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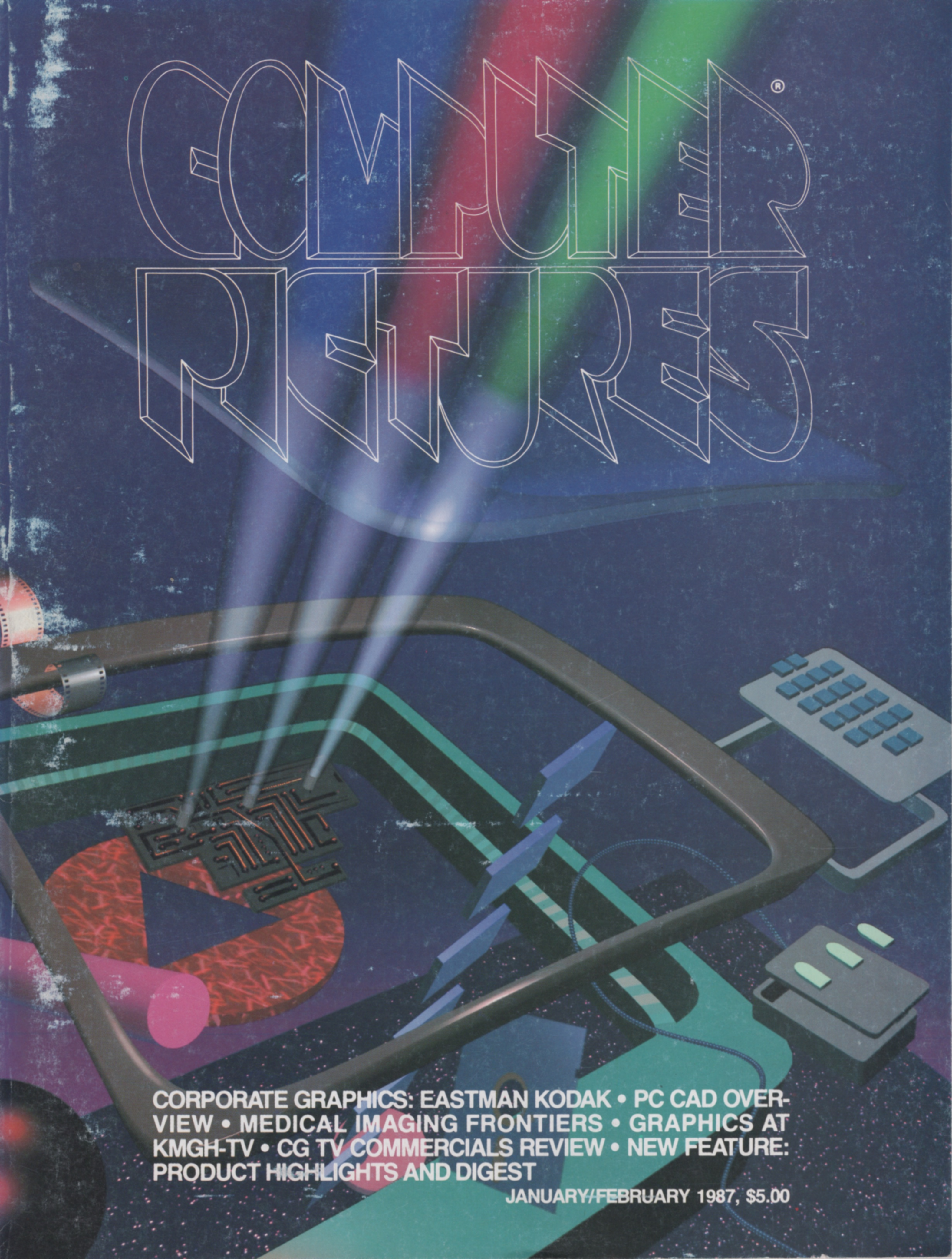

CORPORATE GRAPHICS: EASTMAN KODAK • PC CAD OVERVIEW • MEDICAL IMAGING FRONTIERS • GRAPHICS AT KMGH-TV • CG TV COMMERCIALS REVIEW • NEW FEATURE: PRODUCT HIGHLIGHTS AND DIGEST

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AT THE FRONTIERS OF MEDICAL IMAGING

New computer graphics tools and techniques have taken some of the art out of the science of traditional medical practices such as diagnostics and reconstructive surgery.

By Abigail Christopher

Charles Csuri and Flip Phillips at Ohio State University's Computer Graphics Research Group have been experimenting with automated image processing and segmentation software. Here, the brain and skin of a patient based on CT data.

"If you have to move a bone from the back of the head to the front of the head, you can't take chances. You have to be sure about what you're doing," explains Dr. Court Cutting, a plastic surgeon who is an associate professor at New York University.

Dr. Cutting, like a number of other medical specialists, has developed a medical modeling program for pre-operative planning using the latest three-dimensional computer graphics modeling techniques.

Across the industry, tools such as the Cemax 1000 image processing system, the Pixar Image Computer and the Silicon Graphics IRIS 2400 workstation are changing the way doctors do their business, taking some of the "art" out of the science of surgery and educated guesswork out of neurology.

Reconstructive facial surgery, the custom design of artificial limbs, mammography (or breast cancer diagnosis) and thermography are some of the most outstanding examples.

VOLUMETRIC RENDERING

Perhaps the most significant change to have come about in medical imaging in the past year has been the ability to create true three-dimensional models based on data from sources such as CAT scans and thermography.

Traditionally, 2-D data has been conceptualized in 3-D by radiologists and doctors who have developed a trained eye. Now, however, with the advent of "volumetric rendering" or true 3-D medical imaging, the data can actually be used to present a 3-D model on the screen which can then be interactively manipulated through conventional 3-D animation techniques.

According to Dr. Parvarti Dev of Cemax Medical Products (formerly Contour Medical Systems), "two years ago, the computational speed required to do the 3-D imaging wasn't available.

With the greater memory and processing speed of systems such as the Pixar, we are developing the sophisticated software programs necessary to create the 3-D images."

The Pixar is a pixel-based, programmable general purpose computer that generates and manipulates large digital images, combining computer graphics and image processing techniques.

It processes high-res picture data at 40 million instructions-per-second (ips) using four parallel processors integrated with a large high resolution memory.

The result is the ability not only to perform complex rendering tasks, but to do image processing and computer synthesis in real time.

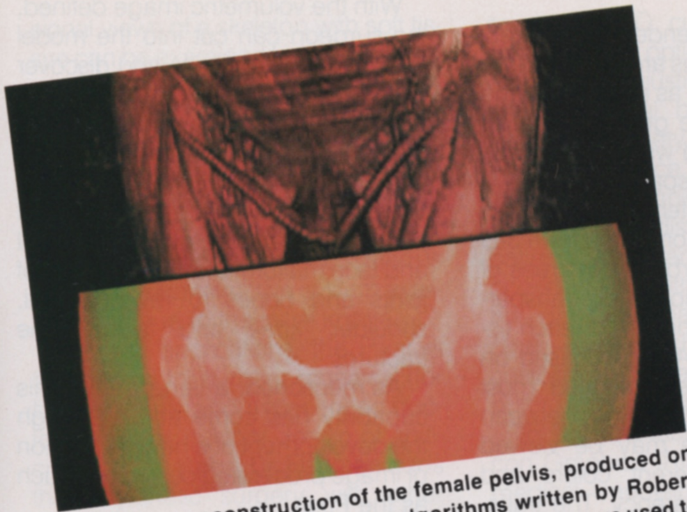
According to Dr. Dev, "there is no commercial volume imaging out there right now—no one is doing volumetric imaging commercially." However, volume imaging techniques for systems such as the Pixar, Silicon Graphics IRIS and Cemax 1000 are just around the corner.

This spring, Philips Medical Systems, part of the N.A. Philips Company and a major medical systems integrator, established marketing agreements with Pixar and Cemax, and bought 10 percent of Island Graphics in order to support research and development for 3-D medical modeling software. Johns Hopkins and the University of Rochester Medical Center are both sites supported by Philips for the development of medical software for the Pixar.

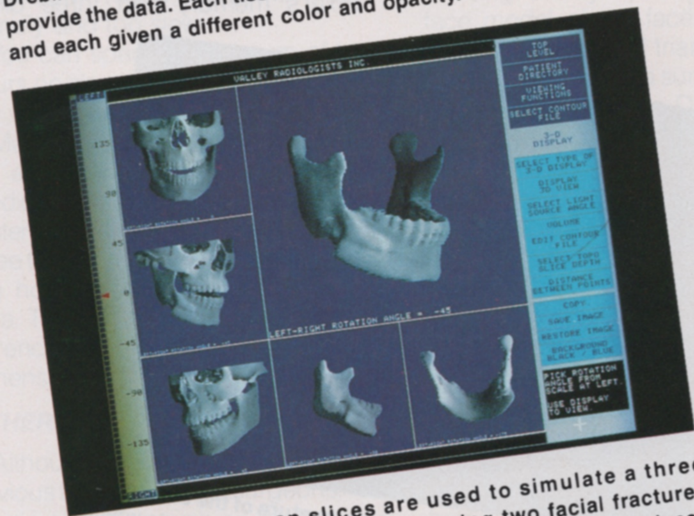
IMAGE PROCESSING REQUIREMENTS

What makes the software development so tricky, and why such computational power and memory are required, is that medical imaging requires extensive image processing in addition to basic 3-D modeling techniques.

The distinctions between computer graphics modeling (in which a syn-



The Volume reconstruction of the female pelvis, produced on the Pixar image computer from algorithms written by Robert Drebin and Loren Carpenter. Forty-nine CAT scans were used to provide the data. Each tissue type can be processed separately, and each given a different color and opacity.



Individual CAT-scan slices are used to simulate a three dimensional view of the skull, showing two facial fractures received during a water skiing accident. Images were produced on the Cemax-1000 by Three-Dimensional Computer Imaging.

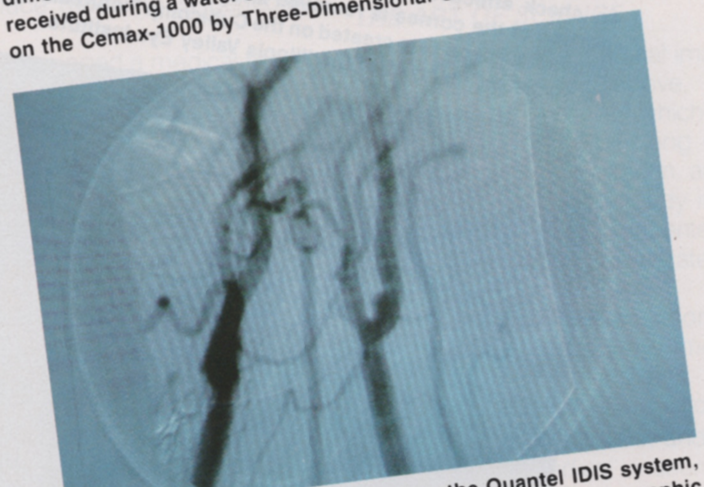


Image of blood vessels produced on the Quantel IDIS system, derived from digital subtraction of data based on fluorographic scanning. The display is presented in real time, permitting use during actual surgery.

thetic object is defined in the database through vertex definition), and image processing (which manipulates and enhances data from a source such as CAT scans or x-rays), had already begun blurring in 1983 with the advent of 3D image processing software such as General Electric's GE3-D83 and GE3-D98 and Siemens 3-D CT running on image processing hardware such as the Cemax 1000.

Image processing systems with 3-D capabilities allow doctors to simulate the surface of a body part such as a bone by adding multiple CAT scans or other x-ray data together.

The basic CAT (computer-aided tomography) or CT scan, developed in the mid-1970s, takes its name from the Greek word tomos—to cut or slice—and refers to the CT scan's ability to provide the physician with views of the body or an organ as if cut into slices—an interior view of the brain, for example, showing the concentric structure of the medulla, cerebellum, and cerebrum.

At the same time the resulting view can be image processed so that extremely fine details can be detected, down to a couple of millimeters.

To create the basic view, a series of x-rays is passed through the body or organ and picked up by a scanner on the other side.

But rather than sending a single beam of rays picked up by a single imaging system (a sheet of film in the conventional x-ray system), the CT-scan repeats the scanning process hundreds of times, shooting the beam from source to scanners through the body from every conceivable angle.

The computer then processes the scanner data, using an absorption table which indicates the specific x-ray transmission/absorption properties of each type of tissue (x-rays pass virtually unchanged through water, but are almost completely absorbed by bone, while other tissue types lie in between).

Because the imaging is done from so many different angles, by manipulating the absorption data from successive scans the CT computer can derive an absorption value for each small area being studied, and in the cross-section slice can display each type of material—soft tissue, bone, or different types of soft tissue, as a different color or grey-scale value.

By adding multiple slices together, the 3-D image processing system is able to simulate a 3-D view of the body part.

The boundaries of the body part to be examined are determined by extracting data about bone and soft tissue and using the data to define a polygon.

The system goes through the multiple CAT slices and displays the outline polygons as a stack of ribbon-like rings (one per CAT scan slice).

The resulting simulation provides a three-dimensional view of the surface of the body part being studied—a bone, for example, or an organ such as the brain.

And it can be rotated and viewed from different angles, revealing surface abnormalities, bone fractures and the like.

LIMITATIONS OF SURFACE RENDERING

The problem with 3-D image processing, according to Dr. Elliot Fishman of Johns Hopkins Medical Center, is that "this kind of 3-D imaging does not present any new diagnostic information to the radiologist since it's based only on a reformation of transaxial slices.

The question often arises as to its clinical utility, and the primary use has been to further understanding of the pathoanatomy of fractures and skeletal structures.

Although these images can be helpful, they are still limited by the user's inability to choose a specific angle or degree of rotation."

Another problem is that although image processing systems running the 3-D software allow users to strip away or remove part of an image (such as a bone in the head) in order to focus on another part of the original data such as the surface of the brain itself, this process takes as long as 45 to 90 minutes per view.

VOLUMETRIC RENDERING ADVANCES

With volumetric imaging software, however, all the data from the CAT scan can be used in constructing a true three dimensional model of the entire body part or organ—not just the exterior shell.

In volumetric rendering, successive CAT scan slices are conceptually stacked up (lofted) as a volume in the computer, and the grey scale information is replaced with gels of varying color and transparency.

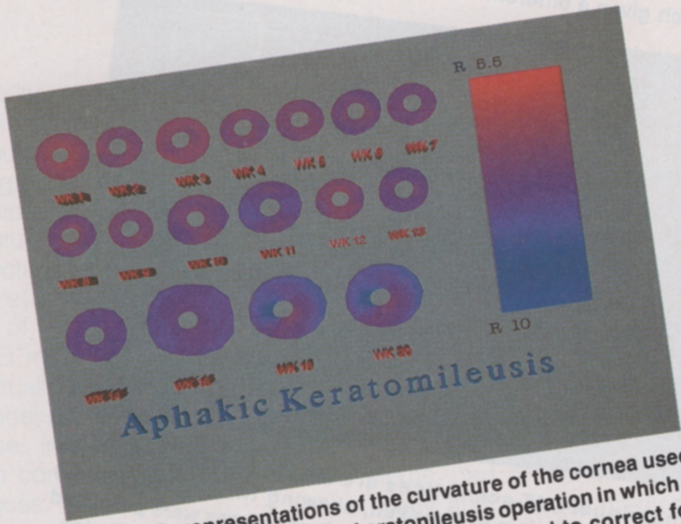
On the Pixar system, color views of a volume can be computed from 3-D angles and with arbitrary degrees of transparency. Color and transparency values are chosen for each tissue type in the CAT scan based on what needs to be examined most closely. The relationships between muscle and bone may be viewed by choosing different colors and degrees of transparency. The transparency or alpha channel of the Pixar supports this kind of volumetric examination.

With the volumetric image defined, the surgeon can cut into the model with an imaginary knife and discover all of the layers of the model which were present in the original scan. And the work is performed interactively, often in real time.

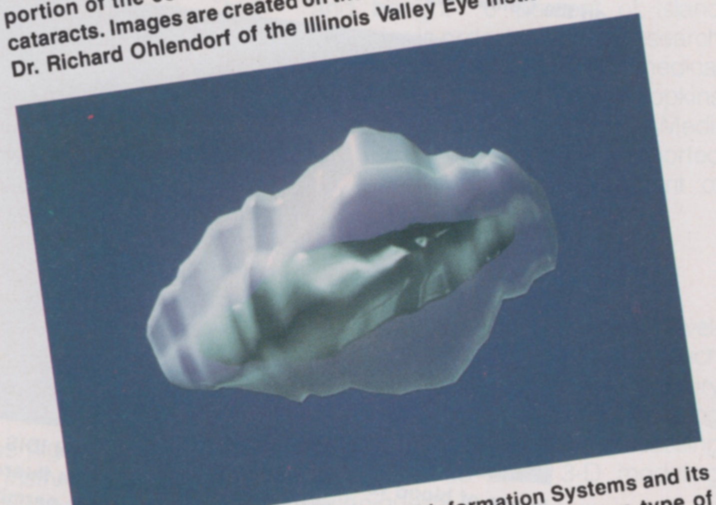
Applications range from pre- and post-operative assessment of skull and face malformations to displays of joints and bones to reveal spinal, shoulder, knee and facial bone fractures.

As mentioned, a large part of this capability has come about through the development of a new generation of image processing computers such as the Pixar.

For example, all the information from a CAT scan can be stored in the Pixar's memory and three dimen-



3-D graphic representations of the curvature of the cornea used to check effectiveness of a keratonileusis operation in which a portion of the cornea is removed and reshaped to correct for cataracts. Images are created on the Cubicomp PictureMaker by Dr. Richard Ohlendorf of the Illinois Valley Eye Institute.



3-D computer animation for Visual Information Systems and its client Roche Laboratories to demonstrate Roferon, a type of interferon. Fantastic Animation produced the 2.5 minutes of animation which includes a transparent model of a cell, DNA, and here, a leucocyte (white blood cell).

sional views of a skeleton with soft tissue can be examined from any angle.

Although nothing is commercially available yet, 3-D medical imaging programs for the Pixar have already been developed at beta and R&D sites. At Johns Hopkins, Dr. Fishman is using the Pixar for orthopedic applications, and reports that the system is "the best reconstructive system available. It is true to the initial image. . . ."

In these applications, the Pixar is being used for surgery rehearsal (for both students and experienced doctors) and the custom design of artificial hips and limbs. Dr. Fishman adds that "synthetic surgery with other systems (such as the Cemax 1000) is impossible. Other systems are too expensive ($250,000), not user friendly and too slow.

You can spend a minimum of two hours on one patient for work eventually used in real time applications."

Maureen Jones, a medical illustrator at the University of Rochester Medical Center, adds that the GE 3-D system that the center has used for three to four years can take as long as five hours to recomposit CAT scan data. The Pixar generates color transparencies of anatomical data in three dimensions very quickly."

OTHER 3-D TECHNIQUES

Although volumetric rendering is of obvious benefit to some surgeons, for plastic surgeons such as Dr. Cutting, described at the beginning of this story, surface modeling is perfectly adequate.

He has developed a medical modeling program using CAT scans on the Cemax 1000 to create 3-D pictures of the face and scull.

For the past two years, Dr. Cutting has had the ability to download the 3-D surface image of a patient's face to the Silicon Graphics IRIS 2400 where it can be manipulated in real time "just as you would in the operating room," Dr. Cutting claims.

He explains that the 3-D data allows him to simulate incisions from ear to ear, pulling the soft tissue over the bones and making a series of cuts in the facial bones.

Because such procedures will make a patient's face swell, it is hard to preplan. With his 3-D surface modeler, Dr. Cutting can "cut up the face; create it in 3-D; cut it up in 3-D; and simulate the optimal movement of bones by adjusting measurements between facial bones precisely to match the variety in structure found from face to face."

In his technique, Dr. Cutting minimizes the distance between the patient's facial "landmarks" while reconciling them with an ideal model of the particular patient's features. In other words, each patient requires a customized operation which the computer helps plan precisely.

To support facial surgery, the Silicon Graphics IRIS and Dr. Cutting's medical modeling software allow plastic surgeons to "make a mosaic of the surface of the face."

Using an eye point on the surface model of the face, Dr. Cutting develops a mesh of triangular tiles—"the smallest unit of a surface you can create," according to Dr. Cutting. To this triangular tile surface model, Dr. Cutting applies Gouraud shading.

This combination of techniques connects the polygons generated by the original CAT scan, providing a much clearer picture of the patient's facial tissue and bones. Dr. Cutting adds that the SGI system's fill polygons, shading and ability to rotate images quickly in free space and interactively look at the image from any point of view might land the system in the operating room one day to help "guide the manipulation of facial bones through an actual operation."

THE ART OF SCIENCE

In addition to the medical imaging advances described above, there is another frontier at which 3-D computer graphics is making major headway: medical illustration, an outgrowth of techniques already in use for applications such as entertainment animation and corporate presentations.

At Cranston/Csuri Productions, for example, Don Stredney, medical illustrator/animator, creates 3-D medical animation for doctors, pharmaceutical companies and manufacturers of medical instruments. Stredney creates sectioned models of the body from scratch using computer animation.

He has done modeling in a number of ways over the past three to four years, starting with plaster of paris molds of individual organs. These models were digitized into a computer and eventually formed a database of the human anatomy that could be animated. This was done to great effect in "The Body Human," a multi-part television series.

Cranston/Csuri has since changed its medical modeling approach, relying almost entirely on computer animation (without plaster of paris models) to describe various surgical techniques and how pharmaceuticals affect the body. For Mount Carmel Hospital, for example, Stredney illustrated the PTCA technique for unblocking arteries using balloons inserted into the blocked blood vessels. Stredney actually witnessed an operation in order to document it for surgeons, medical students and manufacturers of surgical equipment.

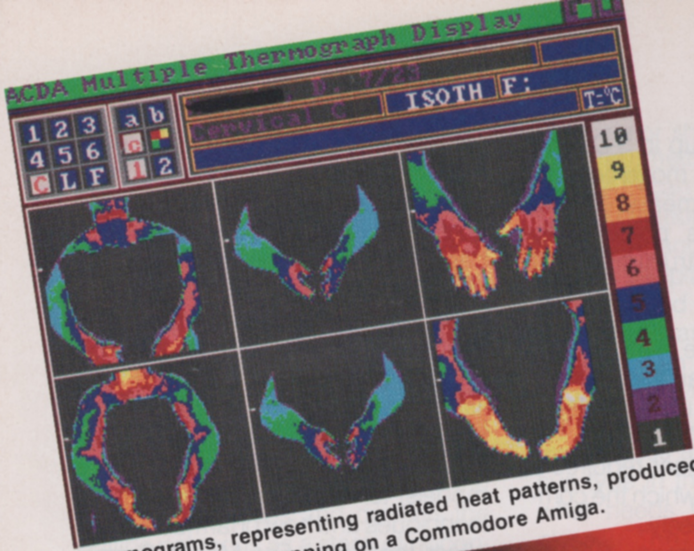
Cranston/Csuri was also contracted to document the effects of a drug designed to "reverse digatoxcisity." Burroughs Welcomes, a major pharmaceutical company worked with Stredney to illustrate the effects of the drug on the heart. Stredney reports that he had to ask the company's pharmacists a lot of tough questions about ions' effect on different pumps in the cell membrane. The major problem in this project was how to illustrate compressing and decompressing time in the molecular structure.

MEDICAL IMAGING WITH PCs

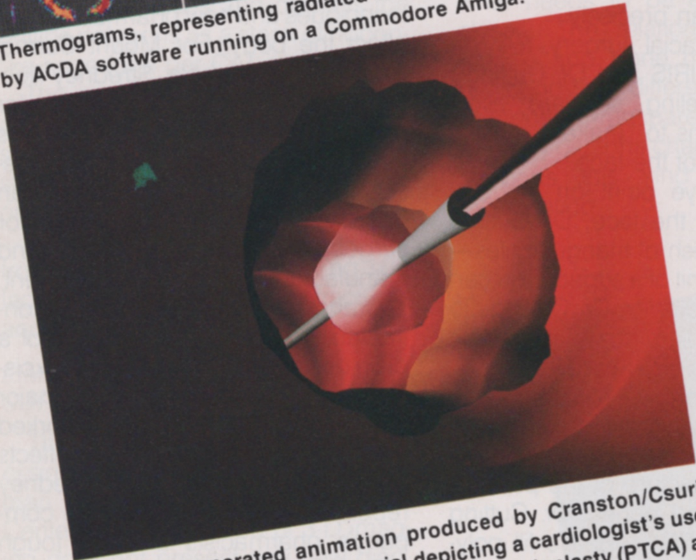
Still one other development in medical imaging must be mentioned: the growing use of the personal computer to support image processing techniques such as those associated with thermography—the ability to sense and display variations in temperature across the surface of the body, scanned into the computer through an infra-red sensitive camera.

Variations as little as 25 percent in the temperature of the skin can indicate tumors lying beneath, especially in areas such as the breasts, and the computer can be programmed to show each temperature range in a different color, instantly alerting doctors if something is wrong.

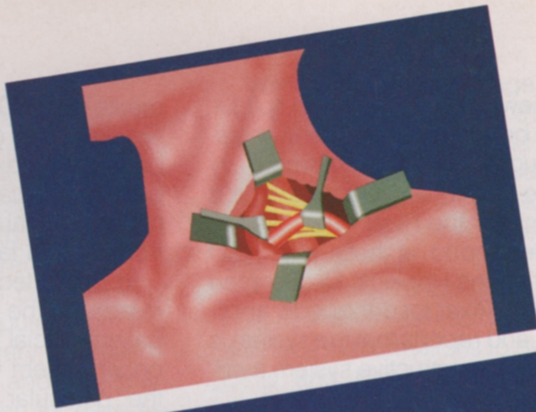
The work has been done traditionally with large and expensive

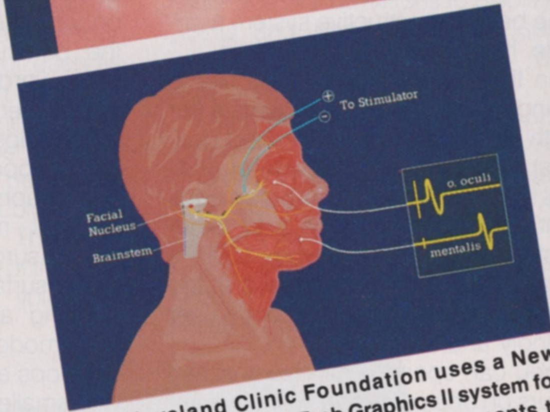


Thermograms, representing radiated heat patterns, produced by ACDA software running on a Commodore Amiga.



Computer-generated animation produced by Cranston/Csuri Productions for a TV commercial depicting a cardiologist's use of a Percutaneous Transluminal Coronary Angioplasty (PTCA) at Mount Carmel Hospital. The device is a catheter tube that inflates and opens blockages in coronary arteries.





The Cleveland Clinic Foundation uses a New England Technologies Tech Graphics II system for a variety of medical illustration assignments to support its staff of 500 doctors, researchers and other professionals.

The "beating heart" animation provided SIGGRAPH attendees this year with a taste of what can be achieved using the Pixar Image Computer in conjunction with a software package such as that from Symbolics. NMR data captured over time provides the data input showing the heart and its blood vessels. Insert shows image processed magnification of portion of data, performed with bicubic interpolation software.

systems.

With new programs coming onto the market from companies such as ACDA, a medical equipment development company in New York City, even the Commodore Amiga can generate images of acceptible quality to the medical community.

Besides the infra-red camera, the system uses a frame grabber developed by A² for the Amiga and enhances the readings with an Amiga paint program.

ACDA is also using the Amiga for other medical thermographic projects, including contracts with UPS and the Long Island Railroad, companies anxious to determine the physical limitations of their employees or potential employees. These companies are also hit with a number of law suits resulting from on-the-job injuries, and by pre-diagnosing employees using medical thermographic systems, they hope to place the right people in the most physically demanding jobs to cut down on accident claims.

Still another ACDA project is a real-time 3-D system for the Amiga that would allow doctors to hang patient-specific information from an ideal anatomical model rather than using abstract contours and wavelines to determine diagnoses. In various configurations supported by American Infrared Systems of Sweden, the Amiga-based thermographic systems range in price from $22,000-$35,000, including image processing, image storage, the A squared frame grabber (customized for the Amiga and compensating for its non-standard video signal recognition), proprietary software and hardware.

And so, medical imaging, like so many other areas of modern technology, is once again undergoing an upheaval thanks to the advent of ever-faster and ever-more-powerful computers and workstations.

Whether the entire industry can be eventually expected to swing over to PC-based systems remains doubtful, given the enormous amount of processing required for techniques such as volumetric rendering.

But both PCs and workstations will find an expanding role in the hospital of the future. □

Abigail Christopher is a Berkeley CA-based writer and consultant in the computer graphics field.

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