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Computação Cita: Cetta, P. C., Di Liscia, O. Pitch-class composition in the pd environment [en línea]. Ponencia presentada en Proceedings of the 12th Brazilian Symposium on Computer Music. São Paulo: USP: SBC, 2009. Disponible en: Resumen: Abstract: This paper presents research on composition-assisted software using the Pitch-Class Sets
technique [Babbitt, 1961] [Forte, 1974]. In order to use the mentioned techique on music composition and analysis, a Library of External Objects for the program Pure Data [Puckette, 2009] was developed. The Pitch-Classes of the tempered system in Sets in
order to exploit their structural properties on atonal music composition and analysis. A latter projection of this system explores the possibilities of disposition of the Pitch-Class Sets in the musical space producing Combinatorial Matrices [Morris, 1984, 1987]. URI: ISSN: 2175-6759 Disciplina: MUSICA Derechos: Access abierto Aparece en las
colecciones: Ponencias Mostrar el registro Dublin Core completo del ítem Over years of teaching pitch-class-set theory and analysis as part of undergraduate twentieth-century theory courses, I have often reflected (and heard perceptive students usually have
come out of several semesters of tonal theory in which, especially in curricula based on Schenkerian principles, they have been taught the elements that provide large-scale coherence to tonal compositions. At the end of the theory sequence, however, students are suddenly presented with a system (pitch-class sets) which accounts for "surface" pitch
relationships in atonal music, but which does not provide a satisfactory way to connect the resulting pitch-class collections among themselves. Various available techniques for the comparison of sets (similarity relations) are based on abstract set relationships, rather than on relationships immediately observable on the actual music. I I intend to
present in this article a technique of long-range pitch connection which I have called "pitch-class-set extension" (PCSE), and that may be found, as I will illustrate, in post-tonal works by such present-day composers as
 Babbitt, Ligeti, or Crumb. Although a presentation of this sort will necessarily have to include technical explanations and formal definitions, I have strived to do so in a language and by means of a methodology which can be easily adapted for pedagogical purposes. This article may also help to dispel the idea, sometimes held by musicians who may not
have examined this repertoire in any depth, that atonal music is made up of series of disconnected or disconne
general principles and questions underlying any study of long-range pitch coherence. 2 1. Prolongation or Association? Does the concept of prolongation apply to post-tonal music? Because any post-tonal music? Because
has been shown to exist in some particular repertoires, if only locally and at the foreground or middleground levels (see, for instance, Morrison 1991 and Wilson 1992). Attempts at formulating a theory of post-tonal prolongation, however, have not produced satisfactory results. (Some interesting studies dealing with this issue are Baker 1983, 1990,
and 1993, Lester 1970, Morgan 1976, Pearsall 1991, Salzer 1962, Straus 1987, Travis 1959 and 1966, and Väisälä 1999). Because I will be presenting a technique of long-range pitch coherence, and the question whether this technique is "prolongational" will necessarily arise, let us first define prolongation. As understood in Schenkerian theory,
prolongation is the unfolding in time of the tonic triad. This element unfolding in time (a) is not actually present at every moment after its first appearance (although its influence remains in effect), and (b) constitutes an underlying structural framework which provides a direction towards a goal (see Salzer 1962, Schenker 1979, and Forte/Gilbert
 1982). In general, the definition in post-tonal music of a single element to be prolonged in time has eluded analysts. Moreover, the prolongational procedures from tonal music do not apply to post-tonal music (see Straus 1987), and as a result no sense of direction towards a predetermined goal can be clearly established. Even in cases in which the
term "prolongation" has been used, what is often meant is "association." In his 1989 article, for instance, Lerdahl recognizes that while tonal space would look more like a free-for-all 'associational' space that plots similarity relations among
motives" (p. 85). Lerdahl also points out that "listeners to atonal music . . . grab on to what they can: relative salience becomes structurally important, and within that framework the best linear connections are made" (p. 84). In Lerdahl's theory, tonal stability conditions are replaced by a set of "salience conditions." 3 Lerdahl's theory, in spite of his
article's title, is more associational than prolongational. Association as "the grouping together of notes according to similarities in register,
metrical placement, duration, dynamics, instrumentation, and so forth," and points out that "these groupings may contain notes widely separated in time" (1987, 21, note 13). Associational models, however, do not attempt to relate these separated in time" (1987, 21, note 13).
events X, Y, and Z, an associational model is content merely to assert some kind of connection between X and Z without commenting one way or another about Y" (1987, 13).5 Boss addresses the complex issue of trying to establish hierarchical distinctions between structural and ornamental pitches in atonal music by proposing nine contextual (that is,
associational) factors which affect the likelihood that a pitch or a sonority will be structural. Although Boss's contextual criteria (having to do with beginning a phrase, length, repetition, loudness, accent, register, timbre, density, and parallelism with another event) are insufficient to determine the structural role of a pitch, he also proposes two
 additional criteria to distinguish structural from ornamental pitches in Schoenberg's atonal music: structural pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried or varied form of some motive in the piece, and ornamental pitches must represent an unvaried form of some motive in the piece of the p
these criteria points at the strongly motivic nature of Schoenberg's music, and at the fact that, as Boss writes, "structural levels are generated in Schoenberg's music through ornamentation [of motives] instead of prolongation" (p. 210). Motives are indeed an essential constructive element not only in Schoenberg's music, but also in much of the post-
tonal repertoire. 7 Allen Forte has shown that the concept of "motive" in twentieth-century music does not necessarily imply registral ordering. Forte has developed the idea of a "motivic set," an unordered pitch-class set which functions as a motive in pitch-class space (Forte 1985, 475 and 478), and has argued not only that motivic sets can prolong a
pitch class, but also that harmonic and linear projections of the same set can generate extended prolongational structures (Forte 1988a and 1992; see also 1973). The concept of motivic set is the point of departure for the purpose of this
 essay is to identify possible pitch cells which have the function and capability to generate extended coherent structures in post-tonal music, and to define the means by which this extension is effected. Existing studies have shown that in the post-tonal repertoire there is not a single type of pitch unit (such as the triad in tonal music) which we could
generally define as being extended. If a pitch collection is extended in this repertoire, it would not be a predetermined collection or set of collection or set of collection or set of collection or set of motivic transformation of pitch
cells abstracted from atonal compositions. In Example 1a, taken from Schoenberg's "Nacht" (Pierrot Lunaire, no.8), transposition of a motive preserves its contour and its ordered interval succession, . While each three-note cell is of the same set-class, [014], we easily perceive the immediate relationship among the three-cells as ordered sets. In
Example 1b (from Webern's Concerto, op. 24, I) the initial cell is not only transposed, but moreover manipulated by means of serial operations. The motive is still preserved (but not its contour), and so is its interval content (but not the order or direction of intervals). The relationship among the four cells in Example 1c, from the same work, is the
same as in 1b, although octave complementation has been allowed here. The motive is still preserved, but intervals in contave equivalence) is added to the possible reordering of intervals, providing a further element of variation (interval-class succession is preserved here, rather than interval succession). All six trichords in
Example 1d (from Crumb's "Primeval Sounds," Makrokosmos, vol. 1, no. 1) also belong to the same set class, [037]. The relative order of pitches, however, varies in each of the three pairs of adjacent trichords, and so does, hence, the intervallic configuration (, , and respectively). In other words, these cells are presented as unordered sets. Example
1a. Schoenberg, Pierrot lunaire, op. 21, no. 8, "Nacht" Example 1b. Webern, Concerto, op. 24, I _|| Example 1c. Webern, Concerto, op. 24, I Example 1c. Webern, Five Movements for String Quartet, op. 5, no. 3 Example 1e (Ligeti, Ramifications)
 illustrates a progression of sonorities related by chromatic expansion, in which the initial [4] grows into [] by a linear process involving contrary half-step expansion in one of the voices. Chromatic expansion of a different type is also the
connective bond in the passage from Webern's Five Movements for String Quartet, op. 5, no. 3 reduced in Example 1f, which presents a more abstract relationship among adjacent and overlapping trichordal cells. The unordered trichords are all of one of the following classes, listed in their order of appearance: [014], [013], [026]. Each of these
trichords may be derived from another trichord in the collection by chromatic expansion or contraction of one or two pitch classes." To be exact, a set class extends another one chromatically if the corresponding members of their respective adjacency interval series
do not differ by more than 1. Thus, [015] extends [014], and so does [013]. What do all of these fragments have in common? In all cases, a pitch cell is extended in time. The means used for this extension are repetition, set-equivalence operations (T or TI), serial operations (T, I, R, or RI), or chromatic expansion or contraction (whether it be applied
linearly or to unordered sets). We will then define three basic principles of extension of a pitch collection: repetition and transformation, and voice-leading. Each of these can take place in pitch space or in pitch-class space. Table 1 clarifies the possibilities for repetition and transformation.8 TABLE 1 1. Repetition In p-space: linearly or to unordered sets).
repetition repetition of a set class (Ex. 1a) 2. Transformation In p-space: motivic transformation by T, I, R, or RI (Ex. 1b)chromatic transformation by T, I, R, or RI with octave complementation—IC succession is preserved (Ex. 1c) pitch reordering (Ex. 1d) linear
transformation of set classes (Ex. 1f) Voice leading as a technique of extension requires some attention. In the diatonic step. It has
often been pointed out that, in the context of the total-chromatic pitch collection, the semitone is the quintessential voice-leading motion. Accounting for an associational "background" in Donald Martino's Pianississimo in which the only voice leading is by semitone, William Rothstein notes that "semitonal motion provides the only possibility for linear
displacement within the total chromatic pitch collection" (Rothstein 1980, 141). In his important study of atonal voice leading, John Roeder follows Schoenberg's own intuition regarding common-tone and semitone relationships in atonal harmonic connections. In Harmonielehre Schoenberg remarks that what he calls "vagrant chords," which have no
clear harmonic function, should be connected "by common tone or semitone in order to compensate for the lack of harmonic relations by 'compelling,' leading-tone-like motion between adjacent members of the chromatic scale" (Roeder 1989, 29. See Schoenberg's Harmonielehre, 134, 247, and 258-59). Jan Maegaard's study of voice leading in
Schoenberg demonstrates the composer's pervasive use of common-tone and semitone voice leading among members of successive vertical sonorities (Maegaard 1972), and Roeder studies the harmonic properties of registrally ordered and unordered sets in the context of semitone voice leading (see Roeder 1987 and 1989).9 Following the intuition
 that common-tone and semitone voice leading provides the strongest connection among non-tonal adjacent pitch collections, I will define them as holding PCSE properties. Moreover, because a whole tone is the nearest possible motion to a semitone, I will also accept it occasionally, and under very specific circumstances which will be defined below,
as having extension properties. In pitch class space, however, the proximity factor provided by the common tone and the half and whole steps loses its significance in favor of interval classes 0, 1, and 2. I will thus accept these three interval classes as holding pitch extension properties, and will abbreviate them henceforth as CT (common tone, or ICO)
represented on the graphs by solid slurs), CHR (chromatic, or IC1, represented on the graphs by dotted slurs or lines with the indication WT). These same principles also account for the pitch-extension properties of "linear intervallic expansion or contraction" and "linear
transformation of set classes" illustrated by Examples 1e and f above.10 The preceding discussion allows us to formulate the following definition: Definition 1. Pitch-class-set extension (PCSE). Pitch-class-set extension is the projection in time of a collection of pitches or pitch classes (an extension cell), ordered or unordered, dyads included, by means
of repetition, transposition, inversion, retrograde-inversion, retrograde-inversion, or by linear intervallic expansion or contraction. This definition suggests a number of questions. In the first place, are any transpositional levels better than others? Not necessarily as far as PCSE goes. However, for the same reasons formulated above with respect to voice
leading, extension cells will be more closely connected if they have some pc in common (CT, or IC0) or if some of their pcs are related by CHR (IC1). And here we should stress that this is not a voice leading connection if by voice leading we understand a motion between registrally-corresponding pitches or order-corresponding pitch classes. Because
 we are defining a pitch connection between cells in pc space, and pitch reordering is a characteristic possibility in this context, exact registral or order correspondences lose their significance. If any pitch or pc in a cell is related to any pitch or pc of another cell by CT or CHR, then the two cells will be said to be connected. Definition 2. Cell
Connectedness. Extension cells are connected if they have at least one pitch class in common (common-tone connection), or if at least two of their respective pitch classes are related by IC1 (chromatic connection).11
Consider, for instance, the fragments from Schoenberg's "Nacht" (Pierrot Lunaire, no. 8) represented in Example 2. The movement is an example of extension of set [014]—, in the frequent statements of the [014], head motive, and in
the long chains of [014] cells in the piano part, measures 19-23.12 Especially interesting, however, are the various passages in which the trichord appears in different compositional levels. Example 2a reproduces the pitch content of the piano part's left hand, measures 14-15. The upper staff (which includes the upper two lines in the
left-hand texture) features a chain of double [014] sets in which the exact interval succession as the original cell. Pitches are reordered,
resulting in two pairs of and sets. Example 2. Schoenberg, Pierrot lunaire, op. 21, no. 8, "Nacht" a. Mm. 11-13 Example 2b reproduces the complete content of the piano part, measures 11-13. The left hand is a further example of PCSE involving repetition and transposition. All the cells in the passage—also [014] sets presented
motivically as a interval succession—are connected by CT with a single case of CHR connection. It will also be noticed that the common tones themselves are connected in chromatic pairs, both in Ex. 2b (G-, E-) and in 2a (G
passages feature, moreover, several layers of extension. In Ex. 2a the three lines of the piano part's left hand present [014] cells moving at different rates: the two upper layers (upper staff in the example) moves in quarter notes. In 3b, a string of eighth-note [014] cells at the
foreground is connected by underlying [014] cells at the middleground, formed by the first note of each eighth-note trichord. At the same time, the right hand outlines melodic [014] cells in the upper and lower voices of a series of [016] chords. The passages from "Nacht" illustrate cases of PCSE and cell connectedness in which a single set is clearly
 dominant. A different type of PCSE is present in the opening of Webern's Five Movements for String Quartet, op. 5, no. 5 (Example 3a). Segmentation is facilitated in this passage by clear textural functions: an almost-ostinato independent bass line in the cello, an upper voice in the first violin which is related to the cello line by complementary rhythm
and an inner-voice accompaniment made up of harmonic tetrachords. The cello line begins with overlapping [014] and [015] trichords, followed by [03] dyads in mm. 3-4, and [0246] in mm. 5-9. The upper voice consists of two tetrachords, followed by [03] dyads in mm. 5-9 (which breaks up into [024] and [026]). The [0247] tetrachords
is accompanied in the inner voices by two vertical tetrachords, [0147] and [0137], each repeated twice. This inner voice accompanied by only two
vertical trichords, [0137] and [0237], while the resulting lines yield three [02] and one [03] dyads. Although we can perceive immediate abstract CHR voice-leading connections among many of these sets which may indicate PCSE, we have not yet established the criteria to compare sets of different cardinalities (that is, sets that include different
numbers of pitch classes) to determine their PCSE relationship. We need then to determine these criteria, and we will do so following some basic intuitions which involve voice leading once again, along with inclusion properties. Example 3d. Example 3d.
Example 3e. 3. Comparing Sets for PCSE: Similarity Criteria 1. If two sets are of the same cardinality and different classes. The principles of CT or CHR voice leading will determine the existence of PCSE. We need to differentiate, for this purpose, between two types of
voice leading: voice leading between actual pitch classes (C to or to B for CHR), or voice leading involving order-corresponding members of the set, as between Edasses (abstract CHR voice leading involving order-corresponding members of the set, as between Edasses (D25] and
[027]; both CHR and WT are present between [025] and [037]). PCSE between sets of the same cardinality and different classes results if: a. The corresponding members of their respective adjacency-interval series (AIS) do not differ by more than 1. Example: [015] extends [014] (AIS and ) (Example 4b). Or, b. The corresponding members of their
respective AIS differ by 2 in no more than one entry, and at least one actual pc in the first set is related to one pc in the second set, but not otherwise. We will refer to this type
of PCSE as WT expansion or contraction (Example 4c). We should note that this type of PCSE allows for all three of the pcs to be transformed by CHR, as between [014] and [015], connection results
if at least one actual pc in the first set is related by CT, CHR, or WT, the sets are maximally connected (Example 4e). d. If the set classes are related by WT expansion or contraction (such as [014] and [016]), connection results only if all the actual pcs in the
two sets are related by CT or CHR (Example 4f). Note: The PCSE and connection criteria outlined above allow for WT voice leading uses only CT or CHR. 3. Sets of different cardinalities. a. A set B of cardinality n+1 extends a set A of cardinality n if and only if A is a subset of
B. Example: [014] is extended by any of the tetrachords which contain it as a subset, that is, [0124], [0125], [0134], [0145], [0146], [0147], [0148], [0147], [0148], [0147], [0148], [0147], [0148], [0147], [0148], [0147], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148], [0148],
extends a set A(n) if and only if B is a subset of A (Example 4g, reverse arrows). d. Set B(n-1) which extends set A(n) will be connected to A if at least one pc of B by CT or CHR (Example 4g, reverse arrows). d. Set B(n-1) which extends set A(n) will be connected to A if at least one pc of B by CT or CHR (Example 4g, reverse arrows).
the first violin lines. Single lines (with double arrows, because PCSE by WT. A comparison of this chart with Example 3c will allow us to place it in the context of Webern's music. In this case, all musically adjacent or simultaneous sets display PCSE, with the only exception of [014]
with either [0247] or [0246]. The connection, in both cases, is made through [024], a subset of both tetrachords, and a musically significant trichord (it begins both [0247] and [026], as well as [024] and [026], in Example 3b. These two pairs of trichords do
appear in Example 3d. The first three charts compare sets from lines and sonorities in mm. 3-9, and finally all the harmonic trichords in mm. 3-9. Only two sets in all three charts do not display PCSE among all the
sonorities in mm. 3-9 resulting from combining the upper line with the accompanying tetrachords. This illustrates relationships among sets of different cardinalities. In almost all cases, adjacent sets are related by PCSE. [01368] is not extended by [01568], but the latter can be represented by its rotation (01378), which makes the relationship
apparent. The last three sets, [01237], [01568] = (01378), and [01348], do not extend each other. However, each of them is related by PCSE to the preceding superset, the pentachord [012378]. A sample of the actual voice leading among adjacent or simultaneous sets in this passage should suffice to illustrate the multiplicity of CT and CHR
relationships featured in the music. Example 3e shows the CT (solid lines) and CHR (dotted lines) are related by set-class PCSE by CHR. The condition for connection is, then, that at least one actual pc in a set be related by CT or
CHR to at least one pc in the next set. Example 3e shows, at a glance, the multiple connections between all pairs of adjacent sets in the fragment. In conclusion, PCSE and connection provide a very strong element of coherence and organic growth in Webern's passage, in such a way that every pitch, musical segment, and section in the fragment can
be referred back to the original [015]-[014] pair by means of a unified scheme of progressive musical unfolding. 4. PCSE and cell connectedness
unquestionably create consistent regions of influence generated by an initial pitch event. They do not necessarily, however, sustain a focus on the actual pitches which constitute the initial event. PCSE based on repetition certainly sustains pitches which constitute the initial event. They do not necessarily, however, sustain a focus on the actual pitches which constitute the initial event.
discussed in Webern's op. 5 no. 5 create very strong pitch or set-class associations which provide cohesion to a musical region. But in the absence of a consistent hierarchical pitch event. Neither do motivic transformations such as Tn, In, Rn, or RIn
sustain the original pitch cell which they transform, although, as in the case of linear association of sets, they do create a region in which the initial cell maintains a "unifying influence" by means of the following
two concepts: Definition 3. PCSE Region. A PCSE region is a musical area in which PCSE of a set or group of sets can be traced. Definition 4. PCSE string is a collection of PCSE-related sets which extends an initial set or group of sets to create a PCSE region. The opening of Webern's "Five Movements for String Quartet," op. 5, no. 3,
(mm. 1-8, reduced in Example 5), may be viewed as a PCSE region extending a collection of two set classes, [014] and [015].14 Each pair of adjacent cells throughout the passage (all of them trichordal) is connected by either CT, CHR, or both. The piece opens with a set of chordal statements of [014]. Cells 1 and 2 are connected by a common B and a
chromatic B-, 2 and 3 by three CHR motions (-A, G-, and B-C), 3 and 4 by a common C. M. 4 features two lines, in first violin and viola, which do not contain any [014] as a trichord of adjacent pitch-classes as they appear on the score ([014] is, however, a subset of hexachord [012468], resulting from considering either the violin or the viola pitches as
unordered sets). Rather, the totality of adjacent trichords—[013], [015], [026] in both violin and viola—presents an intervallic trichordal expansion from [013] to [026] by means of [014] chordssets. If above). The return of [014] chords expansion from [013] to [026] by means of [015] and the "missing" [014] chords expansion from [013] to [026] by means of [015] and the "missing" [014] chords expansion from [013] to [026] by means of [015] and the "missing" [014] chords expansion from [013] to [026] by means of [015] and the "missing" [014] chords expansion from [013] to [026] by means of [015] and the "missing" [014] chords expansion from [013] to [026] by means of [015] and the "missing" [014] chords expansion from [014] chords expansion from [015] and the "missing" [015] chords expansion from [015] and the "missing" [015] chords expansion from [015] chord
at m. 5 is related with the last [026] in the viola by two CHR connections, and by three more [014] chords at m. 5 are themselves related by a CT and three CHR connections, and by three more [014] chords at m. 6, in which chords 1 and 2 are
connected by a common and a chromatic E-, and chords 2 and 3 by a common G and three CHR relationships. It will also be noticed that the three lines which form these chords (violin 1, violin 2, and viola) are also made up of melodic [014] saturation precedes the two converging lines (violin 1 and cello) at m. 7, in
which [015] saturation is featured: each of the trichords formed by adjacent pitches in each of the lines is a [015] cell. The section closes with a return, at m. 8, of the [014] chords (related by a common C and three CHR connections), and a final, cadential statement of [015] in the cello. The unifying principle of this section (besides the pedal in the
cello) is thus the PCSE of two sets, [014] and [015], with multiple CT and CHR connections, and a brief passage of trichordal intervallic expansion. Example 5. Webern, Five Movements for String Quartet, op. 5, no. 3. mm. 1-8 Many other fragments or complete pieces by Schoenberg, Berg, and Webern feature PCSE. Among those which come easily to
mind and which have been analyzed elsewhere, I will briefly mention Schoenberg's "Farben" (Five Pieces for Orchestra, op. 16, no. 3) and Berg's Wozzeck, op. 7, Act II, mm. 465-74. "Farben" features "middleground" extension based on transposition of a single set, [01348], used as a chord which appears in the same position every time it is
transposed, and in such a way that each T of the chord has at least one common tone connection with the previous chord. At the surface level, each T is effected by means of a canon (a motion in each voice). Within each canon, thus connecting by CT the
foreground span between "middleground" chords.15 Berg's passage, on the other hand, includes a harmonic accompaniment in the strings in which a tetrachord constantly in motion creates a strictly connected PCSE space, as evidenced in Roeder's analysis of these measures (which includes a reduced score with annotated set classes; see Roeder
1989, 51-53). The voice leading in the tetrachord is effected mostly by semitone in only one voice, and with one single instance of WT motion between mm. 472-73). Besides this strict actual CHR voice leading among the chords, all adjacent sets
classes in the passage are systematically related by abstract CHR. I will list, as an illustration, the set classes in mm. 465-66: [0247]-[0136]-[0247]-[0136]-[0247]-[0137]-[0136]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[0258]-[025
classes 2 and 3, which feature WT voice-leading. The rotation of set 3 into (0458), however, makes the CHR connection apparent. Techniques of PCSE are not exclusive to the composers of the music of Ruth Crawford Seeger reveal numerous instances of highly connected PCSE. Mm. 20-32
from Crawford's Diaphonic Suite, for instance (reproduced in Straus 1995, 30), are unified motivically by two PCSE strings involving trichords closely connected by CT (overlapping pitches) and CHR. The main string features only the principal cell, [012], and its extension, [013]. An overlapping string includes set classes [016], [015], [014], and [025]
All of the set classes in the passage are linked by the PCSE string [012] [013] [104] [015] [025] [106] (Example 6a). Straus also notes instances of embedded statements of the same motive, in which structures similar to those represented in Example 6a.
Crawford, Diaphonic Suite, mm. 20-32 Example 6b. Crawford, Diaphonic Suite, mm. 1-3; Plano Prelude no. 1, mm. 1, mm. 1-3; Plano Prelude no. 1, mm. 1
 each of which contains seven pairs of chordal sonorities (Example 7a reproduces the pitch content of the first event). Each pair is made up of two unordered [037] trichords related by T6. The resulting seven hexachords, all of the class [013679], are arranged in a network of T5 (or T11) transformations, as indicated over the first pair of chords in
Example 7a. The pairs of T6-related trichords in the example have two CHR connections, while the pairs of T5-related trichords in a line with multiple trichords overlap with adjacent [025] trichords in the example have two CHR connected by a CT. Pitch extension in the pairs of T6-related trichords overlap with adjacent [025] trichords in the example have two CHR connected by a CT. Pitch extension in the pairs of T6-related trichords in the example have two CHR connected by a CT. Pitch extension in the pairs of T6-related trichords in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extension in the example have two CHR connected by a CT. Pitch extensi
CHR connections, as indicated in Example 7b.17 Example 7b.17 Example 7 Crumb, Makrokosmos, vol. 1, no.1, "Primeval Sounds" a. Opening event b. Top voice, opening event while pitch extension is mostly a "foreground" relationships
which establish a level of pitch extension deeper than the surface (see, for instance, Schoenberg's "Farben," and "Nacht," and Crawford's Diaphonic Suite, all discussed above). Similar "middleground" connective devices (in this case covering a much larger formal span) are used by Schoenberg in Klavierstück, op. 33a, and in his Piano Concerto. In the
first of these works, the three long-range combinatorial areas found throughout the complete piece (that is, the families of four rows each formed by a row, its inversional complement, and their retrogrades), A0, A2, and A7, mirror the pitch-class set of the three initial pitches of the row, -F-C, (027). In the Piano Concerto, all twelve combinatorial areas
may be found in the beginning section (mm. 1-333, up to the return of the opening melody). As Andrew Mead has pointed out (1985, 130), the order of pitch classes of the row itself, as first stated in the opening melody. Thus, the row 07e21935t684 produces
the succession of combinatorial areas T0-T7-Te-T2-T1-T9-T3-T5-Tt-T6-T8-T4. 5. Pitch-Class-Set Extension and Musical Space While the definition of background structures in the realm of pitch extension as the ones we have
discussed so far. We may then define such uniformity of musical space, based on our observations and musical space is extended if it contains pitch extension as characterized in Def. 1. "Foreground" extension of musical space results from the literal surface-level
occurrence of associations described in Def. 1. "Middleground" spatial extension results from the occurrence of associations described in Def. 1 at a level deeper than the immediate surface. Definition 6. Connected among
themselves. Definition 7. Uniformity of Musical Space is uniform if (a) it is saturated with a single set and/or (b) its two coordinates display the same pitch-class collection or collections. Musical space is uniform in the
fragments analyzed in Examples 2a (although the complete musical space of the passage, including all the parts other than the left hand of the piano, is not uniform musical space is often closely uniform because of his use of derived rows
Among many possible examples which would illustrate this point, let us examine two passages from the first movement of his Concerto, op. 24. In the reductions of mm. 1-10 and 13-17 reproduced in Example 8 I have applied the principle of octave equivalence for ease of reference. The presentation of the same sets in the actual music includes
compound intervals (as in Ex. 1b) and octave complementation (as in 1c). Example 8. Webern, Concerto, op.24 a. Mm. 1-10 b. Mm. 13-17 The row is divided into four ordered [014] trichords, themselves related by P, RI, R, and I operations, and all following the basic motivic contour (also presented as , , or depending on whether the trichord
considered is a P, RI, R, or I form; and varied in the actual music by the application of octave equivalence, into forms such as , , etc.). The division of the row into four discrete [014] trichords is systematically preserved in the music, where trichords are actually different instruments. Pitch extension thus
arrow. Thus, P0 and R11 feature the maximum degree of connectedness, 3, between their corresponding trichords. Trichordal relationships between R1 and R10 are as follows (with 3 representing a trichord, and the superscript letter indicating the position of the trichord in the row): 3a-3d = 1, 3b-3c = 2, 3c-3b = 1, 3d-3a = 2. A similar relationship of the trichord in the row): 3a-3d = 1, 3b-3c = 2, 3c-3b = 1, 3d-3a = 2. A similar relationship of the trichord in the row): 3a-3d = 1, 3d-3a = 2. A similar relationship of the trichord in the row): 3a-3d = 1, 3d-3a = 2. A similar relationship of the trichord in the row): 3a-3d = 1, 3d-3a = 2. A similar relationship of the trichord in the row): 3a-3d = 1, 3d-3a = 2. A similar relationship of the trichord in the row): 3a-3d = 1, 3d-3a = 2. A similar relationship of the trichord in the row): 3a-3d = 1, 3d-3a = 2. A similar relationship of the trichord in the row): 3a-3d = 1, 3d-3a = 2. A similar relationship of the trichord in the row): 3a-3d = 1, 3d-3a = 2. A similar relationship of the trichord in the row): 3a-3d = 1, 3d-3a = 2. A similar relationship of the trichord in the row in th
trichords between RIO and P1 (first with last, second with second to last, etc.) yields a degree of connectedness = 2 in all four cases, while corresponding trichords between P1 and I1 are related by the degrees 1, 2, 1, and 2. Example 8b shows a further instance of extension and connection. In the passage, Webern exploited the hexachordal and
trichordal invariance between R7 and I2, and I7 and R0. Both pairs of rows are presented horizontally, with the respective common hexachords overlapping, while the remaining two pairs of trichords feature maximum degree of connectedness (grouped R73a-I23c, R73b-I23d, and similarly for I7 and R0, as indicated by the arrows). At the same time
vertical connections between trichords presented simultaneously (see R73b-I73a, R73c-I73b, etc.) produce the degrees 1, 2, 1. In short, both passages (the complete composition, as a mater of fact) feature pitch extension with a high degree of horizontal and vertical interconnections. Musical space is not only extended and connected, it is also
totally uniformed by the exclusive use of two sets: the twelve-tone row and the [014] trichord. We have examined so far PCSE, cell connectedness, and uniformity of musical space in a variety of examples, regardless of the compositional method applied in the particular pieces. We will now focus our discussion on the specific PCSE characteristics of
the twelve-tone row. 6. The Twelve-Tone Row, PCSE, and Uniformity of Musical Space In itself, the twelve-tone row and its derivations extend and uniform music is based on the projection in time of a collection of pitch classes (the row), pitch extension is an intrinsic characteristic of
serialism. All serial music, moreover, produces uniformity of musical space. All twelve-tone music fulfills both conditions (a) and (b) (its two coordinates display the same pitch-class collection
or collections).19 A brief reference to a celebrated passage by Schoenberg will further illustrate the uniforming properties of combinatorial forms of the row. The complementary hexachords (P06a-I56a and P06b-I56b)
are stated simultaneously, so that in the two measures there are four horizontal statements of the row (P0-I5 in the viola-cello) and four vertical statements of the aggregate is an unordered twelve-tone collection, we see that the two coordinates in the
passage display the same pitch-class collection, and hence musical space is uniform (see Example 9). Furthermore, all of these twelve-tone collections are interconnected, both vertically and horizontally, by two invariant trichordal segments between P0 and I5 (D--A and G--C), as indicated by the arrows on the reduction. Space is thus extended,
connected, and uniformed by the row, its combinatorial forms, and their invariant segments. Example 9. Schoenberg makes the following often-quoted remark: The unity
of musical space demands an absolute and unitary perception. In this space, there is no absolute down, no right or left, forward or backward. . . A musical creator's mind can operate subconsciously with a row of tones, regardless of the way in which a mirror might show the mutual relations. . . The employment of these
mirror forms (that is I, R, and RI forms) corresponds to the principle of the absolute and unitary perception of musical space (Schoenberg 1950, 113-115). Babbitt points out that the most immediately powerful cohesive property of a row is the preservation of the interval number succession under T. The totality of twelve transposed sets associated
with a given row constitutes a permutation group of order 12; as such it is closed, disjunct with regard to any member of this totality (Babbitt 1960, 249). Under I, the interval succession of P is substituted by a succession of its complementary intervals. All
T levels of R present the intervallic succession of I in reverse order, while the RI forms presented as complementary intervals, is always preserved throughout all of the serial operations which may be applied to the original
row. The properties of the row as a pitch-extension structure are firmly based on this intervallic element of cohesiveness. Besides the immediate and sufficient PCSE properties of the twelve-tone set, however, composers have often taken advantage of the unique connective properties of specific row relationships. Such is the case, for instance, of
Webern in his first Cantata, op 29, I. The piece has been thoroughly studied by such authors as Rochberg (1962), Kramer (1988), and Mead (1993). Because it displays numerous PCSE properties, however, it is worth reviewing some of its characteristics in the context of our present discussion. All adjacent trichords in the row, reproduced in Example
10a, are of the [014] class. The row is RI-symmetrical, and hence each I form is also an R form. Rochberg and Kramer use the R labels and omit the I forms. Mead, however, has shown that the preserved repertoires of dyads between pairs of voices and of tetrachords between all four voices result from the fixed inversional relations among the rows,
rather than from any ordering property of the row class (Mead 1993, 175-77). I will thus use I forms, although I will keep the conventional integer 0 to pitch A (rather than Mead's labels based on C = 0). Example 10. Webern, Cantata, op. 29, I Because the opening and closing intervals are
both [4], the row offers the possibility of dyadic invariance between the end of one row and the beginning of another as a means of row connection. The transformations which produce such invariance (T9 for P forms, or T3 for I forms) generate a cycle of four rows followed by a return to the row of departure. Example 10b illustrates a cycle connected
by ending/beginning dyads and covering the forms P0-P9-P6-P3-P0. Webern uses four simultaneous strands of such transpositional cycle throughout the movement, thus connecting each pair of adjacent row forms by their invariant dyad. The chain is broken only at mm. 13-14, where the end of the orchestral introduction (covering four simultaneous
half cycles) is not linked to the beginning of the choral section by invariant dyads. Mm. 14-47 (the choral section by invariant dyads. Mm. 14-47 (the choral section and the orchestral conclusion). In summary, the following are the techniques
of PCSE, cell connection, and uniformity of musical space found in this movement: (1) All adjacent horizontal trichords are of the [014] class. (2) All adjacent horizontal trichords are of the pairs
soprano/alto and tenor/bass. (This property results from the simultaneous presentation of any P and I forms of the same row in which the sum of transpositional operators in the choral section, for instance, is always 11 for the soprano/alto pair, and 7 for the tenor/bass)
(4) Resulting harmonic tetrachords are also preserved throughout the entire cycle of transpositions: there are only three tetrachord forms ([0123], [0257], and [0235]), and only six different chords (two groups of three related by T6). The Cantata thus provides examples of extension of a single trichord—the initial melodic [014]—, extension of a
collection of three harmonic tetrachords, connection of twelve-tone row sets by invariant melodic dyads, connection of twelve-tone sets by invariant melodic dyads, and uniformity of musical space resulting from space saturation with a single set, [014]. We will now refer to a final well-known example from the serial repertoire, Schoenberg'
Klavierstück, op 33a, and I will point out the most salient techniques of pitch extension in the opening measures (the first-theme area, mm. 1-11).21 As we have already established, because of the combinatorial properties of the row, the musical space of the piece is uniformed. Extension
and connection techniques in this composition, however, go beyond these general characteristics built into the serial method. Two types of tetrachords of the row are frequently presented as musical units ([0127], [0258], [0146]). In the second place, the simultaneous
presentation of combinatorially-related row forms (such as P0 and I5) results in six tetrachords which include corresponding discrete dyads of both rows (see Example 11a). These six tetrachords form a symmetrical collection of sets: [0257] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0123] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] [0235] 
music is a further element of PCSE (see Example 11b). Thus, mm. 1-2 feature two symmetrical statements of the discrete tetrachords from paired combinatorial row forms; in mm. 6-7 we see a return to two symmetrical succession of tetrachords from paired combinatorial row forms; in mm. 6-7 we see a return to two symmetrical statements of RI5 and RI0, present the symmetrical succession of tetrachords from paired combinatorial row forms; in mm. 6-7 we see a return to two symmetrical statements of RI5 and RI0, present the symmetrical statements of RI5 and RI0, present the symmetrical statements of the discrete tetrachords from paired combinatorial row forms; in mm. 6-7 we see a return to two symmetrical statements of RI5 and RI0, present the symmetrical statements of the single row; mm. 3-5, displaying simultaneous statements of RI5 and RI0, present the symmetrical s
 statements of discrete tetrachords of single rows; mm. 8-9 present two simultaneous statements of the three discrete tetrachords, thus creating a vertical double statements of the same discrete tetrachords, creating both vertical and horizontal symmetry.
Collections of tetrachords are thus not only extended by serial operations, but moreover are presented as closed symmetrical cycles which have extending properties of their own. Example 11. Schoenberg, Klavierstück, op. 33a a. Row forms and tetrachords b. Tetrachords b. Tetrachords b. Tetrachords b. Tetrachords by serial operations, but moreover are presented as closed symmetrical cycles which have extending properties of their own. 1-11 c. Mm. 1
function of set C As shown in Example 11a, the row begins with two fifths (or fourths) each, such as ---F [0257], and D-A-E-B [0257], and D-A-E-B [0257], while the first and last tetrachords of paired combinatorial row forms can also be organized as three stacked fifths (or fourths) each, such as ---F [0257], and D-A-E-B [0257], and D-A-E-B [0257] and [0257] an
pitch level creates an element of direct pitch connection among the row forms in the piece. Because combinatorial areas are extended throughout large spans of the piece (there are only three areas in the competition, A0, A2, and A7, and of these A0 is greatly predominant), the connections relating stacked-IC5 sets at identical pitch levels
 are of very strong structural significance, as shown in Example 11c. The graph is a spatial representation of all the stacked-IC5 sets in the passage, with indication of their function within row forms. Considering the absolute pitch content of all these sets, there are only three different pitch collections, and each has a definite function: set A, C-F-
[027], begins P0 or ends R0; set B, -- [027], begins I5 or ends R15; and set C, D-E-A-B [0257], connects the end of P0 with the beginning of R15 (or the beginning of R15 with the simultaneous beginning of R15 with the simultaneous beginning of R15 with the simultaneous endings of P0 and I5).
 in one of two ways: 1) if the PO/RI5 complex is presented linearly, as in mm. 1-2 and 6-7, then set C acts as a link between the two rows; 2) if the PO/RI5 complex is presented simultaneously, then set C acts as a link between the end of one
complex and the beginning of the next (mm. 10-11).22 7. Conclusions and Pedagogical Applications PCSE provides the means to relate pitch collections in a passage or a composition according to similarity criteria which take mostly into consideration set cardinality, inclusion relationships, pc invariance (CT), and pc voice-leading proximity (CHR or
WT). In summary, two sets are related by PCSE if (1) they belong to the same set class (identity), or (2) they do not belong to the same set class but they have the same set class (identity), or (2) they do not belong to the same set class but they have the same set class (identity), or (2) they do not belong to the same set class but they have the same set class (identity), or (3) they do not belong to the same set class (identity), or (2) they do not belong to the same set class (identity), or (3) they do not belong to the same set class (identity), or (4) they do not belong to the same set class (identity), or (5) they do not belong to the same set class (identity), or (6) they do not belong to the same set class (identity), or (7) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to the same set class (identity), or (8) they do not belong to t
their cardinalities are not the same but their difference is not bigger than 1, and the two set classes are related by inclusion. Passages in which pitch collections, as defined by a very limited set of similarity properties. Cell connection and
 uniformity of musical space imply even higher levels of pitch coherence. As demonstrated in this article. PCSE constitutes a theoretical and analytical tool which contributes to our understanding of extended pitch coherence in post-tonal music. As such, the theory has immediate pedagogical implications. After teaching the basics of pitch-class-se
theory, instructors can easily introduce PCSE, and illustrate its applicability to a very broad repertoire. The short fragments in Example 1 in the present article can be used to introduce the concepts and lead to the basic definitions (Definitions 1 and 2 above).
provide instances of PCSE in larger musical contexts. If serialism has not yet been covered at this point, the concept of PCSE may be revisited later in the course, after serialism is introduced. The above discussions of Webern's Concerto, op. 24, Cantata, op. 29, and Schoenberg's op. 33a can be used for this purpose, and will provide an appropriate
pedagogical link between pitch-class-set theory, serialism, and the principle of long-range pitch coherence in post-tonal music. Finally, although the above section on similarity criteria to compare sets for PCSE may be somewhat demanding due to its more formalized language, its study is perfectly appropriate for advanced undergraduate students or
in courses with sufficient time to explore this type of technique in depth. In summary, PCSE can enrich the students' appreciation of twentieth-century musical structure by providing a means to (a) investigate and understand aspects of long-range coherence associated to (and complementing) their study of pitch-class-set theory; (b) apply the same
analytical techniques to the study of serial compositions; and (c) further apply the techniques to the study of more recent, post-serial repertoires (represented in our discussions by composers such as Crumb and Ligeti), thus stressing the existence of underlying structural currents in twentieth-century post-tonal music, regardless of style. LIST OF
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Twentieth-Century Music," In Aspects of Twentieth-Century Music, pp. 388-476. Edited by Gary Wittlich. Englewood Cliffs: Prentice Hall. 1In numerous studies in recent years, scholars have attempted to define the elements that provide long-range pitch coherence in post-tonal music. Although authors such as Mead (1985), Straus (1995), Wilson
(1992) and others have succeeded in demonstrating extended pitch coherence in specific repertoires, no general methodology has emerged which might be applicable to multiple stylistic repertoires, in some cases at great length: motivic
association and transformation (Boss 1992 and 1993, Forte 1985 and 1993, Lewin 1987 and 1993, Peles 1983-84; and Starr 1978), motivic correspondences
between the horizontal and vertical dimensions (Dean 1973-74, Forte 1988a), large-scale projection of surface pitch collections (Mead 1985), and common-tone and semitonal voice leading (Morris 1998, Roeder 1987, 1989). My contribution in this article is to bring together these and other intuitions regarding long-range pitch coherence in post-tonal
music, and to illustrate the applicability of the resulting theory to a broad spectrum of twentieth-century compositions. 3Lerdahl clarifies the concept as follows: "Given that two events connect, the more stable is the one that is in a strong metrical position, at a
registral extreme, or more significant motivically" (1989, 73). 4Lerdahl has recently stressed that his use of the term 'prolongation.' I employ it as an ordinary English word that resonates with centuries of music theory and
define its specific usage in terms of the atonal theory I am building; they restrict it to a specifically Schenkerian usage" (Lerdahl 1997, 153). See also Väisälä 1999. 6Lester's "division tone" is the atonal equivalent of a passing
tone, although in a division tone no limit is placed on the dividing intervals's size—they need not be seconds. Boss defined as structural in a piece. 7For a compelling study of motive and motivic transformation in the music of Ruth Crawford Seeger, for
instance, see Straus 1995. Much of what Straus uncovers in this music in the form of motivic coherence is pertinent to the present study. 8In his article "Schoenberg's Op. 22 Radio Talk and Developing Variation," Jack Boss shows in much detail that in his 1932 radio talk on the Four Orchestral Songs, op. 22, Schoenberg discussed each of the
categories which I include in Table 1 as types of developing variation (see also Schoenberg's Fundamentals of Musical Composition, pp. 3-9). Boss rewords Schoenberg's kinds of motivic variation into the following categories: (A) every collection having the same succession of unordered pitch intervals between its adjacent pitches (in Boss's example,
all the set forms including the two-interval successions generated by combining ordered pitch intervals (Boss 1992, 132-133). In this article Boss proposes a
model of long-range connection similar to my PCSE, but rather than basing it on pitch and pc-set connections, he bases it on intervallic and pitch-interval successions treated as motives. For a study of linear coherence resulting from motivic permutation in Schoenberg's Das Buch der hängenden Gärten, see Forte 1992. In his article "A Principle of
Voice Leading in the Music of Stravinsky," Joseph Straus discusses the principle of "pattern completion," according to which "a certain unordered collection or set of notes is established as a structural norm for the composition, pervading the surface of the music (both melodic and harmonic) and governing the tonal motion at all levels of structure"
(Straus 1982, 106). Straus's examples in this article illustrate some of the same concepts as my PCSE does. A striking case of this is presented by overlapping forms of set [0134] in all voices. 9Allan Chapman (1978 and 1981) has studied voice leading among registrally ordered sets in terms
of intervallic relationships between adjacent pitches in a vertical. Several authors have recently studied voice leading from a transformational perspective (that is, following the recent theoretical work by David Lewin). See Klumpenhouwer 1991, Roeder 1995, and Straus 1987. The most complete and general study of voice leading that I am aware of
can be found in Morris 1998. 10Similar voice leading principles underlie Richard Cohn's concepts of maximally smooth voice leading connecting two triads, in which two common tones are retained while the third voice
proceeds by semitone or whole tone (1997, 1-2). Referring to the stepwise motion in the third voice, Cohn notes that "this feature is not without significance to the development of a musical culture where conjuct voice-leading in general, and semitonal voice-leading in particular, are enduring norms through an impressive range of chronological eras
and musical styles" (p. 2). Cohn's following observation is also very pertinent to our present discussion of voice leading: "Beginning with (at least) the eighteenth century, the normative status of common-tone retention and stepwise motion is not only statistical but cognitive: one conceives of them as occurring even when the actual leading of the
'voices' violates them, e.g. when instantiations of the common or step-related pitch-classes are realized in different regions" (p. 62, note 5). 11George Perle has noted the significance of what he calls the "basic cell" in free atonal music, as well as of invariant pitches to connect adjacent cells: "It may operate as a kind of microcosmic set of fixed
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intervallic content, statable either as a chord or as a melodic figure or as a combination of both. Its components may be fixed with regard to order, in which event it may be employed, like the twelve-tone set, in its literal transformations: prime, inversion, retrograde, and retrograde inversion. (...) Individual notes may function as pivotal elements, to



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