Cognitive systems for intelligent business information management in cognitive economy

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A R T I C L E   I N F O

A B S T R A C T

This paper will present new theoretical and applied solutions for intelligent data analysis and information management in the fields of cognitive economics. Intelligent data analysis and information management are performed by information systems called cognitive systems, dedicated for semantic interpretation of acquired business information. To interpret the meaning of the analysed data, complex linguistic algorithms must be used, based on which it is possible to find the core information elements for business processes forecasting and economical knowledge management. The presentation of selected methods of semantic data analysis in cognitive economy, which allow to perform both local and global information management forms the main subject of this paper. Here, semantic analysis methods are dedicated to cognitive economics problems, namely the interpretation, analysis and assessment of the meaning of selected sets of economic/financial ratios. The meaning of the interpreted data sets is assessed by analysing the layers of meaning contained in data analysed sets. Obtained semantic information may be used in future business processes evaluation and forecasting.

1. Introduction

Intelligent data analysis and information management tasks performed by advanced information systems (Zhong, Raś, Tsumoto, & Suzuki, 2003) are currently aimed at extracting information from broad data sets or even wider context like company environments, to determine the meaning of such data or information (Bodzioch & Ogiela, 2009; Buchanan & McMenemy, 2012; Hachaj & Ogiela, 2011; Ogiela, 2013a). Originally, intelligent data analysis was understood as computer or machine analysis (Buchanan & McMenemy, 2012). This led to the development of systems for automatic data extraction, analysis and management (Ogiela & Ogiela, 2012a, 2012b). The next step in the development of automatic data analysis systems was to look for solutions capable of recognising various forms of data (the analysis was most frequently applied to numerical data, text or visual information e.g. image data), whose operation would lead to the correct recognition of the analysed information sets (Chomsky, 1988; Cohen & Lefebvre, 2005; Duda, Hart, & Stork, 2001; Ogiela, 2008a, 2008b, 2009).

Enhancing the data understanding process by adding the stage of semantic data interpretation meant that the intelligent

systems for information management now include data understanding capabilities (Ogiela, 2008b; Ogiela & Ogiela, 2012a). As this class of systems was designed based on the cognitive and reasoning processes occurring in human minds, which were applied in automatic/computer solutions, the systems were referred to as cognitive information systems (Ogiela & Srebrny, 2012; Ogiela & Ogiela, 2009, 2010a,b, 2011a,b,c).

Cognitive systems constitute only a part of the entire discipline referred to as cognitive informatics or business intelligence. Its particular advantages consist of the constant linking of psychological/philosophical/neural subjects with informatics/linguistic and economics ones. The description of situations and processes occurring in human cognition constantly inspired researchers to develop new classes of cognitive information systems dedicated to solving various important and complex tasks. These were first developed for image data analysis, and later for analysing ratios and the economic situation of enterprises. This last class of cognitive data analysis systems lies the foundation for the development of a new field of science i.e. cognitive economics understood as a combination of cognitive science with traditional economics. The idea of cognitive economics is presented in Fig. 1.

Semantic analysis can also be applied to various economic/financial ratio evaluation and management (Bernstein & Wild, 2000) used to assess the current and future situation of individual enterprises. Thus the analysis of individual groups of

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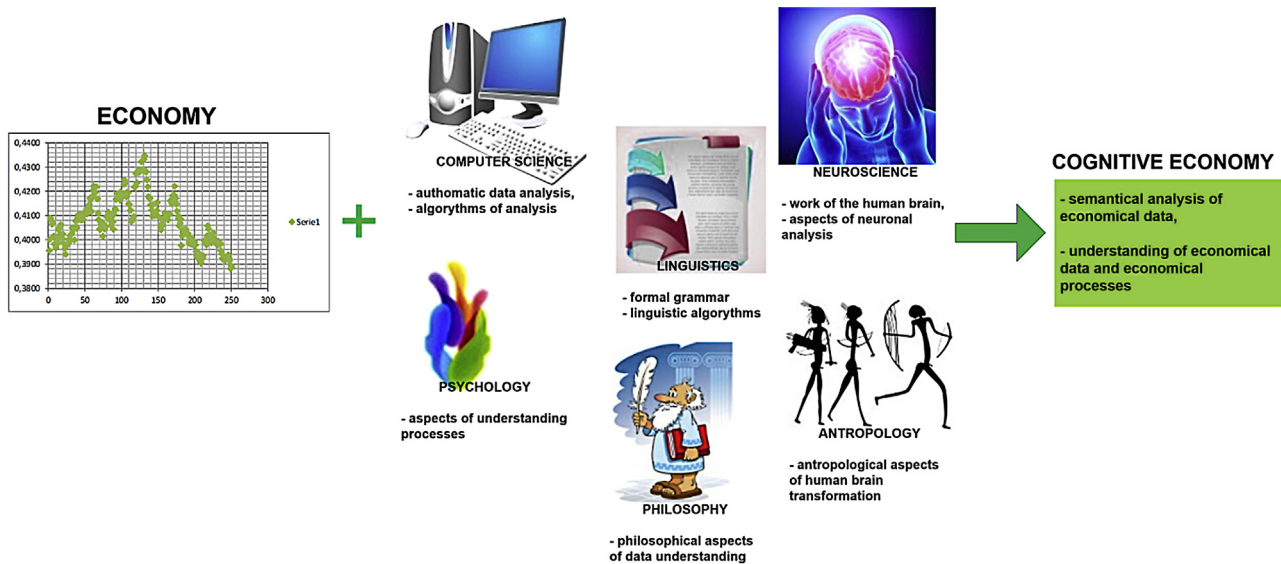 *E-mail address:* mogiela@agh.edu.pl (M.R. Ogiela).

Fig. 1. The idea of cognitive economy.

economic/financial ratios allows one to identify not only the current state, i.e. what is happening in the company at present, but also and primarily suggests new directions of activity by identifying possible future threats.

Hence cognitive economics charts include directions for the contemporary analysis of financial and strategic data as well as for management processes (Laudon & Laudon, 2013; Ogiela & Ogiela, 2012b; TalebiFard & Leung, 2011).

When applied skilfully at the right stages of the enterprise, organisation or structure management, semantic analysis makes it possible not just to assess the current situation, but also becomes the starting point for process forecasting.

2. Cognitive systems in economics and management sciences

Cognitive economics is now treated as a science dealing with analysing economic phenomena and economic situations, managing organisations and taking strategic decisions based on the cognitive analysis of the topics interpreted. Cognitive analysis has been described in many publications, including (Ogiela, 2008a, 2008b, 2008c, 2008d, 2008e; Ogiela & Ogiela, 2009). The essence of its operation is to determine the consistency of the characteristic features with the expectations about the phenomena analysed (data sets, information). Characteristic features are described based on collected data sets while expectations are generated by the system from sets of expert knowledge accumulated in the system knowledge base. By identifying consistencies between the expectations and characteristic features, consistent pairs can be extracted and inconsistent ones rejected. Thus determined consistency of features and expectations leads to cognitive resonance processes (Ogiela, 2010a, 2010b; Ogiela & Ogiela, 2012a), which enables understanding of the analysed situation. On the contrary, when the characteristic features are inconsistent with expectations, dissonance occurs as a result.

The entire process of information analysis and data understanding makes it necessary to define the right linguistic formalisms in the system, namely grammatical formalisms. Linguistic formalisms (Ogiela, 2013a, 2013b, 2013c; Ogiela & Ogiela, 2010b) used in cognitive economics (Grossberg, 2012; Ogiela, 2013a) are usually in the form of sequential grammars, because numerical data (e.g.

financial ratios) are best recorded in the form of a sequence of numerical values.

The semantic analysis process in the field of cognitive economics is presented in Fig. 2.

Cognitive economics is used to describe and semantically analyse the economic/financial situation of enterprises, but also to reason about their current and future situation.

The cognitive analysis performed using the semantic interpretation system applied by a given institution or enterprise may be transferred or expanded onto a broader area or become global, which is related to external conditions as well as the business field of a given enterprise. These options are a consequence of universal cognitive information systems as well as cognitive resonance methods. In practical terms, it means that when such systems are applied, they analyse not just the selected groups of economic indicators characteristic for a given enterprise and reflecting its current financial situation but also take into account the impact of the enterprise's broader environment upon its further development, which determines the current market position of this enterprise or institution.

The essence of the approach proposed here is to take into account both the parameters describing the enterprise's current situation and the impact of external conditions upon the further development of this enterprise, both possible due to cognitive resonance which enables intelligent use of the data and information collected in the process of determining the enterprise's future condition.

It is important to take into account both local and global parameters because enterprise development is seen as an element of a greater system, i.e. it is considered in relation to other enterprises and such factors as the global market, the situation of suppliers, end-users and competition play an important role. When these aspects are included, the semantic analysis of the enterprise's financial data makes it possible to determine the impact of the external market upon the right evaluation of the situation and the company's future position.

The cognitive approach to analysis taking into account both local data and the company's global situation can be found in Fig. 3.

Cognitive resonance applied in the analysis of the economic situation of a given enterprise is used to determine the impact of external factors upon the company's development and to indicate the convergence (consistency) between the external factors and