From Bits to Hits: Video Games Music Changes its Tune Karen Collins

cite as:

Collins, Karen 2005. 'From Bits to Hits: Video Games Music Changes its Tune'

Film International #12, January 2005. pp. 4-19.

When I was a kid, my brother and I would play Nintendo until we were both doubled over with what we'd called "Nintendo thumb". I later learned the technical term for this problem was "carpal tunnel syndrome", but it didn't matter—I was hooked. Hooked on the little cartoonish characters that felt so lifelike to me at the time, hooked on games that led me through time, through history, through worlds known and unknown, and most importantly, hooked on laughing at my brother as I joined in with the quick descending glissando bleeping of the machine, signifying the character's death, and my turn to play.

Those of us who grew up in front of several generations of games consoles take for granted that games music has come a long way from the blips and bleeps of the early machines. After all, even the conservative National Academy of Recording Arts and Sciences has now allowed for Grammy awards for interactive games music.[i] There are also BAFTA and MTV awards now for games soundtracks. In fact, many film composers and popular music groups are becoming increasingly involved in the production of games music, and soundtracks to video games are finding a considerable audience amongst music fans, as more and more games soundtracks become released as music CDs. Howard Shore, composer of the films *The Lord of the Rings* and *The Silence of the Lambs* has recently completed the score for Webzen's *SUN*, and Michael Nyman, famous for his Peter Greenaway film scores, has also produced music for games, such as Sega's *Enemy Zero*. Despite the advances in games technology, many academics have been slow to recognize the growing importance of games music.

As sound technology improved through the last three decades, so did its role in games. Music quickly went from being a catchy gimmick designed to sucker quarters from unsuspecting passers-by in arcades, to being an integral part of the gaming experience. Games music shares most of the functions of film music—it helps establish settings, emphasizes movement, and serves narrative functions (continuity, unity, cuing, foreshadowing, etc.).[ii] In addition to these functions, games audio, due to its interactive elements, has additional functions, such as helping to locate the player in the game, drawing the player in emotionally, symbolizing specific events or items to let the player know when they've done something good or bad, and most importantly, cueing players to take an action, such as warning the player that a bad guy is just around the corner. There have even been games in which music plays a pivotal role in the plot—and players must pay attention to musical cues in order to progress. Any gamer today can tell you that most games are difficult to play without sound on.

A new function today of games music is marketing—either to sell the soundtracks to the games, or to attract music fans to a particular game. Popular music is often included in games today, as is evidenced by Island/Def Jam's recent partnership with Electronic Arts, the largest game manufacturer.[iii] The recent game *Tony Hawk's Underground: T.H.U.G 2*, for instance, has an eclectic range of tracks, from old school punk like the Ramones and the Sex Pistols, to just plain old school like Frank Sinatra and Johnny Cash, as well as contemporary hip-hop artists like Aesop Rock. The music industry is even discovering video games as a new channel for marketing bands, as artists like Andrew WK, Good Charlotte, and Trust Company have successfully gained exposure through the medium.[iv] One survey suggests 55 percent of teenage gamers learn of new music through games now, and a song in a popular game is likely to be heard 600 million times. [v] Games soundtracks are even making their way into the charts, as Electronic Arts' *NBA Live 2003* recently became the first to achieve platinum sales (one million units).

The aims of this paper are to outline and explain what I will refer to as the three main stages of games audio development. The first is the music of the 8-bit machines, that pivotal time of blips and bleeps that many still call to mind when discussing games music. The second stage is the music of the “in-between” years, when developments in technology expanded into MIDI and wavetable synthesis, and subsequently more sophisticated music in games began to develop. The final stage begins with the inclusion of Redbook (CD) audio and takes us to today—when there are few limitations in technology and games scoring has become a lucrative business.

Part One: The 8-Bit Revolution

The earliest video games—those going back to what is allegedly the first, William Higginbotham’s “Tennis for Two” game of 1958, and Steve Russell’s *Spacewar* of 1962—had no sound. Likewise, the earliest home consoles—such as the Magnavox Odyssey—were also silent. It wasn’t until Atari’s *Pong* (1972), an early electronic table tennis game, that a video game included sound, making the beeping “pong” sound when the ball hit the paddle. As Stephen Kent reports, the pong sound was reported by designer Al Alcorn as an accident:

> “The truth is, I was running out of parts on the board. Nolan [Bushnell] wanted the roar of a crowd of thousands—the approving roar of cheering people when you made a point. Ted Dabney told me to make a boo and a hiss when you lost a point, because for every winner there’s a loser. I said ‘Screw it, I don’t know how to make any one of those sounds. I don’t have enough parts anyhow’. Since I had the wire wrapped on the scope, I poked around the sync generator to find an appropriate frequency or a tone. So those sounds were done in half a day. They were the sounds that were already in the machine” (Kent, 2001: 41-42).

Taito/Midway’s *Space Invaders* of 1978 was the first major arcade game success, and also the first game to include a continuous background soundtrack: four simple chromatic descending bass notes which repeated in a loop. Along with the music, the game included six sound effects: a missile shot, explosions, a strike on a saucer, a flying saucer sound, invader hits, and the bonus missile base. Most remarkable about *Space Invaders* is the fact that, despite being the first to include a background track, it also recognized the need for the soundtrack to be interactive—that is, the music’s tempo was affected by the player’s progress in the game. In this case, the four tones became the marching of alien feet that sped up as the game progressed.

Most video games music at the time of the early arcade hits included one or two-channel tunes either as quick title themes or two to three-second in-game loops, although another important invention in games audio came quickly—the ‘cut scene’, an intermission, or break in a game during which players sit back and watch, used as a reward for attaining a particular level. Tohru Iwatani’s *Pacman*, the first game to incorporate a cut scene (1980), enjoyed its most musical times during these scenes, since running audio and player interaction at the same time was typically too taxing on the old processors, but without the player interaction, sound could be boosted. *Pacman* also brought about a mass realization of the catchiness of sound in games—its infamous “waca waca” in-game sound and opening 2-channel title theme became the source of several gimmick songs in the 80s, such as Weird Al Yankovic’s “Pacman”, and Buckner and Garcia’s “Pacman Fever”—the latter of which quickly led to an album of other games tunes, including "Goin Berserk", "Do The Donkey Kong", "Ode to a Centipede", "Froggy's Lament" and "Defender". Video games music may have been viewed as a gimmick, but it was here to stay.

The beginnings of interactive audio only provide the vaguest of clues as to what was to come. Sound was slow to develop, and if one recognizes the poor graphics quality of those early games compared with those of today, it’s not a major leap of the imagination to realize the sound of the old games was equally poor, if not worse. PCs in particular were considered business machines, and audio was not seen to have many business applications, and was therefore not a priority for computer developers. Nevertheless, there were many progressive ideas introduced to the audio of 8-bit machine games, and 8-bit games developed a unique aesthetic that is still enjoyed by gamers and music fans today. In fact, a whole genre of electronic music known as ‘bitcore’, ‘bithop’, ‘bliphop’ or ‘micromusic’ has been spawned by composers who still use 8-bit machines today.[vi]

The majority of 8-bit machines (and early arcade and pinball machines) used what is known as Programmable Sound Generators, or PSG sound. Early PSGs used analogue synthesis, or subtractive synthesis, which starts with a wave form created by an oscillator, and uses a filter to attenuate or subtract specific frequencies and then passes this through an amplifier to control the envelope and amplitude of the final resulting sound. These specifications were usually coded in assembly language, and early sound programmers needed to understand the programming language to engage the chip. This meant that most early composers were in fact programmers working on other aspects of a game, or at best, in-house programmer-musicians who had to work closely with programmers working on other aspects of the game. PSGs offered little control over the timbre of a sound, usually limiting sounds to single waveforms without much ability to manipulate that waveform. Many of these PSGs were generic chips created by Texas Instruments or General Instruments, but some early home computer companies, such as Atari and Commodore, designed their own sound chips to improve sound quality.

International Business Machines (IBM) introduced their Personal Computer (PC) in 1981. The first IBM PCs and clones contained only a tiny speaker that could produce simple tones (typically square waves) of varying frequency but of a fixed volume, designed to indicate errors or other messages, sometimes referred to as a "bipper" or a "beeper"—they were, as the name suggested, business machines, and games were viewed fairly irrelevant to the market. By 1983, seeing the success of companies such as Commodore and Apple, IBM realized that their business could be expanded into a wider market by making the PC more accessible to the needs of the home user. With this in mind, the IBM PCjr was launched in 1984. To better compete with the other home PCs being marketed at the time, several changes were made to the original PC. Enhanced graphics and sound illustrated the importance of video games in the home computer market. Although the PCjr had several failings which held it back from great success,[vii] these problems were improved upon by its popular clone, Radio Shack's Tandy 1000. The Tandy 1000 retained the enhanced 3-voice sound of the PCjr, making it popular with gamers and game developers in the early 1980s.

IBM, in an effort to market the PCjr, hired the US company Sierra to produce a PCjr game that would show off these newly enhanced colours and sound capabilities. Sierra had previously created graphic and text adventures for the PC, such as *Ulysses and the Golden Fleece*, *Mystery House*, and *The Dark Crystal*. Sierra's answer to IBM's assignment was *King's Quest*, the first "3D" graphic adventure game. But Sierra went one step further, creating an Adventure Game Interpreter, or AGI, which would become the standard for programming Sierra's popular graphic adventure series such as *Space Quest, Police Quest*, and *the Leisure Suit Larry* series. The AGI format was designed for and modeled around the PCjr's sound chip, using all available sound channels. The PCjr, Tandy and Macintosh versions of the games' songs were composed of four parts; the melody, two accompaniment parts, and one noise (generally for sound effects). The games could also be played on the IBM PC, although the PC's single channel could only play the melody portion (first channel) of the songs.

Most early games for the PC were coded in BASICA, otherwise known as Advanced BASIC (Beginner's All Purpose Symbolic Instruction Code), the official BASIC of IBM. BASIC as a language for game programming was somewhat limited on the old machines, which had trouble managing sound at the same time as executing other tasks. The processors could only maintain static sound, or, in some cases, a patchy dynamic sound, and the separate channels—for those few PCs that had them, would occasionally experience delay due to the slow execution of the commands.[viii] At best, then, games had a title theme, a theme at key events (such as death of a major character), sometimes tied in with cut scenes, and a game-over sequence. Background music for the early home PCs was rare.

As with the PC, third-party sound expansion boards were built for the Macintosh Apple II models, the most popular of which used General Instruments' AY-3-8192 PSG chip, which provided three tone channels and one noise generator. Sweet Micro Systems' Mockingboard was the best selling of these sound boards to use the AY-3-8912, and was available in four different packages, adding speech synthesis and up to 6 channels of sound. Without many games supporting the music, however, most of the add-on boards were used by home musicians rather than gamers.

It was Commodore which fully recognized the importance of gaming to the home computer market. In 1982, after the success of its VIC-20 model, Commodore released its 64K model, which would go on to become the best selling computer of all time, having sold an estimated 22 million units. The C64 was originally conceived of as a game computer, and the graphics and sound remain evidence of this. The sound chip (called SID, or Sound Interface Device) was a three-voice plus noise generator chip, created by Robert Yannes, who had helped engineer the VIC-20, and would later go on to create the Digital Oscillator Chip for the Apple IIGS, and then to found Ensoniq keyboards. Unlike other PC chips at the time, each tone on the chip could be selected from a range of waveforms—saw tooth, triangle, pulse, and noise. Each tone could also be subjected to a variety of effects and programmable filters including ring modulation. An independent ADSR amplitude envelope modulator enabled the SID to more accurately imitate other instruments than previous chips. The noise channel could also operate as a simple pulse wave modulation 4-bit sampler.

Frogger, released in 1981 in the arcades and 1983 for the IBM PC and C64, reveals the great differences between the machines of the times. The PC (and the Atari VCS 1982 version) could only handle a short two-channel title tune and level intro song, the rest of the game remaining limited to sound effects. The Commodore 64 on the other hand could adapt the song from the arcade version, which had a continuous background medley, including "Yankee Doodle" and "Camp town Races". In fact, Commodore's advanced SID chip allowed for much greater replication of recognizable songs, and the adaptation of songs from the better-equipped arcade versions—a practice known as "porting"—was common on the C64. Other tracks were adapted from popular songs: 1986's *International Karate,* for instance, was inspired by Ryuichi Sakamoto's score for the 1983 war film *Merry Christmas Mr. Lawrence*, and *Monty on the Run*, using a new "pitch bend" code invented by composer Rob Hubbard, was inspired by *The Devil's Gallop* (Charles Williams), the title theme for the 1940s American detective radio show "Dick Barton". As well as these imitations of known tunes, and the use of the copyright-free medleys seen in *Frogger*, songs were also in rare cases licensed specifically for games. For instance, Grigg and Jansen covered the Kingsmen's "Louie Louie" for *California Games*.

Like home computers, the early 8-bit consoles had single PSGs, mostly with three-plus-one channels of audio, and, like PCs, the audio channels had to be downmixed to one mono output. Programmers for 8-bit consoles ran into many of the same difficulties as PC game programmers. There was little room in games for music, so again, at best, a title song or short victory song may have been used. The Intellivision for instance had a cartridge space of 4K, and audio was given perhaps ten percent of this space.[ix] Atari VCS games were lucky to have any music at all.

The Atari VCS (Video Computer System, also known as the 2600) saw limited success when it was first released in 1976. In 1980, however, Atari licensed the arcade hit *Space Invaders*, which became a best seller and helped to spur on the sales of the VCS. Eventually, over 25 million VCS systems were sold, and over 120 million cartridges.[x] The sound chip in the VCS was known as the TIA (Television Interface Adapter), and also handled graphics. The audio portion had two channels, each with a 4-bit volume control, a 4-bit waveform control selector and a 5-bit frequency divider (capable of dividing a frequency of 30 KHz by 32 values). This 5-bit frequency controller was incredibly limited, and used a polynomial counter, a type of binary counter that uses a pseudo-random way of counting, rather than the normal binary incremental/decremental. A chosen frequency was divided down from the system clock, meaning many pitches were not in tune with others, making it difficult to program melodies. Even title themes were uncommon, and if anything a few notes which sounded completely random might be thrown in as a title song.

The lack of programmability meant that the Atari VCS, when it did have music, had more original songs, as porting songs from well-known music was difficult, although attempts were made. The game *Up n' down* in particular shows the distinct effect the Atari's tunings had on the composition of songs, as it turns a bluesy F# minor groove in the arcade version to an almost demented-sounding version in C minor.

Figure 1. ***Up N Down*** **- Arcade Version (Sega 1983)**

Figure 2. ***Up N Down -*** **Atari VCS Version (Sega 1983)**

Mattel's answer to the Atari VCS was the Intellivision, more advanced in sound and graphics. Also important was its modular design, allowing for extensions such as the Entertainment Computer System, a music keyboard and second sound chip, allowing for six simultaneous channels. The original Intellivision used a General Instruments PSG sound chip, the AY-3-8914. Part of a series of GI chips popular with game makers (the chips were used in the ZX Spectrum, Amstrad CPC, BBC Micro, Atari ST, Sega Master System and many arcade machines), the 8914 had three tone generator channels and one noise. Each channel allowed for individual control of frequency, volume and envelope. Pitch was still controlled by the frequency-division method like on the VCS, but the GI chip used a twelve-bit register to set the divisor, allowing for 4096 possibilities instead of only 32 in the VCS. This meant the Intellivision could more create more recognisable renditions of known songs, such as Bill Goodrich's use of "Flight of the Bumblebee" (Rimsky-Korsakov) on the game *Buzz Bombers*.[xi]

Undoubtedly the most popular of all 8-bit machines was the Nintendo Entertainment System, or NES. The NES, released in North America in 1985, used a built-in five-channel PSG with one waveform for each channel—two pulse waves, a triangle wave, a noise, and a sample channel. The pulse and triangle channels had an 11-bit frequency control, capable of about eight octaves. The pulse channels had four duty cycle options and a 4-bit amplitude envelope function, and one of the channels had a frequency sweep function that could create portamento-like effects, and was often used for UFO or laser-gun sound effects. The pulse waves could also be detuned, and vibrato effects could be simulated. The triangle wave channel was set one octave lower than that of the pulse waves, had a four-bit frequency control, but had no volume or envelope control. The fifth channel was a PCM channel sampler, also known as the Delta Modulation channel (DMC).

The NES was shipped with the game *Super Mario Brothers*, a game which would spur composer Koji Kondo into the spotlight in Japan. Although many North Americans probably couldn't recognize Kondo's name, most of them would probably recognize the tune.[xii] Kondo quickly mastered the limitations of the NES sound chip, managing to fill out its three tone channels with a clever use of percussion, catchy melodies, and smooth looping capabilities that used slight variations to keep the song from getting as monotonous as earlier games. Most NES songs consisted of a melody, thickened out with a second channel, a bass line, and percussion, and the limitations meant most songs were melody-based, but some composers explored other possibilities, including Hirokazu "Hip" Tanaka's now well-known score for the *Metroid* game, which intentionally avoided melody-based songs, instead opting for a score perhaps closer to that of science-fiction film music, where sound effects and song blur together to create an atmosphere, and the music disappears into the background.

Figure 3 Metroid title theme (Hirokazu Tanaka) (Nintendo 1986)

NES sound and music was generally allotted about ten percent (4-40Kb) of the total game size,[xiii] although some games used in-cartridge sound chips to add extra channels. For instance, the Konami VRC6 and VRC7 chip, used in *Castlevania* and *Lagrange Point*, generated sound using FM synthesis. Frequency Modulation (FM) synthesis had been developed by John Chowning at Stanford University in the early 1970s, and eventually licensed and improved upon by Yamaha, who would use the method for their computer sound chips, as well as the DX series of keyboards. FM uses a modulating wave signal to change the pitch of another wave (known as the carrier). Each FM sound needs at least two signal generators (oscillators), one of which is the carrier wave and one of which is the modulating wave. FM sound chips found their way into many of the early arcade games of the late 1970s and early 1980s, and into most mid 80s sound cards. Compared with the PSG chips, they were far more flexible, offering a much wider range of timbres and sounds, with a limited amount of memory required. They were, however, too expensive for the earliest home consoles, although they found their way into many early arcade games.

Recognizing that gamers and musicians wanted decent quality sound from their PCs without having to go out and buy new computers, add-on third-party FM soundcards began to develop in the mid 1980s. It's worth noting that sound cards were designed with the gamer in mind: they generally had a joystick game port which could double as a MIDI port with an adapter. As well, lines in/out for speakers, headphones, home stereos and microphones were often included. The first popular PC sound card was produced by the small Canadian company Ad Lib Multimedia in 1986. Ad Lib based their card on a Yamaha FM chip, YM3812, which was a later version of the popular YM3526 used in many arcade games. It had nine FM channels, or six tone channels and five for percussion. The use of FM synthesis techniques meant that game developers could now use a wider range of instruments and sounds. To boost sales, the Ad Lib card was packaged with software capable of playing back MIDI files ("Juke Box"), a MIDI sequencer program equipped with 145 pre-set voices ("Visual Composer"), and an FM synthesis program to design sounds or instruments ("Instrument Maker").[xiv]

Keyboard manufacturer Roland had also begun making soundcards for PCs by the late 1980s. Remarkable for its time, the MT-32 had 32 voices, with 256 pre-set yet programmable instruments ready for MIDI use. What really made it unique, however, was that it used wavetable synthesis. Wavetable synthesis uses pre-set digital samples of instruments, usually combined with basic waveforms of analogue synths. Roland was given a serious boost when the Sierra software company signed a deal with the company along with Ad Lib. As well as becoming a reseller of the products, Sierra would adopt both Roland's MT-32 soundcard and the Ad Lib as standards for their compositions, beginning with *King's Quest IV*.[xv] Sierra would once again show off the capabilities of the hardware components, by bringing on board Grammy and Emmy-nominated composer William Goldstein, and, later Jan Hammer, among others, to compose for the games.

It was around this time that MIDI, a protocol defined in 1982 to allow musical devices (synthesizers, keyboards, sequencers, mixing desks, computers) to be compatible in a standardized format, revolutionized the possibilities for games composing. Only commands, rather than actual sounds, are transmitted, meaning file size was very small—absolutely crucial for games. A MIDI command might, for instance, tell a synthesizer when to start and stop playing a note, at what volume and what pitch, and what voice, or sound, to use. Initially, some of this information would vary greatly depending on the devices used, but in 1991 a General MIDI standard was agreed upon. This standard laid out a template for 128 instruments and sound effects, so that the same number setting would be the same on any MIDI device: so a command saying "play number 39" would always play a slap bass.

Most importantly to games music, MIDI allowed for new innovations in interactivity. One such development was LucasArts's iMUSE (Interactive Music and Sound Effects), in 1991. iMUSE was originally developed for LucasArt's *Star Wars* game for Nintendo, but found use in popular LucasArts games like *Monkey Island 2*, and *Indiana Jones and the Fate of Atlantis*. The iMuse system sequenced MIDI in a way that allowed composers to organize musical cues in such a way that it could jump about within a given track, to interact with what was happening in the game. It could, for instance, change volume, tempo, or add or remove instruments or sound effects in response to a given action in a game—in other words, it could create true interactive games music.

Competing with MIDI in the early stage was the tracker format, also known as module format, or MOD. Tracker programs worked much like modern MIDI sequencers. A tracker program would store data on the notes, volume setting, effects and instrument (like MIDI), however they would also record digital samples of the instruments in the actual file, limited only by the size of file (the 880Kb floppy disk). MOD files had the advantage over MIDI, then, in that music or other sound events would sound as the composer intended, and a wealth of possible sounds was suddenly opened up for the composer to use. MOD files were also easier to program for non-musicians—like many game composers—and made it easy to sequence repetitive loops—also important for game composers.[xvi] The MOD format never really caught on because of its size requirements and the limitations of games cartridges, and the fact that the sound quality of the hardware was generally not as good as MIDI components. Although there were a few game companies that used tracker format (Epic Megagames, for instance), the majority used the better-supported MIDI.

Part Two: The 16-Bit Evolution

The first "16-bit" console was released by the multinational communications corporation NEC in Japan in 1987 as the PC Engine. The PC Engine, or TurboGrafx16 as it became known in the West, was not true 16-bit, but rather had two 8-bit processors. Nevertheless, it did have a 16-bit graphics chip, and 6-channel stereo sound with 5-bit sampling, and was popular in Japan when it was released. When it came time for a North American release, however, the TurboGrafx16 did not fare so well. Part of the reason for this was the fact that Nintendo had many game developing companies under strict exclusive contracts, restricting them from developing for other systems. The TurboGrafx CD model provided gamers at times with options of listening to the system's 6-channel sound generator or pre-recorded CD-audio at select times in the games.

The first real 16-bit console was the 1989 release by Sega, the Megadrive (the North American name was the Genesis). The Megadrive produced many games ported from successful Sega arcade games like *Space Harrier, After Burner* and *Ghouls N Ghosts*. The system originally came packaged with the arcade hit *Altered Beast*, but soon took on Nintendo's *Mario* with their *Sonic the Hedgehog* character. The Megadrive also had superior sound over the NES: it had one PSG 3+1 chip to handle effects and the occasional music part (a Texas Instruments chip, the same used in the Colecovision), as well as a Yamaha FM synthesizer chip, which had six channels of digitised stereo sound, and one PCM 8-bit sample channel which was capable of a sample rate of 22KHz (the same chip used in the Yamaha DX27 and DX100 keyboards). *Castlevania* shows off the rapid improvement in sound quality on the Megadrive.

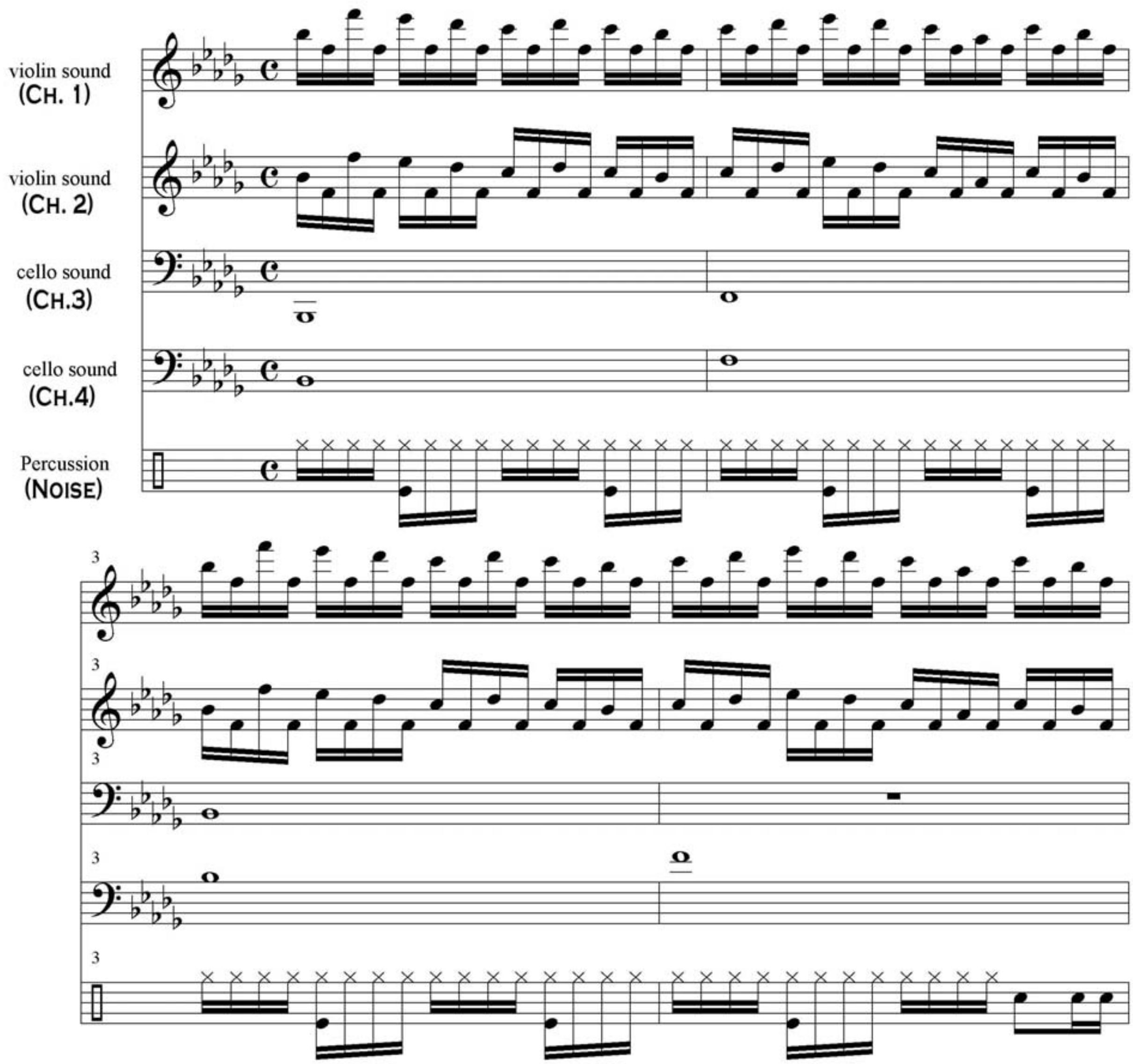

Figure 4 Castlevania Bloodines (Michiru Yamane), Konami 1994. Sega Megadrive

With the Megadrive leagues ahead of the NES in capabilities, Nintendo realized that they would have to build a 16-bit system to compete. By 1991, they had developed their Super Famicom, or Super Nintendo Entertainment System (SNES). The SNES sound module consisted of several components, the most important of which was the Sony SPC-700, which acted as a co-processor with its own memory. The SPC-700 was an 8-bit CPU running at 2 MHz, with an attached 16-bit Sony digital signal processor, essentially a wavetable synthesizer which supported eight stereo channels at programmable frequency and volume, and effects such as reverb, filters, panning, and envelope generators, and with a pre-set stock of MIDI instruments. In addition, there was typically a significant amount (24Mbit) cartridge memory that could be used for sound. For ease of programming, software was developed to convert PC/Mac MIDI files into files executable by the SPC-700, and therefore musicians could spend more time composing the songs.

The Third Stage and the Start of CD Audio

Although by the early 1990s most computers had FM sound cards supporting MIDI, many of these sound cards were cheap, and the FM synthesis made the MIDI music sound disappointing. When CD-ROMS came out, MIDI in gaming was pretty much abandoned, and with it the notion of interactive music. Popular early CD-ROM titles like *7th Guest* came out with high resolution graphics and higher quality music. The CD-ROM technology ensured that there was more room for music in games—previously most games had shipped on 3.5" floppy disks, and, perhaps more importantly to the game composers, since the audio was not reliant on a soundcard's synthesis, composers could know how the music would sound on most systems.

Sega released their CD-ROM based 32-bit Saturn in 1994. The audio alone had two audio processors, running on the Motorola 68000—the same processor that had been used as the Megadrive's CPU-known as the Saturn Custom Sound Processor (SCSP), manufactured by Yamaha. The SCSP consisted of a 32-channel PCM sound generator, capable of 44.1 KHz sample rates and a 16-bit digital to analogue converter. The sound board also had a 32-voice MIDI Yamaha FM synthesizer, whose output could be mixed in stereo using a 16-channel digital mixer and timer. The only drawback to Saturn's sound system was the limited amount of RAM accorded to sound. Because audio samples had to be downloaded raw (decompressed) into the audio memory buffer of 512K, this meant there was a limited amount of space for simultaneous sounds, and so the sample rate was often reduced to conserve memory. The Saturn saw most popularity in Japan, as did the Panasonic FZ-1 3DO and the Atari Jaguar, both systems which have passed into obscurity. The only real relevance to this paper is the Jaguar's release of *Tempest 2000*, one of the first games to have a separate soundtrack for sale, and the inclusion of known popular artists such as White Zombie's soundtrack for *Way of the Warrior* on the 3DO. One of the reasons for the ultimate failure of the Saturn and others to catch on was the competition with the Sony Playstation, a system which was cheaper and easier to program for, and therefore saw the support of more games designers.

The Sony Playstation began its life as a CD-ROM add-on component for Nintendo's SNES system. Nintendo had joined forces with Sony to better compete in the video games market, but the two companies could not agree on the system. Sony decided to push ahead with its own 32-bit system, the Playstation. The PlayStation was enormously successful, selling over 85 million units, most likely due to its affordability and massive library of available games. The Playstation's motherboard featured several graphics chips to handle 3D graphics and texture mapping, and dedicated audio memory and sound chip. The 2x speed CD-ROM drive could also play audio CDs, in fact, there were some games where it was possible to pause the game, and stick in any chosen audio CD to listen to—*Twisted Metal 4*, for instance, a fighting action game. The sound chip was capable of 24-channels of 16-bit digitized sound at CD-quality sampling rate, and allowed for real-time effects like ADSR changes, looping, reverb and pitch modulation. Like the Sega Saturn, the Playstation offered MIDI support for ease of programming the audio, but unlike the Saturn, samples did not have to be compressed, and the typical 4:1 compression rate that was used meant that sound quality could be greatly improved on the Saturn.

After splitting off from Sony, Nintendo bypassed the 32-bit machines altogether, going straight to a 64-bit release in 1996, the Nintendo 64 (N64). The N64 well surpassed the Playstation in capabilities. The main processor controlled the audio, producing 16-bit stereo sound at a slightly higher sample rate than CD quality—48 MHz. Some games supported surround sound, and this was enhanced with the third-party add-on release of RumbleFx 3D Sound Amplifier. It used ADPCM compression, with the possibility of using 13 simultaneous waveforms in real-time on the hardware, and even more using the cartridge. Filters and effects like chorus, panning and reverb could also be implemented in the internal CPU, or in the software.

Changes have come rapidly since the N64 time. The Sega Dreamcast was the first 128-bit console, and used special GD-ROMs (GigaByte Disc ROMs) capable of holding 1.28 GB. Unlike the Nintendo 64, samples did not have to be decompressed, improving audio capabilities. The dedicated audio processors had their own memory, meaning sound quality was not compromised by other aspects of the game. True 3D audio was supported, in CD-quality 64-channel sound, with effects such as delay, reverb and surround sound. The Dreamcast reportedly sold over six million units until it was discontinued in 2002. Similarly rapid to come and go on the market, the Nintendo Game Cube Mini DVD discs held about 1.3 Giga bytes, about the same as a Dreamcast disc, and had an audio capability comparable to that of the Playstation 2.

The follow-up to the immensely popular Playstation ensured that fans of the original would be suitably impressed with the new machine. With the ability to play DVD movies, and the option of add-ons for modem and hard drive, the Playstation 2 was leagues ahead of competition when it came out. Its games were stored on DVDs capable of holding 5.7 Giga bytes, and fully supported the multi-channel DVD sound standards AC3, DTS and Dolby Digital, offering up to eight separate speaker channels. The sound Processing Unit is capable of 16-bit audio with a maximum sample rate of 48 KHz—better than CD audio, and has 48 channels. Of course, the other major contender now in the console industry is Microsoft's XBOX, built around a Pentium III processor with an 8GB hard drive for music, graphics, and saved-game information. The XBox features its own audio processor, supporting Direct X 8.0, 256 2D voices and 64 voices using 3D positional audio.

The downside of the CD-ROM technology in games has been that most CDs could hold a maximum of 72 minutes of music, and with a game included this meant much less real time for music. As such, various compression technologies were developed, the most important of which was MPEG level 3, known more commonly as MP3. MP3 meant that much less data would be required to store audio, and game companies quickly began incorporating MPEG compression into their games music. With large DVD-Rom games, the music can now fill several audio CDs, such as *Final Fantasy IX*, which was released as a four-CD set.

Rise to Honor, the recent Playstation 2 kung fu game starring Jet Li, offers us a good example of the current state of interactive audio. The game even offers users a choice of whether or not they want to hear the dialogue in Cantonese when situated in Hong Kong, though other sequences are in English. Sound is mixed in Dolby Digital Surround, and the game makes use of 3D audio positioning best during fight sequences, where the player can hear the opponents approach, shout, kick, shoot, and throw from all different angles. The music interacts with the game, such as when the player enters "stealth" mode, and it becomes more ambient and subdued, allowing the player to focus on the more difficult moves in this stage. Percussion is the primary focus in the music, speeding up and slowing down as the player runs and fights opponents, and integrating with the sound effects so punches and beats synchronize and work with the player's movements.

The Current State of Digital Interactive Games Audio

As mentioned at the beginning of this paper, games music is finally gaining respect. Several orchestral games concerts have been performed recently, such as the European Symphonic Game Music Concert performed by the Czech National Orchestra, and a sold-out performance of the music from Nobuo Uematsu's score to the *Final*

Fantasy series by the Los Angeles Philharmonic. Although such concerts have been popular in Japan for many years, it has only been in the last couple of years that such events have taken place in the West, and it has also become quite common for games soundtracks to now be released as commercial music CDs. But, as composers warn us, we scholars must recognize the differences between games audio and film or concert music. Andrew Boyd, composer for *The Two Towers* game, reminds us:

> ”In a game, a composer (or music editor, for that matter) usually has no control over how a scene unfolds; the player controls that. There is a very basic disconnect between music and the game, each of which happen over time but according to very different internal logic. Since the goal most of the time is to give the appearance that no matter what the player does, the music is appropriately supporting the action-to make it sound as if the music was composed exactly for the situation at hand, no matter what the situation is-games have begun adopting "adaptive" music systems. This kind of system allows the game's music to be manipulated by the game itself at runtime, according to a set of rules established by the composer/editor. The big issue is managing the tradeoff between moment-to-moment relevance in the soundtrack and some sense of musical integrity. It is possible to constantly switch pieces of music based on the action, but then the music will lose any sense of coherence, flow, and integrity. On the other hand, just letting a piece of music play without regard to the action might end up with very inappropriate music at some points.”[xvii]

Along with the advances in hardware, several PC software solutions have been produced which have enhanced game sound. Beginning with *Windows 95*, the *Microsoft Windows* platform came with DirectX, a series of multimedia application programming interfaces, that improved the speed with which sound and graphics cards could communicate. DirectX allows game programmers to access “specialized hardware features without having to write hardware-specific code”.[xviii] In other words, the DirectX interface bridges software and hardware, allowing for higher-quality 3D graphics, and better control of sound mixing and output. One part of DirectX, DirectMusic, was a particular advance for games music. DirectMusic overhauls the old MIDI protocols by offering the industry-ratified DLS (Downloadable Sound Levels 1) specifications support for hardware acceleration and MIDI: over one thousand channels, with better timing mechanisms, real-time control.[xix] Put simply, DirectMusic offers an upgrade to the interactive possibilities, and opens up MIDI to the possibility of wavetable-like synthesis and sampling, while allowing MIDI to be a triggering mechanism for timing.[xx] Wave files (samples), or sound fonts, could be imported into a collection and manipulated in the same way that MIDI controllers manipulate synthesized sources, allowing for much improved interactive music.[xxi]

The interactive potential of games music has really only just begun to be explored. Earlier games such as the MegaDrive’s *Toejam and Earl* which began an exploration of the possibilities of having music play an important role in the game have been built upon over the last decade. In this case, at various stages in the game players are asked to learn how to “get funky” by mimicking various percussive grooves, in a “Simon Says” style challenge. It wasn’t long before other games popped up which asked users to become involved in producing, mimicking, or dancing to music as part of the game—Playstation’s *PaRappa the Rapper*, Nintendo 64’s *Legend of Zelda: Ocarina of Time*, more recently the Gamecube’s *Donkey Konga*, Playstation 2’s *Bust a Groove*, and of course, the whole *Dance Dance Revolution* series of dancing games. An even more intriguing idea was the bizarre game *Vib Ribbon*, released in Japan in 2000 for the Playstation, which allowed the user to put in his or her own music CDs, which would then influence the game’s generation of maps in various levels. The game scans the user’s CD and makes two obstacle courses for each song (one easy and one difficult), so the game is as varied as the music the player chooses. So now, even non-musical games are now beginning to explore the potentials of including interactive musical elements. The implications of this interactive aspect are vast in terms of how we scholars may approach games audio in the future, but undoubtedly new methodologies for studying the interaction between a listener and a piece of music will need to be formed.

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[i] Game soundtracks may be submitted for best song, best instrumental composition for a motion picture, television or other media, or best soundtrack album.

[ii] See for instance, Lissa, 1965: 115-256, or Gorbman, 1987.

[iii] The first game to be released under the partnership was *Vendetta*, which included hip-hop music by DMX, Scarface, Method Man, etc. Sony Music's Epic Records has previously provided back catalogue music for *Grand Theft Auto*, but in this case the music had previously been released, rather than using the game as a marketing method.

[iv] "Video Games Sell Music: Electric Artists exposes the power of music in games as a sales channel" Electric Artists press release, http://www.digitalgamedeveloper.com/2003/02_feb/news/dleas2403.htm. (Accessed 10/10/2004)

[v] "Kids prefer video games over TV, toys"

http://www.cnn.com/2004/TECH/fun.games/10/27/media.videogames.reut/index.html. (Accessed 28/10/2004).

[vi] In 2000, the band Golden Shower even won "Best Electronic Music Video at the MTV Brazil Video Music Awards, for their video for a song called 'Video Computer System', written entirely using Atari VCS game sounds.

[vii] The 'wireless' keyboard, and expansion capability of various modules were problematic, and the cartridges held less memory than a floppy disk. See "History and Memories of the IBM PCjr and Tandy 1000" http://www.oldskool.org/shrines/pcjr_tandy/ (Accessed 10/10/2004).

[viii] See also Weske, Jörg, 2002, "Digital Sound and Music in Computer Games" http://www.tu-chemnitz.de/phil/hypertexte/gamesound/pcsound-main.html (Accessed 10/10/2004).

[ix] "Intellivision in HiFi" http://www.intellivisionlives.com/retrotopia/hifi.shtml (Accessed 10/10/2004).

[x] See Hunter, William, 2000. "The Dot Eaters Videogame History" http://www.emuunlim.com/doteaters/play3sta1.htm (Accessed 10/10/2004).

[xi] Weske, Jörg, 2002. "Digital Sound and Music in Computer Games" http://www.tu-chemnitz.de/phil/hypertexte/gamesound/history-main.html (Accessed 10/10/2004).

[xii] The jacket cover to Sheff's book indicates that more US American children could, at that time, recognize Mario than could recognize Mickey Mouse.

[xiii] Leonard, Sean, 2001. "Scores of Glory, Fantasy, and Plumbing: The Concise History and Principal Genres of Video Game Music" http://www.seanspace.com/iSphere/scores.htm (Accessed 10/10/2004).

[xiv] "Gamespy Hall of Fame: Adlib Soundcard" http://www.gamespy.com/legacy/halloffame/adlib_b.shtm (Accessed 10/10/2004).

[xv] Much of the information in this paragraph comes from Wing, Eric. 1999. "The History of PC Game MIDI" http://www.queststudios.com/quest/midi.html (Accessed 10/10/2004).

[xvi] Ibid.

[xvii] "Lord of the Rings: The Two Towers" http://www.music4games.net/f_twotowers_stormfrontstudios.html

[xviii] "Frequently Asked Questions about Direct X 9.0" http://www.microsoft.com/windows/directx/productinfo/overview/faq.asp (Accessed 10/10/2004).

[xix] Hays, Tom, 1998. "DirectMusic for the Masses" *Game Developer* Magazine, September 1998.

[xx] Ibid.

[xxi] Yackley, David, 1999. "Microsoft DirectMusic: Creating New Musical Possibilities" http://msdn.microsoft.com/library/default.asp?url=/library/en-us/dnmusic/html/dm_nmp.asp (Accessed 10/10/2004).