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Knowledge-Based System for Assessment of Economic Situation of Enterprise

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Absrtact

In the paper, the author's conception of building an intelligent system for predicting economic situation of enterprises is presented. This conception is captured in the form of the prediction chain (PC). A process of reasoning by analogy is performed using a Case-Based Reasoning (CBR) methodology. In the paper, a model of an enterprise, concentrating on identification of the competence potential and competence gap, is shown. A protocol of an assessment of potential and assessment of competence gap in a given range, using the AHP (Analytic Hierarchy Process), is presented. Individual elements of a system for creating the knowledge are captured in the form of an A-E-AE (Agent-Expert-Acts of Explanation). The structures of classes in the Protege editor are shown. At the end, a coordination diagram in the UML language is depicted. This diagram makes up a diagram of the interface between an expert and a CBR system.

Keywords: enterprise ontology, intelligent systems, predicting, case-based reasoning, expert systems

Introduction

The subject of this paper is a presentation of a structure of an intelligent system for predicting economic situation of enterprises in the SME sector. Prediction methods (Altman 1993) elaborated so far are based on data mining techniques. Elaborated models make it possible to classify the considered enterprise into either a class of enterprises in a good situation or a class of enterprises in a bad situation (bankruptcy). For elaborating models, an index profile of an enterprise is used. Indexes are calculated from financial reports (profit and loss statement, balance) on the basis of financial analysis. Such an approach does not permit to explain an enterprise situation in the cause-effect relationship: symptoms → results. Therefore, the author presents the project of a system allowing the use of the knowledge about an enterprise, especially, taking into consideration the competence analysis. The author uses the CBR (Case-Based Reasoning) methodology as a formal base for construction of the prediction system. The CBR methodology is used for creating "enterprise memory" systems (Watson 2003). Such systems are designed for knowledge accumulation and management. The range of this area is defined by A. Brooking (1999), especially, taking into consideration an intellectual capital. Y. Jussupova and A.R. Probst (2007) elaborated an ontology allowing to capture competence in the following range:

1. Risk analysis in a strategy formulation.
2. Establishing priorities in realization of process according to the assumed strategy.
3. Scheduling processes.
4. Financial analysis in the strategy planning.
5. Analysis of an intellectual capital of an enterprise.
6. Allocation of procedures and technologies.
7. Solving problems and decision making on the basis of the available knowledge.

M. Harzallah, G. Berio, F. Vernadt (2006) presented the Competency Resource Aspect Individual (CRAI) model. In this model, they distinguished three types of competencies: individual competen-

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cies, team competencies, and enterprise competencies. The enterprise competencies are understood as macrocompetencies, being aggregation of competencies oriented towards the leadership in the range of products and services. Competencies encompass three categories of resources (C-resources): knowledge, technologies (know-how), individual behaviors (abilities, talents, experiences). The CRAI model consists of four main classes: competencies, C-resources, individual profile, aspects of analysis. The CRAI model is formulated as an ontology implemented in the Protege editor.

The Unified Enterprise Competence Modelling Language (UECML) (Pepiot et al. 2007) is the most formalized approach to enterprise analysis from the point of view of competence. The authors of this conception define competencies required for realization specific activities (technological operations). The competencies are identified in relation to services of processes and technological operations made by personnel by means of material and immaterial resources adequately assigned. The UECML is captured in the specification framework of the UML language. Models of the competence analysis of enterprises, mentioned above, are included in the modern enterprise theory based on the RCC (Resources, Capabilities, Competencies) paradigm. According to Montresor (2004), a firm is defined as a set of resources (R), both material (e.g., machines) and immaterial (e.g., patents), a set of specific capabilities (C) of configuration, exploitation, and renovation (dynamic capabilities), and competencies (C) being sets of activities concerning problem solving and ordering. Above-mentioned models of competence analysis concentrate on the enterprise competence identification for the effective, innovative process realization.

A competence strategy analysis is crucial from the point of view of predicting an economic situation of an enterprise. The first approach to formulation of the competence strategy analysis of an enterprise was a model of core competencies elaborated by C.K. Prahalad and G. Hamel (1990). Core competencies are realized by business units in the structure of corporation, which have the unique technology in order to produce a high-competitive product. Core competencies can be also determined by abilities, which give significant benefits in the range of costs and in the range of delivering the concrete benefit to a client.

A prototype system of defining group (team) competencies for Group Memory System (GMS) was elaborated by J.A.B. Vasconcelos, C. Kimble, F.R. Gouvela, D. Kudenko (2001). Group competencies are, in this conception, a generalization of abilities, rules of behaviors, experiences, and the practical knowledge of project teams realizing projects. In enterprises managed by projects, such an approach to the formulation of an ontology can be used for competence strategy assessment of enterprises.

V. Seppanen (2002) defines competencies concerning production of software. In this conception, competencies define four elements: domain of application of software, functionality, techniques used for realization of functionality and technologies implemented in software production. These four elements determine four competence strategies: scientific, problem-oriented, technology-oriented and application-oriented.

The approaches, presented above, to defining an enterprise competence ontology, as well as competence strategy, are characterized by conceptualization including faithful description of processes, procedures, events, and resources, oriented to reflection of relationships among those elements, which make possible competence identification, including core competencies. The author shows different conception, relying on determining ranges of competence potential of an enterprise and ranges of competence gap. Profile of employee resources and process resources is associated to each range. This profile includes:

1. Identification of resource availability used for increasing potential.
2. Qualification of employee resources.
3. Profile of abilities (attitudes).
4. Profile of experience.
5. Description of technologies.
6. List of procedures.
7. Set of indexes.
8. Functions of trends of specific parameters of processes.

The author proposes to include resources both material and immaterial to description of technologies. Such resources are used in specific technological operations. Such an approach makes possible assessment of the use of material resources (machines, devices) in the process of increasing the enterprise potential.

Competence strategy of an enterprise will be defined in the relationship: ENTERPRISE COMPETENCE POTENTIAL — COMPETENCE GAP. In the next section, a model of the assessment of the enterprise competence strategy will be shown. This model makes up a base for diagnostic description of an enterprise, which is a definition of a case in the CBR system. The author of this paper shows conception of the intelligent system for predicting economic situation of enterprises in the SME sector based on the CBR (Case-Based Reasoning) methodology (Aamodt and Plaza 1994) using an original A-E-AE ontology. A basis of this conception is a chain of processes of preparing prediction shown in figure 1. This diagram is based on the conception of Porter's value chain (Porter 1980). A model of the knowledge value chain was presented by C.W. Holsapple, M. Singh (Holsapple and Singh 2001) and D. Carlucci, B. Marr, G. Schiuma (Carlucci, Marr, and Schiuma 2004).

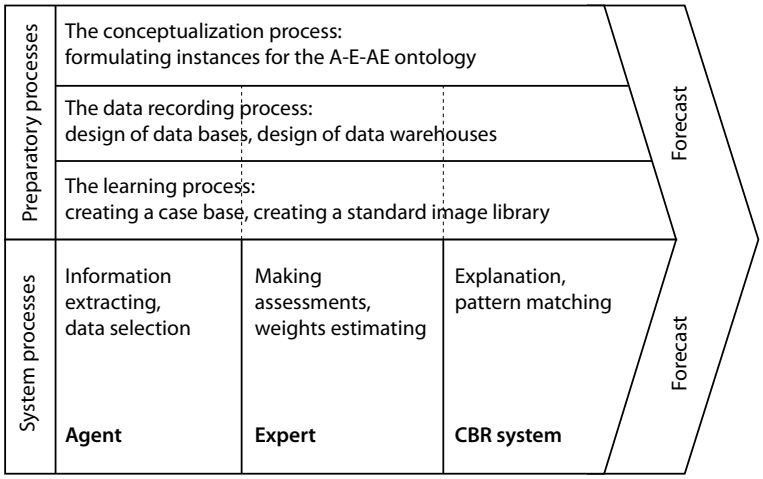

Fig. 1. Diagram of process chain of preparing forecast (PC — Prediction Chain)

The forecast made as a result of realization of system and preparatory processes includes three elements:

1. A protocol of matching score trajectories of a given enterprise to images inserted in a case base.
2. A protocol of predicting the effect of matching a characteristic image from the album of score images typical for the SME sector to a chosen score trajectory.
3. A protocol of explanation of the enterprise position on the basis of indexation algorithms of the CBR system.

The author uses analysis of results of enterprises carried out by J. Argenti (1976). In this analysis, J. Argenti comes to a conclusion that enterprise results analyzed in a given period of time (10–20 years) arrange characteristic images, for which one can assign a specific interpretation. Nwankwo and Richardson (1994) extend three characteristic Argenti's images to four images and call them specific metaphors (bullfrog, drowned frog, boiled frog, tadpole). Figure 2 illustrates four characteristic types of score trajectories.

Forecasting in the accepted conception relies not only on matching a given trajectory of the considered enterprise to the most similar trajectory from a case library, but also on matching patterns of characteristic trajectories, created previously, for enterprises of the SME sector from an album of typical trajectories. There will appear interpretation of predicted economic situation of the enterprise considered. Thus, the first preparatory process is the learning process and the process of inserting cases into a case base (the RETAIN process in the CBR methodology), in which, creating a case base and the album of typical trajectory patterns are performed. Figure 3 shows a generalized score trajectory on the basis of characteristics: EBIDTA, ROE, net profit, income, employment of the exemplary stock enterprise.

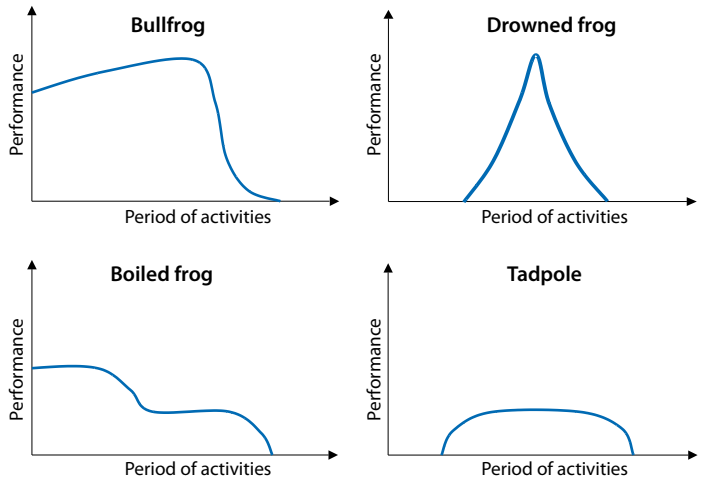

Fig. 2. Characteristic trajectory types

Source: Richardson, Nwankwo, and Richardson (1994)

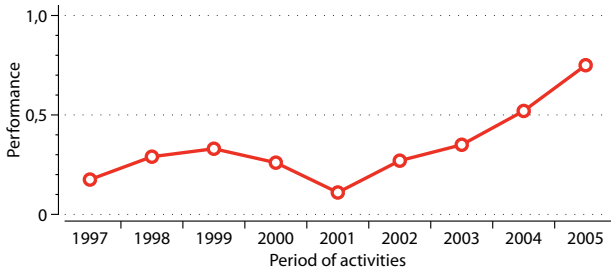

Fig. 3. A generalized score trajectory of the exemplary stock enterprise

Due to a different character of trajectories of individual scores in a specific horizon of performed analysis, a generalized trajectory is created. A procedure of creating this trajectory can be based on algorithms of multi-criteria decision making (Kirkwood 1997). In the CBR methodology, each case recorded in a case base consists of two fundamental parts: a characteristic of a subject diagnosed and solution. The solution in the proposed conception is a score trajectory going beyond a considered period of time for a given enterprise. A characteristic of an enterprise diagnosed is created by an expert on the basis of the A-E-AE ontology. The general diagram of the ontology is prepared using the Protege 3.3.1 editor[1] and the OntoViz tool.

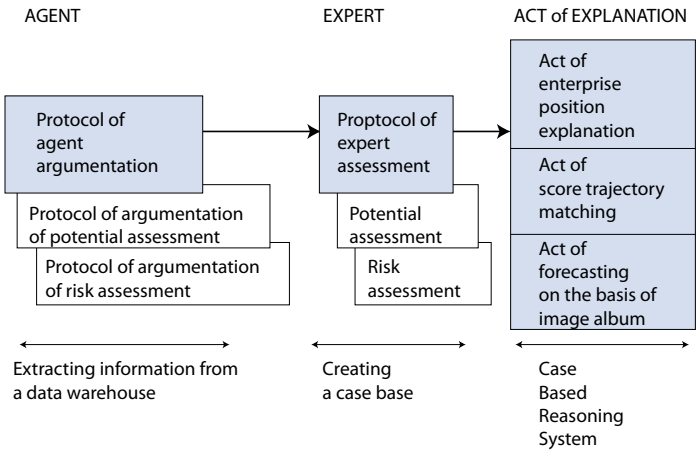

Fig. 4. Diagram of the A-E-AE Ontology

1. See: A free, open-source ontology editor and framework for building intelligent systems at http://protege.stanford.edu/.

1 Enterprise model — a diagnostic approach

Presented conception of an enterprise assessment assumes that the assessment is carried out by experts from a consulting agency on the basis of argumentation presented by a multiagent system (MAS). The multiagent system is built on a data warehouse. Its task is to extract data for an assessment of the enterprise competence in the specific range of analyzed potential of an enterprise and for an assessment of a competence gap in the specific range of analyzed risk of an enterprise. Each expert can perform assessments in certain time instants (for example, every quarter). An enterprise can invite to the assessment external as well as internal experts. Then there are created group assessment images. Experts make an assessment of the enterprise potential on the basis of an assessment of competences defined in individual potential ranges. Experts make an assessment of the risk of the enterprise activity on the basis of an assessment of a competence gap defined in individual risk ranges. Characteristic curves of financial and economic scores of an enterprise in a given period of its activity are extracted from a data warehouse. These characteristic curves form graphical images called score trajectories.

Definition 1. An enterprise assessment Ω consists of a set of images of enterprise assessments $\{e_i\}$ in specific time instants $\{t_i\}$ on the basis of argumentation of artificial agents $\{a_k\}$ of the multiagent system (MAS) built on a data warehouse:

$$\Omega = \{\omega_l\}, \qquad l = 1, 2, \ldots, n \tag{1}$$

$$\forall_{\omega_l} \exists_{e_i} \exists_{a_k} \omega_l = \left\langle A(P)_{e_i}^{t_j} \mid ARG(P)_{a_k}^{t_j}, A(R)_{e_t}^{t_j} \mid ARG(R)_{a_k}^{t_j} \right\rangle \tag{2}$$

where:

Ω — an enterprise assessment,

ω_l — an enterprise assessment image made by the expert e_i on the basis of argumentation of the agent a_k in the time instant t_j,

$A(P)_{e_i}^{t_j}$ — evaluation of the enterprise competence in the range of defined potential made by the expert e_i in the time instant t_j,

$A(R)_{e_i}^{t_j}$ — evaluation of the enterprise competence gap in the range of defined risk made by the expert e_i in the time instant t_j,

$ARG(P)_{a_k}^{t_j}$ — argumentation related to evaluation of the enterprise competence in the range of defined potential, presented by the agent a_k in the time instant t_j,

$ARG(R)_{a_k}^{t_j}$ — argumentation related to evaluation of the enterprise competence gap in the range of defined risk, presented by the agent a_k in the time instant t_j.

The expert makes an assessment of enterprise competences in each determined range of potential according to taxonomy of potential. Figure 5 shows a hierarchical structure of taxonomy of potential consisting of three levels:

- level I: type of potential
- level II: kinds of potential
- level III: ranges of potential for given type and kind

The expert makes an assessment of an enterprise competence gap in each determined range of risk according to taxonomy of risk. Figure 6 shows a hierarchical structure of taxonomy of risk consisting of three levels:

- level I: type of risk
- level II: kinds of risk
- level III: ranges of risk for given type and kind

The expert performs expertise $\varphi(e_i)$ making an assessment of the enterprise competence in each determined range of potential and making an assessment of the enterprise competence gap in each determined range of risk. Additionally, the expert determines the significance of each element of potential and each element of risk for the assessment on each taxonomy level assigning adequate weights to them.

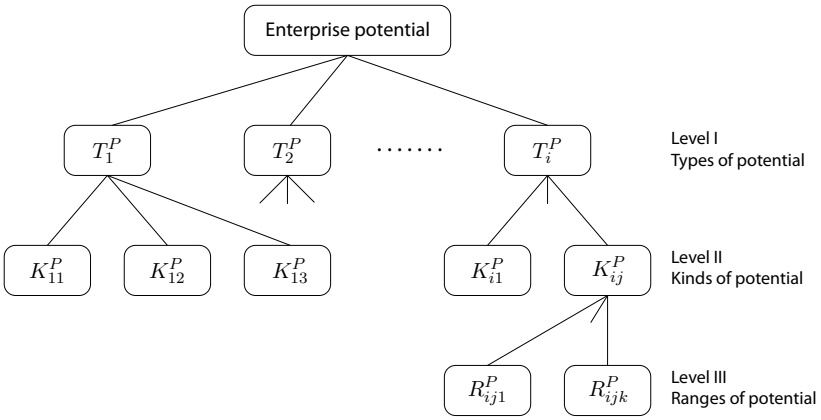

Fig. 5. Diagram of potential taxonomy

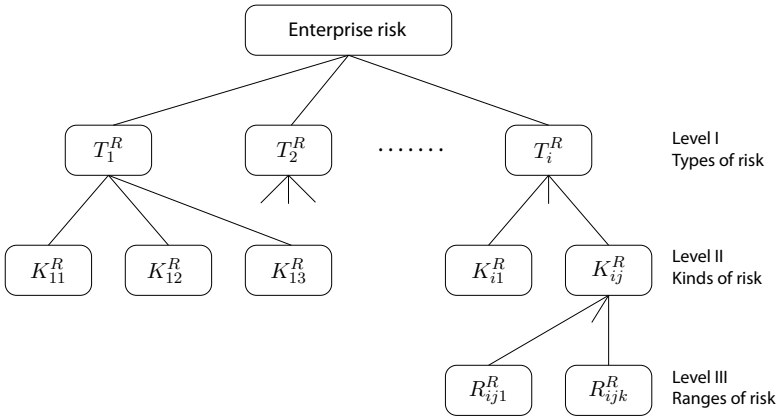

Fig. 6. Diagram of risk taxonomy

Definition 2. Expertise φ of the expert e_i consists of: an assessment of potential $A(P)$, an assessment of risk $A(R)$, a set of weights of the significance of particular assessments according to taxonomy of potential $W(P)$, a set of weights of the significance of particular assessments according to taxonomy of risk $W(R)$:

$$\varphi(e_i) = \langle A(P), A(R), W(P), W(R) \rangle, \tag{3}$$

where:

$$\begin{aligned} A(P) &= \left\{ \forall_{R_{ijk}^P} \exists_{c\left(R_{ijk}^P\right)} c\left(R_{ijk}^P\right) \in \langle 0,1 \rangle \right\} \\ A(R) &= \left\{ \forall_{R_{ijk}^R} \exists_{c\left(R_{ijk}^R\right)} c\left(R_{ijk}^R\right) \in \langle 0,1 \rangle \right\} \\ W(P) &= \left\langle W(T_i^P), W(K_{ij}^P), W(R_{ijk}^P) \right\rangle \\ W(R) &= \left\langle W(T_i^R), W(K_{ij}^R), W(R_{ijk}^R) \right\rangle \end{aligned} \tag{4}$$

Each expert assessment c is a numerical value from the interval $\langle 0,1 \rangle$. Moreover, each single weight of the significance of an assessment is a numerical value from the interval $\langle 0,1 \rangle$. There is argumentation $ARG(P)_{a_k}^{t_j}$ presented by the agent a_k in the time instant t_j on the basis of data extracted from a data warehouse assigned to each range of potential defined at level III of the potential taxonomy. This argumentation is a basis for an assessment of the enterprise competence in the analyzed range of potential.

Definition 3. Agent argumentation for each range of potential is a set of competence assessments with reference to quantitative characteristic of the resource availability, quantitative characteristic of resource qualifications, quantitative characteristic of abilities, quantitative

characteristic of experience, and quantitative characteristic of available technologies, methods and procedures:

$$\forall_{R^P_{ijk}} \exists ARG(P) = \{comR^P, comQ^P, comA^P, comE^P, comT^P\}, \tag{5}$$

where:

$comR^P$ — the quantitative depiction of competence with respect to the resource availability required for realization of the enterprise strategy,

$comQ^P$ — the quantitative depiction of the resource qualifications required for realization of the enterprise strategy,

$comA^P$ — the quantitative depiction of abilities which characterize resources,

$comE^P$ — the quantitative depiction of experience characteristic,

$comT^P$ — the quantitative depiction of technologies (methods) required for realization of the enterprise strategy.

Similarly, there exists agent argumentation for each range of the risk. This argumentation is a basis of an assessment of the competence gap of an enterprise in the analyzed range of the risk.

Definition 4. Agent argumentation for each range of the risk is a set of the competence gap assessments with reference to quantitative characteristic of the resource availability, quantitative characteristic of resource qualifications, quantitative characteristic of abilities, quantitative characteristic of experience, and quantitative characteristic of available technologies, methods and procedures:

$$\forall_{R^R_{ijk}} \exists ARG(R) = \{comR^R, comQ^R, comA^R, comE^R, comT^R\}, \tag{6}$$

where:

$comR^R$ — the quantitative depiction of competence with respect to the resource availability required for realization of the enterprise strategy,

$comQ^R$ — the quantitative depiction of the resource qualifications required for realization of the enterprise strategy,

$comA^R$ — the quantitative depiction of abilities which characterize resources,

$comE^R$ — the quantitative depiction of experience characteristic,

$comT^R$ — the quantitative depiction of technologies (methods) required for realization of the enterprise strategy.

Information on changes in time of different financial indicators (for example, net profit, ROI, ROE, EBIDTA, etc.) and economic indicators (for example, EVA, SVA) and also intellectual capital indicators (for example, VAIC) is extracted from a data warehouse. Quantitative characteristics of these indicators form score trajectories.

Definition 5. A generalized score trajectory is a set of component trajectories and a procedure of generalization:

$$T_{general} = \langle \{T_i\}, PROC \rangle, \tag{7}$$

where:

T_i — component score trajectories,

$PROC$ — a procedure of generalization (determined on the basis of methods of the multiple-criteria decision making theory).

Definition 6. An album of typical images of trajectories consists of a set $T(IMAGES)$ created on the basis of research on enterprises of the SME sector:

$$T(IMAGES) = \{T(IMAGE_i)\}. \tag{8}$$

The presented model of an enterprise disregards the functional structure of an enterprise and varied processes proceeding in an enterprise and its environment. It is oriented to the tripartite analysis concerning:

- an analysis of enterprise competence with respect to defining its potential,
- an analysis of a competence gap identified as a result of analysis of the risk both external and internal,
- explanation of score trajectories on the basis of standard images of score trajectories included in the album of the CBR system.

2 Protocol of the competence assessment and competence gap Assessment with using the AHP method

Making expertise by an expert according to Definition 2 requires to put forward by an agent argumentation for the enterprise competence assessment in the specific range of moulded potential or, respectively, argumentation for the enterprise competence gap assessment in the specific range of defined risk according to Definitions 3 and 4. An expert makes an assessment of the potential and risk on the basis of comparison of two states:

- an actual state of the enterprise (AS) according to documentation delivered by an agent,
- a target state of the enterprise (TS) determined according to the strategy.

It is comfortably to show an assessment protocol by means of the AHP method (Saaty 2001) using software tool called EXPERT CHOICE (Forman and Selly 2001). An attempt to apply the AHP method to enterprise competence assessment is presented by J. Lu, L. Sun, X. Ma (2002). The aim of their analysis is the enterprise competence assessment for obtaining the competence advantage. Below, the screenshot from the EXPERT CHOICE system is shown. It presents the exemplary arrangement of the enterprise competence assessment protocol for a given range of potential. The instance of the COMPETENCE class is the following:

A. Profile of employee resources

- The employee resource availability:
  - available one's own resources,
  - partially available one's own resources,
  - available foreign resources,
  - partially available foreign resources,
  - foreign resources difficult to reach,
- The employee resource qualifications:
  - basic qualifications,
  - special qualifications (certified)
  - unique qualifications.
- Abilities (attitude):
  - teamwork,
  - cooperation ability,
  - creativity,
  - responsibility,
  - decision making,
  - engagement,
  - solution search,
  - articulate
- Experience:
  - success existence,
  - seniority,
  - recommendations,
- Technology:
  - procedures,
  - methods and processes,
  - procedures of the machine and device service,
  - computer aided systems,
  - unique recipes.

B. Profile of processes
- procedures
- indexes (threshold values)
- trends

Definition 7. An assessment of the enterprise competence in the specific range of potential is calculated on the basis of the actual state estimation (AS) and target state estimation (TS) using the AHP method according to the formula:

$$c\left(R_{ijk}^{P}\right) = 1 - (assesmentTS^{P} - assesmentAS^{P}). \tag{9}$$

Definition 8. An assessment of the enterprise competence gap in the specific range of risk is calculated on the basis of the actual state estimation (AS) and permissible state (PS) using the AHP method according to the formula:

$$c\left(R_{ijk}^{R}\right) = assesmentAS^{R} - assesmentPS^{R}. \tag{10}$$

The A-E-AE ontology can be formulated using notation of an open source ontology editor Protege (version 3.3.1) The ontology consists of the following classes: Enterprise image, Act of position explanation, Act of trajectory explanation, Act of forecast explanation, Potential assessment, Risk assessment, Procedure of assessment aggregation, Procedure of determining position in the cluster, Procedure of defining cluster characteristic, Expert assessment according to potential taxonomy, Agent assessment according to potential taxonomy, Expert assessment according to risk taxonomy, Agent assessment according to risk taxonomy, Act of trajectory generalization, Act of generalized trajectory interpretation, Assessment with respect to competence analysis, Assessment with respect to resource availability, Assessment with respect to resource qualification, Assessment with respect to abilities, Assessment with respect to experience, Assessment with respect to technology, Assessment with respect to competence gap analysis, Assessment with respect to resource availability gap, Assessment with respect to resource qualification gap, Assessment with respect to ability gap, Assessment with respect to experience gap, Assessment with respect to technology gap, Estimation of significance of potential type, Estimation of weights of potential kinds, Estimation of weights of potential ranges, Assessment of competence according to potential ranges, Estimation of significance of risk type, Estimation of weights of risk kinds, Estimation of weights of risk ranges, Assessment of competence according to risk ranges.

Conclusion

In the paper, beside presentation of a structure of an intelligent system for predicting economic situation of enterprises in the SME sector, attention is focused on a model of competence assessment of an enterprise. Such a model makes possible elaborating the A-E-AE ontology. The ontology captures three main parts of the system: protocols of argumentation, protocols of assessment of competence potential and competence gap of an enterprise, and explanation acts. In the paper (Andreasik 2008), the author made a classification of enterprise ontology determining the proposed approach as a diagnostic approach. In Section 3, construction of a protocol of competence and competence gap assessment is presented. The author showed a protocol of a position explanation of an enterprise in the paper (Andreasik 2007). Explanation protocols are captured in frameworks of the CBR methodology. Principles of creating a case base and indexation of cases are described in (Andreasik 2007). A diagram of the EXPERT — CBR SYSTEM interface on the basis of competence assessment of an enterprise is shown in figure 7 as a diagram of cooperation in the UML language.

Individual operations, captured in the diagram, concern comparative analysis of a current state and a target state of realization of competence strategy of an enterprise, estimation of weights of individual assessments, aggregation procedures, and grouping in the machine learning process.

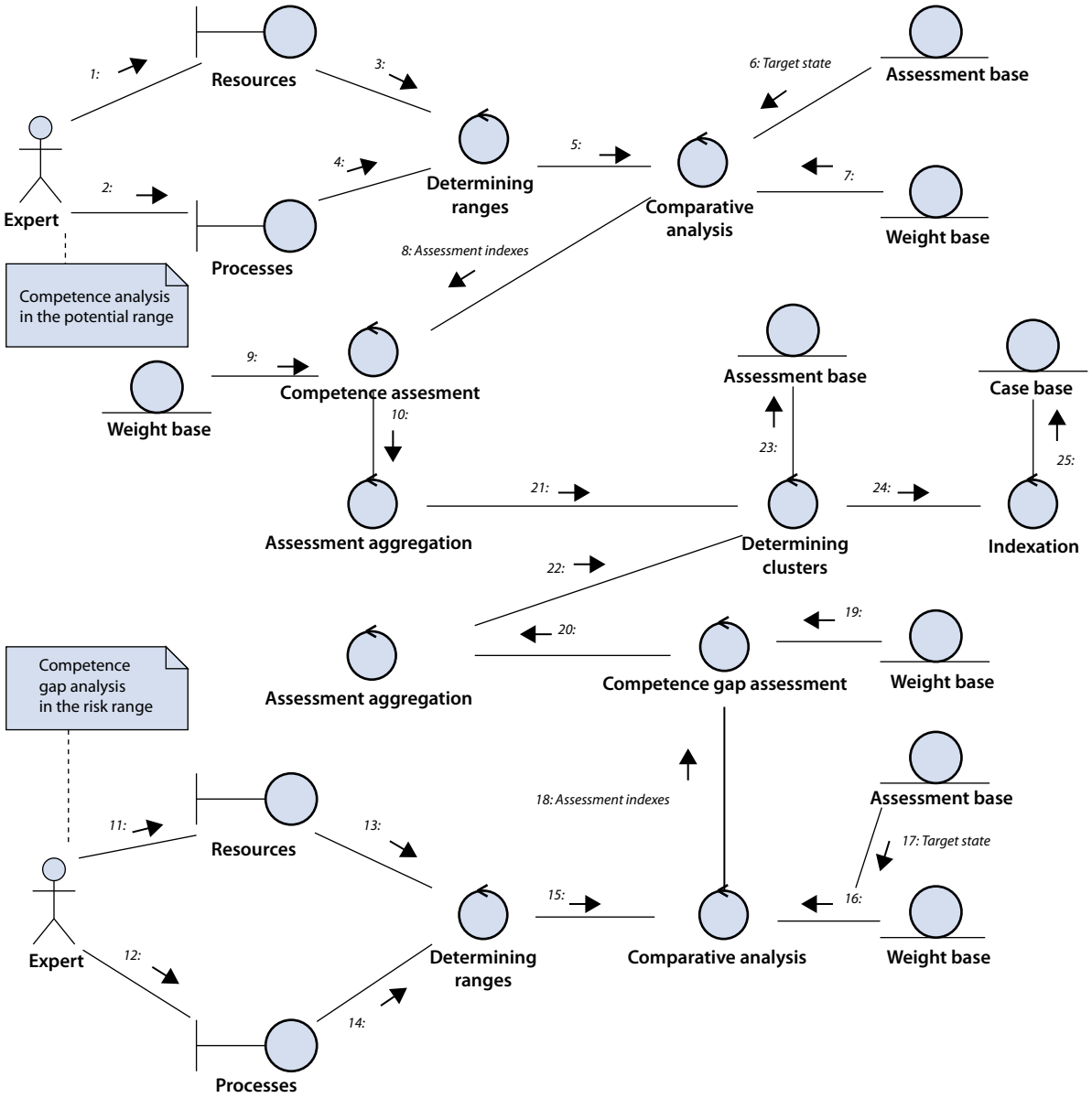

Fig. 7. EXPERT – CBR SYSTEM interface (a diagram of cooperation in the UML language)

Individual procedures of creating the CBR system are under elaboration. According to conception presented in this paper, the author elaborated the system of position analysis of an enterprise within the confines of EQUAL Project No. F0086 managed by Zamość Institute of Management and People Science.

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