1 Virtual Music

Virtual music represents a broad category of machine-created composition which attempts to replicate the style but not the actual notes of existing music (Cope 1993). As will be seen, virtual music has existed in one form or another for centuries. With the advent of computers. however, the potential for virtual music has multiplied exponentially. In this chapter, I provide a brief background of virtual music and then ask you to participate in three listening tests which will challenge your ability to recognize human-composed vs. computer-composed music and to recognize actual Bach and Chopin vs. computer-composed music in their styles.

Early Examples

The figured bass, popular during the Baroque period of music history (1600–1750), demonstrates how composers and performers use combinations of notated music, period style constraints, and performer choice to produce a diversity of results and yet adhere to a composer's style. As in other examples of virtual music, each performance differs, yet each retains its stylistic integrity.

Figured basses constitute the notation for most Baroque basso continuos, the combination of a keyboard instrument (clavier or organ) and a reinforcing sustaining instrument (bass gamba, violoncello, or bassoon). Typically the keyboardist uses a notated bass line, or a bass-line and treble-line depending on the ensemble requirements, above which they freely but stylistically improvise.

Figure 1.1 shows a very simple figured bass in C major. The arabic numerals below certain notes indicate inversions of chords. Performers assume root position or 5/3 intervals above the bass-note unless otherwise instructed. The bass gambist or cellist plays the line as written. The keyboardist, however, must complete the implied chords in the proper key in a manner consistent with the style, yet original in spirit. In essence, the figured bass represents an algorithm or recipe, the realization of which depends upon the application of performance practice and performer style improvisation.

Figure 1.2 provides a very simple realization of the figured bass of figure 1.1. The chords here consist of triads (three-note chords built in thirds) or seventh chords (four-note chords built in thirds) with some notes doubled in octaves. The Baroque period constraints governing which notes should be doubled, as well as how notes should move, one to another, are quite strict and too numerous to present here. The important thing, at least for our purposes, is to understand that the music in figure 1.2 represents only one of many possible realizations of the figured bass of figure 1.1.

Figure 1.3 shows another possible correct realization of the figured bass shown in figure 1.1. Again, the music here consists of triads and seventh chords with some

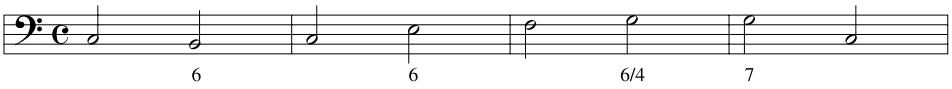


Figure 1.1
A simple figured bass in C major.

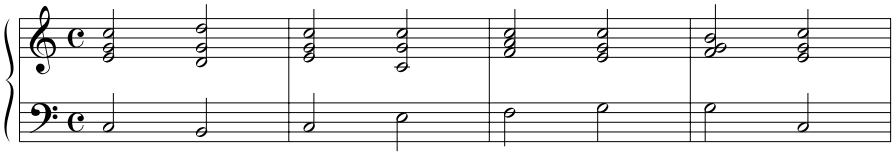


Figure 1.2
One possible realization of the figured bass in figure 1.1.

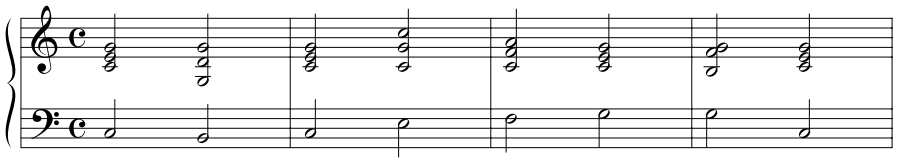


Figure 1.3
Another correct realization of the figured bass shown in figure 1.1.

notes doubled. Comparing figure 1.3 with figure 1.2 demonstrates both their similarity (same note names in each chord) and differences (notes in different registers). In essence, then, we have two different examples of music, in similar block chord style, derived from the same core figured bass.

Figure 1.4 presents a more Baroque-style realization of the figured bass in figure 1.1. In fact, the melody shown in this example might typically be one of the provided elements. While this example tends to resemble figure 1.2 in chord spacing it nonetheless represents a third and distinctly different realization of the figured bass in figure 1.1. In all of these cases, the music has adhered to the constraints of the period using a combination of given music and performer choice, as well as a recombination of right notes and motives.

The *Musikalisches Würfelspiel*

One of the first formal types of algorithms in music history, and another good example of virtual music, is the eighteenth-century *Musikalisches Würfelspiel*, or musical dice game. The idea behind this musically sophisticated game involved

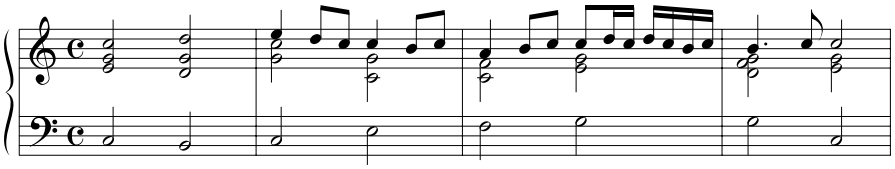


Figure 1.4
A more typical realization of the figured bass presented in figure 1.1.

composing a series of measures of music that could be recombined in many different ways and still be stylistically viable—virtual music. Following this process, even a very simple piece becomes a source of innumerable new works. A typical *Würfelspiel* of sixteen measures, for example, yields 11^{16}, or roughly forty-six quadrillion works, with each work, although varying in aesthetic quality, being stylistically correct (Cope 1996). Composers of *Musikalische Würfelspiele* included Johann Philipp Kirnberger, C. P. E. Bach, Franz Josef Haydn, Wolfgang Amadeus Mozart, Maximilian Stadler, Antonio Callegari, and Pasquale Ricci, among others (see Cope 1996).

Figure 1.5 provides an example of a matrix from a typical *Musikalisches Würfelspiel*, this one attributed to Franz Josef Haydn. The numbers down the left side of the matrix in figure 1.5 represent the eleven possible results of the toss of two dice (2–12). Each number in the matrix links to a previously composed measure of music. Each vertical column of the matrix indicates successive measure choices (A–H here representing an eight-measure phrase). To get a first measure of music, one tosses the dice, locates the resulting number on the left of the matrix, and then looks up the corresponding measure in vertical column A in an associated list of measures of music (not shown here due to space limitations). Subsequent tosses for columns B through H complete an initial phrase, with further phrases produced in the same way using different matrices and musical correlates. A resulting minuet appears in figure 1.6.

Composers of *Musikalische Würfelspiele* created the various measures in such a way that any of the measures in one vertical column would successfully connect with any of the measures in the column to their immediate right. This becomes fairly clear when the actual music for each measure is aligned as in the matrix. However, the music of a *Musikalisches Würfelspiel* is typically arranged arbitrarily so that it is not at all clear that the choices for each measure have the same general musical function. These apparently random arrangements no doubt made such games seem all the more fantastic in the eighteenth-century parlor where they were often played.

A number of composers employed *Würfelspiel* combinatorial techniques to create large-scale works. For example, Josef Riepel (1755) developed "melodic combinations in the construction of minuets, concertos, and symphonies. Within a given model

	A	B	C	D	E	F	G	H
2	96	22	141	41	105	122	11	30
3	32	6	128	63	146	46	134	81
4	69	95	158	12	153	66	110	24
5	40	17	113	85	161	2	159	100
6	148	74	163	45	80	97	36	107
7	104	157	27	167	154	68	118	91
8	152	60	171	53	99	133	21	127
9	119	84	114	50	140	86	169	94
10	98	142	42	156	75	129	62	123
11	3	87	165	61	135	47	147	33
12	54	130	10	103	28	37	106	5

Figure 1.5
A matrix for a first phrase from a *Musikalisches Würfelspiel* attributed to Franz Josef Haydn.

he seeks to achieve optimum effects by substituting figures, phrases, and cadences'' (Ratner 1970, p. 351).

The popularity of *Musikalische Würfelspiele* was extensive during the eighteenth century, particularly in Germany. Each game was capable of producing so much new music that the ''entire population of eighteenth-century Europe, working a lifetime on these games could not exhaust the combinations'' (Ratner 1970, p. 344). The creation of *Musikalische Würfelspiele*, however, did not extend beyond the Classical period nor did the form have much serious consequence. (For more on the *Musikalisches Würfelspiel*, see Eleanor Selfridge-Field's discussion in chapter 11.)

More Recent Examples

Popular music retains many of the same notational properties of the previously discussed Baroque period figured bass and shares a similar objective for virtual music: the ability to create music in many different guises while maintaining the style intended by the composer. Most popular music notation provides only a single line and chord symbols from which performers improvise their own versions of the music within the constraints provided by the implied chords. Figure 1.7 gives an example of this. Note that popular music uses a melody rather than a bass-line and note names representing chords instead of arabic numerals for inversions. However, the same kind of recombinatory principles pertain as those in figured bass.

As with Baroque figured bass, the performer of popular music is expected to supply a large number of the actual notes for the resulting music. Performers are

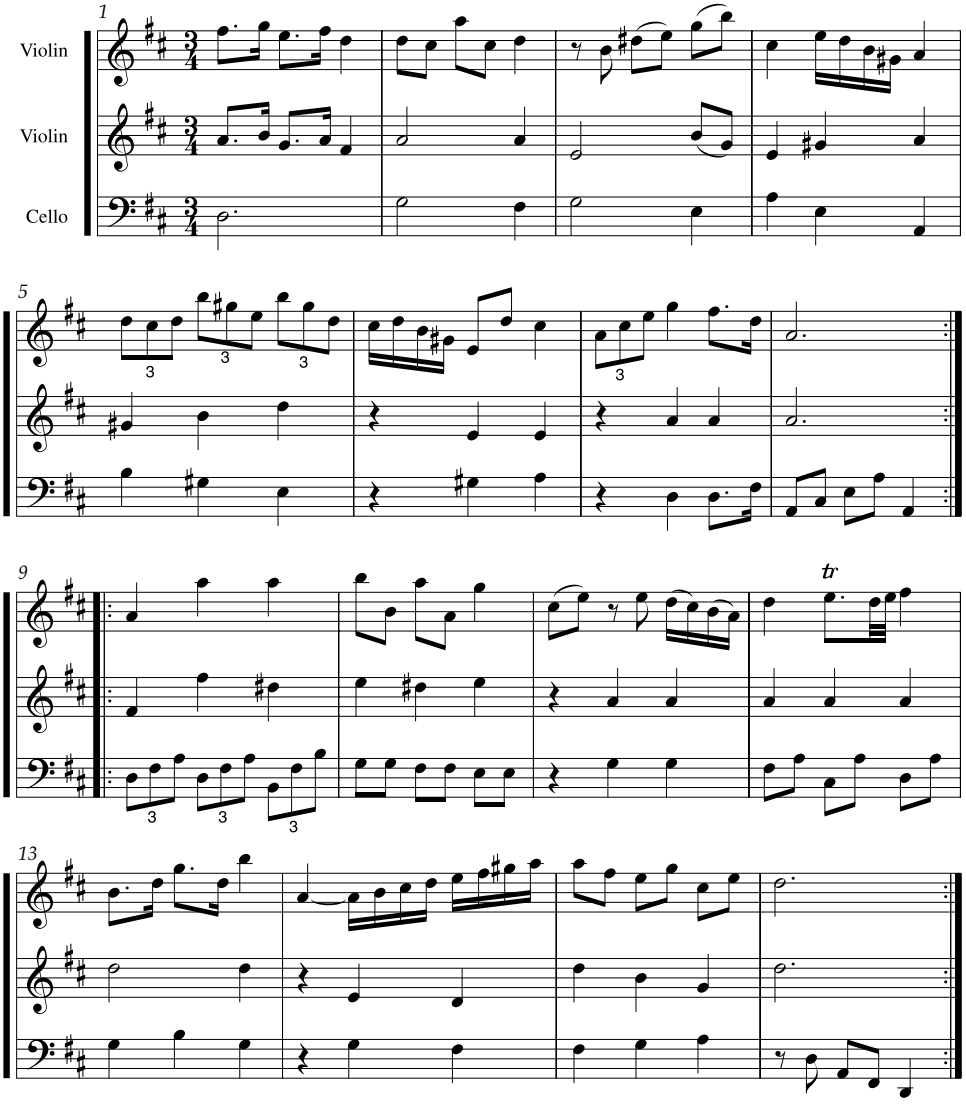


Figure 1.6
A resulting minuet derived from the *Musikalisches Würfelspiel* attributed to Franz Josef Haydn.

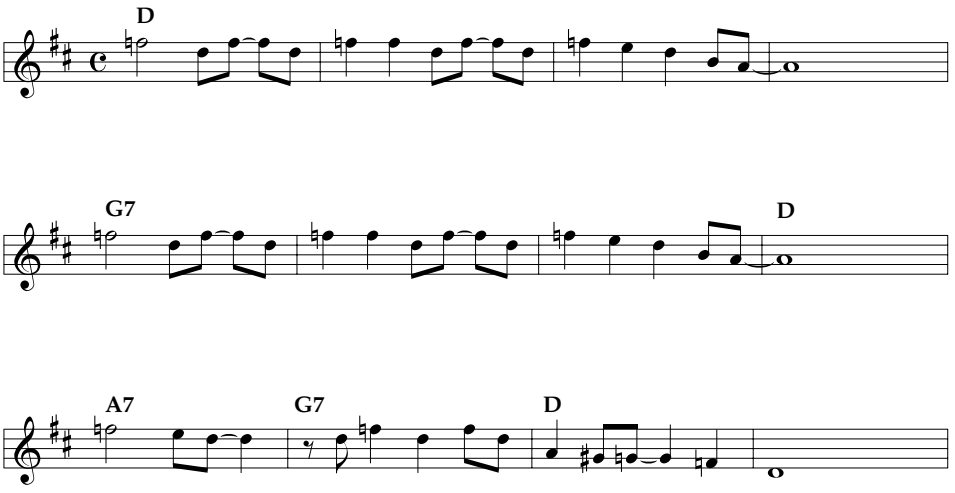


Figure 1.7
An example of popular twelve-bar blues music shorthand notation.

also expected to adhere to a logical style implied by the music as well as (often) by the title and lyrics. Thus, many different realizations can occur. Figure 1.8 presents an extremely vanilla example. Here the chords are simply iterated, much as they were in figure 1.2, the first realization of the figured bass of figure 1.1. The intended style of music barely survives this rather stagnant interpretation. On the other hand, figure 1.9 gives a much more plausible realization. Here, the left-hand figuration and the right-hand chords provide much of what audiences know as blues style. Both figures 1.8 and 1.9 are correct. The latter example, however, adheres to the style implied by the rhythm and notes of the original notation in figure 1.7.

In the Baroque figured bass and contemporary popular music we find many notational and conceptual similarities. First, both notations provide two types of information: musical notation which requires accurate performance and a shorthand for realization or improvisation. Second, both forms have constraints. In the figured bass examples, these constraints take the form of voice-leading rules and the recombination of relevant motives and musical ideas. In the popular music example, these constraints result from recombinations of possible chord notes in various registers and relevant stylistic limitations. Lastly, both examples provide performers with a fairly wide range of freedom regarding what and how many actual notes will occur and when. In short, these examples have a given part, a derived or implied rules part,

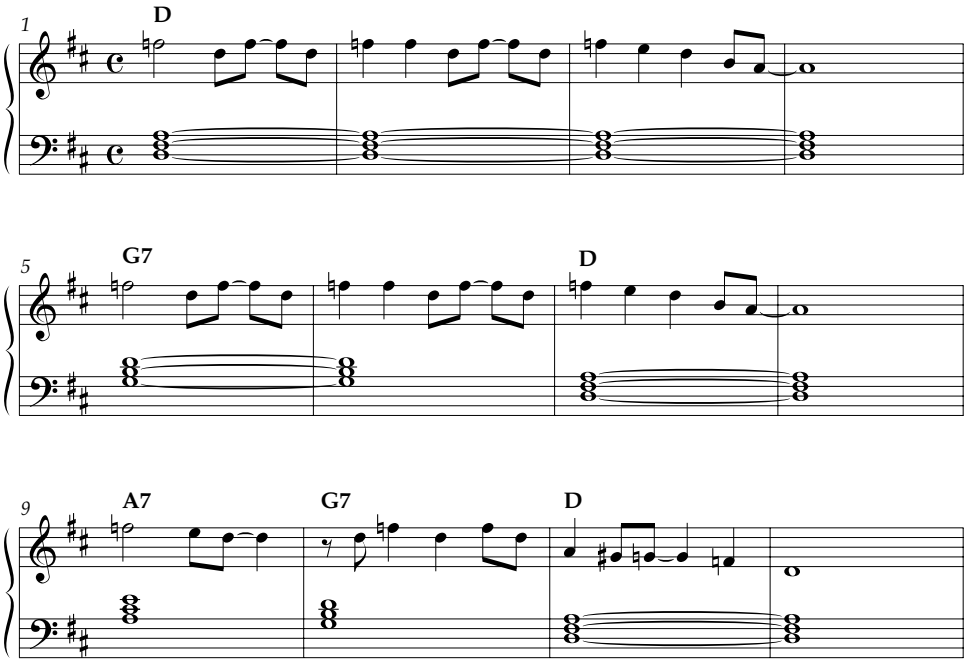


Figure 1.8
One realization of the notation in figure 1.7.

and a free part. Combined, these three elements foster the creation of innumerable style-specific realizations of the same basic given materials.

In the past fifty years or so, computers have provided the principal source for virtual music. One of the pioneers of using computers in this way was Lejaren Hiller who, in collaboration with Leonard Isaacson, wrote programs for the Illiac computer. Hiller and Isaacson's work led to the composition of the *Illiac Suite for String Quartet* in 1956 (Hiller and Isaacson 1959), one of the first such works written using computers. This innovative composition incorporates numerous experiments involving style simulation.

Iannis Xenakis uses mathematical models such as probability laws, stochastics (a mathematical theory that develops predictability from laws of probability), game theory, and Markov chains (Xenakis 1971) to compose his music. Xenakis's works often interweave his own intuitive composition with passages created by his various algorithmic computer programs which ultimately contribute to his overall musical

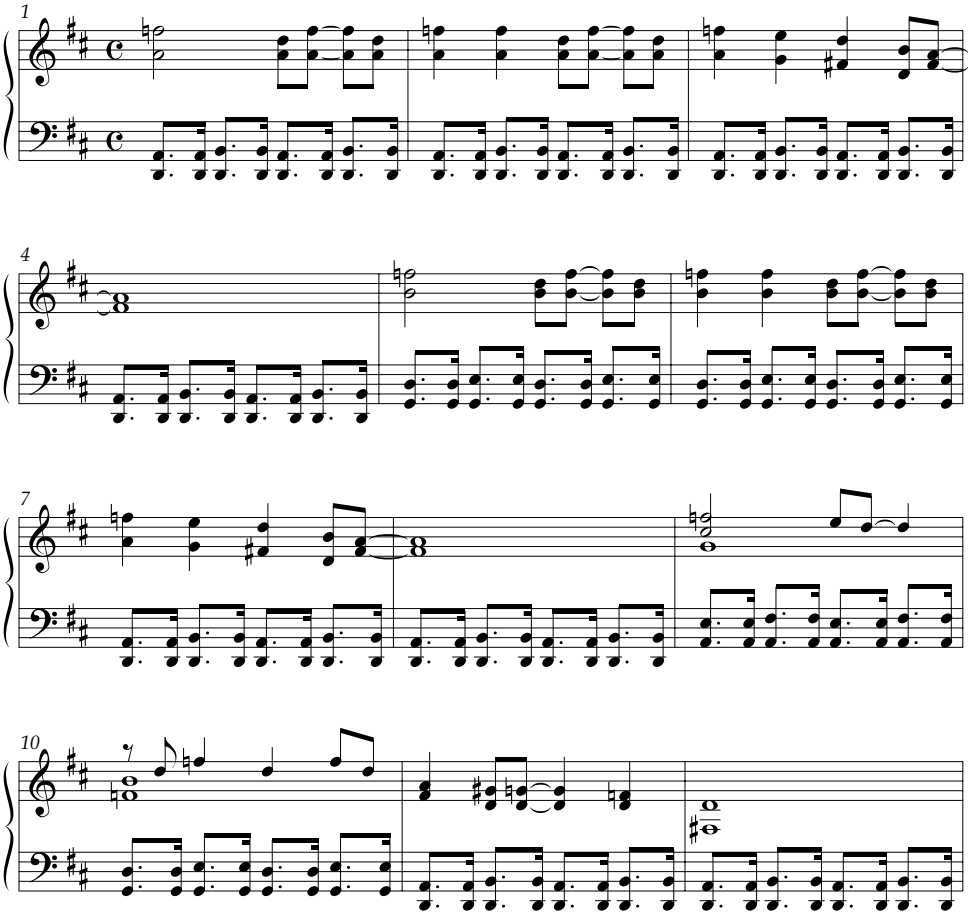


Figure 1.9
A much more stylistic realization of the notation in figure 1.7.

style. Considered by many as the progenitor of computer composition, Xenakis often alters computer-generated material to fit his musical needs.

Kemal Ebcioğlu (1987, 1992) used predicate calculus to develop more than 350 rules of voice-leading for creating chorales in the style of J. S. Bach. His program effectively portrays the basic techniques of four-part writing. William Schottstaedt created Counterpoint Solver (1989) which closely follows the exposition of species counterpoint as given by J. J. Fux around 1725. Schottstaedt's program produces logical counterpoint in a generic sixteenth-century style.

Charles Ames's Cybernetic Composer (1992) creates music in popular and jazz styles. Unlike the programs by Ebcioğlu and Schottstaedt which harmonize given melodies, Cybernetic Composer creates coherent melodies over basic chord progressions. Whether composing rock or ragtime, Cybernetic Composer often produces quite musical results. Christopher Fry's program Flavors Band (1993) produces generic jazz improvisations. Paul Hodgson's software, called Improvisor, mimics, in particular, the styles of Charlie Parker and Louis Armstrong. Improvisor composes in real time and because it mixes rhythmic and melodic patterns includes an element of improvised performance in its output.

Ulf Berggren's doctoral dissertation, *Ars Combinatoria: Algorithmic Construction of Sonata Movements by Means of Building Blocks Derived from W. A. Mozart's Piano Sonatas* (1995), takes snippets of music from sonatas by Mozart and recombines them according to what the program interprets as sensible musical orders. While the music produced often reveals both its sources and the seams by which these sources connect, the program does create occasional moments of interest. Figure 11.7 shows the opening of a first movement Mozart-like sonata as presented in Berggren's dissertation.

Christopher Yavelow's *Push Button Bach* program produces two-part inventions, arguably in the style of J. S. Bach. Figure 1.10 shows one of the works produced by this program. New output is rendered directly in music notation, one of the most attractive features of Push Button Bach. Purists will no doubt argue that this program's output falls far short of being truly Bach-like in style. Its simplicity and accessibility make it nonetheless one of the first such programs freely available over the Internet.

More recently, Dominik Hörnel and Wolfram Menzel (1998) have used neural nets to create music with stylistic similarities to composers of the Renaissance and Baroque periods, focusing primarily on harmonization and melodic variation. Their work departs from previous approaches based on programmed rules. Hörnel and Menzel provide their program with one or more examples of music which the neural network then "learns" through a process called backpropagation.

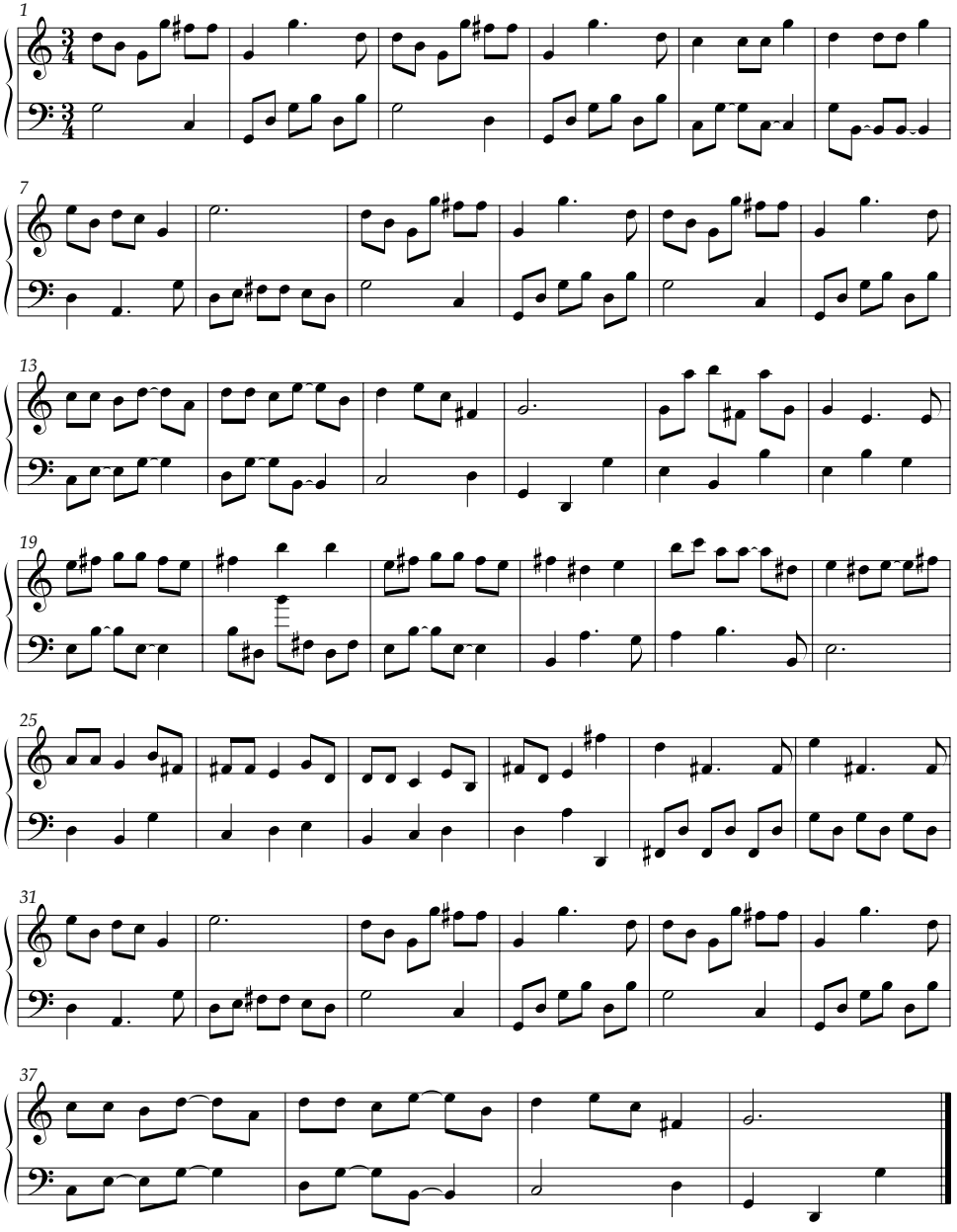


Figure 1.10
A two-part invention arguably in the style of J. S. Bach by Christopher Yavelow's Push Button Bach program.

The Game

To initiate this current study of virtual music I will use a version of what I have called since my youth The Game. The Game requires players to identify styles and composers of complete examples of music. In each of the three versions of The Game played here, four examples of music are used in both musical notation and in performance on the CD accompanying this book. Game players may listen to each work as many times as desired. The only rule requires players to not review music by the original composers (e.g., the Bach chorales or the Chopin mazurkas here). Players who recognize one or more of the examples should disqualify themselves from playing that particular version of The Game.

The first example of The Game involves recognizing human-composed music as distinct from machine-composed music. At least one of the four examples shown in figure 1.11 was composed by a human composer and at least one was composed by the Experiments in Musical Intelligence program. I have removed articulations, dynamics, and trills from the human-composed example(s) since the version of Experiments in Musical Intelligence that composed its example(s) did not have the capability of including these elements in its output. Many ornamentations aside from trills have been included but appear as normal rhythmic notation rather than as smaller notes. In all cases, these ornaments occur *before* the beat rather than on the beat, which may or may not be the best performance practice for this music.

I have chosen works from the literature that are not generally well known. I have also tried to limit my choices to music which I judge as average rather than exemplary in quality so as not to give either type of music an advantage. Mixing weak human-composed music with strong virtual music would simply fool listeners, whereas my real objective here is to determine whether listeners can truly tell the difference between the two types of music. A score of 50 percent thus represents a more significant indicator of listener lack of discrimination than a score of 100 percent in *either* direction.

As mentioned previously, each of the examples appears on the CD accompanying this book. For readers having the ability to perform the examples at the keyboard, playing through each example in the figure may also provide hints as to the origins of the works. Be careful, however; human composers often have different hand sizes and capabilities and thus awkward fingerings and so on do not necessarily indicate machine composition. All impossible-to-play chords should be rolled from bottom to top rather than played simultaneously. Other indicators, such as large leaps, unusual key signatures or accidentals, metric changes, and so on, may or may not be part of a

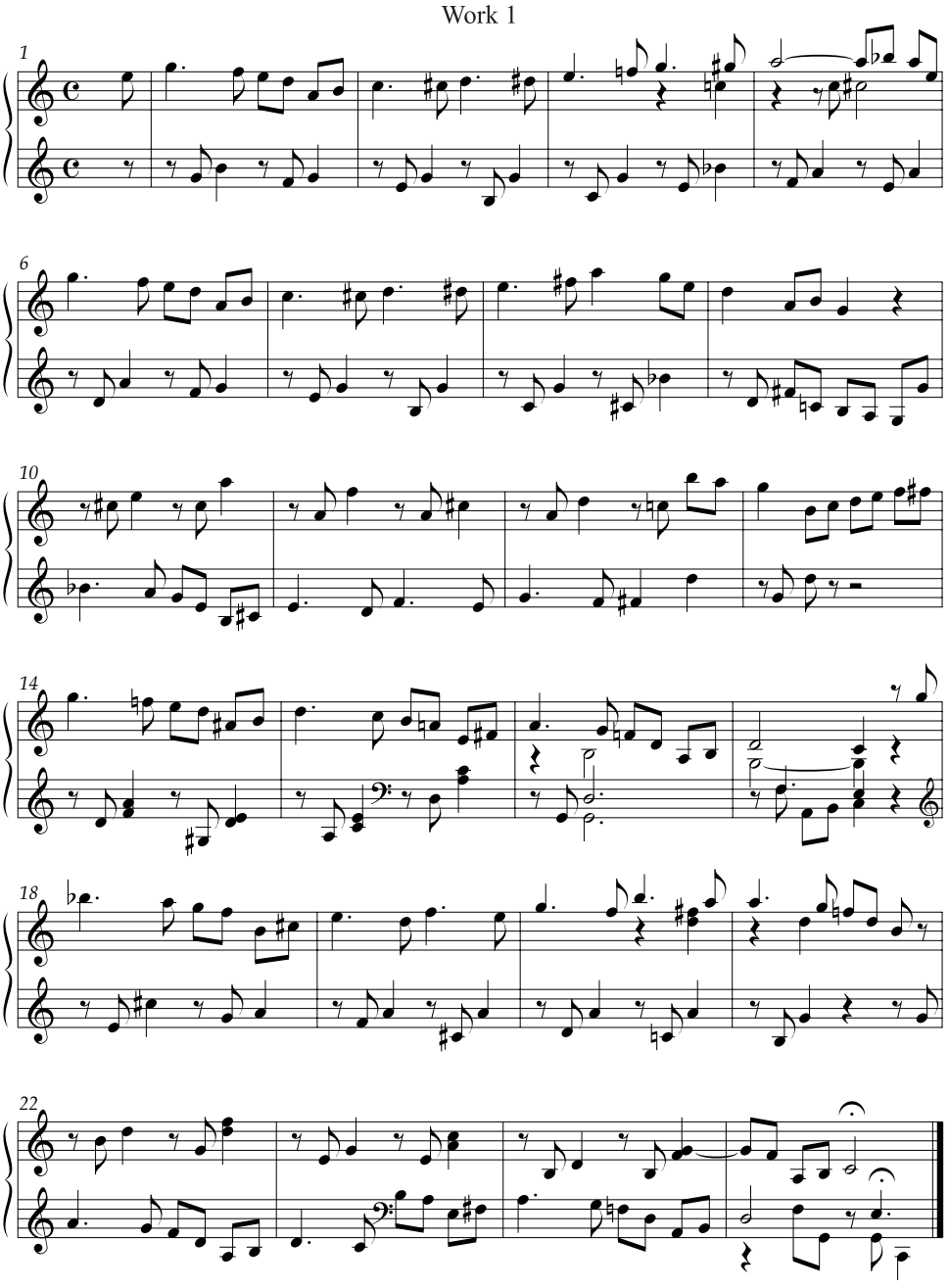


Figure 1.11
Four examples of music, at least one of which was composed by a human composer and at least one of which was composed by the Experiments in Musical Intelligence program.

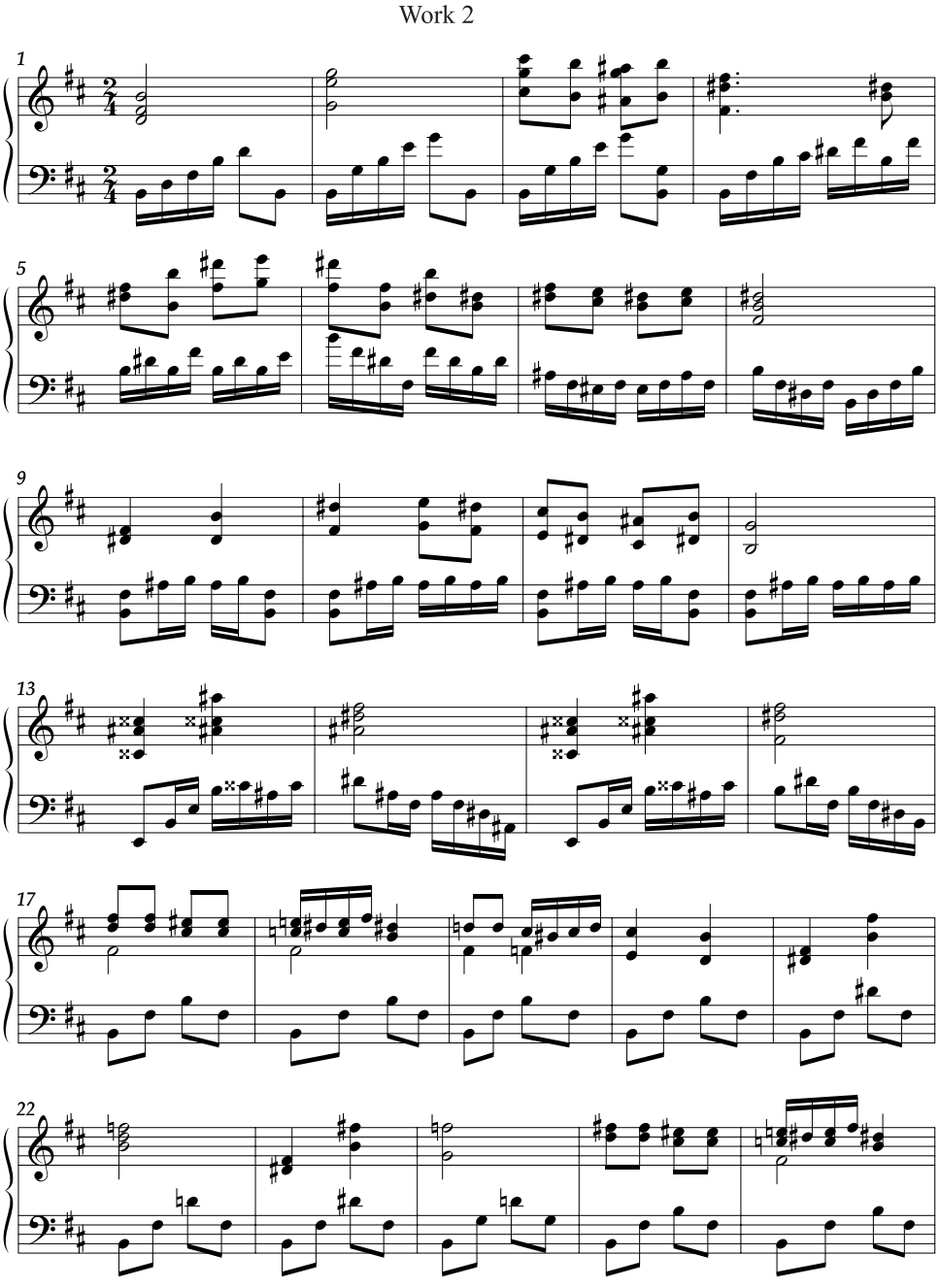
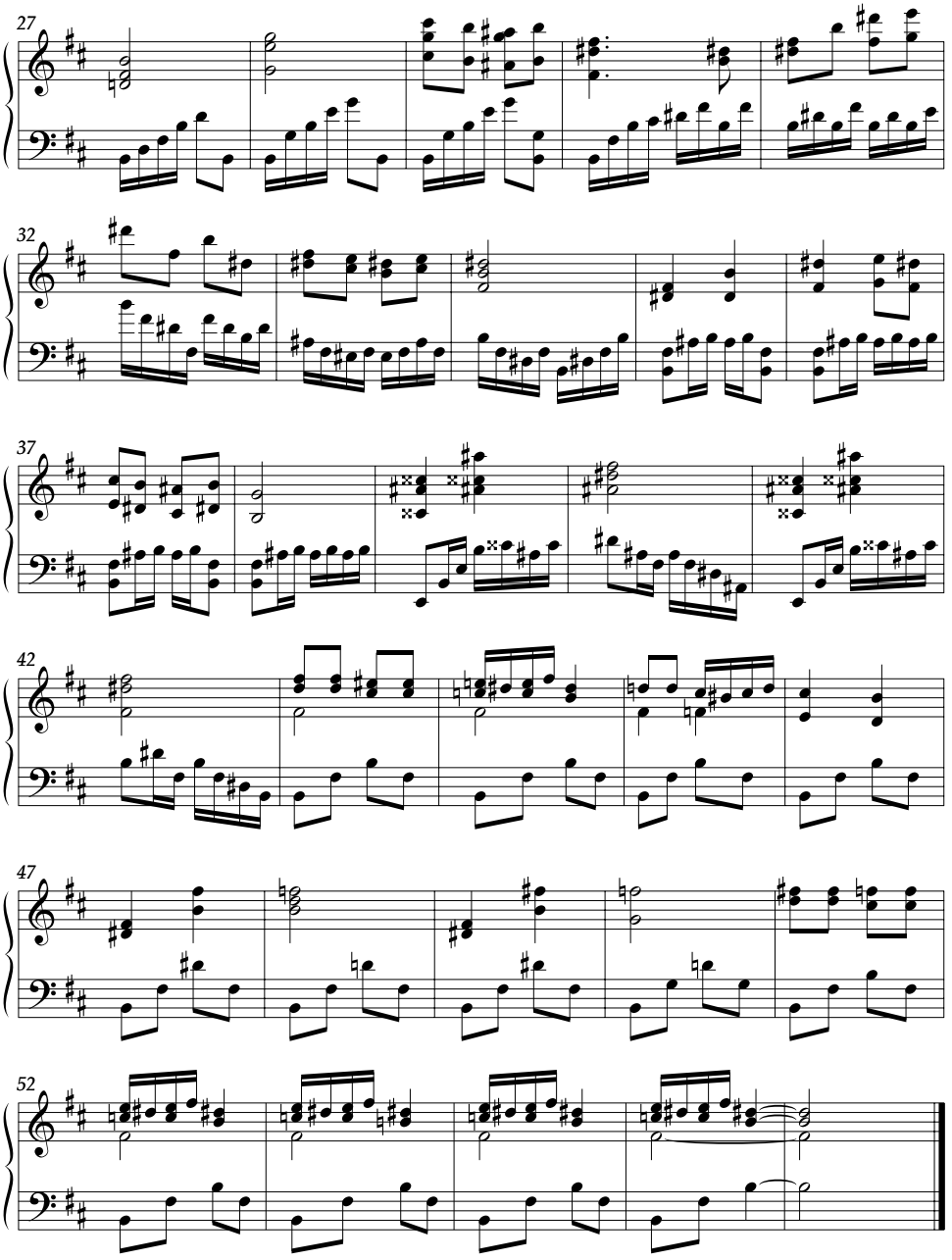


Figure 1.11 (continued)



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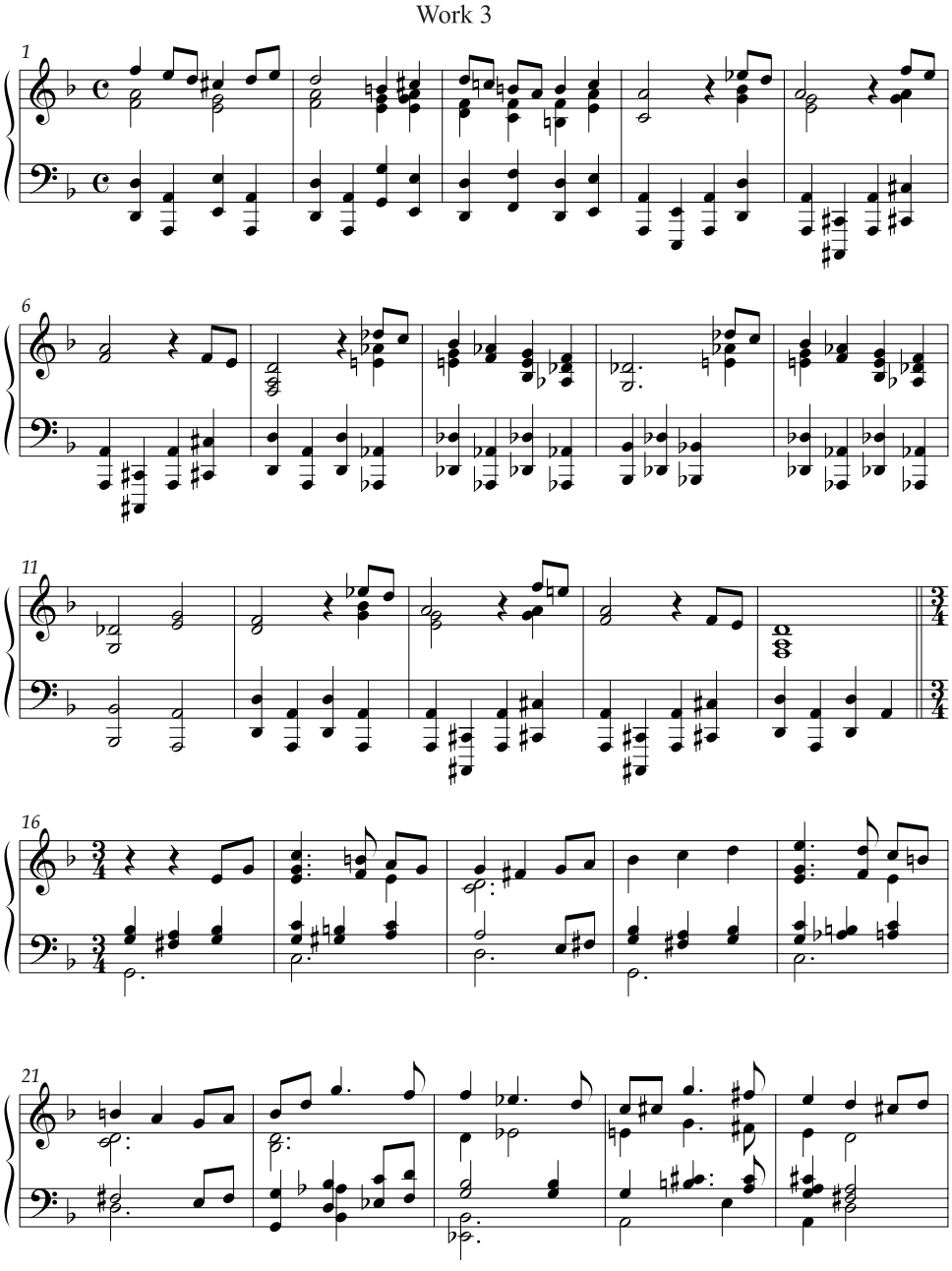

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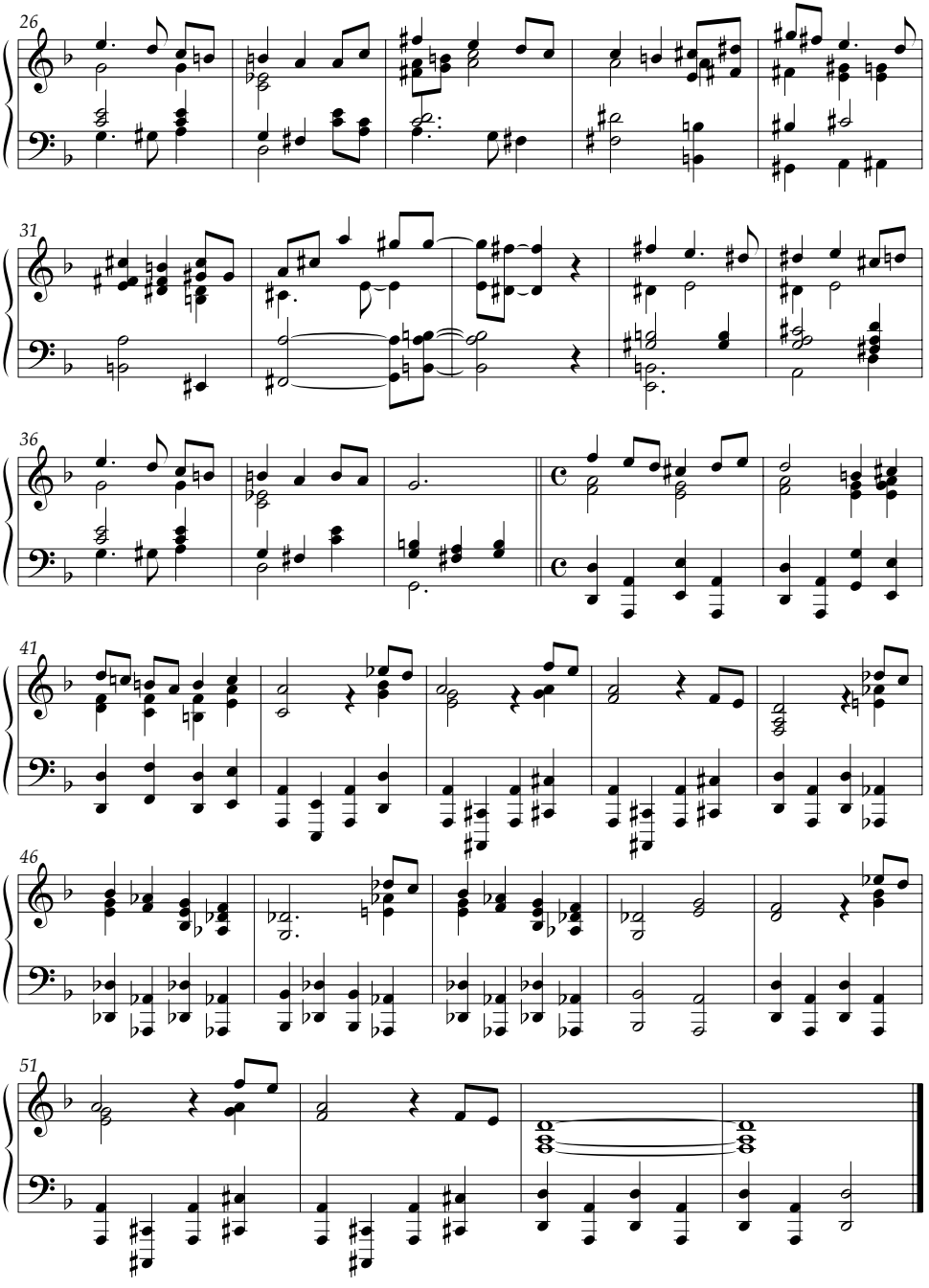

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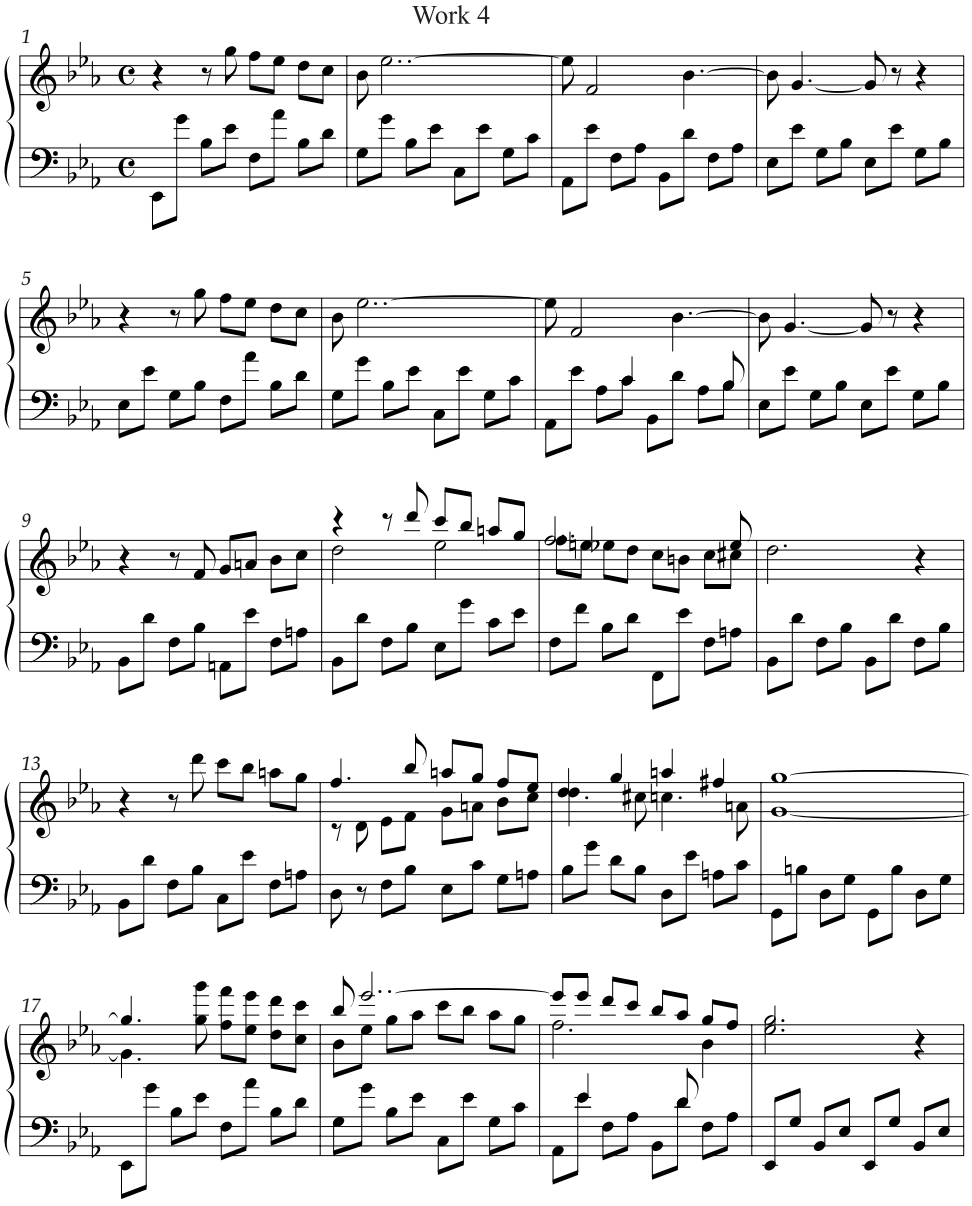

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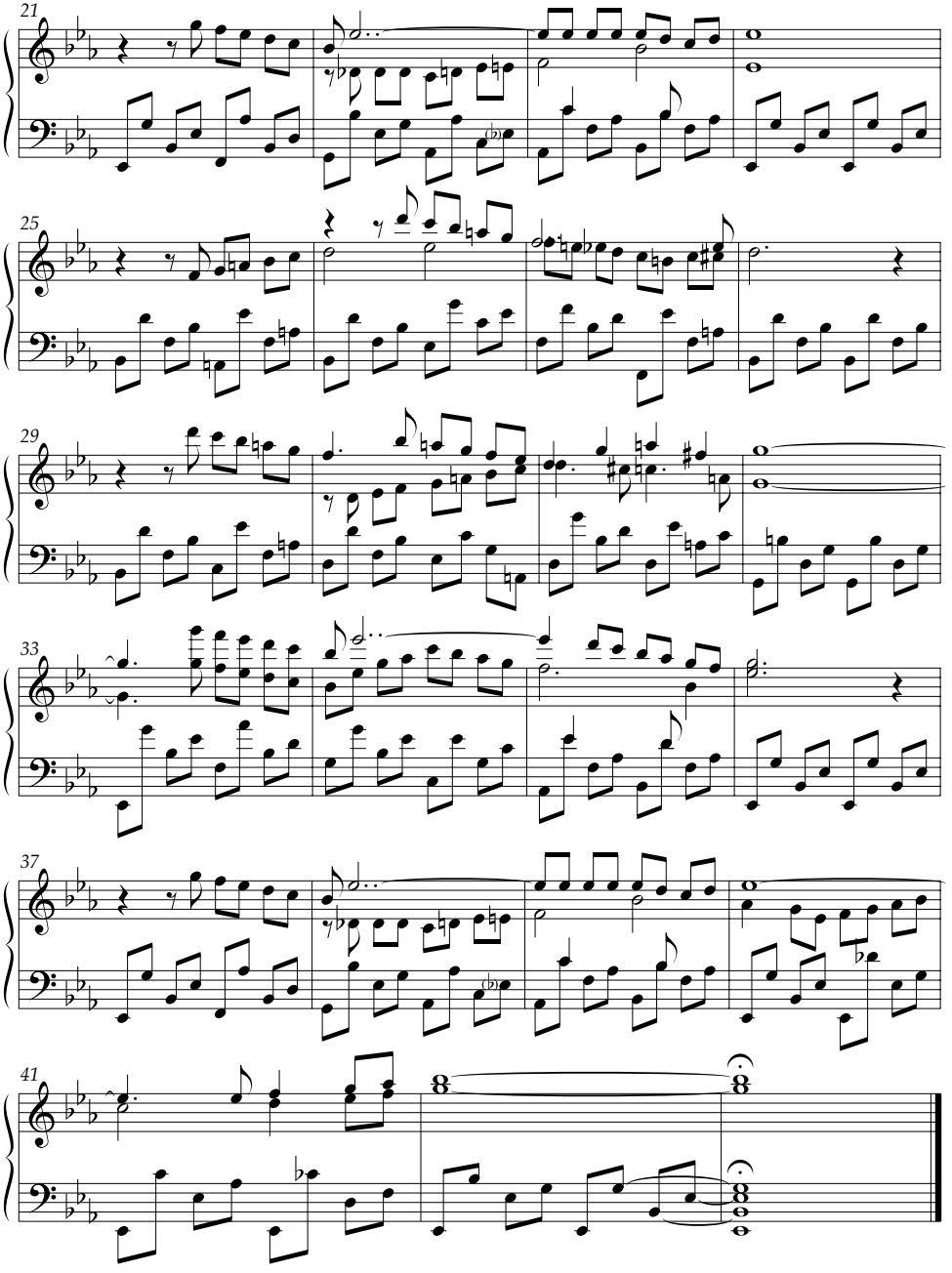


Figure 1.11 (continued)

composer's style and should not be taken here as easy indicators of computer composition. The answers to this game appear in appendix E at the end of this book.

The second example of The Game involves four short chorales in the style of J. S. Bach. One or more of the chorales shown in figure 1.12 is by Bach and one or more by the Experiments in Musical Intelligence program. This particular game requires readers to determine not only which works are human-composed but also which ones best follow the style of Bach. As with the previous version of The Game, looking for simple indicators here will disappoint readers. The machine-composed example(s) do not break the commonly recognized rules of Bach four-part writing, nor do they exceed standard vocal ranges. As previously mentioned, the correct responses to this game appear in appendix E at the end of this book.

The third example of The Game presents four mazurkas in the style of Frédéric Chopin. One or more of the mazurkas in figure 1.13 is by Chopin and one or more by the Experiments in Musical Intelligence program. As I initially indicated, ornamentation, with the exception of trills, appears in standard rhythm and occurs in the preceding beat. There are far fewer mazurkas than any of the types of music used in previous versions of The Game and looking in a book of Chopin mazurkas may be tempting. Please avoid doing so, however. Readers who recognize one or more of the mazurkas presented here should disqualify themselves from playing this version of The Game. As with the other versions of The Game, the answers to this game appear in appendix E.

With a total of twelve possible results for all three games, a score of six indicates a difficulty in differentiating between the human and the computer sources for these works, as well as a difficulty in separating virtual music from originals. Scores of greater than eight or less than four indicate a failure on the part of the computer program to effectively imitate human composers. Readers who scored high (8–12) on these versions of The Game, particularly those who have musical backgrounds and thus used more than luck, should try and identify those characteristics which gave the machine-composed examples away. Readers who scored particularly low (0–4) on these versions of The Game might try to discover what led the machine-composed examples to sound as if they were human-composed. Remember that expert musicologists have failed to recognize many examples of Experiments in Musical Intelligence music, while musical amateurs have randomly identified such examples correctly. Results from previous tests with large groups of listeners, such as 5000 in one test in 1992 (see Cope 1996, pp. 81–2), typically average between 40 and 60 percent correct responses.

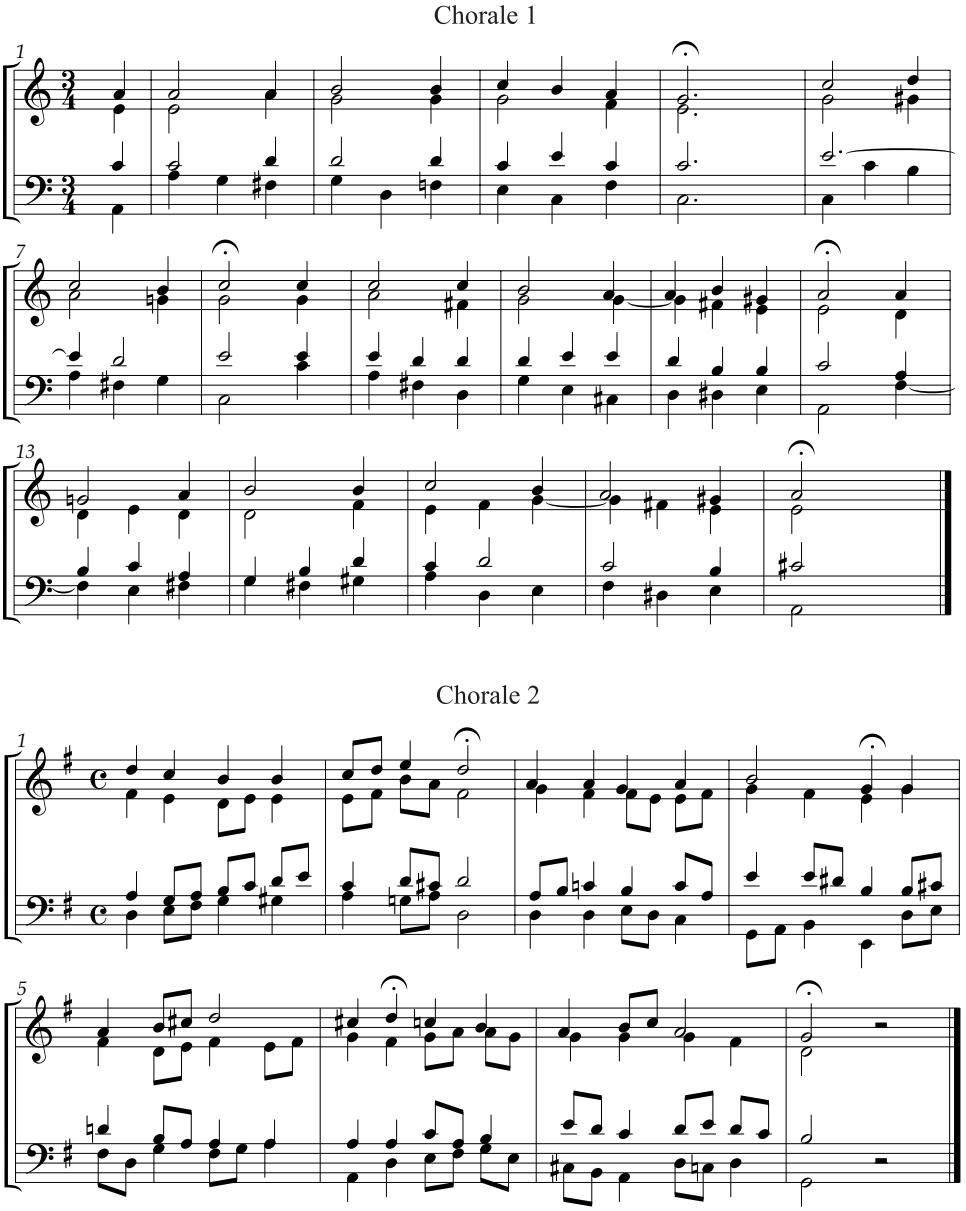
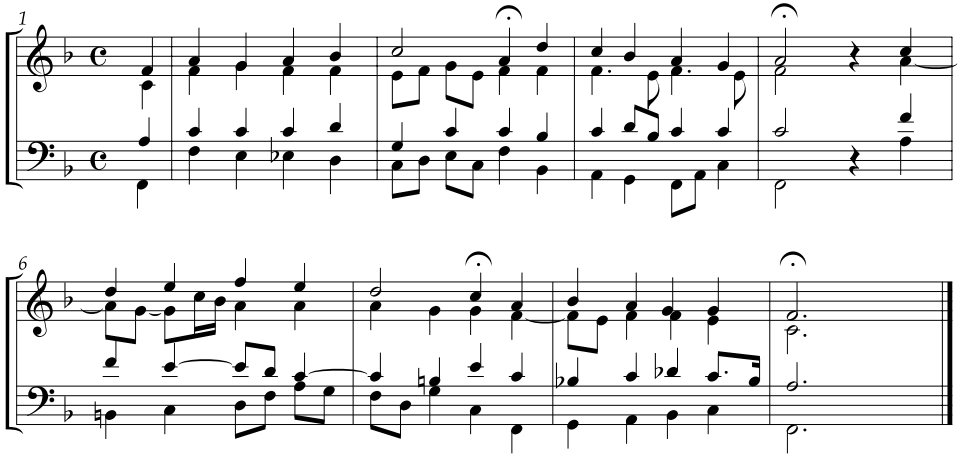
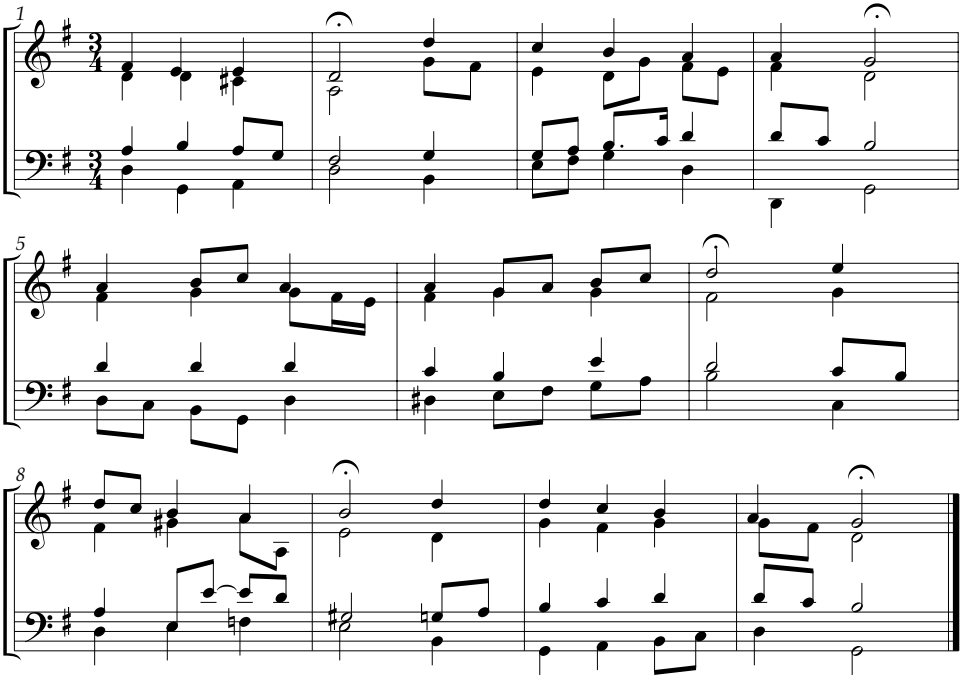


Figure 1.12
Four chorales in the style of J. S. Bach, at least one of which was composed by Bach and at least one of which was composed by the Experiments in Musical Intelligence program.

Chorale 3



Chorale 4



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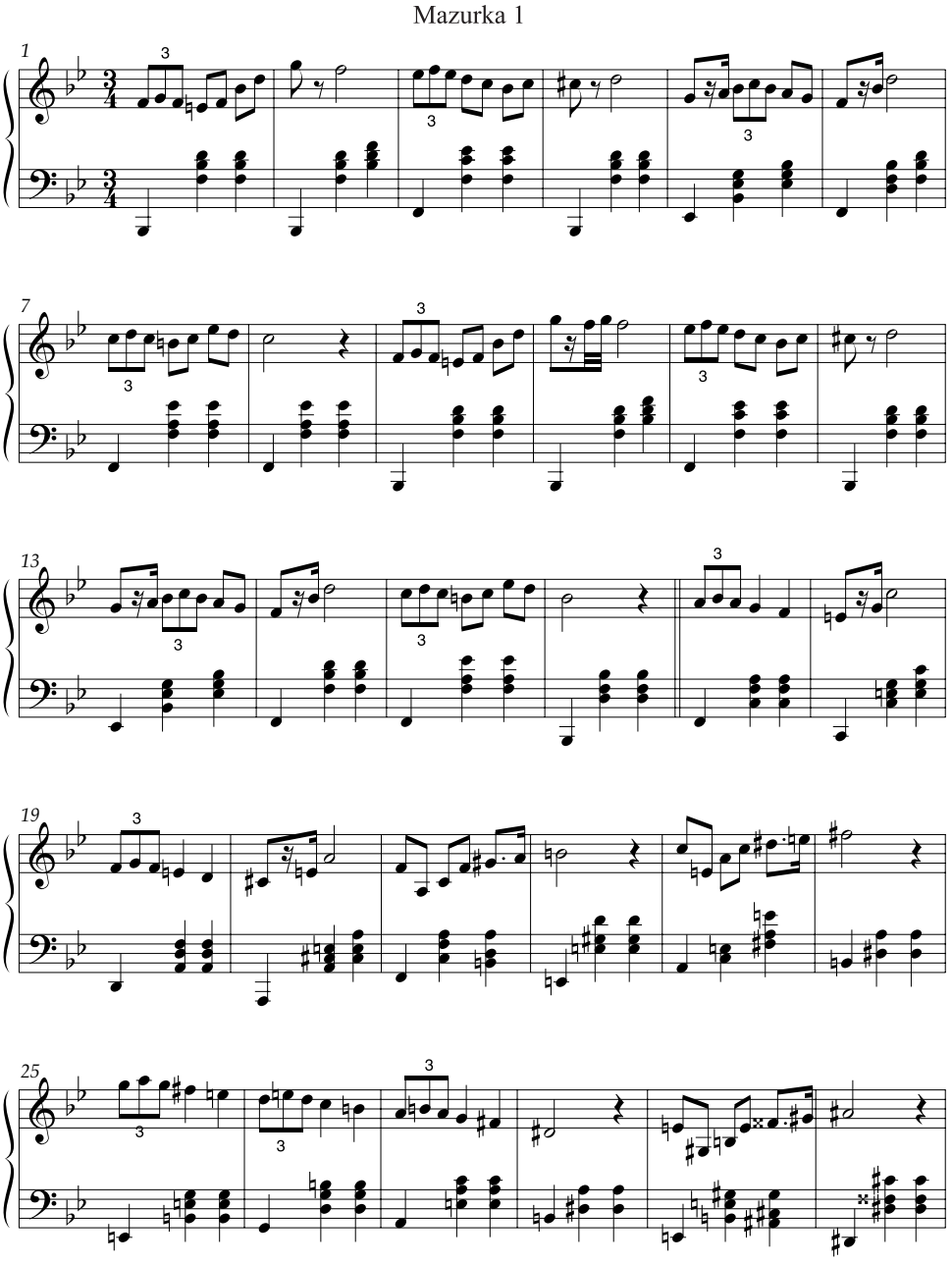
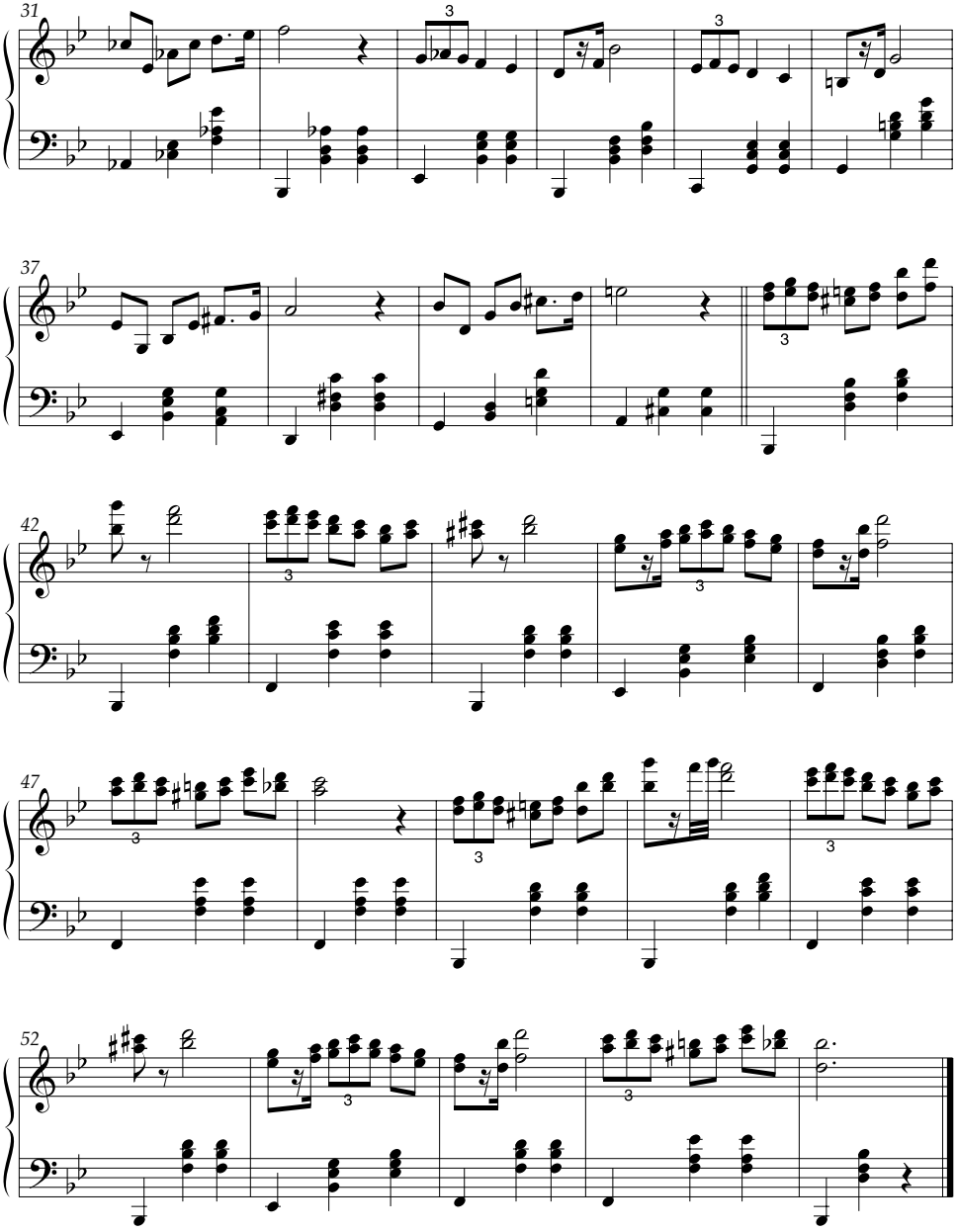


Figure 1.13
Four mazurkas in the style of Chopin, at least one of which was composed by Chopin and at least one of which was composed by the Experiments in Musical Intelligence program.



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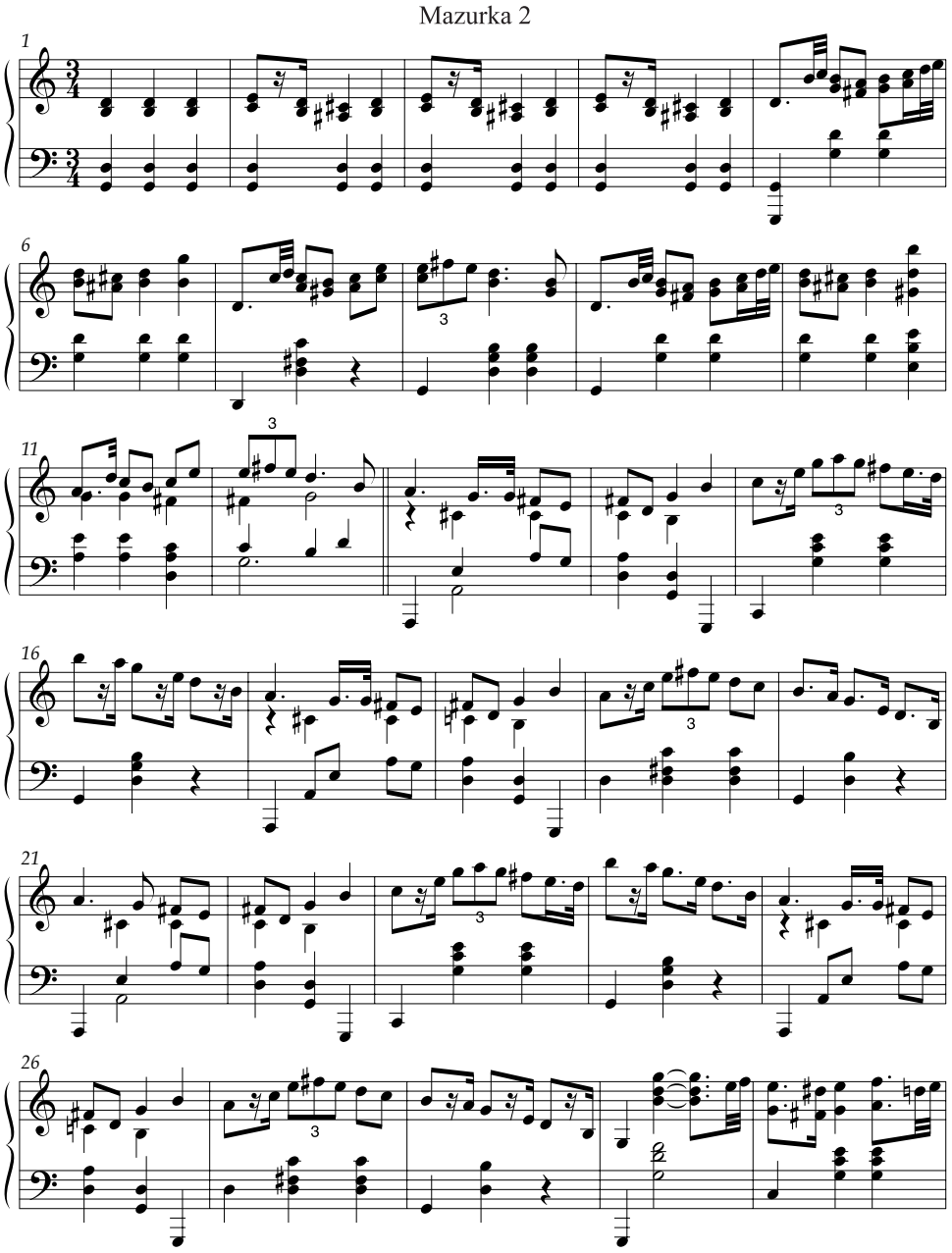

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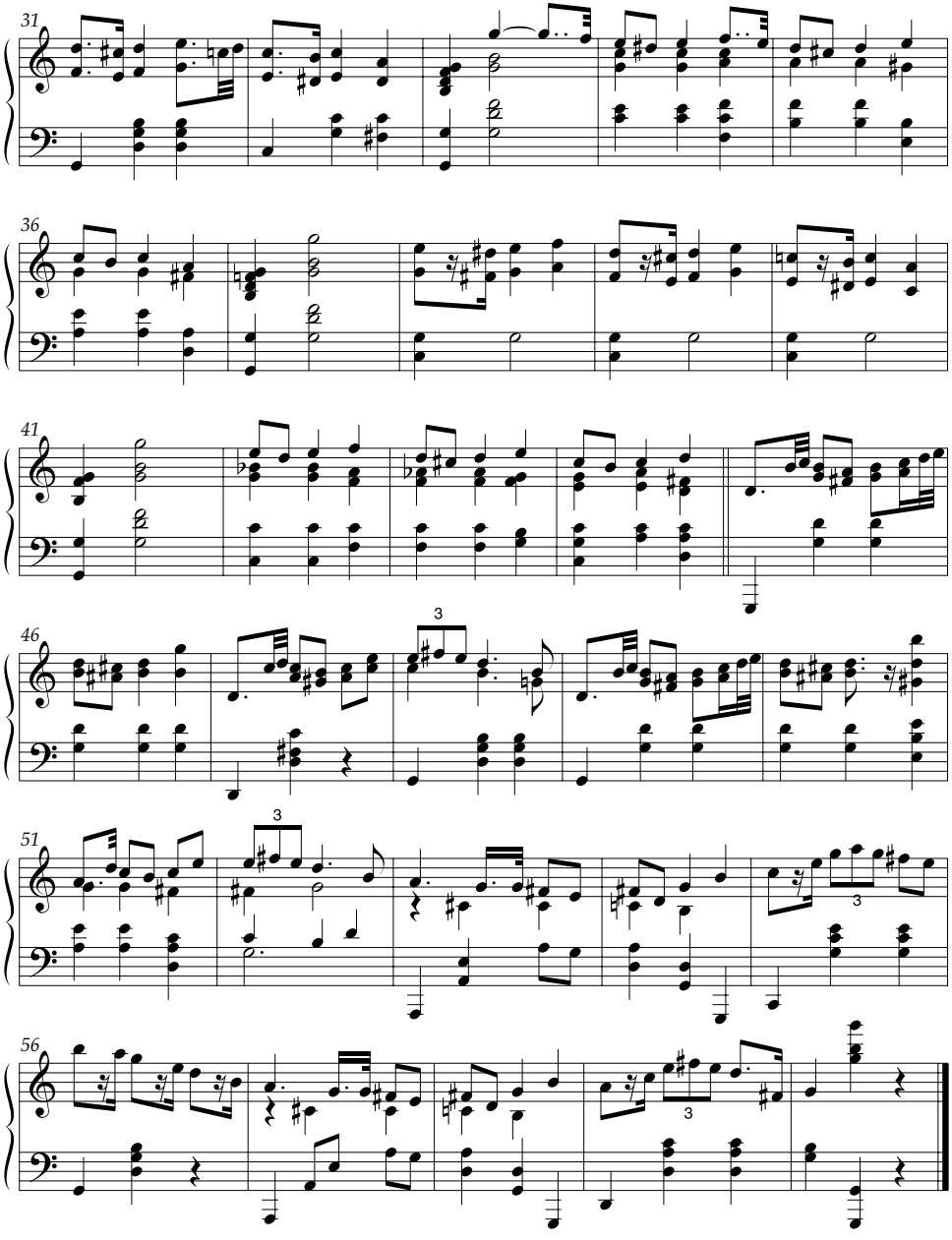

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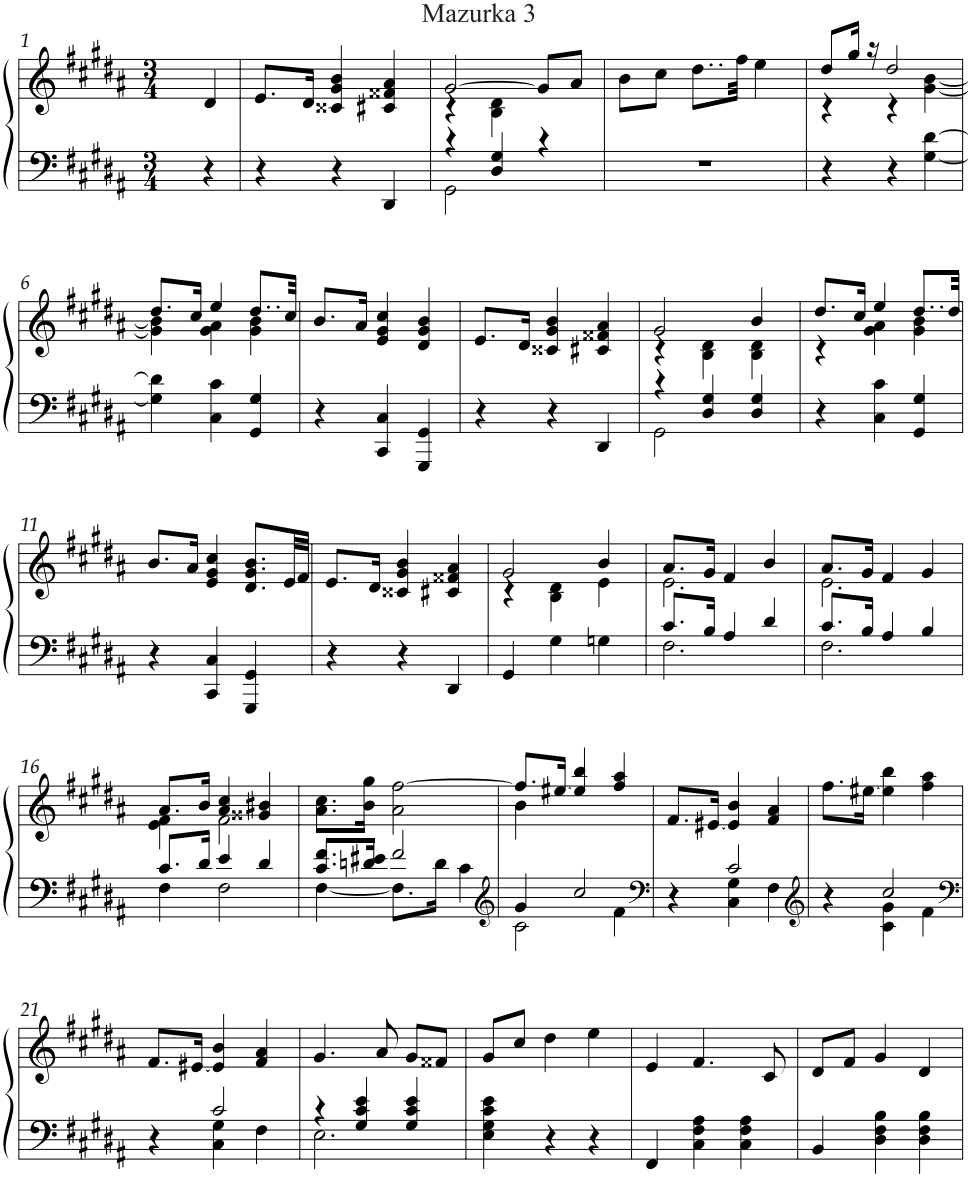
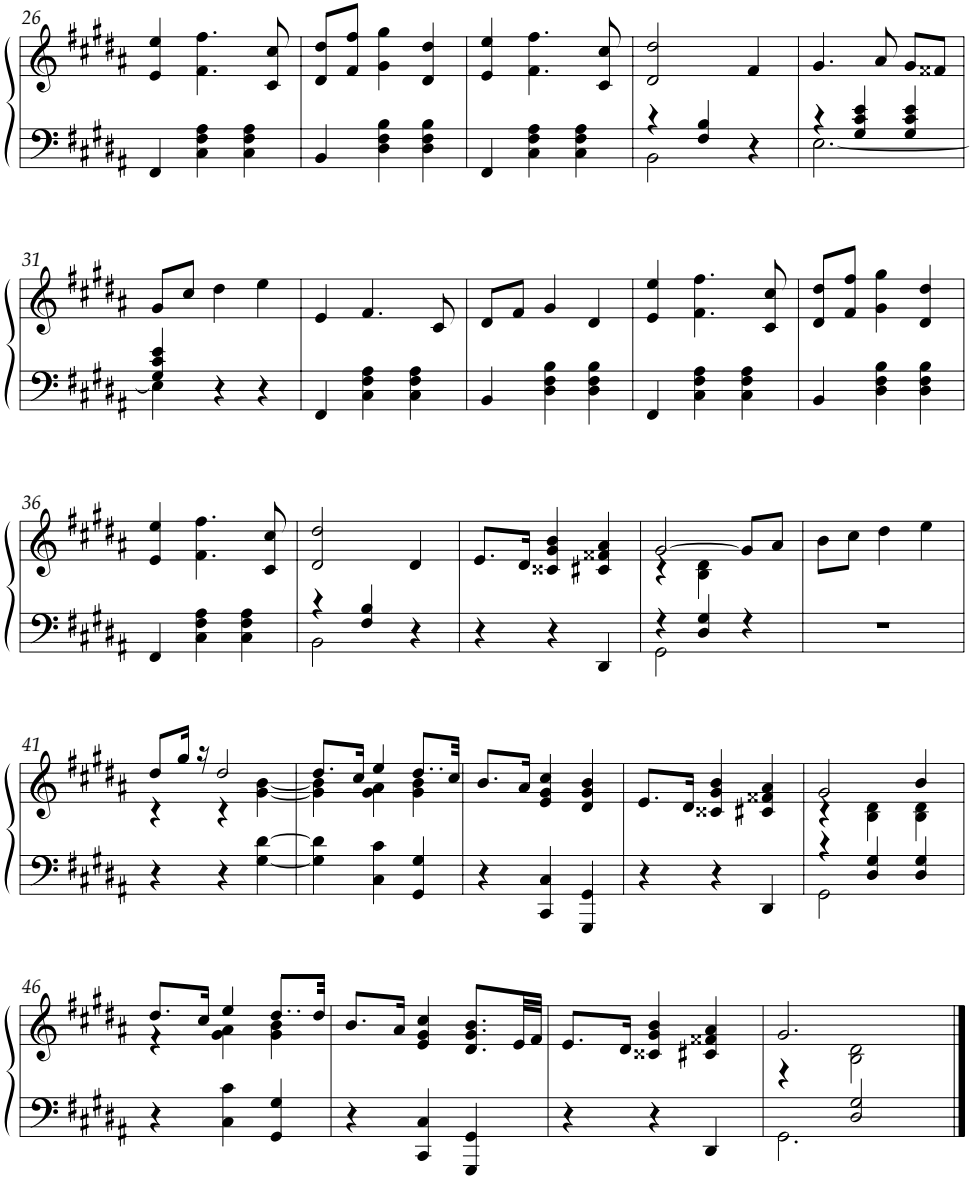


Figure 1.13 (continued)



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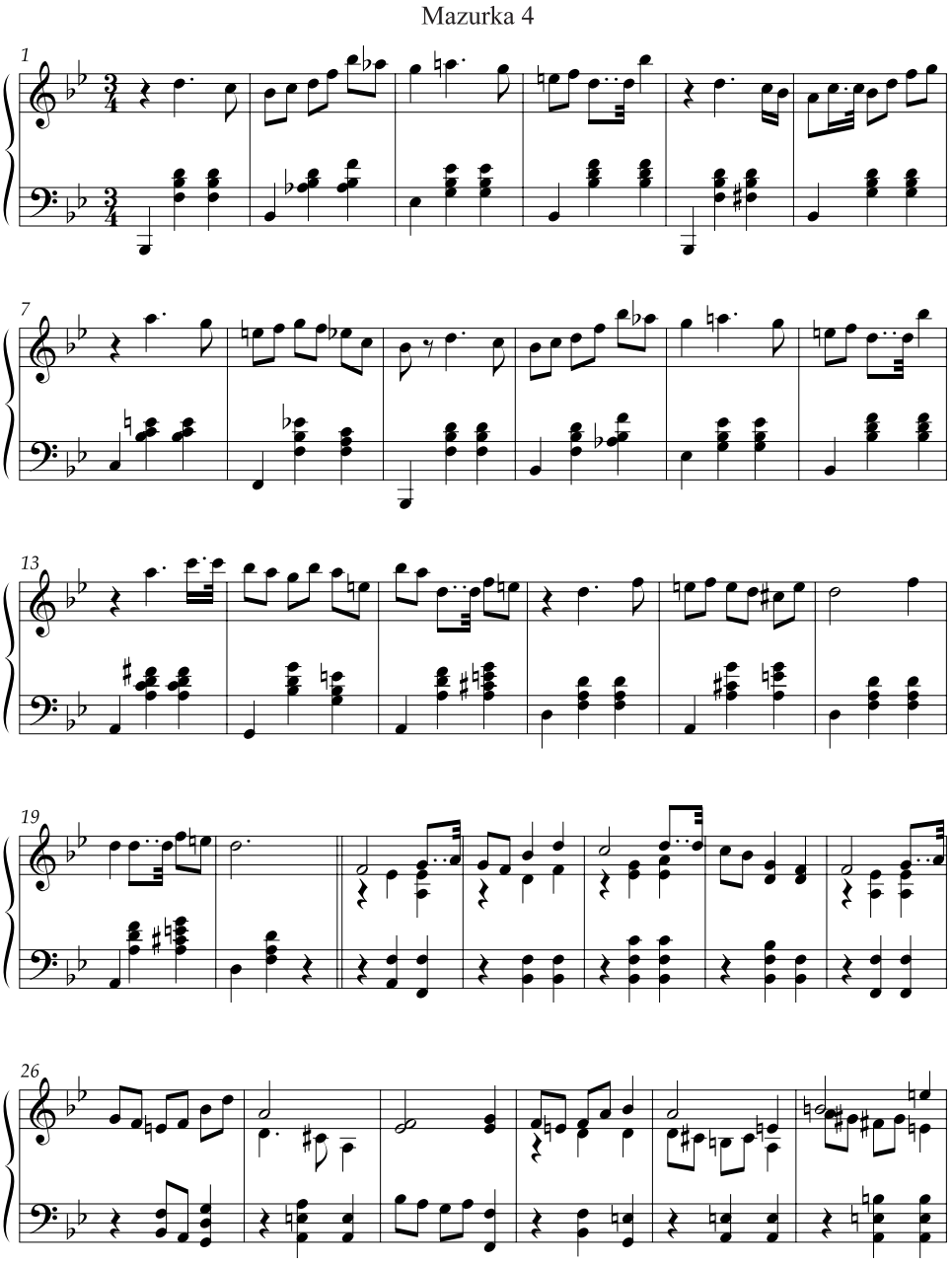

Figure 1.13 (continued)

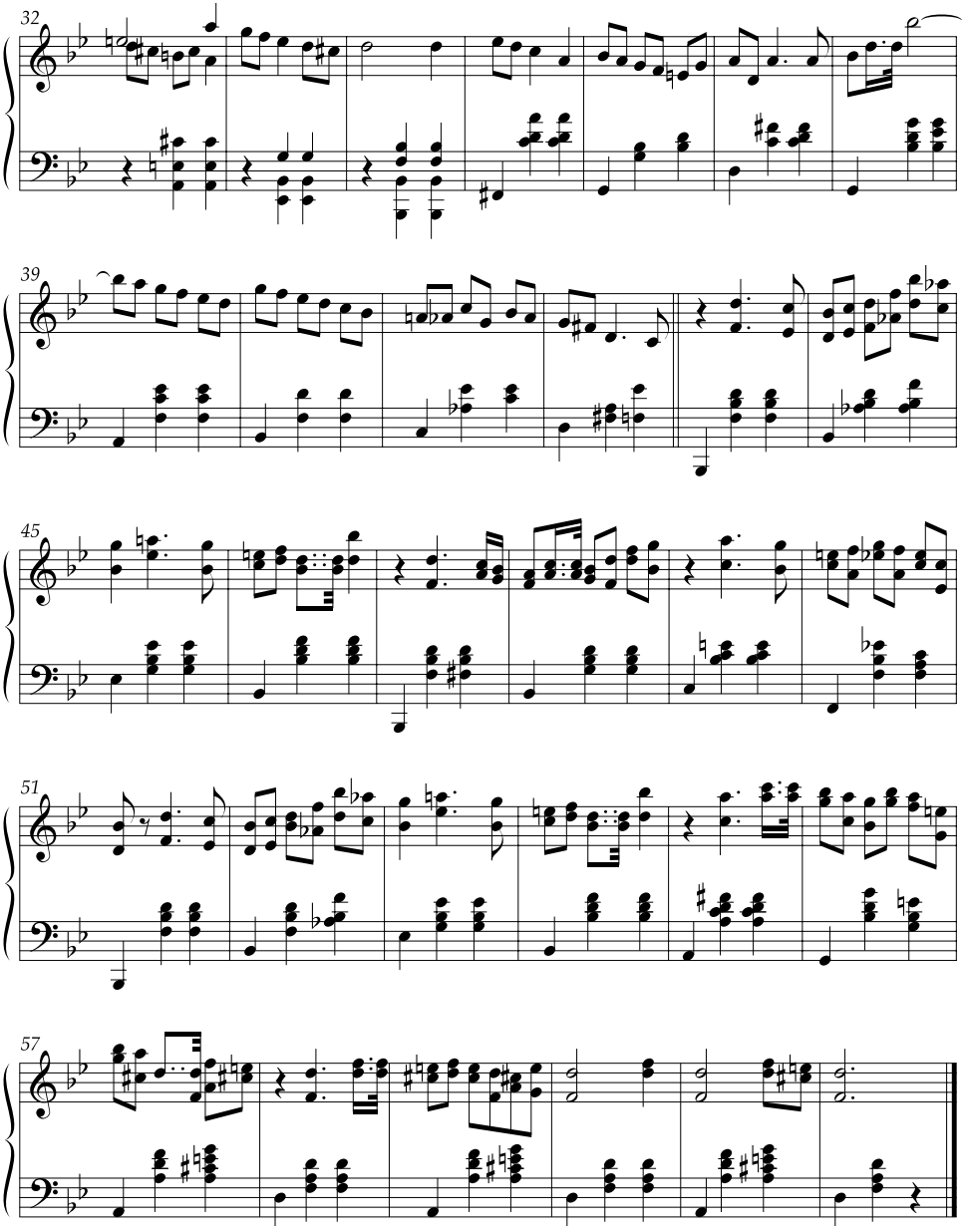

Figure 1.13 (continued)

Whatever the scores of your attempts at The Game, two conclusions should be clear. First, all of the music presented is interesting and, on at least some level, convincing. I do not make this assertion lightly. I make it having seen many people play The Game and witnessed the controversy it often creates. Second, distinguishing human-composed music from that created by the Experiments in Musical Intelligence program is often quite difficult, if at all possible. The following descriptions of the program and evaluations of the results of its programming should help to clarify how such results are possible.