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A FUSION APPROACH FOR PRODUCT-RELATED COMPETITIVE INTELLIGENCE BASED ON KNOWLEDGE ELEMENT MODEL

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Abstract. *Product competitiveness determines the situation of enterprises in the business environment. As a result, efficient collection and analysis of product-related competitive intelligence are considered extremely urgent in the big data era. This paper attempts to explore a knowledge fusion approach to identify and integrate product-related competitive intelligence from diverse sources. On the one hand, it uses knowledge element model to describe product intelligence both from the enterprise inside and outside. On the other hand, a comprehensive fusion process, which is composed of similarity analysis and multi-attribute fusion, is proposed to optimize the knowledge framework of the collected intelligence. The results of a prototype experiment verified the feasibility and validity of the representation and fusion method of the extracted product-related competitive intelligence in this study.*
Keywords: Product-related intelligence, Knowledge element model, Competitive situation analysis, Multi-attribute fusion, Similarity analysis

1. **Introduction.** Product is regarded as one of the critical success factors for enterprises. There is no doubt that product competitiveness determines the situation of the organization in the competitive environment [1]. As a result, product-related competitive intelligence (Prod-CI) has attached much attention in business. Especially in the big data era, efficient collection and analysis of Prod-CI are considered extremely necessary and urgent [2].

The purpose of Prod-CI activities is to identify competitive product information not only from enterprise itself, but also from competitors, customers, partners and other kinds of participants. Above all, Prod-CI fusion and analysis help decision-makers to understand the market dynamic and respond instantly with close tracking of competitive products [3]. Amarouche et al. [4] synthesized the major research done for the different steps of product opinion – Related CI mining. Mariadoss et al.'s study [5], which modeled and tested the relationship between a salesperson's product knowledge, competitive intelligence behaviors and performance, emphasized that salespersons' behaviors and influences related gathering and disseminating CI, especially Prod-CI, for their organizations. Xiao et al. [6] proposed a novel econometric preference measurement model to extract aggregate consumer preferences from online product reviews. Although plenty of studies applied Prod-CI to solving diverse business decisions successfully, almost all of these methods only support a single domain of application. Few researchers extend to propose a standardized knowledge framework to represent Prod-CI for cross-domain application.

As it is, the Prod-CI identification and analysis from different kinds of sources depend on a unified knowledge framework to describe the valuable contents. Knowledge element (KE) is an independent unit with complete knowledge representation [7,8]. In recent years, knowledge element model (KEM) designed by Wang [9] has been used successfully

in some cross-domain management. The basic triple-set of KEM is used with a concrete design as the knowledge representation of Prod-CI in this study.

When Prod-CI are identified and extracted from multi-sources as the form of KEM, an efficient fusion approach, which can discover and filter redundant and interfering data of collected Prod-CI, seems to be necessary to integrate the KEs for further use. In the recent hotspots of information fusion researches, Dempster-Shafer evidence theory (DST) [10,11] and similarity analysis [12] are chosen for Prod-CI KE fusion in this study.

The purpose of this study is to design a knowledge representation and fusion method to identify and describe Prod-CI, which is regarded as the premise of deep mining. On the one hand, it uses knowledge element model to describe Prod-CI both from the enterprise inside and the competitive environment. On the other hand, an efficient fusion process is designed to further optimize the standardized knowledge framework of Prod-CI, which is seen as the basis of subsequent relation-extraction of Prod-CI KEs.

The paper proceeds as follows. Section 2 elaborates the framework of KEM, which is the unified knowledge representation of the extracted Prod-CI from diverse sources. The subdivision of KEs are also explained here. In Section 3, after a statement of the fusion mechanism of Prod-CI KE, two processes of fusion computing, namely similarity fusion and multi-attribute fusion extending DST, are discussed respectively. Section 4 introduces a small prototype experiment to illustrate the representation and fusing processes of instantial Prod-CI KEs from sources. Conclusions are finally drawn in Section 5, along with some recommendations for the future research.

2. Knowledge Element Model of Prod-CI.

From the perspective of holography, everything of the world can be described completely by its attributes. Therefore, Wang proposes KEM to represent things and their relations based on attribute-relation discovery and description. Based on six-level perception model [9], KEM is regarded as a unified knowledge framework which uses a triple to describe objects, as shown in (1), (2) and (3).

$$K = (N, A, R) \tag{1}$$

where N, A and R respectively denote the name-set, attribute-set and attribute-relation-set of the object. For any $a \in A$, which is measured qualitatively or quantitatively, the attribute can be described at length as the following triple:

$$K_a = (p_a, d_a, f_a) \tag{2}$$

where p_a denotes a measurable description of the attribute a, d_a denotes the probability distribution or fuzzy number of the change rules of the attribute, and f_a is a related function if a is time varying. Furthermore, the attribute-relation r ($r \in R$) can be described as the following array:

$$K_r = \left(p_r, A_r^I, A_r^O, f_r\right) \tag{3}$$

where p_r is the literal description of the attribute-relation, A_r^I and A_r^O respectively express the input-attribute set and the output-attribute set of f_r. For any $r \in R$ satisfying $A_r^O = f_r\left(A_r^I\right)$, f_r is the corresponding function describing the relation among attributes of the same KE or even different KEs.

KEM defines a standardized knowledge structure of the descriptive thing. According to the specific description of the object, KE can be divided into two categories, namely meta KE and instantial KE. The former defines the common items of one kind of thing, whereas the latter represents a concrete thing with the state of attributes being assigned.

Table 1 shows the incomplete composition of the meta KE of Prod-CI which can be gradually improved with the collecting of Prod-CI as well as the new demands of business decision-makers. Note that, the general attributes present the basic information and the characteristics of the product as a whole. The technical/functional attributes describe the core competitiveness of technical innovation of the product. The advantage

TABLE 1. Form composition of the meta KE of Prod-CI

	The Triple of Prod-CI KE		
	Name	Attribute	Relationship
Attribute Subset	Product	General attrib. [Prod_ID, Name, Category, Time_to_market, Production, Prod_feature, Position, Target_Cust];	Sales: Price Cost: Production, D&R, Promotion, Service, Pack Profit: Sales, Cost
		Technical/functional attrib. [Parameter, D&R, Core_Tech, Patent];	
		Sales/marketing attrib. [Price, Place, Promotion, Cust_list];	
		Demand/evaluation attrib. [Quantity, Price, Function, Brand, Pack, Service, Appearance];	
		Advantage attrib. [Function, Price, Cost];	
		Statistics attrib. [Sales, Cost, Profit, Market_Share].	

attributes illustrate the dominant position comparing with the competitive products. The sales/marketing attributes record the responses of customers. The statistics attributes computed the data of sales as well as finance.

All the collected Prod-CI should be described as instantial KEs based on the framework of related meta KEs. However, there are several redundant or interfering data that should be integrated. Meanwhile, as mentioned above, the meta KEs should be improved according to the new demands. Therefore, the next section will discuss respectively the two kinds of fusion processes for meta KEs and instantial KEs in detail.

3. **Similarity and Multi-Attribute Fusion Computing of Prod-CI KE.** The fusion mechanism of Prod-CI KEs in our study are shown in Figure 1. All the extracted instantial KEs from Prod-CI sources should be integrated based on similarity analysis twice. The first computing is to combine the same Prod-CI instantial KEs. The second one is to delete the same KEs as the ones in the Prod-CI instantial KE database. After that, instantial KEs without redundancy may further improve the cognitive framework of the corresponding meta KE based on the multi-attribute fusion method. What is more, some implicit attribute-relations of Prod-CI KEs may be discovered, which may add the description of K_r in (3).

In our study, similarity computing focuses on the name-set and the attribute-set of instantial Prod-CI KEs. Assuming that N_m and N_n are the name-sets of two extracted KEs (K_M and K_N) respectively. Then, the similarity of N_m and N_n (defined as $Sim(N_m, N_n)$)

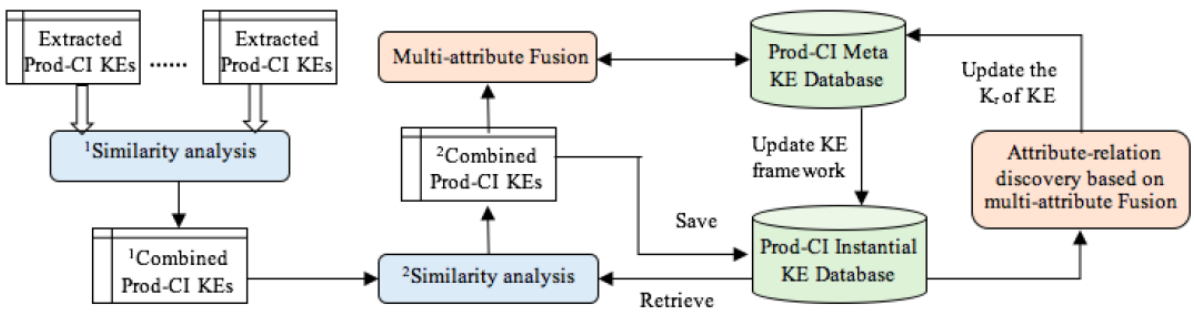

FIGURE 1. Fusion mechanism of Prod-CI KEs extracted from multi-sources

is designed as

$$Sim(N_m, N_n) = \begin{cases} 1 & (N_m \subseteq N_n \text{ or } N_n \subseteq N_m) \\ \dfrac{|N_m \cap N_n|}{|N_m \cap N_n| + \alpha|N_m - N_n| + (1-\alpha)|N_n - N_m|} & \text{others} \end{cases} \tag{4}$$

where α $(0 < \alpha < 1)$ denotes the attention of KE [13]. If $Sim(N_m, N_n) \geq \mu$ $(0 < \mu \leq 1)$, K_M and K_N can be integrated as one Prod-CI KE. Else, the similarity of attribute-set A_m and A_n (defined as $Sim(A_m, A_n)$) should be further calculated as

$$Sim\left(a_m^i, a_n^i\right) = \begin{cases} 1 & \left(a_m^i \subseteq a_n^i \text{ or } a_n^i \subseteq a_m^i\right) \\ \dfrac{|a_m^i \cap a_n^i|}{|a_m^i \cap a_n^i| + \alpha|a_m^i - a_n^i| + (1-\alpha)|a_n^i - a_m^i|} & \text{others} \end{cases} \tag{5}$$

$$Sim(A_m, A_n) = \begin{cases} 1 & (A_m \subset A_n \text{ or } A_n \subset A_m) \\ \sum \theta_l Sim\left(a_m^i, a_n^i\right) & \text{others} \end{cases} \tag{6}$$

where $a_m^i \in A_m$, $a_n^i \in A_n$ and $0 \leq i \leq |A_m|$. If the comprehensive similarity degree of the two attribute-sets $Sim(A_m, A_n) \geq \mu$ $(0 < \mu < 1)$, the two KEs are regarded as the same and should be integrated into one Prod-CI KE. Otherwise, K_M and K_N are regarded as different instantial KEs.

The multi-attribute fusion of Prod-CI KE (shown in Figure 1) is to determine whether to update the meta KE of related Prod-CI. Assuming that the attribute-set of an instantial KE is defined as $A' = \{a'_1, a'_2, \ldots, a'_q\}$ $(q = |A'|)$, and the corresponding meta KE is defined as $A = \{a_1, a_2, \ldots, a_p\}$ $(p = |A|)$. It can be concluded that the framework extends to $A'' = A \cup A'$ based on traditional DST [10,11].

In Sun and Wang's study on the multi-attribute fusion method which extends traditional DST [14], some new uncertainty measures, such as uncertainty degree (Unc) and aggregate support (Sup), are designed to integrate combined evidences. As mentioned above, $A'' = \{A''_1, \ldots, A''_s\} = \left\{\{a_1\}, \{a_1, a_2\}, \ldots, \left\{a_1, \ldots, a_p, a'^l_1, \ldots, a'^l_j\right\}\right\}$ where $s = 2^{p+j}$. Then the fusion process is defined as

$$m_{\cap f}\left(A''_i\right) = \sum_{SupA_i} m_1\left(A''_{i_1}\right) \cdot m_2\left(A''_{i_2}\right) \cdot \ldots \cdot m_r\left(A''_{i_r}\right) \tag{7}$$

$$m_\alpha(A''_i) = m_{\cap f}(A''_i) + q(A''_i) \cdot k \tag{8}$$

where r denotes the amount of weight groups, k denotes evidential conflict, $q\left(A''_i\right)$ denotes weighted average support, and $Sup\left(A''_i\right) = Max\left[Sup\left(A''_{i_1}\right), \ldots, Sup\left(A''_{i_s}\right)\right]$. And fusion result A_f must satisfy $m_\alpha(A_f) = Max\left[m_\alpha\left(A''_i\right)\right]$. As a result, it comes to a conclusion whether the original A should be optimized to a new knowledge framework defined as A_f. If the Prod-CI meta KE should be updated, all the corresponding instantial KEs of Prod-CI saved in the database should be updated as the new framework.

4. **Experiment Results and Analysis.** The purpose of this experiment is to design an original Prod-CI meta KE for a technology-oriented enterprise. Moreover, the prototype fusion process of Prod-CI instantial KEs extracted from different sources, such as interviews, enterprise websites, and other public sources, should be proved.

According to the result of internal investigations, the original Prod-CI meta KE of the product named OAS is described as shown in Table 2, where attributes with # stand for the replaceable parameters when instantiating the KEs.

Based on the meta KE and the corresponding thesaurus, Prod-CI can be identified and analyzed by a content mining system called ROST. On the one hand, by using RostWebSpider, OAS product-related information from public sources can be collected based on some keywords in OAS thesaurus. Text mining are carried out subsequently to discover related attributes of OAS meta KE and instantial KEs extraction are accomplished later.

Table 2. Original Prod-CI meta KE of OAS

	The Triple of Prod-CI KE		
	Name	Attribute	Relationship
Attribute Subset	OAS	General attrib. [#Prod_ID, #Prod_name, #category, #Time_to_market, #Tech_platform, #Prod_feature, #Position, #Target_cust];	Sales: Price Cost: Production, D&R, Promotion, Service, Pack Profit: Sales, Cost
		Technical/functional attrib. [#Parameter, #Department, #Core_tech, #patent];	
		Sales/marketing attrib. [#Price, #Zone, #Uni_or_Gov, #Cust_list];	
		Demand/evaluation attrib. [#Total-Eval, #Price, #Function, #Service, #Interface];	
		Advantage attrib. [#Function, #Price, #other];	
		Statistics attrib. [#Sales, #Cost, #Profit, #Market_Share].	

On the other hand, ROST also supports text processing to further analyze the internal materials of the target enterprise. However, some artificial operations are necessary for assigning the attributes in the instantial KEs based on the semantic analyzed documents by the end of this experimental study.

Partial extracted OAS instantial KEs that are collected from the internal materials of the enterprise's own are shown in Figure 2. What is more, several extracted OAS instantial KEs that collected from the public sources are shown in Figure 3.

All of the above instantial KEs should be integrated based on the fusion approaches in this study. Because the name of these instantial KEs are all the same as 1_OAS, the similarity analysis focuses on computing the similarity of the other attributes as in (5) and (6). Note that, the weight θ_l' in (6) of the attribute "Position", "Uni_or_Gov" and "Producer" are the double of the others with the consideration of the importance. Therefore, $\theta_l' = 0.08$ and the others satisfy $\theta_l = 0.04$ where $n = 22$ (n denotes the number of non-empty attributes) in Figure 2. Similarly, $\theta_l' = 0.13$ and the others satisfy $\theta_l = 0.067$ where $n = 12$ (n denotes the number of non-empty attributes) in Figure 3. Assuming that $\mu = 0.55$, the computing results are shown in Figure 4 and Figure 5.

It can be seen that the integrity of the attribute description of instantial KEs from internal and public sources are different. Based on the multi-attribute fusion method, all the instantial KEs from internal materials and public sources are integrated for the second time. Also as for the importance of attributes, the baseline of multi-attribute fusion is chosen as {"Position", "Uni_or_Gov", "Producer"}. The final fusion result of this experiment is shown as Figure 6.

In this prototype experiment, several OAS CI are identified and represented in the form of Prod-CI instantial KEs. Partial of the OAS-related CI, both from the target enterprise and its competitors, are integrated for further use. Note that, those instantial KEs with high similarity degrees are fused effectively by integrating the same attribute with the same values into one and adding the same attributes with different values into a string for further use. Meanwhile, by using multi-attribute fusion method, some inconsistent descriptions of the attributes of the same KE have been integrated effectively based on the critical baseline attribute-set. It can be concluded that the fusion process of this study is feasible and effective based on the semi-automatic computing and analysis.

5. **Conclusions and Future Research.** This paper demonstrates a fusion approach for identifying product-related competitive intelligence based on KEM, which uses two kinds of fusion processes, namely similarity analysis and multi-attribute fusion, to accomplish

No	General							Technical/function			Sales/marketing				Demand/evaluation			Advantage			Statistics			Producer	Time_to_collect	Source
	Prod_ID	Product name	Category	Time to market	Develop platform	Position	Target customer	Production	Core_technology	Patent	Price	Zone	Uni_or_Gov	Customer list	General	Price	Interface	Function	Price	other	Sales	Cost	Profit			
1	102011001	1_OAS	10201_Cooperative	200109	OA platform	Municipal government	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES	89	Northeast-Liaoning-	Gov	DLSW	Accepted	Rational				Region	89	88	1	01_own	20161015	Internal material
2		1_OAS	10201_Cooperative	200111	OA platform	Municipal government	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES	91	Huaeast-Zhejiang-	Gov	DLSZF	Accepted	Rational				Region	91	88	3	01_own	20161015	Internal material
3	102011002	1_OAS	10201_Cooperative	200203	OA platform	Provincial government	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES		Northeast-Liaoning	Gov	LNSW	Accepted	Rational			LOW	Region				01_own	20161015	Internal material
4	102011002	1_OAS	10201_Cooperative	200207	OA platform	Provincial government	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES		Northeast-Liaoning	Gov	LNSZF	Accepted	Rational			LOW	Region				01_own	20161015	Internal material
5		1_OAS	10201_Cooperative	200301	OA platform	Municipal government	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES		Northeast-Liaoning-	Gov	HZSZF	Accepted	Rational				Partner				01_own	20161015	Internal material
6		1_OAS	10201_Cooperative	200301	OA platform	Municipal government	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES		Northeast-Liaoning-	Gov	SYSZF	Accepted	Rational				Region				01_own	20161015	Internal material
7		1_OAS	10201_Cooperative		OA platform	Municipal government	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES			Gov	FSSZF	Accepted	Rational				Region				01_own	20161015	Internal material
8	102011003	1_OAS	10201_Cooperative	201501	OA platform	University	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES		Northeast-Liaoning-	Uni	DLLGDX	Accepted	Rational	Rational	Custom-made		Region				01_own	20161015	Internal material
9	102011009	1_OAS	10201_Cooperative	201601	OA platform	University	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES		Northeast-Liaoning-	Uni	DLDX						Region				01_own	20161015	Internal material

FIGURE 2. Partial details of the extracted OAS instantial KEs from internal sources

No	General						Technical/function			Sales/marketing			Demand/evaluation					Producer	Time_to_collect	Source
	Product name	Category	Develop platform	Product feature	Position	Target customer	Production	Core_technology	Patent	Zone	Uni_or_Gov	Customer list	General	Price	Function	Service	Interface			
1	1_OAS	10201_Cooperative office	OA platform		Central government	Government;University		RNM;OAP;CA;NOTES	SIFES	Beijing	Gov	GWYBGT	Accepted					01_own	20161015	IDT website
2	1_OAS	10201_Cooperative office	OA platform		Provincial government	Government;University		RNM;OAP;CA;NOTES	SIFES	Northeast-Liaoning	Gov	LNSW	Accepted					01_own	20161015	IDT website
3	1_OAS	10201_Cooperative office	OA platform		Provincial government	Government;University		RNM;OAP;CA;NOTES	SIFES	Northeast-Liaoning	Gov	LNSZF	Accepted					01_own	20161015	IDT website
4	1_OAS	10201_Cooperative office	OA platform		Municipal government	Government;University		RNM;OAP;CA;NOTES	SIFES	Huaeast-Zhejiang-Hangzhou	Gov	HZSZF	Accepted					01_own	20161015	IDT website
5	1_OAS	10201_Cooperative office	OA platform		Municipal government	Government;University		RNM;OAP;CA;NOTES	SIFES	Northeast-Liaoning-Shenyang	Gov	SYSZF	Accepted					01_own	20161015	IDT website
6	1_OAS	10201_Cooperative office	OA platform		Municipal government	Government;University		RNM;OAP;CA;NOTES	SIFES	Northeast-Liaoning-Dalian	Gov	DLSW	Accepted					01_own	20161015	IDT website
7	1_OAS	10201_Cooperative office	OA platform		Municipal government	Government;University		RNM;OAP;CA;NOTES	SIFES	Northeast-Liaoning-Dalian	Gov	DLSZF	Accepted					01_own	20161015	IDT website
8	1_OAS	10201_Cooperative office	OA platform		Municipal government	Government;University		RNM;OAP;CA;NOTES	SIFES	Northeast-Liaoning-Anshan	Gov	ASSW	Accepted					01_own	20161015	IDT website
9	1_OAS	10201_Cooperative office	OA platform		Municipal government	Government;University		RNM;OAP;CA;NOTES	SIFES	Northeast-Liaoning-Fushun	Gov	FSSZF	Accepted					01_own	20161015	IDT website
10	1_OAS	10201_Cooperative office	OA platform		Municipal government	Government;University		RNM;OAP;CA;NOTES	SIFES	Northeast-Liaoning-Jinzhou	Gov	JZSZF	Accepted					01_own	20161015	IDT website
11	1_OAS	10201_Cooperative office		Doc_MGMT;Info_Portal;Daily_office	Municipal government	Government;University				Huaeast-Jiangsu-Xuzhou	Gov	XZSZF	Accepted					15_Competitor	20161015	FW website
12	1_OAS	10201_Cooperative office			Provincial government	Government;University				Northeast-HeiLongjiang	Gov	HLJSWXCB	Accepted					15_Competitor	20161015	FW website
13	1_OAS	10201_Cooperative office			Provincial government	Government;University				Huanorth-Henan	Gov	HNSJTT	Accepted					15_Competitor	20161015	FW website

FIGURE 3. Partial details of the extracted OAS instantial KEs from public sources

Similarity result	No	General							Technical/function			Sales/marketing				Demand/evaluation			Advantage			Statistics			Producer	Time_to_collect	Source
		Prod_ID	Product name	Category	Time to market	Develop platform	Position	Target customer	Production	Core_technology	Patent	Price	Zone	Uni_or_Gov	Customer list	General	Price	Interface	Function	Price	other	Sales	Cost	Profit			
0.76–0.88	1	102011001	1_OAS	10201_Cooperative office	200109;200111;200301;200301;;	OA platform	Municipal government	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES	89;91;;;;	Northeast-Liaoning-Dalian;Huaeast-Zhejiang-Hangzhou;Northeast-Liaoning-Shenyang;Northeast-Liaoning-Fushun;	Gov	DLSW;DLSZF;HZSZF;SYSZF;FSSZF;	Accepted	Rational				Region;Region;Partner;Region;Region;	89;91;	88;88;	1;3;	01_own	20161015	Internal material
	2																										
	5																										
	6																										
	7																										
0.92	3	102011002	1_OAS	10201_Cooperative office	200203;200207;	OA platform	Provincial government	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES		Northeast-Liaoning	Gov	LNSW;LNSZF;	Accepted	Rational			LOW	Region				01_own	20161015	Internal material
	4																										
0.76	8	102011003	1_OAS	10201_Cooperative office	201501;201601;	OA platform	University	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES		Northeast-Liaoning-Dalian	Uni	DLLGDX;DLDX;	Accepted;;	National;;	Rational;;	Custom-made;;		Region				01_own	20161015	Internal material
	9																										
	10	102011010		10201_Cooperative office																							Enterprise website

FIGURE 4. Similarity fusion result of OAS instantial KEs from internal materials

Similarity result	No	General						Technical/function			Sales/marketing			Demand/evaluation					Producer	Time_to_collect	Source
		Product name	Category	Develop platform	Product feature	Position	Target customer	Production	Core_technology	Patent	Zone	Uni_or_Gov	Customer list	General	Price	Function	Service	Interface			
	1	1_OAS	10201_Cooperative office	OA platform		Central government	Government; University		RNM;OAP;CA;NOTES	SIFES	Beijing	Gov	GWYBGT	Accepted					01_own	20161015	IDT website
0.93	2	1_OAS	10201_Cooperative office	OA platform		Provincial government	Government; University		RNM;OAP;CA;NOTES	SIFES	Northeast-Liaoning	Gov	LNSW;LNSZF;	Accepted					01_own	20161015	IDT website
	3																				
0.87	4	1_OAS	10201_Cooperative office	OA platform		Municipal government	Government; University		RNM;OAP;CA;NOTES	SIFES	Huaeast-Zhejiang-Hangzhou;Northeast-Liaoning-Shenyang;Northeast-Liaoning-Dalian;Northeast-Liaoning-Anshan;Northeast-Liaoning-Fushun;Northeast-Liaoning-Jinzhou;	Gov	HZSZF;SYSZF;DLSW;DLSZF;ASSW;FSSZF;JZSZF;	Accepted					01_own	20161015	IDT website
	5																				
	6																				
	7																				
	8																				
	9																				
	10																				
0.8	11	1_OAS	10201_Cooperative office		Doc_MGMT;Info_Portal;Daily_office;::::	Provincial government	Government; University				Huaeast-Jiangsu-Xuzhou;Northeast-HeiLongjiang;Huanorth-Henan;Huaeast-Shanghai;	Gov	XZSZF;HLJSWXCB;HNSJTT;SHSWDX;	Accepted					15_Competitor	20161015	FW website
	12																				
	13																				
	14																				

FIGURE 5. Similarity fusion result of OAS instantial KEs from public sources

General								Technical/function			Sales/marketing				Demand/evaluation			Advantage			Statistics			Producer	Time_to_collect	Source
Prod_ID	Product name	Category	Time to market	Develop platform	Product feature	Position	Target customer	Production	Core_technology	Patent	Price	Zone	Uni_or_Gov	Customer list	General	Price	Interface	Function	Price	other	Sales	Cost	Profit			
102011001	1_OAS	10201_Cooperative office		OA platform		Central government	Government; University		RNM;OAP;CA;NOTES	SIFES		Beijing	Gov	GWYBGT	Accepted									01_own	20161015	IDT website
102011002	1_OAS	10201_Cooperative office	200109;20 0111;2003 01;200301 ;;	OA platform		Municipal government	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES	89;91;; ;;	Northeast-Liaoning-Dalian;Huaeast-Zhejiang-Hangzhou;Northeast-Liaoning-Shenyang;Northeast-Liaoning-Fushun;	Gov	HZSZF;SYSZF ;DLSW;DLSZF ;ASSW;FSSZF ;JZSZF;	Accepted	Rational				Region;Region;Partner;Region;Region;	89;91;	88;88;	1;3;	01_own	20161015	Internal material;IDT website
102011003	1_OAS	10201_Cooperative office	200203;20 0207;	OA platform		Provincial government	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES		Northeast-Liaoning	Gov	LNSW;LNSZF;	Accepted	Rational			LOW	Region				01_own	20161015	Internal material
102011004	1_OAS	10201_Cooperative office	201501;20 1601;	OA platform		University	Government; University	D&R;EG Group	RNM;OAP;CA;NOTES	SIFES		Northeast-Liaoning-Dalian	Uni	DLLGDX;DLDX ;	Accepted: ;	Rational ;;	Rational;;	Custom-made;;		Region				01_own	20161015	Internal material
102011005	1_OAS	10201_Cooperative office			Doc_MGMT;I nfo_Portal ;Daily_off ice;;;;	Provincial government	Government; University					Huaeast-Jiangsu-Xuzhou;Northeast-HeiLongjiang;Huanorth-Henan;Huaeast-Shanghai;	Gov	XZSZF;HLJSW XCB;HNSJTJ; SHSWDX;	Accepted									15_Competitor	20161015	FW website

FIGURE 6. Multi-attribute fusion result of the extracted OAS instantial KEs

the valuable Prod-CI KE discovery and management. This study is seen as a meaningful attempt to build an operational prototypal system of Prod-CI fusion based on KEM from the perspective of integrating multi-source data. Meanwhile, the attribute-relation fusion based on KEM is feasible for implicit Prod-CI mining.

Much work remains to be done, either on theoretical or practical aspects. The algorithm of fusion computing needs to be optimized, especially to cope with the big data. And much more applications of the proposed prototypal system will be carried out to improve the Prod-CI meta database, as well as to optimize the performance of automatic computing.

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