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A Personal Approach to Contemporary Jazz: Works for Saxophone and Computer-Controlled Electronics

Neil Leonard III

BACKGROUND

I was drawn to jazz in the mid-1970s while living in the Philadelphia area. A number of seminal jazz musicians made their home there, including experimental composer/keyboardist Sun Ra. Ra had been active in jazz since its early days, when he arranged for the Fletcher Henderson orchestra. Even the avant garde's detractors praised his compositions and piano solos. Ra was a major proponent of electronic keyboards in jazz. He was the first jazz musician to play the Wurlitzer Electric Piano in the mid-1950s, and he began using the now-famous Minimoog synthesizer while it was still in beta testing and used it extensively for years [1]. Always defying categories, Ra once refused to join the musicians' union on the grounds that he was from Saturn, and could often be found walking the streets wearing antennae or other space-age paraphernalia. While peer innovators in jazz insisted that they were not entertainers, Ra embraced his vaudeville roots and probably donned more sequined outfits and capes than Elvis Presley did.

In the mid-1970s, I began playing alto saxophone in jazz ensembles. I worked with musicians such as trumpeter Michael Ray, who divided his time between Ra's Arkestra, Kool and the Gang, and local groups. I sat in front of Ray on weekly big-band dates as he played solos that climaxed in dense Echoplex-like call-and-response riffs, which he played without electronics and topped off with martial-arts moves. Like Jimi Hendrix, Ray excelled at showmanship without compromising a note. Other peers of this new generation played Coltrane's "Giant Steps" on baroque instruments, performed ancient Yoruba rhythms on homemade scrap instruments and studied composition with George Crumb. I found the crossing of disciplines and blending of ideas from different roots and traditions exciting and inspiring. I came to believe that when styles are passed down without fresh inspiration and modern influences, they harden into stale orthodoxy.

In the late 1970s, I moved to Boston and became part of a jazz scene that anticipated the current "jazz renaissance." Wally's Café was the home of some of the best musicians, and works from Art Blakey's mainstream repertoire were the staple. There I played with performers such as Don Byron, Greg Osby, Frank Lacy and Marvin "Smitty" Smith. It was customary for the pianist, bassist and drummer to drop out during our solos, leaving the soloist stranded on the hardest of tunes. I welcomed the opportunity to refine my improvisa-

tions on Blue-Note classics and Tin-Pan-Alley standards. However, after several years of such work, I saw that no matter how good the players, the new approaches to improvisation that I sought would require a new repertoire to match—one that equaled the sophistication that we had achieved as soloists. So, as jazz took off on a nostalgia binge, I began looking for new directions.

INSTALLATIONS AND INTERMEDIA WORKS

In the early 1980s, I taught myself computer programming, and within a few years I was writing original programs to explore the computer's musical capabilities. I became particularly fascinated by its essential lack of implication as a tool for creating music. It carried none of the traditional baggage of older instruments. When a performer walks into a room with a saxophone, people tend to have certain, very specific ideas of what it is that he or she will do, expecting a sound resembling, for example, that of Charlie Parker or Stan Getz. When it is announced that a performer will play computer music and a saxophone simultaneously, nothing is certain until the music begins. Uses for the computer are evolving so quickly that people tend to listen with few preconceptions and expectations.

It has been through jazz that a number of recent instruments found their first virtuosos and repertoires. Jazz gave the saxophone its voice through the work of musicians such as Coleman Hawkins and Sidney Bechet [2]. It also established the validity of the drum set through the work of Baby Dodds [3] (among others) and that of the electric guitar through the breakthroughs of Charlie Christian [4]. I felt that working with computers would be a way to expand jazz's sonic palette, rethink ensemble interplay and explore new resources for improvisation.

I began collaborating with visual artists on interactive installations, sound performances and soundtracks. For the in-

ABSTRACT

Jazz is often at its best when stretched to incorporate elements that might at first seem foreign or even suspect. It is now clear that computers, critical doubts notwithstanding, provide an important way to extend jazz improvisation and compositional resources. This article discusses how the author's roots in the jazz tradition inform his work using saxophone and computer-controlled electronics. He examines two such works, which draw on diverse traditions and make use of computers to allow jazz to speak in new and different tongues.

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stallation *Gray Scales* (1985) [5], I implemented a computer system that used a video camera to scan a series of black-and-white photographs by media artist Dana Moser, which were projected on a wall of the gallery space. The system used this data to construct musical patterns that were then played on a MIDI synthesizer. Another system created for the installation provided algorithmic control of stepper motors that I installed in turntables to play records in a variety of semi-random forward and backward dual-motion patterns. I also designed a video surveillance system that monitored activity in the gallery and controlled a separate computer system that generated music in response to movement. I went on to create computer-generated works for Constance DeJong and Tony Oursler's performance "Relatives," which was presented in the 1989 Whitney Biennial. I collaborated with poet Angel Cosmos on a computer-processed text performance, and composed electroacoustic soundtracks for Maria Magdalena Campos Pons's film *Rito de Iniciacion* and her video *Bano Sagrado*.

CROSSCURRENTS

Cuba has greatly influenced jazz since 1900, when W.C. Handy went there to study Cuban brass bands [6]. I was first drawn to this root of jazz when I heard Dizzy Gillespie's work with Cuban percussionist/composer Chano Pozo. Gillespie's 1940s big band, which featured Pozo, mixed ancient ritual chants of Cuba's Abakua sect, twentieth-century classical music and jazz improvisation [7]. I was later inspired by the Cuban jazz group Irakere, which furthered these innovations in several extended suites. In 1986 the opportunity to travel to Cuba with a group of musicologists arose and I jumped at the chance. During that visit I played with many musicians, including members of Irakere, attended concerts by folkloric music and dance ensembles and gathered a small collection of recordings.

I also met Cuban composer Juan Blanco, who was one of the first to explore the musical implications of sampling technology. In 1942, he drew up the blueprint of a sampling keyboard that used a separate wire-recording deck for each key on a one-octave keyboard. His design is now in the United Nations Educational, Scientific and Cultural Organization musical archives [8]. Trained as a classical composer, Blanco was equally comfortable writing for gui-

tar virtuoso Leo Brower or jazz saxophonist Paquito D'Rivera. Blanco once directed a live television broadcast in which Irakere interpreted a score consisting of projected, animated geometric forms, which were simultaneously viewed by the audience. For 25 years, Blanco had led the new music movement on the island and, working on a shoe-string budget, fostered one of the most talented schools of electroacoustic composers in Latin America. During this first encounter, Blanco gave me an LP (long-playing) recording entitled *Música Electroacústica* that included his composition "Circus Tocatta," which featured the country's premiere timbale and conga players freely improvising to atonal and polymetric synthesized sounds on tape. "Tocatta" was unlike any piece I have heard before or since. It is my belief that Blanco found the point at which modern composition, live electronics, free improvisation and Afro-Cuban folkloric music could intersect with equal integrity.

In the late 1980s, I moved to Havana to work with Blanco for a year. I was greatly inspired by his pluralistic approach and his ability to make work of the highest quality with the most modest technical equipment.

In Havana, I designed algorithms that later became part of "Legacy" and other compositions for saxophone and computer music system (discussed below). I also created a four-channel audio performance system that enabled the performer to select samples and set loop points, volumes and playback rates using graphic sliders and stochastic processes. At the same time, I played in concerts with Emiliano Salvador and AfroCuba, whose jazz compositions were built on various folkloric sources. On some of AfroCuba's pieces, percussionist Mario Luis Pino played three West African bata drums simultaneously, adding new rhythms to jazz that were as effective as—or perhaps more effective than—most "modern" approaches to highly polyrhythmic jazz that I had heard in the United States. Investigating Cuban music and its impact on North American music became a focal point of my research, and I later published a number of articles on my findings [9]. I also commissioned Blanco's "Espacios V," for solo saxophone and tape, and premiered it as part of his first presentation of live works in the United States [10].

I began experimenting with the computer in concerts in 1985, and presented my first composition that made use of

the computer in concert in 1988 at the Primavera in Veradero, an international festival of electronic music in Veradero, Cuba, where I premiered "Dialect." This piece used a pitch-to-MIDI converter to create a basic digital description of the pitch, amplitude and duration of the notes I played, then transmitted this data to the computer, which analyzed the data and generated a response in real time [11]. I used the software Jam Factory, whose Markov chain capabilities allowed me to set up the basic tonality and rhythms the computer would use as the basis for creating variations in real time [12]. Jazz composers have often been the best arrangers and interpreters of their own pieces, and my work with Jam Factory convinced me that my best performances with microprocessors would occur when I designed and programmed the system myself. In both processes, understanding the motivations and inner workings of the piece at the intuitive level are essential. After two performances with commercial software packages, I set out to design my own system. In the fall of 1989, I spent 2 months at the Banff Centre for the Arts in Alberta, Canada, as a Media Arts Fellow. During this residency, I finished my first interactive music system for use in concerts, and composed "Legacy: San Lazaro" using the C programming language.

"LEGACY: SAN LAZARO"

"Legacy: San Lazaro," for soprano saxophone and computer-controlled electronics, was my first concert piece that used software of my own design (Fig. 1). The instrumentalist's part is largely written for the first half and almost completely improvised for the rest. As in "Dialect," a pitch-to-MIDI converter and original algorithms are used to track the pitch, volume and duration of my saxophone and generate a response in real time. A previously determined sequence of algorithms that runs for approximately 12 min provides the basic form of the electronic sounds. Each section has additional algorithms to modify electronically generated timbres and rhythms that the player can choose to invoke as desired. The player can thus influence the notes and rhythms selected by the computer, but the actual choices are made by the algorithmic processes and are ultimately unpredictable. I think of the algorithms as loosely resembling parts of a kinetic sculpture moving freely on predefined axes as ex-

ternal forces—the musician, random-number generators and semi-stochastic processes such as Markov chain playback—introduce change.

When I first used a drum machine, I felt empowered by its ability to help me compose basic rhythmic patterns. However, I disliked the mechanical repetition and sought to design my own rhythmic composition system that would take patterns composed on a drum machine and improvise on them in real time. Many of my peer drummers in jazz could move fluidly between more conventional periodic rhythms or grooves associated with the post-bop era and aperiodic rhythms associated with so-called “free jazz”; in much the same way, I could move between melodic phrases and extended techniques such as multiphonics and vocalization. I began creating algorithms that could take a basic pattern and create variations in the original meter as well as stylistic variations that used shifting meters. “Legacy’s” rhythmic generator uses a one-bar polyrhythm and continually varies it, using algorithms for reorchestration, beat displacement and layer masking [13]. Each of these variations is initiated by a timer that has been adjusted to count down at a random rate constrained by fixed limits. In addition, the software is programmed such that certain trills played by the performer will cause the rhythmic generator to thicken and thin the number of rhythms that make up the polyrhythm. The software’s rhythms are applied to both pitched and percussive sounds. Later, for my composition “Sacred Bath” (1992–1996), percussionist Ernesto Rodriguez played the rhythms into the computer for me so I could mesh “Legacy’s” devices for rhythmic permutations with Rodriguez’s polyrhythms and timing nuances.

“Legacy” furthered my work with Markov chains, making use of software I created to provide an original Markov module that can analyze my performance and synthesize a melodic imitation in real time. In the first section, its synthetic melodies were mapped to the clave rhythm generated by the rhythm-variation generator. In “In Transition” (1990), I fed intervals played by violist Laura Keunnan into this algorithm. While tonal note sequences played into the Markov module caused it to generate a relatively predictable mimic, the same lines fed into the chain as intervals yielded melodies with mid-phrase key changes. So, through the research began with

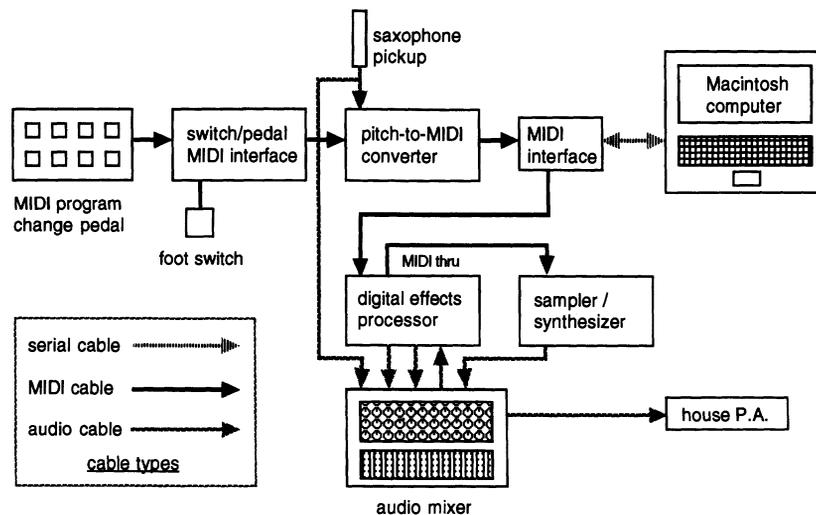


Fig. 1. A diagram of the setup used for “Legacy: San Lazaro” and the “Reflections” series. While the system continues to be upgraded periodically, the basic units remain the same. The system is optimized for portability. The current equipment includes a Kurzweil K2000RS sampler/synthesizer for generating sound; a Lexicon PCM-80 digital-effects processor for processing synthesized and acoustic sounds; an IVL Pitchrider 4000 Mark II; and Roland CP-40 pitch-to-MIDI converters. For some pieces, a CD-ROM drive is connected to the computer, allowing the software to play digital-audio excerpts. The earlier pieces, including the version of “Legacy: San Lazaro” presented at ICMC ’91, were performed on a Macintosh Classic. The current computer is a Macintosh PowerBook 5300cs.

“Legacy,” I found a new way to allude to the pantonal breakthroughs of post-bop musicians and extend them further.

The last jazz group that I worked with prior to writing “Legacy” was led by composer/bassist Jymie Merritt. As a member of Max Roach’s group, he helped pioneer the use of odd time signatures in jazz. At my first rehearsal with his group, the Forerunners, he handed me the drum parts to his composition “Angela,” which was based on the superimposition of rhythmic phrases in several meters, which he called cross-rhythms. The drum pattern was reversed halfway through the figure, creating a palindrome, a device he used for both 4/4 and odd-meter compositions. Merritt was one of the first bassists to play accompaniment with as much rhythmic and harmonic freedom as the horn soloists enjoyed. When we played, his rhythmic pulse would shift between the superimposed rhythms. He would avoid walking or vamping on an ostinato for more than a bar or two. Despite the unprecedented complexity of his lines, Merritt swung no less than he had when playing with Blakey, Gillespie or B.B. King, setting the standard for how organic such developments can be [14]. Playing with him provided further inspiration as I began creating my own systems for rhythmic transformation [15] (Fig. 2).

“REFLECTIONS”

Where “Legacy” explored the ways in which elements of my acoustic work, such as polyrhythmic improvisation, can be extended through automation, “Reflections” uses paradigms that were foreign to jazz. The interactive system used in “Reflections” tracks me via a pitch-to-MIDI converter and uses its analysis of my playing to influence both the form and individual note selection throughout the entire performance. Thus, my playing influences the computer’s global behavior, or “mood.” The machine improvisation can borrow motifs from me or create its own motifs using chaotic models for biological growth and atmospheric convection. Together we navigate through virtual chaotic space. The human-machine ensemble playing ranges from autonomous improvisations to a tightly interactive exchange that can move in a new direction at any time. The systems unfold differently in each performance.

“Reflections” grew out of research that was conducted with visual artist and math educator Hubert Hohn. In the spring of 1992, Hubert invited me to compose the theme music and soundtrack for “Order and Chaos,” an interactive television program broadcast via satellite from Boston to high schools throughout the United States [16]. The

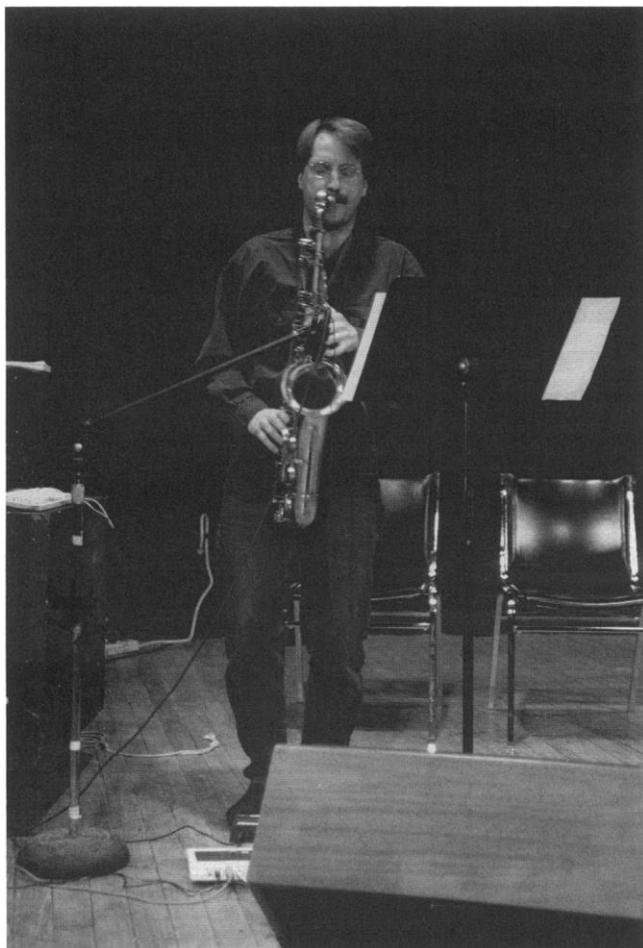


Fig. 2. The author performing at Mobius in Boston, Massachusetts, using the setup described in Fig. 1. (Photo: Bob Raymond)

Fig. 3. The author and bassoonist Janet Underhill performing “Reflections” at Mobius in Boston, Massachusetts (1995), using the setup described in Fig. 1. (Photo: Bob Raymond)



series served as a math class that introduced students to chaos theory through computer programming.

Hubert had worked closely with John Cage, translating many of his ideas to

software. Working in collaboration with Cage, he automated the random-number generation and synthesized speech for a performance of Cage’s *Songbooks* in 1983. They developed software that gen-

erated random numbers for isolated decisions and also helped create larger forms that were not purely stochastic—an experience that convinced Cage to abandon his skepticism about computers and use them extensively during his last years.

Hubert had recognized the appeal of non-linear functions for creating a range of order and chaos in music, and also realized the degree to which sonification of the equations’ output would help students understand the nature of the equations. In the interests of enhancing his show with original music and providing students with an audio version of some of the equations being taught, he asked me to create theme music based on chaos theory for his program. I created different pieces for each broadcast, providing the show with an algorithmic house band. I found that using chaotic data to compose music had instant appeal. Chaotic models provided a continuum of incredibly varied behaviors—with deterministic patterns on one end and the apparent randomness of chaos on the other—available by no other means. As the function’s behavior approaches chaos, the sonic result can be a wealth of variations on short themes, each slight variant of initial conditions yielding completely different values.

While working on the series, I listened to the results of dozens of functions using hundreds of different parameters. I created over 50 short pieces for broadcasting. Each piece explored a different use of chaos theory and used a different computer program. Having identified a core group of functions that yielded particularly rich sonic results, I started a larger work that used these findings as the basis of an interactive system. In 1992, I premiered the first piece for this system, “Turbulent Mirror.”

Later, I refined the software and titled subsequent compositions with the system “Reflections.” The first performances were flat-out saxophone/computer improvisations. Later versions used composed interludes and improvisation cues for multiple human performers (Fig. 3).

Through the use of chaos theory, I found new approaches to harmony and note inflection that were not rooted in jazz or random processes. The first version of “Reflections” iterated chaotic functions in real time. The software searched for certain pitches and used them to set up initial conditions for microtonal chord progressions. By starting multiple iterative processes with mi-

nuscule differences between the initial values, I generated progressions that gradually unfolded to reveal increasing independence of chord voices. Being a saxophonist, I wanted to model some of the expressive nuances that are second nature to horn players. The continuous, yet chaotic, movement of atmospheric convection simulated with Edward Lorenz's butterfly attractor was the basis of one approach to this problem. I used the x , y , z coordinates and acceleration data to model pitch, timbre and volume inflections, as well as tempo maps. I continued to explore this approach to computer-generated expression in several pieces that followed.

I used algorithmically generated two-dimensional plots of ferns to create melodic motives and a two-voice counterpoint for "Reflections" and the television series. Shortly after premiering "Reflections," I began using the computer to generate scores for solo saxophone using these graphs. I alternated horizontal and vertical coordinate pairs of the plots to create melodies in which the melodic intervals steadily decrease until they "resolve" to one pitch and begin a new phrase. The overall shape and jagged outline of each leaf provided a recognizable pitch contour. Each plot became a unique melodic fragment resembling the overall shape of a single leaf in a thicket of ferns.

My intimate understanding of the system creates a synergy between the system and myself that is unpredictable, yet approaches the unity I found with musicians with whom I had worked for years. In order for this rapport to work, I have had to re-evaluate how my playing influences the ensemble's reaction. The system maintains a current analysis of a dozen parametric descriptions of the performer's input and stores melodic fragments in Markov chains. At times, my playing causes shifts in the form; at other times, the result of the parametric analysis is such that the system does not use any of my data to create its output. Creating "Reflections" extended my resources in jazz into new areas and required me to test my theories of interactive improvisation and integrate these experimental sounds and methods into a new musical tradition, outside the old borders and limits of the past.

CONCLUSION

Today's "jazz renaissance" occurs on a plot of land surrounded by "No Trespassing" signs facing inward. The cre-

ative freedoms that yesterday's innovators enjoyed are discouraged by conservatives in the name of an increasingly sacred canon. Yet, the most fruitful periods in the development of jazz have occurred not when practices have hardened into convention, but when innovators have emerged with fresh ideas and practices to rekindle its spontaneity.

Some might argue that my work with computer-controlled electronics is far from the jazz mainstream or outside of the genre. But the same could have been and indeed was said about the use of amplified guitar in 1940. I see my work as an attempt to find new solutions for renovating jazz in the context of contemporary culture. Whether I am playing saxophone with Jymie Merritt or an interactive system, my music is part of an ancient, yet living, tradition whose continued growth is in our hands. As culture evolves, so must jazz—if it is to speak meaningfully to new generations.

References and Notes

1. Ra's LP *Super Sonic Sounds*, released on his Saturn label (which was then on ABC Impulse), featured Ra playing Wurlitzer Electric Piano. Included on the disk is "Advice to Medics," which he played entirely on the Wurlitzer. This LP was recorded in 1956, one year after the release of the instrument. In an interview I conducted with him in the spring of 1996, Tom Rhea, a historian of electronic musical instruments, said: "The Wurlitzer Electric piano was developed by Benjamin Franklin Miessner and introduced in 1955. It has a struck-reed tone generator, with an innovative frequency-modulation pickup that develops a more complex sound than the reed produces acoustically. Miessner and the German Oskar Vierling pioneered the development of electric pianos in the thirties, but these were essentially pianos with their soundboards removed, with pickups for the strings. These instruments found some usage, but their musical impact was minimal. The early 'stringless' electric pianos due to Miessner and Harold Rhodes came along some years after World War II. These were the first electric pianos used in recordings by many contemporary artists, and they mark the beginning of the era of widespread use of the electric piano." Rhea, who was director of marketing for Moog Music, related: "The Minimoog that became one of the most fashionable instruments of the seventies and eighties was actually the fourth generation of that instrument—Model D. There were three earlier generations of the Minimoog, designated models A, B and C, respectively. Those were prototypes or beta instruments. Ra was given a Model B Minimoog. It's an indication of Ra's precocious interest in electronic musical instruments that he was even aware of the existence of the development of the Minimoog." For a detailed history of the development and acceptance of the Minimoog, see the article by Robert Moog in Mark Vail, *Vintage Synthesizers* (San Francisco, CA: Miller Freeman, 1993) pp. 143–150.
2. In the mid-1920s, Sidney Bechet demonstrated new uses for the soprano saxophone in recordings with Louis Armstrong and a 6-month stint touring with Duke Ellington's orchestra. Many believe that his finest recordings were those made during the 1940s, since re-released on Blue Note. Coleman Hawkins laid the foundation for modern saxophone playing with his late-1920s recordings and his seminal 1939 recording of "Body and Soul." Until Bechet and Hawkins took up the saxo-

phone, the instrument was clearly overshadowed by the trumpet and clarinet. The saxophone's less piercing timbre and limited range seemed to suggest that it was more suited to voicing background harmonies than being the lead melodic instrument. Musicians were still learning to cope with the saxophone's unique tuning anomalies and few musicians had found a convincing way to use vibrato. Its unique range of voice-like sounds were exploited by comic acts that used extreme squealing, squeaking and barking effects for satire, perpetuating the notion of the instrument as a novelty.

Bechet and Hawkins's new approach displayed a mastery of the instrument's range of inflections that proved it could be as lyrical and versatile as any lead instrument in jazz. They achieved the sonic intensity of the best trumpet players without having the benefit of the volume and timbral brightness of the trumpet. Hawkins's recording of "Body and Soul" exploited the saxophone's softer dynamic range and possibilities for harmonic richness in the low register to achieve a mysterious, lush quality unattainable by either the trumpet or clarinet. In short, these early saxophonists demonstrated that their instrument was as versatile and rich in possibilities as any other then being used to play jazz.

3. In the early part of this century, jazz percussion consisted of the snare drum, bass drum, hand-held cymbals and other percussive tools borrowed from military and marching bands. In the early 1920s, Dodds and his peers rejected the prevailing notion that each instrument required a separate player and arranged the instruments and others—such as Chinese wood blocks and triangles—around a single percussionist. Dodds was one of the first jazz percussionists to play independent but interlocking rhythms on multiple instruments by using all of his limbs simultaneously. He pioneered the use of drum fills and laid the foundation for the melodic use of percussion in jazz. While he was not necessarily the first musician to develop these techniques, his work was so convincing that he remained the predominant model for years to follow.

4. In 1939–1941, Charlie Christian began to use the electric guitar to match the sonic intensity of brass and saxophone soloists and allow him to solo with large ensembles. He developed a new approach to melody and improvisation suited for amplified guitar. The vast majority of jazz guitarists continue to base their styles on his innovations.

5. *Gray Scales* was exhibited at the Boston Computer Museum.

6. Cuban rhythms have influenced North American jazz and pop music throughout this century. After visiting Cuba in 1900, W.C. Handy wove these enchanting rhythms into his enormously popular "St. Louis Blues" (1914). Since then, Cuban rhythms and lyricism have enormously influenced popular music in the United States.

7. Gillespie's late-1940s collaboration with Cuban conga player and composer Chano Pozo marked a turning point in American music. Gillespie and Pozo co-wrote the jazz masterpiece "Manteca" (1947), which featured Pozo on congas and used repeating percussive patterns, or ostinatos, for the horns and bass. As Gillespie pointed out, this was the first time that a jazz bassist played a repeating syncopated figure. Since then, the ostinato and Latin percussion have become integral parts of jazz and international pop music.

Gillespie and Pozo took the music a step further when they played George Russell's piece "Cubana Be, Cubana Bop," which combined West African Abakua chanting with Russell's combination of bebop and Stravinsky-influenced harmony and counterpoint. "Cubana Be, Cubana Bop's" assimilation of symphonic composition and African roots was unlike anything Gillespie's peers, such as Charlie Parker and Thelonious Monk, had performed. This piece anticipated avant-garde developments carried out over the next 40 years.

8. Neil Leonard, "Juan Blanco: New Music Pioneer," *Rhythm Music Magazine* 3, No. 4, 36–52 (1994).

9. These findings were published in a dozen articles published in *Rhythm Music Magazine*, *Electronic Musician* and compact disc liner booklets. For articles describing music in Cuba, see Neil Leonard, "Los Van Van: Speaking to the Heart of Cuba," *Rhythm Music Magazine* 3, No. 2, 14–16 (1994) and "Los Muñequitos de Matanzas: Living Legacy of Africa," *Rhythm Music Magazine* 3, No. 7, 50–53 (1994).

10. Blanco's first presentation of live works in the United States was held at the New Music Festival at Wesleyan University in Middletown, Connecticut, and one week later at the Institute of Contemporary Art in Boston, Massachusetts, in 1993. I organized this trip along with Boston Creative Music Alliance and the Space.

11. For a basic description of MIDI and electroacoustic instruments, see Samuel Pellman, *An Introduction to the Creation of Electroacoustic Music* (Belmont, CA: Wadsworth, 1994). For a more detailed discussion of pitch extraction and computer-music tools, see Curtis Roads, *The Computer Music Tutorial* (Cambridge, MA: MIT Press, 1996). For an overview of computer-music systems for live performance, see Robert Rowe, *Interactive Music Systems* (Cambridge, MA: MIT Press, 1993).

12. Jam Factory was written by David Zicarelli for the 680x0-series Macintosh computer. It was first published by Intelligent Music, then by Dr. T's Music Software. For a detailed description of Jam Factory, see Zicarelli, "M and Jam Factory," *Computer Music Journal* 11, No. 4, 13–29 (1987). For a description of Markov chains, see F.R. Moore, "Elements of Computer Music" (Englewood Cliffs, NJ: Prentice Hall, 1990) pp. 429–439.

13. N. Leonard, "'Legacy: San Lazaro': The Integration of Composition Performance and Computer Programming," *An International Journal of Computers and Mathematics with Applications*, CAM2391 (1996).

14. Jmie Merritt's mid-1960s mainstream playing is exemplified by his work with Art Blakey and the Jazz Messengers, a group that featured an all-star lineup of Lee Morgan, Wayne Shorter and Bobby Timmons. Merritt's work on Blakey's now-classic recording of Benny Golson's "Along Came Betty" exemplifies his mastery of post-bebop bass accompaniment. This rhythm section set the standard for the style of "straight-ahead" jazz that is emulated by many of today's younger jazz musicians.

In the decades that followed, Merritt moved on to address odd meters, polyrhythms and accompaniment in new ways. Merritt's composition and performance of "Nommo," recorded by Lee Morgan, is representative of the approach he pursued with his Forerunners. On this recording he implies the harmonic and rhythmic foundation without falling back on the post-bop solutions of his earlier work. Following in the path of his former bandmate Max Roach, he further demonstrates that "swing" exists outside of the conventional 4/4 time signature used frequently in jazz. The foundation of jazz is dance music, and Merritt's music always conveys that sensibility, no matter how convoluted the scores seem.

His fluid improvisations over complex rhythmic foundations came 20 years ahead of the work by contemporary champions of similar devices.

15. Like "Legacy," "In Transition" was completed during a residency at the Banff Centre for the Arts. "Legacy" was presented at the 1991 International Computer Music Convention (ICMC).

16. "Order and Chaos" was produced by Massachusetts Corporation for Educational Television, 1991–1994. Each semester, a series of 30 45-min programs were broadcast via satellite to high schools around the United States. The program served as a course in pre-calculus mathematics that students could take for credit. Subscribing schools interacted with the host in real time via telephone links. Music for the introduction and credits was created for each session from number sequences generated by the chaotic models being explored.

17. Rhea [1].

Discography

Armstrong, Louis. *Portrait of the Artist As A Young Man*, Columbia/Legacy CD C4K-57176 (recorded 1923–1934, CD released 1994). Includes Handy's "St. Louis Blues." Baby Dodds plays on a number of pieces on this recording.

Bechet, Sidney. *The Best of Sidney Bechet*, Blue Note CD B21S-28891 (recorded mid-1940s, CD released 1994).

Bechet, Sidney. *The Complete Sidney Bechet, Volumes 1 and 2*, RCA CD 2-07863-66489-2 (recorded 1932–1941, CD released 1995).

Bechet, Sidney. *The Complete Sidney Bechet, Volumes 3 and 4*, RCA CD 2-07863-66607-2 (recorded 1932–1941, CD released 1995).

Christian, Charlie. *The Genius of the Electric Guitar*, Columbia CD CK-40846 (recorded 1939–1941, CD released 1987). Christian performs with the Benny Goodman Sextet on this recording.

Gillespie, Dizzy. *The Complete RCA Victor Recordings, 1947–1949*, RCA CD 07863-66528-2 (CD released 1995). Includes Gillespie's collaborations with Chano Pozo and George Russell.

Handy, W.C. *Louis Armstrong Plays W.C. Handy*, Columbia CD CK-40242 (recorded 1954, CD released 1987).

Hawkins, Coleman. *Body and Soul*, Bluebird CD 5717-2-RB (recorded 1939–1956, CD released 1986).

Morgan, Lee. *Live at the Lighthouse*, Blue Note CD 35228 (recorded 1970, CD released 1996). Includes Jmie Merritt playing *Nommo*.

Smith, Bessie. *The Collection*, Columbia CD CK-44441 (CD released 1991). Includes Smith's rendition of Handy's "St. Louis Blues."

Sun Ra. *Concert for the Comet Kohoutek*, ESP CD 3033-2 (recorded 1973). Includes "Journey through the Outer Darkness," an unaccompanied Minimoog solo by Ra dating from the early 1970s.

Sun Ra. *Super-Sonic Jazz*, Evidence ECD-22015 (recorded 1956). Includes "Advice to Medics," Ra's solo for Wurlitzer Electric Piano.

Glossary

Abakua—The secret society of the Abakua was founded in the Calabar region of West Africa to protect Africans against slave traders. According to Armando Valladares, the artistic director of Los Muñequitos de Matanzas, one of the oldest and most celebrated folkloric ensembles in Cuba, the society of the Abakua no longer exists in Africa. To this day, Abakua rituals and music are preserved by practitioners in Cuba, including members of Los Muñequitos.

Echoplex—an audio effects unit that records on a magnetic tape loop. The recorded signal is passed over multiple playback heads to create an echo-like effect.

Lorenz butterfly attractor—a nonlinear equation developed by Edward Lorenz in 1960 to model the earth's atmosphere. A graph of the data generated by many iterations of the equation resembles a butterfly.

Markov chain—an analysis of a series of events describing the frequency at which specific event sequences occurred. The analysis is used to synthesize a new series of events using probabilities based upon the frequencies of occurrence of pattern units in the original data.

Minimoog—one of the first portable synthesizers to be used widely in jazz and pop music. The Minimoog has become a classic electronic instrument that, along with the Hammond Organ and Fender Rhodes Electric Piano, is frequently emulated by modern-day digital synthesizers. As Tom Rhea has pointed out [17], the Minimoog's control wheels—one each for pitch bend and modulation, situated to the left of the keyboard—have become standard issue for electronic keyboards.

stepper motor—a motor that can rotate clockwise or counterclockwise in discrete steps and is instructed to do so via external electrical impulses.

stochastic—random.

Yoruba—a West African civilization concentrated in what is now known as Nigeria and the People's Republic of Benin. The majority of Cubans of African ancestry are descendants of Yoruba. The Yoruba religion is still practiced widely in Cuba today, and Yoruba music is a fundamental musical influence in Cuba.

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