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# Knowledge level modeling for systemic risk management in financial institutions

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ABSTRACT

The current subprime mortgage crisis is a typical case for systemic risk in financial institutions. In order to further our understanding and communication about systemic risk management (SRM) in financial institutions, this paper proposes a knowledge level model (KLM) for systemic risk management in financial institutions. There are two parts considered in the proposed KLM: ontologies and problem solving method (PSM). Ontologies are adopted to represent a knowledge base of KLM, which integrates top level ontology and domain level ontologies. And then the problem solving method is given to show the reasoning process of this knowledge. The symbol level of KLM is also discussed which integrates OWL, SWRL and JESS. Further, the discussion about Lehman Brother's Minibonds case in 2008 is provided to illustrate how proposed KLM is used in practice. With these, first, they will enhance the interchange of information and knowledge sharing for SRM within a financial institution. Second, they will assist knowledge base development for SRM design, for which a prototype of financial systemic risk management decision support system is given in this study. Third, they will support coordination among different institutions by using standardized vocabularies. And finally, from the design science perspective, the whole proposed framework could be meaningful to models in other domains.



## 1. Introduction

Systemic risk refers to the risk or probability of breakdown (losses) in the individual parts of components, and is evidenced by co-movements (correlation) among most or all parts (Kaufman, 2000). The current subprime mortgage crisis is a typical case for systemic risk in financial institutions. The subprime mortgage crisis was triggered by a dramatic rise in subprime mortgage defaults and related foreclosures in the United States, but has brought huge adverse effects to the banks and financial markets all around the world. Many banks, real estate investment trusts (REIT), and hedge funds have suffered significant losses as a result of mortgage payment defaults or mortgage asset devaluation. Many observers have commented that the turmoil in world financial markets has led to a severe and still unfolding economic downturn in most of the Western economies; as a result, the world has come to the brink of the "worst economic downturn" since the Second World War. Because of this crisis, governments and international organizations are calling for increased systemic risk management (SRM) in financial institutions. To repeat the Nobel laureate, Dr. A. Michael Spence, an important challenge going forward is to better understand these dynamics and complexities of SRM in financial institutions as the analytical underpinning of an early warning system with respect to financial instability (Spence, 2008).

In order to further our understanding and communication about SRM in financial institutions, a knowledge level model for SRM is proposed in this paper. Knowledge level was first proposed by Newell, which was used to distinguish it from the symbol level of information system (Newell, 1981). Knowledge level modeling is a kind of conceptual modeling method. As defined by Mylopoulos (1992), "Conceptual modeling is the activity of formally describing some aspects of the physical and social world around us for the purposes of understanding and communication". Knowledge level modeling means capturing and representing knowledge without specific attention being paid to how it will be implemented (Uschold, 1998). It includes ontologies and the problem solving model (PSM), where ontologies are concerned with static knowledge needed for problem solving and PSM with the dynamic reasoning process with knowledge.

Ontologies aim at capturing knowledge in a generic way and provide a commonly agreed understanding of a domain, which may be reused and shared across applications and groups (Chandrasekaran, Josephson, & Benjamins, 1999). In this study, ontologies were designed at two levels: top level ontology and domain level ontology. Top level ontology represents the general world

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knowledge (Uschold, 1998), and in this study ontology from the CYC project is adopted which is an attempt to build a very large knowledge base to facilitate common-sense reasoning[1] (Lenat, 1995; Lenat & Guha, 1989; Lenat, Prakash, & Shepherd, 1985). Domain level ontology represents knowledge in a specific domain. In this study a general framework of domain level ontology will be given which shows the key concepts and their relationships in the SRM domain.

Problem solving models (PSMs) specify which bodies of knowledge participate in problem solving and how they relate to each other (Uschold, 1998). Many models have been proposed in this area, such as role-limiting method (Marcus, 1988), CommonKADS (Schreiber, Wielinga, & Breuker, 1993), and so on. In this research, a hypothesis-test model is given to detect the systemic risk signal from external institutions which is based on Simon's decision making theory (Simon, 1996).

And in the symbol level, the proposed KLM is integrated within Ontology Web Language (OWL), Semantic Web Rule Language (SWRL) and JESS rules framework which will be very helpful to information system development.

The rest of this paper is organized as follows: Section 2 discusses the background of SRM in financial institutions and outlines the technique used in this research; the knowledge model for SRM is proposed in Section 3, which includes ontologies and PSM; a case of Lehman Brothers Minibonds is used to illustrate our approach in Section 4; the concept modeling quality of our proposed model is discussed in Section 5 and finally the paper ends with the conclusion in Section 6.

## 2. Related works

### 2.1. Systemic risk management in financial institutions

As the integration of financial markets progresses rapidly, regulators and supranational agencies have become increasingly worried about systemic risk in financial institutions (Lehar, 2005). The main concern is that the world's financial system could collapse like a row of dominoes and then could result in a severe economic crisis (Schwarcz, 2008). The most important characteristic for systemic risk is its contagion effect (YE, Wang, Yan, Wang, & Miu, 2009).

The most classic example of systemic risk is within the banking system, for which there are two major sources of systemic risk: first, banks might have correlated exposures with an adverse economic shock resulting in simultaneous multiple bank defaults; second, troubled banks may default on their interbank liabilities and hence cause other banks to default triggering a domino effect (Elsinger, Lehar, & Summer, 2006). With the data set provided by the Austrian Central Bank, researchers have reported that among the two driving sources of systemic risk, the correlation in exposures is far more important than financial linkages (Elsinger et al., 2006). Schwarcz has defined this kind of systemic risk as institutional systemic risk (Schwarcz, 2008).

Further, there is also systemic risk outside the banking system (Schwarcz, 2008). In the modern market, companies are able to obtain most of their financing through capital markets instead of the banking system. As a result, systemic risk can spread through capital market linkages, rather than merely through banking relationships. A typical case of this kind of systemic risk is the Long Term Capital Management (LTCM) event in 1998 (Jorion, 2000; Scholes, 2000). In the LTCM case, systemic risk existed not by reason of its intrinsic status as a hedge fund, but by the sheer size of its exposure to other institutions and market participants (Edwards, 1999). And Schwarcz defined it as market systemic risk which distinguished it from the institutional system risk (Schwarcz, 2008).

### 2.2. Conceptual modeling

A general definition of conceptual modeling has been proposed by Mylopoulos (1992): "Conceptual modeling is the activity of formally describing some aspects of the physical and social world around us for the purposes of understanding and communication". A conceptual model serves four roles in developing domain understanding (Kung & Solvberg, 1986): (1) aiding a person's own reasoning about a domain, (2) communicating domain details between stakeholders, (3) communicating domain details to systems designers, and (4) documenting the domain for future reference. Viewed from this perspective, conceptual modeling can be seen as a process whereby individuals reason and communicate about a domain in order to improve their common understanding of it (Gemino & Wand, 2004).

Various conceptual modeling methods have been proposed by researchers since the 1960s of the last century. Ross Quillian proposed semantic networks as a model of the structure of human memory in 1966 (Quillian, 1966). In 1967 Ole-John Dahl proposed SIMULA, which is an extension of the programming language ALGOL 60, for simulation applications which require some "world modeling" (Dahl & Nygaard, 1966). And then the Entity-Relationship model, which is more advanced than the logical data model, was proposed by Peter Chen in 1975 (Chen, 1976). Doug Ross proposed in the mid-70s the Structured Analysis and Design Technique (SADT) as a "language for communicating ideas", and this technique was used-by Softech, a Boston-based company, in order to model requirements for software systems (Marca & McGowan, 1987).

Lindland et al., proposed a framework to evaluate a conceptual model from three aspects: syntactic quality, semantic quality, and pragmatic quality (Lindland, Sindre, & Solvberg, 1994). Siau and Tan summarized this framework as following Fig. 1 (Siau & Tan, 2005):

In this framework, three important linguistic concepts (syntax, semantics, and pragmatics) are applied to four aspects of modeling: Language, domain, model and audience participation. This work has served as the foundation of International Workshop on Conceptual Modeling Quality (IWCMQ), held in conjunction with the Requirements Engineering Conference.

## 3. A knowledge level model for systemic risk management in financial institutions

### 3.1. Knowledge level model framework

The proposed knowledge level model for SRM in financial institutions is given in Fig. 2. From this figure, first of all, there are two different levels in the framework: symbol level and knowledge level, which follows Newell's model, as mentioned earlier (Newell, 1981). At the knowledge level, there are two parts: ontologies and problem solving method, where ontologies are concerned with the static knowledge needed for problem solving, and PSMs with the dynamic reasoning process with knowledge (Uschold, 1998).

The ontologies part includes domain level ontology and top level ontology. The domain level ontology defines the basic entities in financial markets and relationships among them, which are related to SRM in financial institutions. For example, it defines *securities* which include *basic securities* and *derivatives*. Mortgage backed securities (MBS) and collateralized debt obligations (CDO), which are most important securities for systemic risk in the ongoing subprime crisis case, are both subclasses of *derivatives*.

[1] http://www.cyc.com/.