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Integration of ontology-based decision support and a cognitive map approach to predict flat-screen TV market trends

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ABSTRACT

In previous studies of the ontological approach to context modeling, two issues have remained unresolved: (1) how to update an ontology to adapt to changes in context, and (2) how to make proper inferences from the ontology established. To address the first issue, this study proposed the use of an ontology and cognitive map-based decision-support mechanism that emphasizes the competitive relationships between LCD (liquid crystal display) and PDP (plasma display panel) TVs. We investigated the dynamic competitive relationship between these TVs using ontological and cognitive map approaches by suggesting a robust form of context modeling that adapts to changes in context. This study also addressed how to facilitate the prediction of market trends for LCD and PDP TVs from the ontology established and proposed a new ontological approach to context modeling of the LCD and PDP TV markets.

1. Introduction

Determining the diffusion of high-tech products plays an increasingly important role in marketing, production, and operational strategies. As high-tech products, LCD (liquid crystal display) and PDP (plasma display panel) TVs possess numerous advantages over conventional TVs. For example, LCD and PDP TVs are slimmer and lighter, and have higher resolutions and larger screen sizes than conventional TVs. Since 2004, there has been significant competition between LCD TVs and PDP TVs in the global flat-monitor market.

Being able to predict market trends—the direction of increase or decrease of potential LCD and PDP TV consumers, as well as future shipments of multigenerational LCD and PDP TVs—is worthwhile when making investments and operational decisions. It is therefore essential to develop suitable decision-support systems (DSSs) to use multisource knowledge in forecasting such traits as demand, supply, and price in TV markets. The most general way to predict market trends is through the use of a statistical method (Hung and Hsu, 2011), which requires a sufficient sample size to ensure reliable results.

While previous studies of TV markets have tried to investigate the competitive or dynamic relationships in the markets (e.g., Kreng, and Wang, 2011; Tsai, 2013; Tseng et al., 2012), there are few studies on the use of ontologies for this purpose. Researchers build ontologies to guide and support the development of context modeling so that they will have information indicating which categories or concepts exist in given contexts, the properties of those concepts, and how the properties are related to one another (e.g., Onorati et al., 2014; Pai et al., 2013; Wang et al., 2013). One of the crucial issues in the evolution of the ontology process in context modeling is that ontologies cannot ensure proper maintenance, representation and inferences when the context changes (Flouris et al., 2008; Khattak et al., 2013). It is therefore necessary and

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important to construct a method for extendable and evolutionary domain ontology or include additional factors that cater to the practical decision environment (Wang et al., 2013; Pai et al., 2013). A systematic approach is necessary to make inferences from an ontology and update that ontology when changes in context occur. For instance, one might create a multi-ontology topology that enables managers to reflect on decisions with different ontologies explicitly and to describe the decision-making landscape as contexts in time and space to which several different cause-and-effect relationships may apply (Aaltonen and Holmström, 2010).

In previous studies of the ontological approach to context modeling, two issues have remained unresolved: (1) how to update an ontology to adapt to changes in context, and (2) how to make proper inferences from the ontology established. To address the first issue, this study proposed the use of an ontology and cognitive map-based decision-support mechanism that emphasizes the competitive relationships between LCD and PDP TVs, as fierce competition between them is evident in the global flat-monitor market.

This study also proposed a combination system of cognitive maps and ontology management, referred to as the Cognitive Map-Based Ontology Representation and Inference Mechanism (COMORIM). We investigated the dynamic competitive relationship between LCD and PDP TVs using ontological and cognitive map approaches by suggesting a robust form of context modeling that adapts to changes in context. This study addressed how to facilitate the prediction of market trends for LCD and PDP TVs from the established ontology, proposing a new ontological approach to context modeling of the LCD and PDP TV markets. With the assistance of an illustrative case study, this study showed how the COMORIM can facilitate proper inferences from the established ontology and update an ontology to adapt to context changes.

2. Theoretical background

2.1. Ontology

An ontology represents an explicit specification of a conceptualization. In this study, the term *conceptualization* refers to information about objects that exist and their relationships. Thus, a conceptualization is a simplified and partial representation of the world. The definition of an ontology can, in part, explain such a representation of the world. The ontology can be extracted using machine learning and statistical methods (Navigli and Velardi, 2004) or linguistics (Shamsfard and Abdollahzadeh, 2003). The machine-learning approach provides a set of techniques and algorithms for capturing knowledge in an automated way. Researchers usually apply these techniques together with linguistic or statistical techniques, or both.

By necessity, researchers use the concept of ontology not only with regard to communication between humans and computers, or for the representation, accumulation, use, and reuse of knowledge, but also with regard to inferences made from specific knowledge. From a knowledge-engineering perspective, which is necessary for effective context modeling, an ontological approach can lead to the organization of databases that have information indicating which categories or concepts exist in given contexts, what properties those concepts have, and the relationships among properties. For this reason, a classifying hierarchy structure represents an ontology.

Previous studies have focused on the reasoning behind and management of ontologies, including their revision or merger. For example, Guzmán-Arenas and Cuevas (2010) suggested ontology merging (OM), an algorithm that automatically merges ontologies A and B to yield ontology C, in order to accumulate enough knowledge about a certain topic or area by integrating or fusing the data structures to obtain additional details and better precision from the synonyms, homonyms, redundancies, apparent contradictions, and inconsistencies in the incoming data structures. Ma et al. (2010) suggested an approach to address inconsistencies in ontologies by measuring the relevant ontology constructs, such as semantic partitions, axiom fanouts per concept, minimal incoherence-preserving subsets, incoherence effect value per axiom, and preferable revision weight per concept in the ontology being measured. Jung (2011) suggested a multi-agent system for building indirect alignment between multilingual ontologies, as well as a novel architecture to reuse and compose alignments between ontologies. Park et al. (2011) demonstrated a set of ontology selection standards and new selection metrics for ranking ontologies based on better semantic matching capabilities.

In previous studies related to the reasoning behind and management of ontologies, two issues hold promise for further research. One important research question in the study of ontological approaches to context modeling that remains unanswered is how to update an ontology to incorporate context changes. Once researchers build an ontology, it is relatively unchangeable, and it is difficult to adapt the ontology to changes in contexts. In contrast, context modeling requires the support of users in a timely and intelligent manner in order to improve decision-making. In combination with a cognitive map, the ontological mechanism takes on a flexible and adaptive structure.

The construction of an ontology inevitably involves multiple processes, indicating that no fixed and standardized procedure is possible for building an ontology in a target problem domain. Nevertheless, this study assumed that an ontology consists of classes that indicate concepts, instances that represent things, and properties consisting of concepts.

2.2. Cognitive map

Cognitive maps can be generalized into FCMs (fuzzy cognitive maps) by fuzzifying edge values or causality values. FCMs provide different strengths to each link and appear more reasonable to represent most cases. An FCM can make what-if inferences according to changes in the nodes (Kosko, 1986; Lee and Kwon, 2006). A cognitive map serves to determine the causal relationship between elements, facilitate an interpretation of phenomena with a relevant mechanism, and aid in the research of managerial perceptions and strategies. Researchers have studied cognitive maps briefly in the discipline of business administration and other fields for strategic decision support and in the interpretation of phenomena in knowledge database construction in the field of information technology actualization. Because the main goal in using a cognitive map is to identify the causal relationships among elements and to determine the results with regard to a specific issue, cognitive