The postulates of consensus determining in financial decision support systems

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Abstract—**This article presents the problem of consensus determining postulates defining in financial decision support systems. The consensus determining methods and function is characterized in the first part. Next the general postulates for consensus estimation and their characteristics are presented. The final part of article suggest new postulates pertaining to financial decisions, and the possibility of their use in practical solutions. The application of these postulates, as a consequence, can lead to the process of making financial decisions will be more flexible, and the risk involved in financial decisions will be significantly reduced.**

I. Introduction

MAKING decisions in financial matters has become a key component of any business activity. Problems in this area are typically associated with highly volatile character of financial market [9]. Decisions must be made virtually in real time, since only prompt and accurate reaction to changing market conditions provides tangible benefits, for example high return rate. Another important determinant is the high level of risk involved in financial decisions. Since analysis of information and drawing valid conclusions is a time-consuming process, and since real-time computing is beyond human processing capabilities, the process of making financial decisions is typically supported by computer software, employing a range of computing methods, such as artificial intelligence systems, capable of identifying relevant information and drawing conclusions based on input data. Important area of development in recent years is the use of agent and multi-agent systems [10,18] – these, unlike other AI systems, offer the capability of unaided operation and unaided decision-making, i.e. without user input and irrespective of any external factors.

At present, financial decision support systems (DSS) are typically distributed [2]. These systems offer the potential of fast processing of large amount of data. However, in most cases, distributed systems used for support of financial decision-making processes tend to generate multiple variants of solutions, which may result in knowledge conflict within the system. For example, in multi-agent systems, each individual agent may utilize a different method of decision support and, consequently, arrive at a different solution. Users expect a unified variant – or, to put it in simple terms, they want a single decision. Decision-making process is followed by implementation, and only one decision can be implemented at any given time – ideally, one that will bring tangible benefit to the user, while simultaneously limiting the level of risk involved. If a decision support system generates multiple variants, users face the problem of selecting the best possible variant – the ultimate decision. Since the task of selecting the best possible variant, as already mentioned, should ideally be realized in (or close to) real time, it is expected that the DSS will automatically present a single variant that offers best possible results for the user, thus solving the knowledge conflict. Professional literature presents a wealth of methods that can be used to this effect, such as negotiation methods [4] and deductive computing methods [1]. Negotiation methods allow for determining a solution that best suits all parties involved, based on compromise, but it is burdened with the problem of mass exchange of information between system components, which makes the postulate of real-time computing particularly difficult to achieve – or even impossible. On the other hand, deductive methods of computing (such as those based on game theory, classical mechanics and selection methods) offer high computing power, but do not easily satisfy the requirement of identifying best possible variant with simultaneously limiting the risk of inadequate selection.

It seems that the above inconveniences (and the resulting knowledge conflict) can be resolved with the use of consensus methods [8,15]. Consensus methods offer the benefit of determining a single best variant (or a single decision, in this context) out of multiple possible variants. It must be noted that the single decision determined using consensus methods will not necessarily belong to the domain of variants generated by the system in the first place. This is because consensus methods take into consideration all conflicting parties and interests. The ultimate decision is endorsed by all modules (parties) and the decision represents interests of all parties to a degree that satisfies all conflicting parties.

Sobieska-Karpińska and Hernes [10, 5] argue that using consensus methods for the purpose of identifying and presenting a target solution to the user will offer a reduction of decision-making time, since users are not burdened with the task of analysing and selecting the best possible variant. It also reduces the risk involved in the process, since variants identified and selected by the user may fail to bring the expected benefit, or even result in a loss.

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It must be noted, however, that consensus algorithms used in DSS systems, including systems for financial decision support, must satisfy certain consensus postulates. These postulates represent conditions to be met by consensus-calculating functions. Only proper definition of these conditions will ensure that decisions made with the help of consensus algorithms will bring tangible benefit to the user.

Professional literature (see, e.g. [1,13,14]) does provide some general (universal) postulates for consensus estimation, but those assumptions fail to take into account some important aspects of financial decision-making, such as the risk and uncertainty involved. Therefore, it seems necessary to broaden the list of postulated parameters.

The purpose of this paper is to present the general postulates for consensus estimation (that need to be included, regardless of the problem they are meant to address via consensus calculation) and their characteristics, as well as suggest new postulates pertaining to financial decisions. This will allow for more accurate construction of consensus algorithms and, consequently, development of IT solutions able to calculate consensus results automatically, based on a set of solutions generated by the system. In this approach, the system will present the user with one ultimate decision that may be implemented to best effect. Consequently, the process of making financial decisions will be more flexible, since the system will suggest the most appropriate solution in (or close to) real-time. In addition, the risk involved in financial decisions will be significantly reduced, since users will not be able to manually select a decision that may be burdened with such risk at implementation phase.

II. General Postulates Of Consensus Determining

Purpose of introduction the postulates is determination on their bases classes of functions of consensus or otherwise saying, different methods of a consensus determining.

In addition, because the postulates are conditions which are expected to meet on consensus function, you can get it to justify the use of these functions in practice.

In farthest part of article we will use following symbols:

$\Gamma(U)$ - set of all don't empty subsets of universe U (e.g. set of objects-financial instruments),

$\Gamma'(U)$ - set of all don't empty subsets with repetitions of universe U,

$\cup'$ – sum of set with repetitions.

Let $X, X_1, X_2 \in \Gamma'(U)$, $x\in U$. In farthest part of article we will use next parameters:

$o(x,X)=\sum_{y\in X} o(x,y)$,

$o^n(x,X)=\sum_{y\in X} [\, o(x,y)]^n$ for $n\in \mathrm{N}$.

Let's notice, that parameter $o(x,X)$ represents sum of distance from element x belongs to universe U for elements of profiles X , but largeness $o^n(x,X)$ represents sum of n-powers it distance. This value can be interpreted as measure of evenness of distance from element x for elements of profiles (eg. det of financial decisions) X. if value n is greatest memorial then n, distances are more even.

In work [15] consensus function is defined next:

Definition 1.

Consensus function at space (U,o) we call optional functions of forms:

$$c:\Gamma'(U)\rightarrow\Gamma(U)\,. \qquad (1)$$

For profile $X\in\Gamma'(U)$ each of elements set $c(X)$ we call his *consensus,* however all set $c(X)$ we call *representation of profile X.* . Let C is set of all consensus functions in a space *(U, o).*

Using the overall function of the consensus you can then define the more detailed class consensus functions, relating to the various methods of its determination, including [15]:

a) Constructive methods, rely on solving problem of consensus on two levels: microstructures and macrostructures universe U. Microstructure is a structure of elements U, macrostructure is structure of universe U.
b) Optimizing methods, rely on defining function of consensus behind assistance of optimizing rules. Often in this methods functions quasi-mediane are applying, consensus is most approximated for all solutions from which be appointed, distances of consensuses are even for individual solutions simultaneously.
c) Methods taking advantage bool conclude, rely in the form encoding problem of consensus in bool formula to such manner that each first implicant this formula appoints solution of problem.

Therefore, in order to define the classes of functions relating to the above methods, it can use the postulates for consensus defined as follows (on the basis of [1, 13, 14]):

Definition 2.

Let X is optional profile we say, that consensus function $c\in C$ grants postulate:

1. *Reliability (Re), if*
$$C(X)\neq\varnothing \qquad (2)$$
2. *Consistency (Co), if*
$$(x\in C(x))\Rightarrow(x\in c(X\cup' \{x\})) \qquad (3)$$
3. *Quasi-unanimous (Qu), if*
$$(x\notin C(x))\Rightarrow((\exists n\in \mathrm{N})x\in c(X\cup' \{n*x\})) \qquad (4)$$
4. *Proportional(Pr), if*
$$(X_1\subseteq X_2\wedge x\in c(X_1)\wedge y\in c(X_2))\Rightarrow(o(x,X_1)\leq o(y,X_2) \qquad (5)$$
5. *1-Optymality (O_1), if*
$$(x\in C(x))\Rightarrow(o(x,X)=\min_{y\in U}o(y,X)) \qquad (6)$$
6. *2-Optymality (O_2), if*
$$(x\in C(x))\Rightarrow(o^2(x,X)=\min_{y\in U}o^2(y,X)). \qquad (7)$$

These postulates for function of consensus express primary condition define different method consensus. First postulate (*reliability*) sets up, that it is possible to appoint consensus for each profile always. It answers optimistic attitude each conflict give solve. Reliability is known criterion in theory of choice [3].

Postulate *consistency* requires implementation of condition, that if some element x is consensus for profile X , then after expansion this profile about x ($X\cup'$ $\{x\}$), this element should be consensus for new profile. Consistency is important ownership of consensus, because it allows users to forecast behavior of rule of appointment of consensus, when premises of independent choices are jointed.

According to postulate *quasi-unanimous,* if certain element x is not consensus for profile X, that it will be consensus for profile X^1 inclusive X and n protrude element x for certain n. In other words, each of elements of universe U should be chosen as consensus for such profile, if number of its pronouncement is sufficiently big.

Proportionality postulate is natural ownership enough, because if profile is greatest memorial then difference between its elements and consensus is greatest.

Last two postulates are very particular. First of it, postulate *1-Optymality* require that consensus is nearest (most similar) to elements of profile. This postulate, in literature very well known, it defines concrete function class, called medians. Instead postulate *2-Optymality*, on the other hand, requires, in order to sum of square of distance from consensus for elements of profiles was smallest. Cause of introduction of this postulate results from (also very natural) following condition concerning determination function consensus: consensus have to be „fair"; it means, that its distance for elements of profiles should be the most even. Let's notice, that number $o^n(x,X)$ defined earlier, can be treated as measure of evenness of distance between certain object x and elements of profiles X. Therefore, above-mentioned condition requires, in order to value o^n (consensus, X) be minimal. In work [6, 7] show, that functions granting postulate *2-optymality* are better than function granting postulate *1-optymality*, by the reason of greatest evenness, but they differ from other function of consensus greatest similarity for elements of profiles. From it result, that postulate *2-optymality* is good criterion of appointment of consensus.

Let us note that the first three postulates, namely *Re*, *Co* and *Qu*, are independent of the structure of universe U, represented by a distance function o (used to establish consensus function class in methods based on Boolean reasoning), while the last three postulates (Pr, O_1 and O_2) are formulated on the basis of o function (these postulates are employed in optimization methods). Postulates *Re*, *Co* and *Qu* are also used in cases when distance function (or, in more general terms – the macro-structure) for universe U cannot be specified. For financial decisions, function of distance can always be reliably defined, therefore all postulates can be employed, allowing for the use of both constructive and optimization methods of consensus estimation.

The above general postulates of consensus estimation, as already mentioned, are not sufficient for financial purposes. For this reason, this author puts forward two additional postulates to supplement the above list.

III. The Proposal To Extend The List Of Postulates In Terms Of Making Financial Decisions

A good approach in estimating best possible decisions in financial matters, i.e. when dealing with problems typically burdened with risk and uncertainty, is to employ evenly distributed consensus – that is, one that takes into account all possible solutions, with each solution estimated at equal measure. This helps minimize the risk of ultimate decision, since the potential of putting more weight to an incorrect decision is eliminated. Therefore, if *2-Optimality* postulate offers more even distribution that *1-Optimality* postulate, then a postulate of *n-Optimality* should be defined, to offer even smoother distribution than *2-Optimality* for n>2. Consequently, definition for such new postulate will take the following form:

Definition 3.

The consensus function c∈C grants an n-Optimality postulate (O_n), if

$$(x\in C(x))\Rightarrow(o^n(x,X)=\min_{y\in U} o^n(y,X)). \quad (8)$$

This postulate is a generalization postulates *1-Optimality* and *2-Optimality*.

Another extended postulate on consensus determining in financial decision support systems is a inconsistency of knowledge postulate:

Definition 4.

Consensus function c∈C grants an inconsistency of knowledge postulate (Uk), if

$$(x\in C(x))\Rightarrow(o^n(x,X)>\min_{y\in U} o^n(\{X\backslash y\},X)). \quad (9)$$

The above postulate allows for determination of an element, for which the distance to consensus is larger than the sum of consensus distances of all the remaining elements (in other words, one of the profile elements is markedly more distant from the consensus than the others). Such situation may result from inadequate knowledge on the part of one of the conflicting parties (for example, a software agent). If this is the case, then decisions generated by the defaulting party should not be taken into account. This problem may be solved by adopting a multi-stage process of consensus estimation, as suggested in [16]. Such method is under implementing in a-Trader multiagent system for FOREX platform [11]. These systems consist of the large number (hundreds) of processing agents, which on the basis of the FOREX signals, take the specified decision on buy/sale. The paper [12] presents using the consensus methods to reduce the level of the investment risk, as a strategy of Supervisor Agent in a-Trader System.

Building consensus algorithms on the above postulates is not necessarily a guarantee of success in arriving at best possible solution. For example, the algorithms may find a consensus solution for which a given element of the decision-making process is at the same time adopted and rejected, leading to a contradiction. Some authors also take into account the profile's consensus susceptibility [8]. If a profile (a set of decisions) is not prone to consensus, methods of satisfying its susceptibility may be adopted, such as inclusion of decisions generated by new parties (e.g. new software agents).

However, it must be noted that consensus estimation functions used for the purpose of supporting financial decisions must meet both general consensus postulates and the expanded postulates (these postulates may also be used in order to the other, than only financial problems). Otherwise, the estimated consensus may not warrant tangible benefit to the user, for example – by placing more weight on an inappropriate decision contained in the profile.

IV. Conclusion

Making decisions in financial matters is a complicated process, particularly in the face of high risk and uncertainty associated with this form of activity, since it may lead to unpredictable results. Improper decisions may detriment the functioning of a whole organisation. Distributed systems offering support for financial decisions are a viable solution, provided that they are able to generate a single, reliable recommendation. However, if individual nodes of the system (such as software agents) generate multiple instances of solutions, the overall reliability of the system is considerably lower. Therefore, proper care should be taken to ensure that the user receives the best possible solution generated automatically by the system, so that he or she can make a correct decision that will result in benefit for the organization. Use of consensus methods provides the potential of arriving at a single best decision – one that not necessarily belongs to the original domain of decisions generated by individual nodes, but adequately similar. Consequently, the level of risk involved is considerably lower. If users were to perform own analyses and manually select from decisions generated by the system under time pressure, their choices would be potentially burdened with error – the more so if we take into account the time pressure involved. In addition, consensus methods allow for considerable reduction of decision time, since the system presents the user with a single best solution determined automatically on the basis of variants generated by individual nodes.

For obvious reasons, consensus methods do not warrant absolute accuracy of resultant decision, but they do warrant some degree of satisfaction. Some of the individual variants generated by system nodes may prove more appropriate than the automatic suggestion determined using consensus methods, but one can never be certain that the user would have selected such best variant (if he were to analyse and select it manually). In such a case, selecting the worst possible variant is also possible, which can only increase the risk involved.

However, correct algorithms for consensus estimation should incorporate and take into account all the postulates presented above. Negligence in this respect may result in ill-advised suggestions with negative consequences.

Proper implementation of consensus postulates is, therefore, a prerequisite for correct design of consensus algorithms to be used in financial DSS (decision support systems).

References

[1] Barthlemy J.P., Janowitz M.F., “A formal theory of consensus”, in: Siam J., *Discrete math* 4, 1991.

[2] Coulouris G., Dollimore J., Kindberg T., *Distributed system. Concept and Design*, WNT, 1998.

[3] Daniłowicz C., Nguyen N.T. , *Metody wyboru reprezentacji podziałów i pokryć uporządkowanych*, Oficyna Wydawnicza PWr, Wrocław 1992.

[4] Dyk P., Lenar M., “Applying negotiation methods to resolve conflicts in multi-agent environments”, in: *Multimedia and Network Information systems*, MISSI 2006 Zgrzywa A. (red.), Oficyna Wydawnicza PWr, Wrocław 2006

[5] Hernes M., “Weryfikacja metod consensusu w wieloagentowym systemie wspomagania decyzji finansowych”, *Business Informatics* 22-2011 Prace Naukowe UE we Wrocławiu, Wydawnictwo UE we Wrocławiu Wrocław 2011.

[6] Hernes M., Nguyen N.T., *Deriving Consensus for Incomplete Ordered Partitions*. in: Nguyen N. T.(ed.), *Intelligent Technologies for Inconsistent Knowledge Processing*. Advanced Knowledge International, Australia 2004.

[7] Hernes M., Nguyen N.T., “Deriving Consensus for Hierarchical Incomplete Ordered Partitions and Coverings”, *Journal of Universal Computer Science* 13(2), 317-328, 2007.

[8] Hernes M., Sobieska-Karpińska J., “Susceptibility to consensus of conflict situation in intelligent multi-agent decision support system”, in: Kubiak B.F., Korowicki A. (ed.), *Information Management*, Gdansk University Press, Gdańsk 2009.

[9] Jajuga K., *Podstawy inwestowania na Giełdzie Papierów Wartosciowych*, Giełda Papierów Wartościowych S.A., Warszawa 2007.

[10] Korczak J., Lipiński P. “Agents systems in capital market decision support”, in: Stanek S. , Sroka H. , Paprzycki M., Ganzha M. (ed.), *Evolution multiagent information systems in socialy-economic environment*, Placet Press, Warszawa 2008.

[11] Korczak J., Bac M., Drelczuk K., Fafuła A., “A-Trader – Consulting Agent Platform for Stock Exchange Gamblers”, in: *Proceedings of Federated Conference Computer Science and Information Systems* (FedCSIS), Wrocław, 2012.

[12] Korczak J., Hernes M., Bac M., “Risk avoiding strategy in multi-agent trading system”, in: *Proceedings of Federated Conference Computer Science and Information Systems* (FedCSIS), Kraków, 2013 (in press).

[13] McMorris F.R., Mulder H.M., Powers R.C., “The median function on median graphs and semilattices”, *Discrete Applied Mathematics* 101, 2000.

[14] Nguyen N.T. , *Metody wyboru consensusu i ich zastosowanie w rozwiązywaniu konfliktów w systemach rozproszonych*, Oficyna Wydawnicza Politechniki Wrocławskiej, 2002.

[15] Sobieska-Karpińska J., Hernes M., “Determining consensus in distributed computer decision support system”, in: Dziechciarz J. (red.), *Ekonometria. Zastosowania metod ilościowych*, nr 31, Wydawnictwo UE we Wrocławiu, Wrocław 2011.

[16] Sobieska-Karpińska J., Hernes M., “Consensus determining algorithm in multiagent decision support system with taking into consideration improving agent's knowledge”, *Proceedings of Federated Conference Computer Science and Information Systems* (FedCSIS), Wrocław 2012.