ENGINEERING ANIMATION, INC. (EAI)

Three-Dimensional Anatomy of Human Body, With Animation, for Medical Training

Every day, surgeons operate on thousands of patients around the country. For each operation, the surgeon and support staff have trained in some way to perform the delicate surgical procedures, some of them training on cadavers in medical school and others learning by doing. For each operation, the patient has gone through a learning experience as well, via conversations with doctors and nurses, while first considering and then preparing for the surgery. Occasionally, patients get to see a video of another person undergoing the procedure to be performed on them.

COMPOSITE PERFORMANCE SCORE
(Based on a four star rating.)
★ ★ ★ ★

Animated 3D Anatomy

This ATP project enabled Engineering Animation, Inc. (EAI) — a small company founded in 1988 in Ames, Iowa, and specializing in three-dimensional (3D) visualization — to develop a new set of computer-based technologies for making training tools to help surgeons and patients better understand important aspects of surgical procedures before they are performed. The technology was developed for use in health care, medical research, medical education, surgical planning, rehabilitation equipment design, and patient education prior to surgery.

The 3D aspect is critical, because flat pictures do not provide enough information for a good understanding of anatomy and surgical procedures.

EAI was established to create software that can show animated 3D objects, and its initial products were used in court cases to present re-enactments of car crashes and other events. The company sought ATP funding to develop new methods that would enable it to extend its technical capabilities to depict the inner parts of the body, not just the exterior. In the process, the company hoped to extend understanding of human anatomy. Its attempts would be path-breaking, since there were then no other known efforts to gather digital anatomical data from different sources into one uniform database or to present that data in 3D motion.

The breathing patterns of asthma patients are demonstrated with a computer-generated dynamic model of the lungs. This is one of a sequence of images — the next one in the sequence has the ribs removed.

"Walk-Through" Surgery

During the ATP project, EAI researchers developed algorithms for a system that can show realistic 3D images of human body parts and their motion. The pictures of tissues and organs can be manipulated to present a walk-through of surgery. The 3D aspect is critical, because flat pictures do not provide enough information for a good understanding of anatomy and surgical procedures. Dynamics, or animation, is also important because joints bend, the heart beats and the lungs contract and expand. Seeing these motions is extremely useful to surgeons planning an operation. Realism, too, is critical so that the images look like natural anatomy.

PROJECT HIGHLIGHTS

PROJECT:
To develop computer visualization and computational dynamics technology for presenting animated 3D images of the human body and its parts in order to improve medical education and surgical simulation.

Duration: 7/1/92 — 6/30/95

ATP Number: 91-01-0184

FUNDING (in thousands):

ATP	$1,947	76%
Company	625	24%
Total	$2,572	

ACCOMPLISHMENTS:
EAI developed core algorithms to enable the creation of 3D images from sets of 2D cross-sectional images of the human body. Researchers organized and integrated these digitized images in a large database and developed the technology to present them as animated visualizations of human anatomy. The company also:

- received the Smithsonian Award from *Computerworld* magazine in 1994, for the use of information technology in the field of medicine;
- received the Award of Excellence in Animation from the Association of Medical Illustrators in 1995;
- was a finalist, together with Walt Disney Studios, in the International ANNIE Awards category in 1995, for best animations in the film industry;
- produced and started offering the Virtual Human software, to run on a Silicon Graphics workstation, in June 1995;
- adapted the Virtual Human technology for three CD-ROMs using dynamic 3D visualization and for two publications, all of which are now on the market;
- incorporated the ATP-funded technology in the tools EAI uses to provide custom modeling in biomedicine, health education, and custom animation;
- raised $30.5 million via an initial public stock offering in February 1996;
- opened international offices in 1997 and 1998, in England, France, Germany, Italy, and Malaysia;
- received one of the 25 Technology and Innovation Awards from *Industry Week* in 1996;
- entered into an agreement in January 1997 to develop software that supports Endovascular Technologies' Endovascular Grafting System — a less-invasive, less-costly alternative to open vascular surgery that should lead to lower mortality, fewer complications, shorter hospital stays, and quicker recoveries;
- raised another $26.6 million via a second public stock offering in June 1997;
- was named one of "America's Fastest Growing Companies" by *Individual Investor* magazine, September, 1997;
- had its CEO, Matthew Rizai, recognized as one of the best entrepreneurs of 1997 by *Business Week* magazine, January 12, 1998; and
- was recognized as one of the 100 most dynamic technology companies in the US — with a rank of number eight — by *Forbes ASAP* magazine, Feb. 23, 1998.

COMMERCIALIZATION STATUS:
The new computer visualization and computational dynamics technology developed in this project has been successfully commercialized. Though an early product called the "Virtual Human" was not commercially successful because it could only be run on a very expensive work station, much of the technology was adapted for three CD-ROMs and two print publications and has also been used to create CD-ROMs that supplement medical books and are sold as a bundled package. Increased sales of medical books are attributed to the CD-ROMs. Software to support open vascular surgery is being tested and has shown promising results. This rapidly expanding company is now active in a multiplicity of applications featuring 3D animations which utilize computer visualization and computational dynamics.

OUTLOOK:
Further potential applications of the technical capabilities developed in the ATP project — and extended by subsequent research and product development — appear abundant. When a reduced-price hardware/software system to support the Virtual Human technology becomes available, potential economy-wide benefits should be large as a result of likely wide-spread use of the technology in health care.

Composite Performance Score: ★ ★ ★ ★

COMPANY:
Engineering Animation, Inc. (EAI)
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Phone: (515) 296-9908

Number of employees: 20 at project start, 400 at the end of 1997

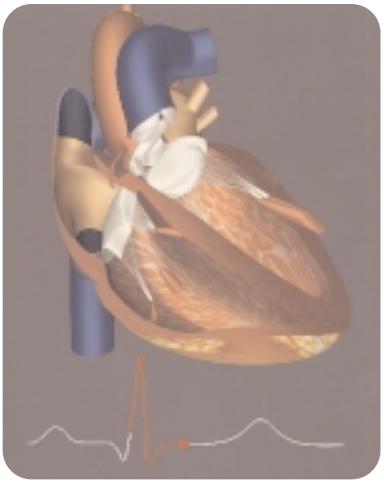
Informal collaborators: The Mayo Clinic, Biomechanics Laboratory; Johns Hopkins University

The realism of these images was achieved by using new databases with digitized, two-dimensional (2D) images showing cross-sections of human cadavers from head to toe. Several organizations provided these databases, including a highly detailed one from the National Library of Medicine. Using newly developed methods to combine 2D images, the researchers put together a complete 3D representation of the human body, including the exterior and all distinct interior parts.

With its ATP award, EAI developed large databases with detailed, digitized images of a generic human body and the associated technologies for storing and accessing the information. The project succeeded in depicting the whole body (male and female versions) as a 3D computer-generated image, as well as separately showing each interior part — bones, muscles, heart, lungs, brain and so forth.

Software Tools Commercialized

Substantial commercialization has been achieved and further effort is under way. After making sufficient progress on the research and development work of the ATP project, EAI used its own funds to combine the new technology



A snapshot of the beating human heart shown with the output of an EKG, at one point in time. In use, both are dynamic — the heart beats in time with the EKG, so medical students can visualize the relation of the beating heart to electrical impulses captured by the EKG.

and databases with its existing software in a new product — the Virtual Human — for use in medical training. The company began offering the Virtual Human at the end of the ATP funding period but was unable to sell a single copy of it because the hardware was so expensive. The costs for setting up the system using a Silicon Graphics workstation and the Unix operating system ran as high as $100,000. The company delayed commercialization of that product to modify the software and databases to operate on lower-cost personal computers running the Microsoft NT operating system. The company has recently successfully converted other products to run on the lower-cost systems, and is on track to do the same for products derived from the Virtual Human product.

. . . 20 employees at project start, 400 at the end of 1997 . . .

In the meantime, much of the ATP-funded technology that went into the Virtual Human has been adapted to three CD-ROMs (The Dissectable Human™, The Dynamic Human™, and CardioViewer 3D™) and two medical books which use unique prints showing layers of body parts. All five products are now being marketed by Mosby-Year Book, a subsidiary of Times-Mirror. In addition, EAI has formed an alliance with Elsevier Science to create 3D multimedia titles in the neuroscience area. These products have achieved several of EAI's original marketing objectives and have been used successfully in training medical students. One professor who used The Dynamic Human™ as a teaching aid reported that her students "seem to retain more information after using this visual tool" and "are more excited about anatomy and physiology when the material is viewed with 3D animation and graphics on a computer screen."[1] The company has also incorporated its ATP-funded technology, both the anatomical database and the motion capability, in the tools it uses to provide custom modeling in biomedicine, health education, human body animation, and entertainment.

EAI is especially interested in offering its software as training tools for surgery via laparoscopy (for example, using a laparoscope to look into the abdomen) or other less-invasive surgical procedures. One candidate for this type of treatment is abdominal aortic aneurysm, which afflicts 1.5 million people in the United States each year. If left untreated, the aorta can rupture, usually causing death. This type of open-surgery repair has a morbidity rate of 15 percent to 40 percent.

In January 1997, EAI entered into an agreement to develop software that will support Endovascular Technologies's Endovascular Grafting System, a less-invasive, less costly alternative to open vascular surgery that should lead to lower mortality, fewer complications, shorter hospital stays, and quicker patient recoveries. The software will automatically calculate key aortic measurements, based on actual CT (computerized tomography) data, and enable doctors to walk through a patient's anatomy on the computer. The software allows doctors to identify structures, discern damaged and healthy tissue, and determine a patient's condition without performing invasive procedures. This application is directly dependent on the technology developed by the ATP project.

Better-Trained Doctors

The CD-ROMs and books developed or bundled with the new technology and databases have benefited anatomy and physiology students. The successful modification of the Virtual Human product for less-expensive computers, which will bring down the cost of the complete system, has the potential for creating large economy-wide benefits.

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In many areas of surgery, less physically invasive procedures are replacing traditional techniques. Angioplasty, for example, can often be used instead of open surgery to repair blood vessels. If the Virtual Human proves valuable in training for these and other surgical techniques, then less-invasive procedures would likely be used more often in surgery. And by reducing the need for painful, highly

A person's body is more than just the "dry bones" of the skeleton; here the heart and major arteries and veins are shown in their proper places within or alongside the bones.

invasive surgeries, the ATP-funded technology would lower the costs and improve the quality of health care. If this happens, the value of the resulting benefits will be counted in the hundreds, possibly thousands, of dollars for each patient treated by a doctor trained with the system — and could amount to life itself.

Transition from Consulting to Software Products

At the beginning of the ATP award period, June 1992, the company had 20 employees. By the end of 1997 it had 400 employees, and near the end of 1998 it had more than 900. Total revenues in 1992 were $1 million. By 1994 they had grown to $5.5 million, and in 1996 they were $20.4 million. By 1997, after accounting for mergers, revenues had grown to $49.7 million.

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EAI reports that the ATP project was a huge part of this commercial success. "This cost sharing enabled us to assemble technology," said Dr. Martin Vanderploeg, EAI executive vice-president, in 1994 during the ATP project. "The award was a major event that launched us into this growth phase," he added. In 1994, EAI's total expenditures on research and development were $869,000, and in that year it received $564,000 from its ATP grant, about 65 percent of its total research and development budget.

When it applied for the ATP grant in 1991, EAI's only revenues were from consulting fees for providing support in court cases, and it had no software products on the market. By 1997, it was no longer reporting this line of business separately, and its computer animation software products had become its major activity.

The company has since its inception sought to exploit synergies among all its technological assets, continually seeking ways for the company's product lines to benefit from and build upon each other. For instance, it utilizes its 3D visualization software products internally, to improve its ability to deliver high-quality, interactive animation software products, such as CD-ROM medical education products, in a timely manner. But the flow of technology works in the other direction as well, according to company publications, because it is continuously modifying and enhancing the 3D visualization software as it develops new interactive software products.

Awards for Technical Achievements Roll In

EAI began to receive awards for its technical achievements in 1994. In that year, it received the Smithsonian Award from *Computerworld* magazine for the use of information technology in the field of medicine. The next year, it received the Award of Excellence in Animation from the Association of Medical Illustrators, and was a finalist, together with Walt Disney Studios, in the International ANNIE Awards category for best animations in the film industry. And in 1996, EAI was one of 25 recipients of the Technology and Innovation Award from *Industry Week*, specifically for its interactive 3D visualization and dynamics products used in the manufacturing sector for product development.

ATP Funding Plays a Crucial Role

According to EAI officials, the company would not have been able do its research and development work without the ATP funds. The award enabled EAI to establish collaborations with the Mayo Clinic and Johns Hopkins University, and work performed during the ATP project facilitated collaboration with the National Library of Medicine on a later project. And it enabled the company to significantly extend its capabilities in computer visualization and computational dynamics, providing new technology that could be applied to other areas of the company's activities.

Having the award and doing the project also made EAI more attractive to potential investors. This was crucial in the early years of the company. In a 1995 interview with a reporter from the *Wall Street Journal*, Matthew Rizai, CEO of the company, noted that winning the ATP award — which was for $1.9 million — gave him leverage with

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private investors, from whom he raised an additional $1.5 million. And the company says the ATP grant continued to be important to investors as it conducted its initial public stock offering in February 1996, a few months after the ATP project ended, raising $30.5 million.

Outstanding Commercial Performance

The company's recent rapid growth, accomplishments, and recognition received are impressive. Over the past 10 years it has emerged from the ranks of start-up to a company employing nearly 1,000 people. It has made the transition from a company heavily dependent on consulting revenues to one which relies on high-value software products. Its success has depended substantially on the internal integration of all its technical assets to develop new products in a variety of fields that draw on its technologies for very large database manipulation and visualization of motion, and on its belief that the company can succeed only if it brings those new products into the market.

In the September 1997 issue of *Individual Investor* magazine, EAI was named one of "America's Fastest Growing Companies." And, early in 1998, two additional magazines recognized the company's achievements.

Awards for technical achievements roll in.

Business Week magazine, in its January 12, 1998, issue, recognized Matthew Rizai, the company CEO, as one of the best entrepreneurs of 1997, and *Forbes ASAP* magazine, in its Feb. 23, 1998, issue, recognized the company as one of the 100 most dynamic technology companies in the United States — with a rank of number eight.