Applications 2000

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Applications have driven the development of computer graphics from the beginning. With so many original technical objectives achieved, the coming decades will likely see a greater emphasis on graphics applications, both taking advantage of these technologies and motivating new ones.

The problem with predicting the future in this fast-moving area is that most "predictions" are already true. That said, let's explore a selected set of application domains and speculate on what the next few years may bring.

Science

Astronomy: Acquisition of images is a central objective of modern astronomy and interplanetary exploration. The Cassini mission to Saturn, three upcoming Mars Surveyors, and the planned Europa Orbiter and Pluto-Kuiper Express will send many exciting new images to Earth. New observatories of unprecedented size and power, such as the Keck in Hawaii, use segmented mirrors, multiple telescope interferometry, and adaptive optics to overcome atmospheric perturbations. Their images will rival the Hubble Space Telescope, itself to be outdone by the Next Generation Space Telescope planned for 2007. The discoveries of extraterrestrial life and perhaps intelligent life, if they occur, will first be observed by someone looking at a graphics display.

Chemistry: Chemists have always used graphics for molecular models and now routinely manipulate and view complex 3D structures in real time. As in many other application domains, the trend is toward increasingly detailed chemical and physical models driving the already well-rendered depictions. Protein folding problems will be solved using interactive simulated annealing to visualize tertiary molecular structure. Tools for designing and predicting properties of new drugs and polymers will dramatically shorten development cycles.

Biology: The Human Genome Project is nearing completion, facilitated by advanced graphics systems for DNA sequencing. The focus of genetic analysis will shift to interpretation of these vast data sets using software for identifying genes and corresponding gene therapies and vaccines. Fully digital, remotely controlled scanning electron microscopes will employ low-temperature and immunochemical labeling techniques to push the envelope in imaging biochemical structures.

Health and medicine: High-speed Internet connections will enable remote diagnostic image reading and consultation. Advanced VR systems will let doctors perform and assist in remote surgical procedures. Surgeons will use head-mounted displays to overlay diagnostic images, patient monitoring, real-time probes, and protocol checklists during operations. Increasingly detailed simulation systems will become powerful tools in medical training. The wireless, pilotable microscopic camera will enable major advances in diagnosis. Digital X-rays will become more cost effective than film. Multimodal imaging devices will create diagnostically useful functional images. The first successful artificial eye systems will be developed.

Physics: Automated analysis of images from the recently completed joint Japan/US Super-Kamiokande neutrino detector will demonstrate that protons decay, as predicted by the Grand Unified Theory. Images from Fermilab's new Tevaton accelerator will lead scientists to refine the Standard Model of subatomic particles. Tera- and peta-byte visualization systems will emerge for aeronautics, space, and earth sciences applications.

Mathematics: Mathematicians will increasingly use visualization tools to form, model, and explore hypotheses, giving rise to new classes of theorems. Researchers will prove $P \neq NP$ using computer-based graph theoretic proofs similar to those used for the Four Color Theorem. New research will focus on geometric and topological problems motivated by massive integrated circuit design and extreme miniaturization assembly.

Environment

Meteorology: Reliable 30-day weather prediction for anywhere on earth will be Web-accessible, with news weather broadcast display quality. Accurate simulation of hurricane tracking and landfall prediction will save countless lives, as will similar techniques for tornadoes, tsunamis, thunderstorms, and air turbulence.

Geology: Ground-penetrating radar and advanced sonagraphic techniques will enable more reliable exploration for oil and gas as well as other natural resources, including precious metals and fresh water. The first useful earthquake prediction displays will appear.

Oceanography: Satellite imaging of ocean levels, temperatures, and currents will greatly increase the accuracy of climate prediction, leading to more accurate crop

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yield prediction and prescriptive agriculture. After the success of undersea robots and sonar imaging in finding the Titanic and Gus Grissom's Liberty Bell 7 space capsule, Amelia Earhart's airplane will be next.

Agriculture and land use: Farming simulations will permit greater precision in selecting crop varieties and planting schedules. Forest fire models combining satellite imaging data with weather measurements and simulation will facilitate forest fire prediction, tracking, and optimized firefighting strategies. Robotized VR systems will enable safer analysis and environmental clean-up at hazardous sites.

Entertainment and the arts

Movies: Synthetic actors are already here. Soon, realistic synthetic rendering of recognized actors will become possible and used to create stunt doubles, fix missing or incorrect scenes, and save expensive actor time. Seamless merging of different takes, facial expressions, and movements will further reduce filming costs. Public personalities will license their synthesizability as an asset and file lawsuits over control of their likeness. The "film" industry will go fully digital, with cameras, editing, and theater projection all dispensing with celluloid, with the same quality (and sales) increase as CD-based music. These same trends will overtake personal photography. Real-time video processing will resurrect "in-camera" special effects.

Television: Whoever said "500-channel TV" was the future missed by a lot: the combination of all-optical, high-speed Internet for the home; ubiquitous, inexpensive cameras; and HDTV-quality streaming will lead to multimillion-channel TV. As many ordinary people will broadcast live and authored TV content as have personal Web sites now. Viewers will control their own instant replay, viewing times, interruptions, and camera-angles for entertainment and sports events. Broadcasters will become service providers, with every TV show (and movie) digitally accessible on demand. Commercials separate from TV content will give way to in-place commercial placements and reprogrammable advertising.

Games and amusements: Alvy Ray Smith's "reality is 80 million polygons per second" is almost here with the newest 3D game rendering chips. Soon we will have real-time TV- and even movie-quality synthesis. The movie and game industries will converge, with the same content, models, rendering, and motion capture reauthored for both passive and (inter)active viewing. Game companies will fund computer graphics research, bringing greater focus on real-time performance and interaction versus today's photorealism emphasis.

Sports: Precision 3D measurement, vision, and kinesiology systems will enable the first practical referee's assistants and automated scoring (and no doubt more controversy). Real-time measurement of parameters like height and duration of jumps and moves will enable comparison to standards and past performances. Exercise equipment will integrate automated coaching (and nagging) as well as fun VR and game technologies.

Fine arts: Image fingerprinting, watermarking, and microanalysis will create reliable forgery detection and theft deterrence for collectors plus copyright protection, distribution, and revenue capture for artists. Microeconomic payment and royalty systems will expand pay-per-use and subscription-based TV, film, books, music, theater, and art. Dance will be taught, transcribed, and analyzed using sports-automation systems.

Archeology: Accurate immersive models of lost or destroyed historical venues are already under way and will extend to recreating historical events and people. Optical, holographic, and thin-film recording techniques will enable permanent archiving of photographic, film, video, and audio recordings.

Other industries

Publishing: Everything than can go digital, will go digital: slides, photos, movies, videotape, and books. Digital books will not displace paper books but will find important niche uses for temporary or time-sensitive data. The number of pixels online on the Web will exceed all pixels previously published.

Manufacturing: The future is already here in many industries where design, prototyping, machining, assembly, inspection, testing, and repair all rely on graphics systems. 3D measurement systems will permit inversion of real objects back to CAD models, creating an explosion of custom-fit, ergonomically optimized goods, exact replacement parts, and perfect replicas.

Transportation: Computer graphics-enabled cars are already here, with heads-up data displays, in-car entertainment, navigation aids, night vision systems, and collision avoidance systems. Miniature cameras will begin to perch atop streetlights and telephone poles, permitting drivers to call up real-time views of the traffic ahead. Computerized instrumentation and control will give us totally "drive-by-wire" cars.

Military: Computer vision-enabled precision-guided munitions, reconnaissance satellites, GPS tracking of machines and personnel, electronic warfare and countermeasures, and advanced radar imaging are standard military capabilities. Under development are a host of unmanned and remotely piloted flying and land-based vehicles. Spycraft, already deep into satellite imagery and electronic intelligence gathering, will extend to ground-based systems such as miniaturized infiltrators for covert, siege, and hostage situations.

Business: The paperless business transacted today exceeds all paper-based business of 10 years ago. E-commerce is about to compound this gain multifold. The "killer app" for VR will be virtual shopping. High-speed, ubiquitous Internet connections will finally lead to useful collaborative applications and teleconferencing.

Whither applications

Affordable real-time 3D graphics is here. Cameras capture a world of images. The Web enables vastly more pixels to flow anywhere. Processing power allows computer graphics, image processing, and computer vision to converge, all driven by real (application) data. 3D images, animations, and interactions mirror our real world. For all these reasons the future of computer graphics will be full of applications. ■

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