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A Forex trading expert system based on a new approach to the rule-base evidential reasoning

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ABSTRACT

Currently *FOREX* (foreign exchange market) is the largest financial market over the world. Usually the Forex market analysis is based on the Forex time series prediction. Nevertheless, trading expert systems based on such predictions do not usually provide satisfactory results. On the other hand, stock trading expert systems called also “mechanical trading systems”, which are based on the technical analysis, are very popular and may provide good profits. Therefore, in this paper we propose a Forex trading expert system based on some new technical analysis indicators and a new approach to the rule-base evidential reasoning (*RBER*) (the synthesis of fuzzy logic and the Dempster–Shafer theory of evidence). We have found that the traditional fuzzy logic rules lose an important information, when dealing with the intersecting fuzzy classes, e.g., such as *Low* and *Medium* and we have shown that this property may lead to the controversial results in practice. In the framework of the proposed in the current paper new approach, an information of the values of all membership functions representing the intersecting (competing) fuzzy classes is preserved and used in the fuzzy logic rules. The advantages of the proposed approach are demonstrated using the developed expert system optimized and tested on the real data from the Forex market for the four currency pairs and the time frames 15 m, 30 m, 1 h and 4 h.

1. Introduction

The most of papers devoted to the Forex market analysis are based on the Forex time series prediction. Pang, Song, and Kasabov (2011) proposed a correlation-aided support vector regression (*cSVR*) for the Forex time series prediction. The proposed *cSVR* is experimented for time series prediction with 5 future contracts (*NZD/AUD, NZD/EUD, NZD/GBP, NZD/JPY*, and *NZD/USD*). Nevertheless, the *cSVR* prediction is found sometime surfing unexpectedly far away from the truth value. In Shmilovici, Kahiri, and Ben-Gal (2009), a universal Variable Order Markov model is proposed and used for testing the weak form of the Efficient Market Hypothesis (*EMH*). The *EMH* is tested for 12 pairs of international intra-day currency exchange rates. However, the authors noted that predictability of the model is not sufficient to generate a profitable trading strategy. In contrast to the earlier techniques, Bahrepour et al. (2011) proposed a high-order fuzzy time series identification scheme which utilises an adaptive order selection scheme and partitions the universe of discourse using self organising maps. This partitioning scheme allows different granularity at different parts of decision spaced. The proposed technique is then applied to the prediction of FOREX daily dataset. However, the possibility of the proposed method to generate profitable trading strategies is not studied. Amiri, Zandieh, Vahdani, Soltani, and Roshanaei (2010) proposed a new integrated eigenvector-DEA-TOPSIS methodology to evaluate the risks of portfolio in the Forex market. The proposed eigenvector-DEA-TOPSIS methodology uses eigenvector method to determine the weights of criteria, linguistic terms such as high, medium and low to assess Portfolio risks under each criterion. Bagheri, Peyhani, and Akbari (2014) proposed an approach to financial forecasting using ANFIS networks with Quantum-behaved Particle Swarm Optimization. They stated that, by implementing and testing the proposed method on real Forex data, they could forecast the market direction and make correct trading decisions with approximately 69% accuracy. Undoubtedly, this a very good result for prediction, but there are no real trading system or trading strategy in this paper.

Opposite to the above papers, in Mendes, Godinho, and Dias (2012) a Forex trading system based on a genetic algorithm and a set of ten technical trading rules is presented. Summarising, the authors wrote ”The strategies that were obtained showed very good performance in the training series but, if we take transaction costs into account, they were often unable to achieve positive

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results in the out-of-sample test series." Obviously, such strategies cannot be used in practice.

Since ideas and methods used for the development of Forex trading system are similar to those used for building stock market trading systems (*SMTS*), here we present a short review of the works devoted to problems of *SMTS*.

The most of papers in this field were devoted to stock prise prediction. Kao, Chiu, Lu, and Chang (2013) proposed a hybrid approach by integrating wavelet-based feature extraction with MARS and SVR for stock index forecasting. A system for predicting stock and stock price index movement using Trend Deterministic Data Preparation and machine learning techniques was developed by Patel, Shah, Thakkar, and Kotecha (2015). Nevertheless, it was shown by Kuo, Chen, and Hwang (2001) that the most of works devoted to the stock price prediction generally used the time series analysis techniques (Kendall & Ord, 1990) and multiple regression models. It was noted by Haefke and Helmenstein (2000) that the models based on the stock prices prediction produced less than successful results when were used for building stock trading expert systems.

Artificial neural networks (*ANNs*) and genetic algorithms (*GAs*) have been applied for the stock prices prediction. However, these researches cannot produce at least satisfactory stock trading expert systems (Baba & Kozaki, 1992; Kim & Han, 2000; Kuo et al., 2001; Mahfoud & Mani, 1996; Mehta & Bhattacharyya, 2004).

The methods of Rough Sets Theory (Pawlak, 1982) for trading rules extraction was used in (Shen & Loh, 2004; Wang, 2003) with rather negative results.

The use of expert's wisdom makes it possible to develop more reliable stock trading systems. Gottschlich and Hinz (2014) proposed a decision support system design that enables investors to include the crowd's recommendations in their investment decisions and use it to manage a portfolio. The stock trading rule discovery with an evolutionary trend following model proposed by Hu, Feng, Zhang, Ngai, and Liu (2015) is implicitly based on the expert's experience and provides good results. The limitation of this study is that, the trading strategy rules are sub-optimal, which may lead to the fact that the rules discovered by eTrend are not global optimal. The use of expert's experience and intuition for the formulation of trading rules may be considered as a basic idea of a new approach presented in the current paper.

The first step in the development of trading system based on the expert's wisdom was made by Dourra and Siy (2002). They presented the expert system based on the fuzzy logic representation of trading rules used by traders. They used the fuzzy logic representation of technical analysis to create the rules which provide sell, buy and hold signals. They directly used the classical Mamdani's general form of fuzzy rules (Mamdani & Assilian, 1975), which provide real-valued outcomes. The Mamdani's approach was developed for fuzzy logic controllers and may lead to creation of somewhat artificial system of fuzzy rules when dealing decision making problems. Therefore, Santiprabhob, Nguyen, Pedrycz, and Kreinovich (2001) developed a new system of the so-called "Logic-Motivated Fuzzy Logic Operators" (*LMFL*) which better reflects the specificity of human reasoning in decision making processes. This system is based on a new approach to the mathematical representation of *t*-norm and Yager's implication rule (Turksen, Kreinovich, & Yager, 1998). Sewastianow and Rozenberg (2004) used the *LMFL* approach to develop stock trading decision support systems. It was shown that these systems provide significantly better results than Mamdani's approach proposed by Dourra and Siy (2002). In Sevastianov and Dymova (2009), two stock trading decision support systems based on *LMFL* and on the synthesis of fuzzy logic and *DST* were developed and compared using the real-world *NYSE* data. Based on the obtained results it was shown that *RBER* approach provides better and more reliable outcomes than those obtained using *LMFL* approach. Dymova, Sevastianov, and Bartosiewicz (2010) developed a new approach to the *RBER* which can be considered as an extension of the known *RIMER* method (Yang, Liu, Wang, Sii, & Wang, 2006; Yang, Liu, Xu, Wang, & Wang, 2007). The advantages of this approach were demonstrated using the developed stock trading decision support system. In Dymova, Sevastianov, and Kaczmarek (2012) this approach was successfully used for the development of stock trading expert system based on the rule-base evidential reasoning using Level 2 Quotes. Rule-base evidential reasoning is based on the synthesis of methods of Fuzzy Sets theory (*FST*) and the Dempster–Shafer theory (*DST*). This approach combine these theories in a synergic way, preserving their strengths while avoiding disadvantages they present when used solely: a capacity for the representation of fuzzy classifiers is enhanced by introduction the measure of ambiguity; limitations of *DST* in providing effective procedures to draw inferences from belief function are softened by integrating the rule of propagation of evidence within the fuzzy deduction paradigm. The synthesis of *FST* and *DST* primarily was used for the solution of control and classification problems (Binaghi, Gallo, & Madella, 2000; Binaghi & Madella, 1999; Ishizuka, Fu, & Yao, 1982; Yager, 1982; Yen, 1990). With the use of the known *COA* method (Yager & Filev, 1995), these models generated the system's output in the form of real values. Nevertheless, when we deal with decision support systems, the outputs can be only the names or labels of corresponding actions or decisions.

Therefore, a more appropriate for the development of decision support systems seems to be the so-ca' *RIMER* method proposed by Yang et al. (2006, 2007). With the use of this method, the final results obtained as the aggregation of belief rules are as $O = \{(D_j, \beta_j)\}$, where β_j, $j = 1$ to N, is the aggregated degree of belief in the decision (hypothesis, action, diagnosis) D_j. Then the decision with a maximal aggregated degree of belief is the best choice.

In Dymova et al. (2010, 2012), a new approach which can be treated as an extension of *RIMER* method was proposed and used to develop the effective stock trading expert systems. The method used in these works is based on the classical Dempster's rule of combination of evidence from different sources. Generally, the method provides good results, but in some cases the unreasonable results were obtained. In the part of such cases, undesirable results were coursed by a large conflict between evidence,which often cannot be eliminated when dealing with the real-world problem (it is well known that the Dempster's rule provide controversial results in such situations). On the other hand, in some cases we also have obtained unreasonable results, when the conflict was very small or even equal to zero.

Inspired by these results, in the current paper we have carried out a study aimed to find a more appropriate combination rules.

Therefore, in this paper, using critical examples, we analyze the known combination rules (including their aggregations) and show their restriction and drawbacks.

At the end, we show that in the cases of small and large conflict, the use of simple averaging rule for combination of basic probability assignments (*bpas*) seems to be a best choice.

We have found that the traditional fuzzy logic rules lose an important in- formation, when dealing with the intersecting fuzzy classes, e.g., such as *Low* and *Medium*, and this property may lead to the controversial results. In the framework of the proposed in the current paper approach, an information of the values of all membership functions representing the intersecting (competing) fuzzy classes is preserved and used in the fuzzy logic rules.

Therefore, the rest of the paper is organised as follows. In Section 2, we present the basic definitions of *DST* needed for the subsequent analysis and with the use of critical examples consider the problems concerned with the known combination rules in *DST*.