Real-Time Interactive Digital Signal Processing: A View of Computer Music

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when i was approached to write a short article for the twentieth anniversary of the Computer Music Journal, i re-read volume 15, number 4, a CMJ issue dedicated to "Dream Machines for Computer Music"...it is a fascinating issue, published five years ago, yet it does not in the least seem dated today...if technology is advancing as rapidly as the media would have us believe, then should not some of our dreams be a reality?...men went to the moon almost 30 years ago (nevermind the reasons) yet what has happened to all our fantasies of space exploration since then?...is the computer music field moving forward as it should, or are we as dependent on market forces as the space "race" was dependent on political forces?...

All endeavors which make use of the computer are defined and confined by two inter-related activities. The first is the continued development of faster machines, motivated by industrial competition. The second activity is the continued development of software which exploits new hardware. My own area of interest, interactive computer music using programmable real-time digital signal processing (DSP), critically depends on hardware and software developments.

Twenty years ago, the majority of computer music practitioners used mainframes, a variant of Music N, and many composers were still using punched cards. *in 1974 i was an undergraduate composition student in Florida, experimenting with tape recorders and a Moog, when Gary Nelson gave a presentation at my school about computer music...six months later i took a month long summer workshop at Colgate with Leland Smith and Dexter Morrill...we learned Music10, the Music N variant in use at Stanford at that time...the workshop was made up of an interesting group of people...many of them are still computer musicians...i met Bruce Pennycook during the course...later i had a frustrating time getting a variant of Music N operational at my school...as an undergraduate without much faculty support for computer music, i did not have the knowledge or influence to push the project through bureaucratic red-tape...meanwhile, i attempted some unusual analyses of natural sounds with a PDP-8 in the psychology department, making use of this data for some instrumental pieces, took some programming courses, and continued making analog electronic music...*

A minority of computer musicians were using mini-computers to control analog synthesizers in real time, *in 1976 i went to study with Larry Austin, who directed the computer music studios (SYCOM) at the University of South Florida...SYCOM had a PDP-11 with very little memory and no hard disk....we used paper tape for storage and we input programs via a teletype...most people wrote BASIC programs to control a Moog and a Buchla in real time via some 12-bit ADC's and DAC's...*and an even smaller minority managed to squeeze some real-time digital synthesis out of these mini-computers. *i struggled to write an envelope follower and a simple sampler in assembler code…trying to follow the example of Roger Meyer who developed software for this system both at SYCOM and at Joel Chadabe's studio in Albany...i made real-time pieces which i programmed in BASIC and assembler, and recorded onto tape since the PDP-11 was far from portable...*

The visionary Groove machine of Max Matthews (Matthews 1970), developed in the late 1960's, existed in a laboratory environment (as did the RCA synthesizer), and its real-time interaction was primarily on an algorithmic level with control over analog devices. One of the first commercially available programmable real-time DSP machines designed specifically for musical applications was Dean Wallraff's DMX-1000, which appeared on the market in the late 1970's (Wallraff 1978). The Fairlight (Levine 1980) and New England Digital companies were starting to build programmable machines. Stanford was working on the Samson Box, Di Giugno had started working on the "4" series at IRCAM, and Allouis was developing the SYTER at GRM (Allouis 1982). *i dreamed of saving enough money to buy a Fairlight...instead, i went to Holland in 1980, to the Institute of Sonology in Utrecht, where the main computer was a PDP-15 mini-computer which was used for real-time digital signal processing...it is rather amazing to look back on the dedication to real-time DSP of Sonologists like Paul Berg, G.M. Koenig, Robert Rowe, Takayuki Rai, Werner Kaegi, Floris van Manen, and Barry Truax...i was quite impressed by Paul Berg's PILE program (Berg 1984) which was designed for real-time signal processing...i continued to make real-time pieces which i programmed in FORTRAN and assembler, and recorded onto tape, since the PDP-15 was even less portable than the PDP-11…*

Di Giugno's IRCAM research (Di Giugno 1981), which culminated in 1980 with the 4X machine, took the concept of speed and power in the domain of real-time DSP to a level which was not challenged for a full 10 years. Practically speaking, the 4X was a laboratory machine like the Groove system (only a handful were manufactured at great expense); nevertheless a small repertory of high-quality real-time music compositions was produced with the 4X by composers such as Pierre Boulez, Philippe Manoury, and Robert Rowe. Well-designed user software for the 4X lagged behind hardware development (as is often the case) until the mid-1980's when Rowe began development of the 4xy programming environment (Baisnee 1986) , and Miller Puckette began using an early non-graphical version of Max to control the 4X. (The original impetus for the Macintosh version of Max (Puckette 1986) was to finally be able to control the 4X machine with a graphical user interface.) *i arrived at IRCAM in late 1985 after a period working at CEMAMu with the UPIC system...an anxiously awaited real-time version of the UPIC system was delayed for a few more years...i originally started using the 4X at IRCAM to realize a piece...i continued with certain threads of ideas I had experimented with at both SYCOM and the Institute of Sonology...i used the 4X for six years, writing 4X micro-code, c code, and Max interfaces for a variety of projects...i composed three pieces with the 4X, but like my previous real-time works, the final results were either tape or tape and instrument pieces, due to the lack of portability of the 4X...*

In the mid-1980's, the 4X and other real-time DSP systems were becoming easier to use due to improvements made to their user interfaces. Commercial MIDI gear began offering composers with little or no programming experience the ability to make computer music, much of it in real time. MIDI software was making great strides in the area of user interfaces, and there was great optimism about the future of computer music. People began questioning the need for real-time DSP machines. In the early 1990's, when the IRCAM Signal Processing Workstation (ISPW) appeared as a timely replacement for the 4X at IRCAM and Di Giugno's MARS workstation (Di Giugno 1991) was developed in Italy, it was clear that the gap between the possibilities offered by non real-time Music N programs and MIDI was still large. The ISPW, designed by Eric Lindemann (Lindemann 1991), was an attempt to fill part of this gap. It was an enormous step for real-time DSP: a portable, relatively inexpensive, *(cheaper than a new car, something I did not own for 15 years)* and powerful DSP engine was finally available. In addition, the ISPW ran a version of Max (David Zicarelli's version was already becoming widely used for controlling MIDI gear) to

which Miller Puckette had added a signal processing library (Puckette 1991). Users were free to write new Max objects in c code, but more importantly, musicians could prototype signal processing algorithms directly in the Max environment without having to write DSP code. *finally i was in a situation where i could compose real-time pieces which could be performed in an interactive environment, rather than transferring the results to tape...Philippe Manoury and Zack-Joel Settel were also very active as composers and researchers exploring the possibilities of real-time interactive music with the ISPW, and we were very lucky that a strong sense of collaboration existed between Puckette and us...i made three real-time interactive pieces at IRCAM with the ISPW...*

Presently, there is little effort in the direction of developing dedicated hardware/software DSP environments for musicians. The Kyma system is one of the only commercially available machines offering real-time programmable DSP. We finally have adequate computing power and software experience. Are composers just not interested in real-time DSP? Or is the lack of commercial interest the real problem? If inexpensive, portable, robust systems for powerful real-time DSP were available, computer musicians would certainly be interested. Programmers are starting to develop real-time DSP software in high level languages for Power PC's, Pentiums, Silicon Graphics (SGI) machines, and other off-the-shelf computers. IRCAM has a beta-version of SGI-Max which is available. *Miller Puckette is using a variant of SGI-Max, doing concerts at UCSD....it is only a question of a few months before i expect to be able to port my ISPW pieces to the SGI platform....but curiously enough, i find myself in the same position as i was 20 years ago: relying on off-the-shelf general purpose machines like the PDP-11 and PDP-15...*

Since general purpose machines are fast enough to do real-time DSP, musicians are not necessarily dependent on commercial efforts—which are feeble at best, and seem to offer a greater obsolescence factor. There is no way to avoid market forces, but depending on the music industry to move real-time programmable DSP forward is like waiting for NASA to offer vacations on the moon. Fortunately, the tendency for computer manufacturers to expend a great deal of research time, money, and effort on the production of faster machines seems to offer a very bright future for real-time signal processing. *after porting my ISPW pieces to the SGI, the next step is to port them to other platforms like the Power PC and Pentium...i hope to see Max or something like Max available for controlling commercial MIDI gear and doing real-time DSP on as many general purpose platforms as possible...i would like to be able to send a piece to a performer over the internet in software form, and expect them to be able to rehearse in their own home with their own real-time interactive DSP system as easily as they can rehearse tape and instrument pieces in their homes now...i firmly believe that empowering performers with the ability to exercise control over an electronic part, based on the performers' musical expressiveness, is an important factor in computer music's future...and i wonder if interactive pieces might eventually have an "obsolescence factor" equal to pieces stored on tape?...*

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