Chapter 8

Cybernetic Composer: An Overview

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The Compositional Process

For each genre in its repertory, the Cybernetic Composer has access to several different *models* describing information pertinent to how pieces can be structured. Each model has a chordal scheme (which also describes the phrase structure) and a thematic scheme.

Cybernetic Composer ensembles have four layers: solo part, background chords, bass line, and drums. The solo and bass parts both are monophonic; the background layer is a homophonic texture in three or four parts; and the drum layer is a polyphonic texture of unpitched drum and cymbal sounds. Except for the information provided by the model, individual layers generally have very little "awareness" of what the other layers are doing. (An exception is the ragtime genre; here the background and bass layers work in close coordination.) Because the instrumental roles in jazz, rock, and ragtime ensembles are well defined, the program often gives the illusion of true interplay when the layers are actually going their separate ways.

Chordal Scheme

The chordal scheme of a model describes a phrase structure and lists alternate chordal progressions appropriate to this structure. To illustrate this, Figure 1 details a four-measure chordal scheme, taken from the Bebop blues model of the Cybernetic Composer's standard jazz genre. The elements in the diagram are

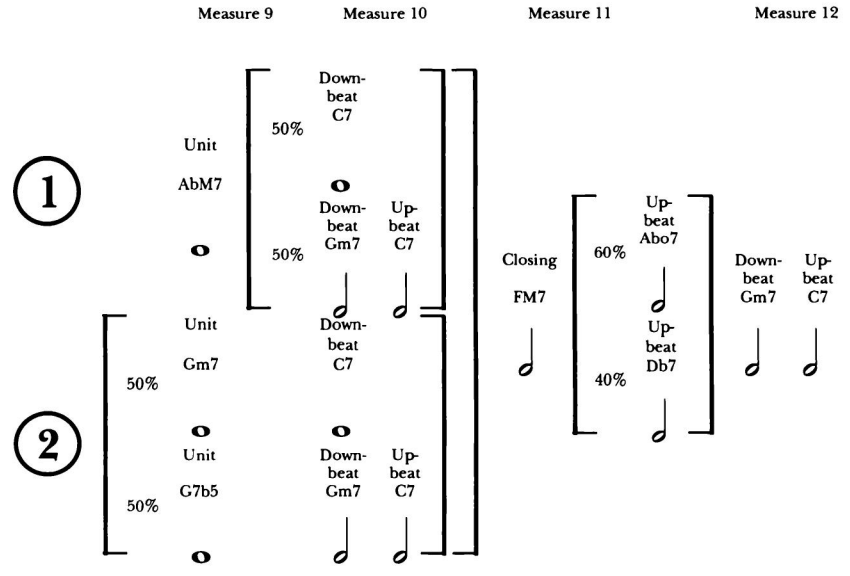

Figure 1. Chordal Scheme for Bebop Blues (measures 9–12).

described by a rhythmic duration, a metric function, a chord root expressed here relative to the key of F, and a chord quality. Chord qualities are designated by the following abbreviations: M7: major 7th chord, m7: minor 7th chord, 7: dominant 7th, 7b5: dominant 7th with lowered 5th, o7: diminished 7th, ø7: half-diminished 7th. Rectangular brackets delimit alternative rhythmic streams; the percentages indicate random weights associated with these streams.

Figure 2 illustrates one of the many alternative progressions described by Figure 1. This progression employs the upper substream of stream 2 in measures 1-2 and the upper stream for beats 3 and 4 of measure 3. Chordal progressions are derived in much the same way for the Latin jazz, rock, and ragtime genres. Ragtime requires additional instructions detailing what kinds of chordal inversions are permissible.

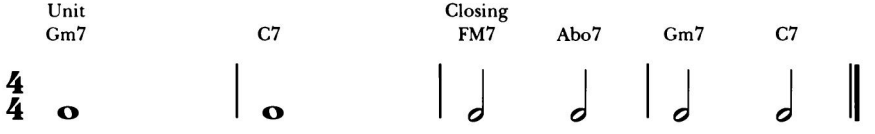

Figure 2. Sample Progression.

Rhythm

The first step taken when the Cybernetic Composer generates a melody is to derive a chordal rhythm such as the sample depicted in Figure 2. The chordal rhythm pro-

vides a basic framework to which the program applies refinements characteristic of particular instrumental roles within each genre. These refinements produce a complete rhythmic description of a melody, including when notes start, how long notes last, and *how notes function melodically.*[1] Each note of the chordal rhythm assumes a *primary* melodic function. In solo and background melodies these primary functions include primary chord tones and cadence tones; in bass lines new chords are anchored by statements of the chordal roots. The *refinements* to the chordal rhythm divide primary notes into chunks and establish these chunks as notes or rests in their own right.[2] The notes generated by refinements can themselves be primary chord tones (sometimes subject to further refinement); they can be repetitions of previous chord tones; they can be scale tones (chordal or nonchordal), which bind melodies by stepwise movement; or they can serve *ornamental* melodic functions as passing tones, neighboring tones, reaching tones, appoggiaturas, and so on.

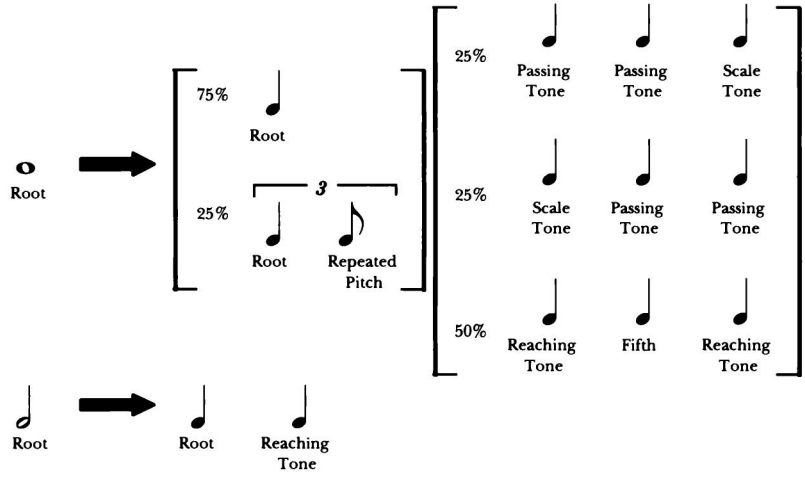

Figure 3. Rhythmic Refinements for Walking Bass Line.

Figure 3 shows the rhythmic refinements employed to derive the walking bass line for the Cybernetic Composer's jazz genre. This is by far the simplest set of refinements used by the program. The arrow in each refinement should be interpreted as follows: "whenever in the current rhythm, a duration and melodic function matches the duration and melodic function on the left side of the arrow, replace the matched duration and function with one pattern described on the right side of the arrow." Rectangular brackets to the right of the arrow delimit alternative rhythmic streams, with percentages indicating the random weight associated with each stream.

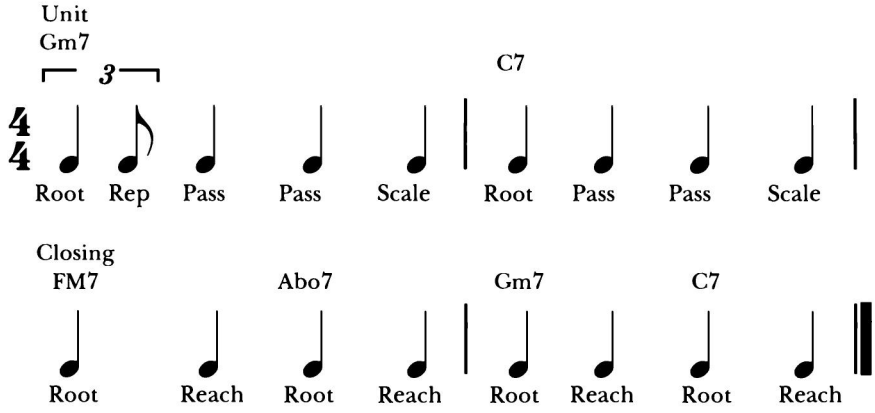

Figure 4. Sample Walking-Bass Rhythm.

Figure 4 illustrates one walking-bass rhythm, which might be obtained from the chordal rhythm in Figure 2.

Pitch

When the Cybernetic Composer creates a melody, it always describes the rhythm completely before it begins selecting any pitches. Selection of pitches is subject to several constraints: pitches must conform to instrumental capabilities; each note's pitch must be appropriate to the note's melodic function; chordal dissonances in the jazz and ragtime genres must be suitably resolved over the long term. Within these constraints, the program also biases pitch-selection with statistical feedback (Ames, 1990) so that melodies do not linger unintentionally upon particular scale

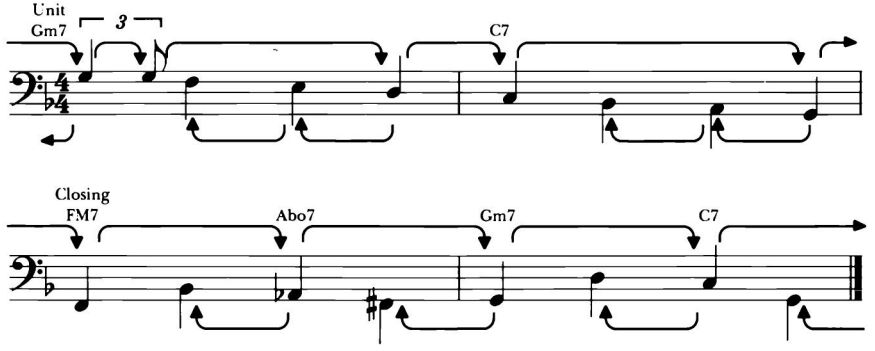

Figure 5. Order of Pitch Selection for Walking Bass Line.

degrees. Often these different objectives come into conflict with one another, so it becomes necessary to consider alternative solutions. This is where AI search (backtracking) comes into play.

Figure 5 illustrates one sequence of pitches, which might have been selected for the rhythm shown in Figure 4. Arrows show the order of selection. The search selects pitches for primary notes (cadence tones, chordal tones, and scale tones) in the order in which these notes appear. When it comes to an ornamental note, the program skips forward in time to the next primary note, then works its way backward in time through the ornamental notes until all the ornamental pitches have been chosen. Sometimes the Cybernetic Composer finds itself at an impasse where no available pitch satisfies all the constraints; in such cases, the program backs up to an earlier-composed note, changes this earlier-composed note's pitch, and tries again.

Thematic Scheme

The thematic scheme of a model describes which sections of a composition employ original material and which sections imitate material from earlier sections. As with chordal schemes, thematic schemes can branch into alternative streams; such branching may or may not be coordinated with choices made in the chordal domain.

For originally-composed sections, the thematic scheme gives the Cybernetic Composer a style (where relevant), a point of pitch liaison, and a point of rhythmic liaison. A point of pitch liaison is only rarely needed. It allows the program to match the opening pitch of an original passage to an earlier pitch. This is useful in thematic schemes such as A B C B A; in this instance, specifying the opening of A as the point of pitch liaison for B directs the program to create an ending for B that will be compatible both with the opening of C and the opening of A. The point of rhythmic liaison enables the program to adapt the close of a newly-composed section so that the rhythm meshes properly into the section's successor (cf. Figures 6a-6b). If an originally-composed section is intended to be used as a repeated motive

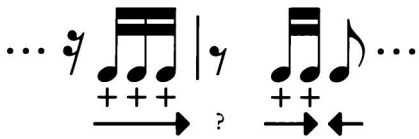

Figure 6a. False Rhythmic Mesh— Pickup Left Dangling.

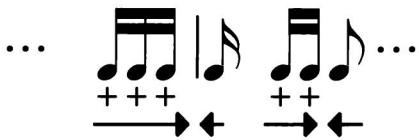

Figure 6b. True Rhythmic Mesh— Pickup Resolved.

Measure	*Chord*	*Section*	*Operation*
1	C7	**A** (meas. 1)	Original; Verse style; Rhythmic liaison with **A**
2	F7	**B** (meas. 2)	Solo: Imitate **A** untransposed (diatonic) Bgnd: Imitate **A** untransposed (diatonic) Bass: Imitate **A** up a perfect fourth (real)
3	C7	**C** (meas. 3-4)	Imitate **A** untransposed (real)
4	C7		Imitate **A** untransposed (real)
5	F7		Imitate **B** untransposed (real)
6	F7		Imitate **B** untransposed (real)
7	C7		Imitate **C** untransposed (real)
8	C7		

Figure 7a. Thematic Scheme 1 for 16-Bar Blues Verse.

Measure	*Chord*	*Section*	*Operation*
1	C7	**A** (meas. 1-2)	Original; Verse style; Rhythmic liaison with **A**
2	F7		
3	C7	**B** (meas. 3-4)	Imitate **A** untransposed (real)
4	C7		
5	F7		50% Imitate **A** untransposed (diatonoic)
6	F7		50% Imitate **A** up a perfect fourth (diatonoic)
7	C7		Imitate **B** untransposed (real)
8	C7		

Figure 7b. Thematic Scheme 2 for 16-Bar Blues Verse.

Measure	*Chord*	*Section*	*Operation*
9	G7	**A** (meas. 9-10)	Original; Bridge style; Rhythmic liaison with **A**
10	F7		
11	G7		Imitate **A** untransposed (real)
12	F7		
13	G7		Imitate **A** untransposed (real)

Figure 7c. Thematic Scheme for 16-Bar Blues Bridge.

Measure	*Chord*	*Section*	*Operation*
15	G7	**A** (meas. 15, beats 1 & 2)	Original; Tag style; Rhythmic liaison with **A**
16 (1 & 2)	C7		Imitate **A** untransposed (real)
16 (3 & 4)	G7		Imitate **A** untransposed (real)
12	F7		Original; Tag style; Rhythmic liaison with verse

Figure 7d. Thematic Scheme for 16-Bar Blues Tag.

or as a riff, then the point of rhythmic liaison will be the section's own starting time. For imitative sections, the thematic scheme gives the Cybernetic Composer starting and ending times for a source section, a transposition, and a *strictness.* The strictest imitations are *real* imitations; these attempt to match pitches exactly. Next come *modal* imitations, which attempt to retain the same scale steps while allowing flexibility with accidentals. *Chromatic* and *diatonic* imitations permit deviations of one and two semitones from the original pitches, respectively. The least strict of Cybernetic Composer imitations retains the original rhythm and melodic functions but makes no attempt to match pitches. In some imitations the transposition and/or strictness will vary from layer to layer.

Figures 7a-7d detail the rock genre's thematic/chordal scheme for 16-bar blues. Figures 7a and 7b give alternative streams for the verse (measures 1-8); one or the other is chosen at random with equal probability of selection. The rock styles are detailed under the specific description of the rock genre; here it is sufficient to know that the Cybernetic Composer chooses from a variety of styles for each of three basic phrase types: verse, bridge, and tag.

Figure 8 illustrates how the program keeps track of thematic relationships. The arrows depict thematic links set up when the imitative rhythms were created (by copying notes from the source). The first three notes of measure 2 are a *modal* imi-

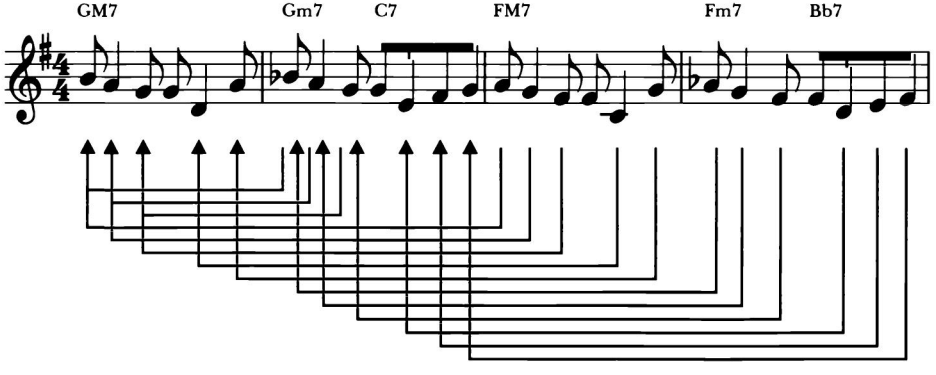

Figure 8. Sample Imitative Linking Structure.

tation of the first three notes of measure 1, while measures 3-4 are a *real* imitation of measures 1-2 transposed down a major second.

For an imitative passage, it is important to specify that the first few notes be *required* to match pitches with their counterparts in the source melody. This requirement prevents stylistic tendencies established immediately prior to an imitative passage (e.g., in Figure 8, measure 1, beats 3 & 4, just prior to measure 2's modal imitation of measure 1's opening notes) from overriding the imitative mandate. Whenever the opening pitches of an imitation fail to conform to these transitional tendencies, the program backtracks and changes transitional pitches until it discovers a suitable transition. Once the imitative character of a passage has been established, the program relaxes its matching requirement so that later imitative pitches can themselves be adjusted to transitional needs. The closest matches are attempted first, but if these do not work then the program seeks outward around the matching pitch until a stylistically appropriate pitch is found.

Such inflexibility at the opening of an imitation might lead to potential impasses without precautions. Consider what would happen if the imitation were at a transposition that shifted a source pitch outside the instrumental range: the Cybernetic Composer would have to backtrack all the way back to the source note before the impasse could be resolved. To prevent such impasses, the program checks all future incarnations of a note whenever it considers a source pitch. Thus when it selected the B at the opening of Figure 8, the program also checked that Bb would be suitable at the opening of measure 2, that A would be suitable at the opening of measure 3, and that Ab (derived from the opening B indirectly through the Bb in measure 2) would be suitable at the opening of measure 4.

The Genres

At this point the reader should understand generally how the Cybernetic Composer creates music. The remainder of this article details how the program emulates specific musical genres. In selecting which among the great variety of jazz, rock and ragtime practices should be incorporated into the program, we were guided primarily by our own background, tastes, and sense of what would be practical. Having played jazz and rock at one point, we had more than an academic awareness of how such pieces were made. All music composed by the Cybernetic Composer favors syncopated rhythms, in part because we enjoy syncopation and in part because we felt that livelier rhythms might provide some defense against the inevitable charge that computer-composed music must intrinsically be sterile. Our sense of the practical led us to avoid involvement with the many rock styles that depend upon nuances of pitch inflection (cf. Roth, 1984) and to avoid as well the nuances of rubato that are critical to slow music in any genre.

The Cybernetic Composer's "standard" jazz genre produces improvisations over chord changes—thematicism is employed only in the Latin jazz, rock and ragtime

genres. The first chorus of each Latin jazz and rock piece is a fully composed tune; later choruses consist of improvisations following the tune's chordal scheme. Ragtime pieces are fully composed throughout.

"Standard" Jazz

The Cybernetic Composer's "standard" jazz improvisations reflect stylistic traits common to small jazz ensembles, which released recordings on the Blue Note label during the late 1950s and early 1960s. Among these traits are the "swing feel" and the dependence upon chordal designs derived from "standards" such as 12-bar blues, *I Got Rhythm*, or *How High the Moon*. The models are twelve–bar blues, AABA, ABAB, and ABCA. A general source of information on jazz idioms is Mehegan (1959-1965). The modal approach widely advocated by jazz theorists (and implemented in a composing program by Fry, 1980) does not give good results; Ames opted instead for a chordal framework with diatonic and chromatic ornaments.

The Solo Layer. To compose a rhythm for the solo layer, the program applies two levels of refinement to a chordal rhythm such as the one illustrated in Figure 2. All notes generated by these refinements retain links to the chordal rhythm, so that the program can access this information rapidly when the time comes to assign pitches. The first level of refinement divides long chordal durations into successions of quarter notes, quarter rests, half notes, and half rests. The method of selection is weighted randomness, subject to the constraints that two rests may not occur consecutively and that cadential chords must always begin with notes. The placement of rests roughly determines the melodic phrasing, which is "fleshed out" by divisions at the second level of refinement:

Quarter notes (column 1 of Figure 9; appoggiaturas not shown) — the program selects a mode of division by weighted randomness:

a) no division (1 unit);

b) swing-eighth division (2 units);

c) eighth-note triplet division (3 units);

d) straight sixteenth-note division (4 units).

In modes (b) through (d), the program decides randomly whether the first unit in the division will function as an appoggiatura. If so, then the second unit becomes the primary chord tone; otherwise, the first unit of the division becomes the primary chord tone. Subsequent units (if any) are assigned any of three functions: secondary chord tone, passing tone, or reaching tone.

Quarter-note rests (column 2 of Figure 9)—the program selects one of divisions (a) through (d) above. In modes (b) through (d), the first unit of the division always becomes a rest; subsequent units become pickups to the next melodic phrase: scale tones, passing tones, or reaching tones.

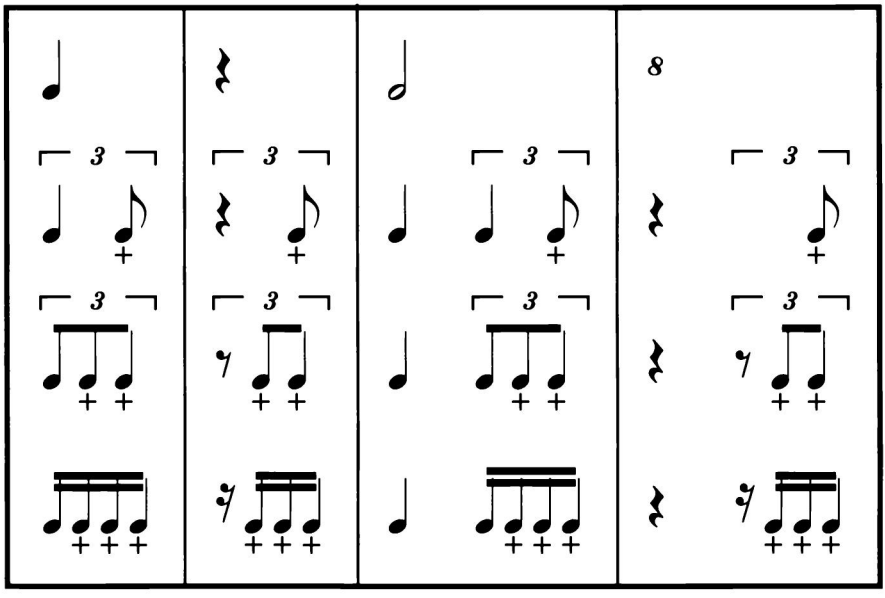

Figure 9. Standard Jazz Solo Embellishments for Quarter Note, Quarter Rest, Half Note, and Half Rest (without appoggiaturas). Each column represents an unrefined duration; each row represents a mode of division. Crosses show secondary chord tones, scale tones and/or ornamental melodic functions.

Half notes (column 3 of Figure 9; appoggiaturas not shown)—the program divides each half note into two tied quarter notes. For the first quarter note, it decides randomly whether to apply a swing-eighth appoggiatura. For the second quarter notes, the program selects one of divisions (a) through (d) listed above. The first unit of this retains the tie from the previous quarter; subsequent units become secondary chord tones, passing tones, or reaching tones.

Half-note rests—(column 4 of Figure 9) the program divides each half rest into two quarter rests. It leaves the first of these quarter rests alone. For the second quarter rest, the program selects one of divisions (a) through (d) above. The first unit of the division also becomes a rest; subsequent units become scale tones, passing tones, or reaching tones.

Pitches are chosen using a search similar to that described earlier for the walking bass line. Most constraints affecting standard jazz solo pitches can be inferred from the rhythmic functions, so the program delegates such constraints to a genre-independent pitch-testing routine. Augmenting these functional constraints are a test forbidding large compound leaps and a test requiring resolution of unstable consonances (e.g., chord thirds) and chordal dissonances (e.g., chord sevenths) within three primary notes. For consecutive primary notes, this test accepts as a resolution any chord tone lying within a major third of the unstable pitch; resolutions deferred for two or more primary notes must be stepwise. An exception is made if

the unstable pitch (or an octave equivalent) reappears within the three-primary-note frame, in which case the instability transfers to the later note.

Ornaments are generated by a "standard ornament generator," which is also employed by the Latin jazz and ragtime genres. This ornament generator first determines a scale by consulting the goal pitch's link to the chordal rhythm. It next compiles a list of ornaments using the following one-note and two-note formulas:

For one-note ornaments, the standard ornament generator considers four candidates:

1) upper diatonic neighbor;
2) lower diatonic neighbor;
3) upper chromatic neighbor, but only if this pitch creates a descending chromatic line from the source pitch (taken from the primary note immediately preceding the ornament) to the goal pitch;
4) lower chromatic neighbor, but only if this pitch creates an ascending chromatic line from source to goal.

For two-note ornaments, the standard ornament generator considers six candidates:

1) the next-upper diatonic neighbor (the pitch two diatonic steps above the goal pitch) followed by the upper diatonic neighbor;
2) the upper diatonic neighbor followed by the upper chromatic neighbor, but only if the upper diatonic neighbor lies a whole step above the goal pitch; if this candidate is not applicable, then the following alternative is considered: the next-upper chromatic neighbor (the pitch two chromatic steps above the goal pitch) followed by the upper chromatic neighbor, but only if these pitches produce a descending chromatic line from source to goal;
3) the next-lower diatonic neighbor followed by the lower diatonic neighbor;
4) the lower diatonic neighbor followed by the lower chromatic neighbor, but only if the lower diatonic neighbor lies a whole step below the goal pitch; if this candidate is not applicable, then the following alternative is considered: the next-lower chromatic neighbor followed by the lower chromatic neighbor, but only if these pitches produce an ascending chromatic line from source to goal;
5) the upper diatonic neighbor followed by the lower diatonic neighbor;
6) lower diatonic neighbor followed by the upper diatonic neighbor.

Once the list of ornaments is derived, the program shuffles the list into random order (in genres employing imitation, the program sorts ornaments so that the closest imitative matches come first). The first ornament that conforms to the ornamental melodic functions (which may specify upper or lower neighbor, or which may forbid nonscale pitches) is the one used; if no ornament is suitable, then the ornament generator communicates its failure to the pitch-selection search, which discards the goal pitch and tries another candidate.

The Rhythm Section. The rhythm section in a "standard" jazz ensemble lays out the points of reference—meter, phrasing, and harmony—from which the solo part takes its meaning. These points of reference are established through a partnership between the walking bass, background chords, and drums:

Walking Bass —The walking bass spells out chord roots and states the rhythmic pulse. It is composed using the procedures described in the first part of this article.

Background Chords —Background chords are usually limited to "punching" the chord changes. Punches tend to be balanced between on-the-beat punches and punches displaced by a swing-eighth note before or after the beat. The refinements used to generate jazz background rhythms differ significantly from the ones described so far: these refinements do not simply divide long notes into shorter notes and rests—they can also annex time from a preceding duration to create an anticipation.

Standard jazz background pitches are chosen in the following way: First, the program composes the topmost background part using the same procedures it uses to compose the solo part, but with the sparse, "punching" rhythms described above. This line is then thickened out in open-position block chords, using a table of chords with an entry for each chord type (e.g., tonic major, subdominant major, submediant minor, etc.) and for each chromatic pitch.

Drums —A jazz drummer combines the time-keeping role of the walking bass with the punches of the background chords; he also articulates the form by playing "turns' at the ends of phrases. Time-keeping is generally kept by playing beats 2 and 4 with the high-hat pedal and by playing common bebop ride-cymbal patterns. Snare and bass drums provide punches around beats 1 and 3 (cf. "Background Chords"). At phrase-endings, the time-keeping role is transferred from the ride cymbal to the bass drum; turns are played on the snare drums and tom-toms. Short (half-measure) turns announce 4-bar boundaries; long (full-measure) turns warn of impending new phrases and choruses.

Latin Jazz

Latin jazz is a hybrid of American Bebop and the Bossa Nova style popular in Brazil during the 1960s; its major champion was saxophonist Stan Getz. Some characteristics of the Latin jazz genre are a syncopated "straight eighth" feel, extended phrases, and chromatic chord-root movement. The models implemented by the Cybernetic Composer are: A only, AABA, and ABAC.

The Solo Layer. The name of the game for Latin jazz solos is understatement. Latin jazz solos often proceed in sustained notes or in syncopated eighths and quarters. The greatest rhythmic activity usually happens in the pickups just before phrase boundaries; here one might encounter a run of several consecutive eighths, or even a bracketed tuplet. As likely as not, strong beats of the measure will be anticipated by an eighth note.

When it generates a Latin jazz solo, the Cybernetic Composer begins as always with the chordal rhythm. Long durations are usually divided up into whole and half notes; if a long note initiates a phrase, then the program sometimes contents itself with applying a pickup rhythm to the end of the note. Whole notes can also sustain with simply a pickup at the end; alternatively one of the appoggiaturas illustrated in Figure 10 can be applied—and possibly a pickup as well. Half notes can be left alone or refined by any of the refinements enumerated in Figure 11; these same refinements also generate pickup rhythms for longer notes. The pitch-selection procedures are identical with those used to compose the standard jazz solo part. Once a refinement has been applied, the program decides (with 50% weight of success, guided by statistical feedback) whether to apply an eighth-note anticipation to the note on the strong beat.

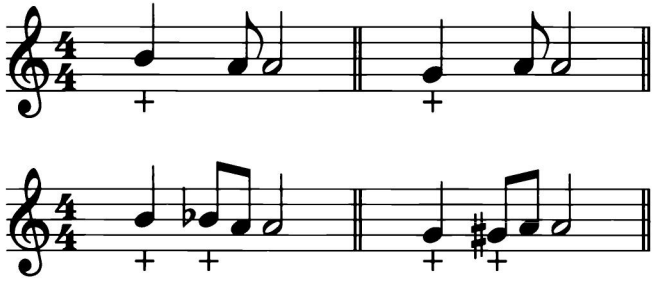

Figure 10. Some Characteristic Latin-Jazz Solo Appoggiaturas Applied to a Whole-Note A. Crosses show dissonances.

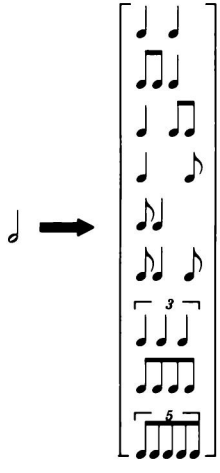

Figure 11. Local Rhythmic Refinements for Latin Jazz Solo Parts. The quintuplet may be used only as a pickup rhythm at phrase-endings.

The Rhythm Section. The Latin jazz soloist gets away with understatement because the Latin rhythm section is much more active than the standard jazz rhythm section. Two things that prevent this activity from intruding into the foreground are (1) the fact that the bass line and background chords have generally simple pitch usage and (2) the fact that although the drum riffs are complex in and of themselves, they quickly settle in with repetition.

Bass Line—The bass is strongly functional and limited almost exclusively to chord roots and fifths, with some reaching tones at chord changes. Downbeats and upbeats are obligatory only at chord changes; otherwise, the bass favors offbeat attacks.

Background Chords—Backgrounds avoid rhythmic intrusiveness by holding onto the same chord for several strokes at time. The pitch-selection procedures are identical with those used to compose the standard jazz background layer.

Drums—The drums play the quarter-note beat on the bass drum and accent the upbeats with the high-hat and left hand (snare and toms). The right hand plays on the ride cymbal or cowbell using syncopated eighth-note patterns. The Cybernetic Composer builds up a Latin jazz drum accompaniment by creating two-measure patterns for each phrase type(vamp, A phrase, B phrase, etc.). These patterns repeat constantly through the duration of a phrase; turns are not used.

Rock

Some consistent features of rock music are 4/4 and related meters and a syncopated straight-eighth feel. Chordal qualities tend to be homogeneous (e.g., all dominant seventh chords or all minor seventh chords)—at least throughout the span of a phrase. Chords roots favor scale degrees I, IV, V, bVI, bIII, bVII, II, and bII (in the key of C these roman numerals translate into C, F, G, Ab, Eb, Bb, D, and Db). Kaye (1969), Feldstein (1978), and Roth (1984) all influenced our formulation of rock idioms.

Phrase Types and Styles. Choruses of the Cybernetic Composer's rock models are pieced together from three types of phrases: *verses*, *bridges*, and *tags*; how phrase types are assembled depends upon the model. The models are 16–bar blues; 8–bar verse with 4–bar bridge; repeated 4–bar verse with 8–bar bridge; and repeated 8–bar verse with repeated 4–bar bridge. Each verse, bridge, and tag can independently assume either a dominant-seventh quality or a minor-seventh quality. In addition, phrase types can independently assume any of four styles:

Eighth-note bass—background chords and drums punch beat 2 and/or eighth-note syncopations; bass mostly plays eighth notes;

Riff bass—background chords and drums as in eighth-note bass; bass plays riffs;

Fast funk—solo, background chords, bass, and drums all play highly active, sixteenth-note syncopations;

Double-time (bridges only)—sustained background chords; bass and drums in sixteenth-notes.

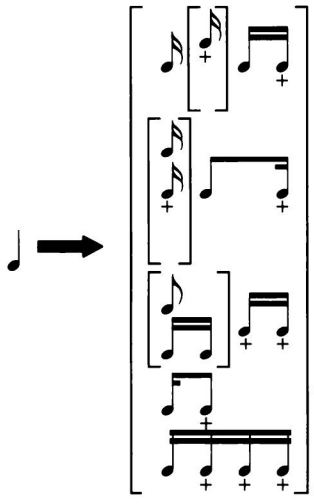

Figure 12. Some 'Regular' Refinements for the Quarter Note in the Rock Solo Layer. Rectangular brackets delimit alternative rhythmic streams; crosses show ornamental melodic functions.

Instrumental Roles. Rock does not share with jazz and ragtime such rigid distinction between solo part and rhythm section. Although the solo part usually remains among the most active of layers, the background chords, bass line, and drums frequently contribute to the musical fabric on equal terms.

Solo—the rock genre employs two types of rhythm for the solo layer: "regular" and fast funk. Regular rhythms are used with the eighth-note bass, riff bass, and double-time styles; fast funk rhythms are used with the fast funk style. To generate regular rhythms, the program begins by dividing the chordal rhythm into quarter notes; each quarter note is then further elaborated by one of many rhythmic refinements. Five of these refinements are shown in Figure 12. Fast funk rhythms are based on the half note instead of the quarter; three fast-funk refinements are shown in Figure 13. The rock solo pitch-selection procedures are similar to those used to compose the standard jazz solo part, with two important qualifications:

1) Rock constraints are looser. Where chord thirds and sevenths are treated as unstable or dissonant in jazz and ragtime, in rock all chord tones are stable.
2) Instead of the standard ornament generator, the rock genre employs a specialized ornament generator, which lists specific, idiosyncratic ornaments (one to three notes) for each member of the basic dominant 7th and minor 7th sonorities. The rock genre also may substitute the fourth scale degree for a chord tone, provided that such notes are embellished by the flattened fifth—a classic rock blue note—and provided as well that such notes resolve downward by step.

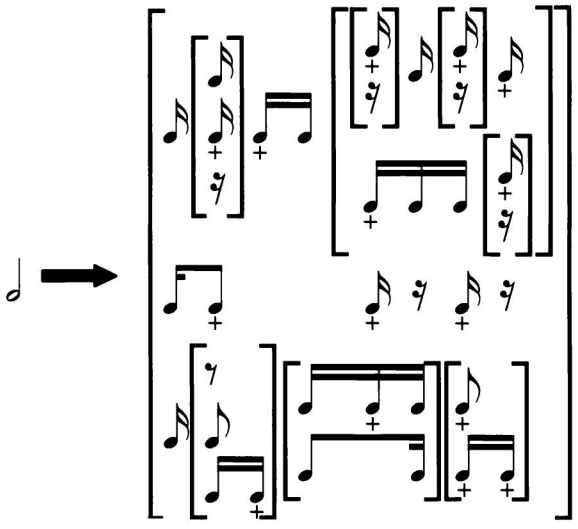

Figure 13. Some Fast Funk Refinements for Half Notes in the Solo Layer.

Bass—The eighth-note bass style is strongly functional, both rhythmically and chordally; the bass plays roots and reaching notes in eighths, dotted eighths, and sixteenths. The riff bass style alternates between strong metric stresses (especially of beats 1 and 2) and sixteenth-note anticipations. Fast funk bass lines feature staccato syncopations and emphatic offbeats. Double time bass parts employ a hard-driving, sixteenth-note ictus, but compensate for their heightened rhythmic drive by sticking mostly to chord roots. The pitch-selection procedures are very close to those used to compose the rock solo part.

Background—Against both the eighth-note bass and the riff bass, the background employs a common style alternating between upbeat stresses and eighth-note syncopations. Fast funk backgrounds emulate the organ playing on Tower of Power's *Urban Renewal* album. Against the double-time bass, the background rhythm consists mostly of sustained whole, half, and quarter notes, sometimes modified by sixteenth-note anticipations.

As with the jazz genres, rock background pitches are selected by first generating the topmost background part, and then thickening out this topmost part in blocked chords. However, nonchord rock ornaments are harmonized by parallel motion: the program skips forward to the next chordal tone, blocks out a chord there, and then works its way back using same chord in transposition for each ornament. The pitch-selection procedures for the topmost closely resemble the procedures used to compose the rock solo part.

Drums—For sample rock drum patterns, readers should refer to Feldstein (1979). Both the eighth-note bass and riff-bass styles employ variations of the less active riffs listed by Feldstein under "Hard Rock" and "Jazz-Rock." The fast funk styles employ

variations of Feldstein's "Funky Rock" riffs, and the double-time style employs variations of Feldstein's more active "Jazz-Rock" riffs. The program builds up a rock drum accompaniment by creating one- or two-measure riffs and by repeating these riffs constantly, with turns prior to important phrase boundaries.

Ragtime

Ragtime is an early 20th century style epitomized by the piano compositions of Scott Joplin. Ragtime forms lend themselves to algorithmic generation. A chorus is invariably constructed of two phrases of eight 2/4 bars, each phrase is constructed in turn from two four-bar units. An individual unit may be through-composed, but more likely it will be built up of repeated half-measure, full-measure, or two-measure figures. Either the second or third unit can imitate the first unit; the fourth imitates either the second unit or the third. The form as a whole almost invariably follows the scheme AA BB A CC DD (The program also uses the abbreviated scheme ABACD), where the B phrase *sometimes* shifts into the dominant key, the C phrase *always* shifts into the subdominant key, and the D phrase either returns to the tonic or remains in the subdominant. Each Cybernetic Composer rag plays a monophonic solo part over an oom-pah accompaniment. Drums are not used.

Solo. Ragtime solo rhythm emphasizes eighths and sixteenths, with frequent sixteenth-note syncopations and anticipations. Figure 14 illustrates some half-note rhythmic patterns. Solo pitches for the ragtime layer are chosen using the exact constraints and ornament generator employed for the standard and Latin jazz genres.

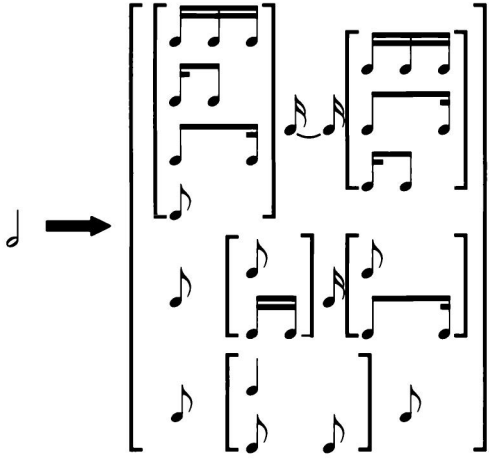

Figure 14. Some Solo Refinements to the Half Note in the Ragtime Genre.

Accompaniment. The ragtime accompaniment deviates strongly from the norm of Cybernetic Composer procedures in that the bass line and background chords are directly coordinated with one another. When it refines a primary note from the chordal rhythm, the ragtime-accompaniment procedure determines at the same moment how the bass and chords will complement one another.

Ragtime chordal progressions describe not only keys, roots, and qualities, but also the discretion available to the program in selecting chord tones for the bass. A common feature of Joplin's oom-pah bass lines is that even with nominal root-position chords, the root does not necessarily sound on the downbeat. Ragtime harmonies are also frequently characterized by passing inversions and by the classical device of a second-inversion tonic chord just before a cadence. All this is considered by the program as it composes its ragtime bass lines.

Once the bass pitches have been chosen, the program directs its attention to the background chords. Instead of filling in block chords under a background lead, ragtime backgrounds have true voice-leading with resolution of dissonances and leading tones, avoidance of parallel perfect consonances, and sensitivity to which chord tones are mandatory (e.g., thirds and sevenths) or optional (e.g., chord fifths). The process of background pitch-selection is aware of what the bass is playing, so the program can act to avoid parallel fifths or octaves with the bass. If the third appears in the bass, the background chords will exclude the third and include the root, and so on.

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Notes

1. The incorporation of melodic functions into rhythmic descriptions was an important feature of Hiller and Ames's Mix and Match program. However, the Cybernetic Composer employs completely different techniques for rhythmic generation and thematic imitation.

2. This is only the latest of many applications of Chomsky's generative grammars to composing programs; see for example Holtzman, 1980 and Ames, 1987b. In Chomskian jargon, our "chordal rhythm" serves as the "axiom," while our "refinements" serve as "productions."

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