Expansion and Contraction in Movements I and VII of Gyorgy Ligeti's Hamburg Concerto

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EXPANSION AND CONTRACTION IN MOVEMENTS I AND VII OF GYÖRGY LIGETI’S HAMBURG CONCERTO

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ABSTRACT

György Ligeti’s final composition, *Hamburg Concerto* (1999, rev. 2002), features his compositional technique of expansion and contraction. The concerto is scored for two flutes, oboe, two bassett horns (both doubling on clarinet), bassoon, solo double horn, four natural horns, trumpet, trombone, two percussionists, and single strings. The natural overtones of the horns offer unique harmonic possibilities that relate to Ligeti’s use of expansion/contraction. While several analysts have examined expansion/contraction in other works by Ligeti, no one has yet looked at this technique in *Hamburg Concerto*, particularly as applied to Ligeti’s use of natural overtones. This paper examines the two outer movements of the concerto and presents evidence for Ligeti’s use of expansion/contraction in the rhythmic, melodic, and harmonic levels of musical structure.
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CHAPTER 1: INTRODUCTION

Few analysts have examined György Ligeti’s final composition, *Hamburg Concerto*, although the dissertations of Anthony Cheung and Charles Corey are two recent additions to the literature.¹ ² Cheung and Corey focus on historical connections between the natural horn and orchestra and the concerto’s juxtaposition of just intonation with equal tempered tuning. However, little theoretical research exists concerning Ligeti’s use of expansion/contraction as a compositional technique in the concerto, even though he uses this technique throughout his oeuvre.

Jonathan Bernard has discussed Ligeti’s canonic writing as it relates to pitch-space expansion and draws connections to large-scale structures.³ Jane Piper Clendinning offers several analytical arguments for the use of expansion/contraction in Ligeti’s compositions across pitch, rhythm, and formal design.⁴ Jeremy Spindler connects the concept of expansion/contraction in six

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compositions spanning forty years of Ligeti’s career. While Spindler mentions the existence of expansion/contraction in *Hamburg Concerto*, he does not explore the idea.

Examining the concept of expansion/contraction in the *Hamburg Concerto* allows us to gain greater insight into how the work is structured. Ligeti uses this technique in multiple ways; indeed, his approach to rhythm, harmony, melody, and formal design revolves around expansion/contraction. While this paper focuses only on the outer two movements, this technique can be seen throughout the entire work.

**OVERVIEW OF COMPOSITION**

The *Hamburg Concerto* was commissioned by the ZIET-Foundation of Hamburg, and was completed in 1999. Six movements premiered on January 20, 2001. While working in Vienna in the second half of 2002, Ligeti wrote a seventh movement and planned an eighth. He dedicated the concerto to Marie-Luise Neunecker, a German horn player, who premiered his *Horn Trio* in 1982.

The concerto is scored for two flutes, oboe, two bassett horns (both doubling on clarinet), bassoon, solo double horn, four natural horns, trumpet,


6 Ibid., 153.


8 Ibid., 362.

9 Ibid., 353.
trombone, two percussionists, and single strings. The concerto’s seven short movements are titled: I. Praeludium; II. Signale, Tanz, Choral; III. Aria, Aksak, Hoketus; IV. Solo, Intermezzo, Mixture, Kanon; V. Spectra; VI. Capriccio; and VII. Hymnus. The title of each movement alludes to its character and divisions into smaller sections.

Throughout the concerto Ligeti often separates the music’s orchestrational and formal structures. In general, he uses instrumental choirs and families in a distinct and static manner; e.g., see mm. 12-17 of the third movement (see mm. 12-17 of Example 1.1). Each instrumental choir, once introduced, maintains its role. The horns play a melodic line displaced across the four instruments, while the winds play sustained harmonies supported by percussion and plucked chords in the strings.

The second movement’s formal construction also reveals separation. The second movement (Examples 1.2a and 1.2b), Signale, Tanz, Choral, divides into three clear and distinct formal sections, perceptible through changes of texture, tempo, and dynamics. The first section, mm. 1-8, is a call and response between the solo horn and natural horns. The second section, mm. 8-15, is a dance with a lilting melody in compound meter. The final section, mm. 16-27, is a chorale.

The brevity of the movements, static orchestration, and formal clarity provide an episodic character to the concerto. One element that transcends the episodic nature of the concerto is expansion/contraction. This technique is

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10 All score examples are in C.
Example 1.1 György Ligeti, *Hamburg Concerto*, mvt. 3, mm. 12-17
applied to the composition’s rhythmic, melodic, and harmonic fabric, thereby supplying unity across sectionalized parts.
II Signale, Tanz, Choral

Example 1.2a György Ligeti, *Hamburg Concerto*, mvt. 2, mm. 1-15
Example 1.2b György Ligeti, Hamburg Concerto, mvt. 2, mm. 16-27
CHAPTER 2: EXPANSION/CONTRACTION AS A COMPOSITIONAL TECHNIQUE

An analysis of Ligeti’s compositional output reveals expansion/contraction in many of his compositions. Jonathan Bernard, Jane Piper Clendinning, and Jeremy Spindler provide ample evidence of expansion/contraction in Ligeti’s music, particularly as it applies to pitch space, harmonic tension, and formal design.

Bernard points out that in the immediate aftermath of Ligeti’s immigration to Germany, his exposure to serialism posed a compositional dilemma. Ligeti believed that pitches and intervals had lost all meaningful relation; all that remained were varying degrees of density.\textsuperscript{11} Bernard’s analyses of several compositions (\textit{Apparitions}, \textit{Atmosphères}, \textit{Three Pieces for Two Pianos}, \textit{Kammerkonzert}, \textit{Lux Aeterna}, and \textit{Lontano}) reveal how Ligeti controlled textural density through canonic structures. Further, Bernard’s analysis of the canonic structures in \textit{Lux Aeterna} shows that it and others like it affect “spatial developments in a wide variety of ways – not only in that the unfolding canons form vertical resultants in and of themselves, but also, in that their dimensions have consequences for the articulation of structure on a larger scale.”\textsuperscript{12}


Clendinning’s analysis of *Continuum* underscores the pitch space expansion described by Bernard and further examines the use of expansion/contraction related to other musical elements. For example, she finds “two typical registral shapings for the pattern-mecanico compositions: an expansion/contraction (of which the opening section of *Continuum* is typical) and an expansion that is broken off at its widest point (used in the second, third, and fourth sections of *Continuum*).”¹³ Her statement certainly supports Bernard’s conclusion that changes in density control the composition’s formal structure, but her analysis also includes additional elements for consideration:

The registral shapings are often accompanied by changes in the amount of harmonic tension present in the music. For example, in the first section of *Continuum*, the expansion and registral filling is accompanied by an increase in harmonic tension. As a result of the harmonic process, the number of perceptually dissonant harmonic intervals between the voice-leading strands of the compound melody increases toward the middle of the section...As range closes and the texture thins, anticipating the close of the section, tension gradually is dissipated rather than “resolving” in a traditional manner.¹⁴

Clendinning’s comment about the increase and dissipation of tension relates to expansion/contraction, as evidenced by the way she connects the ideas of expansion of pitch space and increase in harmonic tension. Clendinning also discusses how expansion/contraction applies to formal shaping:

An additional aspect of formal shaping...is the perceived variation in the pacing, or the speed at which the music seems to move forward. This feature of the music is effected by several surface elements that have already been mentioned: the frequency at which pitches are articulated in the individual melodic lines (determined by the duration of individual...

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¹⁴ Ibid., 206.
pitches of a pattern), the pattern interaction (accent alignment as a marker of progress), and the rate at which the patterns shift in the different voices (rate of change in the pitch content of melodic strands).  

Jeremy Spindler's dissertation describes how Ligeti’s use of expansion/contraction developed throughout his career. Spindler's dissertation connects the expansion/contraction found in Ligeti’s compositions to Robert Gauldin’s concept of a wedge progression.  

Spindler adapts Gauldin’s wedge model to fit non-tonal needs, carefully defining relevant terminology. Spindler argues that Ligeti used the wedge principle throughout his compositional career, beginning with Invention, in which he used the wedge principle to structure the main subject.  

Spindler further points out that beginning with Lux Aeterna, Ligeti varies his use of expansion/contraction. “The gradual increase and decrease in rhythmic activity seen in the first section of Lux Aeterna reveals a stage of transition to a more prominent application of expansion and contraction to other

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15 Ibid., 206.


18 Ibid., 27-30.
parameters."\textsuperscript{19} Spindler illustrates how Ligeti applied expansion/contraction via pitch space, registration at structural divisions, rhythm, and space in the second movement of the \textit{Chamber Concerto}.\textsuperscript{20} Spindler concludes that expansion/contraction assumed greater importance in Ligeti’s later works, as evidenced by his increasingly frequent use of the technique.

\footnotesize
\textsuperscript{19} Ibid., 116.

\textsuperscript{20} Ibid., 127-149. Spindler’s use of the term \textit{space} refers to the illusion of space in non-spatial acoustical compositions. For example, instead of having the ensemble play at a single dynamic level, Ligeti uses the combination of different dynamic levels to create “distance” in the music. This gives the illusion that the ensemble is positioned in different spatial areas.
CHAPTER 3: TUNING OF THE NATURAL HORN

The clashing of the non-tempered natural intonation in Ligeti’s horn writing with the tempered instruments of the orchestra creates a decidedly complex tuning world. In addition to this clash between the just intonation (JI) and twelve-tone equal temperament (12TET), Ligeti combines natural horns with different fundamentals, a combination that creates further tuning complexities. Comparing and discussing these complexities requires examination of differences between JI and 12TET tuning systems as well as a survey of how other analysts handle the matter when discussing this concerto.

The natural horn can only play pitches from its overtone, or harmonic, series. The 12TET system approximates the intervals of the harmonic series and makes free modulation possible.\footnote{Murry Campbell and Clive Greated, \textit{The Musician’s Guide to Acoustics} (New York: Schirmer, 1987), 165-182.} Figure 3.1 presents the first 16 partials of an overtone series based on A1 on a grand staff.\footnote{C4 is middle C.} The pitch A1 has a frequency of 55 hertz (Hz), or cycles per second.\footnote{A4 is 440 Hz.} The table below the grand staff lists the partial numbers (row 1) and compares the frequencies produced by JI (row 2)
and equal temperament (row 3) using Hz. Row 4 expresses the discrepancy between JI and 12TET using cents.\textsuperscript{24}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{overtone_comparison.png}
\caption{Overtone Comparison}
\end{figure}

**The Natural Horn in *Hamburg Concerto***

Ligeti includes instructions regarding the horn's performance technique on the score's instrumentation page. He writes, “The four natural horns always produce non-tempered natural harmonics; therefore, the right hand must not correct the pitches.”\textsuperscript{25} Ligeti uses arrows to indicate intonation alterations from 12TET, and he places a thin downward arrow on pitches lowered "just a bit" 15\% (5th harmonic),\textsuperscript{26} a thick downward arrow for pitches lowered 30\% (7th harmonic), and a hollow downward arrow for pitches lowered a quartertone 50\%


\textsuperscript{26} Ligeti uses percentages in the score to refer to the 12TET half step alteration. There are 100 cents between each half step in the 12TET system; thus one percentage point is equal to one cent.
(11th harmonic). Ligeti specifies only these three harmonics on the instrumentation page, but he does not mention the 10th harmonic (lowered the same as the 7th), the 13th harmonic (lowered 59 cents), the 15th harmonic (lowered 12 cents), or of any of the harmonics that require a slight raising (3rd, 6th, 9th, 12th). Comparing Ligeti’s performance instructions to the horns with the score reveals a conflict between which notes are altered: are all overtones JI or only those he specifies? The following observations help clarify the conflict.

The first altered pitch omitted in Ligeti’s notes is in mvt. 1, m. 3 (see Example 4.1a, page 20). The third horn plays the 10th harmonic, which Ligeti notates with a downward arrow. Ligeti does not specify the 10th harmonic as one that should be altered. His use of the arrow on this pitch indicates that pitch alteration extends to pitches not listed on the instrumentation page. In addition, Ligeti’s instructions in the score imply that the horn player should perform pitches from the requested overtone series regardless of the notated arrow. If the horn player performs as instructed, the overtones will be JI regardless of the notation.

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28 The downward arrow used on this harmonic appears to be one that indicates a harmonic lowered 30% (the same as the 7th harmonic). The 10th harmonic should be lowered 14% (the same as the 5th). It seems Ligeti has mislabeled the pitch. When the same pitch returns in m. 5, he uses the correct arrow. Charles Corey lists this and other errors found throughout the concerto in, “Pitch and Harmony in György Ligeti’s *Hamburg Concerto*,” (PhD diss., University of Pittsburgh, 2011), 159-165.
It may be inferred that Ligeti’s intention was to have the non‐tempered pitches take precedence over the score’s notation.\(^{29}\)

**AN ANALYTICAL PROBLEM**

A problem arises in analyzing intervallic relationships when comparing JI, 12TET, and horns with differing fundamentals. If the comparisons were only within JI, or between JI and 12TET, ratios would be useful for displaying intervallic relationships. For example, in mvt. 1 m. 4 (Example 4.1a, page 20), Ligeti writes for winds, solo horn in B\(_b\), horn in F, and horn in E\(_b\). This example combines the 12TET of the orchestra and the JI of the natural horns based on three different fundamentals. The resulting clash creates a complex web of intervallic relationships, in which the use of ratios proves unproductive. However, the research of other analysts provides helpful observations in finding ways to compare intervallic relationships. Kris Shaffer, Anthony Cheung, and Charles Corey each discuss the concerto and solve the problem of intervallic relationships differently.

Shaffer relies on the score’s notation for lowered pitches. He summarizes that there are several possible variations between any two pitches. Figure 3.2 displays Shaffer’s chart, which shows the possible cent variation for a selected pitch in relationship to C.\(^{30}\) Each pitch class has one of four possible variations: a

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\(^{29}\) Ligeti makes one exception on the instrumentation page: “the last horn chord in movement VI is to be played stopped and sounds a semitone higher.”

partial that does not affect the 12TET pitch, one that lowers it by 15 cents (5th partial), one that lowers it by 30 cents (7th partial), or one that lowers it by 50 cents (11th partial). The four variations of each pitch class create the potential for a wide range of intervals. Figure 3.3 shows another of Shaffer’s charts; this one calculates cent differences between pitches on different partials.\textsuperscript{31} The right column classifies the interval depending on the partial of each pitch; the left column shows the calculation in cents for the interval. Each interval class has eleven variations spanning a range of 100 cents between the lowest and highest variations.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|c|c|c|}
\hline
\textbf{Pitch category} & C & C-sharp/D-flat & D & D-sharp/E-flat & E & F & etc. \\
\hline
\textbf{Partial} & - & 11\textsuperscript{th} & 7\textsuperscript{th} & 5\textsuperspace{\textdegree} & - & 11\textsuperscript{th} & 7\textsuperspace{\textdegree} & 5\textsuperspace{\textdegree} & - & 11\textsuperscript{th} & 7\textsuperspace{\textdegree} & 5\textsuperspace{\textdegree} & - \\
\hline
\hline
\end{tabular}
\end{table}

\textbf{Figure 3.2 Kris Shaffer’s Pitch Variation Chart}

\begin{table}[h]
\centering
\begin{tabular}{|c|c|}
\hline
\textbf{Interval (cents)} & \textbf{Constituent partials (lower, upper)} \\
\textbf{(X=ET int.)} & \\
\hline
x-50 & (-, 11\textsuperspace{\textdegree}) (11\textsuperspace{\textdegree}, -) \\
x-35 & (5\textsuperspace{\textdegree}, 11\textsuperspace{\textdegree}) \\
x-30 & (-, 7\textsuperspace{\textdegree}) \\
x-20 & (7\textsuperspace{\textdegree}, 11\textsuperspace{\textdegree}) \\
x-15 & (-, 5\textsuperspace{\textdegree}) (5\textsuperspace{\textdegree}, 7\textsuperspace{\textdegree}) \\
x & (-, -) (5\textsuperspace{\textdegree}, 5\textsuperspace{\textdegree}) (7\textsuperspace{\textdegree}, 7\textsuperspace{\textdegree}) (11\textsuperspace{\textdegree}, 11\textsuperspace{\textdegree}) \\
x+15 & (7\textsuperspace{\textdegree}, 5\textsuperspace{\textdegree}) (5\textsuperspace{\textdegree}, -) \\
x+20 & (11\textsuperspace{\textdegree}, 7\textsuperspace{\textdegree}) \\
x+30 & (7\textsuperspace{\textdegree}, -) \\
x+35 & (11\textsuperspace{\textdegree}, 5\textsuperspace{\textdegree}) \\
x+50 & (-, 11\textsuperspace{\textdegree}) (11\textsuperspace{\textdegree}, -) \\
\hline
\end{tabular}
\end{table}

\textbf{Figure 3.3 Kris Shaffer's Possible Interval Variation}

\textsuperscript{31} Ibid.
Anthony Cheung uses the intonation alterations supplied in the score but then adds the 10th partial (rounded from 14 cents lowered) and the 15th partial (rounded from 12 cents lowered) to the 5th partial group (lowered 15 cents from 12TET). Cheung adds the 14th partial (rounded from 31 cents lowered) to the 7th partial group (lowered 20 cents from 12 TET). Cheung also adds a group not specified by Ligeti: the 60 cents lowered 13th partial (rounded from 59 cents lowered).\(^{32}\) Cheung’s analysis discusses intervals using a combination of ratios and cents, as well as JI terminology taken from Harry Partch’s *Genesis of a Music*.\(^{33}\)

Charles Corey devotes considerable space contemplating how the horn tunes pitches during a performance. His discussion of tuning ensures that each overtone is represented correctly regardless of the horn’s fundamental.\(^{34}\) Corey analyzes all pitches played by the horns in JI, thereby using a more exact system than Shaffer or Cheung. He uses primarily cents to explain much of his analysis, along with JI ratios or 12TET names. This approach affords a precise comparison of intervals among different tuning systems while maintaining a connection to JI and 12TET. In contrast to his exactness, Corey introduces analytical flexibility by expanding the boundaries of intervals. “The range of possible major thirds (or possible members of interval class 4) is expanded from

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only 400 cents to nearly anything between 350 cents and 450 cents. Depending on context, however, these boundaries might become even larger, or they may be more constricted.\(^{35}\)

**SPECIFIC APPROACH TAKEN IN THIS PAPER**

The approaches above reflect two options for comparing intervals: Shaffer and Cheung approximate each interval as notated in the score, whereas Corey uses the overtone series to calculate the cent differences. Shaffer’s charts facilitate the calculation of intervals while also providing a visually appealing system, but he neglects the 10th, 13th, 14th, and 15th partials. Cheung includes the partials missing in Shaffer’s calculations; however, he too relies on approximations and therefore lacks specificity. Corey’s solution is the most precise, usually rounding intervals to the nearest hundredth cent. The analysis that follows uses cent differences listed in Figure 3.1 (page 13) as well as a wide range of cent values for each interval as Corey suggests. Both methods are needed to examine the expansion/contraction of 12TET interval classes as well as general harmonic motions throughout a movement.

Finding a suitable system to express the relationship between 12TET and JI allows for an in depth discussion of intonation differences. Ligeti uses these differences to expand/contract the melodic and harmonic intervals, often within a single 12TET interval class. The clarification of 12TET and JI relationships allows for greater specificity in the following analysis and therefore a more complete understanding of the concerto as a whole.

\(^{35}\) Ibid., 22.
CHAPTER 4: MOVEMENT ONE

The first movement divides into three sections: mm. 1-8, 9-14, and 15-20. This chapter presents each section individually, examining expansion/contraction of metrical, melodic, and harmonic structures. The final section discusses the inter-relationships of structural points revealing expansion/contraction throughout the movement.

SECTION ONE

The first section, mm. 1-8 (Examples 4.1a and 4.1b), is an expanding wedge that begins with a whole step in the horns and ends with a P5 spread across three octaves and a fifth. Ligeti utilizes expansion/contraction in meter; different whole tones in mm. 1-3; alteration between 12TET and JI in mm. 1-4; and pitch-space expansion in mm. 1-7.

Ligeti’s subdivision of the 12/8 meter groups the eighth notes into an expanding and contracting pattern of 2+3+4+3 instead of the typical division of 3+3+3+3. He adheres to this subdivision throughout the movement with only a few exceptions in mm. 15-17. Ligeti’s division of eighth notes creates a pulse that constantly expands or contracts from beat to beat.

Ligeti creates a web-like structure that expands/contracts the cent value for the whole-tone interval in the first three measures of the concerto.
Example 4.1a György Ligeti, *Hamburg Concerto*, mvt. 1, mm. 1-4
Example 4.1b György Ligeti, *Hamburg Concerto*, mvt. 1, mm. 5-8
(Example 4.1a) by using six distinct whole tones. Figure 4.1 compares the whole tones in the first three measures (the partial is written above each pitch, and boxed numbers indicate the cent value for each interval). The six whole tones used in this passage are 182 cents (10:9 the small just whole tone), 186 cents, 200 cents (12TET whole tone), 204 cents (9:8 the large just whole tone), 231 cents (8:7 the septimal major second), and 235 cents. Ligeti uses three JI whole tones and the 12TET whole tone. He also uses two whole tones (186 and 235) that fail to fit either category; these two whole tones are produced by combining horns in F and horns in Eb.

![Whole Tone Comparison, mvt. 1, mm. 1-3](image)

**Figure 4.1 Whole Tone Comparison, mvt. 1, mm. 1-3**

The horns begin the concerto with six distinct whole tones that enter throughout the first three measures and reach their final collection [Db, Eb, F, G] on the fourth beat of m. 3. In contrast to the horns’ differing whole tones and scattered entrances, the flutes, oboe, and bassett horns enter with the same collection [Db, Eb, F, G] (all in 12TET) and a unified attack on the second beat of m. 4, thereby contrasting the 12TET stability with JI fluctuation.

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36 Names for the JI intervals are taken from Harry Partch, *Genesis of a Music* (New York: Da Capo Press, 1974), 68.
The pitch-space expansion in the first section begins with a whole tone (E♭-F) in m. 1 and expands to three octaves plus a fifth (B♭-F) in m. 7. Figure 4.2 shows this expansion and displays the resulting wedge formation. Each row represents a specific pitch; the lowest is B♭1 and the highest is F5. Pitches used in the example are included in the leftmost column as a reference. Each column represents the measure’s metrical subdivision (2+3+4+3). The numbers indicate the beginning of each measure, and the black cells represent the specific duration that each pitch is held.\(^{37}\)

Figure 4.2 displays how the set class (013) is a basis for the first section’s expansion.\(^{38}\) The expansion’s upper line begins on F4 in the third horn in m. 1 and ascends to F5 in the solo horn and first violin in m. 7; it has four iterations of the (013) set. The first iteration is [F,G,A♭], and the second begins on the fourth beat of m. 4 with [A,B,C]. The third and fourth iterations are connected and overlap with the second as well as with each other: [B,C,D] and [D,E,F], respectively. The expansion’s lower line begins on E♭4 in the fourth horn and descends to B♭1 in the tenor trombone in m. 7; it has only has two iterations of

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\(^{37}\) The pitches for Figure 4.2 are rounded to the nearest semitone in the 12TET. This rounding highlights the expansion of the section. Different instruments may perform each pitch, and the pitches may vary slightly as in mm. 1-3.

the (013) set. The first iteration uses \([C, D^b, E^b]\) and overlaps with the second \([B^b, C, D^b]\).

Figure 4.2 Pitch-Space Graph, mvt. 1, mm. 1-7
The arrival of B♭-F at m. 7 is the first cadence in the concerto, and uses cadential techniques that Ligeti employed in other pieces. Ligeti notes: “I have noticed how often I used octaves and tritones (augmented fourths) in marking off sections of formal structures. The sound gets gradually crystallized; and, on reaching an octave or a tritone, it comes to a sudden halt, to go on again a moment later.” Ligeti marks the section’s end at m. 7 with a P5.

The solo horn enters the concerto in m. 4 on the 7th partial and ascends to the 12th partial in m. 7 (Figure 4.3). The horn melody creates duality of both expansion and contraction. The melody represents the section’s pitch-space expansion and ends on the highest note thus far in the concerto. By contrast the melody’s intervals contract (from 335 to 151 cents) as the horn ascends the overtone series.

![Horn in B♭](image)

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**Figure 4.3 Solo Horn Line, mvt. 1, mm. 4-7**

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40 The solo horn performs as a natural horn in B♭ throughout the first movement.
SECTION TWO

The movement’s second section (mm. 9-15, Examples 4.2a and 4.2b) moves from the polyphonic texture of the first section to a more homophonic texture. The accompaniment alternates between the winds (mm. 9 and 13) and strings (mm. 11 and 14). The section’s harmony expands each sonority’s intervallic content, moving from stacked seconds in m. 9 to stacked fourths in mm. 13-14. The horns provide the melodic material for this section, and each subsection of the melody expands in duration and progressively extends into the following subsection. The melody’s harmonic implications suggest motions of a fifth that relate the second section to the concerto’s first cadence.

Figure 4.4 is a reduction of the second section’s accompanying harmonies. Measure 10 and the second chord of m. 13 represent parenthetical breaks in the harmonic expansion and are discussed in further detail below. Except for the G♭3 bass note, the chord [D♭,E♭,F,G♭,G,A,B♭] at m. 9 is voiced in cluster-like seconds. The section continues with a chord voiced with stacked thirds in the strings at m. 11 [B,D♯,F♯,A,C♯,E]. The accompaniment moves back to the winds in m. 13, expanding the voicing again to stacked P4s [A,D,G,C,F,B♭]. The strings resume the accompaniment in m. 14 with another set of stacked P4s [G,C,F,B♭,E♭]. The intervallic voicing for the chords, alternating between winds and strings, expands over the section, moving from seconds (m. 9), to thirds (m. 11), to P4s (m. 13), and a repetition of P4s (m. 14).
Further examination of the pitch-class sets in mm. 9, 11, and 13 reveal connections between these sonorities and the opening section’s set classes (013) and (024). The cluster-like seconds at measure 9 is the set class (013579) and contains the trichordal subsets (013) and (024). The thirds at measure 11 is the set class (023579) and also contains subsets (013) and (024). Measure 13 is the (024579) set, a transpositional combination of (024) at T₅. The bass notes for each of the chords in this section further connect to the set class (013). The pitch-class set [Gb,E,B,A,C,G] belongs to the set class (013568), a transpositional combination of (013) at T₅.

Three considerations lead to the assumption that m. 10 [E,G#,B,C] and the second half of m. 13 [C,G,A,E] represent parenthetical insertions between the previously discussed chords. First, the orchestration of the two chords separates them from the surrounding accompaniment. The chord at m. 10 is scored for oboe, bassett horns, trumpet, and vibraphone, while the chord at m. 13 is scored for horns and tubular bells. Between mm. 9-14, these two chords are the only moments that use percussion. Second, the function of the pitches in m. 13 differs from the other sonorities. The chord at m. 13 includes the melody from the solo...
Example 4.2a György Ligeti, *Hamburg Concerto*, mvt. 1, mm. 9-12
Example 4.2b György Ligeti, *Hamburg Concerto*, mvt. 1, mm. 13-15
and third horn and is the sole inclusion of melodic material in an accompaniment role. Finally, the voicing of the two chords creates separation. The bracketed chords at mm. 10 and 13 are inverted stacked thirds and are the only instances, with the exception of the chord at m. 9, where a stacking of intervals is inverted so that the chord's intervals are not the same (e.g. all thirds (m. 11), all fourths (mm. 13 and 14)).

The harmonic accompaniment in mm. 9-13 serves two purposes: interval expansion alternating between winds and strings, and interval inversion in mm. 10 and 13. The chord at m. 14 serves both purposes. The intervallic expansion in mm. 9-13 should lead to stacked fifths in m. 14; instead, Ligeti alters the expected fifths by inverting the chord and prolonging the fourths from m. 13. Ligeti ends the section with a chord that represents both an interval expansion and contraction of intervals by inversion.

Figure 4.5 excerpts the composite horn melody from the second section. The numbers above the pitches correspond to their partials, and the melody divides into three sections. The solo horn in B♭ plays (a), the first horn in F plays (b), and the third horn in E♭ and solo horn in B♭ play (c) in parallel fifths until the last note.

Figure 4.5 Composite Melodic Material, mvt. 1, mm. 10-15
The composite rising horn line expands in several different ways in mm. 10-15. Subsection (a) is twelve eighth notes long; subsection (b) is thirteen eighth notes long; and the final subsection is thirty eighth notes long before the movement’s final section begins in m. 15. Notice also that subsection (a) “bleeds” into (b) by three eighth notes, (b) into (c) by six eighth notes, and (c) into the third section by nine eighth notes. The individual duration of each subsection expands, and progressively extends into the following material.

Each subsection is composed of two sets of ascending lines. The first subsection has a set of three ascending pitches followed by two ascending pitches, the second has six followed by two, and the third has four followed by six. The first two subsections both contain a longer ascending group followed by a shorter group, while the third subsection reverses this structure with a shorter group followed by a longer group.

Each subsection’s melodic line expands the range of overtones. The first subsection begins on the 3rd partial and climbs to the 9th, the second subsection begins on the 5th and climbs to the 11th, and the third subsection begins on the 3rd and climbs to the 12th. The general melodic contour of this section simply climbs the overtone series, but the ascent, in both number of pitches and higher overtones, expands among each subsection.

The melodic material in Figure 4.5 strongly implies P5. Subsection (a) begins by outlining an F minor chord and quickly moves a fifth higher to end on B♭-F. The final pitch, F, of (a) carries over to the beginning of (b), combining with the first three pitches [A,C,E] of (b) to outline an F-dominant-seventh chord. The
subsection continues and ends on the F-C dyad. Subsection (c) returns to B♭-F on the first dyad and continues with parallel P5s until expanding to a m7 on the last dyad in m. 14. Had the parallel P5s continued, the final dyad would be B♭-F. The final dyad’s alteration changes the expected outcome in a manner similar to the accompaniment’s P4/P5 inversion in m. 14. Figure 4.6 shows the melody’s implied harmonic motion in mm. 10-15. The first subsection begins on F and moves to B♭, the second subsection returns to F, and the third subsection moves to B♭. The implied B♭ in subsection (c) derives from the parallel P5s. Had the parallel P5s continued between horns in E♭ and B♭, the final pitches would be B♭-F. The motion F-B♭ in (a) expands to F in (b) and B♭ in (c).

<table>
<thead>
<tr>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F–B♭</td>
<td>F7–F</td>
<td>B♭–(B♭)</td>
</tr>
</tbody>
</table>

**Figure 4.6 Harmonic Motion, mvt. 1, mm. 10-15**

The melody’s shape and duration in mm. 10-15 exhibit similarities to the lamento technique Ligeti used in his later compositions. Amy Bauer points out that the lament found in Ligeti’s *Horn Trio*, “plays a role in every multi-movement composition after 1982 (with the arguable exception of the *Hamburg Concerto*).”⁴¹ Richard Steinitz offers a clear set of parameters for Ligeti’s lamento motif:

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Ligeti’s ‘lament’ usually exhibits three or four of the following essential attributes:

1. It is a three-phrase melody, the third phrase of extended duration;
2. Each phrase descends mainly in semitones, recovered by upward leaps;
3. Each ends lower and/or starts higher than its predecessor;
4. Notes of greater expressive significance (e.g., after the upward leaps) are intensified harmonically, often by major sevenths;
5. Different versions of this formula exhibit similarly strict rhythmic talea.42

Bauer is correct in her statement that the Hamburg Concerto does not overtly express the lamento motif, although Steinitz mentions that the lamento motif makes a brief appearance in the sixth movement.43 However, to deny the similarities between the lamento motif and the construction of the melody in Figure 4.5 (page 30) would be a missed opportunity for comparison with points 1, 2, and 3 of Steinitz’s list. The melody divides into three sections through changes in instrumentation and the P5 endings of (a) and (b). The third subsection is considerably longer in duration (thirty eighth-notes) than (a) and (b) (twelve eighth notes and thirteen eighth notes). The melody of Figure 4.5 stands in contrast to Steinitz’s second and third statements – it ascends by harmonic series partials and is recovered by downward leaps instead of descending mainly by semitones and being recovered by upward leaps. While each subsection does not always end on a higher pitch than the previous one, the subsections progressively use higher partials. Clearly, the example of Figure 4.5 is not explicitly related to the lamento motif; nonetheless, interesting relationships exist


between the expansion qualities of the two ideas. Both the lamento technique and Figure 4.5 utilize increasing durations and extend the melodic range. Much of the concerto’s melodic material features similar structures that divide into three parts with each part expanding the previous material.

SECTION THREE

The movement’s final section, mm. 15-20, divides into two parts. The first part (mm. 15-17; Example 4.3, page 35) is an ascending line doubled at a minor 7th above, scored for strings, woodwinds, and trumpet. The second part (mm. 17-20; Example 4.4, page 39) consists of a sustained chord played by horns and bassett horns in mm. 17-18. The strings replace the horns in m. 19 and end the movement together with the bassett horns.

Example 4.3 shows the strings from mm. 15-17. The tempo at m. 15 remains unchanged since the beginning of the movement (eighth note = 110) and accelerates over three measures. Ligeti writes stringendo three times in three measures. Each stringendo increases intensity: poco a poco (m. 15), molto (m. 16), and “as if crazy” (m. 17). The tempo acceleration coupled with the increasing intensity of each stringendo intensifies the tempo compression. Ligeti also compresses rhythmic duration over these three measures. Measure 15 begins with ten eighth notes followed by six eighth-note triplets. The second beat of m. 16 compresses the rhythm more, with a quadruplet in the span of three eighth notes, followed by two sets of eighth-note quintuplets. The first quintuplet is in the space of four eighth notes; the second is in the space of three. The rhythmic values of m. 17 are exactly the same as the first three beats of m. 16.
Ligeti contracts both the tempo and rhythmic durations, creating an intense drive to the movement's final chord.

Example 4.3 György Ligeti, *Hamburg Concerto*, mvt. 1, mm. 15-17 (strings)

The melodic contour of mm. 15-17 ascends from low to high (C♯3 to G♯6 for the lower line and B3 to F♯7 for the upper line). Figure 4.7 shows the lower line with marked ascending pitch groups from mm. 15-17. The three measures divide into two sections, with the first section further dividing into three subsections (x, y, and z). These divisions are based on the ascending line’s melodic intervals noted in Figure 4.7. The leap of 10 semitones is only used twice in the three measures, both of which signify the beginning of a new section. The first leap is found between the first two notes of Example 4.3 (Figure 4.7, first staff) and the second leap is Example 4.3, m. 16, b. 3 (Figure 4.7, second staff). Boxes (x) and (y) both contain three groups of ascending pitches and form a
pattern of two ascending pitches followed by two sets of three ascending pitches. Box (z) follows with only one grouping of seven ascending pitches. The second part begins with the 10-semitone leap, followed by one group of three ascending pitches. The second part begins similarly to the first but erodes after the initial two groups. The remainder of the line has two sets of four ascending pitches, followed by one set of six ascending pitches.

**Figure 4.7 Lower Line Pitches, mvt. 1, mm. 15-17**

The pitch groups display expansion on three levels: groups expand within boxes (x) and (y), the number of pitches in each group expands across the two parts, and the second part’s pitch groups expand quicker than the first part. In boxes (x) and (y), the groupings are 2, 3, 3, but in box (z), there is only one grouping of 7. In other words, within boxes (x) and (y) a group of two pitches expands to two groups of three pitches, and within box (z) the number of pitch groups is reduced to one and the number of pitches in that group is increased to seven. Ligeti juxtaposes an increased number of pitches in each group with a reduced total number of groups in subsections (x), (y), and (z). Comparing parts
one and two reveals a quicker move to larger pitch groups. The second part’s pitch groups are as follows: one group of two pitches, one group of three pitches, two groups of four pitches, and one group of six pitches. This second part removes the repetitive (x) and (y) boxes and instead moves to two groups of four pitches. As each line ascends, the intervals generally become smaller, thereby juxtaposing the expanding number of pitches in each ascending group with the contracting intervals of the ascending line.

The third section’s first part has further connections to sets previously used in this movement. The lowest pitch of each ascending group in the first part, [C♯, D, E, F, G, A] forms the set class (013468), which contains the subsets (013) and (024). In addition to this relationship, the first pitches in boxes (x), (y), and (z) form the set class (013).

**LONG RANGE MOTION**

The first movement displays cohesiveness across all three sections. Each section has some form of either the set classes (024) or (013) or has a P5 relationship. Ligeti unifies the movement by referencing all three elements in the final chord’s construction.

The final chord has strong connections to the set classes (013) and (024). The horns and bassett horns play the chord at the end of m. 17. The strings enter in m. 19 (Example 4.4). The horns fade to niente, leaving only the strings and bassett horns in the movement’s final measure. Figure 4.8 shows the chord’s change between mm. 17 and 20. The only difference between the two measures is the octave displacement of A♭/G♯ from the solo horn to the double bass.
Charles Corey believes that the A♭ octave displacement between mm. 17 and 20 is an error, and he discusses how composer George Benjamin explains the displacement:

The bass part should have been one octave higher, so that its G# would be in the same octave as the solo horn’s A♭. This would copy the relationship between the four higher strings and the four obligato horns, and create a smoother transition. The harmonic the contrabass is playing would result in a G# which is 17.5 cents lower than the solo horn’s A♭. The higher G# is theoretically attainable via natural harmonic, although quite difficult to produce. Replacing it with an artificial harmonic could result in the bass and the solo horn sounding exactly the same pitch.44

While this explanation of the octave displacement creates a smoother transition, the score reveals some interesting connections between the final chord and the rest of the movement.

The A♭/G# displacement adds emphasis to the remaining pitches. The top three notes [B,C,D] form the set class (013), while the lower three notes [Db, Eb, F] form the set class (024). Both sets play an integral role throughout the movement. The whole-tone set class (024) opens the movement in mm. 1-4 (see Figure 4.1, page 22) and the set class (013) is seen in the expansion of mm. 1-7 (see Figure 4.2, page 24).

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44 Corey, “Pitch and Harmony”, 162.
Example 4.4 György Ligeti, *Hamburg Concerto*, mvt. 1, mm. 17-20
In addition, both sets play an important role in the accompaniment of the second section and the first part of the third section (see Figure 4.4, page 27).

Ligeti uses the P5 relationship in the second section’s melodic material as well as at structural points throughout the movement. Figure 4.9 notates the movement’s harmonies and shows implied fifth relationships below the staff.

![Figure 4.9 Structural Harmonic Motion, mvt. 1](image)

The movement opens with the pitches E♭-F. These pitches could imply an F dominant-seventh chord, an implication that gains strength by a ‘resolution’ to B♭-F in m. 7. The second section begins with stacked seconds in m. 9. These pitches are contained in the E♭ overtone series (partials 7-12) and imply a shift to E♭. Ligeti ends the second section (m. 14) with P4s; when inverted, they become stacked P5s beginning on E♭ and prolong the E♭ area from m. 9-14. The final chord combines the set classes (024) and (013) used throughout the movement. The pitches in the (024) are [D♭,E♭,F] and correspond to partials 7-9 of the E♭ overtone series. The (013) pitches are [B,C,D] and correspond to partials 11-13 of the F overtone series. Ligeti returns to the opening two pitches by combining the E♭ and F overtone series. The movement begins with F (m. 1), moves a P5
to B♭ (m. 7), moves another P5 to E♭ (mm. 9-14), and ends by combining F and E♭ (m. 20). This motion shows an expansion (wedge) where B♭ is the center of two P5s (F and E♭) on either side. In addition to the P5 expansion, the movement’s opening and closing moments combine E♭-F, compressing the P5 expansion. The first measure simply uses the two pitches in the opening dyad, while the final chord combines the implied E♭ and F overtone series.
CHAPTER 5: MOVEMENT SEVEN

The seventh movement (Examples 5.1a and 5.1b), *Hymnus*, is a chorale for the four natural horns supported by percussion and strings with defined and undefined pitches. The horns play overlapping four-note flutter-tongued phrases that expand or contract in length after m. 7. The movement divides evenly into two sections, each lasting seven and a half measures. Ligeti connects the final movement to the first movement, providing closure as well as additional examples of expansion/contraction.

**METER**

The seventh movement’s 5/4 meter is similar in its division to the first movement’s 12/8. Ligeti alternates the quarter note subdivision between a measure of 2+3 and a measure of 3+2, thereby creating a rhythmic expansion/contraction over two measures. Moreover, this metric pattern is itself an expansion compared to Movement 1. The eighth note division of 12/8 expands to quarter notes in 5/4, and the one measure division of 2+3+4+3 now expands to a two-measure division of 2+3 and 3+2.

**DOUBLE BASS LINE**

The double bass line doubles the fourth horn at an octave below in mm. 1-8, the third horn at the unison in mm. 8-13, and the fourth horn at the unison
Example 5.1a György Ligeti, *Hamburg Concerto*, mvt. 7, mm. 1-5
Example 5.1b György Ligeti, *Hamburg Concerto*, mvt. 7, mm. 6-15
from m. 13 to the second to last note, where it doubles the first and third horns. The first part of the bass line uses pitches contained within E overtone series (mm. 1-8), and the second part uses pitches contained within F overtone series (mm. 8-15). Figure 5.1 shows the bass line with corresponding overtones from each respective series written above each pitch. The first part divides into three subsections: (a), (b), and (c). The division of the boxes is based on the bass line’s ascent. The first two sections begin on G\# and ascend the overtone series, with the exception of the second pitch in (a). The final box, (c), halts the ascent in box (b), climbs slightly, and then descends, beginning the second part of the bass line. The bass line’s divisions are strikingly similar to the horn melody from the first movement’s third section (see Figure 4.7, page 36). In both examples the phrase divides into two parts, and the first part divides further into three subsections. The three subsections increase duration and ascend in pitch. The two figures also feature a third subsection that separates itself from the first two. The third subsection in Figure 4.7 eliminates the pitch groups of the first two subsections; the third subsection in Figure 5.1 breaks from the ascending pitches of the first two subsections and has an equal amount of descending pitches.

The bass line’s second half moves from pitches contained in the E overtone series to pitches of the F overtone series. The line begins in m. 8 on the sixth partial of the F series and ascends for the remainder of the movement, ending on the thirty-second partial. Ligeti ends the concerto by climbing the overtone series to great heights, as if the music extends toward infinity. To further emphasize this feeling of infinite expansion, Ligeti instructs “to stop
suddenly without an accent” at the end of the score. He often ends compositions and sections with sudden breaks; as Michael Hicks points out, Ligeti uses the phrase “as if torn off” to suddenly end compositions, citing Continuum, Coulée, Second String Quartet, Ramifications, and Chamber Concerto as examples. Clendinning also discusses how Ligeti ends sections by breaking a registral expansion at its widest point in his pattern-meccanico compositions.

CHORALE

The movement’s first half is structured around the D half-diminished seventh chord and the (0258) set class. Figure 5.2 shows the sets for each

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Figure 5.2 Chorale Set Classes, mvt. 7, mm. 1-8

The D half-diminished seventh chord is the first chord in mm. 1, 3, 6, and 8. The chord’s repetition and structural location (the section’s first and last chord) suggests its importance to the section’s structure. Figure 5.3 shows the voice leading for the chord across the first section. Regardless of voicing or instrumentation, the chord always has the same intonation: D is 31 cents flat; F is tempered; G# is 14 cents flat; and C is 2 cents sharp. The voicing of this structural chord provides another example of expansion/contraction. Ligeti voices

\[\text{Figure 5.2 Chorale Set Classes, mvt. 7, mm. 1-8}\]

Both Figures 5.2 and 5.4 arrange the pitches from highest to lowest regardless of instrumentation and supply overtone partials above each pitch. As a result, a line may have the same overtone partial on different pitches. For example, Figure 5.2, m. 4, lowest line, both D and E♭ are marked as the seventh partial. The D is played by the fourth horn in E and the E♭ is played by the third horn in F. Since both are the lowest sounding pitch of that sonority, they are on the lowest line.
the chord so that the outer intervals are swapped between the first two and last
two chords. The first two chords have a tritone as the lowest interval and a P5
and P4 as the highest. The order of intervals is reversed in the last two chords.
The third and fourth chords have the tritone as the highest and a P4 and P5 as
the lowest. Ligeti contracts the highest interval of the first two chords (P5-P4) and
expands the lowest interval of the last two chords (P4-P5). In addition, Ligeti
contracts the interval of the outer voices in the first and last chord. The first chord
is an octave plus a diminished fourth, and the final chord is an octave plus an
augmented second.

![Figure 5.3 D Half-Diminished Seventh Chord, mvt. 7, mm. 1-8](image)

The movement’s second half begins on the second chord of m. 8 and
coincides with the double bass’s switch from the E to F overtone series. Figure
5.4 shows the reduction of the horn lines.\(^{49}\) Between each staff is the cent value
for each vertical interval, and partials are notated above each pitch.

The final chord serves as a focal point for the movement. All four lines
ascend to either an E or F, the intervals between the four lines contract to end on
a 12TET half step, and the bass line ascends to its highest pitch in the
movement.

\(^{49}\) See footnote 48.
The first and seventh movements have an interesting relationship that frames the entire composition. The seventh movement provides closure to the concerto and connects the expansion/contraction concept between itself and the first movement.

Ligeti structures the first movement’s third section (Figure 4.7, page 36) and the seventh movement’s bass line (Figure 5.1, page 46) in a similar way. Both examples divide into two larger parts, and the first part further divides into three subsections. Each of the three subsections display similar tendencies related to the lamento technique.

Figure 5.5 shows the expansion/contraction between the first and seventh movement as it relates to pitch-space expansion. The first movement expands the opening two pitches, E♭-F, to a P5, B♭-F, in m. 7 (see Figure 4.2, page 24). The seventh movement contracts the chords beginning in m. 8 to E-F on the final chord (Figure 5.4, page 49). In addition to the pitch space expansion/contraction...
in the outer movements, the opening and closing pitches provide a further example of contraction. The whole tone E\textsubscript{b}-F of the concerto’s opening measure contracts to E-F at the end of the work.

**Figure 5.5 Expansion/Contraction between mvts. 1 and 7**
CONCLUSION

Expansion/contraction is a unifying technique that Ligeti uses throughout the \textit{Hamburg Concerto}'s rhythmic, melodic, and harmonic construction. This technique provides clarity to the concerto and helps draw connections among disparate musical sections and ideas.

The first and seventh movement's metrical subdivisions expand/contract the pulse. The expansion/contraction not only takes place in individual movements, but also when the movements are compared to each other. The first movement divides the pulse into $2+3+4+3$ eighth note groups, and the seventh movement groups quarter notes into alternating measures of $2+3$ and $3+2$. In addition to each movement's metrical expansion/contraction, the beat unit (eighth notes vs. quarter notes) and expansion completion length (one measure completion vs. two measure completion) display a metrical expansion between the movements.

Many figures illustrate expanding phrase lengths, e.g., Figures 4.5 (page 30), 4.7 (page 36), and 5.1 (page 46). Figure 4.5 illustrates three phrases in which the length of each phrase expands. In addition, the last pitch in each phrase progressively extends into the following phrase or section. Figures 4.7 and 5.1 show a first phrase that divides into three subsections of shorter lengths, followed by a second phrase with a single longer section. In contrast to the expanding phrase length in these figures, Ligeti creates tempo and rhythmic
compression in the first movement mm. 15-17 (page 35) by using progressively faster rhythmic durations and by increasing the intensity of acceleration.

Much of the natural horns’ melodic writing is based on an ascending overtone series (see Example 1.2a, mm. 1-4, page 6; Figure 4.3, page 25; and Figure 4.5, page 30). These examples feature melodic lines that naturally contract intervals as the overtone series rises. The first movement’s opening (mm. 1-7) combines the intervallic contraction of Figure 4.5 with an expanding wedge that moves from a whole tone in m. 1 to a P5 across three and a half octaves in m. 7.

The first movement’s harmonies also expand/contract in several ways. The second section’s accompaniment (see Figure 4.4, page 27) expands the harmonic intervallic content, moving from stacked seconds to stacked fourths. Set classes (024) and (013) underlie many of the first movement’s harmonies and combine to aid in its harmonic expansion. Set class (024) creates conflict between the horns’ JI and the orchestra’s 12TET (mm. 1-4); set class (013) appears in the opening wedge’s construction (mm. 1-7). The two set classes then combine in the final chord’s construction (m. 20), as well as in the accompaniment’s harmony (mm. 9-14). Ligeti uses the first movement’s P4/P5 relationships E♭ (mm. 9-14) – B♭ (m. 7) – F (m. 1) to create an expanding wedge of P5s. The F-E♭ combination in the movement’s final chord collapses the beginning and ending points of the expanding P5 progression.

The outer movements show expansion/contraction between the concerto’s beginning and ending. The concerto opens with an expanding wedge in the first
movement (mm. 1-7) and closes with a contraction of intervals among the natural horns (mm. 8-15). Ligeti also contracts the first movement’s opening whole step (Eb-F) to a half step (E-F) in the seventh movement’s final chord. These examples of expansion/contraction connect the outer movements and frame the entire concerto.

Ligeti’s final composition reveals the unification of disparate musical sections and ideas through expansion/contraction of rhythmic, melodic, and harmonic constructions. While the *Hamburg Concerto* use techniques found in Ligeti’s earlier compositions, it also embarks on new adventures, exploring possibilities and complexities found in just intonation and the use of the natural horn.
BIBLIOGRAPHY


Appendix A – Frequently Used Overtone Series

The + and – symbols indicate that the notated pitches are higher or lower than the 12TET tuning system.
October 8, 2013

Andrew Hanson
2207 Autumn Lane
Marion, IL 62959

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