

Lecture 17. Joystick Culture: Games

Informal and unedited notes, not for distribution. (c) Z. Stachniak, 2011-2015.

Note: in cases I were unable to find the primary source of an image or determine whether or not an image is copyrighted, I have specified the source as "unknown". I will provide full information about images and/or obtain reproduction rights when such information is available to me.



Fig. 1. Games are fun!. Photograph by Z. Stachniak.

Introduction

Games are essential to human experience and, most likely, they always will be. We are many things, creatures who think and create as well as destroy without mercy. But we, like many other animals, are also playful creatures. We can play with sticks and stones, words and thoughts. On a sunny day, in a city park or on a mountain trail, someone picks a stick. She will try to balance it on a tip of a finger, he will throw it high in the air to catch it after a few rotations, effortlessly behind the back – impressive!

Or children on a beach creating magic out of sand, a castle, a city. Then, with a stick or a spade they will defend them every time the sea monster returns with raging force of the ocean.



Fig. 1. Children building a sand castle to defend against the Dark Lord residing in the real castle. *Sand Castle vs Real Castle*. Photograph by Chris Tolga Pehlivan.

Now, imagine what can be done with a computer at home on a rainy day... Like sticks and stones, like a deck of cards or warm sand of a sunny beach, the computer invites to play.

Computer games defined

According to *Digital Deli: The comprehensive user-lovable menu of computer lore, culture, lifestyles and fancy*, computer games are desserts on the menu of computer applications. For some, they are the main course served 24 hours a day. But more prosaically, computer games are programs designed for recreational use on a computer or a dedicated game console in stand alone or networked configuration (e.g. multiplayer games over the Internet).

Computer's ability to generate, display, and manipulate multimedia objects in response to our inputs (or lack of) makes it an irresistible game playing device. Computer can not only imitate a game's board or a scenario, but it can also be an opponent, a partner, a referee, or all of that simultaneously.

Game playing computer can invoke deep emotions (too cliché?): the ecstasy of victory and the agony of defeat, the primordial joy of destruction and victory fed by the sense of duty and justice or fear, desire, revenge, and rage.

Computers offer "gamers" yet another chance, don't mind the late hours, are indifferent to our addictions and eating habits. In short, computers are perfect entertainment boxes.

It seems certain that we will be playing electronic games for as long as there is no better technology to provide us with artificial entertainment (as opposed to "natural" one, such as performing or listening to music, dancing, engaging in sports). There will be claims made of technological advancement induced by the gaming culture and needs and of new forms of artistic expression.

Games will continue to play an important role in education on all levels. One can easily design an undergraduate curriculum in computer science around computer game design, from computational geometry and computer graphics, computer user interfaces, and software engineering, to computer hardware, artificial intelligence, and algorithms.

Of course, it also seems certain that concurrently with the development of the electronics entertainment industry we shall continue the debate on the impact of such forms of entertainment on individual and social development. Are computer games unnecessarily addictive, hazardous to health (especially children's health), could they stimulate or reinforce violent behaviour? Do games change the social makeup by creating individuals mostly isolated from each other, with no or limited social interaction skills, who neither read nor write books? Are virtual games substitute for the real, with us-virtual avatars- with several lives instead of one?

Whatever else can be said or predicted about electronic games and their impact on the society, we shall be always playing games, in one form or another - it's simply genetics.

In this lecture we shall look at the computer and video gaming industries and the continuous interplay between their advancement and social, economic, and cultural changes and demands.

Where do computer games come from?

Computer games haven't been invented by anyone; they have been always a part of our computing experience. Computers are highly interactive devices and that's why we have always been exploring their game playing potential.

I'm not sure whether ENIAC or any of the Colosus computers were ever used as a game playing machines. But already in the 1950s, several researchers and engineers had begun exploring the game playing capabilities of computers. For instance, in the early days of AI, games, such as chess, presented a unique opportunity to study computational aspects of intelligence such as search, knowledge representation, reasoning, and planning.

One of the most difficult early problems in the experimentation with game playing computers was finding a way to successfully visualize a dynamic game environment such as positions of chess pieces on a chess board. The early input-output devices, such as card and tape readers/punchers, were obviously inconvenient and slow even for the implementation of simple board games.

Of course, there were those who tried to use them regardless of the inadequacy of paper tapes and cards. In the mid 1950s, the MANIAC (Mathematical Analyzer, Numerical Integrator, and Computer or Mathematical Analyzer, Numerator, Integrator, and Computer) computer built at Los Alamos Scientific Laboratory was programmed to play a limited variant of chess using paper tape.



Fig. 2. One of the early computer chess programs was written for the MANIC computer built at Los Alamos Scientific Laboratory. The computer's paper tape reader/puncher was used to communicate all the chess moves. Source: www.armageddonchess.webs.com

Rudimentary displays could be designed, for instance, using rows of lamps, as shown on Fig. 2A. Switching some of these lamps on can form display patterns from digits and characters to simple graphical depictions of various objects.



Fig. 2A. A modern LED lights display. Source: <https://www.adafruit.com>

In cases when only a small set of fixed patterns is to be displayed, one could use pattern cells which could be turned on or off as desired. This solution was applied in possibly the first electronic game console – Bertie the Brain designed in Toronto and demonstrated during the 1950 Canadian National Exhibition in Toronto.



Fig. 2B. Bertie the Brain displayed during the 1950 Canadian National Exhibition in Toronto.

Source: <http://spacing.ca/toronto/2014/08/13/meet-bertie-brain-worlds-first-arcade-game-built-toronto/>

Bertie the Brain was a tic-tac-toe playing arcade designed by Josef Kates and built by Rogers Majestic (now Rogers Communications). Kates, who participated in the construction of UTEC—the Canada’s first computer—designed Bertie around an advanced form of vacuum tubes called the Additron. Read the full story at <http://spacing.ca/toronto/2014/08/13/meet-bertie-brain-worlds-first-arcade-game-built-toronto/>



Fig. 2B. Danny Kaye plays against Bertie the Brain during CNE 1950. Photograph by Bernard Hoffman, 1950.

Source: <http://electronicsquid.tumblr.com/image/43498163976>

Cathode ray tubes or CRTs offered a much more sophisticated form of electronic display for games. Such displays were investigated since the end of the 19th century and were in use in the first TV sets as early as 1930s. These tubes were also extensively used in radar and navigation equipment. However, it was not until 1947, when Thomas T. Goldsmith, Jr. and Estle Ray Mann obtained the first patent for an electronic game with CRT display. Their missile firing game was called *Cathode Ray Tube Amusement Device*. The patent was granted the following year but the game was never turned into a commercial product.

A similar interactive gaming device was invented and created in 1958 by William A. Higinbotham – an American physicist and engineer employed at Brookhaven National Laboratory (BNL), in Upton, New York. Higinbotham found a way to keep entertain visitors to BNL by offering a round of *Tennis*

for *Two* game that he implemented with an assistance from Dave Potteron (see [2] and [3]). The game was controlled by a Donner Model 30 analog computer connected to an oscilloscope with a CRT for display.

The court and net were displayed in rapid alternation with the ball motion on the oscilloscope screen. Players hit the ball by pushing a button, and by turning a knob they could adjust the angle of return. An unwise setting would send the ball crashing into the net.

The game was the hit of visitors' days for the next two years. "People would stand on line for hours to play it," recalls one scientist. (cf. [2])



Fig. 3. Recreation of Higinbotham's original Tennis For Two.
Source: <http://www.bnl.gov/about/history/firstvideo.php>, cf. [3].

Did Goldsmith, Mann, and Higinbotham envisioned the enormous market potential for games played on a computer with an electronic display? Probably not. Higinbotham made no effort to commercialize his game and didn't secure the patent for his invention for BNL. Both *Cathode Ray Tube Amusement Device* and *Tennis for Two* remained unrealized and unknown to the rest of the world – ancestors of no game, instantly forgotten the day they were dismantled.

SpaceWar!

The next step in the evolution of computer and video games was taken by MIT students in the early 1960s. In 1961, an MIT programmer Stephen Russell, programmed an interactive space game on a DEC PDP-1 computer (cf. Lecture 7).

The PDP-1 had a CRT display with some graphics capabilities and that inspired Martin Graetz, Stephen Russell, and Wayne Wiitanen to translate their enthusiasm for science-fiction epics into the first computer simulated space game.

There would be at least two spaceships, each controlled by a set of console switches. The ships would have a supply of rocket fuel and some sort of weapon: a ray or beam, possibly a missile. For really hopeless situations, a panic button would be nice.

Graetz recalls the design enthusiasm in [4].

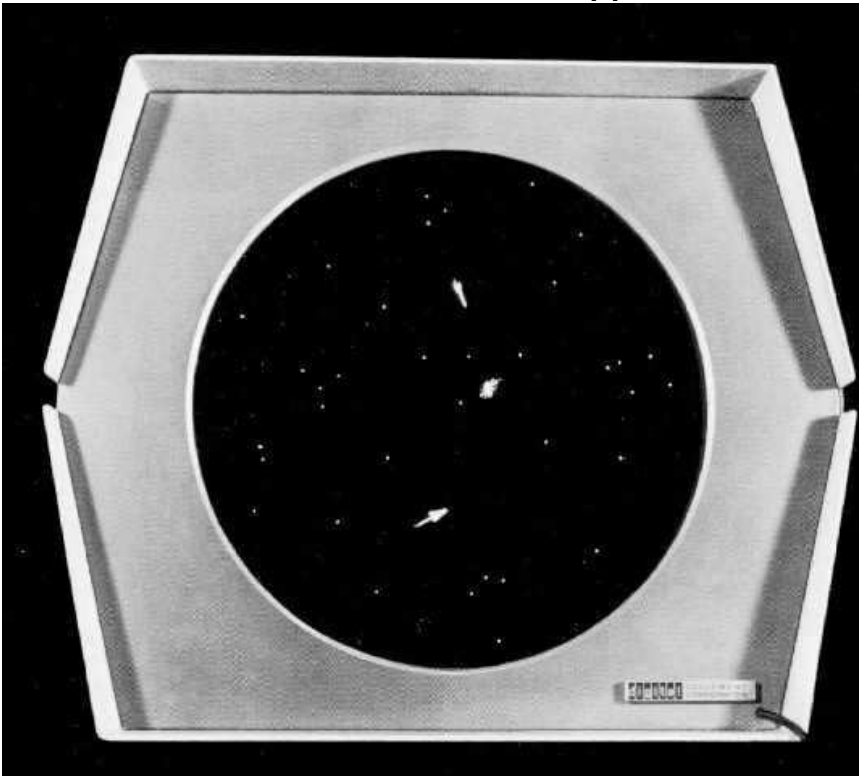


Fig. 4. SpaceWar! screenshot. Source: [5].

In the game's development, Russell was assisted by Peter Samson, Dan Edwards, and Martin Graetz as well as Alan Kotok, Steve Piner, and Robert A. Saunders.



Fig. 5. Slug Russell, Shag Graetz, and Alan Kotok playing their SpaceWar! again. <http://xpressroom.blogspot.com/2010/09/fayerwayer-en-tu-email-flickr-llega-los.html>

They called it SpaceWar! Using console switches of the PDP-1, two players controlled two missile-firing spaceships displayed (as the classic "needle and wedge" space ship outlines) on the machine's CRT display at the opposite-quadrant starting positions. The objective of the game was, as one can easily guess, to destroy the opponent's spaceship in the cosmic combat in some region of cold and vast universe with dangerous heavy stars and black holes. Constellations depicted in the game were modelled after data published in the *American Ephemeris and Nautical Almanac*.

The game was the first widely available computer videogame. Its simple rules created vast number of scenarios making it addictive, irresistible, and an instant success. The game was copied and modified to work on almost every computer platform. Some companies started to complain about lost revenues due to the use of their companies' computers for destroying spaceships instead of crunching payroll numbers.

SpaceWar! had a direct impact on the creation of the video and computer game industries. It inspired generations of game designers and developers and created the first generation of "gamers" and their subculture. It was possibly the first piece of software that demonstrated computers' vast potential in non-traditional areas such as entertainment. Spacewar! combined with the popularity of the *Star Trek* movies resulted in the Star Trek games – among the most popular games of the 1970s.

The arcades



Fig. 1. Once a gamer – always a gamer.
Photograph by Z. Stachniak.

Videogame industry emerged almost simultaneously on two fronts when two companies, Magnavox and Atari, ventured into the world of gaming with radically new ideas for interactive entertainment.

First coin-operated arcade machines from Atari appeared in American bars and game rooms to compete for quarters with pinball machines at the beginning of 1970s. At the same time, a small videogame system for home from Magnavox—the Odyssey—captured the attention of hundreds of thousands of American consumers. With their game playing machines, Atari and Magnavox successfully commercialized the entertainment novelty of SpaceWar!

Commercial coin-operated arcade machines of the 1970s and early 1980s were dedicated electronic game playing devices enclosed in stand alone tall booths or cabinets, with built-in video monitors and all sorts of game controllers. Covered with colorful art work and surrounded by a cloud of electronic sound, they looked irresistible. And, indeed, they were. In dedicated arcade halls and shopping malls, in bowling alleys, convenience stores and movie theatres skinny little arcade geeks were trading their lunch and allowance money for a dose of electronic adventure. And older videogame buffs in T-shirts and jeans or in neatly pressed business suits were shovelling silver into the coin slots for their right to exercise the power over the universe.

In 1969, Nolan Bushnell developed an arcade dialect of *Spacewar!* and packed it in an arcade box. Released in 1971 under the name *Computer Space* by Nutting Associates, it was the first arcade video game: the game's hardware was packed in an impressive-looking futuristic cabinet with a 13-inch black and white display.



Fig. 5. Computer Space arcade game. Source: Computer History Museum, photograph by Z. Stachniak.

The game didn't sell well. It seems that it was simply too new as a concept and too complex for bar regulars (still preferring pinball machines). As it turned out, the destiny of this game was a short bar-life but ever-lasting fame in future museums of technology (one of the *Computer Space* arcades is in the Computer History Museum in California).

Atari Pong

In the beginning there was Colossal Cave. And Colossal Cave begat Star Trek, and Star Trek begat Space War, and Space War begat Pong. And Pong triumphed over Pinball and established Arcades in the Malls of the land. And the descendants of Pong were more numerous than the grains of sand in the sea. [from Info, 17 (1987), p. 29.]

In 1972, Bushnell's new company Atari (co-founded with Ted Dabney) launched another arcade video game that would become one of the most popular early coin-operated games – *Pong*.



Fig. 6. Atari *Pong* arcade game. Photograph by Z. Stachniak.

Pong was an arcade version of the Magnavox *Ping-Pong* game that Magnavox offered for its first game console Odyssey in 1971. In spite of the successful legal claim for copyright infringement by Magnavox, Atari retained the rights to manufacture and sell *Pong* while paying some royalties to Magnavox.

The coin-operated *Pong* was a huge success for Atari and the game would soon rival the dominant position of every bar's favourite pinball machine. It was simpler to play than its predecessor Space War: "Avoid missing ball for high score" read the only instruction placed on the Pong's box. And yet the game required continuous practise to progressively master it to stand a chance in never ending and frequently emotional tournaments. In short, Pong was addictive and that translated into substantial revenues for Atari, quarter after quarter after quarter.

The success of Pong arcade was repeated by its home version—the Home Pong—Atari's first home video consumer product released in 1975. This dedicated home console that played *Pong* on a TV screen sold around 150,000 units in its first year.

Another arcade bestseller of the 1970s and early 1980s was *Space Invaders* released in 1978 by Taito Corporation, a small Pachinko game manufacturer.

Since its introduction, *Space Invaders* was relentlessly copied, sometimes without a licence from Taito, by software firms all over the world.



Fig. 6. Taito arcade games: original (left) and a copy (right). Photograph by Z. Stachniak.

According to some accounts, the Japanese treasury department ran out of the 100-yen coin that was used to operate the game soon after the Space Invaders game was first introduced in Japan (cf. [7], Byte, Dec. 1981, p. 258). True or not, *Space Invaders* ended the dominance of pachinko machines in Japan in the same way *Pong* dethroned pinball machines.

48 bug-like aliens arranged in 6 horizontal rows (the first animated characters in an arcade game) descending down the screen in a zig-zag fashion and shooting at you—the defender—with some sort of laser beams. The more you hit, the faster they advanced. When you have finally eliminated them all, a new squadron appeared ready for invasion, starting one row lower, ad infinitum. There was no fixed ending, just an escalating degree of difficulty.

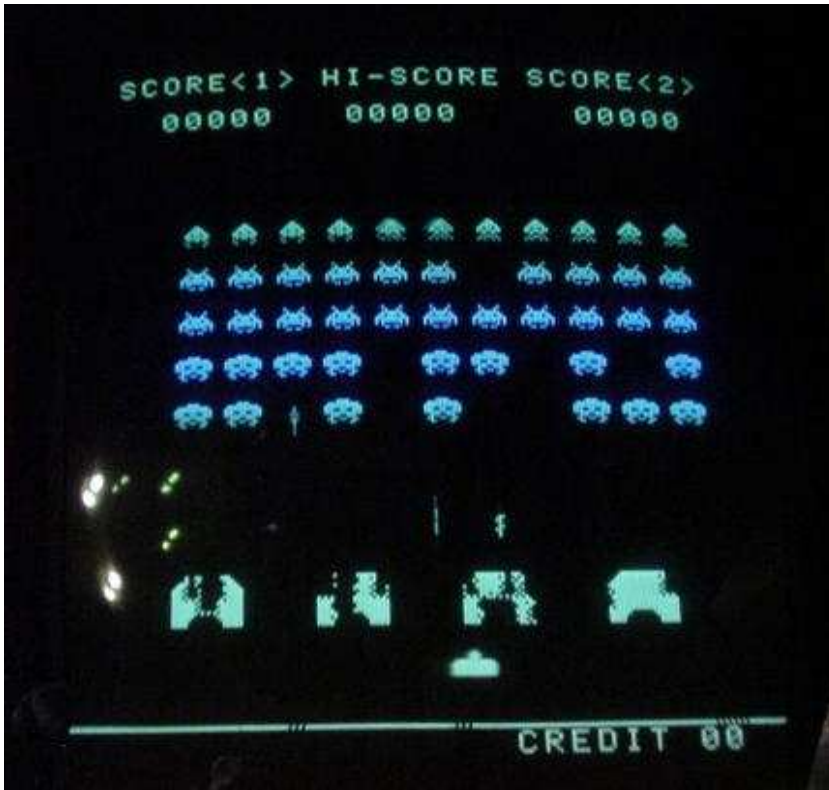


Fig. 6. Bug-like aliens of the *Space Invaders*. Photograph by Z. Stachniak.

Pac-Man forever

The most successful among the coin-operated arcades of the last century was *Pac-Man* designed by Namco game designer Tohru Iwatani. *Pac-Man*, launched by Namco, a Japanese video game manufacturer, in May of 1980 was a simple maze game featuring a pizza-like character with a slice missing.



Fig. 7. Several *Pac-Man* arcades. Photograph by Z. Stachniak.

Pac-Man introduced a new element to video game industry - a digital celebrity. The combination of game simplicity (even a five-year-old could master it) and a uniquely identifiable game character has become a defacto standard in gaming industry, especially in arcades and, later, in hand-held consoles sectors. Mario Brothers have become Nintendo's digital celebrities since their appearance on the gaming scene in 1983, while a cheeky blue hedgehog by the name of Sonic would define Sega as a gaming company.

All these digital celebrities have freed the gaming industry from the necessity of borrowing personalities from other cultural genres to attract gamers, have freed the industry from imitations of iconic Captain Kirk and his Enterprise. They demonstrated that a non-shooting game can also become a mega-hit.

In spite of its triviality, Pac-Man has had a long-lasting effect not only on the gaming industry but also on popular culture and retail. The revenues derived from selling the rights of using Pac-Man for advertising a variety of non-gaming products would be as substantial as from the sale of games (in the game's debut year alone, over 100,000 Pac-Man machines were made and sold around the world).

Pac-Man was licensed to a few hundred companies. There was General Mills Pac-Man cereal and Chef Boyardee Pac-Man Pasta. There were Pac-Man air fresheners, cereal boxes, phones, costumes, record books, and even a hot rod.



Fig. 8. *Pac-Man* Hot rod custom car. Source: <http://www.musclecars.faketrix.com>

In the 1980s, one could not leave a shopping mall without seeing Pac-Man logos, T-shirts, bedspreads, and lunch boxes - not to mention Pac-Man arcades.

In 1982, Pac-Man made its debut in ABC's animated cartoon, *Pac-Man: The Animated Series*. There were Pac-Man spin offs: Pac-Man Plus (Namco, 1982), Ms. Pac-Man (Midway, 1982), Super Pac-Man (Midway, 1982), Mr. and Mrs. Pac-Man Pinball (Bally Midway, 1982), Baby Pac-Man Pinball (Bally Midway, 1982), Pac and Pal (Namco, 1983), Junior Pac-Man (Bally Midway, 1983), Pac-Land (Namco, 1984).

In the fall of 1981, musicians Jerry Buckner and Gary Garcia spoofed Ted Nugent's song Cat Scratch Fever with a song of their own: Pac-Man Fever. Despite the bizarre lyrics, the song became a top-ten hit, climbing to number 9 in March 1982 on the Billboard Hot 100.

Pac-Man Fever by Jerry Buckner and Gary Garcia

I got a pocket full of quarters, and I'm headed to the arcade.
I don't have a lot of money, but I'm bringing ev'rything I made.
I've got a callus on my finger, and my shoulder's hurting too.
I'm gonna eat them all up, just as soon as they turn blue.

Chorus:

'Cause I've got Pac-Man fever;
Pac-Man fever.
It's driving me crazy.
Driving me crazy.
I've got Pac-Man fever;
Pac-Man fever.
I'm going out of my mind.
Going out of my mind.
I've got Pac-Man fever;
Pac-Man fever.
I'm going out of my mind.
Going out of my mind.
.... (cf. [7])

Even today, after more than 30 years from the "first encounter" with Pac-Man, there are numerous Internet sites devoted to the Pac-Man cult, there is even First Church of Pac-Man. There are Pac-Man games re-released for a number of current game consoles (e.g. Xbox360),

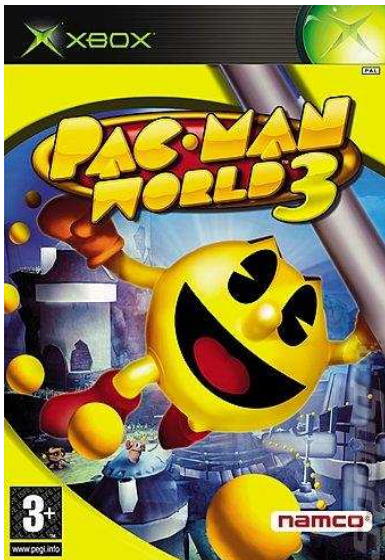


Fig. 8. Nemco's *Pac-Man World 3* for Microsoft's Xbox. Source: Namco.

On May 22, 2010, Google celebrated the 30th anniversary of Pac-Man's release by making a simplified version of the game available for playing while using Google's search engine.

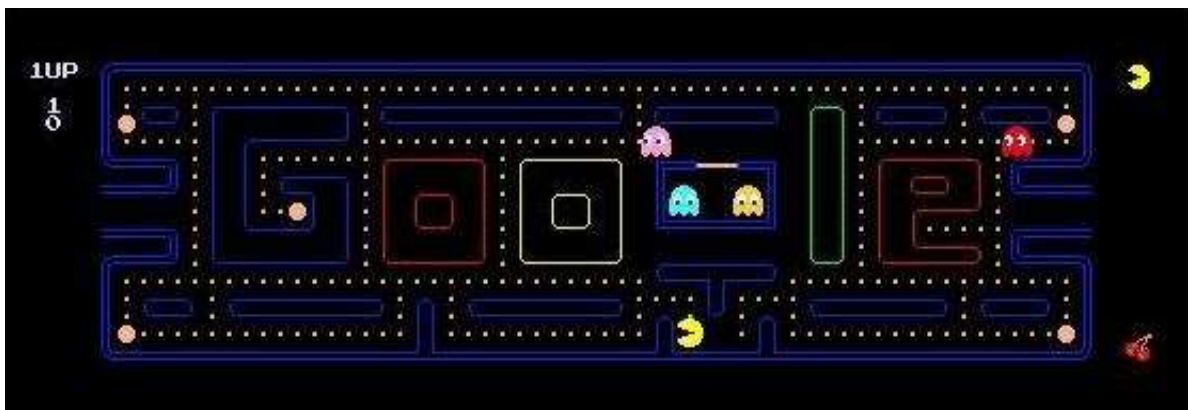
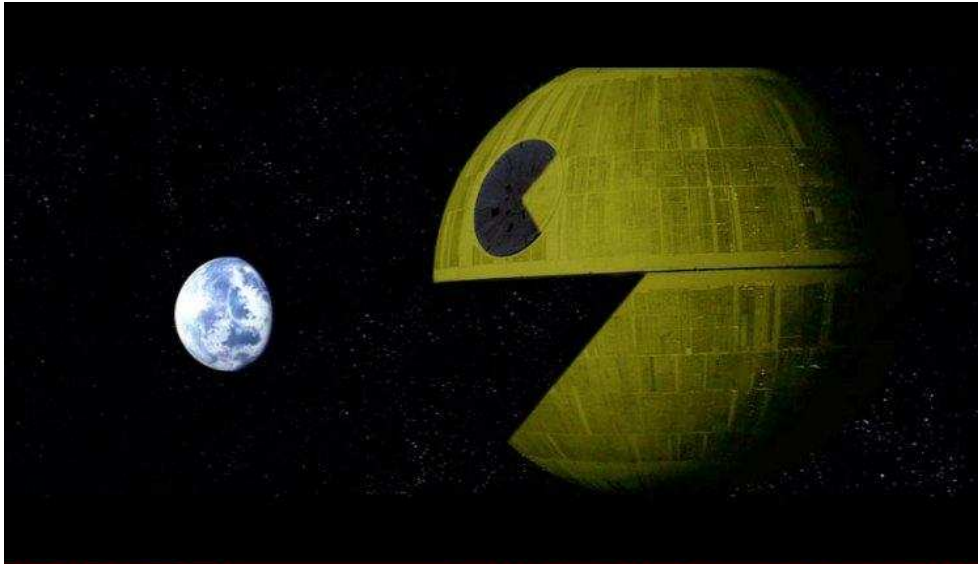


Fig. 8. Google's Pac-Man. Source: Google, <http://www.google.com/pacman/>

Pac-Man Art Gallery



FreakingNews.com

Pac-Man Death Star, image by Prowler2885



FreakingNews.com

Pac-Man Dandelion, image by Kibuy



Arcades at home

Arcades could never succeed at home, for they could only play a single game they were designed for. They were huge, heavy, and expensive, and so, cramming a half-dozen of them into the living-room would be a rather bizarre form of an affordable family entertainment (although there were some small, desk-top versions of Pac-Man and other arcade games).

To enter homes, a videogame system would have to be small, highly interactive, and would have to support not a single but a variety of games.

The Odyssey, a rather rudimentary game console designed by Ralph Baer between 1966 and 1970 and released by Magnavox in 1972, was just that: an interactive and multigame home entertainment system in a perfect symbiotic coexistence with a TV set doubling as a display. The system used plug-in cartridges (half berried in plastic printed circuit boards with no electronic components on them but a few jumpers) to rewire the hardware inside the Odyssey to play different variants of the same generic Odyssey game.

Magnavox supplied the Odyssey with printed plastic overlays which, when placed over the TV screen, provided the various backgrounds for the games (the Odyssey could neither display backgrounds nor generate sound). The player(s) used an assortment of accessories (game boards, scoreboards, dice, chips, money notes, a variety of game cards) to compensate for the similarities of games generated by the console.



Fig. 8. Playing Tennis on Magnavox Odyssey. Source:
<http://www.kymalabs.com/wormwall/displaywall?key=9cc89378626425cc1a0d7e8cdbef6bebd>

Among the games available for the Odyssey, there was Tennis, Baseball, Hockey, Football, Roulette, Shooting Gallery, Interplanetary Voyage. As primitive as the Odyssey was, by 1975, Baer's invention made Magnavox \$22 million richer, selling approximately 100,000 units only in 1972 (see [8], p. 46).

Video games enter the microprocessor age

The success of the Odyssey and, later, of the Home Pong (a portable version of the arcade *Pong* from Atari implied that the future of electronic home entertainment belonged to videogame consoles with good quality graphics and sound capabilities and supported by a large variety of games on easy to operate storage media.

Certainly, the hardware of such a new generation videogame system could be designed around the microprocessor (available since 1972). Storing games on plug-in ROM cartridges would allow almost instantaneous access to a game by simply inserting a selected cartridge into the cartridge slot of the console. The addition of an assortment of game controllers would complete the design.

In August 1976, the video game industry was stunned by the arrival of exactly such a game console from Fairchild Camera and Instrument, an American semiconductor company. Its Channel F video entertainment system was the first game console for home that featured color graphics and games on interchangeable plug-in ROM cartridges. The cartridges were esthetically designed, easy to use, and were programmed with popular games such as *Checkers*, *Space War* and sports games *Pro-Football* and *Baseball*.



Fig. 12. Fairchild Channel F. Photograph by Evan-Amos.

Soon, Fairchild's game console would reach beyond the American home entertainment market; its versions would be sold in Sweden under the name of Luxor Video Entertainment System, it was called the Grandstand in the U.K., and the Saba Videoplay in Germany.

With the microprocessor at its heart and with games stored on interchangeable ROM cartridges, the Channel F become a blue print for the design of the new generation of videogame systems, most notably of the famous Atari Video Computer System. New game consoles would share more design and operation features with small microcomputers than with massive single-game arcades.

Some videogame manufacturers stressed explicitly the connection with the microcomputer culture by including the trendy terms 'computer' or 'microprocessor' in the names of their game consoles. Atari named its first system with interchangeable game cartridges the Video Computer System. Bally marketed its early game console under the name Professional Arcade Computer or Home Library Computer, while APF Electronics called its videogame system the M-1000 Microprocessor.

Furthermore, growing popularity of plug-in ROM cartridges, which could be developed and produced in high volume independently of the game consoles, would effectively split the video game industry into the hardware and software areas much like the makeup of the microcomputer industry.

Atari Video Computer System

Atari's response to Fairchild's Channel F console was the Video Computer System (VCS 2600) a result of cooperative effort of Joe Decuir, Steve Meyer, Ron Milner, and Jay Miner. Released in October 1977 in the midst of the first videogame war, it had to wait long months before the market would eventually turn in its favour and, with the suggested retail price of \$200, elevate the VCS to the most sought after home entertainment system.

By the end of the 1970s, Atari was fully in charge of the video game market with its VCS 2600 and two home computers the Atari 400 and 800. Two thirds of all home video game systems in the U.S. were VCS and its clones.

Coin Operated Games division of Atari continued its success with its new mega hit *Asteroids* (1979) which dethroned Taito's *Space Invaders* as the most popular arcade.



Fig. 13. Atari VCS. Source: unknown.

Atari's video game empire did not remain unchallenged for long; the attacks on its domination in the gaming market would be continuous and on many fronts. To compete with the popularity of the VCS, some companies would go as far as to manufacture special add-ons to their videogame systems that allowed playing VCS games. Others would release VCS clones (e.g., Gemini from Coleco or Dactar Game System from Dactar).

The first real challenge to Atari video game empire came from Mattel Electronics which in 1979 unveiled its Intellivision (Intelligent television) video game console, selling 175,000 of these entertainment systems in 1980 and three times that much a year latter.

The Intellivision was a new generation system much superior to the VCS which had remained unchanged since its introduction in 1977. Although the Intellivision was a fully functional video game system, Mattel referred to it as the 'Master Component' which was to be supplemented in 1981 by the 'Keyboard Component' which when added to the Master Component was to transform the system into a practical home computer.

It looked like the success of the videogame console industry would continue indefinitely. But then came inexpensive home computers offering not only gaming but also computing power. Home computers could be used for entertainment as well as other purposes, such as education. They used dedicated displays, could store data and programs, could print texts and connect to BBS systems. Game consoles "dressed" as home computers were not the match and when the prices of home computers dropped below those of game consoles, people just stopped buying the consoles.

Japanese are coming

In the second half of the 1980s the videogame industry had resurrected itself after the near death collision with the raging business of personal computing. The help came from Japan.

In 1983, Nintendo introduced the Family Computer (or Famicom) in Japan with great success. Two years later, the Famicom arrived in US in a new gray-colored plastic case and renamed Nintendo Entertainment System (NES) for the American gamer. The NES was an old concept videogame system: a microprocessor-based hardware that played games stored on ROM cartridges, used an ordinary TV set for video and audio, and a pair of game controllers.

So it wasn't its name "Entertainment System"—nor even the hardware inside the console that took the continent by the storm. It was the entertainment value of the NES's games, such as *Super Mario Brothers* (Nintendo, 1985) supplied with every NES, that infused new life into the videogame industry in the same way as Taito's arcade *Space Invaders* revived the industry from its first collapse under pressure from home video consoles. Technology alone does not sell game consoles, it never did. Games do: it only takes one or two blockbuster hits in a genre to make a particular videogame platform fashionable again.



Fig. 13. Nintendo NES. Source: unknown.

The NES succeeded because playing games on this small console was entertaining again like playing arcades in the past. The digital pop stars—Mario and Luigi of the *Super Mario Brothers* brought back that arcadeian joy of play that derives from the synthesis of simplicity and skill.

The success of the new generation videogame systems from manufactures such as Nintendo (Famicom, NES), Sega (Genesis), and NEC (PC Engine, Turbo GrafX-16) demonstrated how unpredictable the electronic entertainment industry was, that the debate about the superiority of PCs over video consoles, or vice versa, as the most versatile gaming platform was far from over.

Portable hand-held game systems with interchangeable game cartridges, such as the Game Boy launched by Nintendo in 1989, Sega's Game Gear, or NEC's TurboExpress, became more 'personal' for young children than the new generation of personal computers for home could ever be.

Sure, the Game Boy wasn't a computer, sure it had inferior graphics and sound capabilities. But it was once again a child's close companion, a very own tiny electronic pal that could be carried to school in a schoolbag and to a playground in a pocket.

The Game Boy transformed children's natural hunger for game playing into a distinct cultural phenomenon, and children, in turn, made the Game Boy one of the most successful game systems ever.



Fig. 13. Nintendo Game Boy. Source: unknown.

In the end, the Japanese did come to rescue the game console industry. But Nintendo and Sega did so by flooding the electronic consumer market with inexpensive game systems bringing down the old videogame empires build by Atari, Coleco, and Mattel, and contributing its share of proverbial nails to the coffin of small home computers.

By the mid-1980s, gamers were buying videogame systems again. A decade later the videogame industry was once again a dominant force in the entertainment industry. By the end of the last century, the video game business was bringing \$20 billion a year and the console industry was on the verge of the war for the living room.

In September 1999, Sega released its little console—the Dreamcast, recording a good sales in North America. On October 26, 2000, thousands of American gamers lined up for long hours in front of electronics stores, not always peacefully, sometimes in open air and despite a bitter cold of late October, to get their hands on PlayStation 2 – a new game system from Sony. Dedicated Nintendo followers decided to wait another year for the release of the Gamecube, and almost everyone else for the first videogame system from Microsoft—the Xbox—announced at the Game Developer Conference in San Jose, California, on March 10, 2000, and unveiled at Consumer Electronics Show in Las Vegas, Nevada, on January 6, 2001).

That time around the war was about the future gaming technologies, new forms of interaction, and later, the role of the Internet. The competition brought much progress as it became evident with new technologies such as the Nintendo Wii technology unveiled in November of 2006 or Microsoft's Kinect for XBox.

Enter microcomputers

The first company to offer a game for a microcomputer was the Canadian Micro Computer Machines which released its MCM/70 PC with a handful of games including a horse race simulation. The MCM/70 was equipped with a single line plasma display with no graphics capabilities. In the horse race game, line segments representing horses were dshing from the left-end of the screen to the right-end at random speeds.



Fig. 14. MCM/70 horse race simulation. Image by Z. Stachniak.

According to Mers Kutt, the inventor of the MCM/70, the demonstration of this game on the MCM/70s prototype made an impression on Intel’s co-founders R. Noyce and G. Moore who were impressed with the capabilities of Intel’s microprocessor inside the MCM/70 computer.

It is possible that this game was influenced by a simiular game *Horses* whose BASIC code was published in DEC’s *101 BASIC Computer Games* (cf. [10]). In this book, we find the following comment regarding its source: ”The published program has been around DIGITAL for as long as anyone can remember. Its author is now unknown.” ([10], p. 133)

In August of 1974, Joe Weisbecker, an RCA computer engineer and a dedicated computer educator (who was already mentioned in Lecture 6) published an article ”A practical, low-cost, home/school microprocessor system” (see [9]) in which he discussed in detail the ‘recreational’ applications of future microcomputers listing over 20 games for that could be implemented on even a basic microcomputer, games like TIC TAC TOE, Hexapawn, Football, Bawling, Space War, and Moon Landing, most of them already impelmented on his FRED educational microcomputer.

Star Trek

First microcomputers were built with low amounts of memory (typically between 256 bytes to astonishing (not!) 16K) and could work only with alphanumeric displays. This severely restricted the type of games played on

these early machines to mostly games in "prose" or "text" form. In such games, objects manipulated by a player were either not displayed or displayed statically as strings of alphanumeric characters.

```
THIS IS ROOM 14 ADJACENT TO 1, 17, 2
SHOOT OR MOVE: M
MOVE TO: 1

YOU ARE FARTHER FROM THE WUMPUS.
I HEAR BATS.

THIS IS ROOM 1 ADJACENT TO 6, 14, 16
SHOOT OR MOVE: 6
SHOOT OR MOVE: M
MOVE TO: 6

YOU ARE CLOSER TO THE WUMPUS.

THIS IS ROOM 6 ADJACENT TO 1, 3, 12
SHOOT OR MOVE: █
```

Fig. 15. Hunt the Wumpus published in *Creative Computing*. Source: www.sol20.org/programs.html.

The computer was directing a player with as little typing as it was necessary. Graphics had to be replaced by user imagination and a bit of text describing the current state of the game. Interaction was done by displaying menus, questions, directives, statistics, etc. and entering possible choices into a computer. The result of an action was communicated by a computer in sentences: 'you have destroyed Klignon cruiser', 'you are under attack', 'this room is empty', or 'you have lost the game'.

In the first decade of personal computing, no single piece of software exem-

plified the excitement of computer gaming better than the game *Star Trek* - computerized derivative of the science fiction classic series *Star Trek* conceived by Gene Roddenberry.

The player assumed the role of Captain James Tiberius Kirk of the Starship Enterprise, the mission was to free the galaxy of Klingon intruders (by destroying their ships) and, thus, defending the freedom and well being of the United Federation of Planets. The game's objective was to be accomplished within a certain time frame (the number of stardates) and fixed resources (energy, weapons) which were consumed when moving the Enterprise around or firing weapons at Klingon scum, or replenish at a secret star base.

The game brought the fantasy of exploring faraway galaxies right into your home, you could do better than the famous captain James T. Kirk fighting Klingons.

```

L-R SENSOR  †-MINE  -Processor Technology-  ‡ USS ENTERPRISE ‡
004 008 ??? ‡-ENTPR 0I          ...          I STARDATE      300200
-----  ‡-BASE  1I          *****          I CONDITION      STDBY
009 002 009  ‡-KBC  2I          ^]'''[^          I QUADRANT       0-9
-----  ‡-KMT   3I          |      |          I SECTOR         0-0
005 006 006  ‡-UNKN 4I          [→0 0←]          I PHOTON TORPS   10
PWR DIST   %          5I          | 0 |          I POWER AVAIL    99%
WARP&IMP   20         6I          { - }          I KLINGONS LEFT  052
LR SENSOR  10         7I          /_/_\          I ANTIMATTER PODS 03
SR SENSOR  20         8I          (≡ 8.8 ≡)          I
DEFLECTORS 20         9I          ( (,.) )          I  COMMAND:
PHASERS    09         I-0-1-2-3-4-5-6-7-8-9-I
TORPEDOES  11
STARFLEET COMMAND:(CODE 7)THE KLINGONS HAVE BROKEN INTERGALACTIC
TREATY.  YOUR ORDERS ARE TO ADVANCE TO KLINGON TERRITORY AND
DESTROY ALL KLINGON VESSELS

```

Fig. 16. Processor Technology TREK80; Sol-specific version of the famous star trek game.
Source: www.sol20.org/programs.html.

It is possible that there was at least one *Star Trek*-like game written for every microcomputer platform during the first decade of personal computing, regardless of a computer's hardware configuration.



Fig. 16. Lunar lander published in *Creative Computing*. Source: www.sol20.org/programs.html.

To make microcomputing the fast food of the digital society required the rethinking of the very concept of the personal computer. “Very nice, dear, but what does it do?” asks Mona Lisa holding a computer in her hands on the cover of April 1981 issue of *Practical Computing*.



Fig. 16. Front cover of April 1981 issue of *Practical Computing*.

To fully develop itself into a viable high-technology industry, microcomputing required a new, sizable, and stable target market for its continuous growth. And there it was – the vast consumer electronics market, seemingly boundless and immensely profitable.

In 1981, one of the golden years of video game industry, “Video games raked in almost twice what Hollywood grossed; three times the combined TV revenues and gate receipts of major-league baseball, basketball and football; and four times the amount of money spent on records and rock concerts.” (Cf. [8], p. xii.) With the growing popularity of microcomputers it was evident that the lucrative video game market would not remain an exclusive property of the arcade and video game console manufacturers.

In fact, these were the games and thriving videogame culture nourished by the popularity of the arcade games such as *Pong* (Atari, 1972), *Tank* (Kee Games, 1974), *Breakout* (Atari, 1976), *Space Invaders* (Taito, 1978), or *Asteroids* (Atari, 1979), as well as by home videogame systems from Atari, APF Electronics, Bally, Coleco, Fairchild, Magnavox, and RCA, that created the home computer industry and rapidly expanded the microcomputer market. There was a lot of money to be made in the videogame business and with the microcomputer marketed as a sophisticated entertainment box, a lion share of proceeds from the videogame market could be redirected to the accounts of the microcomputer hardware and software firms.

As it turned out, selling the idea of a microcomputer as a perfect entertainment box was among the most successful (and well understood) marketing strategies. Every home computer had to have at least one joystick or other game controller port. Games occupied prominent position in the software libraries of Apple, Radio Shack, Commodore, Atari, IBM and other manufacturers.

To defend themselves from an immanent invasion of the world of video game entertainment by microcomputers, some video game companies decided to enter the home computer market with their own computers. One of them was Atari which dominated the videogame industry until its claps in 1983.

ATARI Home Computers are simple enough to be used by your children, yet powerful enough to manage complex management tasks.

Bring the quality of coin-operated computer games into your home. You will find that the ATARI Home Computer version of PAC-MAN is virtually identical to its incredibly popular coin-

operated counterpart... A wealth of excitement packed games awaits you at the keyboard of your ATARI Home Computer! (From *ATARI Home Computers Product Catalog*, 1982, pp. 1 and 21.)

In comparison with videogame consoles of the 1970s, home computers had a number of advantages. One could play only commercially distributed games on game consoles while a home computer owner could, in addition to commercial games, play games from other sources. A micro owner could write his or her own game, could copy a game code from one of the many micro-computer magazines, could share games with others.

Home computers could function as text editors, educators, or home finance advisors.

In spite of the listed advantages, microcomputer manufacturers made sure to take advantage from the popularity of the arcades and consoles. They advertised their products as arcades at home (with similar graphics and audio capabilities) and as more able consoles. The campaign was indeed successful and forced some game console manufacturers to search for rather unusual solutions such as special hardware extensions that converted their consoles into rudimentary home computers. That strategy did not work and when the prices of home computers dropped below those of consoles, the console market collapsed.

I'll do it Latter Mom! I'm at a Computer Now!

One of the results of an early studies in computer education done in the late 1960s, was that children were not finding computers difficult, scary, or intimidating when carefully introduced to the new technology.

Young children are natural explorers and they explore computers with the same passion as a garden full of spring flowers. Well set up computer system is a child's toy communicating in secret language via a keyboard, a mouse, or touch of the screen.

In the 1980s, these were frequently children who forced parents to buy the first family computer, these were frequently children who encouraged their

parents to explore the computer with them, to find them useful and enjoyable.

These were also children that made packaged and ready to run microcomputer] software popular. Although in the 1970s and early 1980s fluency in one or more programming languages was perceived by some educators as essential for the development of a modern individual, young children were never good programmers. They wanted to play and were frequently discouraged by the process of typing a computer game program from a magazine for a long time only to be greatly disappointed when the game failed to work due to a bug in a program or not so careful typing.

And the industry did listen to a powerful new customer—children—offering ready to run programs on cassettes, tapes, diskettes, and cartridges, faster computers, better graphics, and game controllers. Children became among the largest consumers of computer magazines. Dedicated software departments created games and educational programs in many age categories proving that a computer game concept can be a valuable educational tool.

The appearance of microcomputers at schools, first Apple IIs, Commodore PETs, and TRS-80s, and later small computers from Atari, Commodore, and Texas Instruments, introduced many children to microcomputing. Microcomputing got hot, and the new fad of computer games spread through the school environment with the speed of flu. Gamers came in all age groups but most of them recruited from elementary and high-school-age children. Older gamers were oscillating between the arcade and computer game cultures. Young gamers could easily be spotted in a crowd since they would never pass peacefully by any sort of a device that resembled a keyboard with a display, be it a bank teller in a nearby branch of a bank or an information terminal in a shopping mall or in a museum. At home, they could spend any time they were allowed to jiggling joysticks and molesting keyboards while eating the second bowl of serial whose box beared Packman or Ms. Pack-man logo(?). They never tired of playing, always demanded one more chance to get to the next game's level before dinner (if any). Their school backpacks had sometimes more games and gaming literature, then textbooks.

Kids with microcomputers at home had a special status: after all, they could play popular games all the time. Those less fortunate were often found

alone practicing keyboarding on a piece of cardboard with a keyboard drawn on it, submerged in the future that included a computer of their own in their own rooms. The children of the first decade of microcomputing—the micro kids— frequently knew much more about computers than their teachers or parents. They learned fast how to load game programs into a computer, how to modify them, save and make copies for others on tapes or disks. Some of the kids could easily write their own simple games, successfully modify and adopt programs written in other dialects of BASIC foreign to their micros. Micros were not remote and forbidding to kids, computers did not overpower them. To the contrary, micro kids found them easy to use, their enthusiasm for small home computers was unrivaled. Perhaps what attracted many of them to the computer was the control and power that they exercised over this exceptional toy, the power of the toy itself. For, microcomputers were frequently those feared by adults machines which they, children, were their masters. While parents often regarded microcomputers as omnipotent, still being immersed in the slide-rule reality, their children found a computer a fascinating companion toy that was taking them into wander lands and galaxies (for us, well, perhaps home accounting? yuck!). The keyboard wasn't a frightening thing that can only make you uneasy when you could not understand why the numeral '1000' could not be entered into a computer as '1,000' without an error, although it was a standard trick to type the letter 'l' instead of the digit '1' on a typewriter, and computers supposed to be more 'intelligent'. For a child a keyboard was just a way to communicate with game characters, neither simple nor difficult, this was just the way one talked to E.T. ? and ? A joystick with a fire button was just the way they exercised the power over a virtual universe.

Long before children's fascination with a computer there was the magic of television. Children's TV programming, from the earnestly educational to the ? commercial, populated children's reality with polyfara of cartoon (cuddly animals?) characters to whom exciting things were happening in nearby neighborhoods and far away lands. There were dazzling stories, jubilant songs, lively fantasies that made ? young eyes, magic. Or just comic: light, plain, soap-ish entertainment. The television animated celebrities spoke children's language, taught basic concepts of good and evil, peace and violence, tolerance and prejudice, and that joy often meets sadness, without ruffling young emotions. The arrival of a personal computer did not change fundamentally children's affection for television. Both share important features,

such as the display which provides a window into fictional realities where characters do things they usually do in children's stories or games. In the eyes of a child, however, the home computer had got a personality of a toy friend and an electronic companion, a status that a television set would never be unable to win.

Little kids adored Micky Mouse, the Bunny Rabbit, Kermit the Frog, and Duckie Duff. They followed with excitement their affairs, they wanted more and more. One thing, however, which they were unable to do with their fictional TV celebrities was to interact with them at any satisfactory level. They could, of course, waive plastic replicas of E.T. and Cookie Monster in front of the screen and sing along with Kermit the Frog: "It's not easy to be green". They could not, however, capture their attention. With a computer, however, a child could not only follow the events as they unfolded in a game or a computer fiction but a child could interact with the characters by communicating with them, controlling their movements, making them stronger and wiser, said or happy. Unlike talking dolls, computers didn't require a good shake or a firm squeeze to generate a single utterance "Mama" or "Wa-wa". Unlike mechanical bunny rabbits and frogs, game characters didn't require to be stabbed in the back with a winding key to make them jump for a while in a rather unnatural way and in a semi-random direction. In games, the computer was as an instant, patient, and loyal partner-companion, a challenging opponent, a trustworthy referee. Computer was instantly adopted as a super toy: it was always there and ready for a kid to be interacted with, it never got mad, or impatient, or sleepy, or too busy to play. And it never made new friends or become more interested in playing with other children. It was a truly ever-faithful companion in good and bad times at school and home, whether they were car racing, exploring the world of BBS, or practicing linear algebra.

For the microcomputer industry, children were the strategic allies in its conquest of consumer electronics market: children were the key to redefining the image of a computer as intimidating and confusing. Advertising put out by microcomputer manufacturers depicted adults operating a home computer and assisted by enthusiastic children no less than young children operating a microcomputer and surrounded by overwhelmed with joy family. The ads were to condition customers to accept a home computer as world's greatest toy, as useful and easy to operate consumer product, exciting, user friendly, and entertaining.

Children's use of a microcomputer for entertainment and education was pivotal to the engineering of the consumer consciousness for mass acceptance of home computing. Marketing storm troopers were charging the technology-conscious parents, challenging them to set up the home computing environment that would enhance the intellectual needs of their children. The ways were many. Apple Computer reported new social phenomenon that "Parents are making Apple the newest family pastime. And kids of all ages are finding how much fun computers can be, and have no time for TV once they've discovered Apple." ¹ For its early TRS-80 Model I campaign, Radio Shack set up a letter writing masquerade in which the Radio Shack marketing department disguised as a father and an owner of a TRS-80 computer writes to other fathers in (of?) the land that his TRS-80 investment had been "one of the most important to our family and to the education of our child that we have ever seen". ² A different marketing strategy was employed by NEC in its advertising campaign of the TK80x single board computer kits. On the cover of the June 1978 issue of *Gakusyu-Computer*, NEC set up a typical 'I want you to buy me' game between a father-the technology provider-and his son-the enthusiastic youth and NEC's agent of change:

One day, after his visit to Akihabara ³, my son said to me: "Dad, I want a microcomputer kit."

"Oh!?" "It's a microcomputer!"

"Yes"

"I really need it." "Then tell me, what can you do with it?"

"Dad, it is not what but how. I can program a microcomputer to do what I want and, then, I can run it to do that for me."

"Well..."

"OK dad?"

My son had always enjoyed playing with all sorts of machines and devices. But I would never imagined that he would be able to put a computer together.

¹From Apple Computer ad in *Creative Computing*, July 1979, p.15.

²Cf. *TRS-80 Microcomputer Catalog* RSC-3, 1979, p. 4. In the 1978 edition of the catalog, the excerpt from the letter reads the the father's TRS-80 "investment is one of the most significant in value to our family and to the future education of our child that we have ever seen." Cf. *TRS-80 Microcomputer Catalog* RSC-2, 1978, p ?. The 1979 rewrite raises the question about the authenticity of the letters.

³In 1976, NEC opened its famous microcomputer showroom Bit-Inn in the center of Akihabara - Tokio's renowned consumer electronics district.

Kids know what they want and they are certainly the masters in the art of getting what they want. Fathers, urged NEC, do not resist your children: become a microcomputer friend, the future of your children is now.

Fourteen-years-old Takashi Hoshino is a 3rd-year student at Ohfuna Junior High School. He has been operating his microcomputer since last year.

“Now, I’m designing a new game. My ideas will turn into a game. Isn’t that great?”

Takashi is working on a new game with his friend Hashida. What kind of a game will they create on Takashi’s microcomputer? Would it be better than Star Trek? ⁴

Like the players of SpaceWar!, the mikrokids of the 1970s also wanted to play games and also dreamed to be game designers.

Intel had never seriously entertained the idea of mass manufacturing of its own personal microcomputers nor had it considered the design of a home computer for young computer users. In 1976, however, Intel did place an ad in *Byte* which showed an enthusiastic kid named Rickey posing with the soldering gun over a sophisticated Intel 8080-based single board computer SDK-80. As portrayed by Intel, Rickey was a curious but otherwise typical kid of his age who liked lizards, hot fridge(?) Sundays, skateboards and microscopes. But now, according to Intel’s ad, “Rickey’s tackling the SDK-80 microcomputer kit for his next science project”.

When his Dad brought home the Intel SDK-80 microcomputer [...], Rickey helped him put it together. It took only four hours [...]. The best part was the instruction manuals. Every step was clearly explained. It was easy. The programming part looked especially interesting. So simple. Just imagine talking to a computer.

The big thrill came on Saturday when [Rickey] went to his Dad’s office to use a terminal. When they connected the SDK-80 to the teletypewriter they got a printout. That was exciting. Within an hour they were talking to the computer, then inventing games. They stayed all day. ⁵

⁴From the cover of *Gakusyu-Computer*, June 1978.

⁵Cf. *Byte*, ? 1976, p. ?

Although the ad indicates (stipulates?) the guiding hand of a knowledgeable parent, the principles of microcomputer operation and programming seem to be so irresistibly well explained on the pages of Intel's SDK-80 manuals that

Now Rickey is building a microcomputer of his own. He may be the first kid on his block with his own computer. ⁶

Did Intel really intend to target the youth with its System Development Kit, which was manufactured as a nucleus around which system engineers could build larger microcomputer systems? Or, perhaps, it was just a marketing strategy to attract more electronics engineers to its microcomputing technology: you see, Rickey can do it, so why couldn't you?

At the end of 1970s microcomputer manufacturers saw all the signs that people could be persuaded to buy a home computer, but finding ways to persuade them was a very challenging marketing task. Computers in education, at schools and in homes, seemed to be a part of the answer. However, the use of a microcomputer in education was mostly an uncharted territory and, despite efforts on the part of some educators, the level of computer literacy among teachers was remarkably low. As a result, parents could not be advised properly about the benefits of a home computer as an educational aid and they would rather see schools assuming the leadership in enriching the learning environment of their children with computer-based tools. And what else could a child do with a computer at home? Was a home computer just a brief trend that would go away next season like Berkeley's tiny computational toys or miniature home chemistry labs? Or, perhaps, this was that unique opportunity to provide their children with a head start to the complex lifestyles of tomorrow, to exciting challenges that awaited them in engineering, research, or space exploration?

In the end, perhaps on reflection that this wasn't the first time the society had been invaded by a new technology they did not understand, parents did buy computers for their children, they did sponsor computer clubs at schools, and they did seat with their children at a keyboard of a home computer, sweating and plowing through the lexicon (lingua?) and concepts of the digital world. In front of a computer, the barriers between an adult and a child, between a teacher and a student were collapsing: these were frequently children who helped their parents to start the journey into personal

⁶Ibid.

computing, these were frequently students who were the partners in setting up early computer education programs and computer clubs in their schools. Like shoveling the snow in winter, racking the leaves in fall, or delivering a local newspaper, almost every neighborhood and community had a wizz kid on the block who could install software, connect a printer, a modem, or would advice a distressed neighbor to check the power bar first before declaring a computer brain dead.

Microkids knew what they wanted and in the end they got what they wanted as the rest of us rushed to populate home and school environments with millions of small microcomputers. By 1979, there were over 43,000 Apple IIs and over 100,000 TRS-80 computers. Introduced in 1980, Sinclair's tiny ZX80 computer sold in excess of 100,000 machines almost as many as the 1980 Apple II installed base (121,000 machines). Sinclair's next machine ZX81 and its U.S. refinement TS1000 sold over 500,000 by the end of August 1982, nearly as many as Commodore's VIC-20s (by the end of 1982, there were over 800,000 VIC-20s world-wide). VIC-20s sales reached the one million mark in early 1983, when Commodore was shipping its small computer at the rate of 100,000 units a month. In the same year, two other manufacturers joined the one million club: both Texas Instruments and Apple Computer shipped over one million of their TI-99/4A and Apple II computers. In 1984, there were over 2 million Apple IIs and, perhaps, even more Commodore 64s, arguably the world's most successful small computers.

References

1. S. Ditlea et al, *Digital Deli: The comprehensive user-lovable menu of computer lore, culture, lifestyles and fancy*, Workman Publishing, 1984.
2. F.D. Schwarz, *The Patriarch of Pong*,
http://www.irational.org/APD/cyber/pong_fas.htm
3. The First Video Game? Before 'Pong,' There Was 'Tennis for Two', Brookhaven Lab History, <http://www.bnl.gov/about/history/firstvideo.php>
4. J.M. Graetz, The origin of Spacewar, *Creative Computing*, August, 1981. See <http://www.wheels.org/spacewar/creative/SpacewarOrigin.html>.
5. D. Burrowes, The History of Videogames, Part II: The Majestic Cosmos,

<http://bnbgaming.com/2011/02/12/the-history-of-videogames-part-ii>.

6. *Byte Magazine*, December 1981.
7. <http://home.hiwaay.net/~lkseitz/cvg/pacmanfever/pacman.shtml>
8. S. Coheen, *ZAP! The Rise and Fall of Atari*, 1984.
9. J. Weisbecker, A practical, low-cost, home/school microprocessor system, *IEEE Computer*, August 1974.
10. *101 BASIC Computer Games*, Digital Equipment Corp., 1973.