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INNOVATIVE FIRM PERFORMANCE MANAGEMENT USING A RECOMMENDATION SYSTEM BASED ON FUZZY ASSOCIATION RULES: THE CASE OF VIETNAM'S APPAREL SMALL AND MEDIUM ENTERPRISES

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ABSTRACT

Purpose: This study aims to apply a classification algorithm based-on fuzzy association rules (FARs) to improve the effectiveness of firms' performance prediction problem. Particularly, this study investigates potential FARs exists between inputs and outputs of firms' performance management process. These extracted FARs could be used to help firm's managers make better dicision to improve firm's performance.

Theoretical framework: Private enterprise development has been identified as key to Vietnam's economy that was commonly depended on state enterprise. For that, understanding and improving firms' performance and productivity is one of the most important tasks, from both macro and micro perspectives. There have been many studies on Vietnam's firm performance, but mostly relying on econometric methods that limit the understanding with structural equations. This study, instead, attempts to utilize new achievements of Artificial Intelligence (AI) for this task. Among AI techniques, fuzzy association rule is able to address the relationship between input factors and firm performance indicators. For each company, the finding FARs can be used to predict its performance and then change the business plan or react to improve weekness of organization.

Design/Methodology/Approach: The proposal model is applied on data of small and medium-sized enterprises (SMEs) of the apparel industry in Vietnam in the period 2010-2015. The sample consist of a total of 23637 observation of Vietnam firms in apparel and textile industry and contains 16 main criterias for those firms.

Finding: A recommendation system (RS) is constructed from disclosed FARs and is a key factor in a novel innovative firms' performance management process. The percentage of classified instances using the mining FARs is not quite high (about 82%), but it is not always the case. Vietnam's apparel dataset includes rare classes of ROA, therefore applying only frequent FARs is not enough. This issue can be fixed by using both frequent and infrequent FARs.

Research, practical & social implications: The proposed model has a great opportunity to use not only in the small and medium-sized enterprises (SMEs) of the apparel industry but other industrial sectors. FARs support the well-understand of firm performance to firm's manager and help them better to react. Besides, FARs could be used to create RSs that makes alerts about risk automatically.

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Originality/Value: The fact, our current study is the first to inspect the ability of FARs on SMEs of the apparel industry in Vietnam. This study provides theoritical potential knowledge and empirical evidence in the application of FARs technology in innovative firm's management.

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GESTÃO INOVADORA DO DESEMPENHO DAS EMPRESAS QUE UTILIZAM UM SISTEMA DE RECOMENDAÇÕES BASEADO EM REGRAS DE ASSOCIAÇÃO DIFUSAS: O CASO DAS PEQUENAS E MÉDIAS EMPRESAS DE VESTUÁRIO DO VIETNAME

RESUMO

Objetivo: Este estudo visa aplicar um algoritmo de classificação baseado em regras de associação difusas (FARs) para melhorar a eficácia do problema de previsão de desempenho das empresas. Este estudo investiga, em particular, a existência de potenciais RAPs entre as entradas e saídas do processo de gestão do desempenho das empresas. Esses RAPs extraídos poderiam ser usados para ajudar os gerentes da empresa a tomar melhores decisões para melhorar o desempenho da empresa.

Estrutura teórica: O desenvolvimento de empresas privadas tem sido identificado como chave para a economia do Vietnã, que era comumente dependente de empresas estatais. Para isso, compreender e melhorar o desempenho e a produtividade das empresas é uma das tarefas mais importantes, tanto do ponto de vista macro como microeconômico. Houve muitos estudos sobre o desempenho firme do Vietnã, mas principalmente contando com métodos econométricos que limitam o entendimento com equações estruturais. Esse estudo, em vez disso, tenta utilizar novas conquistas da Inteligência Artificial (IA) para essa tarefa. Entre as técnicas de IA, a regra de associação difusa é capaz de abordar a relação entre fatores de entrada e indicadores de desempenho firmes. Para cada empresa, os FARs de descoberta podem ser usados para prever seu desempenho e, em seguida, alterar o plano de negócios ou reagir para melhorar a semana da organização.

Concepção/metodologia/abordagem: O modelo da proposta é aplicado aos dados das pequenas e médias empresas (PME) da indústria do vestuário no Vietname no período de 2010-2015. A amostra é constituída por um total de 23637 observações de empresas vietnamitas da indústria têxtil e do vestuário e contém 16 critérios principais para essas empresas.

Constatação: Um sistema de recomendação (RS) é construído a partir de FAR divulgados e é um fator-chave num processo de gestão do desempenho de empresas inovadoras. A porcentagem de instâncias classificadas usando os FARs de mineração não é muito alta (cerca de 82%), mas nem sempre é o caso. O conjunto de dados de vestuário do Vietnã inclui classes raras de ROA, portanto, aplicar apenas FARs frequentes não é suficiente. Esse problema pode ser corrigido com o uso de FARs frequentes e não frequentes.

Investigação, implicações práticas e sociais: O modelo proposto tem uma grande oportunidade de utilização não só nas pequenas e médias empresas (PME) da indústria do vestuário, mas também noutros setores industriais. Os FARs apoiam o bom entendimento do desempenho da empresa para o gerente da empresa e os ajudam a reagir melhor. Além disso, os FARs podem ser usados para criar RSs que fazem alertas sobre riscos automaticamente.

Originalidade/valor: O fato é que nosso estudo atual é o primeiro a inspecionar a capacidade das FARs em PMEs da indústria de vestuário no Vietnã. Este estudo fornece potencial teórico e evidência empírica na aplicação da tecnologia FARs na gestão inovadora da empresa.

Palavras-chave: Regra de Associação Difusa, Sistema de Recomendação, Gerenciamento de Desempenho Firme.

GESTIÓN INNOVADORA DEL DESEMPEÑO EMPRESARIAL UTILIZANDO UN SISTEMA DE RECOMENDACIÓN BASADO EN NORMAS DE ASOCIACIÓN DIFUSAS: EL CASO DE LAS PEQUEÑAS Y MEDIANAS EMPRESAS DE PRENDAS DE VESTIR DE VIETNAM

RESUMEN

Objetivo: El objetivo de este estudio es aplicar un algoritmo de clasificación basado en reglas de asociación difusa (FARs) para mejorar la efectividad del problema de predicción de desempeño de las empresas. En particular, en este estudio se investiga la posible existencia de diferencias entre los insumos y los productos del proceso de gestión del desempeño de las empresas. Estas cuentas anuales extraídas podrían utilizarse para ayudar a los gerentes de la empresa a tomar mejores decisiones para mejorar el desempeño de la empresa.

Marco teórico: El desarrollo de la empresa privada se ha identificado como clave para la economía de Vietnam que normalmente dependía de la empresa estatal. Para eso, entender y mejorar el desempeño y la productividad de las empresas es una de las tareas más importantes, tanto desde una perspectiva macro como micro. Ha habido muchos estudios sobre el desempeño empresarial de Vietnam, pero la mayoría se basa en métodos econométricos

que limitan la comprensión con ecuaciones estructurales. Este estudio, en cambio, intenta utilizar los nuevos logros de la Inteligencia Artificial (IA) para esta tarea. Entre las técnicas de IA, la regla de asociación difusa es capaz de abordar la relación entre los factores de entrada y los indicadores de rendimiento de la empresa. Para cada empresa, los FARs de hallazgo se pueden utilizar para predecir su desempeño y luego cambiar el plan de negocios o reaccionar para mejorar la debilidad de la organización.
Diseño/Metodología/Enfoque: El modelo de propuesta se aplica a los datos de las pequeñas y medianas empresas (pymes) de la industria del vestido en Vietnam en el período 2010-2015. La muestra consta de un total de 23637 observaciones de empresas vietnamitas del sector textil y de la confección y contiene 16 criterios principales para dichas empresas.
Hallazgo: Un sistema de recomendación (RS) se construye a partir de FARs divulgados y es un factor clave en un proceso de gestión del desempeño de empresas innovadoras. El porcentaje de instancias clasificadas que utilizan los FAR de minería no es muy alto (alrededor del 82%), pero no siempre es el caso. El conjunto de datos de prendas de vestir de Vietnam incluye clases raras de ROA, por lo que no es suficiente aplicar solo FAR frecuentes. Este problema puede solucionarse utilizando FAR frecuentes e infrecuentes.
Investigación, implicaciones prácticas y sociales: El modelo propuesto tiene una gran oportunidad de uso no solo en las pequeñas y medianas empresas (pymes) de la industria de la confección sino en otros sectores industriales. Las FARs apoyan la comprensión del desempeño de la empresa por parte del gerente de la empresa y los ayudan a reaccionar mejor. Además, los FAR podrían utilizarse para crear RS que generen alertas sobre el riesgo automáticamente.
Originalidad/Valor: El hecho es que nuestro estudio actual es el primero en inspeccionar la capacidad de las FARs en las pymes de la industria de la confección en Vietnam. Este estudio aporta conocimiento teórico potencial y evidencia empírica en la aplicación de la tecnología FARs en la gestión de empresas innovadoras.

Palabras clave: Regla de Asociación Difusa, Sistema de Recomendación, Gestión del Rendimiento Empresarial.

INTRODUCTION

Firm performance management is key to any business. Many studies have tried to understand what factors that have significant impacts on firm perfomance, such as (Darroch 2005; Goyal, Rahman, and A A Kazmi 2013).

To better manage firm performance, firms not only need to understand what factors are important but also need to have a control system in place to take action. That is why many studies have looked into how a management system should be designed and implemented (Demartini 2014).

In line of innovation in big data and AI, more work has been done on the application of machine learning in firm performance management. One popular approach is to use a recommender system. However, most of current recommender systems focusing on improve the communication with and understanding customers (Fleder and Hosanagar 2009; Huang, Zeng, and Chen 2007). Not many study or work has been put on a recomender system for internal firm performance management.

This study tries to look into the potential of applying a recommender system for firm performance management in a broader scope than only customer-producer relation. It, instead work on the basic input-output production function.

Recommander System Based on Association Rules

Recommander system has became an important information filter or a decision support function in complex information systems. There are different approaches to construct a recommendation system such as collaborative filtering, content-based filtering, hybrid filtering and data-mining techniques based approaches (Cao et al. 2020; Das, Sahoo, and Datta 2017; Jannach et al. 2010; Ricci, Rokach, and Shapira 2015). In cases, a mandatory task of a recommendation system is predicting an user's preference and giving rating of possible choices. RS has used variant methods such as machine learning techniques, data mining techniques including Association rules, as crucial techniques to classify user preference (Do Van et al. 2023; Yin and Han 2003).

Association rule (AR) mining is a crucial technique used in RS due to the descriptive and easily understandable nature of the rules. AR was first introduced and used to extract item relationships on market data, since then it has been applied in many other domains. An association rule is an implication of the form A⇒B, where A and B are itemsets that are frequent normally in a transaction database and $A \cap B = \emptyset$. The rule A⇒B presents a term as "if itemset A occurs in a transaction, then itemset B will also likely occur in the same transaction" (Agrawal and Srikant 1994; Srikant and Agrawal 1996). The value of an association rule is commonly estimated by using the support and confidence measurements. Association rules mining focus on extracting rules have high confidence and acceptable support, in common the minimum thresholds for confidence and support are set by users.

The classification algorithm used association rule can be divided into two fundamental phases: Mining ARs and Classifying by extracted ARs (Goyal, Rahman, and Alice A Kazmi 2013). The mining of association rules works in an unsupervised manner normally, in which the researcher focuses on both value of ARs and time consuming. The second part, classification, is a process that select the best appropriate rule to apply for an input instance. In general, an AR that has antecedent closer to an input transaction and has higher support and confidence is more likely to used by a classifier. Definition of the suitability of a rule for an instance can be modified depends on applications.

Advantages of using Fuzzy Association Rules

The associative classification has to deal with quantitative attributes in many fields in applications. In these cases, continuous attributes' domains are usually divided into equal-width or equal-frequency intervals (Lu, Xu, and Yang 2003), however its consequent problems are

that equivalent width partitioning can not embody the actual distribution of the data, and the sharp boundary also cause several issues.

In most cases, the problem of quantitative association rules is improved by using fuzzy association rules, which softens partition boundary of the domains (Giap and Linh 2017; Verlinde, De Cock, and Boute 2005). FAR change the boolean membership function by an fuzzy membership function that has value in dual intervals [0,1]. FAR has fuzzy logic characteristic by far, it matchs fuzzy sets to linguistic terms and let FAR is more closer to human maner (Hong, Lin, and Lin 2014; Hong and Wu 2011; Lin, Hong, and Lin 2015).

Research Objective and Implementation

This study intends to apply FAR to build and classification tool and uses this tool to form a Recommender System for Firm performance management. The first research ojective is to extract the potential FARs exists between inputs and outputs of firms' performance management process, using a part of the enterprises survey data conducted by General Statistic Office of Vietnam as a training data. An classification is built from extracted FARs and tested in a small set of testing data that has the same structure with training data.

In the remain, the brackground knowledge of fuzzy association rule, classification algorithm and related works are briefly reviewed in the second part. The third part describes the proposal model of classifier based-on FAR comprehensively. A potential application framework of Recommandation system in Firm performance management is introduced in the fourth part. Several empirical result and future works are discussed in the last two parts.

BACKGROUND

Fuzzy Association Rules

In this part, the background of Fuzzy Association Rule (FAR) is introducted briefly. The definition of FAR is extended from ordinary Association Rule(AR) (Hong et al. 2014; Hong and Wu 2011; Lin et al. 2015) in which the crucial extension is the modification of a membership function in crisp data to a fuzzy membership function.

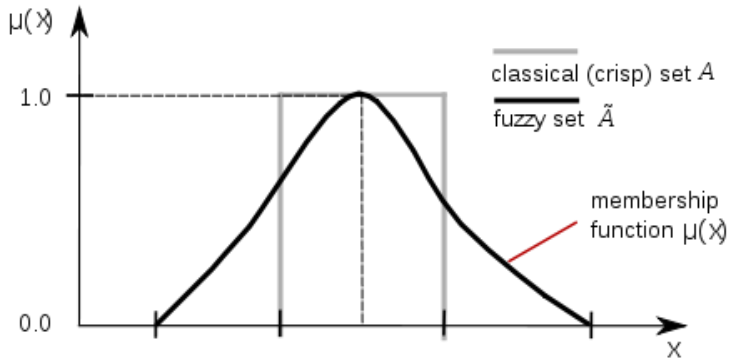
Particularly, in a crisp dataset a membership function is defined in a universal set i.e. X, that presents the membership of an element in X to subset A. The membership funcion of an element x gets value 1 if x in in A and 0 for x is not in A.

$$\iota_A(x) = \begin{cases} 1 & \text{if } x \in A \\ 0 & \text{if } x \notin A \end{cases}$$

Meanwhile, a fuzzy membership function indicates the membership degree of an element $x, \forall x \in X$ to a fuzzy set $\widetilde{A}$ by a continuous interval, normally a fuzzy membership function is formed $\mu_A(x) \in [0,1]$. The extream values 0 and 1 mean that x is completely not in the fuzzy set $\widetilde{A}$ and x is fully in the such fuzzy set. The remain values present that x partially belongs to the fuzzy set $\widetilde{A}$. Clearly, a fuzzy membership function is an extention of a crisp dataset a membership function, and it can be used to present better data relationships in some real life situations.

A fuzzy dataset is created by converting a crisp dataset, that use fuzzy membership functions on different attibutes. In this process, each transaction of original dataset is transformed into a new form one by one. Particularly, each transaction of a finite set $t_i = \{x_1, x_2, ..., x_n\}$ is clustered into the set of m fuzzy cluster $C = \{c_1, c_2, ..., c_m\}$ that commonly presented by an linguistic set. The fuzzy dataset expressed by a patition matrix, that represents the memberships of each element to c fuzzy cluster, the fuzzy patition matrix μ has size $n \times c$, where $\mu_{ij} \in [0,1],\ \forall i \in (1,n)\ \&\ \forall j \in (1,m)$. In practice, there are different types of fuzzy membership functions, one of the most popular type is triangular fuzzy membership function. The triangular fuzzy membership function shape is presented bellow.

Figure 1: triangular fuzzy membership function



Source: Prepared by the author

Fuzzy Association Rule

Given a fuzzy transaction dataset $D_f = \{t_1, t_2, \dots, t_N\}$ contains N transactions, each transaction is a nonempty subset of a fuzzy item sets I_f. The fuzzy transaction dataset D_f is converted from a crisp dataset, and each fuzzy item comes from an original crisp item but one crisp item can be converted into more than one fuzzy item. In such fuzzy transaction dataset, a

fuzzy association rule (FAR) is formed as $A \Rightarrow B$, $\forall A,B \subset I_f$ and $A \cap B=\phi$, and A, B do not contain any pair fuzzy items that are converted from one original attribute.

For a FAR, the support and confidence measurements are extended from AR support and confidence definitions, and they are defined generally as follow:

$$D_f supp(A \Rightarrow B) = \frac{\sum_{i=1}^{n} A(x) \otimes B(y)}{|D_f|}$$

And,

$$D_f conf(A \Rightarrow B) = \frac{\sum_{i=1}^{n} A(x) \otimes B(y)}{\sum_{i=1}^{n} A(x)}$$

Where,

$\otimes$ is a T-norm.

Based on the above definitions, the problem of extraction fuzzy association rule from a fuzzy transaction dataset is finding FARs have high support and confidence. It means that figuring out all FARs have supports and confidences satisfy below constraints:

$$D_f supp(A \Rightarrow B) \geq Min\_supp;$$

$$D_f conf(A \Rightarrow B) \geq Min\_conf$$

Min_supp and Min_conf are two thresholds commonly set by end users for each domain.

In order to mining the FARs on dataset of firms, this study uses minimum T-norm operation in formulas of support and confidence measurments.

Definition 1: Given a fuzzy transaction dataset has N transactions, the frequency of a fuzzy itemset is defined as follow.

$$f(A(x)) = \sum_{t=1}^{N} A(x)_t$$

Where

$$A(x)_t = \min\{a_i(x_i)\} \ \forall \ a_i \in A$$

General Fuzzy Association Rule

Definition 2: Given FARs formed as $A \Rightarrow B$, and $A' \Rightarrow B$,where $A, A', B \subseteq X_f; A \cap B = \emptyset; A' \cap B = \emptyset$; and $A \cup B$; $A' \cup B$ do not contain any pair fuzzy items that are converted from the same original attribute. The rule $A' \Rightarrow B$ is a more general rule than $A \Rightarrow B$ if A' is a subset of A.

Example: an example of extracting FARs from scrisp dataset of apparel companies is show bellow.

Table 1. Scrisp dataset of apparel companies

Tid	Total capital	Debt ratio	Share of female employees	ROA
	A	**B**	**C**	**Y**
1	243098	0,921	0,151	0,0252
2	280838	0,868	0,689	0,0002
3	62661	0,640	0,336	0,1065
4	351014	0,899	0,641	0,2085
5	452868	0,691	0,455	-0,0193
6	779527	0,818	0,731	0,0021
7	350707	0,669	0,869	0,0004

Source: Prepared by the author

Table 1 show an brief data of several companies in Vietnamese apparel industry. The attributes of each company data includes Total capital (A), year-opening debt ratio (B), share of female employees (C) and Return on Assets -ROA(Y). Using triangular fuzzy membership functions, the scrisp data will be transformed into an correlated fuzzy dataset of all companies showed in table 2.

Table 2. Fuzzy dataset of apparel companies

TID	Total capital			Debt ratio			Share of female employees			ROA		
	A.Low	A.Midle	A.High	B.Low	B.Midle	B.High	C.Low	C.Midle	C.High	Y.Low	Y.Midle	Y.High
1	0,142	0,858	0,000	0,000	0,000	1,000	1,000	0,000	0,000	0,633	0,367	0,000
2	0,000	0,982	0,018	0,000	0,000	1,000	0,000	0,703	0,297	1,000	0,000	0,000
3	0,944	0,056	0,000	0,000	0,533	0,467	1,000	0,000	0,000	0,000	0,668	0,332
4	0,000	0,766	0,234	0,000	0,000	1,000	0,000	0,863	0,137	0,000	0,000	1,000
5	0,000	0,453	0,547	0,000	0,363	0,637	0,725	0,275	0,000	1,000	0,000	0,000
6	0,000	1,000	1,000	0,000	0,000	1,000	0,000	0,563	0,437	1,000	0,000	0,000
7	0,000	0,767	0,233	0,000	0,437	0,563	0,000	0,103	0,897	1,000	0,000	0,000

Source: Prepared by the author

From table 2, the frequence and support value of all fuzzy elements/items are calculated and show in the table 3. When an user set an support threshold, the system can extract all frequent elements/items easily.

Table 3. The frequences of fuzzy items by support threshold

Item	frequence	support	Item	frequence	support	Item	frequence	support
A.Low	1,086	0,155	C.Low	2,725	0,389	Y.Low	4,633	0,662
A.Middle	4,882	0,697	C.Middle	2,508	0,358	Y.Middle	1,035	0,148
A.High	2,032	0,290	C.High	1,767	0,252	Y.High	1,332	0,190
B.Low	0,000	0,000						
B.Middle	1,333	0,190						
B.High	5,667	0,810						

Source: Prepared by the author

The table 4 show all frequent elements/items that sastify the suport threshold 0.5 and table 5 will show the support and confidence of all FARs built from such frequent elements/items.

Table 4. The frequent fuzzy items regarding to a support threshold 0.5.

Item	Support value
A.Middle	0,697
B.High	0,810
Y.Low	0,662

Source: Prepared by the author

Table 5. The FARs extracted with support and confidence values $\langle 0.5, 0.8 \rangle$.

Item	Support value	Confidence
{A.Middle -> Y.Low}	0,548	0,785
{B.High -> Y.Low}	0,548	0,676
{ A.Middle , B.High ->Y.Low}	***0,519***	***0,882***

Source: Prepared by the author

Relate Works

Since Lotfi A. Zadeh introduced the concept of fuzzy set and its operations (Zadeh 1965, 1996), this concept has been widely applied and fuzzy association rule is one successful application case (Bai and Chen 2008; Ho et al. 2012; Naeem and Naeem 2022; Yadav and Singh 2011). The authors presented a fuzzy rule-based approach to classification problem or fuzzy expert system that are useful for performance prediction and performance inference issues. The study (Yadav and Singh 2011) introduced a Fuzzy Expert System (FES) that was applied to predict student performance. The study inlustrated the the principles behind Fuzzy Logic could be used to inference the relationship between factors that impact to performance of a student. Other study (Ho et al. 2012) introduces a financial data analysis tool based on

fuzzy association rules. The extracted FARs represent relationships between financial attributes and might be used to build a recommender system that can help investment decision making.

Focus on the domain of firm performance, association rule in general and fuzzy association rule, in particular, have been studied and applied in serveral of case studies. Tsai et al used AR to investigate important factors affecting firm performance in terms of invisible values (Tsai and Yen 2010). Here the intangible value of a firm is the market value instead of its book value (usually expressed through capacity, efficiency in creation, expansion, and application of knowledge). The proposed model is applied to a dataset of enterprises of various industries in Taiwan. The analysis results showed that 6 factors including R&D intensity, family, participation in management, pyramids in owner structure, profitability, and dividend have a great impact on Tobin'Q index - a variable representing the intangible value of enterprises. Phebe Abraham and Suganthi used fuzzy association law along with a hierarchical analysis process to discover latent relationships in production sectors where firm performance is measured through the customer satisfaction index (Abraham and Suganthi 2013). An intelligent quality management system built to transform data into knowledge in the form of fuzzy rules. The experimental results reflected that customer satisfaction takes precedence over profitability, and 5 mined rules expressed different conditions to achieve higher customer satisfaction. Ezhilarasa and Ramani (2017) proposed an analytical framework that uses adjusted clustering techniques combined with FARs to predict retail efficiency (Ezhilarasan and Ramani 2017). This framework was applied to the retail data set collected from the e-commerce website. The process of clustering user data was done according to each group of data sold together, and from the results, recommendations will be made to increase the efficiency of selling products and also understand the customer-supplier relationship. Onur Dogan (2023) built a recommender system in which FAR mining is performed concurrently with consideration of the profit that can be obtained for the business from products that frequently appear together in the frequent item set (Dogan 2023). From there, the system will suggest suitable products for customers and can bring the highest profit for businesses. The model was applied to analyze for near one million sales transactions, including 339 different products of over 460,000 customers from an international e-commerce company. The experimental results revealed that the proposed system can be a forceful tool to enhance e-commerce sales and maximize profits for firms.

From aspect of AR mining technique, the FP-growth tree structure is the state of the art to improve time consuming. However, due to the definition of frequency of fuzzy itemset's it

is very difficult to contruct a FP-growth tree for mining FARs. Some modifications of FP-growth tree structure introduced to solve this problem (Hong et al. 2014; Hong and Wu 2011; Lin et al. 2015). In these researches, MFFP-tree and CMFFP-tree used to store and extract frequent fuzzy itemsets. The proposals have similar structure with the original FP-growth tree, however it requires to to reorder all transaction to has descending order of fuzzy items based on member values. This task take a lot of computing time (Hong et al. 2014). Meanwhile, the proposed MCMFFP-tree improves CMFFP-tree by storing more values of frequencies of itemsets, thus it cost much more memory (Hong and Wu 2011). These researches were not success to propose a good design of FP-growth tree based for FARs, and therefore this study still focus to common FAR mining technique (Arora et al. 2022).

Classification Algorithm Based-On Fuzzy Association Rules

The classification model for a Firm performance Management system has two stages. The first stage extracts value FARs and the second stage constructs a classifier from value FARs.

The input data of Firm performance system is crips data, therefore it must be transformed into fuzzy dataset by a fuzzilizer that use fuzzy membership functions constructed manually. The second step in the first stage is extracting FARs by the algorithm that introduced in (Giap and Linh 2017). Using a simple algorithm, the FARs can be generated from frequent fuzzy item-sets, therefore the most challenging and indispensable task here is to figure out the frequent fuzzy item-sets from a fuzzy transaction dataset. In this progress, the thresholds of confidence and support will lead to the number of frequent itemsets. The higher thresholds shorten the frequent itemsets and shorten FARs consequentially.

When the value FARs are found, the classifier based-on FARs is called C_FAR, and is shown as follows.

The crucial for prediction algorithm above is to choose the most suitable rule for each input transaction. In crisp data, the suitability of a rule is represented by a score that is regularly evaluated by preference of rule. It means that, between all rules that have antecedent fits to an input transaction, the algorithm chooses the rule that has highest confidence. An improvement of rule estimation is calculated by a new formula presented in the next session.

Rule Evaluation

In fuzzy transaction dataset, to select the best FAR to generate a prediction (e.g a clasification of a observe), two issues must be considered. The fisrt issues is the preference of FAR, that presents the confidence of rule and the support of rule. The second issues is the membership or fitness of a rule to a transaction. To combine two aspects, a new score formular is proposed below:

$$\text{Score}(r, T) = \alpha.\,\text{pref}(r, T) + (1 - \alpha)\text{memb}(r, T)$$

$\alpha \in [0,1]$ is a parameter to control the bias of predictor. If α closer to 1, it means that predictor bias to the preference measurment of a FAR and vice versa. Generally, the predictor is more likely to use a rule that has higher preference and has antecedent closer to input transaction.

For each prediction requirement transaction T, considers a FAR formed $r\{A \Rightarrow B\}$, the preference of r is calculated by the following formula:

$$pref(r,T) = \begin{cases} \beta \,.\, \dfrac{supp(A \cup B)}{supp(A)} . supp(A \cup B) + (1-\beta).\dfrac{|A|}{|T|} & if\ (supp(A \cup B) < 1) \\ conf(r) & if\ (supp(A \cup B) = 1) \end{cases}$$

This formula presents that the preference of a rule is estimated by rule's confident, support and size of rule's antecedence. The parameter $\beta \in [0,1]$ show the bias between support value of a rule and length of rule antecedent. If β close to 1, the predictor prefers on rule's support and vice versa. Besides, if $supp(A \cup B) = 1$, the FAR r appeared in all transactions then the $pref(r,T) = \ conf(r) = 1$ and other issues are not matter.

The membership value of a FAR r to a transaction T presented by this formula:

$$memb(r,T) = 1 - \frac{1}{|A|}\sum_{1}^{i} |1 - w_{ai}|$$

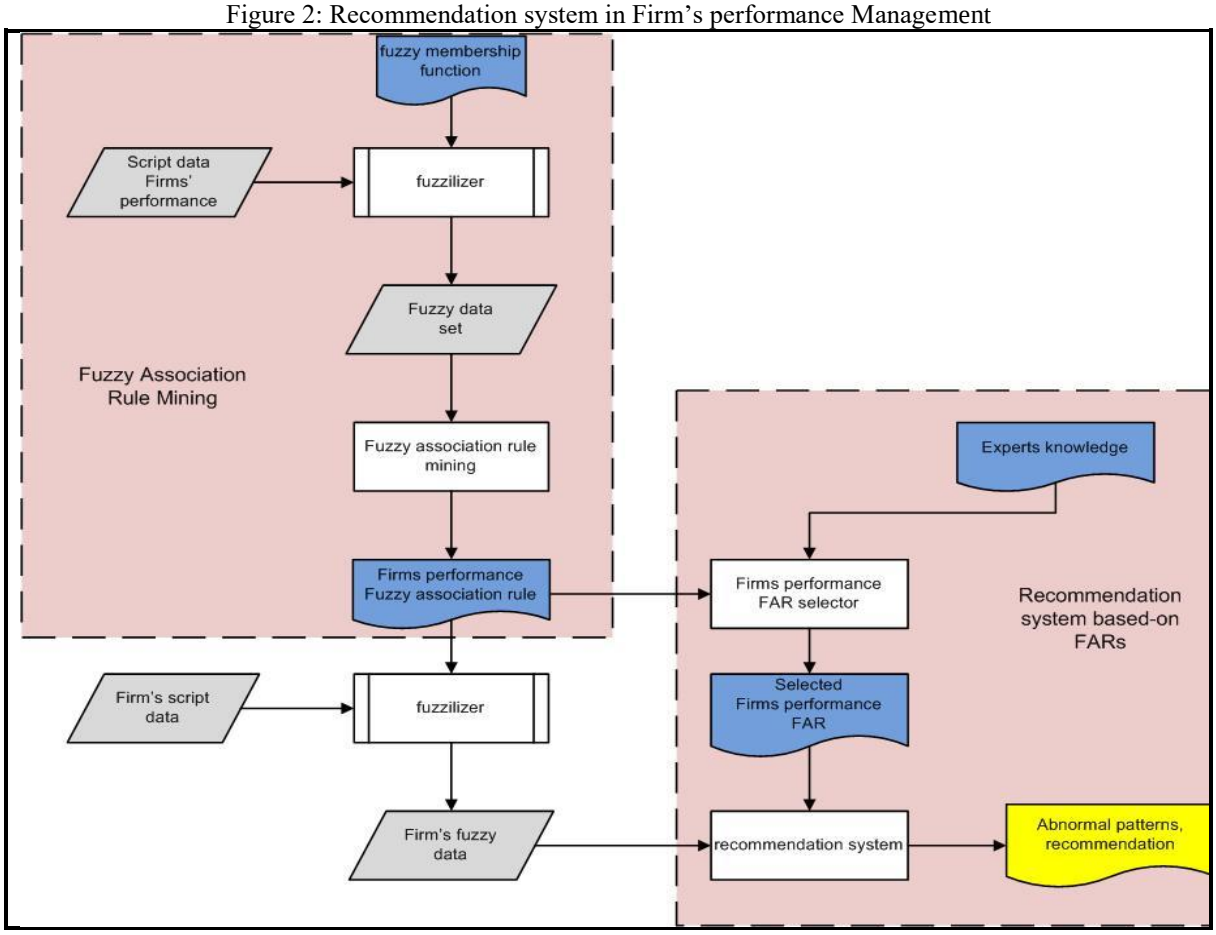
A membership value is depended on the antecedence A of rule r only, and it is calculated by the belonging of each fuzzy item in A to T. $memb(r,T) = 1$ if all fuzzy items $a_i \subset A$ fully appears in T, or the membership value $w_{ai} = 1$. In this case $r\{A \Rightarrow B\}$ perfectly fits to T.

PROPOSAL MODEL

Recommender System Based on Far for Firm Performance Management

The proposal application framework of using Recommender system based on FAR for Firm performance management is introduced in the following figure 2.

Figure 2: Recommendation system in Firm's performance Management



Source: Prepared by the author

Above figure depicts the entire processes in SR for firm performance management. These process includes two major stages, fuzzy association rule mining and recommendation system based-on FARs.

The purpose of the first stage is extracting all valid FARs from the training data set. The background of this task is mentioned in the part 2, and this study using an Apriory –based algorithm. This algorithm is not the most efficient algorithm however it will extract all valid FARs that satisfy the user's support and confidence thresholds.

The purpose of the second stage is forming a recommendation system from useful FARs. To choose useful FARs, the "Firm performance FARs selector" uses valid extracted FARs from the first stage and Expert knowledge to remove redundant rules. The system will

list the set of redundant FARs rules, and let the experts choose what rules will be remain and the other rules will be remove. A set of redundant FARs rules includes such rules have the same confidence and there is one rule that has antecedent included in antecedents of other rules.

Using useful FARs, the RS classifies an input instance to suitable class and also recommends a set of FARs that belong to a higher performance class, and such recommending FARs are "close" to input instance. One input transaction (T) and a FAR (r) are said "close" when its score $\mathbf{Score}(\mathbf{r}, \mathbf{T})$ is larger than a specific threshold that choosed by user. By this way, the system shows the abnormal items in the input instance to the user.

One innovation of this system is that the system does not prune the redundant FARs by technical only but also using Expert knowledge as an important resource to select valid FARs for classifier. Using expert knowledge help the system recommends the suitable FARs that can be interpreted in human manner.

EXPERIMENT RESULT

Data Description

Using the enterprises survey data conducted by General Statistic Office of Vietnam, this study select the data of apparel small and medium enterprises in the period 2010-2015 as experimental data. The sample consist of a total of 23637 observation of Vietnam firms in apparel and textile industry and contains 16 main criterias for those firms. These variables reflect different aspects of each firm including business tax ID, type of business, gross revenue, owner's equity, etc. The descriptive statistics of them are shown in Table 6.

Table 6. Descriptive of the indicators

Indicator	Minimum	Maximum	Average	Standard deviation
Type of business	1	14	8.746162	1.617733
Percentage of state shares (%)	0	100	2.638515	15.42037
State-ownership status	1	2	1.734756	0.4414683
Total number of employees	0	84142/ 85206	266.7381/286.2036	1446.006/1492.412
Total assets (VND million)	0/-3	2.30e+07/ 2.11e+07	47649.8/ 54563.48	348189.6/ 384611
Business size [1=SME, 2=big]	1	2	1.180837	0.384888
Export value/Total Revenue ratio (%)	0	1123383	213.7195	10042.91
Import value/Total expense ratio (%)	0	1.08e+07	992.6158	63532.59
Share of female employees (%)	0	100	62.97274	22.54055
Percentage of insured employees(%)	0	100	51.95555	34.51667
percentage of core-business employees(%)	0	100	99.47981	4.19263
average earnings of employees (VND million)	0.0820433	40759.2	115.7294	274.4316
Gross revenue (VND million)	0	2.66e+07	68131.32	484021.7
ratio of core business revenue to gross revenue (%)	0.3681967	100	98.99562	6.98948

year-opening debt ratio [total debt/total capital]	-18.465/ -431.1231	118.9608/ 1173.035	.6064608/ .6617531	1.112437/ 7.331723
Owner's equity ratio (%)	-117.9608/-1172.035	19.465/ 432.1231	0.4020023/0.3466956	1.107324/ 7.287936

Source: Prepared by the author

Experiment Result

Vietnam's apparel companies dataset includes 23637 instances, and it is devided into a training set including 21237 instances and a testing set including 2400 instances. Mining discriminal Fuzzy association rule for ROA output with *minSup= 0.1* and *minConf=0.87*, we have found 244 rules, however, using experst's knowledge, we remain only 9 rules for classification. The valid FARs listed below:

Table 7. Valid discriminal fuzzy association rules

N0	Rules	confident
1	{tile_nk=none }==> {roa=very low }	~ 0.9
2	{co_chiphoi=b; tile_nk=none } ==> {roa=very low }	~ 0.9
3	{quymo=c; tile_nk=none} ==> { roa=very low}	~ 0.9
4	{co_chiphoi=b; tile_xk=none; tile_nk=none} ==> {roa=very low}	~0.88
5	{co_chiphoi=b; quymo=c; tile_xk=none; tile_nk=none} ==> {roa=very low}	~0.88
6	{tile_xk=none; tile_ldngchinh=high; tile_vonnn=none} ==> {roa=very low}	~0.88
7	{co_chiphoi=b; tile_xk=none; tile_ldngchinh=high; tile_vonnn=none} ==> {roa=very low}	~0.88
8	{co_chiphoi=b; quymo=c; tile_xk=none; tile_ldngchinh=high; tile_vonnn=none}==> {roa=very low}	~0.88
9	{quymo=c tile_xk=none tile_ldngchinh=high tile_vonnn=none}==> {roa=very low}	~0.88

Source: Prepared by the author

Classification Testing Results

The label – based measures [20] used to evaluate classification performance as follows:

Accuracy = (TP + TN)/ (TP+ FP+ FN+ TN).
Precision = TP/(TP + FP);
Recall = TP/(TP+ FN);

The testing result of classification using FARs with different parameters are showed below:

Table 8. classification using FARs for Vietnam's apparel companies

Dataset	Options	% Classified Instances	Accuracy. %	Precision. %	Recall %	Number of used rules
Vietnam's apparel companies	minSup = 0.1 minConf=0.90	77.4	84.2	81.6	87.5	7
	minSup= 0.1 minConf=0.87	82.6	83.8	83.8	85.3	9
	minSup = 0.1 minConf=0.85	82.7	80.0	81.4	84.3	20

Source: Prepared by the author

CONCLUSION

This study investigates potential FARs exists between inputs and outputs of Vietnamese firms' performance management process, and construct a recommendation system from disclosed FARs. The new proposal process takes experts' knowledge into account and uses it coincident technical measurements for ranking the meaningful of the mining FARs. This approach restricts use of redundant FARs from the various FARs determined and improves the fitness of applying rules. Moreover, it also creates a framework for managers to control and modify a RS of firm performance management.

Experiment proved the potential of FARs for building a good recommender system for Firm performance Management. The percentage of classified instances using the mining FARs is not quite high (about 82%), but it is not always the case. Vietnam's apparel dataset includes rare classes of ROA, therefore applying only frequent FARs is not enough. This issue can be fixed by using both frequent and infrequent FARs.

This proposed model has a great opportunity to use because FARs support the well-understand of firm performance for end users, so it supports users better to react. Besides, Expert knowledge is used to select optimal FARs for RS, and it improves the performance of algorithms that only use the technical measurement. In ideal cases, the fuzzy association rule mining technique generates rules automatically to help managers make rational decisions or gives fundamental knowledge to emerge study on firm's situations.

This study has some limitations on experiment. The data set contains a lot of exceptions and bizarre instances resulting from the survey method of the General Statistic Office of Vietnam, therefore, thus the result needs to be improved to match reality.

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