ORIGINAL ARTICLE



A study on the method to visualize the product development cycle by predicting patent applications for each product

Estudio sobre el método para visualizar el ciclo de desarrollo de productos mediante la predicción de solicitudes de patentes para cada producto

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ABSTRACT

Knowing the growth process of a company's business and products is a valuable insight for innovation. While launching the first product is a prerequisite for innovation, the process after the launch of the first product is equally important. In many cases, a business is finally established after several generations of product launches. In this study, we show a method to visualize the product development cycle of each generation by predicting the transition of the number of patent applications for each product. Furthermore, as part of the discussion, we apply this method to Seiko Epson projector products and demonstrate that our results were valid. We observed that Seiko Epson repeats the product development cycle in the growth process of its projector business and products. Based on the findings, we discuss the method's applicability to the analysis of a company's business and product growth.

Keywords: Product Development Cycle; Inverse Problem Analysis; Projector.

RESUMEN

Conocer el proceso de crecimiento del negocio y los productos de una empresa es una valiosa información para la innovación. Si bien el lanzamiento del primer producto es un requisito previo para la innovación, el proceso posterior al lanzamiento del primer producto es igualmente importante. En muchos casos, una empresa se establece definitivamente tras varias generaciones de lanzamientos de productos. En este estudio, mostramos un método para visualizar el ciclo de desarrollo de productos de cada generación mediante la predicción de la transición del número de solicitudes de patentes para cada producto. Además, como discusión, aplicamos este método a los productos proyectores de Seiko Epson y demostramos que los resultados son válidos. Visualizamos que Seiko Epson repite el ciclo de desarrollo de productos en el proceso de crecimiento de su negocio de proyectores y productos. Basándonos en los resultados, discutimos la aplicabilidad del método al análisis del crecimiento del negocio y de los productos de una empresa.

Palabras Clave: Ciclo de Desarrollo de Productos; Análisis Inverso de Problemas; Proyector.

INTRODUCTION

Previous studies have shown that it is important to repeat the innovation process in order to grow a business and product.^(1,2,3,4) Itami et al.⁽¹⁾ argued that it is critical for product growth to refine the functionality and performance of the first product by responding to customers' unreasonable demands and then to launch the second and third products.

© Este es un artículo en acceso abierto, distribuido bajo los términos de una licencia Creative Commons (https://creativecommons.org/ licenses/by/4.0) que permite el uso, distribución y reproducción en cualquier medio siempre que la obra original sea correctamente citada According to Fujiyama and Haruyama et al.⁽³⁾ the most important aspects of business development are framing the innovation process and conducting interviews. They describe each factor and how it is applied in the aforementioned innovation process at each stage of introduction, growth, and maturity. Products and businesses are suggested to grow through an iterative innovation process. However, many of the previous studies used interviews and other methods that limited the number of companies that could be surveyed.

On the other hand, since patents are published worldwide, they contain information on products, technologies, and markets, and can be quantitatively analyzed. Moreover, there have been many previous studies on innovation based on patent searches. Suzuki et al.⁽⁵⁾ identified the core technology of a certain product and analyzed the transition of technology by searching patents, and they showed that the trends of business sales and the number of patents were similar However, because patents do not contain information about specific products, extracting patents relating to specific products is difficult.

In this study, we present a method for visualizing the product development cycle of each product by predicting the transition of the number of patent applications for each product.

We also apply the method to Seiko Epson projector products to verify the method's validity and demonstrate that Seiko Epson repeats the product development cycle as its projector business and products grow. Based on our findings, we discuss the method's applicability to the analysis of a company's business and product growth.

METHODS

Patents are applied for during the product development process. Immediately after the start of product development, patents are applied for during the process of revealing the technical configuration. In the early stages of development, patent applications for product innovations tend to increase first, followed by those for process innovations.^(5,6)

Shortly before the time of product launch, the technical configuration of the product and process are determined. Therefore, it can be predicted that the number of patent applications will increase immediately after the start of product development and decrease as the product launch date approaches. Based on this idea, we developed a method to separate the number of patent applications for each product.

The following (1), (2), and (3) are the outlines of the method: (1) Classify product groups according to the degree of changes from the previous product. (2) For the same product group, the period and waveform of the predicted number of patent applications are the same, however, the amplitude of the wave is different for each product. (3) From the actual number of patent applications, an inverse problem analysis is performed to satisfy conditions (1) and (2), and the predicted number of patent applications for each product is derived.

Specifically, each product is divided into two groups: product group A, which has a large degree of change from the previous product, and product group B, which has a small degree of change from the previous product. The development period is longer for product group A than for product group B. The first product is in product group A. Table 1 shows the parameters of each product group. The basic waveforms of the predicted number of patent applications for each product group are pa(n, l) and pb(n, l). Since the amount of development resources varies by product, *kai* and *kbj* are multiplied by pa(n, l) and pb(n, l), and $kai^*Pa(n, l)$ and $kbj^*Pb(n, l)$ are the predicted number of patent applications for each product for each product. The total predicted number of patent applications can be expressed as in equation 1. From the actual number of patent applications *P2* (*l*), *P1* (*l*) in equation 1. is derived by an inverse problem analysis.

$$P_{1(l)} = \sum_{i=1}^{u_1} k_{a^i} \cdot P_a(n,l) + \sum_{j=1}^{\mu_1} k_{b^j} \cdot P_b(n,l)$$
(1)

Table 1. Parameters of each product group				
Development period of product group A and product group B (years)	ma, mb			
Years of development for each product (years)	n			
Years elapsed since the start of the first product development (years)	l			
Projected number of patent applications for product group A	kai*pa (n, l)			
Projected number of patent applications for product group B	kbj*pb (n, l)			
Coefficients to be set for each product in product group A and product group B	kai, kbj			
Basic waveforms of predicted number of patents in product group A and product group B	pa (n, l), pb (n, l)			
Number of each product in product group A and product group B	i, j			
Number of product types in product group A and product group B	oa,ob			
Predicted number of patent applications in year l	P1(l)			
Actual number of patent applications in year l	P2 (l)			

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Case study analysis on Seiko Epson's projectors

Using the above methodology, we analyse Seiko Epson, the world's largest projector manufacturer. Since the launch of its first product, the VPJ-700, Seiko Epson has expanded its business to achieve the world's No. 1 market share in the number of projectors with 500 lumens or more for 19 consecutive years, with cumulative global sales of 30 million units.⁽⁷⁾ The verification and discussion of this method requires accurate information on product launch dates, specifications and development status, and the analysis is limited to the period when such information was available in the literature. Table 2 shows Seiko Epson's released models and main specifications for the 16 years from the first product launch.^(8,9,10,11,12,13) Here, product groups are divided using the degree of specification change from the previous product as an indicator. For specifications indicated by quantitative values, the value of the specification of the previous product is Spb and the degree of change in specification is R, as shown in equation 2. In the case of a specification with desirable characteristics, the degree of change R is shown in equation 3.

$$R = Sp_{a/}Sp_{b} - 1$$
(2)

In the case of a specification of a desirable small characteristic, the modification degree R is shown in equation 2.

$$R = Sp_{b} / Sp_{a} - 1$$
(3)

For specifications with large desirable characteristics, R = 1 when the value of the specification is doubled; for specifications with small desirable characteristics, R = 1 when the value of the specification is halved. R=1when an item related to the interface changes, and R = 0 when there is no change. Products with an average value of R more than 0,5 are in product group A, and products with an average value of R less than 0,5 are in product group B.

Table 2. Seiko Epson Projector Product Trends

Years since the development start	5	5	7	10	10
Model name	VPJ-700	VPJ-1000	VPJ-2000	ELP-3000	ELP-3500
target	Personal	Personal	Personal	Corporate	Corporate
Number of pixels	70,4K	211,2K	211,2K	307,2K	307,2K
Size Volume(mm3)	13965K	-	22988K	17538K	14267K
Mass (kg)	7,6	-	10,8	7,7	6,7
Brightness (lm)	100	-	70	250	650
Uniformity (%)	30	30	30	70	85
Video Connection	NTSC	NTSC	NTSC	Automatic	Automatic
Power Supply	100V	100V	100V	Universal power supply	Universal power supply
Product price (yen)	480,000	980,000	880,000	898,000	698,000
Mean rate of change	-	0,30	0,02	0,96	0,33
Years since the development start	12	14	15	15	16
Model name	ELP-5100	ELP-7300	ELP-7500	ELP-8000	ELP-500
target	Corporate	Corporate	Corporate	Corporate	Corporate
Number of pixels	480K	786,4K	786,4K	786,4K	480K
Size Volume (mm3)	11284K	12600K	6911K	17326K	4095K
Mass (kg)	7,6	6,2	4,2	8,3	2,6
Brightness (lm)	450	1000	800	2200	800
Uniformity (%)	30	30	30	70	85
Video Connection	Automatic	Automatic	Automatic	Automatic	Automatic
Power Supply	UC	UC	UC	UC	Universal power supply
Product price (yen)	898,000	1,500,00	-	-	-
Mean rate of change	-0,04	0,19	0,09	0,18	0,28

The first product, the VPJ-700, and the ELP-3000, which had an average change ratio of 0,5 or higher, are in Product Group A. All other products are in Product Group B because the average change ratio was less than 0,5. Based on information obtained from interviews with projector developers, the development period for product group A was set at five years, and the development period for product group B mb was set at three years. According to Table 2, we performed an inverse problem analysis, thus the predicted number of patent applications for each year approached the actual number of patent applications. Figure 1 shows the predicted number of patent applications and the actual number of patent applications obtained from this analysis. The actual number of patent applications and the predicted number of patent applications are in good agreement and the correlation coefficient between them is 0,99. In this case, the correlation coefficient C was calculated in accordance with formula 4.

$$C = S_{ab} / S_a^{\times} S_b$$
(4)

Where Sab is the covariance of kbj * pb (n, l) and kbj * pb (n, l), and Sa is the standard deviation of kaj and pa (n, l), Sb is the standard deviation of kbj and pb (n, l).



Figure 1. Seiko Epson's actual and predicted number of patent applications

Figure 2. Predicted number of patent applications for each generation of products



Years since the development start

Figure 2 plots the predicted number of patent applications for each product in each year. We were able to separate the number of patent applications by each product: the first and third cycles belong to product group A, while the rest belong to product group B. Within each product group, the same cycles and waveforms are used. For all waveforms, the predicted number of patent applications increased at the start of development and decreased before the product was sold.

DISCUSSION

Seiko Epson's projector product transition and market reaction

The first cycle VPJ-700 and the second cycle VPJ-2000 were received negative feedback from the market

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and was not sold well. However, the third cycle ELP-3000 became an explosive hit, and since then Seiko Epson has increased its market share by introducing new products one after another every year. Since one of the key points of growth for Seiko Epson's projector business was the period leading up to the sale of the ELP-3000, Table 4 summarizes the product concept and market response up to that point. As shown in Table 4, the product concepts of both the VPJ-700 and VPJ-2000 did not meet the market demand. Seiko Epson learned from the market response to its first two product cycles and transformed its projector products from "dark" to "bright" and from "personal" to "corporate". This made the ELP-3000 an explosive success.⁽⁶⁾

Table 4. Main product concepts and market reactions before the ELP-3000 was marketed				
Product	Product concept	Market reaction		
1st cycle	The world's first personal projector for home theater	Purchasers are mainly corporations.		
VPJ-700	applications.	Dark and poor image quality.		
2nd cycle	Descend projector that embedies "heautiful white"	Purchasers are mainly corporations.		
VPJ-2000	Personal projector that embodies beautiful write .	Dark image quality.		
3rd cycle	Compared and bright and instant for compared	An explosive hit.		
VPJ-3000	compact and bright projector for corporate.			

Discussion about the peak number of patent applications for each product

The peak number of patent applications in the first cycle is about 20, which is about 1/30 of the maximum number of patent applications for Seiko Epson projectors per year.

The peak number of predicted patent applications in the second cycle is higher than that in the first cycle. This can be explained by the fact that the Video Equipment Division was established at the beginning of the second development cycle and the development organization was strengthened. The peak in the predicted number of patent applications for the third cycle is lower than that for the second cycle. This can be explained by the fact that the failure of the second cycle led to a significant reduction in development resources. From the fourth cycle onwards, the predicted number of patent applications increases from year to year, which may be due to the increase in personnel for business expansion as a result of the success of the third cycle.⁽⁸⁾

Thus, the increase and decrease in the peak number of predicted patent applications for each product can be explained by the actual development situation.

Incidentally, after the third cycle, business of Seiko Epson's projectors is moving from the introduction stage to the growth stage.

Discussion for the validity of this method

Limited to the Seiko Epson projector case, we were able to verify the validity of the results obtained by this method because of the following three points.

(1) The total predicted number of patent applications, which is the sum of the predicted number of patent applications for each product, showed a positive correlation with the actual number of patent applications with a correlation coefficient of 0,99.

(2) For both product groups A and B, the predicted number of patent applications increases in the early stages of development and decreases as product sales approach, showing an upward convex shape. This is consistent with our hypothesis.

(3) The increase and decrease in the peak in the predicted number of patent applications for each product can be explained by the actual development situation.

However, in order to use this method, at least the following conditions are required.

- Sufficient patents must be applied for during product development.
- A product must have been commercialized, not just researched and developed.

CONCLUSION

We showed the method to visualize the product development cycle by predicting the number of patent applications for each product using an inverse problem analysis. Limited to the Seiko Epson projector case, we were able to verify the validity of the results. The analysis using this method showed that Seiko Epson has been repeating the product development cycle in the process of growth of its projector business and products. We also found that Seiko Epson, which is currently the world's largest manufacturer of projectors, runs a small product development cycle for its first product. By using this method, the following analysis may be possible for other companies and products.

• It may be shown that repeating the product development cycle is one way to achieve business and product growth.

• It may be analyzed that trends related to development investment for each generation of products. However, the method in this study is limited to one company and one product and it has not been confirmed whether it is applicable to other companies and products. In addition, there are many cases that sufficient patents are not applied for during product development and a product are not commercialized. In such cases, it is difficult to apply this methodology as it is.

In the future, we will verify whether this method can be applied to other manufacturers and products.

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CONFLICTS OF INTEREST

None.

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None.

AUTHORSHIP CONTRIBUTION

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