Computer-aided Knowledge Extraction and Management for Decision Supporting Processes

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***Abstract*—This publication presents the essence of the process of obtaining knowledge for the purpose of managing data in strategic decision-taking processes. A method of analysing selected datasets will be described by reference to the semantic analysis and interpretation of data. A new class of systems supporting strategic information management processes – Understanding Based Management Financial Leverage Ratios Support Systems (UBMFLRSS) – has been chosen for the analysis. These systems are designed for cognitively analysing financial leverage ratios (financial debt ratios) and reasoning about sources financing the company's assets and the proportion of external capital based on analyses of short-term and long-term liabilities, as well as about the effectiveness of expenditure and the interest paid. Based on the semantic analysis of the value of leverage ratios, it is possible to assess the current standing of the enterprise and its future situation by indicating the direction of change that should be made.**

Keywords-cognitive financial systems; knowledge extraction; data mining; semantic interpretation

I. INTRODUCTION

The authors of this paper have been developing cognitive systems for the semantic analysis of various data for many years. These have been discussed, among others, in the following publications [5], [8], [9], [10], [11], [12].

Cognitive data analysis systems have been divided into various classes according to the type of data they analyse [3], [10]. Thus, the following classes of systems were developed: decision-making, image data analysis, signal data analysis, personal data analysis, automatic control and management process support [5], [10], [11].

The subject of this paper is to discuss the class of systems supporting strategic information management processes [2], [4], [13].

The class of cognitive data analysis systems which support management processes has been split into four main subclasses. The essence of this split is the interpretation of groups of financial ratios which influence (which bring about) the current standing of the enterprise.

Four main system classes have been distinguished in the group of systems supporting financial data management processes [10]:

- Cognitive Understanding Based Management Liquidity Ratios Support Systems (UBMLRSS) – systems for analysing enterprise liquidity ratios, which reason about the amount and the solvency of the working capital of the company as well as about the company's current operations;
- Cognitive Understanding Based Management Activity Ratios Support Systems (UBMARSS) – systems for analysing turnover ratios, which reason about how fast assets rotate and how productive they are;
- Cognitive Understanding Based Management Profitability Ratios Support Systems (UBMPRSS) – systems for analysing profitability ratios, which reason about the financial efficiency of the business of a given unit based on the relationship between the financial results, the sales of goods and services and the cost of sales, and also
- Cognitive Understanding Based Management Financial Leverage Ratios Support Systems (UBMFLRSS) – systems for analysing financial leverage ratios (financial debt ratios), which reason about the sources financing the company's assets and the proportion of external capital by analysing short-term and long-term liabilities; they also reason about the effectiveness of expenditure and the interest paid.

The classes of systems for analysing enterprise liquidity ratios, turnover ratios and profitability ratios have already been analysed and discussed, among others, in publications [9], [10].

The class of systems for analysing debt ratios has not been discussed yet and this is why it is the main subject of this publication. This is an innovative solution that supports cognitive data analysis processes of financial leverage ratios and processes for supporting enterprise financial figure management based on an analysis of debt ratios.

The purpose of this study is to present algorithms for semantic data analysis in the group of UBMFLRSS systems which are used to support strategic decision-taking in management processes.

Semantic analysis processes are used to interpret various sets of data/information, but this publication will only discuss semantic analysis processes dedicated to supporting

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information management processes. The semantic analysis conducted using UBMFLRSS systems allows the current standing of the enterprise to be identified and also shows what decisions should be taken in the future to improve the current situation or maintain it (if the standing of the enterprise is very good). This kind of analysis should be conducted not only for a selected enterprise, but should also identify the impact of the external environment. This is why systems for the semantic analysis of data used for analysis and supporting enterprise management, concentrate their action around [9]:

- Analysis of the internal situation of the company;
- Analysis of the external situation of the company;
- Predicting the future situation;
- Improving decision-making processes;
- Support strategic decision-making;
- Support enterprise management processes;
- Support enterprise management processes in the global aspects.

This situation is shown in Figure 1.

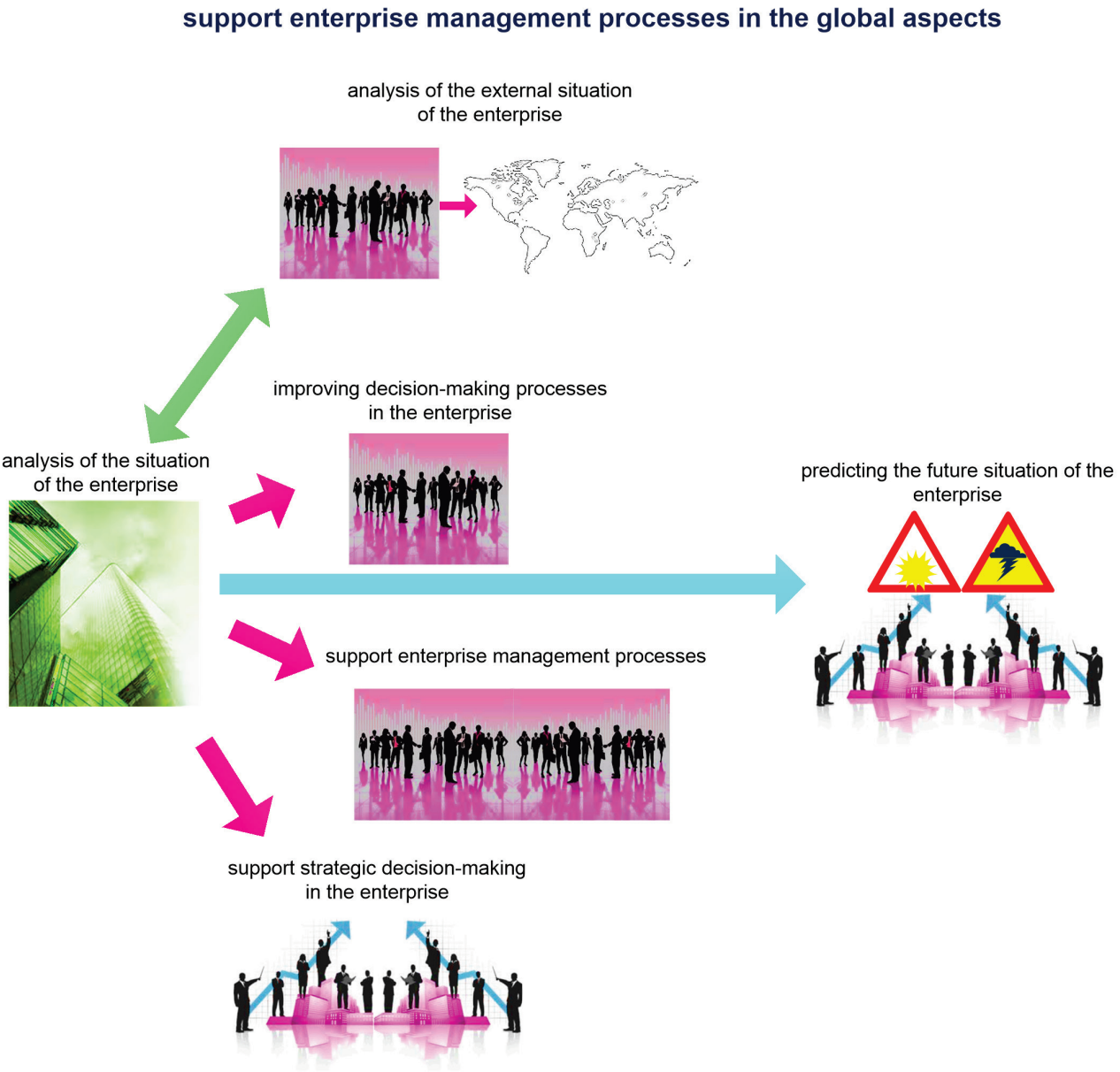

Figure 1. The enterprise management processes in the global aspects.

The analysed datasets and the standing of the enterprise can be cognitively analysed by assessing various datasets. This publication describes an analysis of ratios used to assess the level of debt of a given enterprise.

In Section 2, we will present three sub-classes of UBMFLRSS systems as examples of intelligent enterprise debt analysis systems – the UBMFLRSS-$G_{(td\text{-}ld)}$ systems, the UBMFLRSS-$G_{(td\text{-}ls)}$ systems, and the UBMFLRSS-$G_{(dsc\text{-}ic)}$

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systems. Section 3 concludes the paper with a summary of the conducted research.

II. UBMFLRSS AS AN EXAMPLE OF ENTERPRISE DEBT ANALYSIS SYSTEMS

Enterprise debt applies to a situation in which the enterprise uses any form of financial support and not just exclusively its own capital. It applies to any situation in which the enterprise users external capital. In this situation, the enterprise is indebted.

The assessment of the enterprise debt situation is aimed at determining the extent to which the enterprise finances itself with its own funds and to which it is financed with funds coming from outside. In this context, it is possible to assess the proportion of own capital to external capital in financing the enterprise. The most important element in assessing the debt situation is to determine the impact of external capital on enterprise operations and the degree to which the financial independence of the enterprise is at risk [1]. This type of assessment also results in identifying the costs of using external capital and the cost-effectiveness of this solution.

The values of the following debt ratios can be analysed:

- Debt level ratios;
- The company's ability to service its debt.

The following ratios are distinguished in the group of ratios identifying the debt level [1]:

- Total debt ratio;
- Long-term debt;
- Debt to equity;
- Long-term debt to equity;
- Liability structure;
- Long-term liability coverage with net fixed assets;
- Interest coverage.

The following ratios are distinguished in the group of ratios identifying the ability of the enterprise to service its debt:

- Debt service coverage;
- Interest coverage;
- Debt service coverage with the cash surplus.

Semantic data analysis systems are used to assess the current situation of the enterprise based on the semantic interpretation of a selected group of ratio data [7], [9].

In cognitive financial systems, the following may be analysed [9], [10]:

- The financial situation of enterprise – financial ratios;
- The economic situation of enterprise;
- The surroundings of enterprise;
- The situation and condition of:
    - customers,
    - providers,
    - others companies,
- And the influence of the environment of the company.

In cognitive systems for the semantic analysis of data, namely debt ratios, it is possible to determine:

- The degree to which enterprise operations are financed with its own funds;
- The degree to which enterprise operations are financed with external funds – the enterprise's debt;
- The proportion of own capital to external capital in corporate finance;
- The debt situation – by determining the impact of external capital on enterprise operations and the degree to which the financial independence of the enterprise is at risk;
- The costs and profitability of using external capital for enterprise operations.

Computer-aided cognitive enterprise management systems analyse various types of financial ratios. Based on the situation of the enterprise, the next part of analysis is the selection of type financial ratios that will be important and analysed [10].

After this, a proper class of cognitive financial systems should be selected, based on the type of analysed indicators [1].

In this systems, it is necessary to define a formal grammar to analysed selected data and indicators for the semantic features of data sets [5], [6], [8], [11], [12], [13], [14].

The next part of analysis and computer-aided enterprises management [7] is the evaluation of the enterprise situation, based on the important financial ratios. This analysis is especially important for [10]:

- Describing the present situation of the enterprise;
- Supporting enterprise management processes;
- Understanding of the current state of companies;
- Understanding of the causes of the current situation of the company;
- Describing the future situation of the enterprise.

The process of data mining in computer-aided enterprises management systems is shown in Figure 2.

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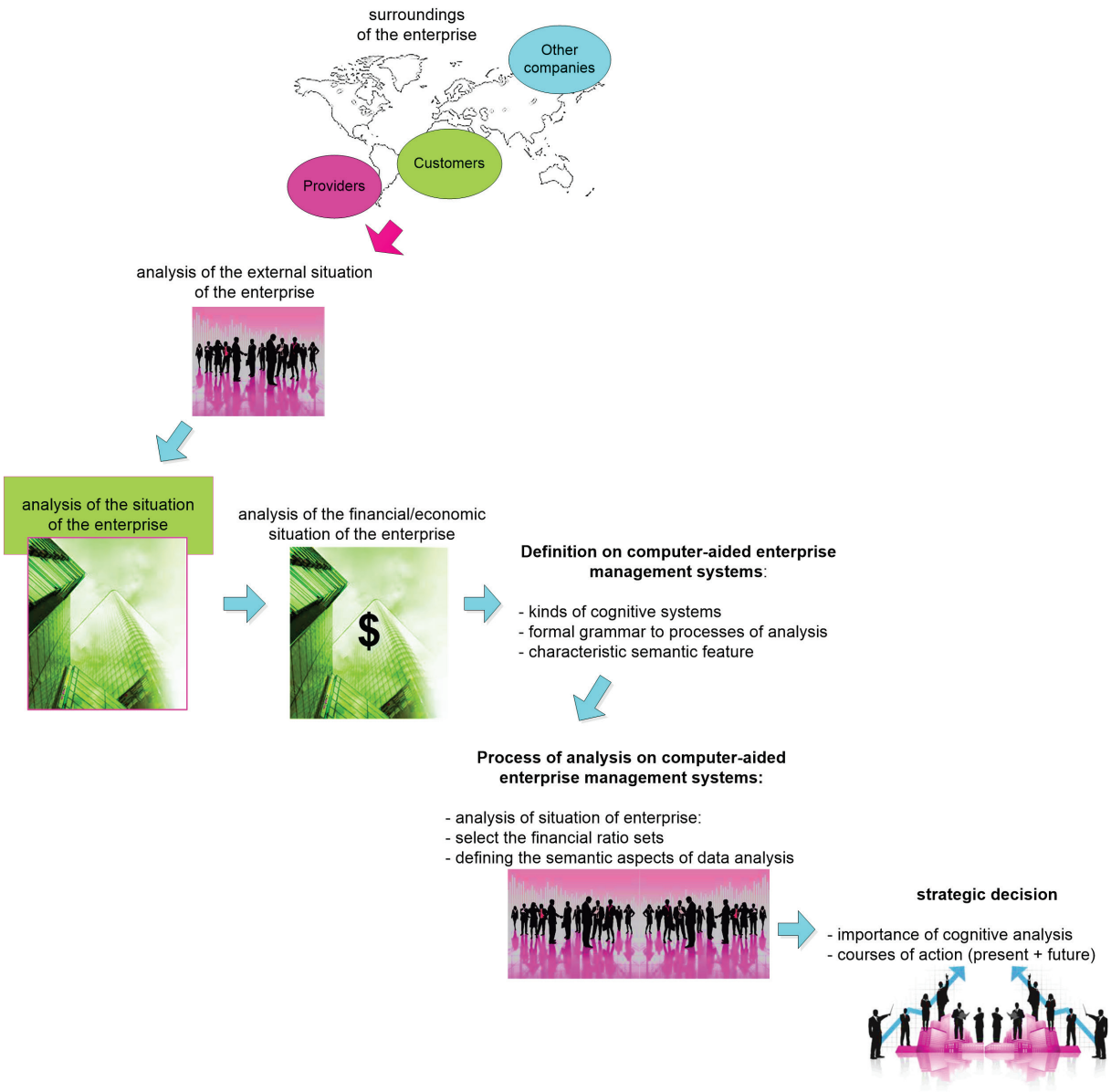

Figure 2. The process of data mining in computer-aided enterprise management systems.

This paper will discuss UBMFLRSS systems designed for the semantic analysis of enterprise debt.

In the financial cognitive UBMFLRSS systems, supporting enterprises management, authors proposed a sequential grammar [9], [10], [11] as a formal definition.

In this paper, the semantic analysis procedures will be adopted for enterprise management and strategic-decision making tasks using cognitive information systems – example UBMFLRSS.

A. The UBMFLRSS-G$_{(td\text{-}ld)}$ Systems

The following ratios have been adopted to analyse enterprise standing in UBMFLRSS systems as described after interpreting selected corporate debt ratios:

- total debt ratio,
- long-term debt ratio.

In UBMFLRSS-G$_{(td\text{-}ld)}$ systems for the semantic analysis of the debt value, the following symbols have been introduced:

- v_{td} – the value of the total debt ratio,
- v_{ld} – the value of the long-term debt ratio.

A formal grammar definition in these systems has the following form:

$$G_{(td\text{-}ld)} = (V_{N(td\text{-}ld)}, V_{T(td\text{-}ld)}, P_{(td\text{-}ld)}, S_{(td\text{-}ld)}) \quad (1)$$

where:

$V_{N(td\text{-}ld)}$ = {DEBT1, HIGH_DEBT1, OPTIMAL_DEBT1, LOW_DEBT1} – the set of non-terminal symbols,

$V_{T(td\text{-}ld)}$ = {a, b, c}– the set of terminal symbols,

where:

a ∈ [0; 0,57), b ∈ [0,57; 0,67], c ∈ (0,67; 1]
$S_{(td\text{-}ld)} \in V_{N(td\text{-}ld)}$,
$S_{(td\text{-}ld)}$ = DEBT1,
$P_{(td\text{-}ld)}$ – set of productions:
1. DEBT1 →HIGH_DEBT1 | OPTIMAL_DEBT1 | LOW_DEBT1 |
2. HIGH_DEBT1 → BC | CB | CC
3. OPTIMAL_DEBT1 → BB
4. LOW_DEBT1 → AA | AB | AC | CA | CB
5. A → a
6. B → b
7. C → c.

B. The UBMFLRSS-$G_{(td\text{-}ls)}$ Systems

The second example of UBMFLRSS systems for the semantic analysis of data described by interpreting selected enterprise debt ratios was created for analysing the following ratios:

- total debt ratio,
- liability structure.

In UBMFLRSS-$G_{(td\text{-}ls)}$ systems for the semantic analysis of the debt value, the following symbols have been introduced:

- v_{td} – the value of the total debt ratio,
- v_{ls} – the value of the liability structure ratio.

A formal grammar definition in these systems has the following form:

$$G_{(td\text{-}ls)} = (V_{N(td\text{-}ls)}, V_{T(td\text{-}ls)}, P_{(td\text{-}ls)}, S_{(td\text{-}ls)}) \quad (2)$$

where:
$V_{N(td\text{-}ls)}$ = {DEBT2, HIGH_DEBT2, OPTIMAL_DEBT2, LOW_DEBT2} – the set of non-terminal symbols,
$V_{T(td\text{-}ls)}$ = {a, b, c}– the set of terminal symbols,
where:
a ∈ [0; 0,57), b ∈ [0,57; 0,67], c ∈ (0,67; 1]
$S_{(td\text{-}ls)} \in V_{N(td\text{-}ls)}$,
$S_{(td\text{-}ls)}$ = DEBT2,
$P_{(td\text{-}ls)}$ – set of productions:
1. DEBT2 →HIGH_DEBT2 | OPTIMAL_DEBT2 | LOW_DEBT2 |
2. HIGH_DEBT2 → CC
3. OPTIMAL_DEBT2→ BB | BC | CB
4. LOW_DEBT2 → AA | AB | AC | BA | CA
5. A → a
6. B → b
7. C → c.

C. The UBMFLRSS-$G_{(dsc\text{-}ic)}$ Systems

The third example of UBMFLRSS systems for the semantic analysis of data described by interpreting selected enterprise debt ratios designed for assessing the enterprise ability to service its debts was created for analysing the following ratios:

- debt service coverage,
- interest coverage.

In UBMFLRSS-$G_{(dsc\text{-}ic)}$ systems for the semantic analysis of the company's ability to service its debt, the following symbols have been introduced:

- v_{dsc} – the value of the debt service coverage ratio,
- v_{ic} – the value of the interest coverage ratio.

A formal grammar definition in these systems has the following form:

$$G_{(dsc\text{-}ic)} = (V_{N(dsc\text{-}ic)}, V_{T(dsc\text{-}ic)}, P_{(dsc\text{-}ic)}, S_{(dsc\text{-}ic)}) \quad (3)$$

where:
$V_{N(dsc\text{-}ic)}$ = {DEBT_SERVICE1, HIGH_DEBTSERVICE1, MEDIUM_DEBTSERVICE1, LOW_DEBTSERVICE1} – the set of non-terminal symbols,
$V_{T(dsc\text{-}ic)}$ = {a, b, c}– the set of terminal symbols,
where:
a ∈ [0; 1), b ∈ [1; 1,5], c ∈ (1,5; 2,5]
$S_{(dsc\text{-}ic)} \in V_{N(dsc\text{-}ic)}$,
$S_{(dsc\text{-}ic)}$ = DEBT_SERVICE1,
$P_{(dsc\text{-}ic)}$ – set of productions:
1. DEBT_SERVICE1 →HIGT_DEBTSERVICE1 | MEDIUM_DEBTSERVICE1 |LOW_DEBTSERVICE1
2. HIGH_DEBTSERVICE1 → CC
3. MEDIUM_DEBTSERVICE1 → BB | BC | CB
4. LOW_ DEBTSERVICE1 → AA | AB | BA | AC | CA
5. A → a
6. B → b
7. C → c.

The three examples of systems for the semantic analysis of financial data presented above are designed for assessing the debt level of an enterprise and the ability of this enterprise to service its debt.

Three independent linguistic formalisms in the form of sequential grammars, each for a separate subclass of UBMFLRSS, have been proposed for the semantic analysis of financial data.

The semantic analysis conducted in UBMFLRSS allows the debt situation of the enterprise to be assessed and indicates its possible consequences. In this sense, it can be used to support information management. What is supported in the described case is the management of financial figures describing the debt situation of the enterprise.

Examples of cognitive data analysis systems illustrate systems that support decision making based on extracted knowledge elements. In UBMFLRSS systems for the semantic analysis of data, the knowledge means information about the financial standing, and particularly the debt of the enterprise as well as its ability to service the debt contracted. Extracting knowledge elements in UBMFLRSS systems is fund components of information sets, which components will be used directly to assess the situation of the enterprise. Extracting significant features that undergo the semantic analysis process helps to more effectively manage the information held and adds the elements of the semantic interpretation of financial information to the processes of managing this information.

An example of the operation of a UBMFLRSS system is shown in Figure 3.

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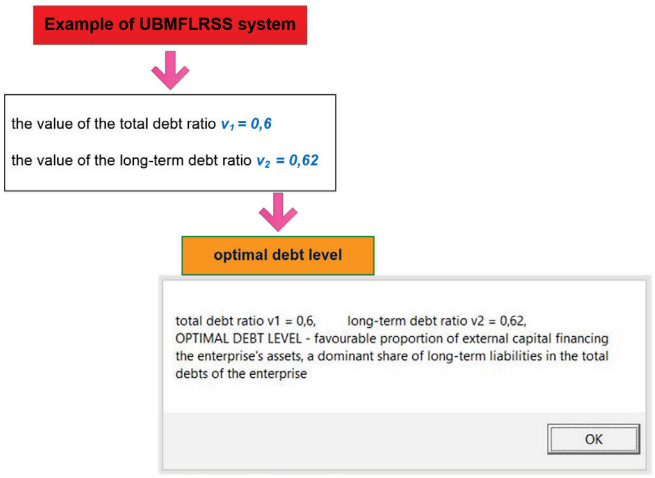

Figure 3. Example of UBMFLRSS-$G_{(td\text{-}ld)}$ cognitive financial systems.

The example of the UBMFLRSS system presented here is used to analyse ratio data, namely selected groups of debt ratios: the total debt ratio and the long term debt ratio.

Based on this semantic analysis, the system interprets the situation of the enterprise as good from the perspective of its debt level. The semantic interpretation is to determine the optimal level of debt understood as a favourable proportion of external capital used to finance the company's assets and its operations, as well as a dominant share of long term liabilities in the total debt of the enterprise.

Based on the analysis of selected financial ratios the situation of the company is described. The example of cognitive analysis of financial ratios shows how the two selected ratios shape the situation of the enterprise.

III. CONCLUSIONS AND FUTURE WORK

Cognitive data analysis systems are used for semantic analysis which consists in extracting semantic information from analysed datasets and interpreting this information. Thus, cognitive analysis processes ensure that data/information will be analysed with regards to its meaning. Linguistic formalisms in the form of definitions of formal grammars (sequential, tree or graph) are used to describe the analysed data sets. Financial information management systems are an example of cognitive data analysis systems. In this class of systems, linguistic formalisms in the form of sequential grammars have been proposed for the formal description of the analysed data.

The analysis of ratio data in cognitive systems was proposed for the purpose of improving processes of strategic (financial) information management. This improvement is possible because linguistic formalisms are used in the process of analysing financial data. This not only allows the analysed financial values to be interpreted, but it also helps assess the situation of the enterprise and indicates the possible directions of its change if necessary or it shows that there is no need to implement any remedial action. In this publication, we proposed a new approach to the semantic analysis of financial data. Evaluation of the effectiveness of the proposed solutions will be the subject of future work.

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