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Research on a Matching Method based on Determining Life Cycle Stage

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Abstract

Modern manufacturing companies are facing great market competition, and their requirements for corporate management and market resilience are getting higher and higher. The research and utilization of the product life cycle are important means for companies to improve original products, develop new products, and formulate various business strategies correctly. This paper proposes a product life cycle matching method, which matches the existing product data with the original product in the knowledge base to obtain the life cycle stage of the existing product. It can make full use of the existing product life cycle characteristic data in the knowledge base, reducing the matching time and the amount of data required for matching. After the matching is completed and the data knowledge of the life cycle stage is obtained, the promotion data knowledge of the original product stored in the knowledge base can be used to quickly obtain the promotion decision that the existing product should take. Since the realization of new product decision-making needs to rely on the knowledge or database of the enterprise's original product, the method in this paper requires the enterprise to have a relatively complete knowledge base to be able to make more accurate decisions. This method is not only suitable for promotion decision-making but can also be applied to other aspects of production management.

Keywords: *Product life cycle, Matching, Characteristic data, Promotion*

1. The feature quantity and matching function of each life cycle of the product

The product life cycle generally includes four stages: input stage, growth stage, mature stage, and decline stage. The division of product life cycle stages is mainly based on the characteristic quantity characteristics of products in different life cycle stages. For example, in the product input period, the sales volume and profit are very low, while the production cost and sales cost are high. In the product maturity period, the sales volume reaches the highest value in the whole life cycle, while the cost is low [1][2]. The typical characteristics of the four life cycle stages characterized by sales volume, production cost, sales cost, and profit are shown in [Table 1]. The changes in sales volume, production cost, sales cost, and profit in each stage also have their characteristics, as shown in [Table 2].

Definition 1. The characteristic quantity of the product life cycle.

Product life cycle characteristics can be defined as a 4-tuple sequence, $T = \{Q, P, C, G\}$, among them, $Q = \{q_i i_{k=1}\}$, q_i is the sales volume during the product period. $P = \{pi^{n}_{k=1}\}$,

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p_i is the production cost during the product period. $C = \{c_i|_{k=1}^{n}\}$, c_i is the cost of sales during the product period. $G = \{g_i|_{k=1}^{n}\}$, g_i is the profit during the product period.

The time period can be divided according to the characteristics of the product life cycle. Products with a longer life cycle can have a longer time period. k=1, …, n. Represents multiple basic time units contained in a time period.

Table 1. Typical characteristics of the life cycle phase

Product Lifecycle	Sales volume	Cost of production	Cost of sales	Profit
Investment period	Low	High	High	Low
Growth period	Middle	Middle	Middle	Middle
Maturity	High	Low	Low	High
Recession	Middle	Low	Low	Low

Table 2. Changes of characteristics in each life cycle stage

Product Lifecycle	Sales volume	Cost of production	Cost of sales	Profit
Investment period	slow growth	High	High	Low, often negative
Growth period	fast-growing	Cost reduction	Decline	Rise rapidly
Maturity	Change slowly	Change slowly	Change slowly	Change slowly
Recession	More uncomfortable	Change slowly	Change slowly	Decline

For ease of analysis, it is assumed that the life cycle data in Definition 1 is close to smooth. If it is not close to smooth, perform smoothing processing [3]. Thus, a continuous function is constructed for the above data. For example, sales volume $Q = \{q_i|_{k=1}^{n}\}$, Construct a smooth continuous unimodal function Q(t), 1≤t≤n Make Q(k) ≈q. On this basis, construct 2 functions as the matching function of sales volume

$$\begin{cases} F_{q_1}(t) = \dfrac{(Q(t) - min}{\big(maxQ(t) - minQ2(t)\big)maxQ(t)} + 0.5 \\ F_{q2}(t) = Q^2(t) \end{cases} \tag{1}$$

$$1 \le t \le n$$

Among them, min Q(t) represents the minimum value of product sales Q(t) from time t=1 to time t, and represents the maximum value of product sales volume from time to time [4]. The matching function $F_{q_1}(t)$ is to match the changes of the data, and the matching function $F_{q2}(t)$ is to match the magnitude of the data. The combination of the two can achieve a better matching effect. In the same way, the matching functions of production cost, sales cost, and profit can be obtained as

$$\begin{cases} F_{p1}(t) = \dfrac{\big(P(t) - minP(t)\big)}{\big(maxP(t) - minP(t)\big)maxP(t)} + 0.5 \\ F_{p2}(t) = P^2(t) \end{cases} \tag{2}$$

$$\begin{cases} F_{C1}(t) = \frac{(C(t) - minC(t))}{(maxC(t) - minC(t))maxC(t)} + 0.5 \\ F_{C2}(t) = C^2(t) \end{cases} \quad (3)$$

$$\begin{cases} F_{g1}(t) = \frac{(G(t) - minG(t))}{(maxG(t) - minG(t))maxG(t)} + 0.5 \\ F_{g2}(t) = G^2(t) \end{cases} \quad (4)$$

$$1 \leq t \leq n$$

Nature 1 Function $F_{q1}(t) = \frac{(Q(t)-minQ(t))}{(maxQ(t)-minQ(t))maxQ(t)} + 0.5$, It is a continuous monotonic non-increasing function in its domain.
Prove The function $F_{q1}(t)$ is continuous. To prove that the continuous function is a monotonic non-increasing function, Only need to prove that $Fq1'(t) \leq 0$, *Assume* $t = t_1$, $Q(t)$ gets the maximum value, which is max $Q(t) = Q(t_1)$.

1. When $1 \leq t \leq t_1, \max_{1-t} Q(t) = Q(t)$, $t \neq 1$, $F_{q1}(t) = \frac{(Q(t)-minQ(t))}{(Q(t)-minQ(t))Q(t)} + 0.5 = \frac{1}{Q(t)} + 0.5$, $F'_{q1}(t) = -\frac{Q'(t)}{Q^2(t)}$, $Q'(t) > 0$, therefore $F'_{q1}(t) < 0$

2. When$t_1 \leq t \leq n$, *If* $Q(n) \geq Q(1)$, $\max_{1-t} Q(t) = Q(t_1), \min_{1-t} Q(t) = Q(1)$,
$F_{q1}(t) = \frac{(Q(t)-Q(1))}{(Q(t_l)-Q(1))Q(t_l)} + 0.5, F'_q(t) = \frac{Q'(t_t)}{(Q(t_t)-Q(1))Q(t_t)}$,
Because at this time $Q'(t) < 0$, therefore $F'_{q1}(t) < 0$

3. When$t_1 \leq t \leq n$, *If* $Q(n) < Q(1)$, *Then there must be something* $ta(t_1 \leq t_a \leq n)$, *Make* $Q(ta) = Q(1)$. When$t_1 \leq t_a \leq n$时, versus 2) similar ; When $t_a \leq t \leq n$, max $Q'(t) = Q(t_l)$, min $Q(t) = Q(t)$, $Fq1(t)$ =0:5, $F'_{q1}(t) = 0$. The proposition is proved

2. Feature matching of existing products and original products

The sales volume data knowledge of the existing products and the sales sequence data knowledge of the original products in each life cycle stage are calculated according to the first formula $F_{q1}(t)$ of the matching function, respectively, with the input period, the growth period, the mature period and the decline period to match, you can get

$$|F_{q1}(1) - F^u_{q1}(1)|, |F_{q_1}(2) - F^u_{q1}(2)| \cdots |F_{q1}(n) - F^u_{q1}(n)|, u = 1,2,3,4 \quad (5)$$

u takes 1, 2, 3, and 4, which respectively represent the four stages of the product's input period, growth period, maturity period, and decline period.

According to the sixth formula, $F_{q2}(t)$ of the matching function, the sales volume data knowledge of the existing product and the sales sequence data knowledge of the original product in each life cycle stage are matched and calculated [5], respectively, with the input period, the growth period, and the maturity period. Match with the recession period to get the sequence respectively.

$$\left|F_{q2}(1)-F_{q2}^{u}(1)\right|,\left|F_{q2}(2)-F_{q2}^{u}(2)\right|\cdot\cdots\left|F_{q2}(n)-F_{q2}^{u}(n)\right|, u=1,2,3,4 \qquad (6)$$

With the arithmetic average of formula (5) and formula (6) respectively, we can get

$$T_{q1}^{u}=\frac{1}{n}\sum_{i=1}^{n}\left|F_{q1}(n)-F_{q1}^{u}(n)\right|, u=1,2,3,4 \; and \; T_{q2}^{u}=\frac{1}{n}\sum_{i=1}^{n}\left|F_{q2}(n)-F_{q2}^{u}(n)\right|, u=1,2,3,4$$

Similarly, the production cost, sales cost, and profit data knowledge of the existing product and the original product life cycle stage sequence data knowledge are matched and calculated according to the matching function [6], and the arithmetic average is taken to obtain

$$T_{P1}^{u}=\frac{1}{n}\sum_{i=1}^{n}\left|F_{p1}(n)-F_{p1}^{u}(n)\right|$$

$$T_{P2}^{u}=\frac{1}{n}\sum_{i=1}^{n}\left|F_{p2}(n)-F_{p2}(n)\right|, u=1,2,3,4$$

$$T_{C1}^{u}=\frac{1}{n}\sum_{i=1}^{n}\left|F_{c}(n)-F_{c1}^{u}(n)\right|$$

$$T_{C2}^{u}=\frac{1}{n}\sum_{i=1}^{n}\left|F_{c2}(n)-F_{c2}(n)\right|, u=1,2,3,4$$

$$T_{g1}^{u}=\frac{1}{n}\sum_{i=1}^{n}\left|F_{g1}(n)-F_{g1}^{u}(n)\right|$$

$$T_{g2}^{u}=\frac{1}{n}\sum_{i=1}^{n}\left|F_{g2}(n)-F_{g2}^{u}(n)\right|, u=1,2,3,4$$

Definition 2. The difference in the sales volume of the existing product and the original product in each life cycle stage is

$$DISQ(u)=\left(\frac{T_{q2}^{u}-minT_{q2}}{maxT_{q2}-minT_{q2}}+0.5\right)\times\sqrt{\frac{T_{q1}^{u}-minT_{q1}}{maxT_{q1}-minT_{q1}}+0.5},$$

where,

$$T_{q1}=\left\{T_{q1}^{1},T_{q1}^{2},T_{q1}^{3},T_{q1}^{4}\right\}, T_{q2}=\left\{T_{q2}^{1},T_{q2}^{2},T_{q2}^{3},T_{q2}^{4}\right\}.$$

In the same way, the difference between the production cost of the existing product and the original product in each life cycle stage can be obtained as

$$DISP(u)\left(\frac{T_{p2}^{u}-minT_{p2}}{maxT_{p2}-minT_{p2}}+0.5\right)\sqrt{\frac{T_{p1}^{u}-minT_{p1}}{maxT_{p1}-minT_{p1}}+0.5},$$

where,

$$T_{p1}=\left\{T_{p1}^{1},T_{p1}^{2},T_{p1}^{3},T_{p1}^{4}\right\}, T_{p2}=\left\{T_{p2}^{1},T_{p2}^{2},T_{p2}^{3},T_{p2}^{4}\right\}.$$

The degree of dissimilarity between the current product and the original product's sales cost at each life cycle stage is

$$DISC(u)\left(\frac{T_{C2}^{u}-minT_{C2}}{maxT_{C2}-minT_{C2}}+0.5\right)\sqrt{\frac{T_{C1}^{u}-minT_{C1}}{maxT_{C1}-minT_{C1}}+0.5},$$

where,

$$T_{c1}=\{T_{c1}^{1},T_{c1}^{2},T_{c1}^{3},T_{c1}^{4}\},T_{c2}=\{T_{c2}^{1},T_{c2}^{2},T_{c2}^{3},T_{c2}^{4}\}.$$

The difference between the profit of the existing product and the original product at each life cycle stage is

$$DISG(u)\left(\frac{T_{g2}^{u}-minT_{g2}}{maxT_{g2}-minT_{g2}}+0.5\right)\sqrt{\frac{T_{g1}^{u}-minT_{g1}}{maxT_{g1}-minT_{g1}}+0.5},$$

where,

$$T_{g1}=\{T_{g1}^{1},T_{g1}^{2},T_{g1}^{3},T_{g1}^{4}\},T_{g2}=\{T_{g2}^{1},T_{g2}^{2},T_{g2}^{3},T_{g2}^{4}\}.$$

After obtaining the difference in sales volume, production cost, sales cost, and profit of the existing product and the original product in each life cycle stage, the total matching degree is calculated. Due to the differences in the influence of sales volume, production cost, sales cost, and profit in the judgment of the existing product life cycle [7]. Therefore, the weight coefficient v_I is introduced to it, i = 1,2,3,4, $0 \le v_i \le 1$. v_1, v_2, v_3, v_4, Respectively indicate the degree of influence of sales volume, production cost, sales cost, and profit on matching.

Definition 3. The overall matching degree between the existing product and the original product is defined as

$$MAT(u)=1-(v_1^{-1}DISQ(u)+v_2^{-1}DISP(u)+v_3^{-1}DISC(u)+v_4^{-1}DISG(u))/(\sum_{u=1}^{4}(v_1^{-1}DISQ(u)+v_2^{-1}DISP(u)+v_3^{-1}DISC(u)+v_4^{-1}DISG(u))),u=1,2,3,4$$

Existing products belong to the life cycle stage with the maximum matching degree, and are usually related to the life cycle stage with the second-largest matching degree value [8]. Therefore, the decision of the existing product can be calculated according to the following formula.

$$DCI(x)=\left(1-\frac{1}{2}\left(\frac{maxMAT(u)-secmaxMAT(u)}{maxMAT(u)-minMAT(u)}\right)\right)\times DCI(u_{max})+\frac{1}{2}\left(\frac{maxMAT(u)-secmaxMAT(u)}{maxMAT(u)-minMAT(u)}\right)\times DCI(u_{secmax}),u=1,2,3,4。$$

Where, $\mathrm{DCI}(x)$ is the decision of the existing product, $max\mathrm{MAT}(u)$, and $min\mathrm{MAT}(u)$

They are the maximum and minimum values of MAT (u), $\mathrm{sec}max\mathrm{MAT}(u)$ is the value adjacent to and next to $max\mathrm{MAT}(u)$, $\mathrm{DCI}(u_{max})$ is the decision of the stage corresponding to $max\mathrm{MAT}(u)$, $\mathrm{DCI}(u_{\mathrm{sec}max})$ is the decision of the stage corresponding to $\mathrm{sec}max\mathrm{MAT}(u)$.

3. Example analysis

After obtaining the life cycle stage of the product, you can use the existing product life cycle characteristic data in the cloud manufacturing knowledge base to formulate production, promotion, distribution channels, price, and other strategies suitable for this cycle stage. This article takes product promotion decisions as an example to illustrate [9].

The usual product promotion decisions include advertising (TV, newspaper, media advertisements, billboards, etc.), public relations (reports by reporters, donations, seminars, etc.), personnel sales (sales display, visits to customers, etc.), sales promotion (gifts, discounts, cash Return, etc.), direct marketing (using the telephone, mail, e-mail, Internet direct communication, etc.) and other methods [10][11][12][13], the advantages and disadvantages of which are shown in [Table 3].

Table 3. Advantages and disadvantages of several promotion methods

Promotion decision	Advantage	Disadvantage
Advertising	Multiple media, large selection, strong expression, large coverage	High cost, greatly affected by media coverage
Public Relations	To win the goodwill of customers and facilitate the establishment of a good corporate image	Suitable for short-term application, the average effect
Personnel sales	Face to face, easy to cultivate relationships	Narrow coverage
Sales promotion	Motivating and easy to attract customers	Restricted application and high cost
Direct marketing	Low cost, individualization, timely information update	Poor promotion effect

For a specific product, it is not necessary to use all of the above-mentioned promotional methods, but a targeted selection of low-input and high-efficiency promotional decisions should be made. For the selected promotion decision, in different life cycle stages, the determination of the specific promotion focus and capital investment is also a problem that needs attention. In a system that does not use a knowledge base, the promotion decisions of existing products need to be re-established and adjusted and improved during the production and sales process, which increases the time and cost of decision-making. In a system that uses a knowledge base, the knowledge of promotion decisions for original or similar products can be retrieved from the knowledge base, and fine-tuned and updated, which can greatly reduce the time and cost of making promotion decisions for existing products.

An air conditioner manufacturer has developed and produced a new type of air conditioner based on the original product. After some time, the company hopes to strengthen its marketing work and needs to make promotion decisions. Assuming that the data of each stage of the original product has been stored in the knowledge base, the sales volume, production cost, sales cost, and profit of each stage of the original product's life cycle typical period (in monthly units) stored in the knowledge base are as follows [Table 4] shows.

Table 4. Each stage typical data of the original product life cycle

Product Lifecycle	Serial number	Q/ (ten thousand station/ month)	P/ (ten thousand station /station)	C/ (ten thousand station /station)	G/ (ten thousand station /station)
Investment period	1	0.5	3 200	400	90
	2	0.55	3 200	390	93
	3	0.62	3 180	388	94
	4	0.79	3 160	380	95
	5	0.94	3 157	390	94
Growth period	1	3.3	3 055	320	132
	2	3.4	3 055	320	131
	3	3.5	3 050	302	141
	4	3.5	3 045	290	139

	5	3.7	3 040	290	140
Maturity	1	5.1	2 780	238	155
	2	5.3	2 782	245	155
	3	5.5	2 800	238	160
	4	5.5	2 798	240	158
	5	5.4	2 800	235	162
Recession	1	2.7	2 850	200	116
	2	2.7	2 845	202	121
	3	2.8	2 853	198	120
	4	2.7	2 852	198	119
	5	2.8	2 854	200	121

The sales volume, production cost, sales cost, and profit of the existing products in a period are shown in [Table 5].

Table 5. Each stage typical data of the existing product life cycle

Serial number	Q/ (ten thousand station/ month)	P/ (yuan /station)	C/ (yuan /station)	G/ (yuan /station)
1	2.2	2 875	330	108
2	2.4	2 880	325	110
3	2.7	2 870	330	114
4	2.9	2 870	333	112
5	2.9	2 869	335	109

Select v1 = 1:10 v2 = 1:00 v3 = 1:05 v4 = 1:05, Using the aforementioned matching method to calculate, the matching degree between the existing product and the original product at each stage of the life cycle can be obtained as MAT (1) = 0:78MAT (2) = 0:81 MAT (3) = 0:65 MAT (4) = 0:76. Therefore, the existing products belong to the growth period and are adjacent to the investment period. The promotion decision should be based on the growth period model, and at the same time, the investment period characteristics should be used to assist the decision-making.

Suppose that the promotion methods and investment funds of the original products stored in the knowledge base during the typical periods of the full life cycle are shown in [Table 6].

Table 6. Promotion decision of original product

Product Lifecycle	Advertising	Public Relations	Personnel sales	Sales promotion
Investment period	1 000	200	0	100
Growth period	800	100	0	300
Maturity	300	0	50	900
Recession	0	0	30	700

Using the formula (4), the existing product promotion decision can be obtained by calculation as

$$DCI(x) = \left(1 - \frac{1}{2} \times \left(\frac{0.81 - 0.78}{0.81 - 0.65}\right)\right) \times DCI(u_{max}) + \frac{1}{2} \times \left(\frac{0.81 - 0.78}{0.81 - 0.65}\right) \times DCI(u_{secmax})$$

$$= 0.91DCI(u_{max}) + 0.09 \times DCI(u_{secmax})$$

Therefore, the existing product promotion should be based on advertising investment of 8.18-million-yuan, public relations promotion of 1.09 million yuan, and sales promotion of 2.82 million yuan.

4. Conclusion

This paper proposes a product life cycle matching method, which matches the existing product data with the original product in the knowledge base to obtain the life cycle stage of the existing product. It can make full use of the existing product life cycle characteristic data in the knowledge base, reducing the matching time and the amount of data required for matching. After the matching is completed and the data knowledge of the life cycle stage is obtained, the promotion data knowledge of the original product stored in the knowledge base can be used to quickly obtain the promotion decision that the existing product should take. Since the realization of new product decision-making needs to rely on the knowledge or database of the enterprise's original product, the method in this paper requires the enterprise to have a relatively complete knowledge base to be able to make more accurate decisions. This method is not only suitable for promotion decision-making but can also be applied to other aspects of production management. In future research work, we can consider optimizing the method and applying it to other decision-making problems.

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