they do not set goals, monitor or evaluate their learning. The notion of the self-directed employee is perhaps more an ideological concept than a wide-spread reality. Apart from the fact that employees are not always able or willing to steer their own lifelong learning, there is also the real danger that employees experience severe difficulties in choosing the right career steps, and the best learning and training activities out of the entire set of possibilities, which was clearly demonstrated in [1]. If we really want them to take charge of their own career and lifelong learning then we need to offer an infrastructure that supports them in the process of making informed decision about these issues.

A theoretical notion of Learning Network has been proposed [6, 7, 14] that addresses facilitation of lifelong competence development. A learning network is an ensemble of persons, institutions, and learning activities that are interconnected through and supported by information and communication technologies in such a way that the network self-organizes. A lifelong learner, a member of a learning network, can provide learning activities (e.g., courses, training programs, assessment, and learning materials) and can engage in a series of learning activities offered by others to reach a goal, such as acquiring a certain competence. In order to offer learning activities in learning networks, many different recommendation technologies such as structured and collaborative filter have been proposed along the years [4]. According to learner's goals/needs (represented in terms of competences with proficiency levels) and preferences (e.g., types, learning styles, and learning strategies), the personal recommender attempts to find all suitable learning activities and to rank them based on some measure of "goodness", so that the "best" matches receive the highest ranks. In TENCompetence project [17] various personal recommenders have been implemented as Learning Network services to offer learners with suitable learning activities. It releases learners' burden to search and choose learning opportunities.

Based on our experiences with this topic, we set out to develop an integrated system that not only supports lifelong learning, but also supports competence-based employment and related business processes. The benefits of such an integrated system could be to help lifelong learners to determine learning goals/needs and choose learning activities in the interest of lifelong employability, to seek suitable intellectual products and business opportunities, and to seek partners for making up a virtual company, and to support job-hunting and recruitment procedures based on automated competence tracking and management. For providing high quality recommendations in this system, at minimum two pre-conditions must be met: 1) information about competence-related objects such as persons, institutions, learning activities, assessment, tasks, jobs, and job applications has to be accurately and completely captured, 2) the criteria and analysis logic used to make decisions coincide with those of the learners. However, it is difficult to capture the reliable competence information [9]. Users may assess and represent competences of related objects higher or lower than the actual competences. In particular when applying for a job, a person may intentionally describe his/her personal competences higher. Sometimes, learners have no clearly outlined learning goals, needs, and preferences. In addition, these will likely change because of unforeseen and situated factors. They even change their criteria and analysis logic on the fly. Analogue to a tourist, s/he sometimes may have no particular destination when visiting a city. Goals, needs, and preferences may change as time and context changes. For example, he may be interested in getting information about hotels as he arrives and the information about restaurants at lunch time. He suddenly decides to visit a museum because he just now found out that this afternoon the museum charges no entrance fee and there is a bus line to the museum from the current position. When he makes decisions, the factors, criteria, and logic may change as well. Sometime, time is the most important factor and sometimes the cost is the more important factor. These changes may be situated and are triggered by unpredictable events. The final decision may be a compromise of several factors using multi-criteria. In these situations, recommendations based on pre-defined goals, preferences, criteria, and analysis logic may be not effective to create a set of "good" matches.

In this paper, we present the design of an abstract conceptual model of the target system. The design of this model is partially based on TENCompetence Domain Model [16] and partially based on Ostyn's work [10]. In particular, we design the model to address the problems described above. We design a data model necessary for: 1) dealing with inaccurate, incomplete, and inconsistent competence information, 2) involving lifelong learners in decision-making processes, and 3) presenting relevant competence information in a structured and visualized manner. The remainder of this paper is organized as follows. First we present the main concepts of the system as data types. Then we specify the conceptual model as state spaces using the defined data types. The section thereafter discusses the challenges for a realization of such a system. Finally, we present our conclusions.

2 Concepts

In this paper, we present the main design ideas (note: not a whole system design) using the Z language [15]. There are a number of reasons to choose Z. Firstly, Z has the advantage that it is able to specify a system accurately and unambiguously. Secondly, the functional specification can be used to express design ideas at an abstract level without specifying concrete implementation algorithms. Thirdly, Z can be used to describe a specification of a large system by breaking it down into a number of subsystems, which can be specified in separate documents piece by piece accompanied by informal explanation [15].

This section presents important concepts as data types. First of all, we define basic types. The following notations represent the types of natural number, integer, real number, Boolean, string, and text respectively as: [$\mathbb{N}$ $\mathbb{Z}$ $\mathbb{R}$ BOOLEAN STRING TEXT]. In order to ease discussion, we don't consider the detail and internal structure of some data types such as time, duration, status, meta-data, money, location, url, source, rating, percentage, and globally unique identifier in our model. These data types are introduced as basic types as well: [TIME, DURATION, STATUS, M_DATA, MONEY, LOCATION, URL, SOURCE, RATING, PERCENTAGE, GUID]

We acknowledge that the concept of 'competence' or 'competency' is the subject of ongoing discussion. According to IEEE Reusable Competency Definition (RCD) [11], a competency is defined as any form of knowledge, skill, attitude, ability or educational objective that can be described in a context of learning, education or training. RCD does not address the aggregation of smaller competencies into larger competencies. In this paper, we use the broadly recognized definition of Cheetham and Chivers [2] who defined competence as 'effective overall performance within an occupation, which may range from the basic level of proficiency through to the highest level of excellence'. According to this definition, a competence can be simply regarded as a competency in a particular context. In our model a *competence* is defined as a data type with attributes id, title, description, definition, and meta-data as does the RCD. Note that most data types defined in the model have attributes id, title, description, and meta-data. In order to save space, these attributes will not be specified for the other data types although the reader should assume their presence.

Competence

id: GUID; title: STRING; description: TEXT; definition: STRING; meta-data: $\mathbb{P}$ M_DATA

A *proficiency level* is used to evaluate a competence. According to the European Qualification Framework, we define ProficiencyLevel = $\{ r: \mathbb{R} \mid 0 \leq r \leq 8\}$.

In the *competence model*, a competence can be decomposed into several lower level competences which represent the facets of the competence, component competences, or both. As specified below, all competences in the model can form a directed acyclic graph (DAG). As an abstract model, the concrete decompositions of competences (the hierarchic structure) will not be discussed in detail in this paper.

CompetenceModel

competences: $\mathbb{P}$ Competence; isComponentOf: Competence $\leftrightarrow$ Competence

mapTo: $\mathbb{P}$ (Competence $\times$ ProficiencyLevel) $\twoheadrightarrow$ Competence $\times$ ProficiencyLevel

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dom isComponentOf $\subseteq \mathbb{P}$ competences $\wedge$ **ran** isComponentOf $\subseteq$ competences

disjoint < isComponentOf$^+$, **id** Competence >

$\forall$ c, f: Competence; children: $\mathbb{P}$ (Competence $\times$ ProficiencyLevel);

father: Competence $\times$ ProficiencyLevel $\mid$ c $\neq \varnothing \wedge$ f $\neq \varnothing \wedge$

c $\in$ **first** children $\wedge$ f $\in$ **first** {father} $\wedge$ (children $\mapsto$ father) $\in$ mapTo $\bullet$

c $\in$ competences $\wedge$ f $\in$ competences $\wedge$ c $\neq$ f $\wedge$ (c $\mapsto$ f) $\in$ isComponentOf

A *competence profile* (CP) is a set of competences with associated proficiency levels that link directly to the work to be performed. Usually there are several competence profile items in a competence profile. Each competence profile is specific to a person, an institution, a software agent, a learning objective, an assessment, a task, a job, or a job application. We call all these entities competence-related objects. Note that each item in a competence profile is more or less credible.

CompetenceProfile

CompetenceModel;
competenceProfileItems: Competence $\times$ ProficiencyLevel;
confidenceRating: competenceProfileItems $\twoheadrightarrow$ PERCENTAGE;
creationTime: TIME;

A *person* represents a human user of the system in a computational form. The personalCP represents a claimed competence profile, which may be different from the potential/actual competence states of the person. The learning goals and learning needs are represented using competence profiles. The preferences such as preferred learning strategies, learning styles, and work styles are modelled using a basic type [PREFERENCE]. The reliability is used to represent the degree of trustworthiness of the person according to his/her behaviours in the system. This issue will be discussed later in the paper. A person should have more attributes to characterize him or her as a user in the system. These are omitted in this abstract model,

Person	
name: String;	personalCP: CompetenceProfile
learningGoals: CompetenceProfile;	learningNeeds: CompetenceProfile
preferences: ℙ PREFERENCE;	reliability: PERCENTAGE
availableTimeForLearning: DURATION;	availableMoneyForLearning: MONEY

An *institution* represents a company, a learning institute, a certification organization, etc. in a simple computational form. A *software agent* represents a software tool such as a pedagogy agent or a Latent Semantic Analysis (LSA) tool. We do not explicitly present the definitions. Note that data types Institution and SoftwareAgent have attributes institutionType/agentType and institutionCP/agentCP, repectively. The *actor* is defined as a generic term (data type) for a person, an institution, or a software agent as Actor ::= person <<Person>> | institution <<Institution>> | softwareAgent <<SoftwareAgent>>.

A *unit of learning* represents a course, a train program, a learning material, and etc that can be used for learning. A unit of learning is characterized in terms of a required competence profile and an objective competence profile. In this model, we do not consider the internal structure of a unit of learning.

UnitOfLearning	
prerequisites: CompetenceProfile;	objectives: CompetenceProfile
creationTime: TIME;	estimatedTime: DURATION;
averageTime: DURATION;	averageRating: RATING
cost: MONEY;	type: UnitOfLearningType;
associatedResources: ℙ RESOURCE;	features: ℙ PREFERENCE;
location: LOCATION;	address: URL

A *unit of task* represents an abstract or an authentic work item. It can be used to represent a business opportunity and a training/assessment case for acquiring and demonstrating competences. A *unit of assessment* represents an online assessment, an interview, a simulator-based test, a 360 degree feedback, self-assessment, a formal examination, and etc. Because UnitOfTask and UnitOfAssessment are defined similar to UnitOfLearning, we do not explicitly present them in the paper. The primary difference is that UnitOfTask and UnitOfAssessment are characterized using one competence profile associatedCP, whereas UnitOfLearning are associated with two competence profiles. In addition, UnitOfTask and UnitOfAssessment have their own types. Note that taskType can be defined as an ontology, which can be referred to by jobs (see the definition below).

A *job* represents an open job offer. The status of a job may be valid, cancelled, expired, or recruited. The required competence profile is represented as requiredCP. What types of tasks one is expected to do can be listed in associatedTasks.

JobPost	
status: STATUS;	owner: Institution
requiredCP: CompetenceProfile;	associatedTasks: ℙ taskType
salary: MONEY;	location: LOCATION;
creationTime: TIME;	validDuration: DURATION

The data type of JobApplication is defined in a similar form to the JobPost, except that the claimedCP replaces the requiredCP and associatedEvidenceRecords replaces the associatedTasks. Note that in the JobPost and JobApplication, certain information that may be important in real recruitment, is omitted here for our purpose.

An *evidence record* is an information object concerning an actor and associated with a competence profile. Usually, it is based on certain forms of performance and assessment. The sources of an evidence record may be articles, designs, models, responses to questionnaires, interview protocols, certificates, and demonstration recorded in various forms of media. Obviously, different evidence records merit different levels of confidence. An evidence record may be provided by a person her or himself or by someone else at a point of time.

EvidenceRecord

status: STATUS;	owner: Person
associatedCP: CompetenceProfile;	confidenceRating: PERCENTAGE;
evidenceType: EvidenceType;	evidenceSources: ℙ SOURCE;
creator: Actor;	creationTime: TIME

A *distillation request* represents a request for making a judgment on a competence of an actor at a given proficiency level based on a set of evidence records.

DistillationRequest

associatedPerson: Person;	associatedEvidenceRecords: ℙ EvidenceRecord
associatedCompetence: Competence;	associatedLevel: ProficiencyLevel

A *competence record*, the result of the distillation process, represents a judgment made by an actor based on certain evidence records at a time point about the associated actor on a certain competence at a given proficiency level. A competence record may be valid or expired. A competence record is more or less reliable.

CompetenceRecord

status: STATUS;	associatedActor: Actor;
associatedCompetence: Competence;	associatedLevel: ProficiencyLevel;
confidenceRating: PERCENTAGE;	associatedEvidenceRecords: ℙ EvidenceRecord
creator: Actor;	creationTime: TIME

There may be many competence records associated with the same actor on the same competence created by the same/different actors at the same/different time based on the same/different evidence records. Individual records are more or less trustworthy and credible. There is a need to fuse relevant competence records to produce an estimate of the competence status, which is more trustworthy and credible than each single competence record. Moreover, competence records associated with different competences, which are related and can be rolled-up as a higher level competence, can be fused as different facets of the higher level competence according to the competence model. A *fusion request* is modeled as below.

FusionRequest

associatedActor: Actor;	associatedCompetenceRecords: ℙ CompetenceRecord
associatedCP: CompetenceProfile;	

So far we have specified the important concepts as data types in Z notation. In the next section, we describe the design of the abstract system model.

3. An Integrated Competence-based System

A *community* consists of a set of actors which is divided up in persons, institutions, and software agents. In a community, a person could be a friend of another person.

Community

persons: ℙ Person; institutions: ℙ Institution;
softwareAgents: ℙ SoftwareAgent; actors: ℙ Actor;
isFriendOf: Person ↔ Person

ran institution = institutions ∧ **ran** softwareAgent = softwareAgents ∧
ran person = persons ∧ (**dom** isFriendOf ∪ **ran** isFriendOf) ⊆ persons
<persons, institutions, softwareAgents > **partition** actors

A *learning management* subsystem is specified within the community, in which actors create units of learning, units of assessment, and units of task. Persons can perform and rate them (e.g., quality, easy and difficult). As we can see, this is a self-organized learning environment.

LearningManagement

Community
createUoL: Actor ↔ UnitOfLearning; takeUoL: Person ↔ UnitOfLearning
createUoA: Actor ↔ UnitOfAssessment; takeUoA: Person ↔ UnitOfAssessment
createUoT: Actor ↔ UnitOfTask; takeUoT: Person ↔ UnitOfTask
rateUoL: Person × UnitOfLearning ⇸ RATING
rateUoA: Person × UnitOfAssessment ⇸ RATING
rateUoT: Person × UnitOfTask ⇸ RATING

dom createUoL ⊆ actors ∧ **dom** createUoA ⊆ actors ∧ **dom** createUoT ⊆ actors
dom takeUoL ⊆ persons ∧ **dom** takeUoA ⊆ persons ∧ **dom** takeUoT ⊆ persons
ran takeUoL ⊆ **ran** createUoL ∧ **ran** takeUoA ⊆ **ran** createUoA ∧
ran takeUoT ⊆ **ran** createUoT

In the *employment management* subsystem, institutions post jobs; persons can apply for jobs. All information about which person got which posted job and which institution accepted which job applications is captured.

EmploymentManagement

Community
postJob: Institution ↔ JobPost; applyJob: Person ↔ JobApplication
gotJob: Person ↔ JobPost; acceptApplication: Institution ↔ JobApplication

dom postJob ⊆ institutions ∧ **dom** applyJob ⊆ persons
dom getJob ⊆ persons ∧ **dom** acceptApplication ⊆ institutions
ran gotJob ⊆ **ran** postJob ∧ **ran** acceptApplication ⊆ **ran** applyJob

The *competence profile management* subsystem is responsible for the management of information about evidence records, competence records, competence profiles and confidence rates. When a person ‘takes’ a unit of learning/assessment/task, the system will create an evidence record. The performance information and products (e.g., articles, designs, responses to questionnaire) will be captured and wrapped in the evidence record automatically. Persons are allowed to provide evidence records to include external evidence sources. On demand distillation request with a set of evidence records will be created and published. Relevant actors, which have sufficient competences and interests, can receive and respond to the request and create a competence record according to the distillation request. Then, the system will fuse relevant competence records to produce an estimate of the current competence state of the associated person according to the confidence rating of the records and the reliability of the associated person timely or on demand. Meanwhile, the system will evaluate the confidence rating of each competence record and evidence record, and update the confidence rating based on the current estimate. Finally, the reliability of a relevant person may be updated according to his/her behaviours on providing, assessing, and distilling evidences.

—CompetenceProfileManagement ———————————————

CompetenceModel;
Community;
LearningManagement
learningOutcome: takeUoL → EvidenceRecord;
assessmentOutcome: takeUoA → EvidenceRecord
performance: takeUoT → EvidenceRecord;
provideEvidence: Person ↔ EvidenceRecord
createDistillationRequest: Actor ↔ DistillationRequest
distillation: Actor × DistillationRequest ⇸ CompetenceRecord
createFusionRequest: Actor ↔ FusionRequest;
fusion: FusionRequest ⇸ CompetenceProfile

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dom provideEvidence ⊆ persons; **first** (**dom** distillation) ⊆ actors
dom createDistillationRequest ⊆ actors ∧ **dom** createFusionRequest ⊆ actors
∀ p: Person; l: UnitOfLearning; e: EvidenceRecord | (p ↦ l) ∈ takeUoL ∧ ((p ↦ l) ↦ e) ∈ learningOutcome • e.owner = p ∧ e.associatedCP = l.objectives ∧ e.creator = system ∧
($\exists_1$ r:DistillationRequest • (system ↦ r)∈createDistillationRequest ∧ r.associatedPerson=p ∧
r.associatedCopetence ∈ l.objectives ∧ r.associatedEvidenceRecords = e);
∀ r: **ran** createDistillationRequest • r.associatedEvidenceRecords ⊆
(**ran** learningOutcome∪**ran** assessmentOutcome∪**ran** performance∪**ran** provideEvidence);
∀ a1, a2: persons; r: DistillationRequest; c: CompetenceRecord |
(a1 ↦ r) ∈ createDistillationRequest ∧ ((a2, r) ↦ c) ∈ distillation •
c.owner = r.associatedPerson ∧ c.creator = a2 ∧
c.associatedCompetence = r.associatedCompetence ∧
c.evidenceSources = r.evidenceSources;
……

———————————————————————

The main design ideas have been described above. Because an operation described in Z is specified by presenting the changes in the state space, the implementation method is not explicitly specified. Especially in our model, the processes such as how to distilling and fusing competence information are open questions. We will not describe operations. For a better understanding of the system and problems, we present a highly simplified scenario, which presents some dynamic behaviors of the system from the perspectives of the users.

John, an unemployed civil engineer and a frequent user of the system, uses the system for seeking job offers. After login he sees a 3-dimensional competence space, which consists of three axes corresponding to three main civil engineering competences (structural design, construction physics, and building material). According to his proficiency levels of these competences, his competence profile is represented as a specific point (displayed as an icon) in the competence space. John controls the view by selecting the job offers and the screen shows only the points representing jobs. The distance between the points in this space represents the similarity of the competence profiles. Presumably, John can get basic and more detailed job information by clicking on the job icon. Unfortunately, there are no suitable job offers around his icon. Then he clicks to include the job applications in the competency space so he sees a number of persons' icons around his icon, meaning that many candidates with quite comparable competences are looking for a job in the same area. He decides to explore jobs in a larger scope and finds a cluster of (valid and expired) job posts. These are jobs for energy consultants. He browses and reads the tasks described in the job posts and finds them very interesting. The average salary is acceptable and the geographical locations of several job posts are near his location. He compares the distance between his icon and the cluster of job icons and he concludes that his competences on structural design and building material are sufficient, but his proficiency level on construction physics is below acceptance. Then he decides to check what other competences are necessary for a job as an energy consultant. He shifts to the competence space consisting of axes corresponding to the main competences for this particular profession.

Now he can see his competence profile icon in the new competence space for energy consultants. He observes that the main competence he lacks is financial support. Then he clicks on the button for searching learning activities and the results will be presented as directed lines in the competence space. He can control parameters such as costs, time and preference using sliders in the UI; the learning activities displayed in the competence space will change (e.g., in colors, pattern, style and etc) accordingly. He can also directly manipulate the icons to compare alternatives. After some deliberations and experimenting he chooses several courses and training programs, which show up as a route from his icon to the cluster in the competence space and he saves this as a competence development plan.

After some months of study following the plan, he decides to assess his progress and therefore he clicks the button to present tasks that are surrounding his icon. He chooses a task icon in between his icon and the cluster, about thermal isolation. The selected task is an authentic case and is associated with the jobs for an energy consultant. After having performed the task, he creates and publishes a distillation request with a collection of evidence records produced when he performed the task. The system will check who have recently done the same or similar tasks or are developing the same competence with a comparable level. Then the system sends an internal message to them.

Julia receives an internal message with John's request. Recently, she applied for an energy consultant job. The system checked whether she has qualified levels of all required competences for the job. It found that her competence record on thermal isolation has expired and the confidence rating of this record is low. An online assessment has been suggested to Julia. Now the system sends her an email with John's distillation request. She knows that she has to demonstrate that particular competence by providing additional evidence. She reads the materials (the task done by John and associated evidence records) and fills in the assessment form regarding

John's proficiency level on thermal isolation. She judges John's solution is not good enough and rates his competence proficiency level is 3.2. However, because her current competence record on thermal isolation is expired, the confidence rate of her judgment is rather low. The system is currently working with two threads to handle this case. The first one is to collect all John's competence records on thermal isolation and fuse these to produce an estimate of this competence. At the same time the system creates a distillation request after Julia finishes the assessment. John receives this request and judges Julia's level on the same competence as 6.2. However, the mean of all judgments about Julia's level is 5.1. The confidence rate of this competence record is low (28%) because there are no real experienced persons involved in the distillation and there are many deviations like John's 6.2. However, almost all judgments about John's level on thermal isolation are consistent and the fusion result is 3.1. The confidence rate of this competence record is 85%, because almost all judgments ware made by people with competence levels higher than his one. The deviation of John's judgment about Julia reinforces the estimate of the system that his level is not high. When the employer concedes Julia's application, the system shows that the confidence rate of Julia's competence on thermal isolation is not high although the proficiency level (5.1) is acceptable. The employer asks Julia to take a formal assessment on it. John is informed by the system that his level on thermal isolation is insufficient for a qualified energy consultant. He will look for learning activities starting from this level.

4. Challenges

Developing a system as described meets with a formidable set of obstacles, all of which need to be removed before it can be used in practice. Apart from other problems (e.g., on sociability, privacy, and security), there are many technical problems. In this paper, we restrict ourselves to the three main technical challenges.

Producing accurate and reliable competence information: Individual actors' judgment and representation of competences will likely not be accurate and complete, resulting into unreliable information [9]. In our model the attribute 'confidence rate' is used to represent the reliability of competence profile items, actors, evidence records, and competence records. However, it is an open question how to produce appropriate estimates of competences from large amounts of information coming from different sources and different types of sources, which may be inconsistent. Information fusion may be a promising solution to solve this problem. Information fusion aims at achieving improved accuracies and more specific inferences that could not be achieved by the use of any single source alone [5]. It has been applied in many domains such as defense, robotics, medicine, and weather forecast. Competence information fusion is more challenging because the "sensor" is usually human being.

Supporting complicated decision-making processes: The process of decision making implies planning of a professional career, the determination of learning goals and learning needs, and selection of the best course of activities to achieve the goal within certain constraints (e.g., preferences, ratings, cost, and time). Such decision is made by a lifelong learner on the basis of logical analysis of facts coupled with his or her knowledge of the decision-making environment/context as well as his or her experience. As this is a complicated process, it involves repeated consideration of feasible alternatives using multi-criteria with regard to action, their evaluation, comparison and, ultimately, selection of the best solution. The decision making process is thus iterative, integrative and participative. How to apply decision support techniques to support lifelong learners is a challenging research issue.

Development of spatial index and browsing structures and visualization of competence information objects: In our model all competence-related objects can be characterized with one or two competence profiles. Each competence profile consists of several competences with proficiency levels ranged from zero to eight. Thus, a multi-dimensional competence space can be defined. The dimensionality of the competence space consists of axes that correspond to individual competences. Competence-related objects like persons, jobs, and units of learning can be represented as points, hyper-cubes, and directed lines in the multi-dimensional space. By presenting competence-related information objects visually and allowing interaction through direct-manipulation, the learner can traverse competence space rapidly and intuitively. Even if some objects are not accurately described and can not be exactly matched, the learners can browse interesting objects within an area. The combination of visualization of competence-related objects and decision support mechanisms make it possible to provide an interactive and recursive problem solving environment in which the learner proceeds by multiple passes, making use of his own experience, knowledge, and intuition. In order to achieve this goal, we have to take the challenges to reduce dimensionality, build spatial indexing structures and browsing structures, and visualize competence-related objects in dimensional spaces.

5. Conclusions

Competence-based systems serve as a critical medium in many competence-related or competence-driven business processes. They provide management with information and services necessary to make and support decisions. In this paper we propose to extend the concept of a Learning Network by integrating employment management. The importance and benefits of such an integrated lifelong learning and employability support system have been discussed. An abstract conceptual model has been developed and the design ideas have been presented using Z notation. The abstract conceptual model addressed the problems of incomplete and inaccurate competence information and uncertainties of criteria and decision logics. It provides a basis for further analyzing problems, identifying requirements, and developing detail designs.

There is a long way to go for a realization of the target system. Apart from organizational and social problems, we have to face, minimally, three significant technical challenges: 1) to produce accurate and reliable competence information by fusing a large amount of data coming from different sources and different types of sources, 2) to support complicated decision-making processes, and 3) to reduce high dimensionality, develop competence specific indexing structures and browsing structures, and visualize competence-related information in dimensional spaces. The possible technical solutions for these challenges are indicated in the paper.

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