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Inter-Element Relations in the Configured Systems: Second Dimension of the System Complexity from the Case Study of the Japan's ANIME Industry

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ABSTRACT

The inter-element relations in a configured system are defined as the second dimension of system complexity. This conceptualization is validated by applying the matrix theory associated with axiomatic design and by comparing two different animation manufacturing systems in Japan's anime industry: the cel-anime and the CG-anime. The inter-element relations in the configured diagonal matrixes in CG-anime help in reducing system complexity because of the independent relations among the six elements. On the contrary, the inter-element relations in the configured full matrixes in cel-anime lead to an increase in the complexity. This study shows that the complexity of anime content manufacturing systems can be reduced by focusing on the inter-element relations in the system.

KEYWORDS: anime; system complexity; inter-element relations; full matrix; diagonal matrix.

1. INTRODUCTION

This paper is to conceptualize the inter-element relations in a configured system as the second dimension of system complexity. In this paper, the manufacturing processes of animation content are described as a system with complex inter-work relations. The complexity in this system is determined by the "relation" between the elements composing the system and "the level of difficulty" associated with each element.

The critical elements of an animation manufacturing system are observed at the manufacturing site as the following six; "teams (or roles)" to be involved in a development of animation content, various "activities," "artifacts (specification and so on)," "components" where design issues are implemented, "functions" of the components, and "requirements" for executing the functions.

2. PROBLEM

2.1 Obsolete Work Processes

Currently, the animation industry in Japan is at the crossroads for its competitiveness and it strives to focus on strategies for improving the efficiency, i.e. promoting the usage of computer animation, for augmented efficiency of coloration. This attempt is not new. For example, the original Japanese "omission technique", aka the limited animation was invented as one way to reduce the manufacturing costs for animation. Adding to these methods, in order to improve the work efficiency by reducing the complexity of the manufacturing sites, approaches that take into consideration the difficulty associated with the components have been proposed.

However, very few of these approaches consider inter-element relations. The traditional celluloid-template-based animation (cel-anime) manufacturing, in which a given team makes up an artifact by carrying out all processes in a cooperative manner remains unchanged. This method is thought the best among all the presently available methods in Japan.

Nonetheless, currently celluloid templates are rarely used for animation content manufacturing because celluloid production has been discontinued; however, the basic process that a lot of pictures are drawn to set in move has not been changed.

While computers are frequently being used for drawing in the cel-anime, there is no substantial change in the role of the animation process and the obtained products. Production companies employ specific approaches, which include methods of specialization of each process in animation development or methods of dividing the work among various teams or entrusting the responsibility of the entire process to each team.

The problem is that even though the cel-anime industry in Japan strives to augment efficiency by intensive co-operations in the manufacturing system it is widely observed degraded efficiency appears consequently. Lamarre [1] attributed this 'paradox' to the imposed hierarchy and close co-operation network in a guild association for cel-anime manufacturing.

2.2 Previous Studies

The anime is one of major contents industry of Japan which represents the Cool Japan, the cultural value of that country (Ingulsrud and Allen [2]). Accordingly Napier [3] pointed out that the Japanese anime tended to be understood in the context of the 'Techno-Orientalism'.

Previous studies generally treat the manufacturing methods of the Japanese anime as inseparable from the sophisticated expressions and cultural values (e.g. Ueno [4]). This perspective sometimes goes too far to refer to elements of the weirdness of the Japan's popular culture in the visual device industry including the game-software industry (Wezorek [5]). However, there have been few studies focused upon the manufacturing efficiency with systems approach on the Japanese anime industry.

3. TWO CONTRASTIVE SYSTEMS

3.1 Two anime manufacturing models

There are two contrastive animation manufacturing systems: one is the celluloid-template-based manufacturing system, aka cel-anime, which is the major system in Japan; and another is the CG manufacturing system, aka CG-anime, which is emerging as the major system in Hollywood.

Three are another dichotomy from the expression methods of anime; the full anime and the limited anime. Fig. 1 shows the mapping of different styles of anime manufacturing of Japan and the United States in comparative way.

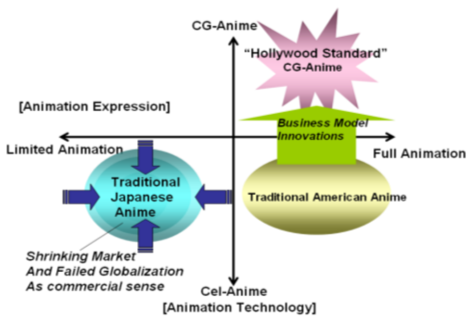

Fig.1. Mapping of Two Anime Models.

The Japanese anime market is shrinking. And the cel-anime industry allegedly failed to be commercially globalized. Fig.2 describes the stagnant sales in the domestic market of the cel-anime. On the contrary, the so-called Hollywood standard CG-anime contents companies constantly expand their sales globally (Price [6]).

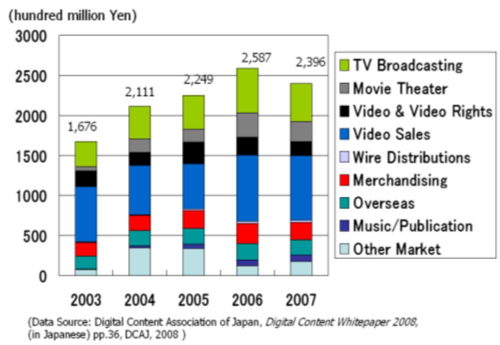

Fig.2. Stagnant Amine Market of Japan.

3.2 Matrix Verifications

Our objective is to study the theory of ideal content manufacturing system by a comparative verification of these two methods with systems-approach and matrix method; the cel-anime and the CG-anime.

3.2.1 Cel-Anime Manufacturing System

The cel-anime manufacturing system and its work-flows are ostensibly simple and single-lined. Fig.3 shows the work-flows of the TV cel-anime manufacturing system.

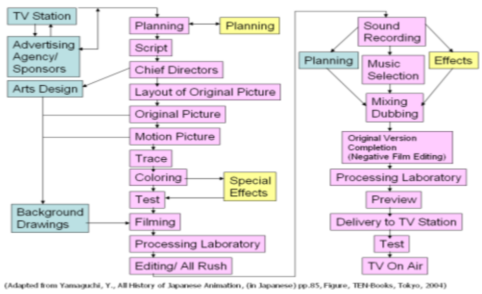

Fig.3 TV Cel-Anime Manufacturing System.

The cel-anime manufacturing system is united through processes in most cases, and one team takes charge of several processes all together regardless of its original specialty, although this system varies among different manufacturing companies. First, the team that is assigned the task of drawing original pictures creates original drawings, and subsequently, the same team that is assigned the task of producing moving images develops animation. Then, the completed celluloid templates are colored and finally filmed. The filming process is executed as a single piece of work, wherein individual scenes in the film are edited and subsequently connected. A specialized team takes the responsibility of carrying out each task. The relations between individual elements in the manufacturing process are represented in the Fig.4.

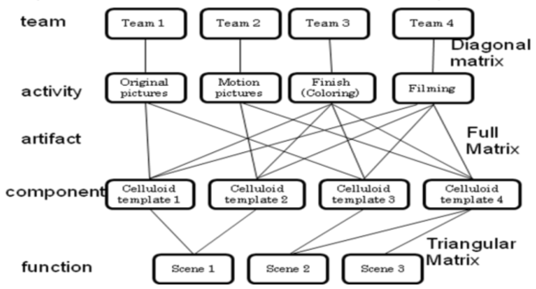

Fig.4 Inter-element Relations of Cel-Anime System.

The cel-anime manufacturing system is observed to be based on complex inter-element relations. The relations between the work teams and the scenes can be consequentially represented as n:m. Further, it is shown that the creation of a scene requires accurate control of various elements.

These complex relations between the teams and their activities can be expressed by the following matrix and vector.

$$\overrightarrow{activity} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \times \overrightarrow{team} \qquad (1)$$

Thus, the entire cel-anime manufacturing system can be organized as follows by using determinants.

$$N = \begin{pmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \times \begin{pmatrix} 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 \end{pmatrix} \times \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad (2)$$

$$= \begin{pmatrix} 1 & 1 & 2 & 2 \\ 1 & 1 & 2 & 2 \\ 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \qquad \overrightarrow{function} = N \times \overrightarrow{team}$$

3.2.2 CG-Anime Manufacturing System

The CG-anime manufacturing system is a specialized system in which individual teams that carry out different sub-processes involved in the overall manufacturing process. Fig. 5 is the work processes of the CG-anime manufacturing system based upon authors' interview conducted on December 28, 2009 with the CG-anime artists and manufacturers.

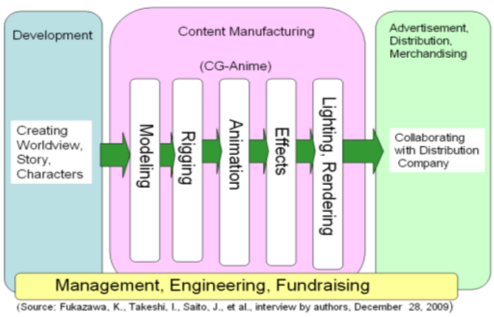

Fig.5 CG-Anime Manufacturing System.

The manufacturing processes trail several flows from modeling, to rigging, to animation, to effects, to lighting and rendering. Because of the computerized and systemic features these flows look ostensibly perplexed.

The abovementioned tasks are supposed to be carried out on each object. Fig.6 shows the organization of the relations between individual elements that comprise the CG-anime manufacturing system.

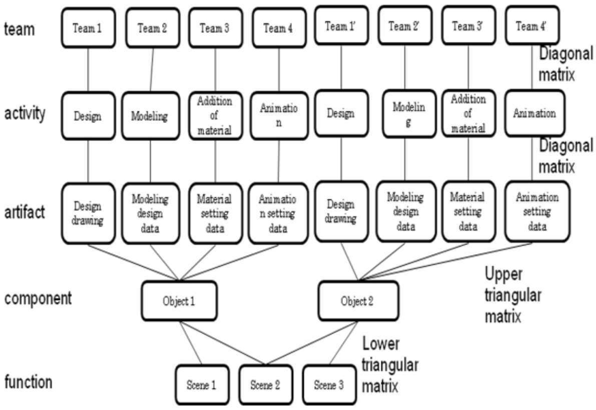

Fig.6 Inter-element Relations of CG-Anime System.

Nonetheless, unlike the cel-anime system, the relations between the work teams and the scenes can be considered as 1:n, and the elements that influence a certain scene can be traced.

$$M = \begin{pmatrix} 1&0&0&0&0&0&0&0\\ 1&1&0&0&0&0&0&0\\ 0&1&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0 \end{pmatrix} \times \begin{pmatrix} 1&1&1&1&0&0&0&0\\ 0&0&0&0&1&1&1&1\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0 \end{pmatrix} \times \begin{pmatrix} 1&0&0&0&0&0&0&0\\ 0&1&0&0&0&0&0&0\\ 0&0&1&0&0&0&0&0\\ 0&0&0&1&0&0&0&0\\ 0&0&0&0&1&0&0&0\\ 0&0&0&0&0&1&0&0\\ 0&0&0&0&0&0&1&0\\ 0&0&0&0&0&0&0&1 \end{pmatrix} \times \begin{pmatrix} 1&0&0&0&0&0&0&0\\ 0&1&0&0&0&0&0&0\\ 0&0&1&0&0&0&0&0\\ 0&0&0&1&0&0&0&0\\ 0&0&0&0&1&0&0&0\\ 0&0&0&0&0&1&0&0\\ 0&0&0&0&0&0&1&0\\ 0&0&0&0&0&0&0&1 \end{pmatrix}$$

$$= \begin{pmatrix} 1&1&1&1&0&0&0&0\\ 1&1&1&1&1&1&1&1\\ 0&0&0&0&1&1&1&1\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0 \end{pmatrix} \qquad \overrightarrow{function} = M \times \overrightarrow{team} \tag{3}$$

This relation can be expressed in the form of a determinant, as mentioned earlier in the text.

3.3 Analysis using matrix models

As described above, the relations between the work teams and the scenes are n:m for the cel-anime system and nearly 1:n for the CG-anime system. The relations can be expressed as above matrix calculation when replaced with matrix.

When establishing relations between the elements comprising the manufacturing system, each element is shown by a full matrix in the system for the cel-anime. Moreover, In the CG-anime system, the relations between individual elements are expressed by means of a diagonal matrix.

In a word, CG-anime can be considered a system in which the interdependency between the tasks is weak; this is because in contrast to the cel-anime, in which the elements are complexly intertwined, the elements in CG-anime are independent of each other.

Then we ask how the complexity changes in a diagonal matrix or a full matrix. The relation between interdependency, difficulty, and complexity is discussed on the basis of the nature and size of the matrices.

Definition of complexity (4)

Complexity is defined as follows.

Complexity ＝ difficulty × interdependency

The matrices for each manufacturing system are defined as follows:

Cel-anime matrix
= a full matrix with N columns (n × n)

CG-anime matrix
= a diagonal matrix with M columns (m × m).

From the definition of complexity, it becomes plausible that even if the difficulty is constant, the overall complexity of the system can be reduced if the interdependency decreases. In other words, the difficulty of elements can be counterbalanced by decreasing interdependency between elements. Therefore, it is important not only to decrease the difficulty of elements but also to decrease the interdependency between elements for reducing the complexity of the system.

The overall complexity of the system also depends on the number of elements: the more elements exist in the system, the more complexity the system may entail.

3.3.1 Basic Concept of the Matrix Model for the System Complexity

This subsection is to explain the inter-element relations and determine the complexity from the system matrix and each constituent matrix.

3.3.1.1 Eight Elements

Eight elements; needs, feature, requirements, functions, components, artifacts, activities, and teams are extracted as the constituents of a system.

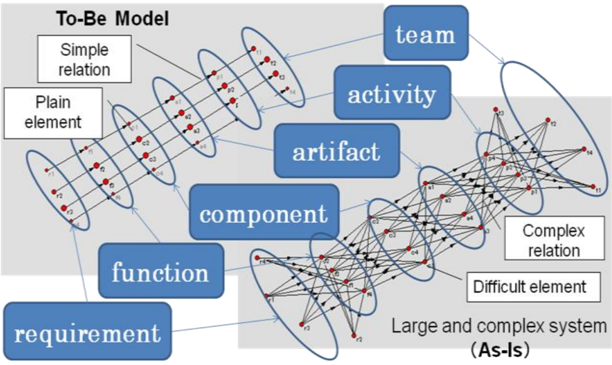

Fig.7 Network Associations; To-Be & As-Is

The requirements for a manufacturing system are defined by first understanding the needs and then organizing them as features. Next, we explain the function design to meet the requirements. It is necessary to identify the components of the functions for meeting the aforementioned requirements; in addition, it is imperative to create artifacts to organize the design content and determine the function components. Each team in the system carries out the necessary activities to create artifacts.

We have designed a model that simulates a situation in which design information is exchanged smoothly among all elements, which is shown as network association models in Fig.7. The elements are mutually independent, and multiple elements are never intertwined (Fig.7-Left; To-Be Model), as shown in this figure (needs and features are the same but explanations is abbreviated in this subsection), when the inter-element relations are simple. In such a case, the design information is reflected to each and every element and curved as long as the difficulty associated with each element is not high. However, each element intertwines complexly and varies in difficulty (Fig.7-Right; As-Is Model) in many of the present large-scale systems. Therefore, the design information is not adequately reflected to each component, and the manufacturing quality and the quality of each artifact become lesser than those when the components are mutually independent.

This idea is identical to the design theory "axiomatic design" by Nam [7] in the field of mechanical engineering.

3.3.1.2 Transforming into the Matrix model

Quantitative analysis can be carried out by organizing the inter-element relations into a network association chart, as is shown below, and by expressing the relations with the help of a matrix (Fig.8).

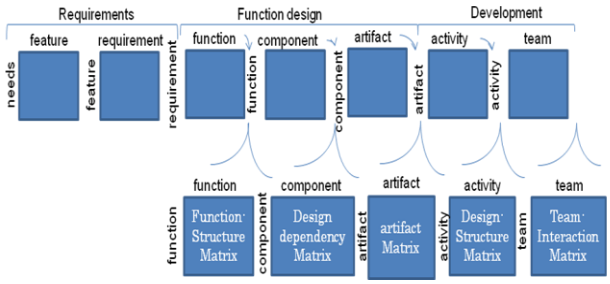

Fig.8 Network Diagram to Matrix

The relations between the elements needs, features, requirements, functions, components, artifacts, activities, and teams are expressed by matrices. The relations in the overall system are established by inserting a matrix that shows a relation among same elements between the main matrices; this matrix can act as a document that manages artifacts in identical components (five matrices at the bottom of Fig.8).

3.3.2 Matrix analysis

Each case is analyzed as follows. We attempt to analyze the relation between difficulty, interdependency, and complexity on the basis of the following simplified model in order to understand the characteristics, although a higher-order matrix should be employed because at least 50 people join the manufacturing process at an actual site.

Assuming n and m to be the orders of full matrix A and diagonal matrix B, respectively, we examine the complexity characteristics for A and B; complexity is represented as the product of difficulty and interdependency in each case. Here, the difficulty of A and B is defined as a norm of A and B; the interdependency is defined as a norm of the distance between A and E and that between B and E, respectively.

The cel-anime manufacturing system is considered first.

A diagonal matrix and a full 3 × 3 matrix (E = a unit matrix) (5)

Assuming a full matrix $N = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$,

The interdependency (N_i) can be written as

$$N_i = \|N - E\| = \left\| \begin{pmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{pmatrix} \right\| = \sqrt{6}.$$

The difficulty (N_d) is expressed as

$$N_d = \|N\| = \left\| \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} \right\| = \sqrt{9} = 3,$$

And the complexity (N_c) is expressed as below:
$N_c = N_i \times N_d = 3\sqrt{6} \risingdotseq$ <u>7.35</u>

Next, we describe matrix M (a case of a system for CG-ANIME), which is not a full matrix.

When a = 1 (a non-diagonal element is equal to 1) (6)

By assuming $M = \begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$,

the interdependency (M_i) and difficulty (M_d) can be expressed as follows, similar to the calculation.
$M_i = 1$,
$M_d = 2$.
Therefore, the complexity (M_c) = 2.

When a = 2 (two non-diagonal elements are equal to 1) (7)

When assuming $M = \begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{pmatrix}$, with similar calculations.
$M_i = \sqrt{2}$,
$M_d = \sqrt{5}$, and therefore, $M_c = \sqrt{10} \risingdotseq 3.16$.

When a = 3 (three non-diagonal elements are equal to 1) (8)

$$M = \begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \\ 0 & 1 & 1 \end{pmatrix},$$

$M_i = \sqrt{3}$,
$M_d = \sqrt{6}$, and
Therefore, $M_c = 3\sqrt{2} \risingdotseq 4.24$.

It is understood that full matrices (the matrix for the cel-anime) always have higher complexities than does the matrix for the CG-anime, as mentioned above.

3.3.3 Discussion

3.3.3.1 Characteristics according to the type and order (n,m) of matrices

It is possible to express the matrix model described above by further generalization of the idea (however, the elements values of the matrices are assumed to be either 0 or 1). (9)

$N_i = \sqrt{n(n-1)}$, $N_d = n \quad \Rightarrow \quad N_c = n\sqrt{n(n-1)}$.

$M_i = \sqrt{a}$, $M_d = \sqrt{m+a} \quad \Rightarrow \quad M_c = \sqrt{a(m+a)}$.

Therefore, the condition for $N_c = M_c$ is

$$m = \frac{1}{a}n^4 - \frac{1}{a}n^3 - a,$$

(m, n, and a are integers that are greater than or equal to 1)

Thus, the relation Nc < Mc holds in the upper area of the graph, while the relation Nc > Mc holds in the lower area of the graph.

When a ≠ 0, n and m are assumed to be integers of one or more (at a = 0, complexity is assumed to be equal to difficulty and the elements values of the matrix are assumed to be 0 or 1). The abovementioned results of equations are graphed in Fig. 9.

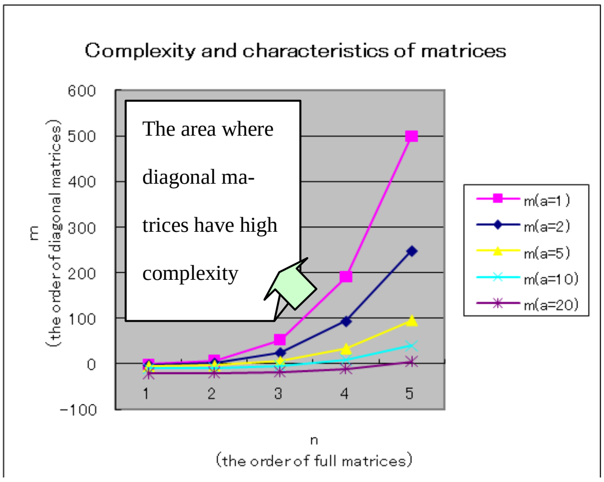

Fig.9 Results: Complexity and Matrix

Values in the Fig.9 are as shown in the Table 1 (shadowed cells indicate that events do not occur for these values).

Table 1. Values of Fig.9.

N	m(a = 1)	m(a = 2)	m(a = 5)	m(a = 10)	m(a = 20)
1	–1	–2	–5	–10	–20
2	7	2	–3.4	–9.2	–19.6
3	53	25	5.8	–4.6	–17.3
4	191	94	33.4	9.2	–10.4
5	499	248	95	40	5

Fig.9 and Table 1 are explained as follows. For instance, when the order (n) of a full matrix (cel-anime) is 3 (a 3 × 3 matrix), a diagonal matrix (CG-anime) with equal complexity will be a 53 × 53 matrix if a = 1 and a 25 × 25 matrix if a = 2. Moreover, the work done by 499 people (a = 1) in the diagonal matrix (CG-anime) can be interpreted to be as complex as a cooperative task executed by five people in the full matrix (cel-anime).

Thus, the complexity of full matrix A becomes lower than that of diagonal matrix B, and the relation $A_C < B_C$ holds in the area where "$m > n^4/a - n^3/a - a$" holds when a is assumed to be a non-diagonal matrix element whose value is other than 0. However, the relation $A_C < B_C$ may not hold, as opposed to the case of manufacturing systems with the same scale, as can be seen from the table above. For example, in development project by new technologies that have not been used yet, the total complexity is assumed to be high because both difficulty and interdependency are high in this case.

Therefore, it can be said that work in a specialization system is generally less complex, easy to manage, and efficient.

3.3.3.2 Difference in the manufacturing system configuration

The cel-anime is composed only of teams, activities, components, and functions. On the other hand, the CG-anime is composed of five elements: teams, activities, artifacts, components, and functions.

This difference matters. Pictures are designed in the CG-anime but drawn in the cel-anime. Drawings are created by digitalization and rendering. As a result, although drawing pictures is thought to be a talent (creation), it can be generalized by adopting a design process.

Moreover, although the cel-anime comprises only a few kinds of elements and appears to be simple, it is actually very complex. This is clear also from the fact that the result of multiplying three kinds of matrices is a full matrix. The cel-anime is ostensibly thought to be simple because independent elements are treated, regardless of the inter-element relations.

3.3.3.3 Tendency of content development to become a large-scale process

The CG-anime is simple in most cases, as shown in chapter 3.3.1, and is consequentially more efficient. The only exception, by the comparison of a large-scale development case with a small-scale development case, is that the cel-anime may be superior only under rare circumstances.

It should be noted that the complexity may be reduced in the cel-anime in certain cases depending on the scale of work and the manufacturing system. For instance, the cel-anime production is superior to the CG-anime production, if the system can be beneficiary of longer manufacturing period and a large number of low-paid workers. Nonetheless, such a manufacturing advantage with long working hours and low-paid workers is observed unsustainable in the Japanese ANIME industry, which has already lost relative advantages of lower wages compared to her Asian competitors. Therefore, the competitive advantage of the Japanese ANIME industry cannot be gained from the manufacturing system with the guild-type and small anime-creators' group going through all manufacturing processes with long working hours.

3.3.4 Addressing the labor cost incurred with employed creators in two systems

It is assumed $y = A_c x$ (A_c is a full matrix) and $y' = B_c x'$ (B_c is a diagonal matrix) because $A_C > B_C$ holds in many cases, as is evident from the situation described in the above subsections.

When assuming units such as y (yen) = Ax (people, months), the matrix A indicates productivity (yen/people, months). In matrices A and B, the relation $A > B$ generally holds, as mentioned above, and hence, the relation $x < x'$ holds when $y = y'$.

In sum, the number of creators who can be engaged in the cel-anime should be lesser than the number of creators in the CG-anime if the manufacturing budget is the same. Further, the labor cost should be lesser in the cel-anime than in the CG-anime when considering this theoretical computation. Therefore, this theoretically leads to the conclusion the difficulty to increase the labor cost associated with creators in the cel-anime to match that in the CG-anime when the scale of manufacture is the same.

4 .CONCLUSION AND FURTHER RESEARCH AGENDA

4.1 Conclusion

The quantitative analysis in this paper showed that the CG-anime manufacturing system, in which the complexity of the system is less and each task can be executed independently, is more efficient than the cel-anime manufacturing system, although the latter's efficiency has been conventionally thought to be the best in Japan. Cost over-runs of anime projects and poor labor conditions of cel-anime creators, which are often heard in Japan, may be resolved by the industrial evolution to the CG-anime. Since the CG-anime can perform better in efficiency through streamlining inter-relations of creators in the matrices of manufacturing tasks.

This conclusion is drawn from the new concept; the second dimension of the systems complexity shown in this paper. Decreasing the interdependency between system-elements reduces the systems complexity and thus improves the system efficiency. This new findings may stimulate managers of Japanese anime projects and drive them adopting the systems-based manufacturing methods embedded in the CG-anime system.

4.2 Further Research Agenda

The further research will be directed toward empirical studies to alleviate complexity and to improve productivity of systems at various industries. The empirical and comparative studies with applying the complexity analysis matrix method used in this study to diverse cases are the center for our further research agenda.

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