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〔Article〕

2DCG for Labour Saving, 3DCG for New Expression:
The Introduction of Computer and Digital Technology to the Japanese Animation Industry

Jun SAKAMOTO

Introduction

The development of computer and digital technology has influenced many industries, and the animation industry is no exception. Not only is digital technology an integral part of today's animation productions, it is still evolving. The use of digital technology in the animation industry began with the question of whether it was possible to streamline the time-consuming and labour-intensive process of drawing each animation by hand, copying it onto cels, and colouring it with help from computers. Such experiments have been carried out since the 1970s by New York Institute of Technology (NYIT), Cornell University, and Peter Foldes. Alongside this pioneering work, systems such as ANTICS (UK, 1972), a 2D animation system, and the Videocel Animation System (USA, 1975) were developed to offer automatic inbetweening and cel painting.(1) In Japan, Toei Animation, the largest Japanese animation studio, began to consider introducing a system of computerised animation production in 1974.(2)

In the 1980s, production companies specialising in computer graphics began to be established in Japan, and the use of 3DCG was seen not only as a help for animation production, but also as a way of enabling new expression that differed from hand-drawn animation. Apart from the use of 2D technology, as mentioned above, the use of 3DCG was shown to be effective in reducing simple works. It was hoped that this would help the Japanese animation industry to move away from being labour-intensive industry and improve the working environment. 3DCG is also used to achieve expressions that are difficult to express with traditional hand-drawn animation, and depictions such as a camera moving in three-dimensions, subjects rotating, natural phenomenon and geometric objects

(1) The system developed at NYIT, called Digital Ink and Paint, was of a practical standard, with computerised drawing and colouring functions, as well as advanced 3D representation and automatic interpolation between key frames to save labour. The results of this work can be seen in "Sun Stone" (1979) and "Works" (1979). Masashi Washitani, "Kontentsu prodeyusu kino no kiban kyoka ni kansuru chosa kenkyu: animeshon seisaku" (Research on strengthening the foundations of the content produce function: animation production), Creek & River, 2004, p. 23.

(2) Takayuki Oguchi, *Kompyuta grafuikkusu no rekishi: 3 DCG to iu imajineshon* (A history of computer graphics: The imagination of 3DCG), Filmart, 2009, pp. 184–187.

have become frequent in animation. Since then, CG animation has developed a hybrid method that mixes cel animation with 3DCG, or a method called "cel look (cel shading)" that realises expression like cel animation even if it is 3DCG, and in recent years, full 3DCG animations have been produced for both film and TV using such methods.(3)

This article focuses on the introduction of computer and digital technology to the Japanese animation industry. It examines the process of technological development, focusing on three companies that actively attempted to introduce new technology from an early stage: Toei Animation, Japan Computer Graphic Lab., and Toyo Links. In particular, this paper explores why these companies introduced computer and digital technology and how these new technologies changed animation production.

1. The introduction of digital technology aimed at supporting animation production

From the mid-1960s onwards, the Japanese animation industry experienced its first animation boom, characterised by a marked increase in the number and length of animations produced. In 1963, when "Testuwan Atomu" (Astro Boy) was first broadcast, 2,625 minutes of TV animation were produced. In 1964, the number jumped to 8,865 minutes (337.7% of the previous year's total); in 1965, due to a significant increase in new TV animations, it reached 14,640 minutes (165.1% of the previous year's total). At that time, as many as ten 30-minute TV animations were broadcast each week. The number of minutes continued to increase, reaching 17,806 minutes in 1966 (121.6% of the previous year's total) and 20,985 minutes in 1967 (123.5% of the previous year's total). These totals surpassed the 20,000-minute mark, recording a growth of 837.5% in just four years since 1963. In addition, the number of new TV animation alone increased significantly, from 2 in 1963 to 4 in 1964, 7 in 1965, 8 in 1966 and 12 in 1967. In 1964, "Testuwan Atomu" recorded the highest television viewership in the history of animation, at 40.3%. Alongside the growth in the number of minutes produced, this was a phenomenon worthy of being called an "animation boom".(4)

The increasing quantity of TV animation led to a shortage of production staff and soaring labour costs in the animation industry. As a result, many animation production

(3) Masami Sano, "Nihon anime no tame no jisedai 3DCG seisakusha ikusei ni kansuru kosatsu: Senkushatachi ga 3DCG ni hikitsukerareta miryoku no kensho kara manabu" (The importance of 3DCG in bringing up the next generation creators for Japanese animation), *Journal of the Japan Information-culture Society*, vol. 13, 2006, p. 83; Jo Ito, "Animeshon to dejitaru gijutsu: Sutoppumoshon to rotosukopu no fukko to hatten" (Animation and digital technology: Reconstruction and development of stop motion animation and rotoscope), *Communication in Culture*, vol. 14, 2020, p. 13.

(4) Hiromichi Masuda, *Dejitaru ga kaeru anime bijinesu* (Digital changes the animation business), NTT Publishing, 2016, p. 15; Hisateru Furuta, "Gorudo rakku no zanei: Animeshon no tairyo yushutsu ni kansuru ichi kosatsu" (Reverberations of Glodorak: The mass exportation of Japanese animation), *The Seijo University Arts and Literature Quarterly*, vol. 204, 2008, pp. 47–49.

companies fell into difficult financial situations. Mushi Production went bankrupt in 1973 and Toei Animation was forced to drastically reduce its workforce. In 1969, Toei Animation had sales of around 900 million yen and an operating profit of approximately 5 million yen; however, due to soaring production costs, Toei Animation also had a loss of around 16 million yen in operating profits on sales of 900 million yen in 1970. In 1971, Toei Animation posted an operating loss close to 127 million yen on sales of 1.2 billion yen; in 1972, the company posted an operating loss of around 153 million yen on sales of 1.4 billion yen. After 1970, production deficits became the norm; from 1971 onwards, 10% sales deficits occurred continuously.(5) In response to this situation, Chiaki Imada, who became the head of Toei Animation in 1974, proposed the introduction of computers as a restructuring measure.(6) The next section examines the introduction of digital technology by Toei Animation, which marked the beginning of such technology in the Japanese animation industry.

1.1. Attempts to introduce digital technology in Toei Animation

Toei Animation launched an internal research group in 1974 and officially established a technical development committee in 1977. Investigations began into ways to computerise animation production. Initial discussions were held with Dainippon Screen, KnacK, and Hitachi. In 1978, the Computer Animation Development Office was set up, led by Jiro Yoshimura of the Cinematography Department. This office held a series of discussions and experiments on system design with various companies and research institutes.(7) In this context, Toei Animation's preferred partner in the 1980s was IBM. However, in 1985, when talks with IBM had progressed to the stage where it was possible to simulate the digitalisation of the production process in concrete terms, it became clear that the estimated costs were too high and the project had to be abandoned.(8) Next, Toei

(5) Hirotaka Ichifuji, "Toeidoga no saiko to Imada Chiaki: 1970 nendai chuban kara 80 nendai shoto no henkaku" (Chiaki Imada and the restoration of Toei Animation: From the mid-70s to the early 80s), *Bulletin of the Graduate School of Education, Hiroshima University*, Part II, vol. 68, 2019, p. 120.

(6) Takeyasu Ichikoji, "Nihon anime sangyo ni okeru joho gijutsu donyu" (The introduction of information technology in the Japanese animation industry), Akámon Management Review, vol. 11, no. 6, 2012, p. 364; Masuda, op. cit., pp. 19–20.

(7) Kanebo Research Institute, Toray, Mitsubishi Rayon, Graphica, Matsushita Research Institute Tokyo, Teijin Advanced, Nippon Univac, Pentel Electronics, Agency of Industrial Science and Technology, Aiden Control, Ampex, Victor Company of Japan, Sumitomo Corporation, IBM, Totsu, NYIT, Cornell University, Kanematsu Corporation, Ikegami Tsushinki, Hitachi, Matsushita Electric, Sharp, Sony, Fuji Photo Film, Toshiba, Yokogawa Electric, and others. Many of these companies only discussed the idea, but Pentel Electronics designed a colour graphic image display in 1980 and experimented with it at Toei Animation. Although it was never applied to animation production, it was used for image processing in TV Asahi's TV programme "Hint de Pinto" (Oguchi, op. cit., p. 187; Masuda, op. cit., p. 20).

(8) The estimated cost of the hardware and software needed to produce 100 anime episodes per year was 3.8 billion yen for both. This figure does not include the cost of script, storyboards, drawings, post recordings, or any other parts of the process. With these costs included, the production cost per episode totalled more than 40 million yen (Masuda, op. cit., pp. 22–23).

Animation conducted joint research with Fujitsu and began to develop CATAS (Computer Aided Toei Animation System), an animation production-support system.[9] This system was intended to use the functions of FIVIS/VWS, Fujitsu's image processing workstation, to process inbetweening, tracing, painting, special effects and filming on a computer. Experiments with this system began in 1989, and by the end of 1991 a 10-minute test film had been completed. However, this system was never put to practical use because the initial cost of 800 million yen could not be agreed, although Toei Animation alone invested 100 million yen in its development. What made CATAS so expensive was the fact that Fujitsu had designed a workstation specifically for CATAS, a very unsuitable specification for mass-produced TV animation. For TV animation, in which a huge number of shots had to be processed efficiently, it was crucial to reduce the cost per system, while increasing the number of systems. The ideal solution was to use several commercially available PCs.[10]

As mentioned above, Toei Animation has been attempting to introduce computer and digital technology into animation production since the 1970s. Initially, the company is said to have had one simple criterion for the introduction of new technology: if it was more cost-effective than the conventional system, it would be introduced; if not, it would not be introduced. The developments discussed above were never used, because the change to a computer-based production method seemed likely to incur far higher production costs than the old method. For this reason, Toei Animation decided to wait for computers and peripherals to become more powerful and less expensive.[11] At the time, the company's development policy did not include computerising the drawing process because Imada, who had proposed introducing computers, believed they could not draw pictures. Therefore, the introduction of digital technology at Toei Animation was focused only on improving the efficiency of the process after drawing key animation.[12]

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(9) The CATAS specification, compiled in 1985, listed the following points as its "basic objectives and conditions": (1) It must be an animation video production system; (2) The system must be capable of producing images on 35mm film; (3) The system should be based on 35mm film output, and the quality of the images should be equal to or better than that of the production systems of the time; (4) The system must be able to expand its expressive functions; (5) The system must be a factory production system with a huge amount of work; (6) The system must be capable of high-speed automation; (7) The system should be able to solve ergonomic problems and (8) The system should be able to achieve cost reduction. Hiroshi Ikeda, "Nihon animeshon gakkai zenshi" (The prehistory of Japan Society for Animation Studies), *The Japanese Journal of Animation Studies*, vol. 11, 2010, p. 53.

(10) Oguchi, op. cit., pp. 187–188; Ichikoji, op. cit., p. 364; Masuda, op. cit., pp. 22–23; Washitani, op. cit., p. 23; 50 shunen jikko iinkai/50nen shi hensan chimu, *Toei Animation 50nen shi 1956-2006: Hashiridasu yume no saki ni* (50 years of Toei Animation), Toei Animation, 2006, p. 73.

(11) Hiroshi Ikeda, "3DCG no yoake: Nihon no furu CG anime no mirai wo saguru, vol. 20" (The Dawn of 3DCG: Exploring the future of full CG animation in Japan, vol. 20), 2014, http://www.toei-anim.co.jp/sp/ee_cgmovie/interview/020.html (accessed 12 September 2021).

(12) Masuda, op. cit., p. 23.

1.2. The introduction of RETAS! PRO for cost and labour saving

In the 1990s, the performance of computers gradually improved, and the price, which had been a major problem, decreased. In addition, RETAS! PRO[13], a colouring and filming software developed by Celsys[14] (established in 1991) led to the full-scale introduction of digital technology at Toei Animation. In 1992, Toei Animation began using RETAS! PRO on an experimental basis to produce the game software, "Hokuto no Ken" (Fist of the North Star). When RETAS! PRO went on sale in 1993, Toei Animation introduced the software on a trial basis as part of the TV animation "GS Mikami" (Ghost Sweeper Mikami) in the same year, thus establishing a certain level of digitisation in animation production. In 1996, the initial sum of 150 million yen was spent to fully implement the software, and RETAS! PRO became a standard animation-production tool. RETAS! PRO was designed with an understanding of the Japanese animation-production process and, above all, an emphasis on shared work. Many previous systems did not work well because they were designed to do everything using one system, which made the software slow and costly. In addition, functions could not be used for a shared workflow. Celsys focused on this issue and divided the RETAS! PRO functions into three categories: (1) inbetween scanning, (2) colouring, and (3) compositing cels and backgrounds, camera work, and video recording. RETAS! PRO was designed to run on either Mac or Windows, allowing the use of commercially available PCs and solving the cost problem. By introducing RETAS! PRO, Toei Animation achieved a cost reduction of 20%. After "GeGeGe no Kitaro" in 1997, the company promoted full-scale digitalisation and abolished all production using cels.[15] With the success of Toei Animation's digitalisation and Fujifilm's discontinuation of cel

(13) The initialism "RETAS" stood for Revolutionary Engineering Total Animation System.

(14) Celsys was founded by Yosuke Kawakami, who wanted to systematise cel animation. Kawakami wondered whether any market in Japan could make use of digital graphic tools, such as CG, which was gradually becoming more common around the world; at the time, digital graphics was in its infancy. He thought that the analogue process to produce cel animation could be replaced with PCs. This led to the creation of Celsys and the development of RETAS! PRO. Famitsu.com, "Doroingu sofuto no shinka ha serushisu no rekishi: CLIP STUDIO PAINT ni itaru made" (Evolution of drawing software is the history of Celsys), https://www.famitsu.com/news/201504/02075715.html (accessed 12 September 2021).

(15) Using RETAS! PRO, key animations and inbetweens on paper were scanned and converted into digital data, which were then coloured. This made it possible to drastically reduce the cost of consumables such as cels, paints and film, which had previously been essential. In the case of the TV animation "Kindaichi shonen no jikembo" (The Kindaichi Case Files), which began broadcasting in 1997, costs were greatly reduced, particularly in the areas of colouring and film, with an average saving of 1.17 million yen per episode. At the time, Toei Animation had about 5 series of TV animation per week, which meant that there were about 250 episodes per year. It is said that the direct production cost reduction due to digitalisation amounted to 300 million yen per year for TV animation alone. The funds generated by the cost reduction were used to purchase new hardware and software, and to manage and maintain the system as digital technology was introduced. Tomoya Kimura, *Toei doga shi ron: Keiei to sozo no teiryu* (Toei Doga history: The undercurrent of management and creation), Nippon Hyoron sha, 2020, pp. 335–336.

production for animation in the mid-1990s, many other companies decided to go digital. One reason for actively adopting digital technology, was the fact that productions increased rapidly with the growth of late-night animation in the late 1990s. Companies needed to make the production process faster and more successful.(16)

As this paper has discussed, Toei Animation's main reason for introducing computer and digital technology was to save labour and reduce the cost of traditional cel animation. Although the workflow, including the storyboard, layout, key animation, inbetweening and background art, remained the same, animations after inbetweening were scanned and converted into digital data, and the finishing process was carried out entirely on RETAS! PRO. In the 2000s, the use of tablets with LCD screens and STYLOS software, developed by Celsys, made it possible to digitise both drawing key animations and inbetweens. Digital drawing eliminates the need for paper and scanning, as well as the need to remove dust during the finishing process; this further reduces costs. However, due to the high cost of tablets and the problems involved in reproducing the feeling of using a pencil in analogue drawing, Japanese animation-production companies have never fully adopted digital drawing.(17)

2. The introduction of 3DCG technology for new expression

This article has examined the introduction of computer and digital technology by Toei Animation for the purpose of labour saving and cost reduction. In the period of the introduction of digital technology, Toei Animation succeeded in computer-assisted animation production and digitalising the process after colouring by using 2DCG technology. However, on the other hand, before Toei Animation introduced digital technology, some companies had already computerised the drawing process and produced animation. The following section examines companies such as Japan Computer Graphic Lab. and Toyo Links, which began using computer and 3DCG technology in the drawing process before Toei Animation and took a different approach to introducing digital technology to the animation industry.

2.1. The establishment of Japan Computer Graphic Lab. and computerisation of the process after drawing key frames

In the late 1970s, when Toei Animation began to consider the introduction of digital technology, Mitsuru Kaneko, at the animation production company MK, had developed a deep interest in computer-assisted animation production. Together with Takeshi Agui and Masayuki Nakajima of Tokyo Institute of Technology, who had been working on 2D computer animation since 1975, Kaneko began to research the commercialisation of

(16) Oguchi, op. cit., p. 188; Masuda, op. cit., pp. 27–28; Ichikoji, op. cit, pp. 364–365.
(17) Oguchi, op. cit., pp. 188–189; Ichiroji, op. cit., p. 355, 362.

computer animation. This began a collaboration between MK, NYIT, and Tokyo Institute of Technology. From Japan, veteran animators and designers such as Shuichi Seki, Shichiro Kobayashi, and Yoshishige Kosako were sent to NYIT, where they created a pilot film of "Kojika Monogatari" (The Yearling).[18] Based on this experience, Kaneko received technical cooperation from NYIT in 1981 and established Japan Computer Graphics Lab. (JCGL) in Shibuya, Tokyo, as a joint venture between MK, Kodansha, Toho, Canyon Records, and Nippon Telework (later joined by Toppan Printing). Initially, JCGL aimed to streamline the production process for TV animation and make it more productive, while also achieving smooth full animation and a high-quality finish free of dust and cel scratches.[19]

In 1982, under an exclusive contract with NYIT, JCGL began operating one of the largest hardware systems in the world (Table 1, 2). This system was computer-aided for the post-inbetweening process; unlike previous systems, such as Toei's CATAS, it was capable of carrying out all tasks in parallel, thus making efficient use of the hardware. The new system consisted of the following software: TWEEN[20] was used to input key animations from a tablet and create inbetweens automatically; Black & White SCAN and COLOR SCAN software for inputting key animations on paper; TWEEP to colour the drawings input by TWEEN and Black & White SCAN; IMAGES was used to create background art with free strokes, free colours, and free effects; COMPOSITE to layer the finished picture, in accordance with the animation shooting sheet and RECORDING for outputting the finished picture to film or video.[21]

The first film to use this system was NHK's 1983 animated TV series, "Kojika Monogatari", which attracted much attention, particularly for its second episode, which

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(18) NYIT was in the process of completing a labour-saving system for hand-drawn animation. At the same time, they were trying to use technology to make software that could achieve something that could not be done using hand-drawn animation. Mitsuru Kaneko and Toshihiro Komma, "JCGL ni okeru genjo to doko" (Current situation and trends in JCGL), *National Convention Record of the Institute of Television Engineers of Japan*, vol. 20, 1984, p. 409.

(19) Oguchi, op. cit., pp. 189–190.

(20) Although TWEEN was a well-developed piece of software, it slowed down the whole system, due to the time-consuming and error-prone properties of the actual work, for instance because of difficulty to enter points to change drawing lines. In addition, it took a genius animator to draw key animations directly on the tablet. For this reason, a key frame was drawn on paper in the usual way; the operator then traced and input it, eliminating the pre-colouring tracing process, but arising a new process of inputting the key animations. When this process went smoothly, function of inbetweening became very important, especially when mass producing multiple, almost identical intermediate images for the high-speed effect, which were impossible to create via the conventional method. Tatsuo Shimamura, "Nihon ni okeru kompyuta animeshon shisutemu no genjo hokoku" (A field report on computer animation systems in Japan), *Institute of Television Engineers of Japan Technical Report*, vol. 6, 1982, p. 34; Mitsuru Kaneko, "Dejitaru gijutsu ni yoru anime no henkaku shi" (Technical history of anime production), *The Journal of the Institute of Electrical Engineers of Japan*, vol. 132, no. 7, 2012, p. 434.

(21) Kaneko and Komma, op. cit., pp. 411-412; Shimamura, op. cit., p. 33.

Table 1. The hardware configuration of JCGL.

	Hardware	Number of units
CPU	VAX-11/780	2
	PDP-11/44	2
	PDP-11/23	6
	LSI-11/03	4
Auxiliary memory	TU78 tape drive	2
	RM80 (100MB)	2
	RM05 (256MB)	2
	RL02 (10MB)	22
Peripheral	RGB monitor	10
	Framebuffer (Genisco, DeAnza)	21
	Film recorder (Dicomed D48)	2
	Colour scanner (DeAnza)	1
	Graphicus 80	2
	Vector display	1
	1-inch VTR (BVH-2500)	1
	12-inch tablet	8
	VT100	16

Source: Kaneko and Komma (1984), p.410; Shimamura (1982), p. 34.

Table 2. The JCGL systems, its functions and hardware configurations.

System	Hardware configuration	Function
IMAGES station	RGB monitor Framebuffer (3 units) PDP-11/23 Tablet VT100 RL02 (2 units)	Processing of coloured images.
TWEEN station	Graphicus 80 PDP-11/24 RL02 (3 units) VT100	Creating motions with line drawings and reviewing them.
COMPOSITE station	Framebuffer (3 units) VT100 RGB monitor	Composting and transforming images.
3D Movie station	Vector display VT100	Creating motions of 3D objects with line drawings and reviewing them.
3D Make station	Framebuffer (6 units) VT100 RGB monitor	3D rendering, shading, and anti-aliasing.
Film Recording station	VT100 Film recorder	Film output of works.
Video Recording station	VT100 1-inch VTR	Video output of works.
Scanning station	Scanner VT100	Camera input for static materials.

Source: Kaneko and Komma (1984), pp. 411–412.

was produced entirely in CG.[22] However, Japanese TV animation was not a good fit for TWEEN, as production costs were kept low by the use of overseas subcontractors, production times were extremely short, and Japanese creators emphasised a unique sense of motion to compensate for the awkwardness of Japanese limited animation. Japanese animation also had many finely detailed characters, which the automatic inbetweening system could not reproduce, increasing the need for manual correction work.[23] For these reasons, JCGL decided to change course, moving away from CG, as a substitute for hand-drawn animation, to 3DCG, which could create effects that were impossible to achieve with hand-drawn animation.[24]

Starting in the latter half of 1982, JCGL created TV commercials and programme titles, architectural-simulation images, and images for the Tsukuba Science Expo using 3DCG. In 1984, JCGL tried its hand at mixing 3DCG with the cel animation produced by Madhouse for the animated feature film, "SF Shin-Seiki Lensman" (Lensman: Secret of The Lens).[25] In 1985, JCGL introduced Cranston/Csuri Production's 3DCG software for more advanced visual expression; this became "JCGL System 2". At the same time, it strengthened its production department by introducing an internally developed painting system, which became "JCGL System 3".[26] In this way, JCGL pioneered the introduction of digital technology into animation and pursued expression of 3DCG; ultimately, the

(22) However, the computer of the time, the VAX-11/780, was so expensive that it was cheaper to colour the cels manually. At that point, the company returned to produce this work using cels. Masayuki Nakajima, "Anime to Kompyuta" (Animation and computer), *Information Processing Society of Japan Magazine*, vol. 39, no. 7, 1998, p. 614.

(23) As for the TWEEN used in "Kojika Monogatari", it has been pointed out that it was not well suited to the slow and deliberate motion of the characters in the Japanese animation, as compared to the more cartoon-like motion of the American animation. In addition, as this is a juvenile literature, there is a lot of emotional description, which did not match the mechanical inbetweening. Masaaki Taira, "3DCG no mirai: CG anime to medeia rireshon, vol. 40" (The future of 3DCG: CG animation and media relations, vol. 40), 2021, https://www.toei-anim.co.jp/sp/ee_cgmovie/interview/040.html (accessed 12 September 2021).

(24) Oguchi, op. cit., p. 190; In addition, the work is done on a workstation screen in computer animation, whereas in hand-drawn animation, inbetweens were drawn on paper, traced onto cels and coloured. The colours and textures were therefore very different from those of the cels, making it difficult for animators to grasp them. Toshihiro Komma, "Kompyuta animeshon no genjo to sono mondaiten: JCGL deno keiken to deta ni motozuita hando animeshon tono hikaku" (Computer animation in JCGL), *Bulletin of Japanese Society for the Science of Design*, vol. 52, 1985, p. 89.

(25) Takayuki Oguchi of JCGL experimented with toon shading (also known as cel shading) in the pilot version of this film. Toon shading is a non-photorealistic expression technique that produces the cel-shaded texture of hand-drawn animation. Although this work was rejected at the test stage, toon shading, which is full CG animation with contour lines, is now considered a uniquely Japanese CG expression. The first commercial film to use toon shading is said to have been "The Lion King" (1994), which featured one cut of a large herd of gnus, but Disney did not use toon shading after that. Takayuki Oguchi, "Nihon ni furu CG anime ha nezuku noka? Shikisha ni kiku wasei 3DCG animeshon no mirai, vol. 3" (Will full CG animation take root in Japan?: An interview with an expert on the future of Japanese 3DCG animation, vol. 3), 2012, http://www.toei-anim.co.jp/sp/ee_cgmovie/interview/003.html (accessed 12 September 2021).

company was unable to overcome the generational changes in CG production and the problem of productivity; it was dissolved in 1988. Many JCGL staff members moved to the game manufacturer Namco, where they helped to develop 3D versions of the company's theme park attractions and game software. Namco produced some highly successful people, who would later play an active role in developing the 3DCG industry in Japan.(27)

2.2. Animation production using 3DCG technology by Toyo Links

Alongside JCGL, the first dedicated CG production company in Japan, Toyo Links was also an important player in the early days of CG animation in Japan. Film producer Mataichiro Yamamoto launched Toyo Links when he began planned production, using a new graphics processor that was being researched and developed at the time. The company was established in 1982 as a joint venture between Filmlink International and Toyo Labo. The graphics processor was the LINKS-1 system, developed by Koichi Omura and his colleagues at the Osaka University Department of Electronic Engineering; the system used ray tracing to generate images via parallel processing. LINKS-1 made it possible to calculate ray tracing at a practical speed, becoming the first production company in the world to specialise in ray tracing, using this system.(28) The 3DCG generation system of LINKS-1 uses ray tracing to enable a wide variety of expressions. The following are some of the typical examples: (1) Many kinds of primitives are available, which can be freely combined to create the shape of an object; (2) The ability to use 17 million colours to create subtle surface textures; (3) Multiple lights can be used by combining colour, direction, position and luminosity; (4) The position and angle of the camera can be freely set and the angle of view can be changed and (5) Objects can be freely arranged and easily manipulated. In the field of animation, Toyo Links created the title sequence and helicopter attack scene in the 1983 animated feature "Golgo 13" using

(26) "JCGL system 2" is based on the rendering software by scanline algorithm and the animation software using IMI-500. It can express reflection and refraction similar to ray tracing, and its speed in rendering is almost the same as ordinary rendering model. Moreover, by mapping 2D images made by "JCGL system 3", or patterns by video input, almost an unlimited material feeling can be obtained. Koichi Omura, Yoichiro Kawaguchi and Noji Suma, *CG in JAPAN: Kompyuta gurafuikkusu no saizensen* (CG in Japan: The forefront of computer graphics), Graphic-sha, 1985, p. 54.

(27) Oguchi, *Kompyuta gurafuikkusu no rekishi*, pp. 190–191; Masuda, op. cit., p. 24.

(28) In order to create high quality images with a high degree of realism, it is necessary to simulate all the optical phenomena of shadowing, transmission, refraction and reflection. Ray tracing fulfilled almost all of these requirements. It is a method of extracting three-dimensional information as a 2D image by tracing an object placed in space with a bunch of rays passing through each pixel on the screen to be represented. The number of rays is the same as the number of pixels, so that as the resolution of the image increases, so does the number of rays and computation. The fast parallel processing with LINKS-1 makes it possible to cope with such situations. Koichi Omura, "Kompyuta gurafuikkusu shisutemu LINKS-1 ni tsuite" (Computer graphics system LINKS-1), *Systems and Control*, vol. 30, no. 4, 1986, p. 25; Koji Ichihashi, "LINKS-1 shisutemu ni yoru CG eizo" (CG images with LINKS-1 system), *FUJITSU*, vol. 36, no. 2, 1985, p. 168.

CG. The company also created "The Universe" (We are born of stars), the world's first OMNIMAX 3D film, for the Fujitsu Pavilion at the Tsukuba Science Expo in 1985. This work was a co-production between Fujitsu, Dentsu, and IMAX and the first 3D movie for a whole sky screen in the world, produced using LINKS-1.(29)

Although LINKS-1 helped to produce ground-breaking 3DCG images, hardware changes were needed to strengthen its computing power, and there were limits to how fast this could occur. The LINKS-1 had about 10 times the processing power of the VAX-11/780, but even with this system it took 10 to 30 minutes to produce a single NTSC-quality image with 525 scanning lines. This meant that a production of a 15-second commercial film required two to four days on the LINKS system, and including the retakes requested by the client, a single production required approximately one month on this system. In addition, the production of HD films with 1,125 scanning lines and cinefilm with more than 4,000 resolutions required an even greater amount of work. As a consequence of this background, it was inevitable that a faster computer would be required, but if a supercomputer such as the CRAY2 was used, the cost of leasing and maintenance would greatly exceed the CF production budget, and even if it was not, the vectorisation of the accumulated rendering software would be a considerable burden. To overcome these problems and significantly improve the production capabilities of ray tracing, Toyo Links developed a new system, LINKS-2, in 1987. The new system had a highly flexible configuration and could process calculations and communications in parallel. In April 1987, Toyo Links integrated the ACME system, IMAGICA's internal CG department, and established a production system using scanline algorithms.(30) It also developed a range of 3DCG software, including "Personal LINKS" which enabled advanced CG production on NEC's PC-9801 and helped to popularise CG. In 1988, Toyo Links became the Links Corporation; in 2000, it merged with IMAGICA's motion-capture division, Sakuratei Studio, to form Links Digi Works. Along the way, this company sent as many people to the Japanese CG industry as JCGL.(31)

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(29) Oguchi, op. cit., pp. 192–193; Masuda, op. cit., pp. 24–25; Hiroshi Yoshimura, Takashi Fukumoto, Akira Yoshida and Hiroyuki Hayashi, "CG senyo shisutemu LINKS-1 ni yoru eizo seisaku" (Image production using a dedicated CG system LINKS-1: Toyo Links), *PIXEL*, vol. 26, 1984, pp. 74–75.

(30) The ACME system used a scanline algorithm with software called MOVIE.BYU to produce the images. A 3D rendering system using Z-buffer algorithm and ray tracing was also used, all three systems running on a VAX-11/780. Kinji Odaka, Masayuki Ota, Masanori Ihara, Masanori Hoshino, Toshio Tsukada and Tetsuzo Tokunaga, "Kompyuta gurafuikkusu ni yoru tokushu koka: CG shisutemu to mapping ni yoru seisaku shuho, ACME system" (Special-effect aided by computer graphics), *PIXEL*, vol. 36, 1985, pp. 117–119; CGWORLD.jp, "ACADEMIC meets INDUSTRY: Wakayama daigaku shisutemu kougaku bu shisutemu kougaku ka shikaku medeia kenkyu shitsu" (Academic meets industry: Wakayama University Faculty of Systems Engineering), 2020, https://cgworld.jp/regular/202005-ami-11.html (accessed 14 September 2021).

(31) Toshiyuki Kawai, Shinichi Yamashita, Hiroshi Ohno, Hiroshi Yoshimura, Hitoshi Nishimura, Shinji Shimojo, Hideo Miyahara, and Koichi Omura, "Heiretsu gazo seisei shisutemu LINKS-2 no akitekucha" (Architecture of LINKS-2, a parallel image generation system), *Transactions of the Information Processing Society of Japan*, vol. 29, no. 8, 1988, p. 730, 738; Oguchi, op. cit., p. 193; Masao Takakuwa and Hiroshi Yoshimura, "G-PROCESSOR LINKS-2", *PIXEL*, vol. 50, 1986, p. 130.

Conclusion

This article has focused on computers and digital technologies in the Japanese animation industry, reviewing how they were introduced by Toei Animation, JCGL, and Toyo Links. As for the motivation of these companies to introduce digital technology into animation production, the first reason was that they wanted to save labour and reduce costs by using computers to support the production process, which was very time-consuming and labour-intensive. Toei Animation, in particular, was experiencing financial difficulties and labour disputes in 1970s. The rationalisation through digital technology was seen as a way to rebuild the company. During this time, which could be called the second animation boom, the company needed to respond to the rapid increase in animation productions. Although Toei Animation experienced twists and turns when it introduced digital technology, the company finally solved cost problems by running RETAS! PRO on commercial PCs. From the latter half of the 1990s onwards, Toei Animation promoted full-scale digitalisation.

As for JCGL, at the time of its establishment, it aimed to streamline of the production process and improve the quality of TV animation. When the company failed to reach an agreement on costs, it decided to change its policy and pursue digital technology as new artistic expression. This was the second motivation for introducing digital technology into animation production. Toyo Links, in a similar vein, considered the introduction of a system for producing 3DCG images from the beginning, so that the digital technology was oriented towards new expression. However, although Toyo Links used 3DCG for TV commercials, TV programme pilots, and exhibition images, it was hard to argue that 3DCG was well-suited to the Japanese animation industry; overall, 3DCG was rarely used to produce animation because of the large number of TV animation productions, limited costs of these productions, and consumer preferences.[(32)]

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(32) According to Hiroyuki Seshimo, who worked at Toyo Links in the 1990s, “CG was still a rarity, and it was the status quo for cutting-edge companies to use CG for their CI in commercials. It was a time when it was considered standard to spend about a million yen to make a one-second commercial. It was mainly the commercial clients who could afford such a budget. So, it was an impossible dream to produce a long story animation in CG”. Hiroyuki Seshita, “3DCG no yoake: Nihon no furu CG anime no mirai wo saguru, vol. 26” (The Dawn of 3DCG: Exploring the future of full CG animation in Japan, vol. 26), 2016, https://www.toei-anim.co.jp/sp/ee_cgmovie/interview/026.html (accessed 12 September 2021). As others have noted, there were differences in budget scale and project duration in Japan when compared to the US. In Japan, many TV and OVA productions had to be produced on limited budgets in a short period of time. The know-how accumulated through the process of hand-drawing cel animation has become a major feature of the industry, making it different from CG animation in the US. Masashi Hara, “Gurobaru kyoso jidai ni okeru nihon no dejitaru kontentsu sangyo shuseki no kyoso yui to inobesyon no hokosei: SD gandamu fuosu purojiekuto wo jirei ni” (Competitive advantage and innovation of digital content industrial clusters in Japan in global competition era: A case for “SD GUNDAMFORCE” project), *Annals of the Association of Economic Geographers*, vol. 51, 2005, p. 78. For more information on the acceptance of 3DCG images in Japan, see Masami Sano, “3DCG shiyoho no chigai ni kiin suru anime to hi anime no kyokaisen no kosatsu” (Consideration of the borderline between animation and non-animation due to differences in 3DCG usage), *Studies in media and culture*, no. 4, 2008.

When assessing what digital technology has brought to each animation production, it is worth mentioning "labour saving" and "new expression". As discussed above, digital technology has had a great impact on the process of animation production in terms of labour savings; today, animation production is no longer possible without digital technology. On the other hand, new expressions using 3DCG are limited; only in recent years have full 3DCG animations appeared on TV and film.(33) Compared to the digitalisation that followed the finishing process, 3DCG was a radical innovation, requiring changes to the organisation, production systems, and skills that were completely different from those required for hand-drawn work; even today, 3DCG is not widely adopted. However, in the process of introducing 3DCG to the Japanese animation production scene, a hybrid style combining traditional hand-drawn animation with 3DCG was created. This particular style, which combines key animation drawn with analogue techniques with 3DCG in the background art, has become commonplace in Japanese animation production.(34)

As previously mentioned, computer and digital technology have been introduced to the Japanese animation industry in a step-by-step manner. This article mainly examined the relatively large companies that were early adopters of new systems and technologies, such as Toei Animation, JCGL and Toyo Links. However, there are other companies that, although smaller in scale than these three, have had a significant impact on the later Japanese animation and CG industries; for example, SEDIC, which was founded at the same time as JCGL and Toyo Links and produced short films such as "MIROKU-Maitreya" (1984), and SHIROGUMI, which was founded in 1974 as a studio specialising in animation and special effects and started operating a CG system in 1983. By including the analysis of these companies in future research, it will be possible to understand in more detail the process of the introduction of digital technology in the Japanese animation industry and its impact on animation production and works. In addition, as this paper focused on the "technology" used to support animation and CG production, there was limited discussion of the "consumers" who accept works produced using such technology. The relationship between demand and technology is also an area for future study, as changes in consumer preferences and demand are likely to have a significant impact on the motivations of companies to adopt technology.

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(33) For studies of 3DCG animation in the Japanese market, see Koichi Noguchi, "Nihon shijo ni okeru CG animeshon no genjo: *Rakuen tsuiho: Expelled from Paradise* wo chushin ni" (Present situation of CGI animation in the Japanese market: A case study of *Rakuen Tsuiho: Expelled from Paradise*), *The Japanese Journal of Animation Studies*, vol. 18, no. 1, 2016; Atsushi Matsumoto, "Anime no seisaku purosesu to bijinesu kozo wo henka saseru 3D gijutsu: *Aoki hagane no arupejio: arusu nova*, *Seikai suru kado*, *Kemono furenzu* ga shimeshita 3tsuno hokosei" (3D technologies that will bring about changes to the production processes and business structures of animation: Findings from *Arpeggio of Blue Steel*, *Kado: The Right Answer* and *Kemono Friends*), *The Japanese Journal of Animation Studies*, vol. 19, no. 2, 2018.

(34) Ichikoji, op. cit., p. 358, 372.

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Abstract

This article examines why computer and digital technology were introduced in Japanese animation industry, and how these new technologies changed animation production. The use of computer and digital technology in the animation industry began in the 1970s with the question of whether it was possible to streamline the time-consuming and labour-intensive process with help from computers. This paper explores the process of technological development, focusing on three companies that actively attempted to introduce computer and digital technology from an early stage: Toei Animation, JCGL, and Toyo Links. As for the motivation of these companies to introduce computer and digital technology into animation production, the first reason was that they wanted to save labour and reduce costs. Toei Animation, in particular, succeeded in computer-aided animation production and digitalising the production process by using 2DCG technology. JCGL and Toyo Links, on the other hand, used 3DCG technology to pursue new artistic expression, which is the second motivation. This study suggests that computer and digital technology have brought “labour saving” and “new expression” to animation production.