ty of Tsukuba, and other schools.

And more are on the way. Megumi Takata, director of the Center for Advanced Science and Technology Incubation Ltd. (CASTI), the licensing organization affiliated with the University of Tokyo that helped to set up Effecter, expects another company to be formally established this year and several more by next spring. Officials of the licensing organization affiliated with the University of Tsukuba know of at least three groups working on business plans. And Biofrontier's Ohtaki says he is getting inquiries "from all over Japan."

These new entrepreneurs are taking advantage of a raft of changes in government policies. "There wasn't just a single bottleneck," says Ohtaki. "It was more like a jigsaw puzzle with too many pieces missing." In the past few years financial regulations that made it nearly impossible for start-ups to raise money and offer shares to the public have been relaxed, restrictions on the use of stock options loosened, and tax incentives created for financial "angels" to get behind venture businesses. Earlier this year, legislators enacted what is seen as the Japanese version of the 1980 Bayh-Dole Act, the U.S. law that gives universities the right to commercialize publicly funded research. But there's one big difference: In Japan the rights go directly to researchers. To help national university and institute researchers patent and market their discoveries, the government has also authorized special technology licensing organizations.

Although these regulatory moves are important, scientists say, a shift in attitude among both private sector researchers and university professors will be essential. It's still extremely rare for someone like Murai to give up a well-paying, secure position at a big company for a risky start-up. And even a decade ago it would have been "considered unseemly for academics to engage in commercial activities," says Matsubara. Most faculty at top schools join a university after receiving their doctorate and spend their careers climbing the ladder. Indeed, a pool of retired but still active professors may be a key to success: Kanegasaki says he would not have given up his professorship to start a business before reaching retirement age, and Matsubara also retired before launching his business career.

A distaste for business shows up at every stage of the process. Kanegasaki says opposition from his former colleagues at University of Tokyo's Institute of Medical Science, for example, prevented him from renting lab space for his fledgling company. Many start-ups even try to retain an academic flavor by using "institute" or "research laboratory" rather than "company" in their corporate names. And few professors plan to take their companies public, says Kazunori Kondo, who studies venture businesses at the National Institute of Science and Technology Policy. Such privately held businesses, he argues, are less likely to become powerful engines of economic growth.

Those who break through these prejudices face a different set of problems. Whereas faculty members can license rights to their discoveries, their active participation in private companies is still strictly limited. They cannot serve on a corporate board, for example, although they can serve as scientific advisors. And mid-career moves are still a lot more treacherous in Japan than in the United States, says Takata. "This makes it difficult for the start-ups to find the bench-level researchers they need to turn a discovery into a product," he notes. One bright spot may be the growing ranks of researchers entering the scientific workforce after completing postdoctoral appointments (*Science*, 3 September, p. 1521). An even bigger problem, Ohtaki warns, may be a shortage of managers capable of building companies from the ground up. "There isn't such a pool of managers in Japan now," he says. The only answer, he says, is to start more businesses so that potential managers can get the necessary on-the-job training.

Good management principles are uppermost in Murai's mind, too. Sitting in his office at a conference table that once served as a kitchen table, he explains that his company's immediate goal is to show that the protein Kanegasaki discovered really has the potential to be developed into a drug. At that point, he says, the company could sell stock to the public and use the proceeds to conduct clinical trials or hook up with an established drug firm. But long before Effecter gets that far, Murai says, it's going to need a second round of venture financing.

Even while spouting the language of a venture business manager, however, Murai is carrying out his share of the lab work. While that combination may be rare—"I don't think there are many like me in Japan yet," he says—he believes that his training is right for the job: "I think it's going to be easier for researchers to learn about starting businesses than for business managers to learn about biotechnology." —DENNIS NORMILE

COMPUTER GAMES

Physics Meets the Hideous Bog Beast

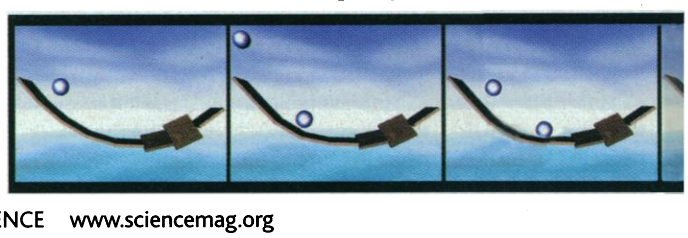
Programmers are turning to physics to add more reality to computer games, but so far the early market tests have been disappointing

When you slime a hideous bog beast with your laser blaster in real life, the beast doesn't consult a table to figure out which way it is supposed to fall. In the virtual world of most computer games, however, that's exactly what happens. A programmer has carefully scripted each potential event—like the fall of the blasted bog beast—long before you tear the shrink-wrap off your new game. If a particular combination of causes and effects isn't found in the programmer's predetermined table of allowed possibilities, it just doesn't happen.

While this approach worked well enough when Pong was the state of the art in video games, many game designers think the traditional scripted game is becoming too restrictive. Their attempts to exploit advances in computer technology and inject more natural behavior into gaming have given birth to a whole new form of interactive entertainment: physics-driven computer games.

So far only one physics-driven game, Trespasser, has made it to market—where it flopped. Nevertheless, several companies are now spending millions of dollars developing new games and the software engines to drive them. In one sense, the computer game industry is driven by novelty, and the potential payoff of the first truly physics-driven game is huge. "We are all looking for the next big thing," says David Wu of Pseudo Interactive Inc., a Toronto-based game design company, "and physics is the biggest frontier in gaming right now."

Computer games are all about movement: prowling through a dungeon in search of treasure, skidding around corners in a high-speed chase, or sending an opponent tumbling with a well-placed flying drop kick. In a scripted game, movement is like a



Balancing act. Simulation calculates forces exerted by two balls on a bridge to determine movements of individual planks. (See www.mathengine.com) movie with several different endings. For each choice a player makes, a graphic designer has pre-recorded a video clip of the resulting motion. Although game designers are expert at linking the clips to produce an almost seamless illusion of continuous motion, they can't always cover every possibility. Inevitably, bugs creep into the animation code and the seams start to show.

Although serious gamers don't expect the virtual world to be perfectly true to life, the last few years have seen dramatic advances in computer graphics that are raising players' expectations. "As the graphics get more realistic, your eye starts to pick out movement problems," says Chris Hecker, founder of the Seattle-based game company Definition Six. The inconsistencies can cause players to "lose the suspension of disbelief that makes a game fun," says Hecker.

But how can a programmer possibly account for all the complexities of real motion? That's where the physics comes in. Instead of scripting each event, the new generation of programmers uses physical laws to create objects that obey a specific set of rules in all circumstances. Instead of saying that a car traveling around a curve at high speed will always skid into the wall and then creating a film clip showing the crash, the programmer writes in the appropriate coefficient of tire friction. Then the computer handles the gritty work of summing all the forces on the moving car to determine where it moves next. And if the car hits the wall, the computer can even predict the flight path of errant tires as they bounce over the wall into the grandstands.

To apply the laws of physics, the game developer breaks down each physical object in the game into a collection of simple geometric components—cubes, spheres, or cylinders—connected by joints. "Then you assign masses to the parts of the body and add the properties of real joints, like a ball-and-socket or a hinge," explains Anselm Hook, a game-physics developer at the London-based company MathEngine. The objects can be as simple as a boulder or as complicated as the human body.

When two bodies interact, the physics "engine," the portion of the computer code that handles the physics, first computes the forces on each object, including gravity, collisional impulses, and friction. It then solves the constrained differential equations of motion governing the components of each body and moves them forward in real time.

As you might imagine, the physics engine soaks up precious computational resources. At any given moment, a game player's view might include several other creatures and various objects, and the engine must continuously monitor the forces on every item in the scene. "You can't forget about a box on a table if you want to keep it there with forces," says Hecker. Top-of-the-line home computers

Tanking along. Rolling, bouncing, and sliding of jointed tank is simulated mathematically.

and commercial video games have only recently acquired the horsepower to drive these complex engines.

While the inexorable increase in computer speed should soon take care of that problem, physics-based games face other hazards. "Physics engines can get blown up" when a differential equation solver becomes unstable, says MathEngine's Bryan Galdrikian. Instability—a central problem in numerical analysis—happens when tiny differences between the numerical solution and the "real" solution accumulate, causing the computer to lose track of the "real" solution.

Instabilities were one explanation for the commercial failure of the first physics-based computer game, Trespasser. Based on the movie *Jurassic Park 2: The Lost World*, Trespasser placed players on an island filled with malevolent dinosaurs that obeyed only the laws of physics. After several years in development and almost $7 million, Trespasser was released with all the fanfare—and hopes for profitability—that a Jurassic Park tie-in can provide. Unfortunately, few people bought it. "It looked more like a research project than a game," says Wu. And Trespasser was plagued with instabilities that caused weird things to happen. "An object could suddenly sink into a rock," says Galdrikian.

Bloodied but unbowed by Trespasser's flop, game designers are turning to academics to learn how to build more robust engines. Wu, for one, is looking to the world of robotics for better ways to control the creatures in his games. "I spend a great portion of my time reading research papers and journals," says Wu. "If you want to innovate in game development, you must look deeper—into more focused and less applied research." But that can be a hard assignment for game designers. Hecker, an entirely self-taught physicist, estimates he has spent "3 years and counting" studying game-related physics.

Alan Milosevic thinks he has a better idea. "Game developers are not experienced in physics," he points out, "and they are gasping for help." Instead of forcing developers to learn physics, he argues, why not provide them with a general-purpose physics engine that they can plug directly into their game? With a prepackaged engine controlling movement in the game, designers would be free to worry about making the game fun.

Betting that developers would rather buy an engine than learn physics, his company MathEngine—and competitors Ipion and Telekinesys—are working furiously to get the first fully functional engine to market. MathEngine has hired several physicists to help with the design, but Milosevic says that potential employees need more than an advanced research degree to succeed in gaming. "We can't just solve the fluid dynamics equations," says Milosevic, "so our employees have to be able to improvise and imagine."

After all, physics-based games need to be more than physically consistent: They need to be fun. Some video game aficionados worry that physics-based games will be dully realistic. If you can't jump 30 feet, they say, what's the point? But Galdrikian argues that "realistic doesn't mean the game has to be completely real, and gravity doesn't have to equal Earth gravity, or even be constant. It could change in a game." Says Hecker: "The real motivation behind incorporating physics engines isn't reality at all," but creating total consistency. If all the objects in a game obey a consistent set of rules, a gamer's absorption is less likely to be disrupted by actions that don't "feel right."

Although game designers are betting that the "rightness" of physics-based games will eventually strike a chord with consumers, few are yet willing to risk years and millions of dollars to produce the next Trespasser. So, instead of sinking the entire investment into a game completely driven by physics, game designers are focusing on creating entertaining games while slowly incorporating more physics. For the time being, physics will be used "as eye candy, until we get used to it," says Hecker.

–MARK SINCELL

Mark Sincell is a science writer in Houston, Texas.

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