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An Interview with Max Mathews

Max Mathews was last interviewed for *Computer Music Journal* in 1980 in an article by Curtis Roads. The present interview took place at Max Mathews's home in San Francisco, California, in late May 2008. (See Figure 1.) This project was an interesting one, as I had the opportunity to stay at his home and conduct the interview, which I video-recorded in HD format over the course of one week. The original set of video recordings lasted approximately three hours total. I then edited them down to a duration of approximately one and one-half hours for inclusion on the 2009 *Computer Music Journal Sound and Video Anthology*, which will accompany the Winter 2009 issue of the *Journal.* The following article is a lightly edited transcript of that edited video recording.

The Early Years

Park: Could you tell me a little bit about your background: where you grew up, where you went to school—a little bit about your background that we don't usually hear in interviews.

Mathews: Oh, I'd be glad to. I was born and grew up in the middle of the country in Nebraska. My parents were both schoolteachers. They both really liked teaching sciences. My father taught physics, chemistry, and biology in high school and was also the principal of the high school. It was a small school, with class sizes of about twelve students, and it was a very good place to begin an education. My father let me play in the physics, biology, and chemistry laboratories, so I enjoyed making lots of things—making motors that would run, making barometers out of mercury, playing with mercury—you could do that in those days.

Park: Hopefully you didn't hold it in your hands.

Mathews: Oh yes, I held it in my hands, and I am still here at 80. One of the important things I

learned in school was how to touch-type; that has become very useful now that computers have come along. I also was taught in the ninth grade how to study by myself. That is when students were introduced to algebra. Most of the farmers and their sons in the area didn't care about learning algebra, and they didn't need it in their work. So, the math teacher gave me a book and I and two or three other students worked the problems in the book and learned algebra for ourselves. And this was such a wonderful way of learning that after I finished the algebra book, I got a calculus book and spent the next few years learning calculus by myself. I never really graduated from high school; I just stopped going there.

This was in 1944, and instead I took an exam for the Navy and enlisted as a radar repairman and essentially fell in love with electronics at that time. [Editor's note: Mr. Mathews moved to Seattle.] I did find out that the two schools that the teachers in Seattle recommended were Cal Tech [California Institute of Technology] and MIT [Massachusetts Institute of Technology]. Since [my wife] Marjorie was in California and was going to Stanford [University], I chose Cal Tech, and that was a very lucky and wise choice, as the undergraduate education I got at Cal Tech was superb. The techniques I learned in math and physics in freshman and sophomore classes at Cal Tech were the techniques that enabled me to pass the doctoral qualifying examinations when I went to MIT for my graduate work. On the other hand, even though I graduated from Cal Tech in electrical and mechanical engineering, when I got out of Cal Tech I didn't know how to simply build a simple audio amplifier; but at MIT I learned how to build complicated computer circuits out of the rudimentary operational amplifiers that were around at that time.

Another great stroke of luck came when I was refused employment at the 3M Company after they had offered me a job, as a result of a back injury that I had, so instead of going to Minneapolis—which I

Figure 1. Max Mathews at his home in San Francisco in late May 2008. (Photo by Tae Hong Park.)

Figure 2. Max Mathews and an IBM mainframe at Bell Laboratories. (Courtesy Max Mathews.)

favored, since my family still lived in Nebraska—I went to Bell Telephone Laboratories (Figure 2), where I went into the Audio Research Department to study new and better ways of compressing and encoding speech so it could be transmitted over the very limited-channel-capacity wires and radio that were available in those days.

Developing a Computer Music Language

Mathews: I also was very lucky that I had a boss who was very smart, very famous, very lucky, and very powerful. His name was John Pierce, and he's best known for the invention of, or the propagation of, communication satellites. Pierce was very interested in music. He was interested in information theory, how much information there is in speech—which is a good question [to answer in order] to know how to compress speech, and how much information there is in music. He himself liked to play the piano and to compose pieces.

He invited me to many concerts, and we went together. At one of these, a local pianist played some [Arnold] Schoenberg, which was very good, we thought, and some [Karl] Schnabel, which we detested. In the intermission, John suggested to me that perhaps the computer could do better than this, and that since I had the equipment to convert computer-digitized tapes into sound, I could write a program to perform music on the computer.

Park: It seems to me that you really got into the research in computer music after that particular concert where you heard Schoenberg with John Pierce. Was that an important turning point?

Mathews: Well, that was the actual provocation for my writing Music I. Now, if we hadn't gone to the concert, I think I would have gone on to write music programs anyhow, because I was very interested in this. My interests came from two things. One was that, although I've always loved to play the violin and I've had an amateur string quartet going most of my life, I was never very good at it, and so I wanted to be able to make better music that didn't require such manual dexterity as almost all [musical] instruments require. I also felt that there were many composers who would compose a piece for an orchestra and who would never hear the piece, or its performance would be delayed for years, and so [the computer] would provide a way for composers to write something and hear it almost immediately.

Park: Was there anyone else doing this sort of thing—anywhere in the U.S. or around the world?

Mathews: There were a lot of people who wanted to get music out of computers. [Years later, we learned that] in Australia there [had been] a significant effort. There were some people in the United States

who could get printers to produce pitches, and they would write a program that would play *Mary Had a Little Lamb* or something like that with the printer's sound. But I certainly think that my program was one the earliest ones that would actually generate arbitrary sound waveforms. [Editor's note: Mr. Mathews is being modest here; there is no evidence of any previous program with such a capability.]

Sampling Theory and Corollary

Mathews: Essentially the sampling theorem shows that there are really no limits to the sounds you can make from samples. Any sound the human can hear, you can make with the right number, accuracy, and combination of samples, so the computer is a universal instrument. Other instruments, the violin in particular, are beautiful, lovable, but they always sound like a violin—or at least it's very difficult to make them sound not like a violin. And I think the sampling theorem is true, but I now think there is a corollary to it, and that is that of all the classes of sounds you can make from a sequence of samples, most are not musically interesting, plenty are unpleasant, and some are even dangerous.

If you are trying to make music, there is a psychological tendency to make sounds that are dangerously loud. I myself feel that the temptation for composers is that if they have made a timbre that doesn't satisfy what they wanted to say, they hope that by making the sound louder it will have the kind of power that they really intended. That's led to [the use of] earplugs and should lead to the use of sound-level meters and things like that.

The Right People

Mathews: We need better understanding of the physical correlates of beautiful sound—beautiful as judged by the ear and the cortex of the listener. Computers have contributed to our understanding—computers in the hands of the right people. Two of the right people were Jean-Claude Risset and John Chowning. Now, I wrote a number of papers describing Music III. The fundamental paper was published in the *Bell System Technical Journal*. But the paper that had the most important impact in my opinion was a paper I published in the magazine called *Science*. And the reason it was so important was that Risset, who was studying for a doctorate degree in physics at the University of Paris, and John Chowning, who was at Stanford also studying for his musical doctorate degree, read the paper and saw the potential in this and were interested in it.

Risset persuaded his thesis professor to send him to Bell Labs to work with me, and he ended up working more than two years in two separate sections, discovering some of the fundamentals of timbre for traditional instruments. John Chowning both read and understood the paper, and he came back essentially for a day's visit to Bell Labs. We talked more about it, and he returned to Stanford and wrote his own computer programs. Risset and Chowning together made enormous advances in the production of beautiful music.

Now, what was Risset's contribution? At that time, people realized that the spectrum of sounds rather than the time waveform of sounds was a better way of characterizing how the ear would hear these sounds. By spectrum, I mean the average spectrum of, let's say, a single note or a sustained sound from the instrument. People knew a little bit about the attack and decay characteristics. They knew the piano had a sharp attack and a short decay. Using Music IV and V, Risset could produce these spectra controllably and accurately, but they didn't sound like the instruments. And what Risset discovered was that it was important to control the attack and decay of each overtone in the spectrum independently. His initial example was the brass timbre, where he showed that during the build-up of a note (the attack phase), the higher-frequency components had to increase faster than the lower-frequency components; otherwise, it didn't sound like a brass sound. By manipulating separate attack and decay functions for the different overtones, Risset was able to make useful approximations to a lot of different types of timbres and to extend the instrumental sounds so that you got interesting variations of the sounds of the instrument—which was not [actually] what Risset was after. He wasn't trying to imitate

instrument sounds, but he wanted to get the same richness that the instruments had and vary it.

If one wants to individually modulate the attack and decay of a lot of components, it's a very expensive process computationally—and in those days, the expense of the computer was significant. Chowning discovered a more efficient way of modulating the attack and decay of the overtones, and this was a different application of frequency modulation: FM synthesis. This was a different use of FM than anyone else had made. It was essentially done with two oscillators or very few oscillators, so it was a much more efficient technique than Risset's technique, and it led to similar results of musical interest.

In addition to being smart, Chowning also was lucky in that his innovation, his discovery of the FM synthesis techniques, came at just the time when complex computer chips were understood well enough so that it was feasible to design special-purpose chips to do particular operations—in this case, FM synthesis. In addition to his musical and technical talents, John has another talent. He is a super salesman, and he was able to convince the Yamaha Company to spend several years and a lot of money and a lot of effort to design and test and redesign this FM chip. But when they had finished the design and incorporated the chip into what I characterize as their second-generation synthesizer, the real winner was the DX-7 synthesizer. The reason it was a winner was that it was very inexpensive compared to alternative means. I think the DX-7 was about $2,000 in 1983. The number of people making digital music, I would say, increased from a few hundred worldwide to thousands, particularly in the domain of popular music. This almost overnight swept the United States and the rest of the world. As I say, Risset's and Chowning's reading the *Science* article was the start of a very essential and important movement in computer music.

Another early musician who was involved was Jim Tenney. Tenney was a student of Lejaren Hiller at the University of Illinois. John Pierce visited Hiller and hired Tenney to spend a couple of years at Bell Labs. Hiller himself was interested in composing music with a computer program, which was also a big interest of John Pierce. It was not

quite a significant interest for me. I was interested in having a computer perform music. Actually, the composing of music using computers predated the performance of music with computers. I did do some experiments of, let's say, my own, for computer-related compositions—never with great success, but with a certain amount of interest. But it was a much more difficult problem in terms of the logic of the program to produce it, and that was one the reasons I shied away from trying to compose music on the computer: It was too difficult for me.

I felt that one of the important problems in computer music was how to train musicians to use this new medium and instrument. One procedure was to invite a small number [of people] when we could to come to Bell Labs for visits—maybe long visits, as with Jim Tenney or Jean-Claude Risset, or perhaps very short visits. But that was a relatively slow way of getting the media into as broad a usage as we thought was appropriate. So one of the things that I did was to write a book. [It] was essentially an instruction manual for how to use computer music. It's this book that came out in 1969, *The Technology of Computer Music*. It was mostly intended as an instruction manual for using the Music V program.

At that time, the big [Bell Labs] Computation Center computer, or any digital computer, was not fast and powerful enough to make interesting music in real time. I really missed the possibility of playing the computer as one would play a traditional instrument, so that one could hear and modify the sounds, timbres, things you were making as you made the music—the kind of things that performers are so expert at doing with traditional instruments. And furthermore, you couldn't really play in a musical ensemble where you played with other performers, which to me has always been a great joy: to relate to [what] other people are playing. F. Richard (Dick) Moore, who is now at the University of California at San Diego, and I put together what we called the GROOVE system, which was a hybrid system. The control end of the system was a digital computer, and the sound-generating end was a modular analog synthesizer. [Digital] sound-wave synthesis has to be computed at audio sampling rates, which are [nowadays about] 44,000 samples per second. [By contrast,] the control end of a digital

Figure 3. Early controller design. (Courtesy Max Mathews.)

system only has to be able to follow the motion of a performer who is controlling the music, and this requires sampling perhaps a hundred times a second. Dick and I put together a system with a small but fast digital computer at one end and connected a number of different sensors to the computer, so that it could track the motions or changes the performer was making in the sensors.

The output in the digital computer was a set of, in this case, 14 analog signals that were sent to an analog synthesizer that had a lot of voltage-controlled equipment. Controls that were available on the GROOVE system consisted of a normal electric keyboard and a rather remarkable three-dimensional "magic wand" which you could move up and down, left and right, back and forth, and potentiometers would record the position. But in addition to potentiometers controlling [and measuring] these three motions, there were motors on the device, so that the computer could also move the wand. So you could not only move it by hand but also feel the position or feel whatever the computer "wanted" you to feel (or the program you had written).

It was never very popular, for one very good reason: it cost about US$ 20,000 in 1960s dollars to build. So, as far as I know, only one was ever built. But we did use this device to make quite a few pieces of music. One of those pieces is Emmanuel Ghent's *Phosphones,* and we have a good video of Mimi Garrard's dance company performing to this. Not only did Ghent get the GROOVE system to make the music, but [he also got it] to control the light sources that were illuminating the dance company. [Editor's note: See this work on the 2008 *Computer Music Journal Sound and Video Anthology* DVD.]

The GROOVE system worked at Bell Labs in the late 1960s and continued on until the early 1980s, when that computer was then finally retired. And a number of composers would come out to Bell Labs at night when we were not using the computer for speech research, which was its other function. Emmanuel Ghent was one of these; Laurie Spiegel was another notable one; Richard Boulanger came down from Boston. So a fair amount of interesting music was made. [Pierre] Boulez came out and tried it and asked me if I could use these kinds of techniques to control the tempo of a tape recording, so that if
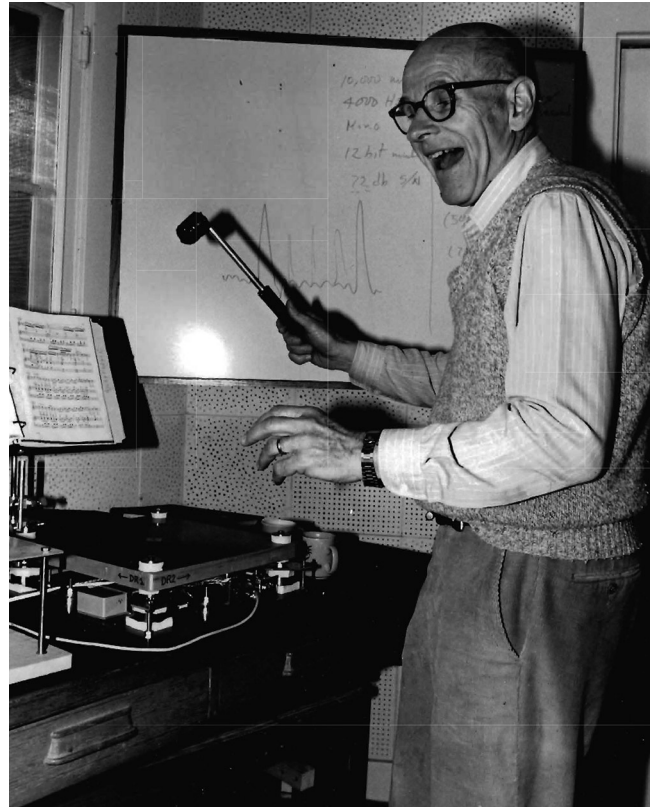
you had the accompaniment for a soloist on a tape you could then control the tape to maintain a good ensemble with the performer. I probably changed my interpretation of Boulez's request to what I call the Conductor program, which I am still interested in.

The philosophy behind the Conductor program (see Figure 3) was that the performer of a computer-based instrument should be doing a job more similar to what the conductor of an orchestra does than to the way the violinist plays the violin. With the Conductor program, the score of the piece to be played was in the computer memory as a sequence. Eventually, MIDI files became the preferred way of putting the score in a computer program. And the job of the performer was to control the expression of the way in which the score file was performed. Now, what are the expressive factors that could be controlled? Well, the tempo, of course, and the micro-tempos in the piece, which are one of the most important expressive factors. In watching

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Boulez conduct, [I saw that he has,] in my opinion, a very precise motion of his conductor's baton, so he beats time in a very detailed and exact way and, I believe, hopes that the orchestra will follow his beat. So, I made the rules of my Conductor program do as closely as possible what I thought Boulez was doing.

Another expressive function is the dynamics, of course. Still another expressive function is the balance of the various voices in the ensemble. Still other expressive functions are the timbres of the voices. All of these things can be controlled with the performer's conducting motions. But one needs to be very careful about overloading the performer; you can only control so many things. And the way of limiting what the conductor had to do at any one time was essentially to write in the particular factors that needed to be emphasized in a given part of the performance. For example, bring out the flute in this section and assign a given controller to the flute for that particular section, and then later on, where the oboe was the critical instrument, to change the assignment of the limited number of controls.

So the Conductor program really divided the expressive quantities into those that would be written out in detail in the score and those which would be assigned to the human conductor. This then led me to an instrument that I have been working on since the mid 1980s—the Radio Baton as a controller. The idea of the Radio Baton was that it would be a controller that could sense the motion of the conductor's hands and use those motions to control the expressive quantities of the instruments. So, initially I built an instrument called the Radio Drum. This instrument had a set of wires in two dimensions: *x*-going wires and *y*-going wires underneath a plastic cover. When you would hit the plastic cover, that would cause one of the *x* wires to contact one of the *y* wires, and then you could tell where you had hit this grid. The instrument had a contact microphone on the back plate, and the strength of the pulse from the contact microphone could tell how hard you hit it. So you could then use where and how hard [you hit] as controls to control whatever aspect of the music you wanted.

This was a relatively easy instrument to build. I made one for IRCAM [Institut de Recherche et Coordination Acoustique/Musique] and took it over to Paris. One of the percussion players at IRCAM, a very good percussion player, played a Bach chaconne with this. Boulez listened and pointed out a wrong note in the score, and I was delighted to hear that, because then I fixed the wrong note and it was forever OK. But the instrument was overall not a success. One of the problems was that the wires kept breaking at the points where they hit each other. Another problem was that you only got information from the instrument when you hit it physically, but if you just waved the baton (or the drumstick in this case) around above the instrument, you didn't get any information. So, when I got back to Bell Labs, I talked to one of my associates there, Bob Bowie, and he thought very long and hard about making a radio sensor that could track the motions of a little radio transmitter in space. At least he came around to this; he tried several other things before this. This turned out to be the instrument that I kept on working on for the 19 years I was at Stanford. With it I achieved not a full three-dimensional sensing, but at least what I call a two-and-a-half-dimensional sensor. So, the instrument consists of this radio-receiving antenna, and if you are close enough to it, you can see from the pattern of the metallization that there are four separate antennas on this plate. Here's the current version of the stick. If I remove the pad, you can see at the end of the stick a metal ring, which is the transmitting antenna. So the strength of the signal depends on how far you are from the receiving antenna. Tom Oberheim and I have been working on this device together for about a decade. He has joined me out here in California, and I have joined him.

Amazing Place and People: Bell Labs

Park: Bell Labs must have been an amazing place, offering a healthy environment for collaboration and creativity.

Mathews: I think you and I and everyone in the world has wondered about that, because it was a very, very fruitful environment. You put your finger right on one of great things about Bell Labs: that we had experts in various fields in physics and chemistry and mathematics, and they were all

willing to listen and talk to each other and spend enough time listening to understand the question that someone from another field might have and possibly, if they got interested, to actually help that other person solve the question. I had a number of mathematical questions come up that I was unable to deal with, and I was always able to find a mathematician who often was able to advise and sometimes solve the problem for me. One of those exceptional mathematicians was David Slepian.

When I changed to a university job, I've been sort of disappointed that the interactions between real experts in various fields are much more limited, and I don't understand why this is. I think one possible explanation is that the support for the research department, at least the research area at Bell Labs, came as a lump sum to the vice president in charge of research, and then he assigned various amounts of money to the various departments, and it was a very generous support, so that no one really had to spend time writing proposals, going out searching for money, and competing with associates. So maybe that certainly made people much more willing to interact. But there may have been other reasons.

My job for most of the time when I was at Bell Labs was managing the Behavioral and Acoustical Research departments. And these were experimental psychologists, physicists, some engineers—mostly electrical engineers—and some computer scientists. I always felt that my job was to try to recruit people who seemed both very smart and who seemed interested in problems that were broadly related to the work of the Bell System communications. But when I say "broadly," we could study how the human ear worked physiologically and even try to deduce how the cortex worked, understand such things as masking of one sound of another in speech or in music, so we could support basic research in these areas. So I always tried to find people that I thought were both smart and interested in useful problems. But then I would explain to them that when they came, they would have to choose their own work and that we're not going to hand them a problem to work on, and they both had to be able to recognize useful problems and make some progress on them or eventually we would figure someplace else for them to work. In other words, my job was

more or less finding the right people and then letting them alone to do their thing and then finding out what they had accomplished and understanding what they had done. Among other things, it left me a certain amount of time to do my own work.

Park: It seems like it was a great environment for creativity and innovation. I think that sort of environment is perfect for smart people to come up with smart things.

Mathews: Yes . . . it was . . .

Park: I also noticed Bishnu Atal was there and LPC . . . obviously that has been used a lot by composers like Charles Dodge and Paul Lansky. Have you had any collaboration with Bishnu Atal?

Mathews: Oh yes. In fact the most interesting paper that I was involved [with] in the speech area was with Bishnu, and G. G. Chang, and John Tukey, a very well-known statistician.

Park: Is that the Tukey in the short-time Fourier transform Tukey?

Mathews: Yes, that's the Tukey–Cooley algorithm, which I still think is important. Anyway, the question was—in recognizing speech, it would be useful, or people thought it would be useful, if you could take the spectrum of the sound and from that spectrum deduce the shape of the vocal tract, because we didn't know how shape was related to "p" and "d" and "ah" and "oh" and so forth. And that research seemed to be always problematic, so the four of us decided maybe that problem was not solvable, and this is basically what we call the ventriloquist paper, and it proved that you could make speech sounds which are absolutely indistinguishable by the human ear with very different configurations of the vocal tract.

The most important things in sounds are the positions of the three lowest resonances—the three formants—and so we would synthesize the sound with those three formants with the given configuration of the vocal tract, and then we would gradually change the configuration but with the constriction that the first three formants would not change. We had a program to do that, written by G. G. Chang. You could make a progression

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Figure 4. Max Mathews with Joan Miller. (Courtesy Max Mathews.)

of small changes that would result in a very big change. So this essentially said that the amount of information in the sound wave isn't sufficient to specify the shape of the vocal tract, and you need more information if you want to do that precisely. That was the last paper that I did involving speech work—and that was with Bishnu.

Park: I noticed, just reading books and whatnot, that [Jim] Flanagan was at Bell Labs, and he did a lot of research with phase vocoders. I was wondering if you had anything to do with the phase vocoder or research with Flanagan in any way.

Mathews: That's right. No, I didn't do any direct research with Flanagan. We were in the same area for a long time and I know him very well. I didn't work on the phase vocoder, either.

Park: One particular name that keeps surfacing is also Joan Miller, and I was wondering if you could perhaps talk about her a little bit. Her contributions, collaboration [with you] . . .

Mathews: Oh, yes. She was a close associate of mine; we did a number of research projects together (see Figure 4). She studied at [University of California]

Berkeley and had an advanced degree in statistics, but she too liked the computer as a device, and she was a very good programmer, and she could use this [ability] in her research. She did some of the most complicated code in the Music V program. This was the code to interpret the numbers on the IBM punch cards (the p-fields) and put them in their right place. We worked on speech for a while. She did a little bit of music, but not too much. She got very interested in learning to play as a professional violinist and did that. After she retired, she kept on playing violin in various professional groups around New Jersey. She's one of the people whom I try to see when I go back to New Jersey, and in fact we often get together for playing something.

Collaboration Outside the "Cage"

Park: I was wondering what sort of collaboration you had with [John] Cage. I couldn't find out much about it.

Mathews: Well, let's see. There were two main collaborations. Cage envisioned a piece for orchestra where all the musicians would have contact microphones and they would come into a big mixer. Originally, he hoped to have one loudness control for each musician, but we ended up with a compromise. I built the mixer for him, really an octopus of wires.

The New York Philharmonic programmed the piece. The mixer had enough knobs on it so that Cage wanted someone else to help him conduct the piece. Tenney and Cage were joint conductors at the mixer, so they could set the levels of sound and they could route the sound to one or several of about eight or ten loudspeakers that were positioned all around the hall.

The piece had problems. The first problem was Leonard Bernstein, the music director. He came in after the rehearsals were well along and told the musicians that if they didn't want to put the contact microphones on the instruments they didn't have to. That infuriated me, because the piece depended on that, and also because I had thought rather carefully about this problem and had previously suggested that the instruments not be their "number one"

instrument but one of their lesser instruments. (Most violinists have several instruments.) And I had arranged the contact microphones to be attached to the bridges of the instrument, and bridges have to be replaced every now and then. Original Stradivarius bridges are, I think, no longer with any instrument, and so the contact mics were unlikely to produce any permanent damage to any instruments. The brass players and most of the other players were quite happy to have mics taped onto their instruments.

I was about to resign, take my mixer with me, and say, "Forget about all this crap." Anyhow, Cage saved the day by inviting me and my assistant to a nice Austrian restaurant in New York City, and feeding us a Sachertorte, which cheered us up enough to come back. But the piece really had problems. Cage again rose to the occasion and added a piano piece to the program—*Atlas Eclipticalis* I think, that was played by his favorite pianist whose name will come back to me in a moment [David Tudor]. But the other problem in the piece was that we had not counted on the feedback to the stage from the loudspeakers. [It] was really bad for people sitting near the loudspeakers, and so I felt badly about the sound levels that I subjected some of the people to.

But anyway, I certainly enjoyed working with Cage. He would come out and visit us, and we occasionally went for walks in the woods behind our house. He would look for mushrooms. I'd ask him if he ever ate random mushrooms, and he would say absolutely not. He knew what would happen in those circumstances. The other interaction with him, he had been using the *I Ching* as a way of generating random numbers. The *I Ching* produces a rather exactly specified way of getting the random numbers, which I've forgotten at the moment. But Cage wanted a computer to be able to produce a sequence of *I Ching* statistical numbers, so this turned out to be not too hard to program. I did that for him, and that was interesting.

I saw him a fair bit. Boulez and other composers at IRCAM had great respect for him, and he came over to Paris once and we saw each other. Near the very end of his life, he came out to Stanford, where a number of his paintings were exhibited.

He really lived off the proceeds of selling paintings rather than off concerts, because paintings then, as now, are much more highly paid for than music. He was very depressed at the time, and the lecture I went to he was unable to finish. And the thing that he said was depressing him was the growth of the population in the world, and what he felt was the terrible conditions that having too many people imposed on great regions of the world. And I guess I still share that concern that the environment is heavily stressed now by the human population and seems to continue to be worse and worse. Merce Cunningham was a close friend of Cage's. I once asked a performer [Laurie Anderson] who knew both me and Cage—telling her about Cage's last talk and his depression—and she was of the opinion that Cage was depressed not necessarily by population issues but rather because he and Cunningham had just broken up as friends at that time. But I asked Cunningham if this was the case. (He also came out to Stanford with his dance company a year or so ago.) But he said ". . . no, that was not true," that he and John never had a break-up. So I don't know who to believe, but I do know that Cage was exceedingly unhappy in his very last few days and this was not typical of him. He otherwise was, I think, a very resilient man who not only wasn't depressed, but could resist depressing situations in the world.

Park: Did you work with Bernstein after that?

Mathews: No. I did not. I didn't work with him before then either. I think the feeling would have been mutual.

Recent Research

Park: Max, could you tell me a little bit about some of the more current research that you have been conducting?

Mathews: Well, my most recent has concerned a slightly different kind of filter called a phasor filter that is better behaved when you dynamically change the parameters of the filter while at the same time passing a signal through the filter. These are single resonant filters. In engineering terms, they

are described by a single pair of poles that produce a peak in the frequency response of the resonant frequency, so the two parameters controlling these filters are the resonant frequency and decay time. Now, these are infinite-impulse-response filters, and various forms of them have been around for a long time. But the normal equations now called bi-quad equations, which will produce two poles and a couple of arbitrary zeros if you want them, are not very well behaved if you suddenly change the frequency or the Q of the filter while at the same time passing the signal through it. So this often introduces a discontinuity or click or some undesirable sound.

Phasor filters are also based on a difference equation, but a slightly different and more complicated difference equation, so that the discontinuity introduced by dynamic changes in the parameters is smaller than the discontinuity of normal bi-quad filters. The expense that you pay for this greater dynamic stability is that these resonant filters basically require twice as many multiplications to produce the resonance as the bi-quad filters. Today, computers are so fast that you can afford this additional computation time. So with the phasor filters, most any laptop today that runs with a processor speed of at least 1 GHz can simultaneously produce perhaps between 500 and 1,000 resonant filters.

An example I have been working on recently is making a vibrato filter where the vibrato is not the change in pitch of the driving voice (or whatever you're trying to put a vibrato on), but rather is a change in the filter's resonant frequency, and this change would occur not at auditory frequencies but modulation frequencies—vibrato frequencies of three to perhaps ten cycles per second. Julius Smith and I gave a paper on the resonant filters at a meeting in Stockholm, one of the SMAC [Stockholm Music Acoustics Conference] meetings in 2003. Since then, I have been trying to get some interesting musical timbres out of these filters using a laptop platform to produce these timbres, and to get the whole thing running in real time so that this would eventually be a musical instrument that could perform live or be part of an orchestra or something like that.

Alternative Controllers

Park: Do you have thoughts about alternative controllers and new controller designs? It seems to me that there is a movement where musicians and engineers and just about anybody are building their [own] controllers, and the technical aspects don't seem to be a hindrance really, I think—but the musical results tend to be the problem in many cases. Any thoughts on this sort of phenomenon/trend?

Mathews: Yes, this is a question we struggled with in particular in our human-computer interface course, where the students actually built new instruments with all sorts of different sensors. Students are very, very imaginative at constructing new sensors. One person made a bicycle sensor where the music was controlled by the handle-bars, brakes, and pedal. It's easy to make these things, and enjoyable; the class is very popular. Everything is exciting until the final presentation, where we ask the students to get some music out of their device, and they almost never succeed by my standards of what I like in music. They are almost always quite interesting sounds, though.

I think that designing new controllers for music is a very difficult field, because it takes so long for a performer to learn to play a new instrument. And the music "scenes" in this world are full of old instruments that no longer are made or no longer exist—just lots of variations on violins, or bassoons, or reed instruments, or keyboard instruments, so that the learning problem and the investment of time to test a new instrument is probably a decade before you get really expressive on the instrument. And since in the end many of the promising ideas don't prove to be very successful, I don't know how to deal with this unpredictability of the really expressive qualities of new controllers, or how to shorten the learning process, or how to evaluate a controller to see how it's expressive.

The controller I worked mostly with is the Radio Baton, and the thing that makes it playable is the fact that the score is the computer memory, and you play it as a sequence. So that removes one of the mechanical problems that performers of normal

instruments have, who have to select each note at the proper, usually rapid rate. But that also limits the kind of things that can be done with the Radio Baton/Conductor program combination. It's not very good for jazz or improvisatory music. So I don't know in the end whether that will be a successful instrument or whether it will also be relegated to the museums.

Evolution

Park: How do you think computer music will evolve in the near future and the distant future?

Mathews: I can tell you what I hope will happen. In the past, computation was expensive and slow. Originally, with the computers in the 1960s, to make interesting timbres and music, it usually took about 100 seconds to make one second of sound. Now, computers are incredibly more powerful than even the big computers were in the 1960s. The modern laptop computer, which you can buy for a few thousand [U.S.] dollars or even less, is at least 10,000 times more powerful and faster than the [IBM] 7094, or even more than that [compared to the IBM] 704 on which we started the music-synthesis sound-processing programs. This means that a laptop computer can literally make a symphonic orchestra of separate instruments in real time. We divide the 10,000 by 100 to get the complexity figure and still work in real time, and you still have 100 left over for multiplication. So, basically what this says is that the computer power that is available to musicians now far exceeds what they now know how to use effectively; the bottleneck is no longer in the computer.

What do I feel are the limitations to what kind of music we can produce digitally? What are the things that we need to study in the future? What are the directions we should develop in digital music? I think the limitations are the basic understanding of what the human ear and higher auditory sensors in the brain recognize as beautiful, inspiring music. So I think the question which is going to dominate the future is now understanding what kind of sounds we want to produce rather than the means of usefully

generating these sounds musically. This is going to revolve around experimental psychological studies of how the brain and ear react to sounds, but these kinds of studies have been going on for many decades without producing appreciable music. The reason is that they were being done by psychologists rather than composers and musicians. My feeling is that it is much easier for a composer who has whatever mystery composers have—musical ears, a desire to make music, something they want to say musically, something they want to communicate musically— I think it's much easier to teach composers the techniques of modern psychology so that they can study the musical effects in the human brain than it is to teach psychologists how to be composers and make them want to be composers. So I think that the next era will add to the burden of the [composer].

Let's say composers need to make music; we've already added the necessity of dealing with computers to their burden. But now we need to add the kinds of experimental techniques that psychologists have developed to understand the reaction of the human brain not only to various timbres, but also to various sound sequences, harmonies, chords, and other things. Composers have always dealt in an intuitive way. Now, they need to deal in a way that will relate to physical sound waves. So, I think this will be a very long and gradual study and improvement, but a very interesting one, so that it will always be exciting.

And I think there are new scientific tools that are already yielding results that are exciting. One of these tools is the NMR brain-scanning techniques, which are very crude [compared] to the complexity of the brain, but they do show what parts of the brain are activated by various stimuli. There is a very interesting book that a friend and associate, Dan Levitin, has recently published, entitled *This Is Your Brain on Music* (Levitin 2006), in which he looks at these questions of how the human brain (as much as is known of it) responds to music. He and a medical doctor did a study of how the brain responds to listening to a Beethoven symphony. They showed that there was a sequence of areas in the brain that were activated by listening to the music. The lower-level auditory centers and eventually the

auditory cortex and then the so-called pleasure center became active. They also showed that it was a high-level activation, and that it was not simply responding to the timbres of the sounds, because if one took the same music and chopped it up into short sections and scrambled the order of the short sections so that the short-term sequential effects were destroyed but the timbres were essentially retained, the activation of the other centers did increase, but the pleasure center was not activated.

I recently went to a rock concert. I don't go to very many. And I was really amazed at the continuous and loud and driving rhythm that was in this concert, and how much the audience apparently enjoyed hearing this rhythm for an hour and moving to the rhythm. Even though they were sitting in the chairs, they would stand up. So, I wondered myself how rhythms stimulate the pleasure centers, and I would be willing to bet they do.

Anyway, that's one reaction. Another reaction, though, is that random noises—where you can control the spectra and put attacks and decays on it and things like that—in my opinion have lately become too popular in computer music. I guess for me they produce a negative stimulation of my pleasure center, and I wonder why people like this driving rhythm and why (I believe) they like the random noise-like signals. So, as I say, I think the future lies in understanding the reaction of the human brain to music, and that will be a great area coming up.

Important Contributions to Computer Music

Park: What would you consider, let's say, the three most important innovations/contributions in computer music and why?

Mathews: My music programs III through V, as far as computer science goes, were what were called block-diagram compilers, where in this case the block diagrams were the unit generators. I think that is probably the most innovation that I had a hand in. Music V block diagrams, where the musician can assemble these blocks and the instruments, came just a little bit before Moog and Buchla and others made their voltage-controlled patchable analog synthesizer boxes. The digital and

analog things were developed within a few years of each other. So there was a zeitgeist of the times, really. So that's one thing.

[Interviewer's note: According to Jean-Claude Risset (in an e-mail exchange dated 20 April 2009), diagrams, modularity concepts, and their implementations were already included in Music III (1961), which was clearly earlier than when Donald Buchla and Robert Moog built their first voltage-controlled patchable analog synthesizer boxes, and earlier than when Paolo Ketoff in Italy built what became the Synket. It is often assumed that synthesizers inspired Max Mathews's design of Music III, Music IV, and Music V. However, it seems that it is the other way around. Even though the digital domain was seemingly not Robert Moog's forte and inclination at the time, he knew of the developments of Mr. Mathews's work at Bell Labs. In the winter of 1964, while Jean-Claude Risset was working at Bell Labs, Robert Moog and Jean-Claude Risset had exchanges and correspondences about these topics.]

I think another popular and very important contribution here was by Miller Puckette, later in association with David Zicarelli, and this was a graphic interface for block-diagram compilers, so you could actually draw them on a computer display. I think this has proved to be very, very amenable and pleasant, desired by most musicians as a way to make their instruments. I didn't have graphical interfaces of that kind when I started, so I've always learned just to use written statements to connect and interconnect my blocks. I am very comfortable with that, and I haven't jumped into Miller's program, Max/MSP, but I highly respect it, and think that it's a very, very popular program.

And of course Risset's understanding of timbres, and Chowning's efficient ways of synthesizing timbres [that] are all related to modulations of spectra, is probably the third area that I think is the most important. I guess another area is sampled systems, where one records digital files—samples of traditional instruments or sounds from nature or vocal samples—and then processes these samples in the computer program. That would be another area that I think will continue to be vital in my foreseeable future.

Negative Pleasures

Park: You mentioned noise negatively influencing your pleasure zones. Can you think of any other such examples?

Mathews: I am certainly critical of timbres based on noises that are played dangerously loud and are to me inherently disagreeable. I do remember one of the very first computer-music concerts where we had a short piece of computer music presented. I think it was Newman Guttman's *Pitch Variations.* This was in an auditorium in New York City, and there were other composers there, one of whom was La Monte Young, and he had a piece of tape music played there. [Interviewer's note: This concert possibly took place at the Village Gate, near Edgard Varèse's home on Sullivan Street, where Varèse introduced the piece showing his early interest in computer music, according to Jean-Claude Risset.]

The tape recorders, which were quite expensive at that time, were in the auditorium, and there were a [lot] of policemen surrounding the tape recorders to protect them from the audience. Now, I don't think the audience had any particular dislike of the computer music piece *Pitch Variations;* for one thing, it was a short piece. But La Monte Young's piece was called *Two Sounds*—one of which was the sound of someone running his fingernails down the blackboard, and the other, the sound of a door with rusty hinges being gradually opened and closed. These sounds were played very loud and for a long time, and that was the reason for the police protection that was needed at the concert.

I also went to some other concerts where La Monte Young had pieces, one of which involved burning a violin. I consider that piece a complete failure, because in truth you could hardly hear it; it just made a little "plink." I think Young had another piece, though, where he threw a piano out a window; probably that was a little more successful. I guess the pieces were certainly memorable; I can remember them, and in that sense they were important music, but I still don't have any pleasant memories of them. On the other hand, I do appreciate one piece that La Monte Young wrote, which was simply a set of instructions, and it said, "Select a piece of music you like. Play it on your instrument as well as you can." That's a great piece, and I have always tried to do that.

Nonsense

Park: Audio engineers, concert engineers, musicians, et al., often discuss analog sound versus digital sound. Even now there seems to be a lot of debate as to which sounds "better" and as to the analog "warmth" of tape machines. Do you have any thoughts regarding this?

Mathews: I think this kind of debate is nonsense myself. One can make very close approximations of analog sounds digitally; you can even put LP record noise onto otherwise noiseless digital recordings. I believe that it probably comes from a strong respect for—and a love for—history, and that's perfectly appropriate. But one of the things that I did when I came to Stanford was to transcribe a number (all we could lay our hands on) of the analog tapes from tape music into Wave files and CD-ROMs, to preserve this music, because I think the CD-ROMs are likely to last longer than the analog tapes, and they can certainly be copied exactly. [Editor's note: Mr. Mathews is referring to the International Digital Electroacoustic Music Archive (IDEAMA), which aimed to preserve masterpieces of classic tape music. IDEAMA was a joint project of Stanford's Center for Computer Research in Music and Acoustics (CCRMA) and the Zentrum für Kunst und Medientechnologie (ZKM) in Karlsruhe, Germany.]

Father of Electronic Music

Park: You are often regarded by many as "the father of electronic music." I was wondering how you felt about that—how you see yourself in this context. The second question that relates to this is: Are you today where you thought you were going to be when you started out at Bell Labs?

[Interviewer's note: Although Max Mathews is usually called "the father of computer music," I

intentionally used the word "electronic" here. The terms "electronic" and "electric" are not entirely distinctive to many, and they are regularly used interchangeably, especially outside the engineering community. However, the terms are commonly applied in quite specific contexts in engineering and the sciences. Generally speaking, electric circuits usually, but not always, deal with high voltages, high power, and alternating-current (AC) systems, as well as electro-mechanical relay technologies, among others. The term electronic, however, is usually reserved for systems that encompass low-voltage, direct-current (DC) circuitries; these systems are more often used in situations encompassing solid-state devices such as semiconductors and computers. I have used the appellation "father of electronic music" for Max Mathews in this context.]

Mathews: My training is as an engineer, and I consider that I'm not a composer, I'm not a professional performer of any instrument. I do love music. If I've done anything, I am an inventor of new instruments, and almost all the instruments I have invented are computer programs. I have built a few electronic violins. (See Figure 5.) So if I am remembered for anything, I would like to be remembered as one of the inventors of new instruments. I think that this occurred not because I did anything special, but because I was in at the beginning when computers first became powerful enough to deal with sound and music. I guess I didn't have any way of predicting the popularity of digital music, and that popularity was the result of many people other than me making it easy to do and far less expensive. And I certainly had no idea of the rapid advance in computer power that we have seen in the last 50 years, and I don't think anyone else did either, or at least very few people [did]. I didn't realize how popular digital music would become, especially for popular music (not so much for historical symphonic music).
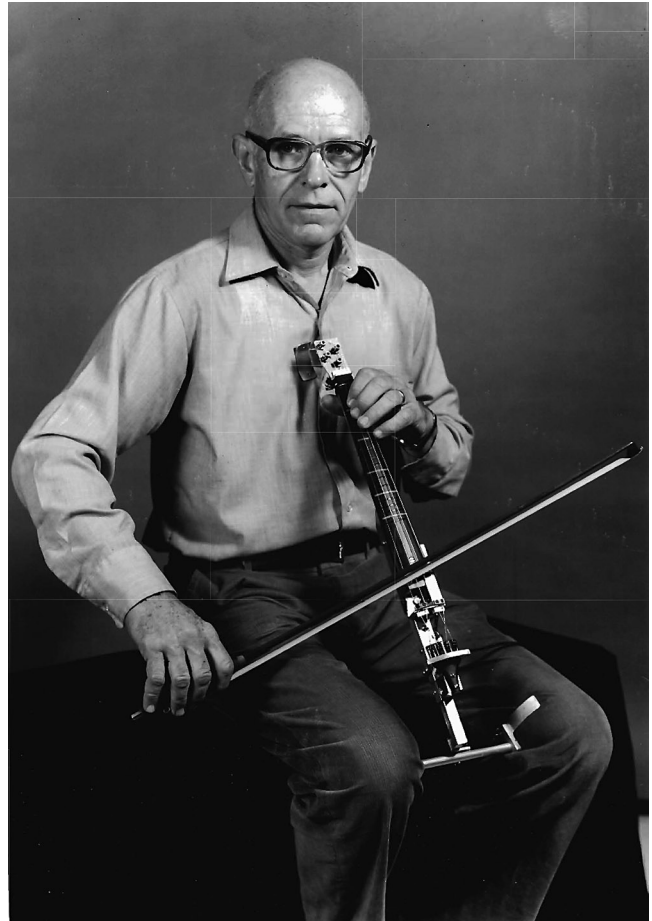
References

Computer Music Journal. 2008. *Computer Music Journal Sound and Video Anthology Volume 32*. DVD. Cambridge, Massachusetts: MIT Press CMJ DVD-32-4.

Levitin, D. J. 2006. *This Is Your Brain on Music*. New York: Dutton Adult.

Mathews, M. V. 1969. *The Technology of Computer Music*. Cambridge, Massachusetts: MIT Press.

Risset, J.-C. 2009. Personal communication, 20 April.

Roads, C. "Interview with Max Mathews." *Computer Music Journal* 4(4):15–22.