9 Computer games

Video games are bad for you? That's what they said about rock and roll.
Shigeru Miyamoto[1]

The first computer games

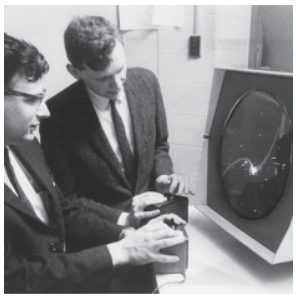
Since the earliest days, computers have been used for serious purposes and for fun. When computing resources were scarce and expensive, using computers for games was frowned upon and was typically an illicit occupation of graduate students late at night. Yet from these first clandestine experiments, computer video games are now big business. In 2012, global video game sales grew by more than 10 percent to more than $65 billion. In the United States, a 2011 survey found that more than 90 percent of children aged between two and seventeen played video games. In addition, the Entertainment Software Association in the United States estimated that 40 percent of all game players are now women and that women over the age of eighteen make up a third of the total game-playing population. In this chapter we take a look at how this multibillion-dollar industry began and how video games have evolved from male-dominated "shoot 'em up" arcade games to more family-friendly casual games on smart phones and tablets.

Fig. 9.1. Alexander (Sandy) Douglas created a version of tic-tac-toe or noughts and crosses for the Cambridge EDSAC computer in 1952. The output was displayed on a CRT screen.

One of the first computer games was written for the EDSAC computer at Cambridge University in 1952. Graduate student Alexander Douglas used a computer game as an illustration for his PhD dissertation on human-computer interaction. The game was based on the game called tic-tac-toe in the United States and noughts and crosses in the United Kingdom. Although Douglas did not name his game, computer historian Martin Campbell-Kelly saved the game in a file called *OXO* for his simulator program, and this name now seems to have escaped into the wild. The player competed against the computer, and output was programmed to appear on the computer's cathode ray tube (CRT) as a display screen. The source code was short and, predictably, the computer could play a perfect game of tic-tac-toe (Fig. 9.1).

Like OXO on the EDSAC, most of the early computer games ran on university mainframe computers and were developed by individuals in their spare time. The game Spacewar! (Figs. 9.2a and 9.2b) was one of the earliest

(a)



(b)

Fig. 9.2. (a) Dan Edwards (left) and Peter Samson, two of the original student developers at MIT, playing Spacewar! on the PDP-1 display in 1962. (b) Spacewar! screenshot.

and most famous of these computer games. It was created in 1962 by Steve Russell (B.9.1) and Martin Graetz, with other young computer programmers at MIT. The game ran on a PDP-1 minicomputer that had been donated to MIT by Digital Equipment Corporation (DEC) for the students to develop interesting applications – although DEC probably did not expect them to create a video game application. The game was inspired by the "space opera" science fiction of E. E. "Doc" Smith. It is a two-player game, with each player having control of a spaceship and attempting to destroy the other using photon torpedoes. The gravity field of the sun, in the center of the screen, pulls on both ships, and players need to avoid falling into it. In an emergency, a player can enter hyperspace and return to a random location on the screen. Spacewar! was later used by engineers at DEC as a test program on every new PDP machine before shipping it. The DEC sales force also distributed Spacewar! with newly installed DEC computers, and many interesting variants of the program were developed.

From these early beginnings, the development of games on university computers grew rapidly, mainly through students writing experimental game software in their spare time. The *Star Trek* TV series, first shown in 1966, created a loyal fan base and inspired several computer game versions. One of the most popular of these "find and fight Klingons" *Star Trek* games was written by an eighteen-year-old schoolboy named Mike Mayfield. He had access to a Sigma 7 computer at the University of California, Irvine, and he wrote the game in BASIC during the summer of 1971. The game delighted almost everyone who saw it, and it was *ported* (transferred from one system to another) and modified to run on many different computers. Mayfield produced a version in HP BASIC that Hewlett-Packard put into the public domain and made available on tape. DEC also distributed their version of the code, which became the basis for versions of *Star Trek* that ran on personal computers like the Apple II (Fig. 9.3), the Commodore, and the BBC Micro.

Don Daglow (B.9.2), a student at Pomona College in California, developed the first interactive baseball game on a PDP-10 in 1971. A few years later, he wrote Dungeon, one of the first role-playing computer games. Role-playing games focus on character development and problem solving rather than action. Daglow's game was based on the board version of Dungeons and Dragons. The game used text; *line-of-sight graphics*, in which the player had to have a clear view of an object to act on it; and maps of the dungeons to show in which direction the player should explore. Daglow also continued to develop his baseball game, and a version was released for the Apple II in 1981. It was also the basis for

B.9.1. Steve "Slug" Russell was one of the first computer game developers. In 1961 he wrote the first version of the Spacewar! program as a student at MIT. In 1968 he was working for the Computer Center Corporation – informally known as C-Cubed – in Seattle as their hardware chief. It was there that Paul Allen and Bill Gates developed their deep knowledge of the PDP-10 that served them so well when they came to write the BASIC interpreter for the Altair. It was Russell who first introduced Allen to PDP assembler code.

Fig. 9.3. Screen shot of *Star Trek* on the Apple II.

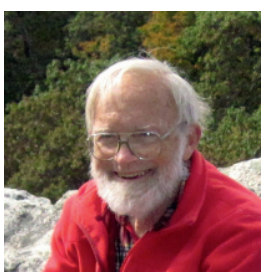
other commercial versions. Daglow went on to become one of the leaders of the new profession of computer game designers.

In the early 1970s, William Crowther (B.9.3) worked at Bolt, Beranek and Newman (BBN), a defense contractor that was developing the ARPANET, the precursor to today's Internet. In his spare time, he created a text-based exploration game in FORTRAN on BBN's PDP-10:

> I had been involved in a non-computer role-playing game called Dungeons and Dragons at the time, and also I had been actively exploring in caves – Mammoth Cave in Kentucky in particular.... I decided I would fool around and write a program that was a re-creation in fantasy of my caving, and also would be a game for the kids, and perhaps some aspects of the Dungeons and Dragons that I had been playing. My idea was that it would be a computer game that would not be intimidating to non-computer people, and that was one of the reasons why I made it so that the player directs the game with natural language input, instead of more standardized commands. My kids thought it was a lot of fun.[2]

He called his game Colossal Cave Adventure, or just Adventure. The player explores a virtual cave system by entering simple two-word commands and then reading the new text that the command generates. Crowther released the game on the ARPANET in 1975, and it rapidly became popular among the ARPANET community. Crowther's Adventure was perhaps the first *interactive fiction* game, in which the player helps guide the action. Crowther was contacted a year later by Don Woods (B.9.4), a graduate student at Stanford University, who asked for permission to make enhancements to the game. Adventure was mainly an exploration game, and Woods added many more magical objects as well as creatures like the elves and trolls of author J. R. R. Tolkien's Middle Earth trilogy. This extension of Crowther's original Adventure game is probably the first example of a "mod," short for "modification." Many games produced for PCs are now designed so that technically able users can make modifications and thus add extra interest to the games. A team of students at MIT – Tim Anderson, Marc Blank, Bruce Daniels, and Dave Lebling – were also inspired by Adventure and created Zork, another early interactive fiction game. "Zork" was MIT hacker slang for an unfinished program. Although the game was originally

B.9.2. Don Daglow is an eminent game designer who has been associated with many landmark computer games, such as *Star Trek*, Dungeon, Baseball, and Utopia.



B.9.3. William Crowther was part of the BBN team that built the ARPANET. He was an ardent caver and wrote the Colossal Cave Adventure computer game to entertain his daughters.

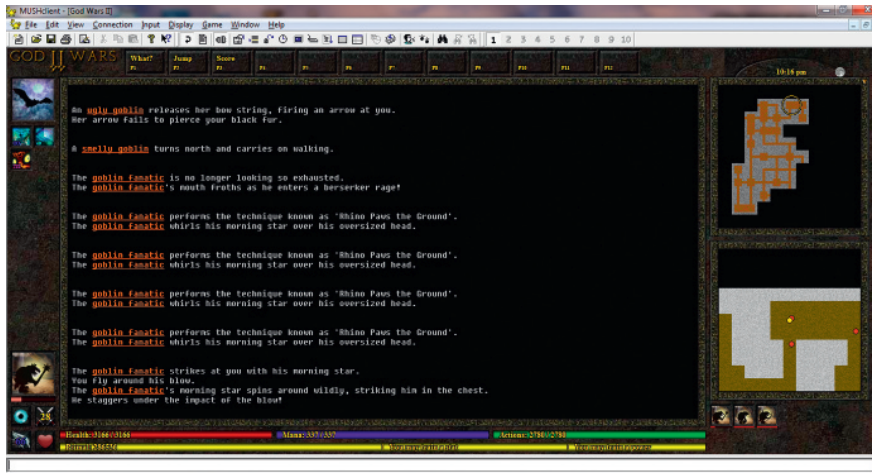


Fig. 9.4. Dungeon crawling in a typical MUD game.

written for the PDP-10 minicomputer, the authors recognized the potential of text games for personal computers and founded Infocom in 1979. Several commercial versions of Zork were released.

Roy Trubshaw, a student at the University of Essex in England, was in turn inspired by Zork to create a multiuser version of an adventure game for his university's PDP-10 computer. He called his game MUD (Fig. 9.4), for "Multi-User Dungeon," and made the game available to the outside world through a guest account accessible using the Internet. MUD was the first multiplayer online role-playing game and spurred the development of many similar games. The name MUD became used for a variety of multiplayer adventure games on the Internet. In a typical game, players read descriptions of rooms, objects, and other players, and interact with them by typing commands such as "hit the troll with the Elvish sword." The object of the game is to explore a fantasy world, slaying monsters and completing quests along the way, and gaining skills and special powers.

In the early 1970s, these games were mainly text based, using words rather than graphics. Players used teletypes as computer terminals to play these games on a university mainframe or minicomputer. In the mid-1970s, teletypes began to be replaced by computer monitors with much faster output capabilities and a much more flexible graphical user interface. With the advent of personal computers, computer games became a main driver for innovation in computer-generated graphics.

B.9.4. Don Woods was a co-author of the Colossal Cave Adventure game. As a student at Stanford he discovered an early version of the Adventure. He was immediately hooked by the game and decided to extend it by adding new features.

Arcade video games

Russell's Spacewar! was the inspiration for a coin-operated version called Galaxy Game that was installed in a student union building on the Stanford University campus in 1971. That same year, Nolan Bushnell (B.9.5) and Ted Dabney, founders of the Atari computer game company, produced another variant of Spacewar! called Computer Space. This was the first computer arcade video game, equipped with a coin-slot mechanism, but it was not a great

Fig. 9.5. Pong was Atari's first computer video arcade game.

commercial success. The game that was a success, and which led to Bushnell and Dabney setting up Atari, was Pong, a simulated table tennis game where each player controls the position of a paddle.

The first example of a computer table tennis game had been created by physicist William Higinbotham in 1958 and was called Tennis for Two. The game display was an oscilloscope screen that had been programmed to show a side view of a tennis court. The game was played by two players each using controllers to "hit" the ball over the net. The players had to take into account the effect of gravity on the tennis ball when deciding on the trajectory of each stroke. The game was used to entertain visitors to Brookhaven National Laboratory on Long Island, New York. Bushnell had the idea to produce a similar tennis game as an arcade game. With engineer Al Alcorn, Bushnell built a prototype, added a coin box, and installed it in a bar in Sunnyvale, California, to test customer reactions to the game. It was a stunning success: people started coming into the bar, not to buy beer, but to play the game. The game was played by two players using a "paddle" to hit the ball as it rebounds from a wall. Atari shipped the first version of Pong in November 1972 and by 1973 had more than $3 million in sales (Fig. 9.5). Many imitators of Pong soon appeared, and by 1977 there was a glut of Pong clones on the market.

After the success of Pong, Bushnell and his colleague Steve Bristow had the idea to create a single-player game in which the player would try to hit a ball against a wall and destroy the wall, brick by brick. Steve Jobs was commissioned to design a prototype of what became the game Breakout. For a fee of $750, Jobs promised to deliver a working version within four days. He enlisted the help of Steve Wozniak and, after a marathon effort with little or no sleep, Woz delivered the Breakout prototype on time.

It was a Japanese game designer, Tomohiro Nishikado (B.9.6), who created the first video game to depict human-to-human combat and thus began the debate about violence in video games. In Japan, the game was called Western Gun and was released by Taito Corporation in 1975. The game could be played in single-player or two-player versions and was the first video game to show an actual gun on the screen. It also introduced dual *joystick controls*, levers that could be moved to control the action on the screen, one for the movement of the player and the other for the shooting direction. The Japanese version of the arcade game used special-purpose hardware, but the U.S. version was rewritten for the Intel 8080 microprocessor. It was released by Midway Manufacturing Company in the United States under the title Gun Fight. This was the first microprocessor-based arcade video game, and its success in the United States opened the way for Japanese games to enter the American market.

In 1977, Nishikado decided to use a microprocessor to design and implement a new arcade game called Space Invaders. This turned out to be one of the most successful shoot 'em up games, in which the player shoots at targets, in this case multiple waves of aliens descending from the top of the screen. Space Invaders was a huge commercial success and is said to have caused a coin shortage in Japan. More than 360,000 arcade units were sold worldwide, and by 1982 the game had earned more than $2 billion in quarters and 100-yen coins. The game is said to have begun the "golden age of arcade video games."[3]

B.9.5. Nolan Bushnell, founder of Atari – the name is a reference to the game of Go where the call *atari* is similar to *check* in chess. Bushnell had first become interested in computers as an engineering undergraduate at the University of Utah when he took a course on computer graphics given by the graphics pioneers David Evans and Ivan Sutherland.

B.9.6. Tomohiro Nishikado is one of the most well-known Japanese video game developers. His first games were the early team sports games, *Soccer* and *Davis Cup*, both released in 1973. Nishikado claims that *Soccer* was Japan's first video game and that his 1974 driving race game, *Speed Race*, was "possibly the first Japanese game in America." His most successful game, *Space Invaders*, was released in 1978 and began "the golden age of video arcade games."[B1]

The success of Space Invaders was followed by similar games such as Asteroids from Atari and Galaxian from Namco Limited. Color was introduced into arcade games at the end of the 1970s. In 1980, Namco succeeded in creating a new genre of video game in addition to shoot 'em up and sports games. The game was Pac-Man (Fig. 9.6), a maze game in which the player controls a character, Pac-Man, through the twists and turns of a maze, eating various objects on the way. When all the objects have been eaten, the player proceeds to a new stage after an intermission in which Pac-Man is chased by four different enemies. The game's designer, Toru Iwatani (B.9.7), said that he had designed the enemies with distinct personalities and behavior to keep the game from being boring but also to ensure that it was not impossibly difficult to play. The game generated a new audience for video games because it appealed to female players as well as the traditionally male gaming community. The game sold more than 350,000 units and had an estimated thirty million active players in 1982. A perfect Pac-Man game occurs when a player eats all available objects and vanquishes every enemy on all of 255 levels. The first person to achieve this was Billy Mitchell of Hollywood, Florida, in 1999, who finished the game in about six hours. Arcade games continued to be popular throughout the 1980s but began to decline in popularity as home game consoles and personal computers became more popular in the 1990s.

Console wars

In 1951, the U.S. inventor Ralph Baer was developing television technologies for an electronics company based in New York. Instead of just using patterns on a television screen to calibrate the equipment, he realized that it was possible to give the viewer the ability to manipulate what was displayed on the

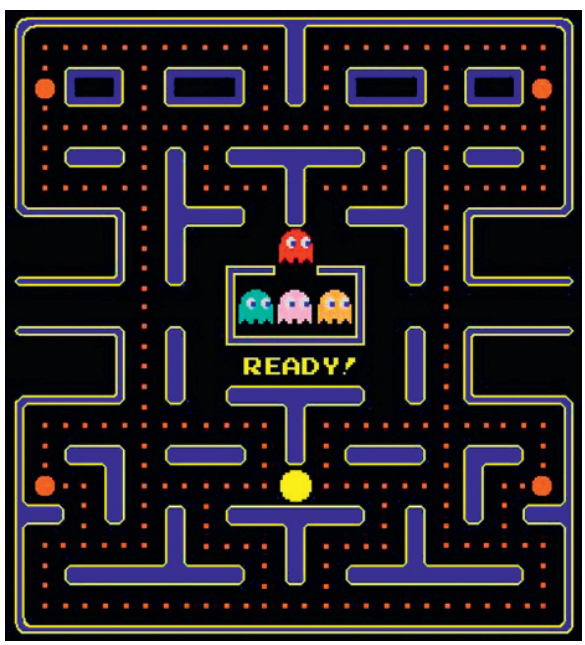


Fig. 9.6. Pac-Man is one of the most influential video games of all time. It was the first game to introduce a character as a gaming icon, and it established a new genre of games featuring mazes. It was the first game to include "power-ups" – in which the characters get extra powers or abilities for a short time. It also introduced the idea of "cut scenes" – brief animations or videos that give more detail about the character and the game. Pac-Man is credited with opening up video gaming to female audiences.

B.9.7. Toru Iwatani was born in Tokyo and joined the computer software company Namco in 1977. He led the team that designed and built the arcade version of what was called Pac-Man in the United States, and the game was first released in Japan in 1980. The game quickly became an international success and was one of the first video games to appeal to players of both sexes.

screen. Although the company was not interested in pursuing his idea, Baer did not give up. In 1966, now working for a different company, he and colleague Bill Harrison developed a game called Chase. This used a "console" – a special-purpose box of electronic circuitry – to allow the user to control images displayed on a TV screen. This was the first video game to use a standard television for its display. The technology was licensed to a company called Magnavox, which released the world's first home video game console, the Magnavox Odyssey, in 1972. Through a system of plug-in devices called *cartridges*, the same console was able to play a small number of different games, including table tennis and various shooter games. After a TV advertising campaign that starred Frank Sinatra, Magnavox sold more than one hundred thousand consoles in 1972. During its entire life span, more than two million Odyssey systems were sold.

In these early consoles, the games were hard wired into the electronic circuitry, as in the early arcade machines, and it was difficult to add new games. Bushnell was frustrated by this limitation and wanted to produce a flexible video game console that could play all of Atari's current games. However, to bring such a console to market, Bushnell needed more funding so he sold Atari to Warner Communications in 1976. However, after a series of disagreements with Warner managers, Bushnell left the company in 1978. By the second half of the 1970s, the software for video games was being developed for consoles that contained microprocessors. Game cartridges were now programs burned into ROM (read-only memory) chips that could be plugged into a slot on the game console. In 1977, the Atari 2600 was released offering nine different games and soon became one of the most popular consoles of the time. However, it was not until Atari made a console version of Space Invaders that the company had the first "killer app" for video game consoles. Atari released its last console, the Atari Jaguar, in 1993. It was not a commercial success, and sales of the console ended in 1996.

In 1985, the Japanese company Nintendo reenergized the video game console market with the release of its Nintendo Entertainment System (NES). The hardware came bundled with two controllers and the game Super Mario Bros. This game was designed by the Japanese game designer Shigeru Miyamoto (B.9.8). He based Mario on a character, originally called Jumpman, that he had used in his earlier arcade game success Donkey Kong. After the failure of Nintendo's Radar Scope arcade game in the United States in 1980, the runaway success of Donkey Kong had saved the company from financial collapse. For the game Super Mario Bros. on the new NES console, Miyamoto gave Mario a big mustache and Italian nationality, and based him in New York City because of its "labyrinthine subterranean network of sewage pipes."[4] In the game, Mario has to explore eight different worlds and defeat many enemies to rescue Princess Peach. Jumping to access places is a key ability in Mario games. The game also used the idea of "power-ups." Mario can acquire three different power-ups: the Super Mushroom, which causes him to grow larger; the Fire Flower, which allows him to throw fireballs; and the Starman, which gives him temporary invincibility.

Nintendo's Super Mario Bros. game was the first successful "side-scrolling" game. *Side scrolling* is a computer graphics technique in which the action is viewed from the side and the on-screen character moves from left to right through the scene, but can also go backward as well as forward. This technique is typically used for what are called "platform" games – action games featuring characters

B.9.8. Shigeru Miyamoto is the creator of the Donkey Kong, Super Mario Bros., and The Legend of Zelda franchises for Nintendo. He is one of the most successful game designers and is often referred to as "the father of modern gaming."[B2]

that run, jump, and climb over obstacles through the different levels of the game. Donkey Kong, Miyamoto's earlier game with Mario as a character, was the first game that allowed players to jump over obstacles and cross gaps. Since his appearance in 1985, the character Mario has appeared in more than one hundred different games and is the anchor for what is now the best-selling video game franchise of all time with more than two hundred million games sold.

Miyamoto followed up his success with another innovative game for the NES console, The Legend of Zelda, released in 1986. In this game, Miyamoto deliberately decided to focus more on puzzles and riddles than just adventure and battle scenarios. Exploration was also a key feature of the game. He took inspiration from his childhood in Kyoto, Japan:

> When I was a child, I went hiking and found a lake. It was quite a surprise for me to stumble upon it. When I traveled round the country without a map, trying to find my way, stumbling on amazing things as I went, I realized how it felt to go on an adventure like this.[5]

Miyamoto had heard of Zelda Fitzgerald, wife of the famous novelist F. Scott Fitzgerald, and decided to name Princess Zelda after her because he thought the name sounded "pleasant and significant." The Legend of Zelda is the fourth best-selling title for the NES console. It was the first console game that allowed players to stop playing and save the state of the game for them to resume later.

In 1991, the Sega Corporation introduced Sonic the Hedgehog for their Genesis console. This was a platform game like Mario, and the blue hedgehog Sonic soon became the mascot of Sega's video game business. The Sonic the Hedgehog franchise made Sega's console very competitive in the early 1990s – at one point they had 65 percent of the market in North America. However, they faced strong competition, first from Nintendo, and then from Sony, when the PlayStation console was launched in 1994. The PlayStation or PS1 was the first console to sell more than one hundred million units. Faced with such competition, and with the Microsoft Xbox launching in 2001, Sega dropped out of the console market in 2001. The company has since focused on producing video games, including their Sonic the Hedgehog franchise, for other console manufacturers.

By the early 2000s, there were only three major game console suppliers left in the market – Nintendo, Sony, and Microsoft. Nintendo had introduced new consoles at regular intervals after the NES with the Super Nintendo Entertainment System (SNES) in 1991, Nintendo 64 in 1996, and the GameCube in 2001. Although the GameCube was profitable, its worldwide sales of twenty-two million units placed it well below Sony in popularity. Sony had introduced the PlayStation 2 (PS2) console in 2000, and within a few years the console had sold more than 150 million units, making it the best-selling console of all time. The video game series Grand Theft Auto, which put players in the role of gangsters, had been a major success for Sony's PS1 console, and the company secured a brief exclusive on the PS2 for Grand Theft Auto III, the groundbreaking three-dimensional version of the game.

Microsoft released its Xbox console with a game called Halo: Combat Evolved, or simply Halo (Fig. 9.7). Halo was a first-person shooter (FPS) game, in which the player aims and shoots at targets seen from the viewpoint of the main character. Halo was extremely successful in North America and Europe, and Microsoft

Fig. 9.7. Halo: Combat Evolved was the launch title for the Microsoft Xbox in 2001. The initial game has spawned many sequels as well as a prequel in Halo: Reach. The writer Brian Bendis has compared the cultural effect of Halo to that of the *Star Wars* movies.

followed this by launching its Xbox Live service in 2002. This service uses the Internet (see Chapter 10) to support online gaming among multiple players. Halo 2 was released in November 2004 and soon became the most popular online game. By June 2006, more than five hundred million games of Halo 2 had been played with more than seven hundred million hours played on Xbox Live. However, although Xbox sold more than twenty-four million units, comparable to the sales of Nintendo's GameCube, both were well behind the sales of Sony's PS2.

Competition in the manufacture of video game consoles continues to be fierce. Sony introduced the PlayStation 3 (PS3) in 2006, but its unconventional hardware architecture with IBM's novel cell processor made it a difficult platform for game developers. The PlayStation 4, launched in 2013, returned to a more conventional microprocessor chip based on the Intel x86 architecture. The Microsoft Xbox 360, introduced in 2005, competed directly with the PS3, and by 2013 both consoles had sold more than seventy million units. Nintendo launched the innovative Wii in November 2006. The Wii incorporates a handheld pointing device that can detect motion in three dimensions. This enabled Nintendo to broaden the appeal of their console beyond the core gaming community and the Wii sold more than eighty million units, outselling the Xbox 360 and the PS3. With the launch of Kinect in 2010, the Microsoft Xbox gaming console introduced another mode of interaction by allowing gamers to control the Xbox using spoken commands and gestures. After Kinect had sold eight million units in the first sixty days after launch, *Guinness World Records* recognized it as the "fastest selling consumer device."[6] The competition between the Microsoft Xbox One and the PS4, both launched in 2013, promises to be interesting to watch.

Computer graphics and video games

The term *computer graphics* was first used in 1960 by William Fetter, a graphic designer at the Boeing Company. Much of the early research on computer graphics was inspired by the Semi-Automatic Ground Environment (SAGE) air defense project at MIT's Lincoln Laboratory. The SAGE system used a CRT monitor for display and a light pen device developed at the Lincoln Lab for user interactions with the screen. In 1959, Wesley Clark and others at the laboratory created the TX-2 computer. Ivan Sutherland, then a graduate student at MIT, developed Sketchpad, a revolutionary graphics software program that allowed users to draw simple shapes on the TX-2 computer screen using a light pen. In 1967, David Evans recruited Sutherland to the computer graphics research group at the University of Utah. During the 1970s, many of the important breakthroughs in computer graphics research originated from the Utah research group.

Computer displays are built up from two-dimensional grids of small rectangular cells called *pixels* – "picture elements." The picture is built up from these cells, and the smaller and closer the pixels are together, the better the quality – or the "higher the resolution" – of the image. Modern displays and printers are *raster devices*, which produce an image by scanning it as a series of lines. A *raster scan* is the pattern of parallel lines that construct an image on a CRT screen. A raster graphics image or *bitmap* is just the rectangular grid of pixels that make up the image. The bitmap corresponds bit-for-bit with the image displayed on the screen and is characterized by the width and height of

the image in pixels and by the number of bits per pixel. For color images, each pixel needs to hold a minimum of three numbers – to specify the intensity of the three red, green, and blue components. Raster graphics images cannot be scaled up in size because the image will appear *pixelated* – that is, the individual rectangular pixels making up the image will become visible.

An alternative way of representing images in a computer program is to use *vector graphics*. This technique uses simple geometrical shapes such as points, lines, curves, and rectangles to represent images. Thus a square would be represented by just four points, one for each corner. Each of these points has information that tells the computer how to connect the points – with straight lines in the case of a square – and what color to use to fill in the enclosed shape. Vector graphics images can be resized with no loss of detail – the vector points are just spread out or shrunk as required and the computer can easily redraw the image. However, for printing, vector graphics images need to be converted to a bitmap/raster format. The SAGE air defense system was one of the first to use vector graphics displays.

In the early 1980s, the computer graphics technology used by game designers for the 8-bit microprocessor personal computers of the time was quite primitive compared to the state of the art in computer graphics research. Nowadays, the hardware technology in game platforms has advanced so much that computer game companies are now some of the leaders in graphics research. We illustrate some of the early techniques used by game developers for personal computers by looking at how games were implemented on the Atari 800 and the Commodore 64.

One of the standard devices for platform video games such as Mario was side scrolling, in which the characters move across a background screen. Many of these 8-bit microprocessor-based computers offered hardware support for scrolling and for *sprites*, small graphic elements of fixed width and height that can be positioned independently on the main screen (see Fig. 9.8). Atari's 2600 video game console had hardware support for up to five sprites that could be moved independently of the game background. The Atari 800 home computer had a similar hardware capability and supported four sprites eight pixels wide to represent characters and one sprite eight pixels wide that could optionally be split into four two-pixel wide sprites to represent missiles. The characters could be moved horizontally and vertically, and the software specified priorities – that is, which image would be visible – whenever two sprites ran into each other. The computer hardware also supported scrolling the background by up to fifteen pixels in the horizontal and vertical directions. Larger scrolling movements required shifting the start of the screen display in memory. The Commodore 64 had similar graphics capabilities and provided hardware support for scrolling and for eight sprites. Both the Atari and the Commodore supported a palette of sixteen colors, and the Atari also provided eight *luminance* settings. Luminance specifies the amount of light emitted from a given area and is an indicator of how bright the surface will appear.

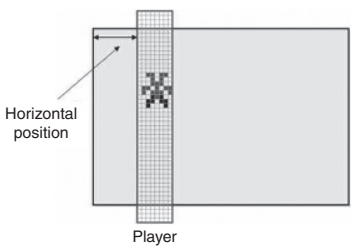


Fig. 9.8. Sprites were graphics devices used to represent characters or missiles in early computer games. This figure shows the Player/Missile sprite for the Atari 800 home computer.

By the 1990s, as predicted by Moore's law, microprocessors had become cheaper and more powerful, and the two-dimensional tricks of these early video games gave way to true three-dimensional models. Instead of two-dimensional shapes like circles and rectangles, three-dimensional models allow a *wireframe*

representation of any object. A wireframe model uses points, lines, and curves to show the edges of an object, including the opposite sides and any internal features that would be normally hidden from view. A whole range of techniques is now available to generate all sorts of complex shapes and curves. The file specifying the game scene contains the geometry of the objects in the scene and their relative positions. The game designer also has the freedom to view the scene from different perspectives and to specify different choices of lighting. The process of converting the resultant three-dimensional model to a two-dimensional image on a screen is called *rendering*. The computer has to calculate which surfaces are behind any given object from the viewer's perspective and which should therefore be hidden when the two-dimensional image is created. The rendering process also adds lighting and surface texture effects. The graphics research group of Evans and Sutherland in Utah created the first *hidden-surface algorithms* to realistically display overlapping objects – that is, sets of rules to determine which surfaces would not be visible from a certain viewpoint and so should be hidden.

Computer graphics is now the foundation for whole new industries. Computer animation is the process of using computers to create moving images, and computer-generated imagery (CGI) is now a standard technology for the movie industry. In 1995, Pixar Animation Studios released *Toy Story*, the first full-length computer-generated animation movie. Computer-aided design (CAD) uses computer graphics to assist the design process in many industries, including automotive, aerospace, and shipbuilding. Computer graphics technologies also underpin modern scientific and information visualization.

The modern era of computer games

In 1991, Sid Meier's (B.9.9) Civilization game was released for the PC. This is a single- or multiplayer strategy game in which players attempt to build an empire in competition from other civilizations and under attack from marauding barbarians. Each player starts with one settler unit and one warrior unit and by exploration, warfare, and diplomacy, attempts to become the dominant civilization. The game begins in 4000 B.C. before the Bronze Age and can continue to 2050 with a future space-age civilization expanding to settle new stars. As time advances during the game, players can choose to invest in new technologies – from the wheel and pottery in the early stages, to nuclear power and spaceflight near the end of the game. Wise investments in science and technology can often bring decisive advantages for a civilization, as in real life. In 1996, *Computer Gaming World* magazine chose Civilization as the best game of all time, explaining:

> While some games might be equally addictive, none have sustained quite the level of rich, satisfying gameplay quite like Sid Meier's magnum opus. The blend of exploration, economics, conquest and diplomacy is augmented by the quintessential research and development model, as you struggle to erect the Pyramids, discover gunpowder, and launch a colonization spacecraft to Alpha Centauri.… Just when you think the game might bog down, you discover a new land, a new technology, another tough foe – and you tell yourself, "just one more turn," even as the first rays of the new sun creep into your room … the most acute case of game-lock we've ever felt.[7]

B.9.9. Sid Meier on stage at the Game Developer Conference in 2010. Meier was born in Ontario, Canada, and graduated from the University of Michigan. He cofounded the game companies MicroProse and Firaxis Games. His hugely successful game, Sid Meier's Civilization, was released by MicroProse in 1991.

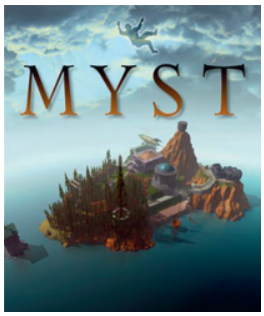


Fig. 9.9. Myst is an adventure game during which the player explores the virtual world of a mysterious island. It introduced a new type of puzzle-based adventure game.

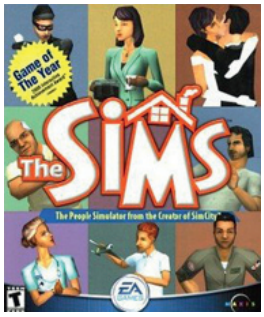


Fig. 9.10. The Sims is a life simulation game. It has become one of the most popular computer game franchises worldwide. The franchise has sold over 175 million copies (August 2013).

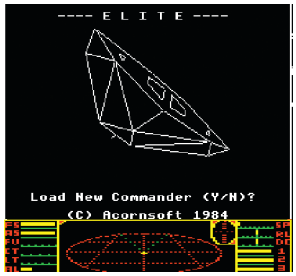


Fig. 9.11. Elite was written for the BBC Micro by two Cambridge University undergraduates. It was the first game to introduce three-dimensional graphics.

The *real-time strategy* (RTS) genre of computer games came of age in 1992 when Westwood Studios released Dune II. An RTS game allows the player to issue commands to vast armies as the action unfolds. The game continues to run even if the player is not actively giving commands. The plot of Dune II is loosely based on the 1965 science fiction novel *Dune* by Frank Herbert and on the 1984 movie of the same name. The goal of the game is to harvest valuable "spice" from the deserts of the planet Arrakis at the same time as fighting off enemy troops and avoiding the giant sandworms that can destroy the huge spice harvesters. From the profits made from trading spice, players can generate more units and build up military bases. The game starts with an overhead view of a map with the "fog of war" covering all areas not within sight of the player's units. As the units explore, the fog lifts and more of the map is revealed. The game features a model economy for the trading of resources and the building of bases as well as detailed management of military units. Dune II became the standard template for future RTS games and was the inspiration for Westwood Studios' later Command & Conquer video game franchise.

The game Myst (Fig. 9.9) introduced a new style of puzzle-based adventure games and became a surprise hit. It was developed by the brothers Robyn and Rand Miller in Spokane, Washington, and was released for Apple's Macintosh computer in 1993. Myst went on to become the best-selling PC game in the 1990s, and its sales remained the highest until overtaken by the life-simulation game The Sims in 2002 (Fig. 9.10). Myst was one of the "killer apps" that made CD-ROM drives a standard feature on PCs. (CD-ROM stands for "compact disk read-only memory.") CD-ROMs are made from plastic coated with a thin layer of aluminum to make a reflective surface. A CD stores binary data as a series of microscopic "pits" separated by "lands." The changing intensity of the pattern of reflected light from a laser shone onto the disk can be converted back to binary data. CDs can store up to 700 megabytes (MBs) of data, a huge increase in storage capacity compared to a floppy disk with a capacity of only a few MB. (MB stands for megabyte or 1,000,000 bytes of storage.) Further improvements of this technology have led to DVDs with a capacity of five or more GB. (GB stands for gigabyte or 1,000,000,000 bytes.) DVDs are now used for distributing copies of movies. The movie industry has also introduced Blu-ray Discs, which have a capacity of 25 GB and allow the distribution of high-resolution versions.

In 1984, two Cambridge University undergraduates, David Braben and Ian Bell, created a game called Elite (Fig. 9.11) for the BBC Micro. The BBC Micro was built by Acorn Computers Ltd. for a British Broadcasting Corporation project to promote computer literacy in the United Kingdom. Elite combined a traditional combat game with space trading between star systems. While making a hyperspace jump between stars, the trading ship could be attacked by enemy ships. Players could gain credits by trading, asteroid mining, piracy, and bounty hunting. They could use these credits to upgrade their ships with better weapons or increased cargo capacity. The major technical innovation introduced in Elite was its use of three-dimensional wireframe graphics. This technique created a genuine three-dimensional world and allowed realistic movement in all directions. A galaxy in Elite contained 256 planets to explore, and the game's universe consisted of eight galaxies. The player could follow the state of the game on a three-dimensional radar display. For the program to fit into the 14

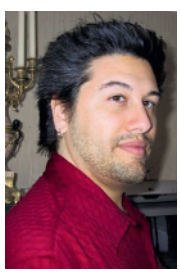
Fig. 9.12. A visual representation of the World of Warcraft.

kilobytes of memory available on the BBC Micro, Braben and Bell had to write it in the low-level microprocessor assembly language. The success of the game with its revolutionary three-dimensional graphics meant that it was ported to all popular computers as well as to Nintendo's NES console.

During the 1990s, the increasing power of microprocessors and the falling price of computer memory made three-dimensional graphics much easier to implement. The 1993 game Doom from id Software was one of the first to take advantage of this technology advance (B.9.10). The game not only introduced more realistic three-dimensional graphics but set the ground rules for FPS video games. In the game, the player is a space marine who has to fight his way through hordes of invading demons from hell. Doom's graphic violence and its satanic imagery generated considerable controversy. The game was played by more than ten million people within two years of its release.

In 1996, a company called 3dfx Interactive introduced Voodoo Graphics, an affordable three-dimensional *graphics accelerator card* for personal computers. Graphics accelerator cards have a specialized processor that performs three-dimensional rendering, which otherwise would take up large amounts of computing power, thus freeing up the main CPU for other tasks. A modern *graphical processing unit* (GPU), a computer chip that performs rapid mathematical calculations for drawing images, now plays the same role of accelerating the graphical rendering process. This increase in graphical processing capability allowed Roy Trubshaw's original concept for text-based MUDs to be transformed to graphical multiplayer games. With the increasing availability of the Internet, these graphical MUDs evolved into a genre known as *massively multiplayer online role-playing games* (MMORPGs). The first game in the Warcraft (Fig. 9.12) series, Warcraft: Orcs and Humans, was released in 1994. A decade later World of Warcraft was published, and by 2009 World of Warcraft had more than ten million subscribers. RuneScape, a free MMORPG, was developed by Andrew and Paul Gower in Cambridge, England, and was released in 2001. As of November 2010, RuneScape was credited by *Guinness World Records* as having more than 175 million registered users.

Minecraft is a recent example of a game that has "gone viral" – become a huge success – with no publisher backing and without any commercial advertising (Fig. 9.13). The original PC version of the game was developed by Swedish programmer Markus "Notch" Persson (B.9.11). Minecraft released an "alph" version in 2009 and the full release in November 2011. In less than one month, more than one million copies of the game had been sold. By March 2012,



B.9.10. John D. Carmack (left) and John Romero are two of the founders of id Software, a Texas-based video game development company. Carmack and Romero were responsible for introducing new realism into PC games with their three-dimensional graphics technology. Their breakthrough game was Wolfenstein 3D in 1992, followed by Doom in 1993 and Quake in 1996. Doom defined the FPS genre and was the first PC game to be ported to Linux.

Fig. 9.13. A screen shot of Minecraft. The game runs on multiple platforms such as PCs, consoles, and smart phones. Markus Persson designed the game just for fun, and never expected that it would achieve such popularity. Initially the game just featured a landscape with a collection of blocks and few people would have predicted its runaway success. Majong, Persson's company that develops Minecraft has no publicity department and the news about the game is spread by word of mouth – or through the Internet. The game is a *sandbox* game and gives the players freedom to modify the world that they are playing in.

Minecraft had become the sixth best-selling PC game of all time. As of February 2014, the game has sold more than fourteen million copies for the PC and more than thirty-five million copies on all platforms. In 2012, Minecraft was the most purchased title on Xbox Live Arcade and the fourth most played title on Xbox Live. Minecraft – Pocket Edition was developed for the Android platform and has now reached more than twenty-one million copies.

What is the reason for the phenomenal success of Minecraft? Part of the reason for its success is its seemingly endless variety and extensibility. At its most basic, it is just a survival/construction game – a sort of digital Lego – in which the players can build various three-dimensional structures from textured cubes. They can also grow crops, raise farm animals, and collect the resources necessary for survival. There are mines where players can dig shafts and search for iron ore, coal, gold, and gems. The iron ore can be smelted to craft a pickaxe, sword, or armor. These tools come in handy for fighting the zombies, spiders, dragons, and the other hostile creatures that pervade the landscape. In multiplayer mode, players can participate as a team and join together to construct buildings or entire cities, share resources, or fight enemies. Another element of Minecraft's success is the ability to incorporate user-generated content and a wide variety of mods are available for download from the Internet. Minecraft has turned out to be not only "just another creativity game" but has also been used in a number of educational applications, including history and science. The game has also been used to sketch out ideas for architectural and urban design. In 2012, Cody Sumter, then a research assistant at the MIT Media Lab, said "Notch hasn't just built a game. He's tricked 40 million people into learning a CAD program."[8] Google is even using the game to entice bright students to learn about quantum mechanics:

B.9.11. Markus "Notch" Persson is the Swedish creator of Minecraft and cofounder of Mojang, the game company he formed in 2010. He started programming at the age of seven on a Commodore 128 personal computer and developed a text-based adventure game when he was eight. Notch was his login ID when he started playing computer games and the nickname stuck. Despite the phenomenal success of Minecraft he still considers himself as a "garage developer" who writes games for fun and not necessarily for profit.

Fig. 9.14. Nintendo's Game Boy hand-held video game device was introduced in 1989.

> Millions of kids are spending a whole lot of hours in Minecraft, not just digging caves and fighting monsters, but building assembly lines, space shuttles, and programmable computers, all in the name of experimentation and discovery. So how do we get these smart, creative kids excited about quantum physics? We talked to our friends at MinecraftEdu and Caltech's Institute for Quantum Information and Matter and came up with a fun idea: a Minecraft modpack called qCraft. It lets players experiment with quantum behaviors inside Minecraft's world, with new blocks that exhibit quantum entanglement, superposition, and observer dependency.[9]

The 1980s saw the beginnings of the video games industry with much experimentation and many new games being developed. During the 1990s, the games industry matured and the graphical images and animations became increasingly realistic. Games began to be designed by large teams rather than individuals, with a corresponding increase in costs. Because of the increased focus on visually richer and more complex games, there has been a decline in the number and variety of new games being produced. This trend has continued into the twenty-first century with an increasing emphasis on a small number of very successful game franchises to reduce the risk of expensive failures. Minecraft is an encouraging exception to this trend. And technology still has some surprises: the inexorable progress predicted by Moore's law and the rapid growth of smart phones has created new opportunities and challenges for the computer games industry.

Angry Birds and casual gaming

The availability of more powerful microprocessors together with advances in screen technologies allowed the development of handheld gaming devices not requiring connection to a TV. Nintendo led the way with the introduction of the Game Boy (Fig. 9.14) in 1989. One of the games that came bundled with the Game Boy was the puzzle game Tetris (Fig. 9.15), in which users have to manipulate falling blocks in a variety of shapes to form complete lines. The game is recognized by *Guinness World Records* as being "the most ported game in the history of video games,"[10] and versions of Tetris have now appeared on more than sixty-five different gaming platforms.

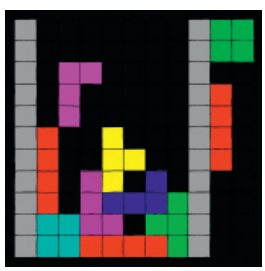


Fig. 9.15. Tetris was designed and programmed by Alexey Pajitnov while he was working at the Soviet Academy of Sciences' Computing Center in Moscow, Russia, in 1984.

Mobile phones became a gaming platform with the introduction of the game Snake by Nokia in 1997. Snake was originally developed in the 1970s. The player controls a snake that moves around the screen with the objective of avoiding hitting its own tail. As the snake moves around, it eats food and its tail grows longer, making it increasingly difficult to avoid. After Nokia preloaded the game onto its phones, the popularity of Snake exploded. This was one of the first examples of a "casual game" – a game with limited complexity that can be played while waiting or traveling. Because of the small phone screen and the very limited amount of memory and computing power available on mobile phones, these early casual games needed to be very simple.

The cost of computing technology has now become low enough to make smart phones and tablets with as much computing power as a PC widely available. Casual games explicitly designed for short play sessions are now among

Fig. 9.16. The idea for Angry Birds came from one of Rovio's designers, Jaako Iisalo. He created a screen shot showing a cartoon flock of round birds looking cross. One of the directors of Rovio, Niklas Hed said: "People saw this picture and it was just magical."[F1]

the most popular applications for smart phones. One of the most popular of these games is Angry Birds (Fig. 9.16), developed by the Finnish company Rovio Entertainment Limited. In the game, players launch cartoon birds from slingshots to destroy cartoon pigs. The two cousins who run the company, Mikael and Niklas Hed, realized in early 2009 that the smart phone market for games was about to take off. The cousins had developed more than fifty games before Angry Birds and, armed with this experience, they had set out to create a game that was entertaining for ordinary people, not just for hard-core gamers. When Niklas saw his mother distracted from cooking the Christmas dinner by playing Angry Birds, he realized they had a hit on their hands. He said, "She doesn't play any games. I realized: this is it."[11] The game became available in Apple's App Store in December 2009, and more than twelve million copies had been sold by 2013.

The casual game FarmVille introduced a new social element into mobile gaming by its association with the Facebook social networking site. The game was launched by Zynga in June 2009 and reached more than ten million daily users within six weeks. The game was inspired by a Chinese farming simulation game called Happy Farm that allowed players to grow crops, trade with others, sell produce, and steal from neighbors. At its peak, the game had more than twenty million daily users in China and Taiwan. Although Happy Farm and FarmVille have now declined in popularity, many new games are now available. In 2011, in the United States and Western Europe there were more than sixty million casual gamers on Apple's iPod touch, iPhone, and iPad platforms who downloaded an average of 2.5 games a month. Half of all paid and free downloads on Apple's App Store in these countries were games. On Facebook, more than 50 percent of users play games and there are more than 250 million people playing games on the site every month.

Worryingly, nearly 20 percent of Facebook users say they are addicted to playing games. Video game addiction is now becoming a real problem in many countries. During the last decade, there have been a handful of horrific deaths caused by serious video game addiction – deaths of players and of children being neglected while their parents played games. In 2005, a young man in South Korea died after playing a video game continuously for fifty hours. In 2010 a woman in the United States was convicted of second-degree murder after she told investigators that she had shaken her baby to death because its crying had interrupted her playing FarmVille. As early as 1981, a bill called the Control of Space Invaders (and other Electronic Games) Bill had been introduced into the British Parliament and was only narrowly defeated. In 2007, the Chinese government introduced restrictions on online gaming that required Internet games operating in China to identify users by their resident identity numbers. After three hours of continuous play, players under eighteen are prompted to stop playing the game and take some physical exercise. If they continue the game, their game points are reduced and, after five hours, all their game points are erased. This legalistic approach is just one attempt to address the serious problem of addiction that is accompanying the continuing rise in popularity of computer video games.

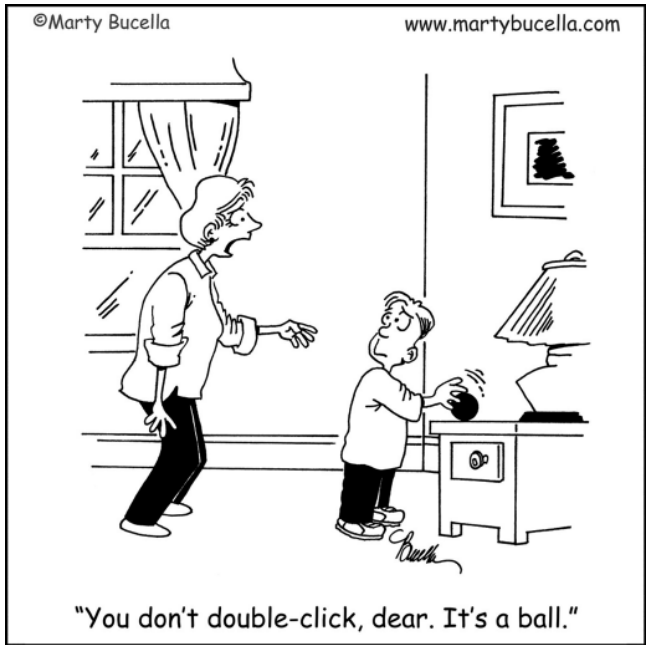
Keyconcepts

- Genres of computer games
  - Action games

- Ball and paddle
- Space opera
- Maze
- Platform

- Adventure games
- Simulation and management
- Real-time strategy or RTS
- First-person shooter or FPS
- Role-playing games or RPGs
- Multiuser dungeons or MUDs
  - Massively multiplayer online role-playing games or MMORPGs
  - Casual games

- **CD-ROMS, DVDs, and Blu-ray disks**
- **Computer graphics technologies**
  - Pixels and bitmaps
  - Raster graphics
  - Vector graphics
  - Side-scrolling and sprites
  - 3-D modeling
  - Rendering



Stewart Brand and *Rolling Stone*

In 1972, ten years after Slug Russell created Spacewar!, Stewart Brand, a writer and computer enthusiast who had worked with Doug Engelbart on the "Mother of All Demos" in 1968, watched students at the Stanford Artificial Intelligence Laboratory enthusiastically playing the game. The game ran on a PDP-10 computer costing $500,000 and differed greatly from IBM-style batch computing. Although the game was not yet personal computing, it was clearly a very personal use of the PDP-10's time-sharing system. Students were using the computer for fun, interactively, with no thought for the cost of the computer time, just as personal computers would be used only a few years later. Brand investigated the personal computing and gaming culture further, and Bob Taylor allowed him to talk to the researchers at Xerox PARC. The result was that PARC researchers and their laid-back, freewheeling style of research appeared in a story in *Rolling Stone* in December 1972 (Fig. 9.17). The story was titled "SPACEWAR: Fanatic Life and Symbolic Death Among the Computer Bums" and featured photographs by Annie Liebowitz and an interview with Alan Kay. Needless to say, this publication caused considerable embarrassment back at Xerox's conservative East Coast headquarters and resulted in the company ordering a more formal system of computer access at the Palo Alto laboratory.


· ROLLING STONE · 7 DECEMBER 1972 ·

SPACEWAR

SPACEWAR

Fanatic Life and Symbolic Death Among the Computer Bums

by Stewart Brand

Fig. 9.17. Stewart Brand's "Spacewar" article in *Rolling Stone*.

Teletypes

The teletype (Fig. 9.18) was an electromechanical typewriter developed in the last century that could be used to send and receive typed messages using point-to-point connections. Teletypes were quickly adapted to provide a text-based user interface to the early mainframe computers and minicomputers. Although they were soon replaced by punched card readers and fast line printers for most purposes, teletypes continued to be used as interactive time-sharing terminals. It was not until computer terminals with monitors – video display screens – became widely available in the mid- to late 1970s that the teletype finally became obsolete. However, some of their heritage still lives on. When video displays became available, these could display thirty lines of text in a few seconds instead of the minute or so required for printing on paper. On a teletype, users typed commands after a *prompt character* was printed. Initially, games kept the same user interface for the video display screen and this is why the *command line interface* and *prompts* used by professional software developers look the way they do today.

Fig. 9.18. The photograph shows the Teletype Corporation's Model-33 terminal also known as an ASR-33 (ASR stands for Automatic Send Receive). The model was introduced in 1963 and more than half a million teletypes had been produced by 1975. The 500000th machine was plated with gold and exhibited.