Who will educate the next generation, when all the top computer scientists are lured away from academe with higher industry salaries? This is the perennial concern parroted by the press in the United States. Yet American industry generously supports American educational institutions with equipment, software, research grants, and even personnel. Support of educational institutions has been a Western tradition.

There is lively cooperation between industry and higher education in Japan as well, but it is founded on a very different system. The Japanese do not readily move from position to position as is customary in the US. Computer graphics scientists and others in Japan do not pop back and forth between academe and industry. Wherever they start their careers is usually where they end them as well.

This tradition of devoting one’s life to a single institution is so strong that it might as well be codified. Such opprobrium would attach to any who attempted a move that future employment would be virtually unattainable. It is not an exaggeration to say that a Japanese professional would have to move all the way into the Western world to make such a change.
Shades of the old system

Toshiyasu Kunii, professor of computer graphics at the University of Tokyo and head of that institution's Computer Graphics Laboratory, explains that this is a result of a long history of serfdom. The shogun system is long since gone, he says, but today's employees belong to their employers in the same way that samurais (warriors) once belonged to their shoguns. Almost like slaves, people did not "leave" a shogun's rule then, and people do not leave an employer's today.

The touted Japanese system of consensus is, at least in part, an accommodation to the system within which one must work for a lifetime. The dissident faces ostracism, and the uniform behavior that results is just beginning to emerge. Students at the University of Osaka, for example, entered in the SIGGRAPH 85 Film and Video Show a film whose theme was the fear of losing individuality in the system.

The cross-seeding of academia and industry in the West, then, is in large part a natural result of the movement of professionals between the two. Just as obviously, neither can thrive without the other. Yet even without this particular brand of cross-pollination, computer graphics in Japan is moving at a very fast pace. The nation as a whole is much further ahead than many in the West realize.

Added impediment

Another factor in the separation of higher learning and industry is a law peculiar to Japan. American college professors can and often do spin off into companies of their own that offer products, software, or consulting services, while the professor continues to function in academia. This is not possible in Japan. Those who teach in state-supported institutions (and nearly all are) are forbidden by law to have any holdings whatever in private companies. Thus another avenue to interactivity is effectively blocked.

The very need for an interrelationship, since it is not satisfied by peripatetic professionals and cannot be directly fed by dual-career paths, seems more stark in Japan. Cooperation has been the answer. It is a basic of Japanese life, and in computer graphics it has fueled stunning advancement.

"Links" are a favorite subject of Koichi Omura—inventor of the superpowerful Links System—links between people, between systems, between fields of endeavor. Such links are what we see all over Japan, and we are going to look a little more closely at several of them.

Ricoh Company, Ltd.

Hideko Kunii can look out her office window and see the University of Tokyo, from which about 25 percent of the employees in her software center received their degrees. There are 50 members of Kunii's center, including six team leaders, two of whom have their doctorates from the University of Tokyo. Kunii herself got her doctorate elsewhere. She went to Ochanomizu University for a master's degree in physics, then did work at the Stanford University Information Processing Center (in
California) and after a brief stay in Japan returned to the United States to earn her PhD from the University of Texas at Austin.

Kunii’s doctoral thesis described the Graph Data Language (GDL), a high-level, access path-oriented language. She brought GDL with her to Ricoh, and it is now the basis of some very ambitious projects. In her thesis Kunii described GDL as a language that “allows execution efficiency without losing data independence,” and one that can be compactly implemented. GDL is founded on graphs and an algebra that operates on graphs. The Graph Data Model (GDM) is the framework for GDL. GDM formulates schemata as directed graphs and data operations as algebraic operations on these graphs.

“GDL allows dynamic creation and deletion of link types,” she reported. “Because of this feature, the restriction that queries are represented as a path on a connected graph does not limit the power of the language. It also supports data independence, since the user can redefine record types and links as a schema evolves.”

Of the six groups working under Kunii, two are working on the GDL database management system, known now as G-Base, which is growing out of Kunii’s doctoral work. One group, headed by Katsumi Kanasaki, works on fundamentals, while another, headed by Akio Urabe, works on the user interface.

**Solid modeling**

One of the most important projects underway at Ricoh is a solid modeler. It has a number of useful features, but one of the most utilitarian is the UNDO and REDO commands for rectifying a single mistake? Many such programs require that an entire drawing be reexecuted. There is rounding in other systems, but this one can handle both cylindrical and free-form local rounding.

Hiroaki Chiyokura, the team leader on this project, has provided line drawings and a finished image rendered with this system (see Figures 1 and 2). The Ricom 3200, hardware by Ricoh, is the workstation on which Figures 1 and 2 were modeled (see Figure 3). It can output to a variety of devices, including the new Ricoh laser printer.

There is another group doing the 2D mechanical CAD, which is headed by Nobuhiro Ajitomi.

**Apparel modeler**

Shin Yamaguchi heads the team working on an apparel modeler that can be used in 3D to model garments and then translate into 2D to make patterns.

**Chinese characters**

The sixth research group is putting Chinese characters on Unix. When completed, this will probably support several systems, using phonetics to input more than 2000 possible characters of Kanji. It employs the shift JIS Code, which is a Japanese industry standard to represent the characters.

You can see some of the people involved in all these projects in Figures 4 and 5.

**Contributions to academia**

So the company is OEMing computer hardware in the US and is hard at work on some excellent software. But
Toshiyasu Kunii, professor at the University of Tokyo, can help clarify for us some of the cultural milieu in which Japan's computer graphics achievements take place.

The students at Osaka University are not the first to fear for their individuality. In 1968 Kunii headed the Raster Technology Project, whose mission it was to rescue the textile industry. He came up with a graphics database and a CAD system with a minimum of 4096 colors that could handle textures as well. He wrote papers about it, pushed the system hard, even came to the US to present his first paper to 300 people at the very first SIGGRAPH conference in 1974. He believed strongly then in the necessity for scientific intercourse among nations, as he does to this day.

While this all sounds adventurous and productive, there was a problem: Many top professors in Japan at that time felt vector technology was king. And here was Kunii pushing raster technology in a country where the majority not only rules but supersedes. There is, according to Kunii, no protection in Japan for the minority view, as there is in the US.

"We have gone in 450 or 500 years from an agricultural to an industrial nation," says Kunii. "But we have also gone from a military-shogun system to the present democracy. Under the shogun, to secure employment, all people registered in the temple. Five families watched each other. It was a mutual watching system with no freedom. That system has actually never broken down. Now all people register with an employer. Within companies people watch each other. Before it was samurais. Now it is workers."

Kunii talks of the many difficulties he has had since he championed raster technology. But he has continued to teach, to research, to run the Computer Graphics Lab at the University of Tokyo. He researches octree structures, works in solid modeling and robotics, and travels around the world giving tutorials and technical sessions at SIGGRAPH, Graphics Interface, Computer Graphics Tokyo, etc. He writes papers on his work and teaches computer architecture to undergraduates and software engineering to graduate students.

Why does he keep on teaching when he is forbidden by law to realize any of the fruits of his invention and knowledge directly? "You don't want to leave," he explains, "because then who would educate the students?"

The research done by Kunii and his students is eventually used by industry. It works like this: Once a research project is finished in a state-supported university, it must be put on the open market because the research was done using machines and equipment that officially belong to the federal government. They are donated to the Ministry of Finance by private companies, but the companies know where they are needed and for what research. The Ministry distributes this equipment. When the research is finished, a company can hire the students who were involved in the project, and it can purchase the research results as well.

Kunii says more than 90 percent of the money coming to his laboratory at the University of Tokyo comes from

Figure 4. These are four of the team leaders working under Hideko Kunii at Ricoh Software Research Center. From left, Akio Urabe, Katsumi Kangasaki, Hiroaki Chiyokura, and Nobuhiro Ajitomi.

Figure 5. This is Hideko Kunii as she appears in the most recent Ricoh Annual Report.

what is its link with Japan's academic institutions? It has many. It contributes heavily to research done in campus labs, including the University of Tokyo and Keio University, a private institution from which come some of Ricoh's PhDs.

There is a mutuality of interest: The universities whose research programs are underwritten by Ricoh make the obvious gain, but then Ricoh turns around and hires some of the well-trained graduates its altruism has helped fund.

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private industry. Private enterprise donates money and equipment that supports his work in mechanical CAD, fashion, 3D CAD, and many other projects, all supported by his database system. He is heavily engaged in applicational engineering, defining software applications and pushing them down to the chip level, for speed and more efficient operation, for lower prices, and for more intelligent displays.

Kunii's latest contribution has been a new scientific journal for computer graphics, *The Visual Computer*, which is written in English by computer graphics scientists from all over the world. It is published by Springer-Verlag.

**A sought-after school**

Leaving Kunii and the University of Tokyo, we move through the Japanese countryside on the famed bullet train. We pass villages usually composed of a temple on a hill surrounded by the houses of the village, ponds where eels are farmed, hills sprinkled with tea plants, rice paddies, and view after view backed by snow-capped peaks. At the end of the line is Osaka, one of Japan's industrial centers and home of Osaka University.

This is where Koichi Omura sits in the shadow of his own Links System, the very one he built by hand. This parallel processing system is probably comparable to most supercomputers, except that it doesn't come in a neat box. Here, at Toyolinks in Tokyo, at Nippon Institute of Advanced Educational Media, and at the other places where there are Links, the system resides without designer packaging. Its cards sit in their shelves with tails draped over whatever is handy, fans going all the time to hold down its heat (see Figure 6).

Omura's office is a little like the Links System itself. It is jammed full of ideas in the works, with VDTs, digitizing boards, cameras, etc., strewn everywhere. An entire wall holds documentation for software, with the overflow stuffed in every available nook. Omura's own pixielike humor shines through in this unusual documentation, with line-drawn cartoon characters grimacing over computer problems right along with the user.

What goes on in this engineering school is so exciting that competition to get into the computer graphics program is fierce. This is where Omura practices his links theory. He brings in artists and challenges them to come up with ideas they would like to execute at the computer, but can't. The minute they do, he sets a team of graduate students to work on the idea as a research task. Assignment: Make it possible. Write software that will give the artist a new tool to accomplish the dreamed-of goal.

When the noted artist Yoichiro Kawaguchi came up with the concept for his film *Growth II: Morphogenesis*, he couldn't realize it with the usual polygons. He needed a new kind of software. Naturally he turned to Omura. Omura's students developed the Metaball software that Kawaguchi used to create his prize-winning film.\textsuperscript{16}

**Links**

Koichi Omura has been at Osaka University for many years. Born in Shanghai in 1938, he came to Osaka to get his bachelor's degree in communications engineering in 1960, and continued on to get his master's and doctorate there in 1965. Today he is associate professor of electronic engineering, father of the Links System, and he has published and presented several papers internationally.\textsuperscript{17,18}

Omura is more than just fascinated with show business and the builder of one of its great creative mediums, the Links System. He has also done a bit of his own filmmaking. At Expo 85 one of the exhibits was a stereo and Omnimax film titled *We Are Born of the Stars*. This 10-minute film took one and a half years of links across the sea to produce. Five minutes were done by a Japanese team with Omura directing. The other five minutes were done by a Fujitsu team, which included two US members, under the direction of Nelson Max of Lawrence Livermore National Laboratory.

Omura speaks with a twinkle in his eyes when asked to
explain the name he has given his supercomputer. "Links," he muses. "We link many computers. We also link artist and engineer. I think it is very important to bring artist and engineer together." As a result of these links Omura's approximately 20 graduate students get to work with many exciting projects.

Tsukuba

At Expo 85 in Tsukuba one of the most popular exhibitions was the Panasonic pavilion where they displayed a stereo TV using five projectors and a lenticular screen. As you move from camera to camera, you see the picture change, but at each camera your right and left eyes are seeing together a stereo image. Yoshiko Nakagawa was the art director.

Geometry for tots

A TV program to teach very young children about geometric shapes was done in color, and then two years later the geometric shapes were put on skates (see Figure 7).

Digitizing board

Omura has reasoned that it is distracting for an artist to keep glancing up at the screen to see what has been produced. The same artist working with any other medium would see results right under the pen or brush. So Omura has put together another team of graduate students to work on a digitizing board where the picture, instead of being projected on the screen, will be projected underneath the board, so the artist can work on it directly.

No bigger than a breadbox

Links II: That will be the next great announcement from Omura. He has teams of grad students working on it now. It will be a multicomputer system, able to connect as many as 100 units in parallel to build a network. Links I is 65 units, but Links II with just one unit will be even faster. Put another way, one unit of Links II will be 100 times faster than one unit of the powerful Links I. A Links System on every desk?

Live action with computer graphics

A feature-length film with live action and computer graphics is being done by Omura and Matsichiro Yamamoto, the well-known motion picture producer. To achieve this a number of problems have needed solving. The camera work is to be managed by a computer graphics robot. The robot must follow the motion of the real camera photographing the live actors, then synthesize the two. The top of the robot has a helical mast-type arm. This is built on units having six poles each, the center pole of which can extend and contract.

A team of graduate students in mechanical engineering, working under ME professor Yasayuki Seguchi, is working on that project. "See, another link," Omura says with a grin at the idea of mechanical and electrical engineering students working together on this big project.

A test strip has already been shot of a singer on a computer graphics floor with computer graphics background (see Figure 8).
The links go further than just mechanical and electronic engineering on this project. Toyolinks, the company built around Omura's Links System, will be in on the project as well. Omura holds no interest in Toyolinks whatsoever, of course, because he teaches in a state-supported school. But he can work with the company. So this film will have three teams: a university team, headed by Omura; a robot team, headed by Seguchi; and the Toyolinks team, headed by Yamamoto. And with that we are ready to travel back to Tokyo.

**A film company**

Not much needs to be said about Toyolinks. The company's films tend to show up at every major computer graphics conference. Just last year they were shown at NCIA in Dallas and at SIGGRAPH 85 in San Francisco. But there has been a recent accomplishment most computer graphics artists only dream about: a full-length animated film done on computer. This high-adventure film, *Golgo 13*, has a scene where a helicopter flies into a glass skyscraper and a variety of vivid and dramatic characters, first sketched and then rendered in full color on the Links System (see Figure 9).

**An artist teaches**

Yoichiro Kawaguchi is not only a world-renowned artist, he is a living example of Koichi Omura’s “links.” Kawaguchi started experimenting with a computer in the 1970's. He was doing black and white line drawings. Then he met Omura at a computer graphics event in Tokyo. “He had a small computer, and he was doing his own programming,” says Omura. “But he had no engineering support. And more than anything else he wanted to do
Figure 10. These three images come from Morphogenesis, Kawaguchi’s second Growth film.

animation.” The link was formed, and Kawaguchi wound up with a Links I installed at Nippon Institute of Advanced Educational Media, where he teaches.

The rest is computer graphics history. In 1983 Kawaguchi’s Growth I: Mysterious Galaxies premiered at SIGGRAPH. The next year Growth II: Morphogenesis debuted (see Figure 10). Last year Growth III: Origin was part of the SIGGRAPH 85 Film and Video Show. The common thread throughout all Kawaguchi’s work is growth. Growth I featured flexible texture effects and used ray tracing for transparency effects (see Figure 11).

Kawaguchi writes some of his own software, and he also goes to Omura for some of it. In fact Omura has set some of his graduate-student teams to work filling Kawaguchi’s artistic needs.

Kawaguchi works with shapes from nature, studying such things as seashells endlessly. He will take a shape, like the helix of certain shells, and grow it in an evolutionary fashion. He believes strongly in the marriage of artist and scientist, and as the world rockets into the future, he sees the combined vision of the two telling us things we shall need to know about our own and our earth’s future and maybe even about life on other planets.

More than an artist

Film-making is not Kawaguchi’s only concern. As a professor at Nippon Institute he carries on some quite unusual activities. He gives classes in architecture, engineering, and CAD/CAM studies, which is not so unusual. But he also presides over huge classes in computer graphics art. The size of his classroom for this activity is astounding, as is the number of VDTs all together in one room.

New students learn basic computer techniques and mathematics with C language on Unix. Most students, he explains, come with experience on their home computers in Basic, so one important beginning point is learning C. Then they study drawing for half an entire day once a week, both on and off the computer. Kawaguchi teaches them commercial TV (titles, shining effects, etc.), mechanical modeling, animation with 3D, and fractal techniques.

The first-year students get into computer graphics programming. They learn shadowing, and they learn reflection and transparency after viewing the work Turner Whitted did when he was at Bell Labs. Whitted is now at the University of North Carolina, having made the transition from industry to academe that is so common in the US. So Kawaguchi’s teaching forges another link.

Finally the students go through the simple test of making a molecule with a program Kawaguchi got from Nelson Max (another link).

The second-year students delve more deeply into the subjects they learned the first year. You can see progressive students’ work in Figure 12.

Protege

Another link was snapped into place when Harold Ohrbach came over from the US to study computer graphics art with Kawaguchi. Ohrbach has now gradu-
Figure 11. This series of images is from Kawaguchi's 1985 film, *Origin*. You can see in these progressions how one shaping evolves into another. If you can imagine these small pictures projected on a theater screen, you begin to grasp the overwhelming power of Kawaguchi's art.

Figure 12. Students studying with Kawaguchi progress in levels. In (a) we see a first-year student's work showing reflections and shadowing. In (b) a first-year student executes reflection and transparency after viewing the work of Turner Whitted (another international link). Second-year students in (c) and (d) build sophisticated structures showing reflection, refraction, shadowing, and transparency.
ated and joined the faculty of Nippon Institute himself, teaching computer graphics technical concepts in English, so students can gain some knowledge of the American and Western concepts in computer graphics. He is also teaching AI, mostly in Japanese.

Ohrbach works closely with Kawaguchi, helping edit the master's words in English, a favor returned by Kawaguchi when Ohrbach gets into Japanese. They work together a lot in Kawaguchi's office-studio, as you see in Figure 13.

Summary

So we see a thriving world of computer graphics in Japan (and we have only tiptoed over the surface), in spite of stringent laws about capital ownership, about patents on university-developed research products, and even harsher customs of single-path, employer-dedicated career development. The law is enforced by annual inspections and by rules that fill a large manual. Are the laws ever breached? Omura says with a twinkle, "Well, there is a good custom in Japan: looking in another direction."

Meanwhile Japan's computer companies know what is needed by the nation's source minds in the universities, and they have already rolled up a long history of giving gifts where they will do the most good. Has computer graphics in Japan arrived at approximately the same place as computer graphics in the US? Probably so; but through what a different route in such a different world!

Acknowledgments

My sincere appreciation goes to Tosiyasu and Hideko Kunii and members of their staffs, and to Koichi Omura and Yoichiro Kawaguchi and their colleagues for so generously giving their time, sharing their thoughts, and spending their energy, both in Japan and later in the US, to make this article possible. Nelson Max was kind enough to make a critical foray through the work—based on his own knowledge from having worked in Japan with several Japanese artists and scientists—for which I am most grateful.

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