Knowledge Based Modeling of Financial Decision Support Systems

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Abstract. Financial markets are perceived as dynamic systems of interacting agents whose modeling and prediction are based on computer technology. Decision support systems analyze the state parameters of controlled systems and external factors in order to make the appropriate decisions. The aim of this paper is to analyze the techniques for system dynamics and decision-making process modeling. The simulation of controlled systems' models, modeling the decision-making processes and goals modeling are connected in a whole. All different types of models are analyzed in one process area. Also the conceptual example of controlled financial process is presented.

Keywords: decision support, system dynamics, knowledge base

1 Introduction

The research area of computational economics combines economics and computer science. Financial market is perceived as a dynamic system of interacting agents whose modeling and prediction are based on computer technology.

In particular, the main effort is to model complex economic processes, the influence of different factors to the final result and the interdependencies of these factors. First of all the models of real life processes are created and then they are simulated in order to experimentally analyze the various possible scenarios. Decision support systems (DSS) analyze the state parameters of controlled systems and external factors in order to make the appropriate decisions.

The main research question is how to increase effectiveness of identification of anomalous situations in financial markets. Combining intelligent data analysis methods, multi-criteria modeling and knowledge based decision making can solve this problem. It allows more accurately evaluate the markets efficiency and better forecast upcoming crisis.

But first of all we need effective methods for easier modeling of complex mechanisms of financial systems. Different types of factors that affect the financial markets must be integrated in models. Turning this to knowledge base which is used by decision support systems can increase the efficiency of such systems. The simulation of controlled systems' dynamics, modeling the processes of decision making and goals versus risks modeling must be connected in a whole.

The aim of this paper is to analyze the techniques for systems dynamics and decision-making process modeling. In order to achieve this, we present different types of models in one process area (PA). In the section 2 we explain how these models can be connected in the formalized way and present the conceptual example of controlled financial process. In section 3 we present the review of methods for modeling system dynamics, decision-making process, goals and risks.

This paper serves as theoretical background for past authors' works (e.g. "Dynamic simulation of pension funds' portfolio" [12], "Research of customer behavior anomalies in big financial data" [11], "Multi-criteria model for choosing long term investments" [13]) and for future works. In the future researches we will try to increase modeling and prediction effectiveness by incorporating irrational factors that affect financial markets in addition to traditional fundamental and technical analysis indicators.

2 DSS modeling methods in one research area

First of all we need to have the methodology for connecting different types of models and their elements in a whole. The main aim is to correctly identify hierarchical structures and relationships between system elements. There are different methodologies for systems modeling, such as ontology based modeling or metamodeling.

Ontology is an explicit specification of a conceptualization (T.R. Gruber 1993) [3]. Ontology defines the concepts of investigated domain, types of entities (events, objects), conceptual hierarchies, the interrelations of entities types and their interdependencies, axioms, rules, patterns of entities' types and relationships, case studies [9]. According to J. Dietz (2006), as a branch of philosophy, ontology investigates and explains the nature and essential properties and relations of all beings, as such, or the principles and causes of being. [5]. We distinguish ontology based modeling methods offered by J. Dietz, because they are based on process modeling. This can be applied to modeling the processes of financial markets. Assuming our goal is to create a model of real word (a simplified representation of a certain reality), the importance of **metamodeling** must be understood.

According to S. Mellor (2004) a meta-model is a model of a modeling language. The meta-model defines the structure, semantics and constraints for a family of models [14]. S. Clark (2008) states that a meta-model is a model of a language that captures its essential properties and features. These include the language concepts it supports, its textual and/or graphical syntax and its semantics (what the models and programs written in the language mean and how they behave). Correct meta-model is ontology, but not all ontologies are explicitly modeled as meta-models [3].

Further in this paper we analyze process area and elementary management cycle, proposed by S. Gudas [7]. In original work it was applied for enterprise modeling. In this approach we apply it to the decision support systems (DSS) of financial markets. The main objective is to interconnect process simulation of controlled system (financial market domain), decision-making process modeling and objectives versus risk modeling.

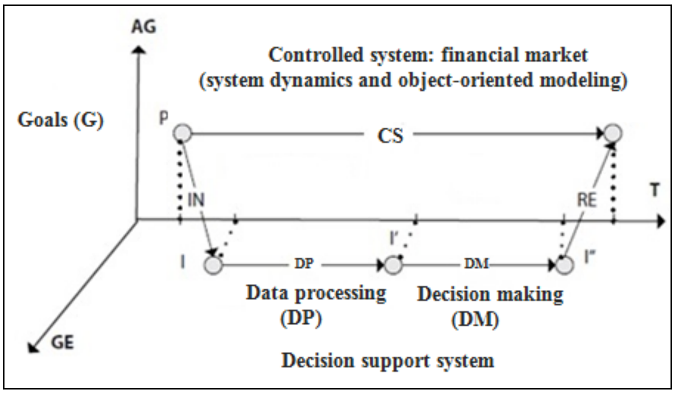

Fig. 1. EMC and three types of models in one Process area (based on S. Gudas. Theory fundamentals of information systems engineering [7])

The diagram of Elementary management cycle (Figure 1) shows how the managing system (DSS) interprets the parameters of the controlled system and implements decisions in accordance with the goals model.

All three types of models (controlled system, decision-making process, goals and risks) can be displayed in one research area.

Process Area (PE) has three axes: aggregation (AG), generalization (GE) and time (T). They express the processes that form the hierarchy of the modeled systems entities [7]:

- AG axis forms the hierarchies of material entities. Usually it means the technological processes, roles and data of enterprise. In our case it means the processes of investment, market data, shares etc. *i* is the index of aggregation hierarchy level.
- GE axis forms the hierarchies of conceptual entities (only informational processes and objects). *j* is the index of generalization hierarchy level.
- T axis forms the sequences in time of material and conceptual entities. It also forms causality of processes and objects. *t* is the index of time hierarchy level.

Process area (PE) is designed to investigate the management processes of controlled system. Modeled objects of real world are called entities:

- Material entities are modeled in plane (AG, T). The term „material“ comes from enterprise modeling and usually is connected with technological processes. But in our case it is perceived slightly different. In this plane we present models of investment processes, factors affecting these processes and actors involved in them. Object oriented modeling and system dynamics are combined to investigate operating principles and causalities of controlled financial domain. These modeling methods are analyzed more deeply in section 3.2.
- Conceptual entities are modeled in plane (GE, T). Models of managing system (DSS) cover data processing and decision making processes, as well as data and knowledge structures. Architecture of DSS is presented in section 3.1.
- Goals and risks are modeled in plane (AG, GE). All decisions are made according to them. Methods for goals modeling are presented in section 3.3

During the process simulation of controlled system its' entities and factors affecting them gain various values. Every moment of time (t) managing system processes the data, makes decisions according to goals and risk management rules.

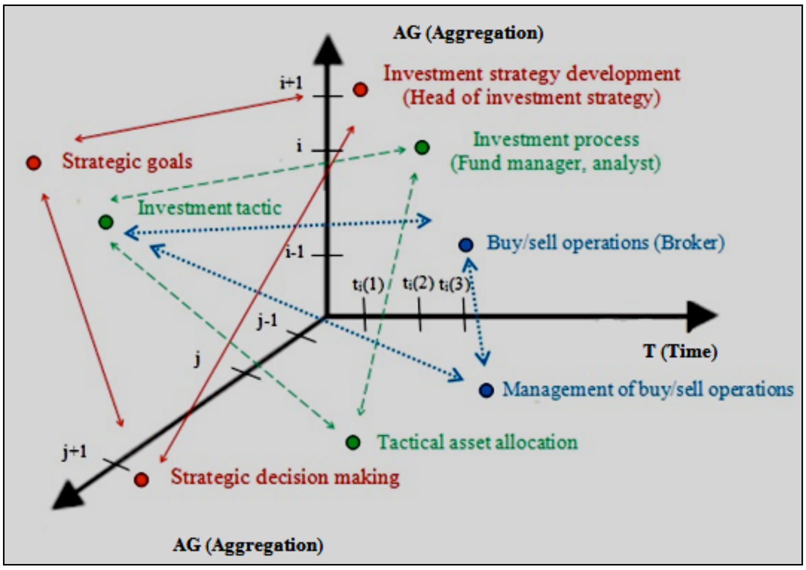

Fig. 2. Components of portfolio management EMC

Figure 2 presents the author's example of elementary management cycle of financial market domain. Managed object is the investment portfolio.

Head of investment strategy development makes strategic decisions in time moment $t_i(1)$ and formulates strategic goals (i+1, j+1). Investment strategy is actual for the entire period of time t_i. Strategic goals are detailed and investment tactic is prepared. In accordance with tactical goals the fund manager analyzes the market and makes asset allocation decisions in time moment $t_i(2)$ (i, j). Broker finds best time and performs buy and sell operations in accordance to tactical goals (i-1, j-1).

Figure 3 is also designed by author and shows these three separate EMC in one coordination plane. ECC* corresponds to strategic investment planning. ECC stands for fund management process, ECC' corresponds to the lowest level – buy and sale operations management.

This method enables to connect models in a formalized way. It also allows analyzing the hierarchical structures of entities and establishing relationships and informational transactions between them.

There is a wide variety of possible coordination cases. They are classified by S. Gudas [7]. Our example is consistent with the coordination type A3.1.

Coordination type A3 (i≠i`; j≠j`; p = p`; r= r`; t= t`) theoretical basis. The two (in general may be more) EMC belong to the same type of management function (r) and the same period of time (t). But their hierarchy levels of aggregation (..., i, i + 1,...) and generalization (... , j; j + 1, ...) differ.

They both manage the same object, but „see" it from different angle. More detail, coordination type A3.1. means that coordinated managing process is at higher aggregation and generalization levels than controlled processes. Such modeling type reveals specification and concretization aspects of managing and controlled systems [7]. Higher-level EMC can be described as (i + 1, j + 1, t, r, p), when controlled EMC has indexes (i, j, t, r, p). Managing information (orders, limitations) is transferred from higher to lower level EMC. In our case that means strategic goals and tactics of asset allocation. Some system elements can be modeled very deeply, other can have only brief description. But the main objective is to gain understanding of what system consists of and what elements should be modeled.

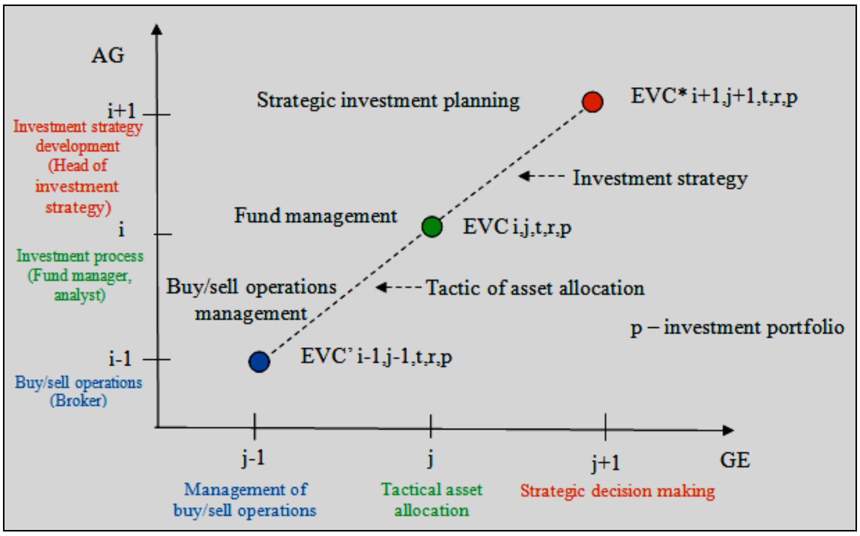

Fig. 3. Coordination of EMC

3 Modeling methods review

3.1 Decision making process modeling

One of the most popular models of decision making was developed by Herbert A. Simon (1960) [15]. The model consists of three steps: intelligence, design, and choice [19]. Figure 4 presents the architecture of decision support system. One of its essential components is models subsystem. It contains all types of models discussed in preceding section of this paper. This subsystem communicates with data subsystem, which process internal data of controlled system and values of external factors affecting it. All decisions are made in knowledge management subsystem. Users communicate with DSS through interface subsystem. Best decisions are saved in knowledge base and can be reused later [4] (Fig. 4). Such architecture allows separating data from decision making mechanisms and developing their components independently.

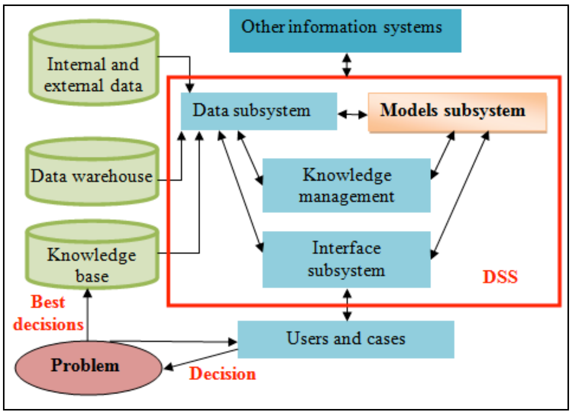

Fig. 4. Architecture of Decision support system(based on Decision making.T120B120 [4])

3.2 Process simulation of controlled system

Model is an abstract construct that attempts to replicate some properties of the real system. The main objectives are deeper insight and better knowledge of the system or its elements [18]. Dynamic simulation of systems processes are closely related to the knowledge-based IS engineering. Both uses models of controlled domain and knowledge database [8]. Internal modeling and process simulation allows looking inside the system: monitor the changes of the status of system components, analyze the impact that various factors make to the final results and to each other. For example, when simulating the process of investing to funds, we can see not only the final portfolio value, but also monitor its changes over time and analyze what factors has the most significant influence.

System dynamics is the methodology intended for modeling and analysis of real world systems. It is an applied discipline which allows understanding the behavior of such systems [16]. Term *system* means an interdependent group of items forming a unified pattern. Generally in system dynamics internal structure of the system is often more important than external events [17]. But modeling the *financial market* domain requires broader approach – external factors affecting the system are also involved.

Two main types of diagrams are used in system dynamics: *causal loop* diagrams and *stock and flow* diagrams. The *causal loop* diagram shows the circular chains of cause-and-effect in the actual system. [17]. The chain of the causes can be extended us much as analytic can understand the system. As mentioned above, most causal loop diagram involve not only internal elements of system, but also external factors that are outside the system and makes influence to it.

As with a *causal loop* diagram, the *stock and flow* diagram shows relationships among variables which have the potential to change over time. But unlike a causal loop diagram, a stock and flow diagram distinguishes between different types of variables: stocks, flows, and information [17]. Stock and flow diagrams are widely used in process simulation software. The most popular of them are iThink®, STELLA, Powersim Studio, Vensim, Anylogic, Insight Maker.

UML diagrams can be used beside *causal loops* or *stock and flow diagrams*. For example a *class diagrams* can represent the static structure and relationships between system elements or factors affecting it. *Activity diagrams* can show the possible scenarios of system behavior. *Sequence diagrams* can represent the users interaction with decision support system. For UML modeling we can distinguish Magic Draw (commercial), SmartDraw and Visual Paradigm (both free) tools.

3.3 Goals modeling

KAOS methodology refines goals into requirements and includes 4 model types: Goal, Agent, Operationalization and Object. KAOS Goal model has 5 elements: Agent, Object, Operation, Requirement, Expectation [6]. Agent models depict agent responsibilities and can be inferred from the goal models. Object Model specifies objects used in the goal model. The syntax is similar to that of a UML class diagram [6].

URN is the first international standard for business goals, scenarios and relationships modeling in a graphical way. It includes **GRL** (Goal-oriented Requirement Language), which is a graphical notation designed for modeling the goals and requirements of different stakeholders.

The focus of GRL is to design the *why* and the *what* aspects of a model. GRL divides its modeling elements into three main categories [1]:

- Intentional elements are the constructs which are used to model the system.
- An actor represents a stakeholder or a system.
- Links are used to connect intentional elements and actors

It‘s important that GRL can be successfully integrated to UML. For this purpose a special UML profile is used for goal modeling. In such way goal diagrams (prepared using GRL methodology) can be connected with other UML diagrams. [1]. We can't state, that UML doesn't allow to model goals. The problem is that UML doesn't specify goals as separate element. There is no unique element class for it. But GRL integration to UML solves this problem.

4 Conclusions

Financial markets are perceived as dynamic systems of interacting agents whose modeling and prediction are based on computer technology. The main effort is to model complex economic processes, the influence of different factors to the final result and the interdependencies of these factors. All such information is used in decision support systems in order to provide profitable solutions.

First of all the models of real life processes are created ant then they are simulated in order to experimentally analyze the various possible scenarios. Decision support systems (DSS) analyze the state parameters of controlled systems and external factors in order to make the appropriate decisions. This area covers different types of models and different types of factors that affect the financial markets must be integrated in models. There is a need to have a formalized way to analyze complex processes of financial systems and their management.

In this paper we presented different types of models in one process area (PA). The dynamic controlled systems' modeling, modeling the processes of decision making and goals versus risks modeling are connected in a whole. The conceptual example of funds' portfolio management explains how complex systems and processes can be described in such formalized way. Knowledge of controlled systems behaviour is turned to knowledge base which is used by decision support systems. All types of models are also saved in models subsystem and used for decision making.

The analysis of techniques for systems dynamics and decision-making process modeling was made. For dynamic simulation of system model causal loop and stock and flow diagrams can be used. UML diagrams can be used in conjunction with them. KAOS and GRL methodologies can be used for goals modeling.

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