UNIVERSITY OF CALIFORNIA

SANTA CRUZ

EXPRESSING NARRATIVE FUNCTION IN ADAPTIVE, COMPUTER-COMPOSED MUSIC

A dissertation submitted in partial satisfaction
of the requirements for the degree of

DOCTOR OF MUSICAL ARTS

in

MUSIC COMPOSITION

by

Daniel Lankford Brown

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The Dissertation of Daniel Lankford Brown
is approved:

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Professor David Cope, Chair

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Professor Paul Nauert

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Professor Michael Mateas

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Tyrus Miller
Vice Provost and Dean of Graduate Studies

Contents

ABSTRACT

Daniel Brown

Expressing Narrative Function in Adaptive, Computer-Composed Music

Computer gaming has grown over the last decade from simple entertainment to a high-level art form. Today, more and more computer games have intricate plots, interesting characters, and sophisticated narratives. It is for this genre of game that I have created a computer program, called *Mezzo*, that procedurally composes music in the style of the Romantic Era to accompany gameplay. By composing game music procedurally, there are two problems that *Mezzo* addresses. First, how to keep music from becoming repetitious, as prerecorded, looped music often becomes when a game experience stretches on for long periods of time. Second, how to computationally define and compose music that evokes the narrative states occurring in a game, and to change from one state to another as the game changes. *Mezzo*'s design is based on the idea that repetition is more than just a necessary means of extending musical material over time. Patterns of repetition actually have signifying functions; they express a wealth of musical states by creating different degrees of markedness and unmarkedness.

Mezzo uses three musical features as vehicles for conveying markedness: harmonic tension, formal regularity, and energy. It takes in small melodic motives and harmonic progressions from a user, and then composes, with a genetic algorithm, its own different harmonic progressions that conform stylistically to those given to it. It uses these progressions to compose music during a game in which the input melodic motives are organized and developed in ways that reflect the various states of the game story. This process is based on the idea that certain patterns of melodic repetition combined with harmonic function became conventionalized in the Classical Era as normative forms. Each musical form has a normative structure, and various ways in which this structure can be deformed. 'Formal regularity' refers to how close an instance of such a form adheres to its normative structure. Forms that deviate from their normative structures have various levels of irregularity and hence markedness. *Mezzo* composes forms during gameplay and deforms them in order to convey various levels of markedness that correspond to game action. Furthermore, it applies these deformations stochastically, in order to avoid repetitiousness. The type of forms composed, the deformations applied, and the stochastic constraints on how these deformations are applied are all determined by the state of the game narrative, in accordance with a semiotic model of the expressive qualities of formal irregularity.

Three scores written by *Mezzo* are included, each written in real time as an accompaniment for a different computer game. Each piece is analyzed in terms of its musical form and its semiotic relations to the game narrative it accompanied.

Acknowledgements

I could not have undertaken three years of research on this untraditional subject without the guidance and support of several uncommon people.

I happened on a misshelved book by David Cope one afternoon at the Emory library in Atlanta. In the eight years since, he has become a mentor and friend. An archetypal grievance among graduate students is how aloof their advisors are. Dave, on the other hand, met with me regularly every week, for several hours, at his office, his house, or hiking around the UCSC meadows overlooking Monterey Bay.

Michael Mateas introduced me to narrative theory and its modern applications in computer games. Márta Grabócz's writings opened the door to the fascinating world of musical narratology, and her personal encouragement and assistance kept me going during the difficult dissertation process. Amy Beal, Leta Miller, Larry Polansky and Bill Manaris gave me crucial professional and theoretical guidance. Noah Meites, Young-Shin Choi, Mark Davidson, and Lucas McGranahan were friends and colleagues. Emily Saltz listened and cared. My parents' and my brother's support lifelong encouragement surpasses my understanding.

Finally, I am grateful for the time I've been able to spend with Paul Nauert, the smartest person I've ever met. And the funniest.

Part I

Music

ANNÉES DE CHÔMAGE

Three computer-composed accompaniments
to video game scenes

arranged for two pianos
by Daniel Brown

The following three pieces were composed entirely by the computer program *Mezzo* in real-time, as accompaniments to videos of computer game walkthroughs. They were arranged for two pianos by the author of the program, Daniel Brown. The scenes they accompany come from the following games:

I. *By Sweat and Toil* (Red Dead Redemption)

II. *$(SW^2)^2$* (Star Wars: The Old Republic)

III. *Bowser's Castle* (Super Mario 3D)

At the time of the writing of these pieces, the videos of the game walkthroughs that these piece accompany were available for public use at the website youtube.com, at the following addresses:

By Sweat and Toil: http://www.youtube.com/watch?v=LSIdhm_EOec

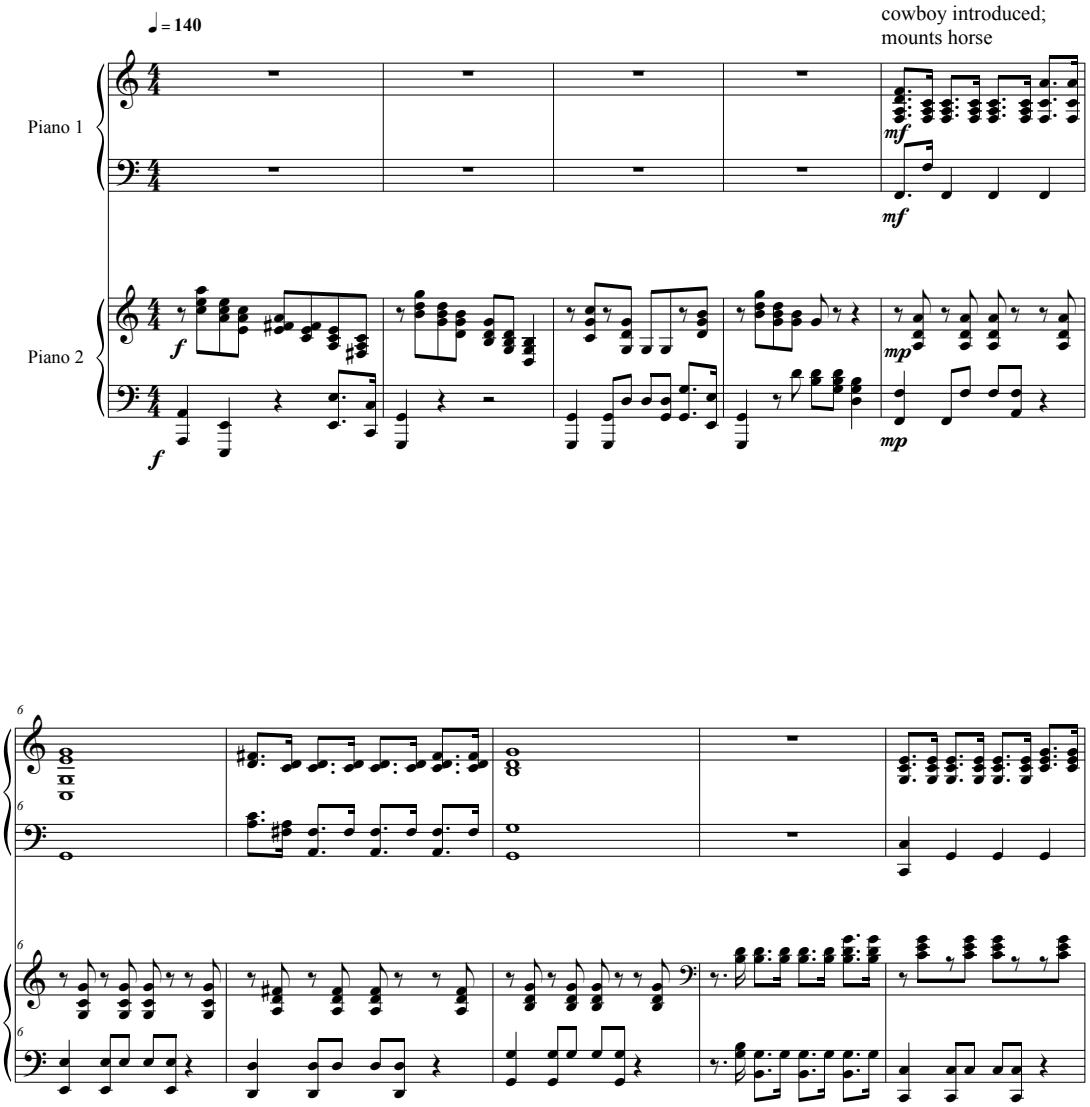
$(SW^2)^2$: http://www.youtube.com/watch?v=X1ZWJdbdsCM

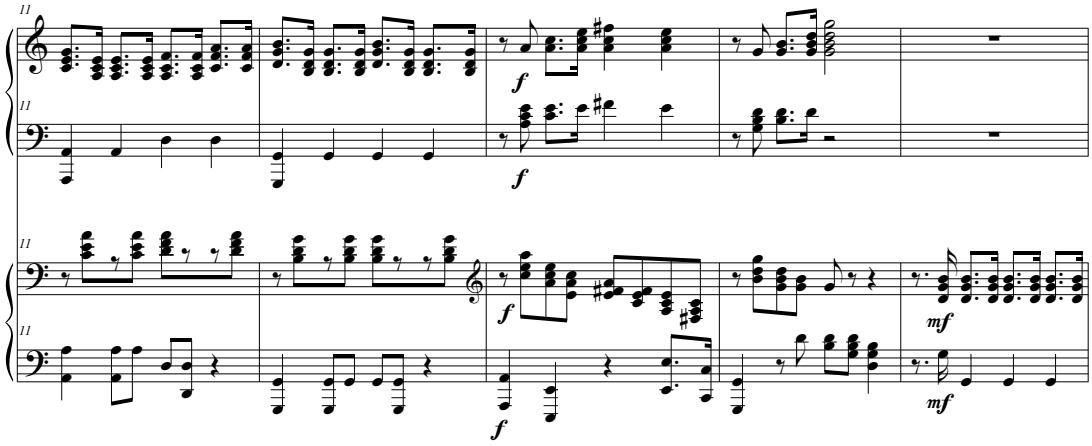
Bowser's Castle: http://www.youtube.com/watch?v=-9-WfJLlhXE

Score

ANNÉES DE CHÔMAGE

I. BY SWEAT AND TOIL

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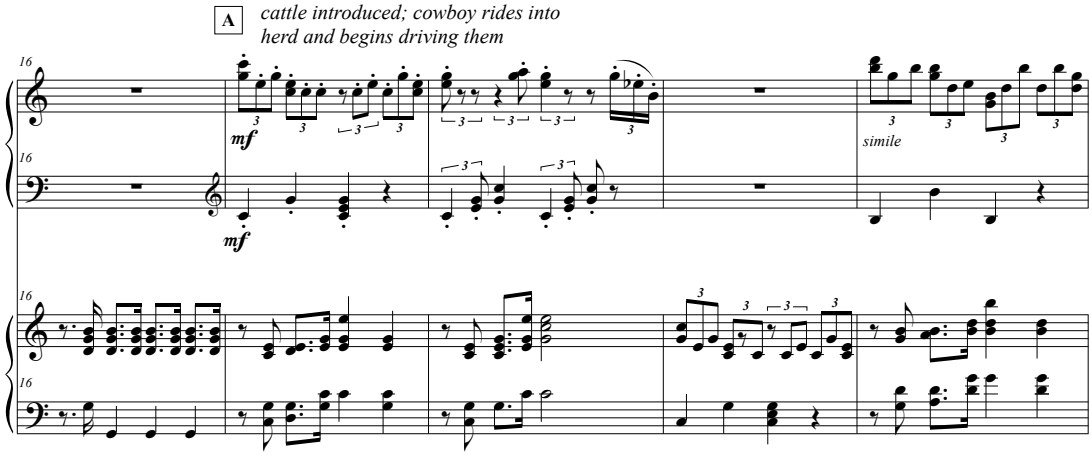
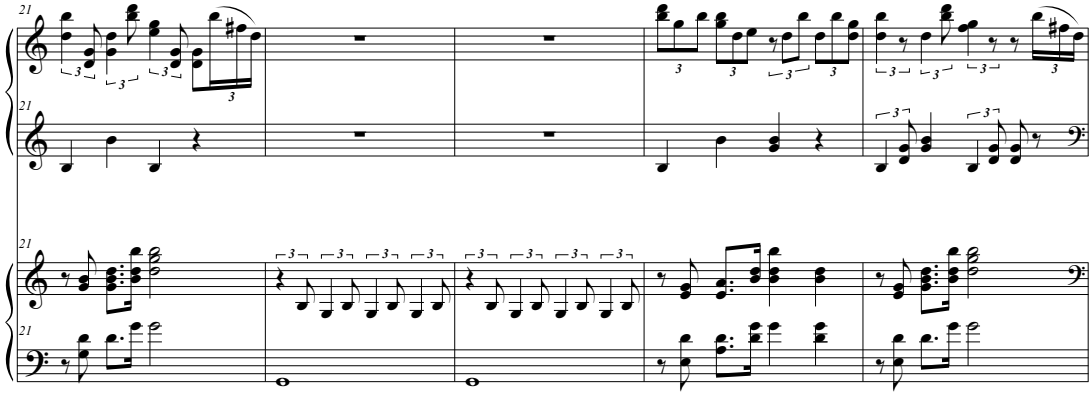
f
f
f
mf
mf


A
cattle introduced; cowboy rides into herd and begins driving them
16
mf
mf
simile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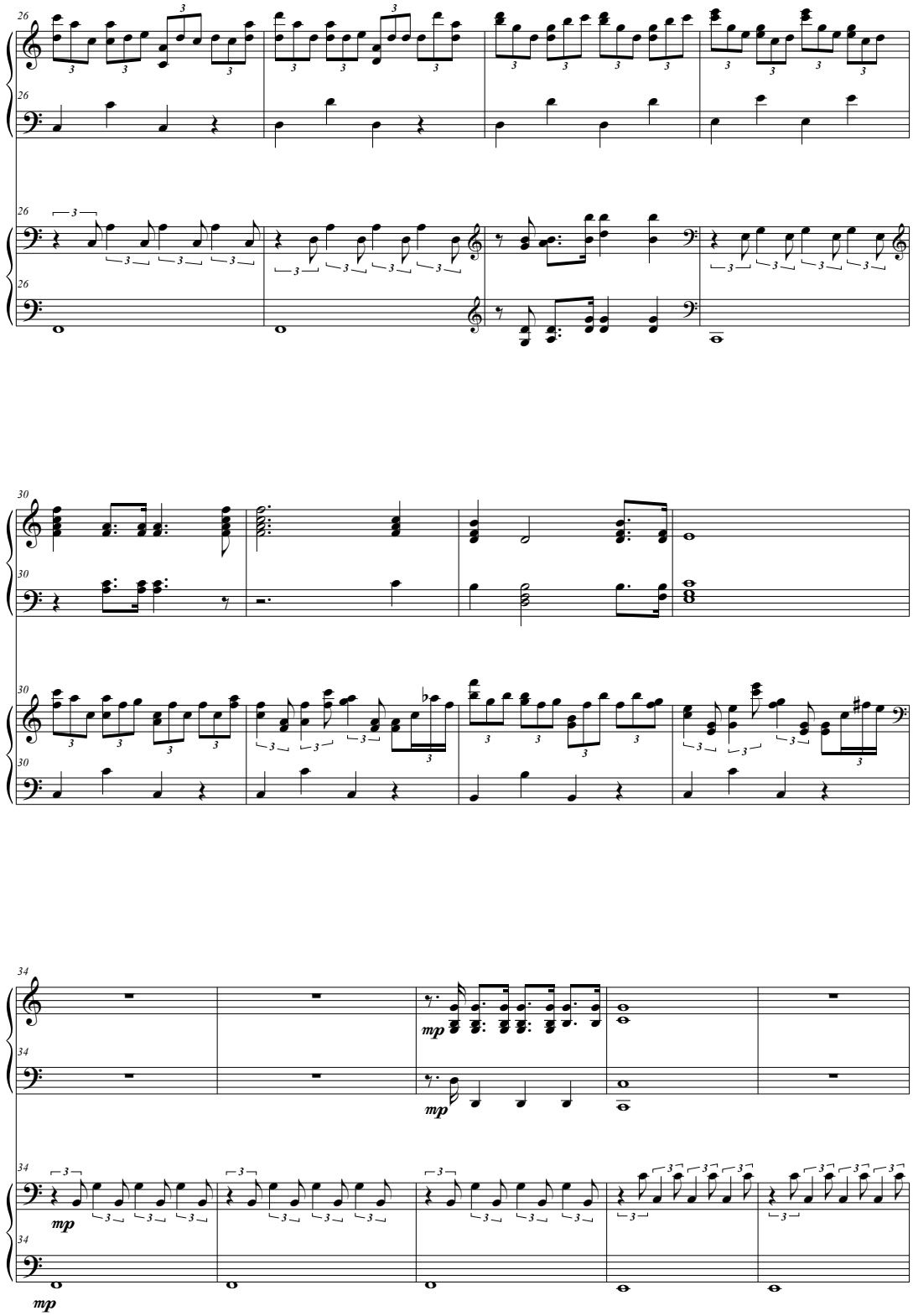
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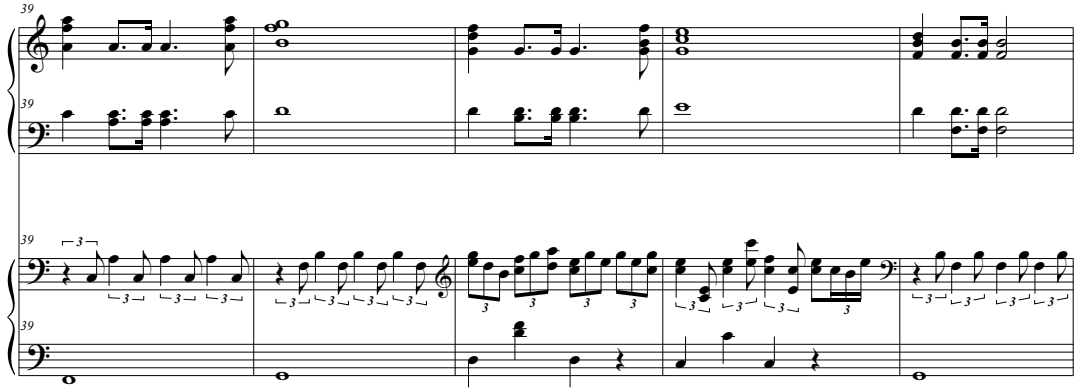

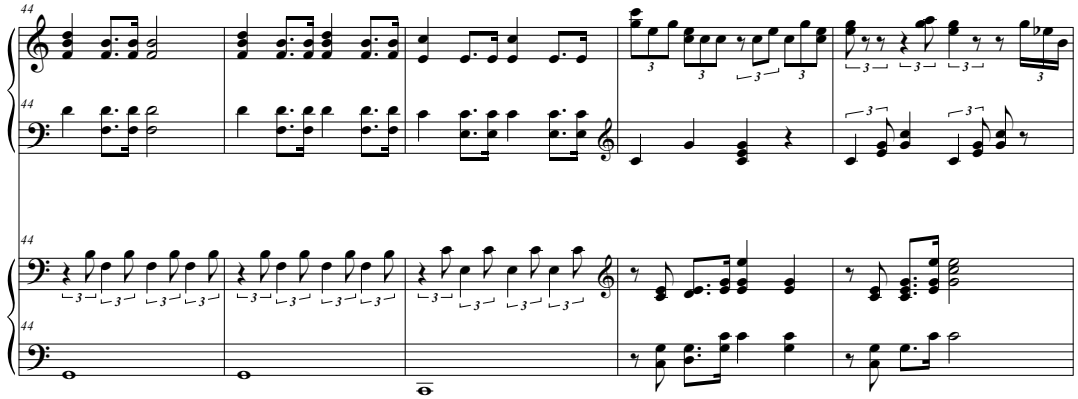

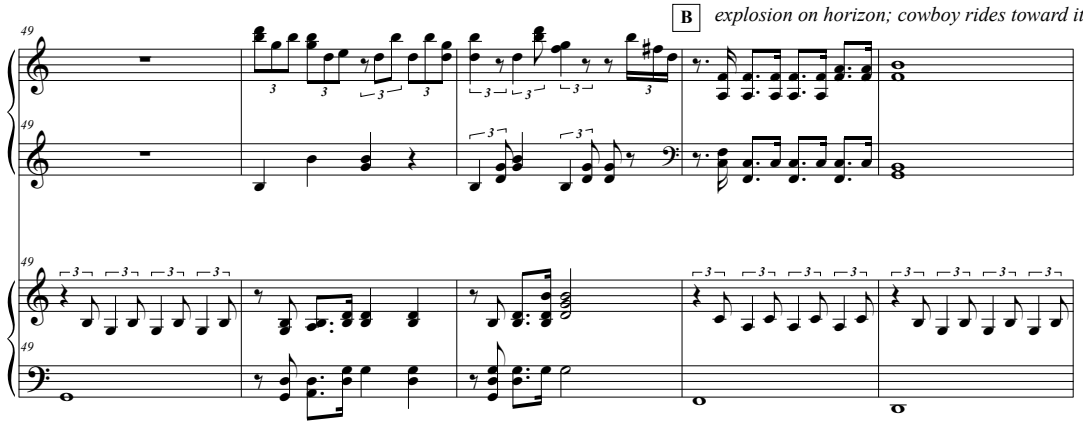
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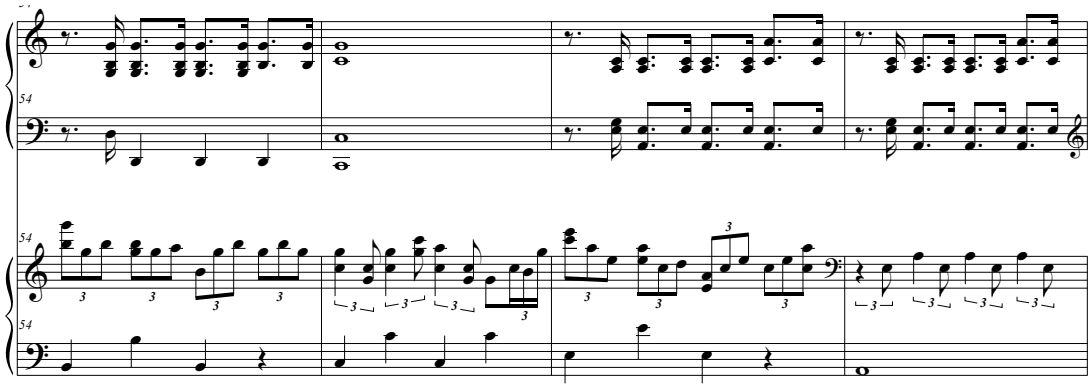
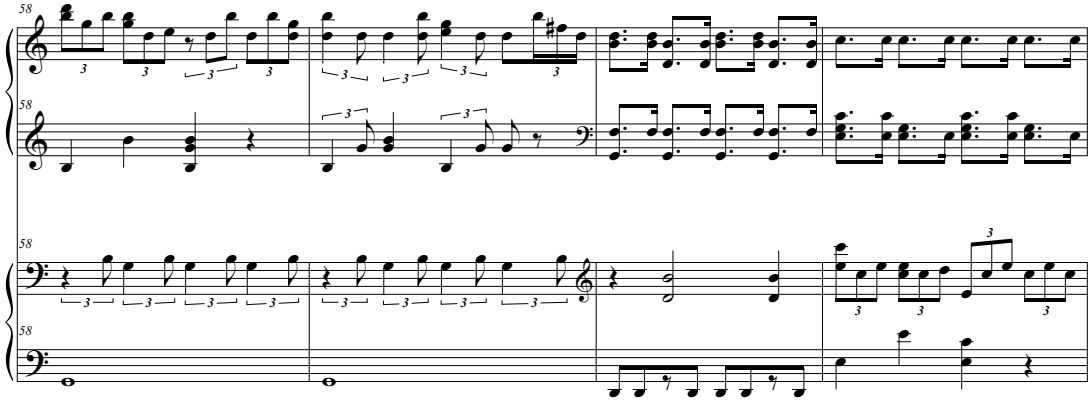
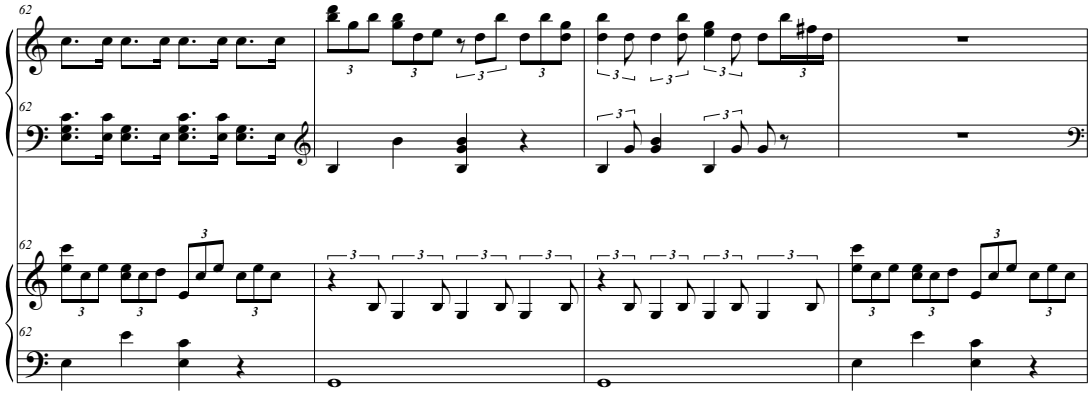
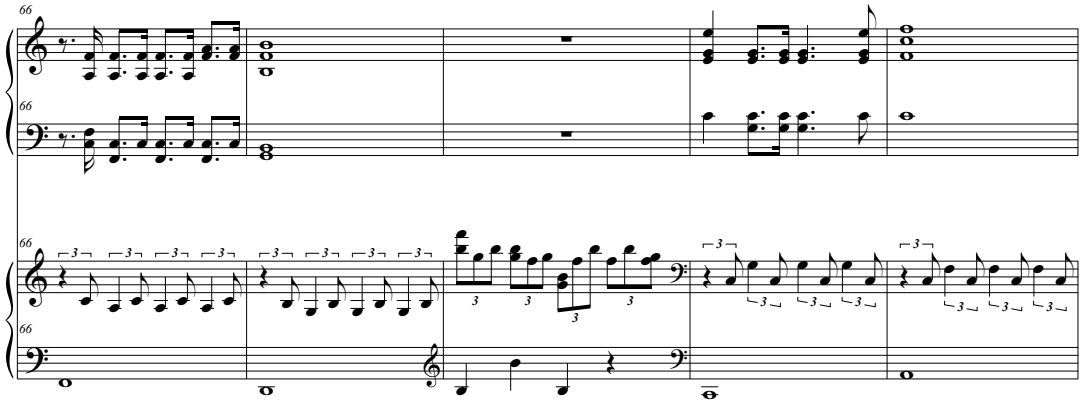
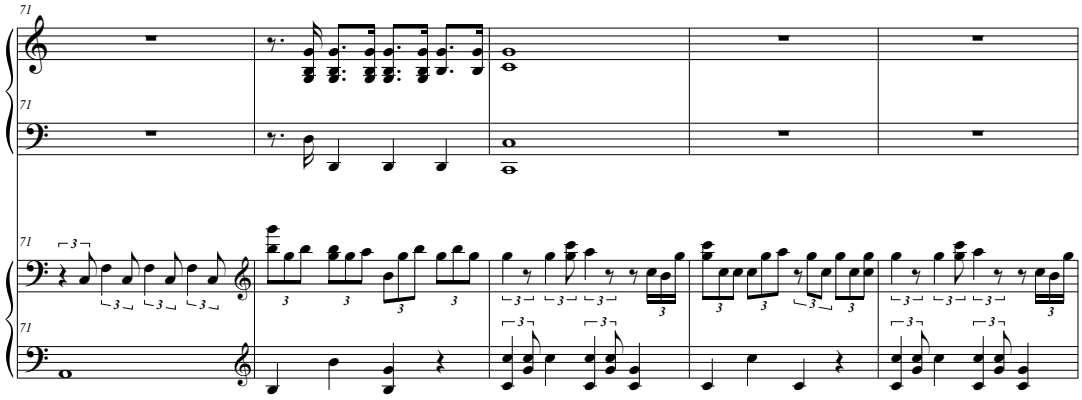
explosion on horizon; cowboy rides toward it



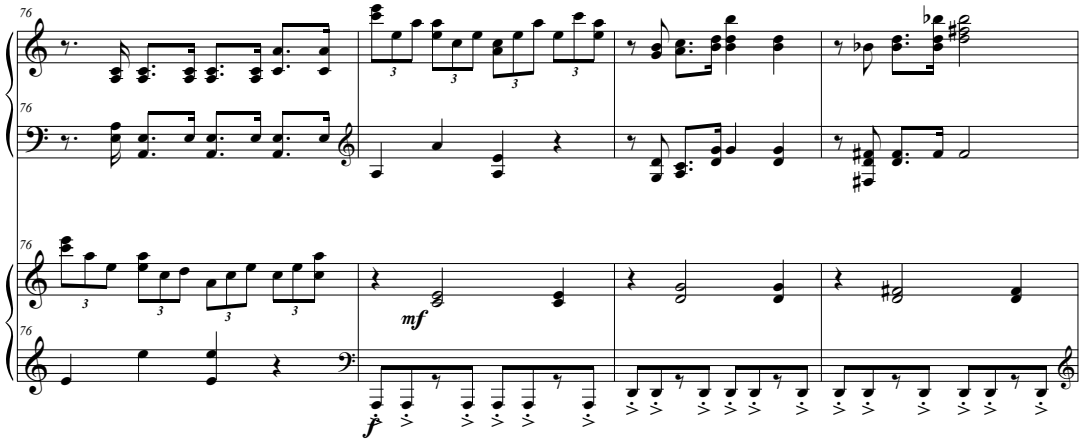


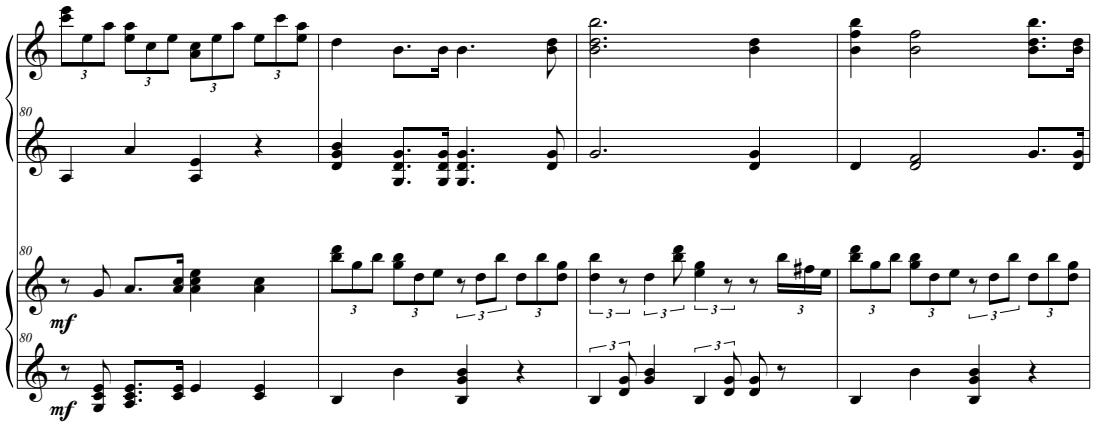






C *cowboy and cattle encounter train robbery in progress*

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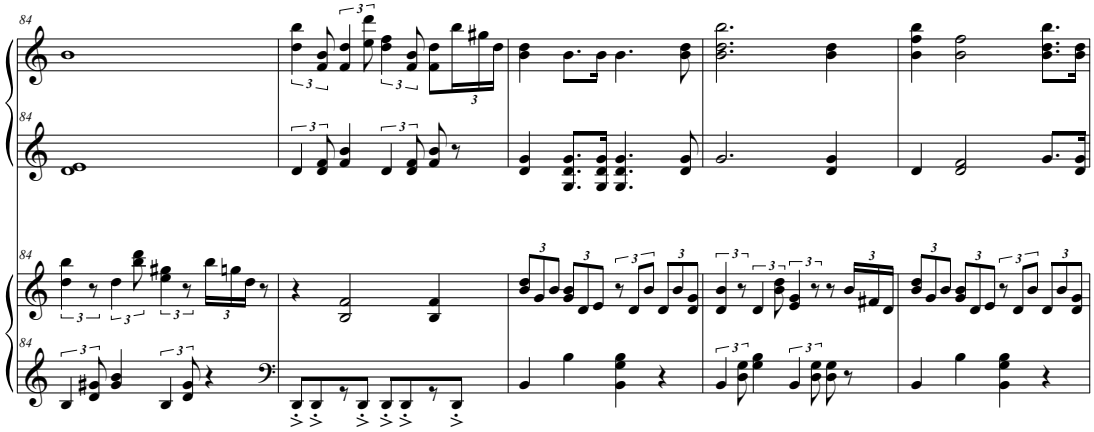
mf
80
mf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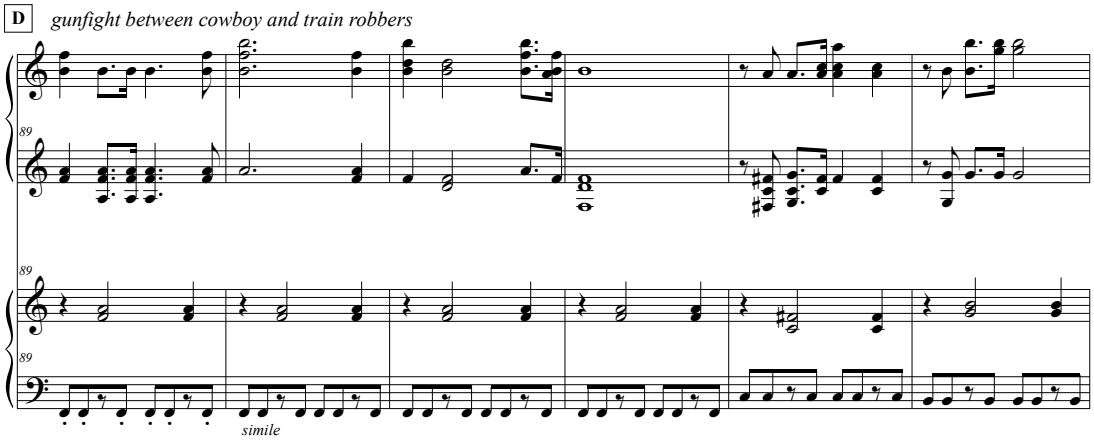
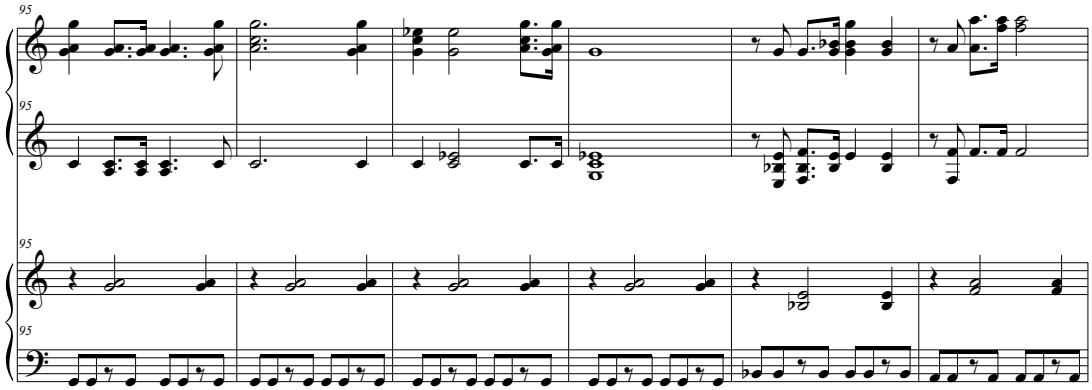

D
gunfight between cowboy and train robbers
89
89
89
89
simile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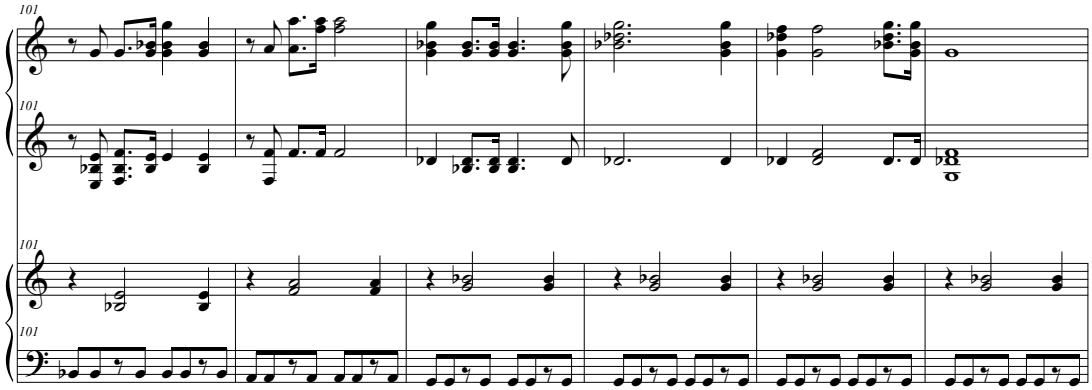
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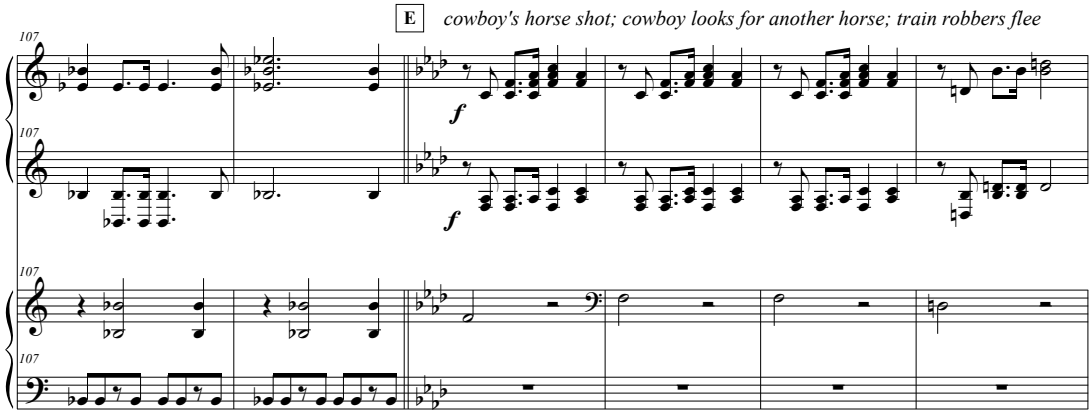
E
cowboy's horse shot; cowboy looks for another horse; train robbers flee
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f
f
107
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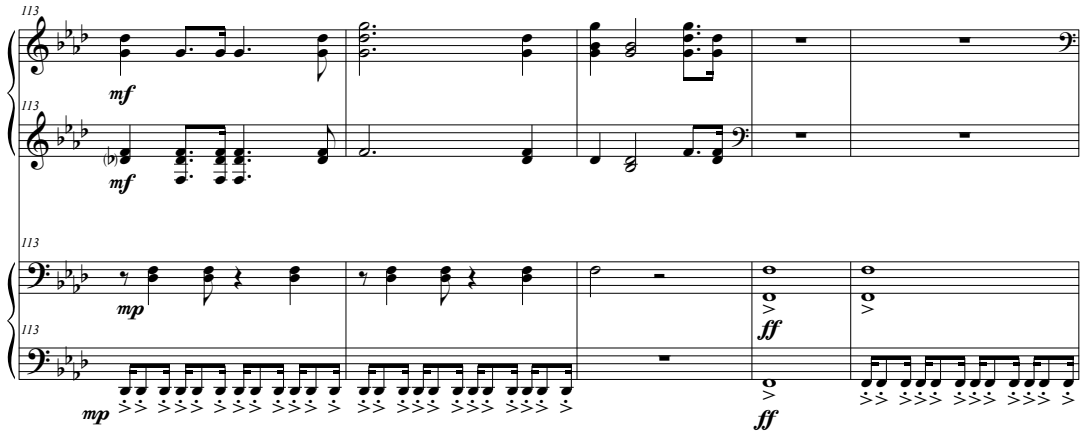
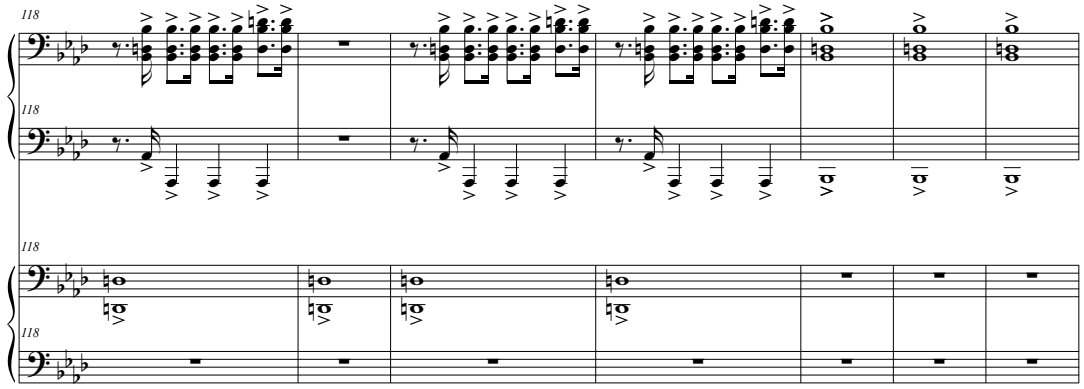
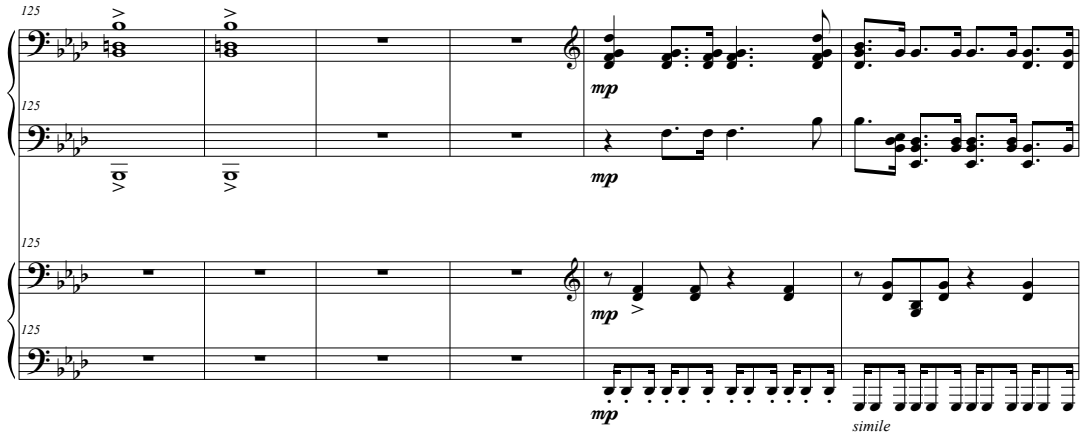
107

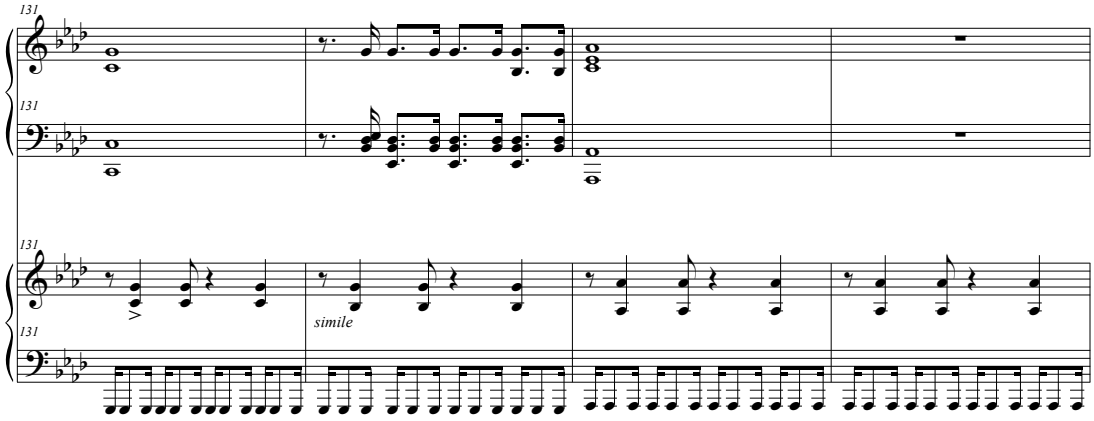




cowboy mounts new horse and bids farewell to train passengers he rescued from robbers

F

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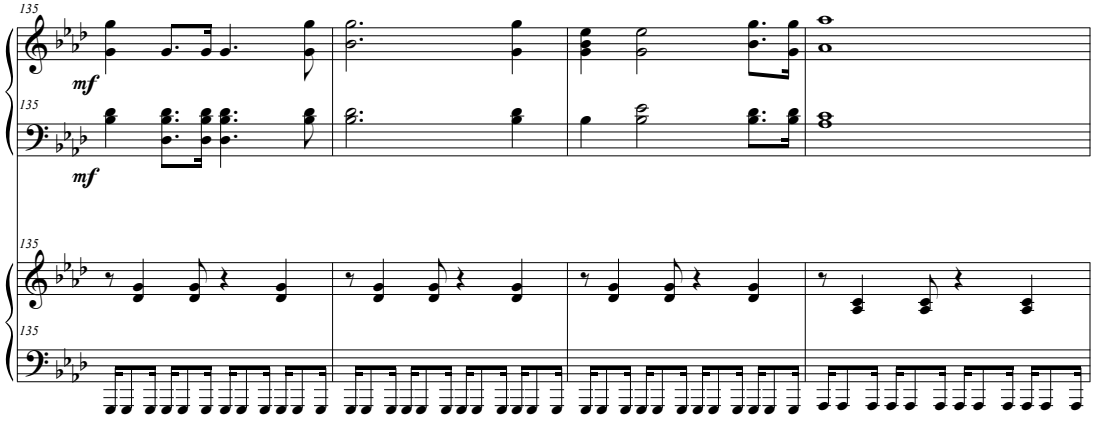
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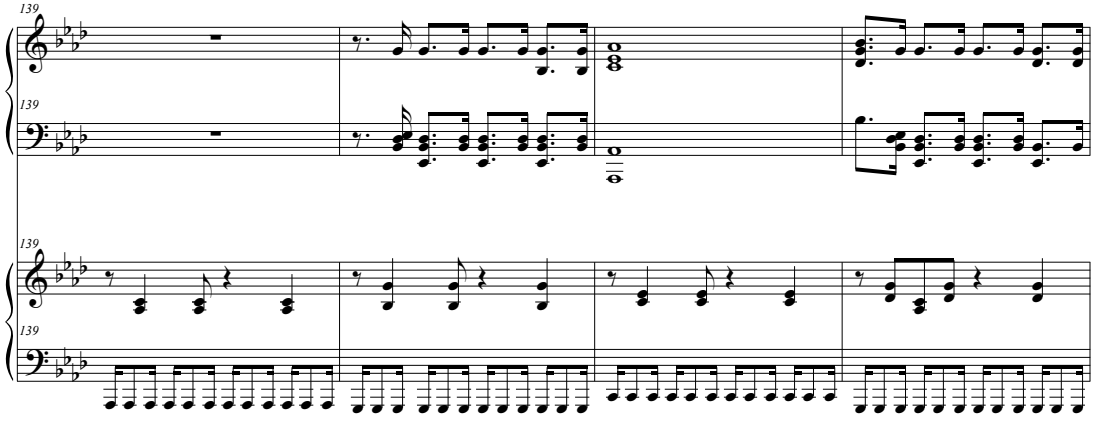
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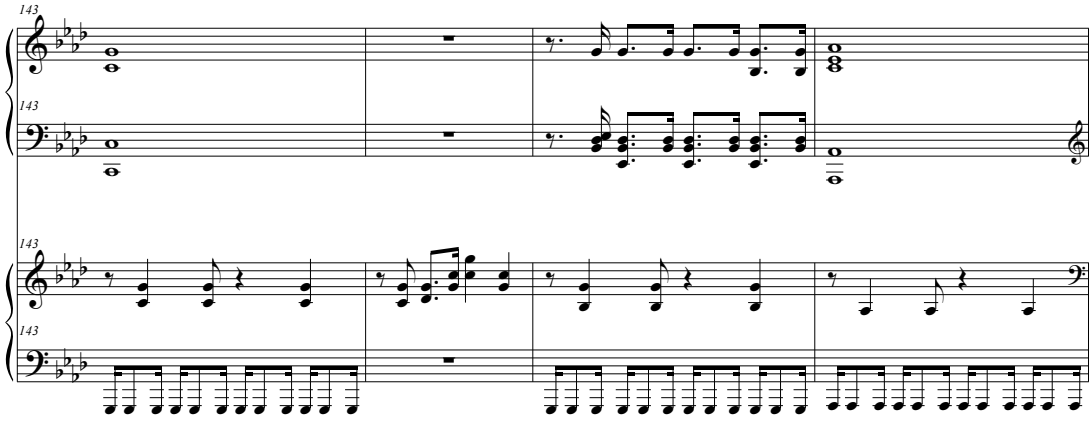
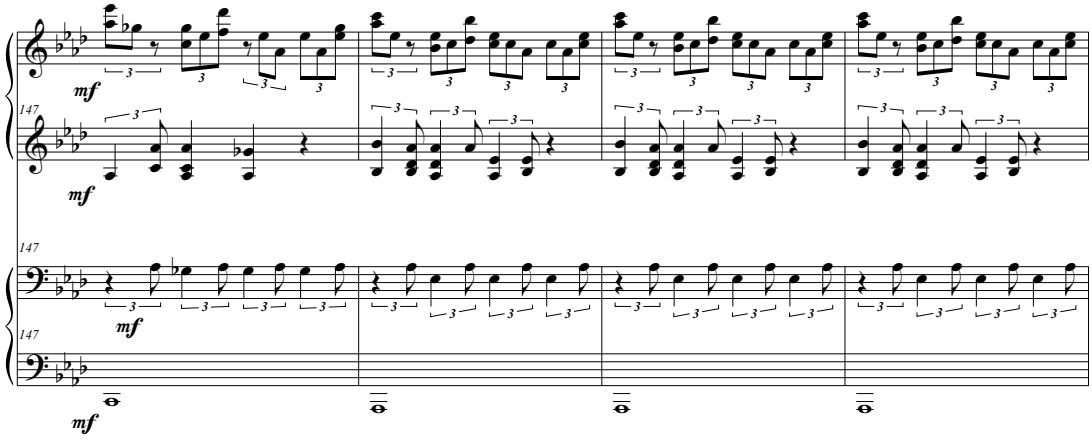
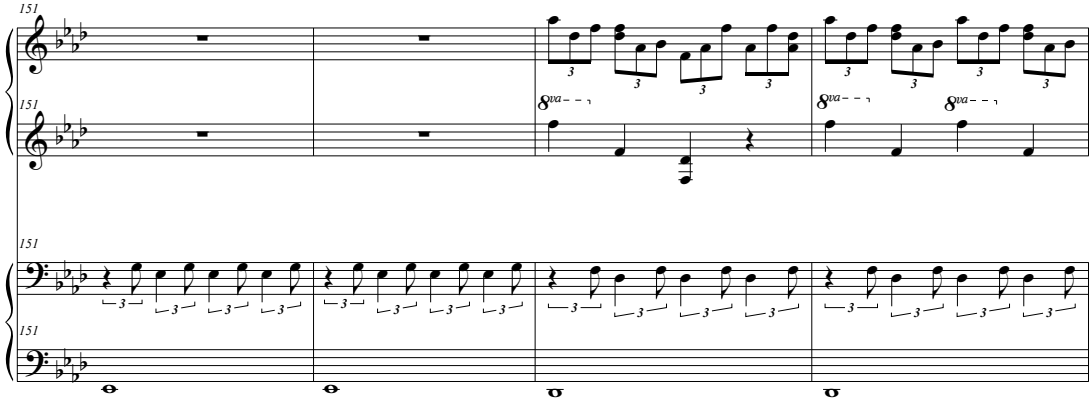
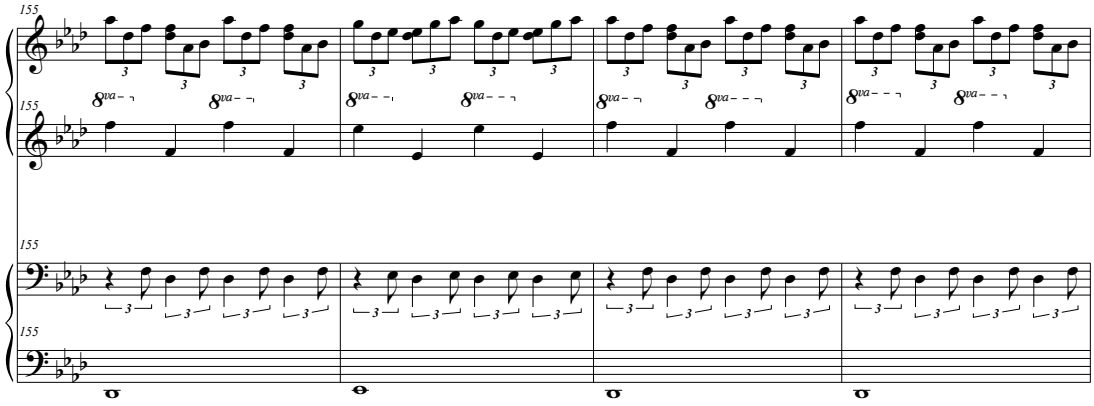


G *cowboy attempts to marshal cattle that have scattered during commotion of train robbery*



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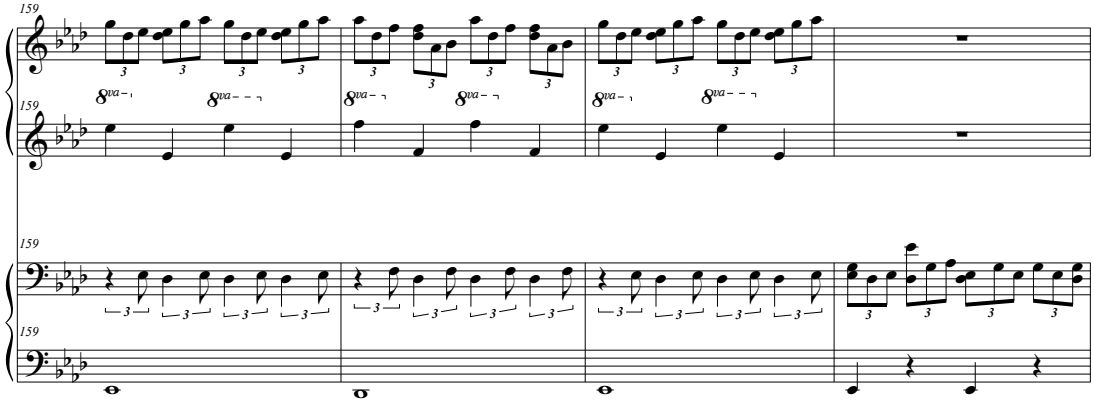
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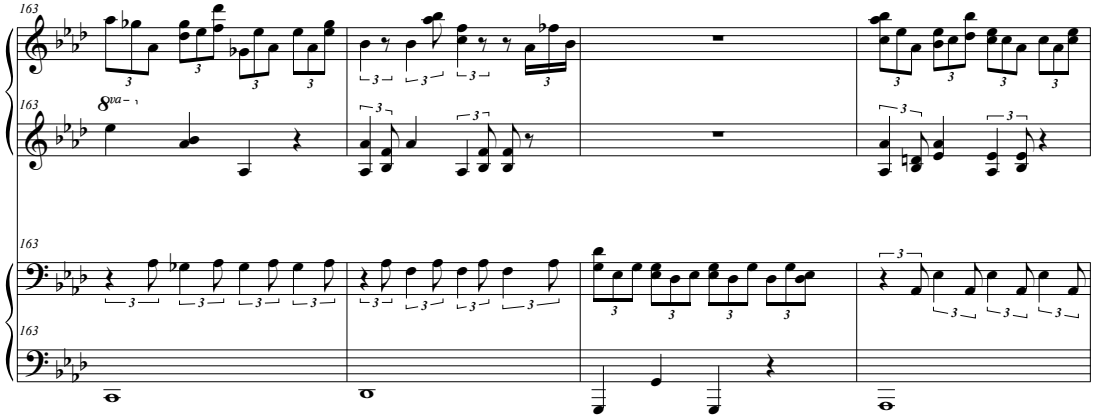
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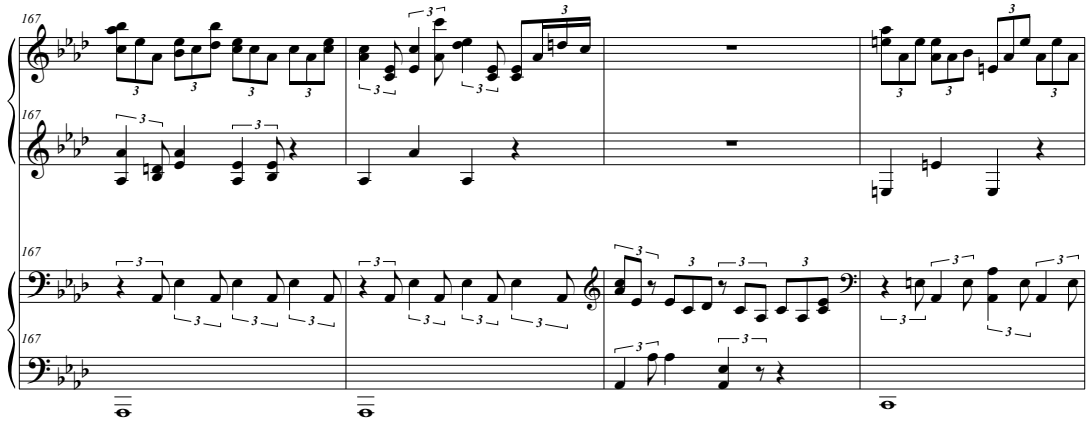
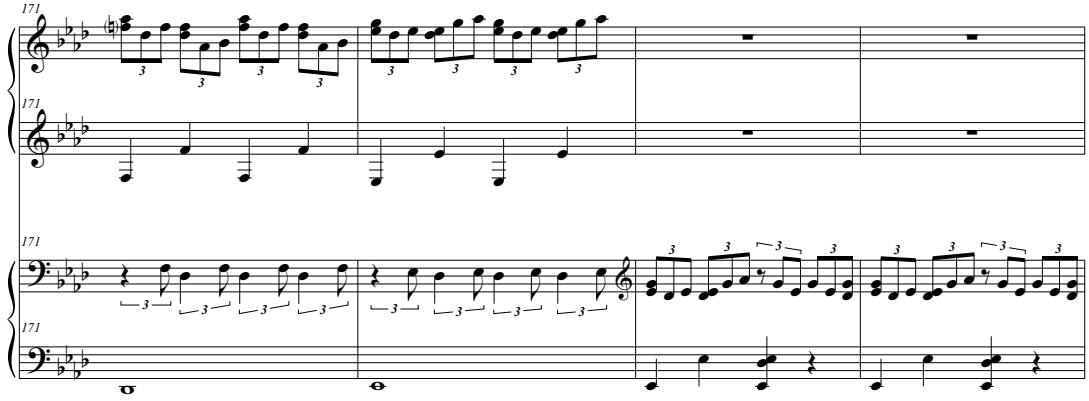
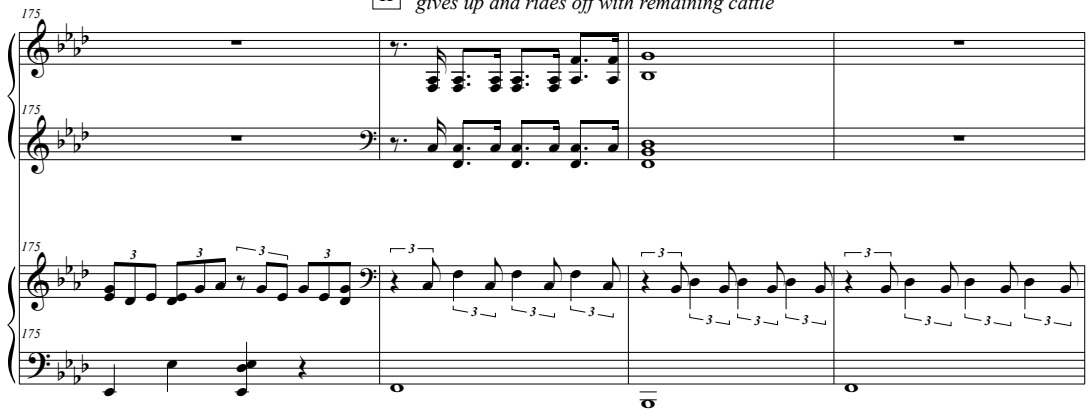
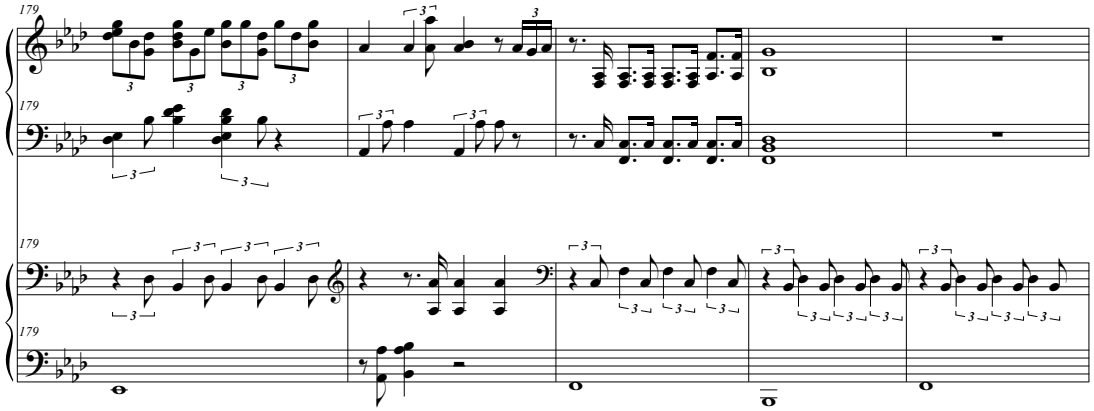
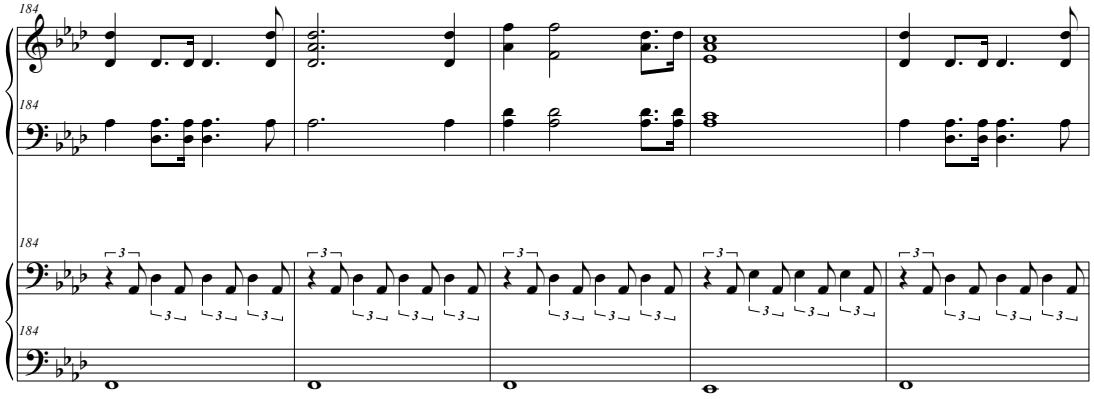




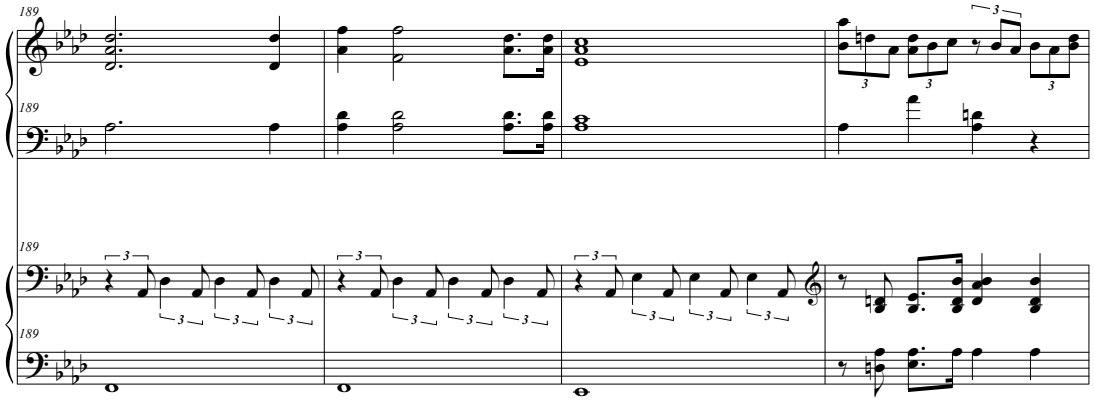
H *cowboy tries to corral one errant cow back to herd;*
gives up and rides off with remaining cattle

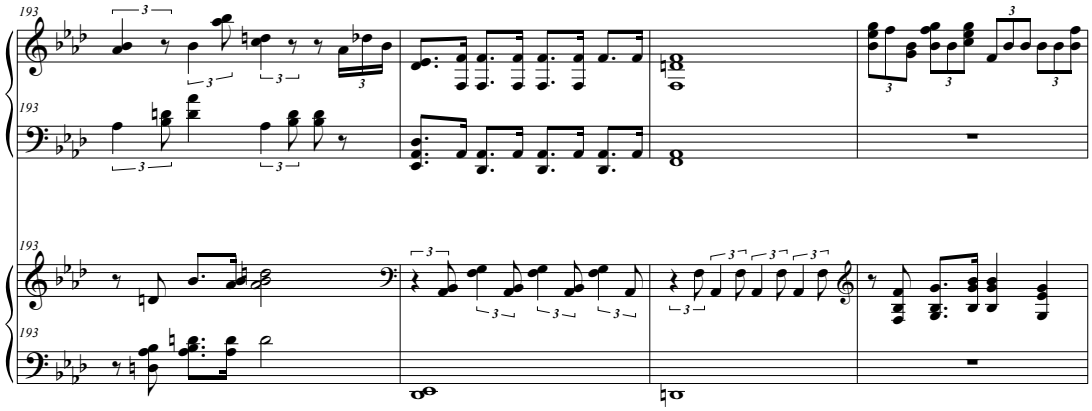


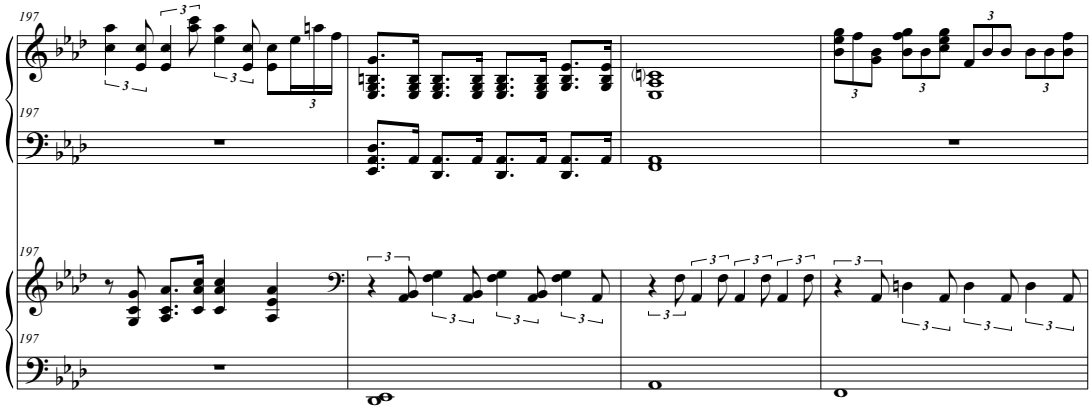


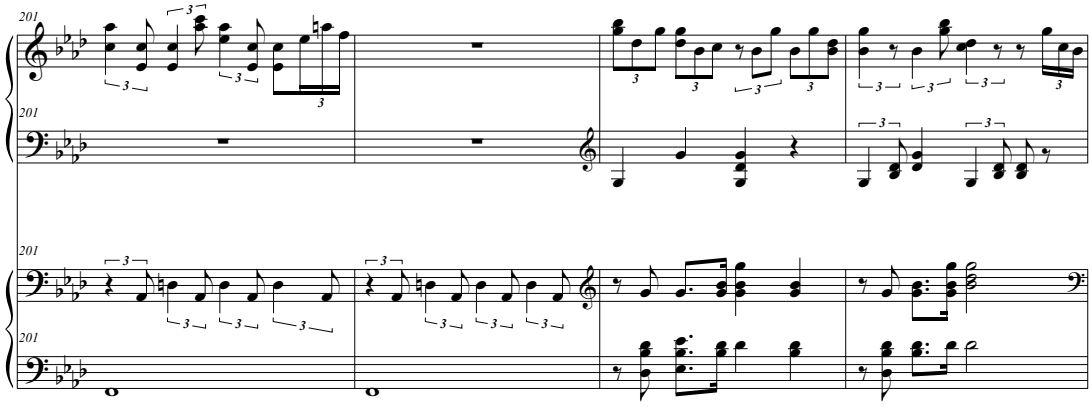


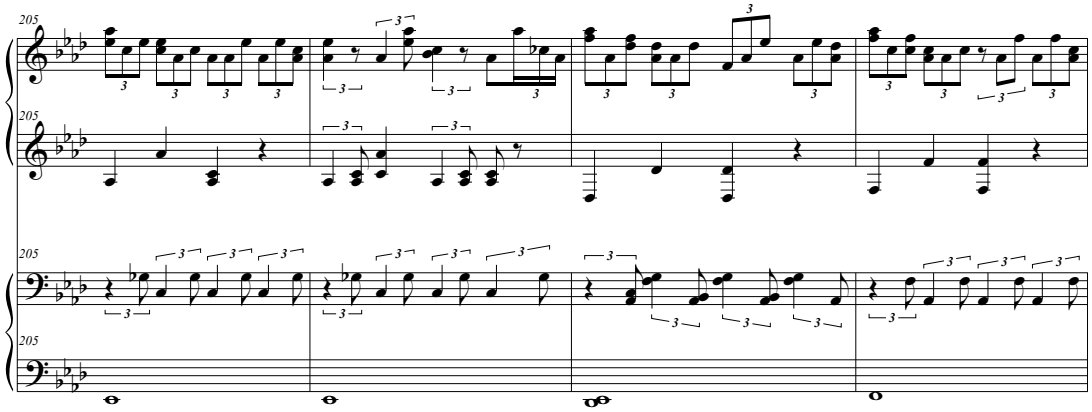
I *the herd, minus one cow,*
reach the sought-after pasture
and begin grazing happily

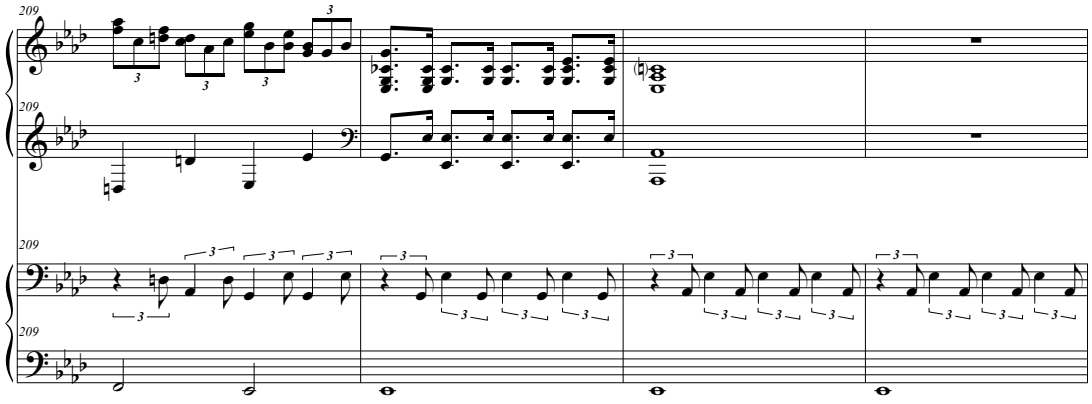




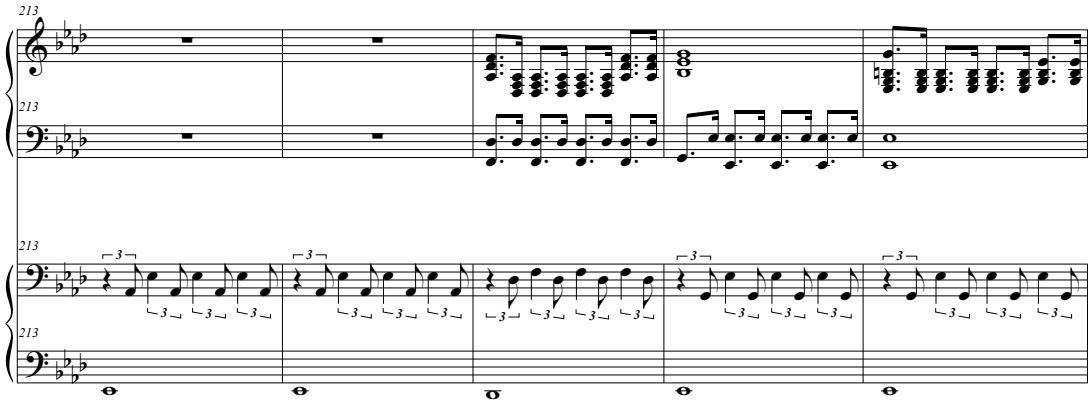


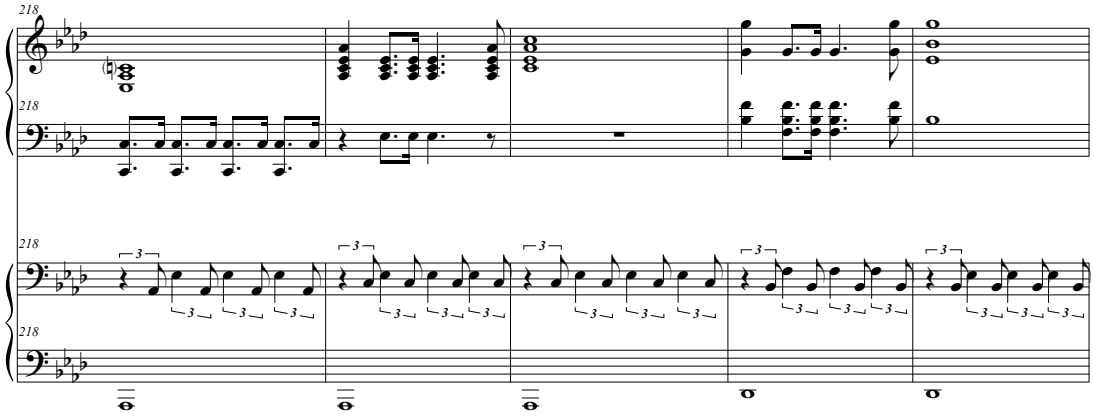






J *cowboy rides home, mostly successful*

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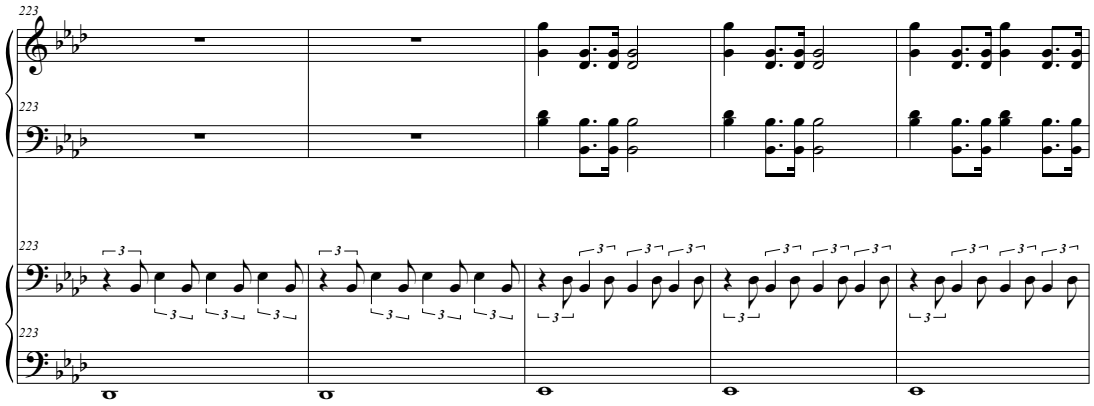
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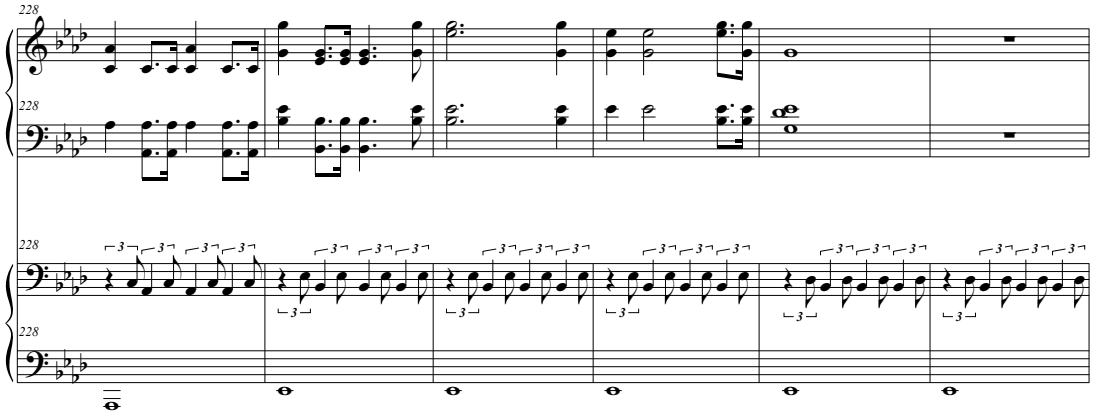
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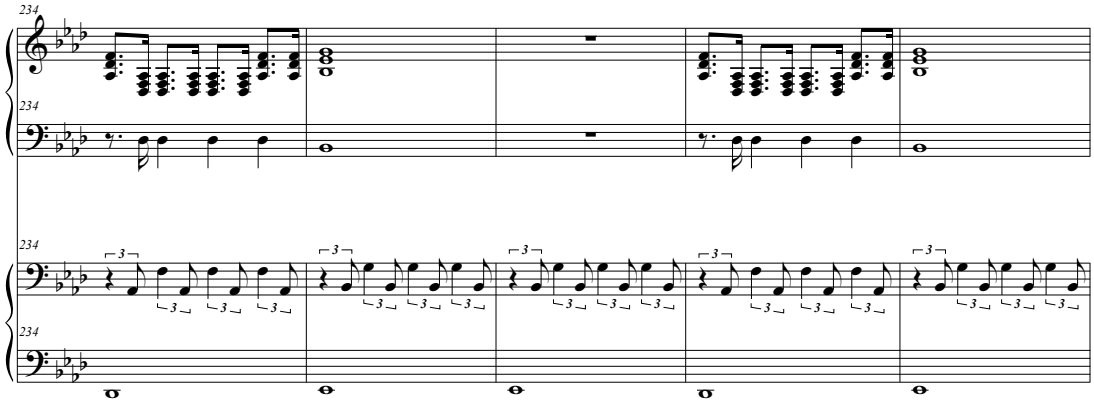
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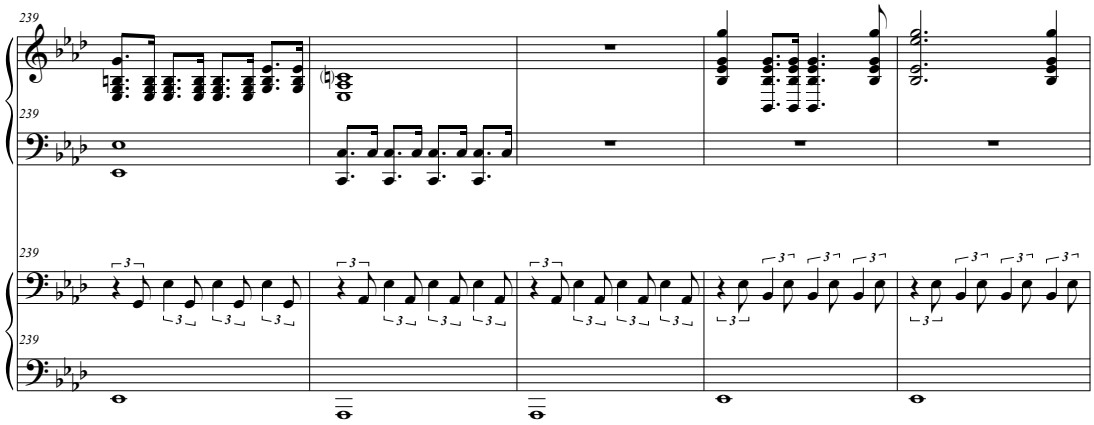
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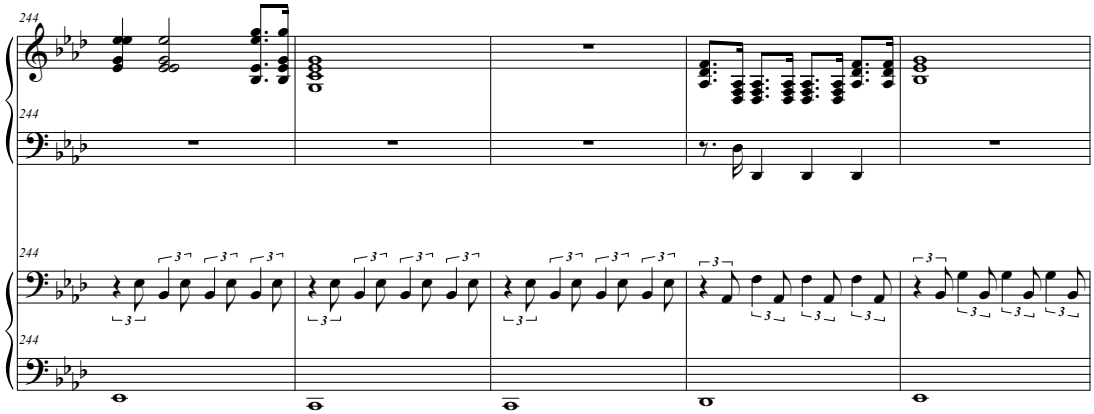
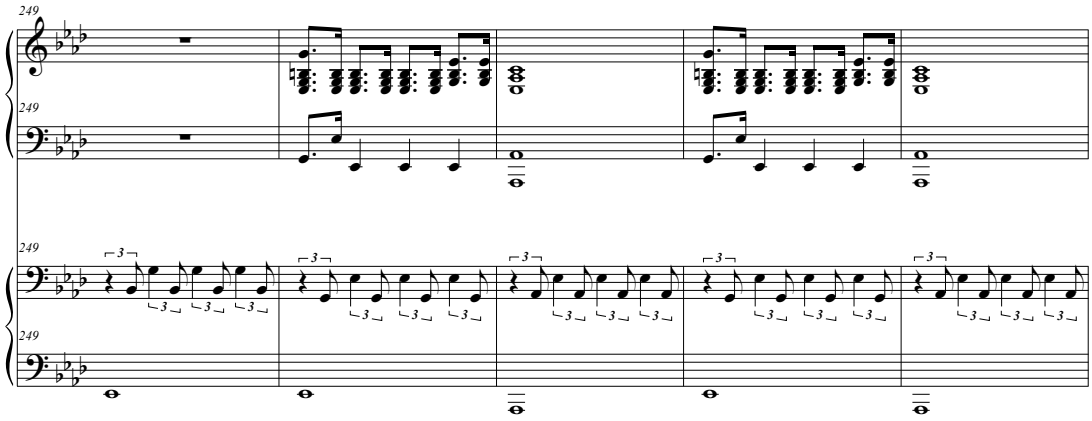
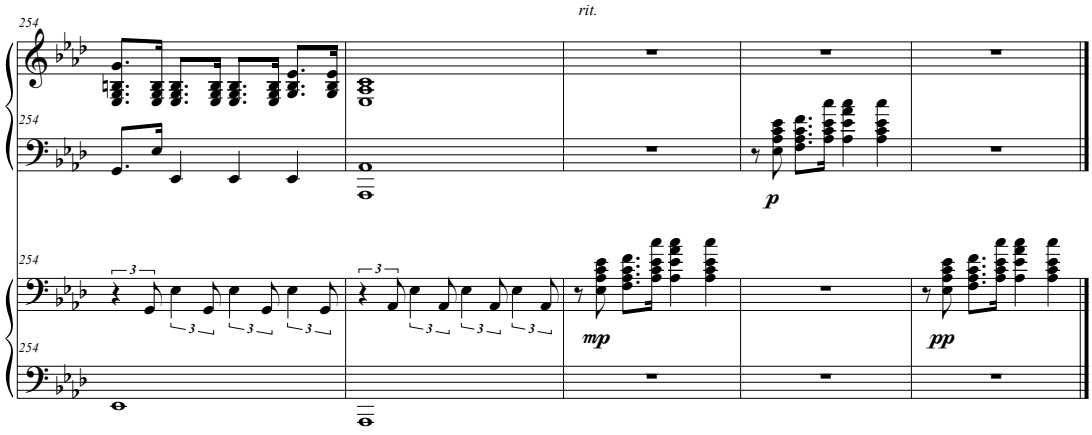

244
244
244
244

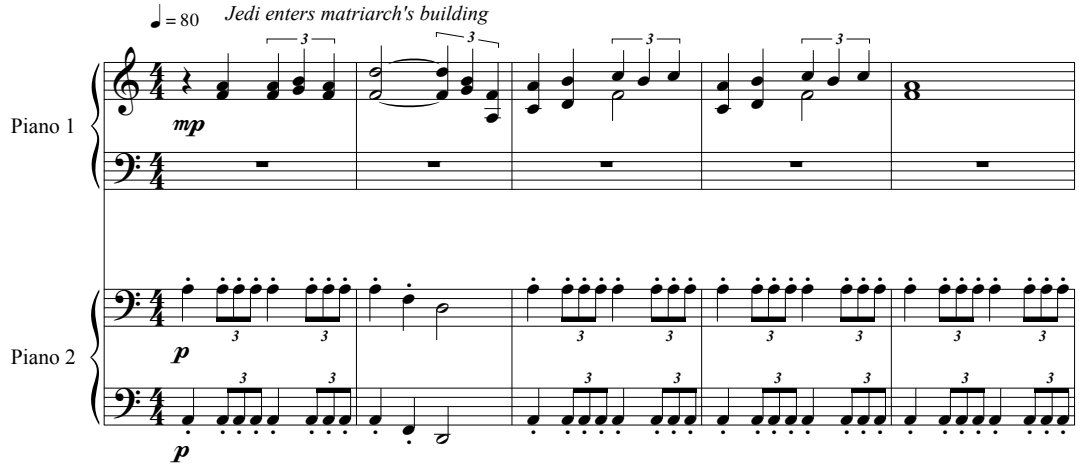

249
249
249
249

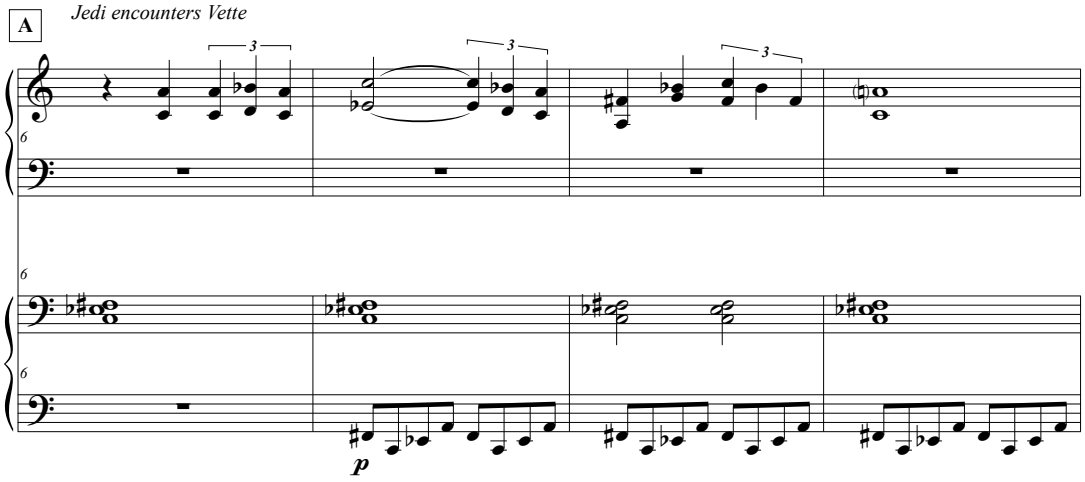

rit.
254
254
254
254
p
mp
pp

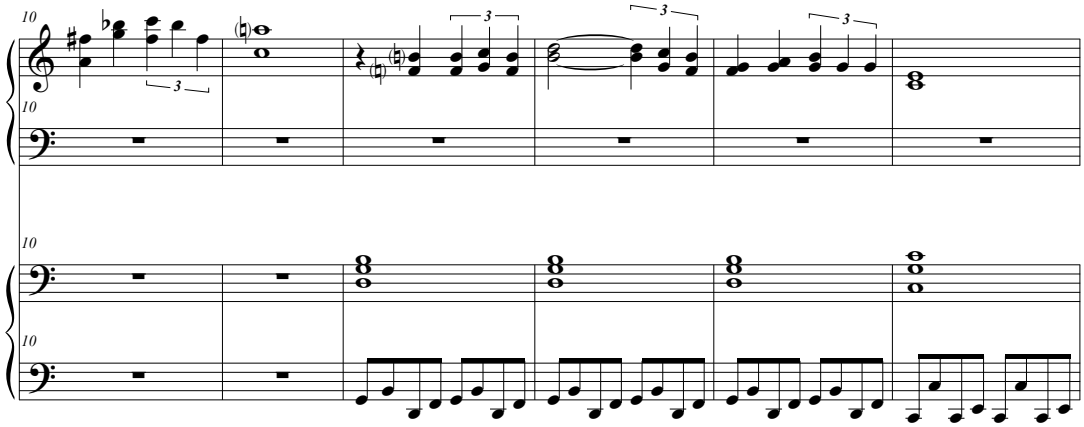
II. $(SW^2)^2$

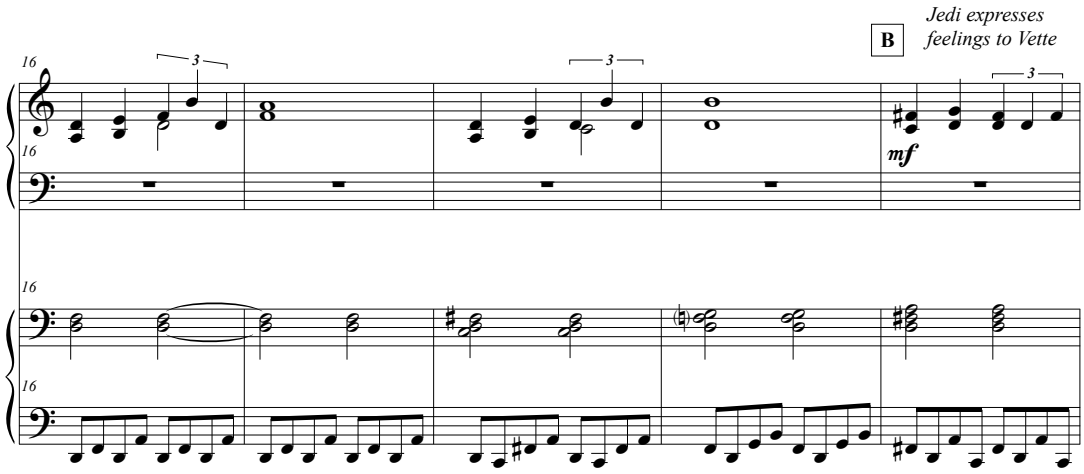
SONG WITHOUT WORDS:

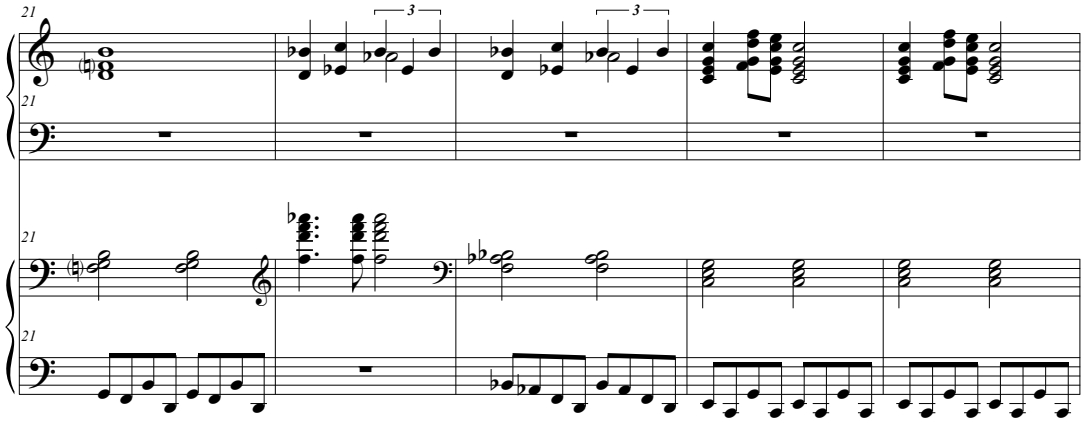
STAR WARS WALKTHROUGH

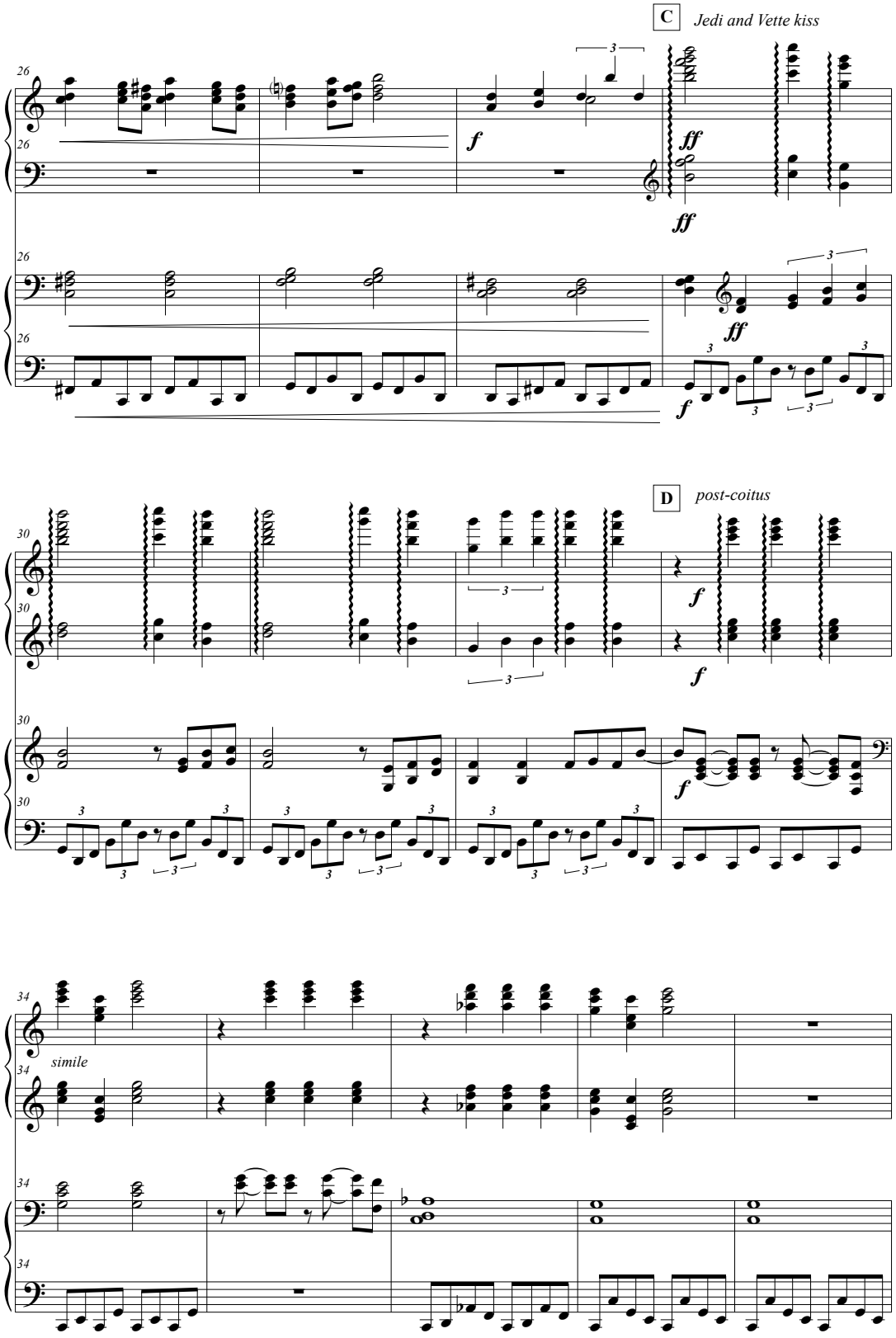


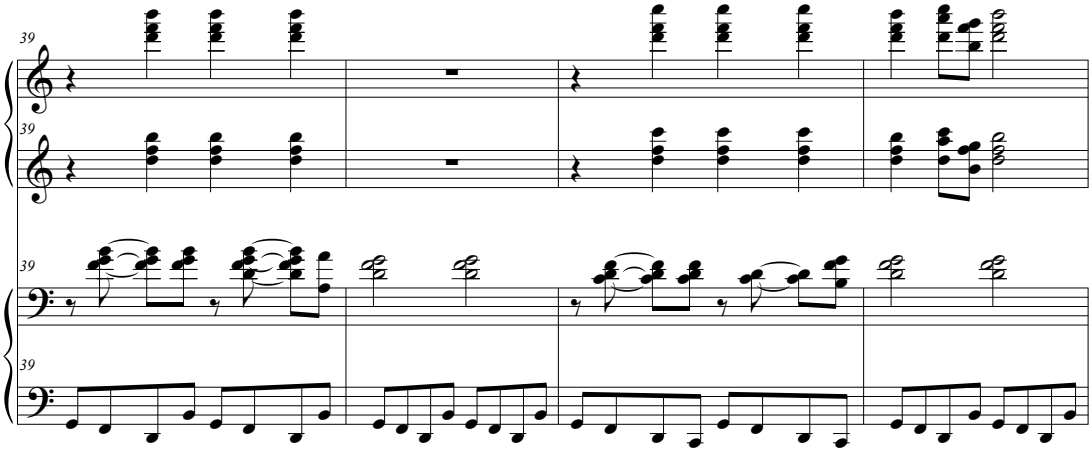


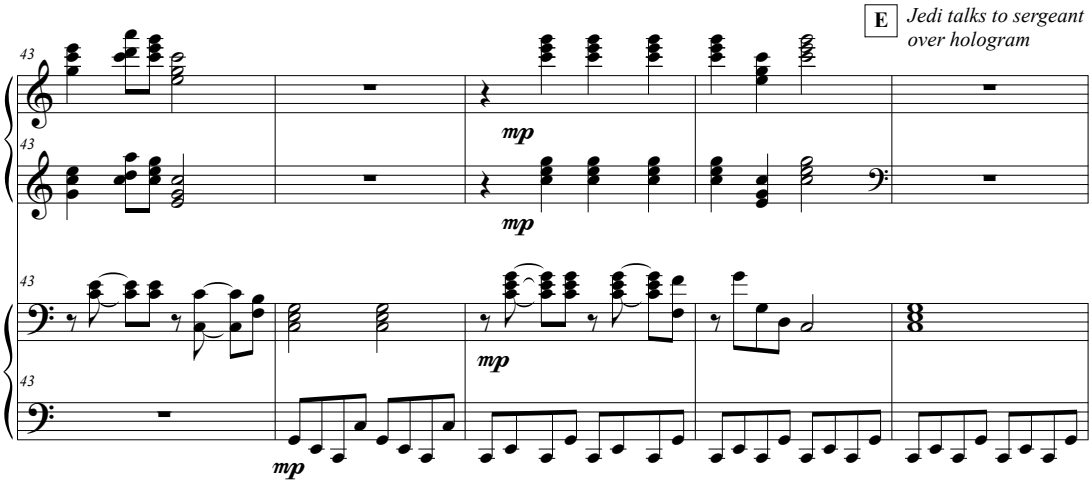


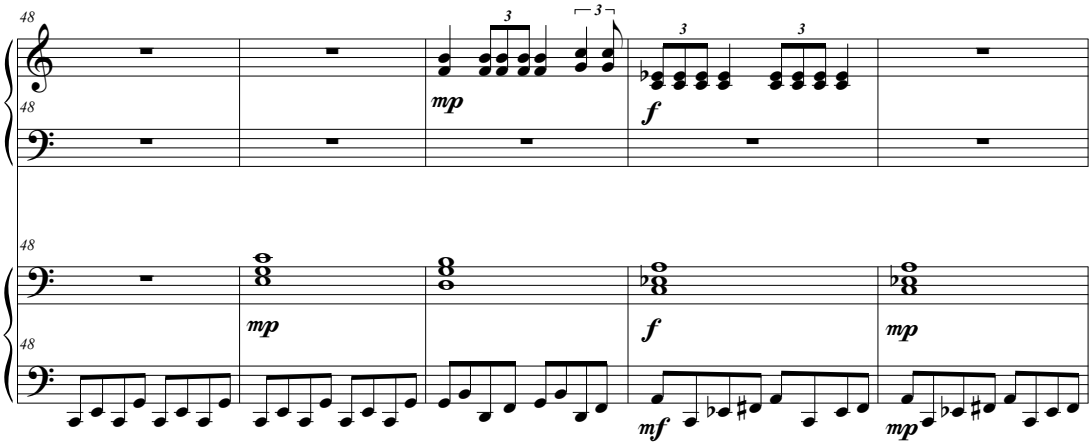

B
Jedi expresses
feelings to Vette
mf

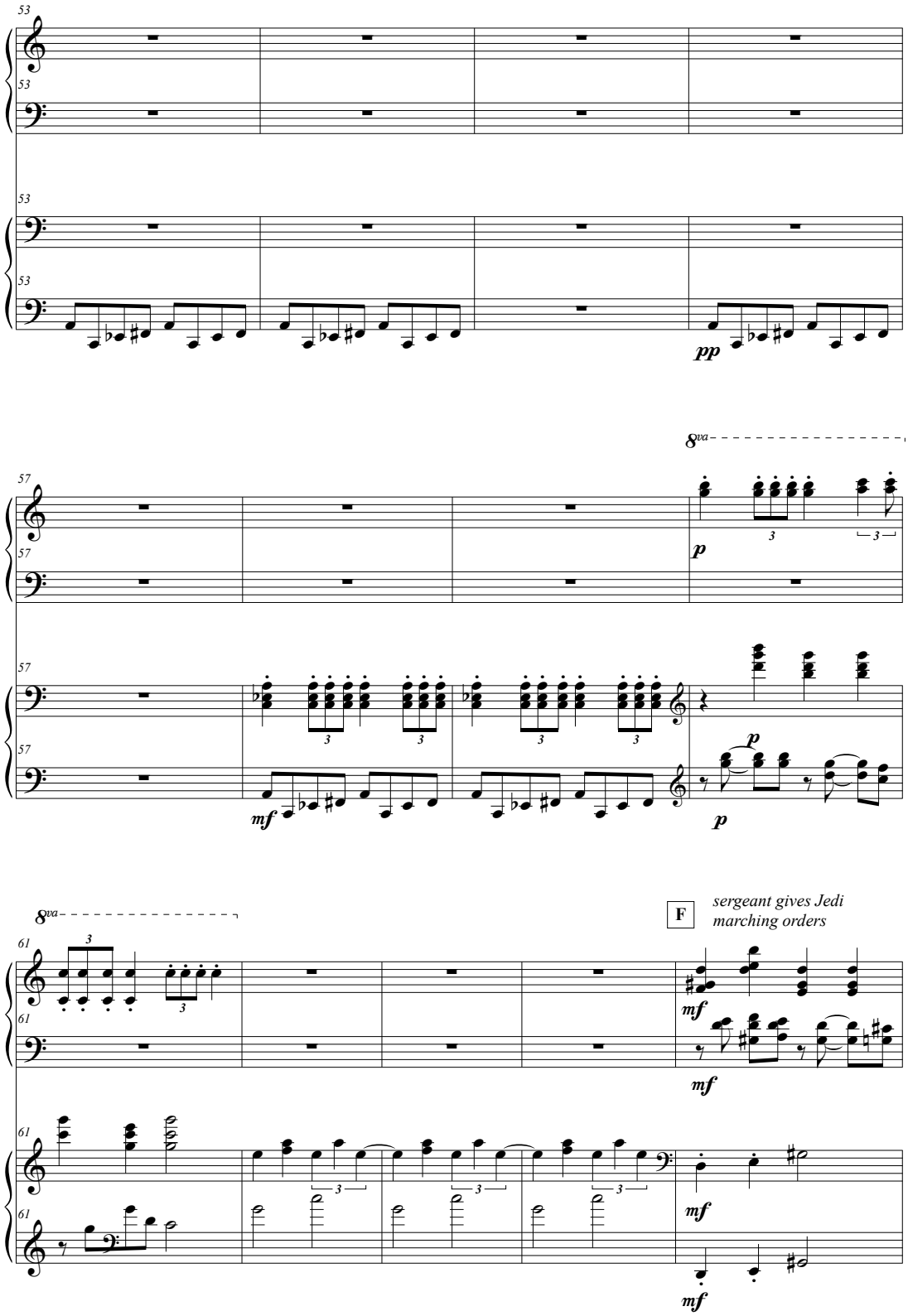


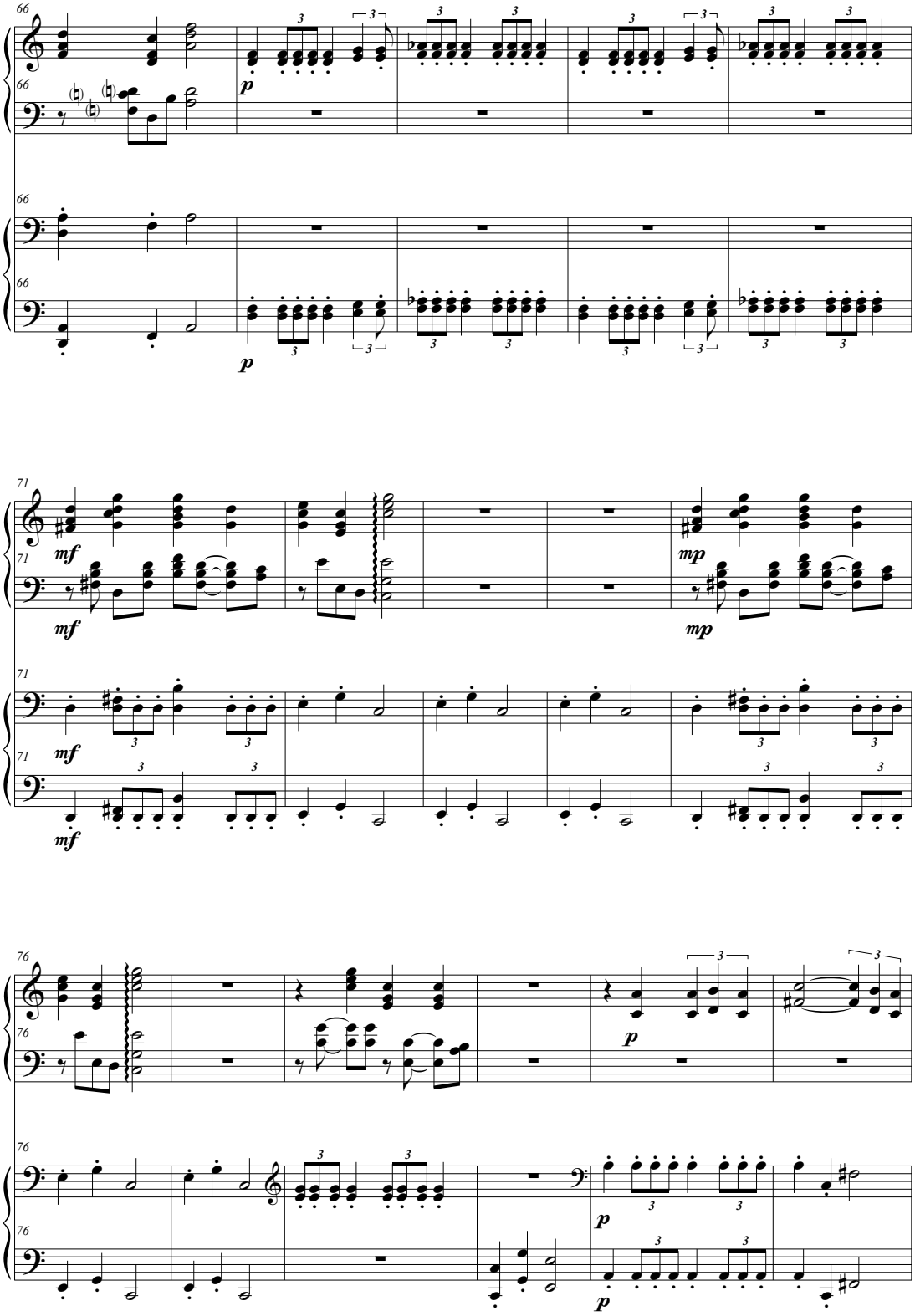

C
Jedi and Vette kiss
D
post-coitus
simile

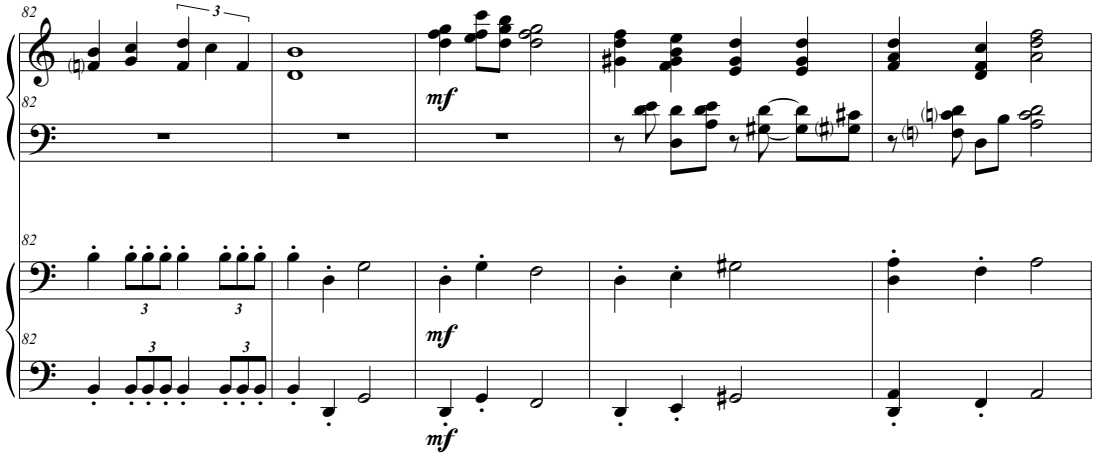


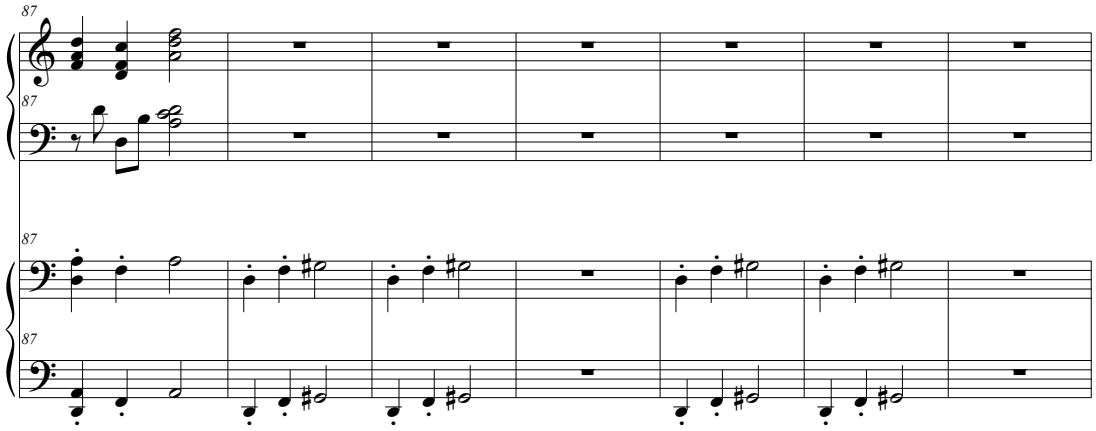

E
Jedi talks to sergeant over hologram
mp
mp
mp
mp

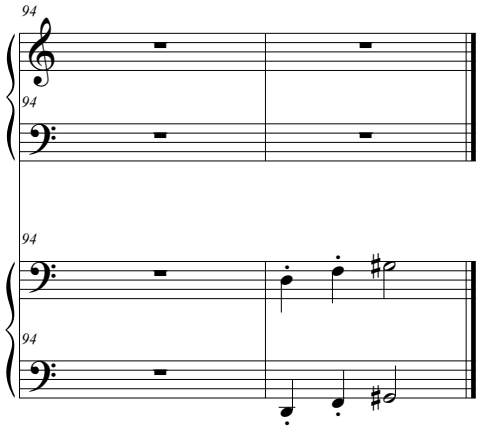

3
3
3
mp
f
mp
f
mf
mp


53
pp
8va
57
p
mf
61
F
sergeant gives Jedi
marching orders

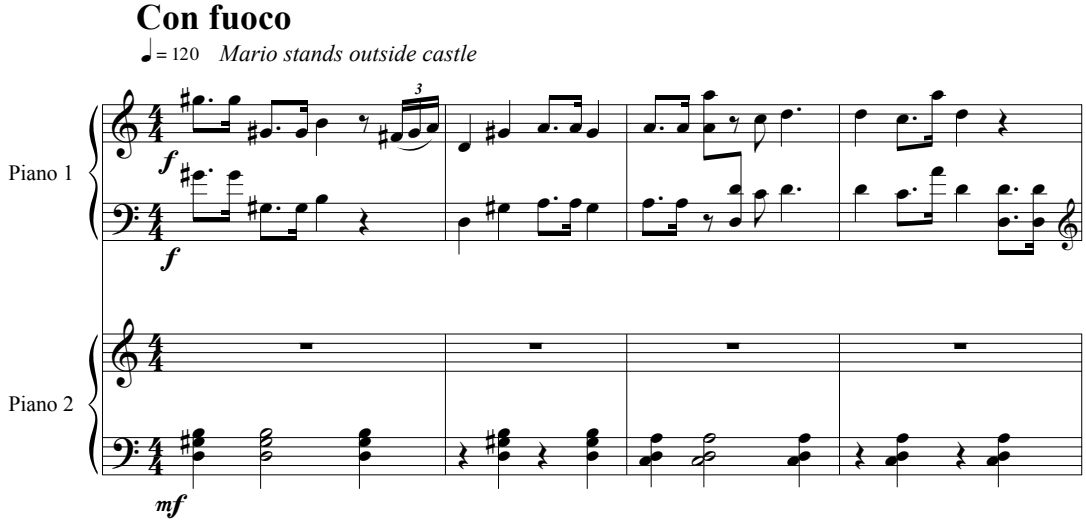

66
p
71
mf
mp
76
p

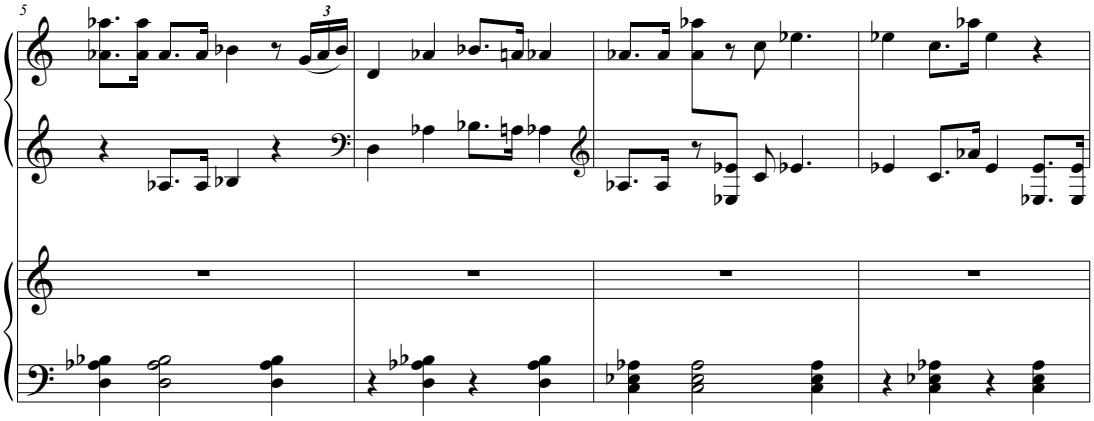

82
3
mf
82
82
3
3
mf
82
3
3
mf

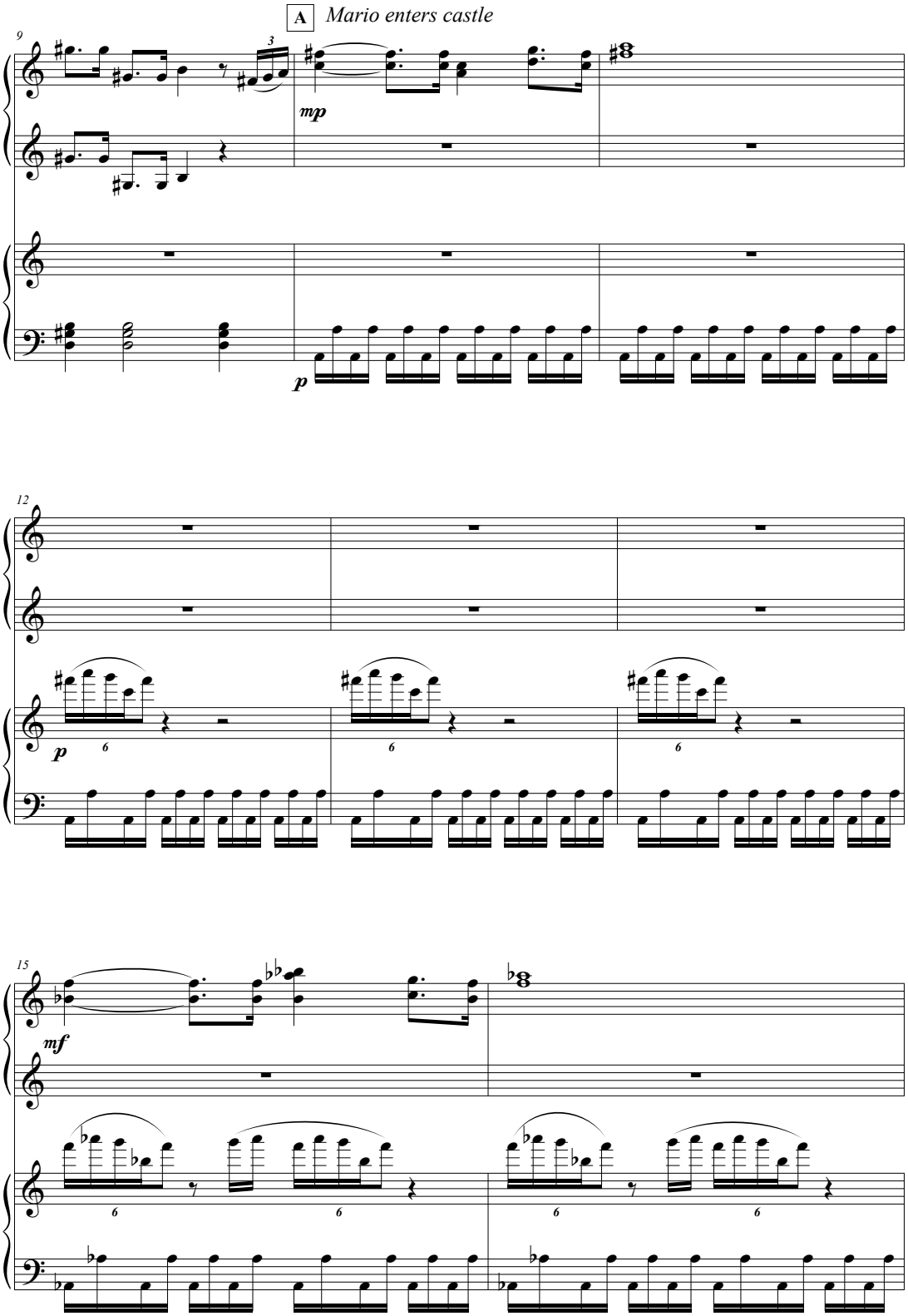

87
87
87
87

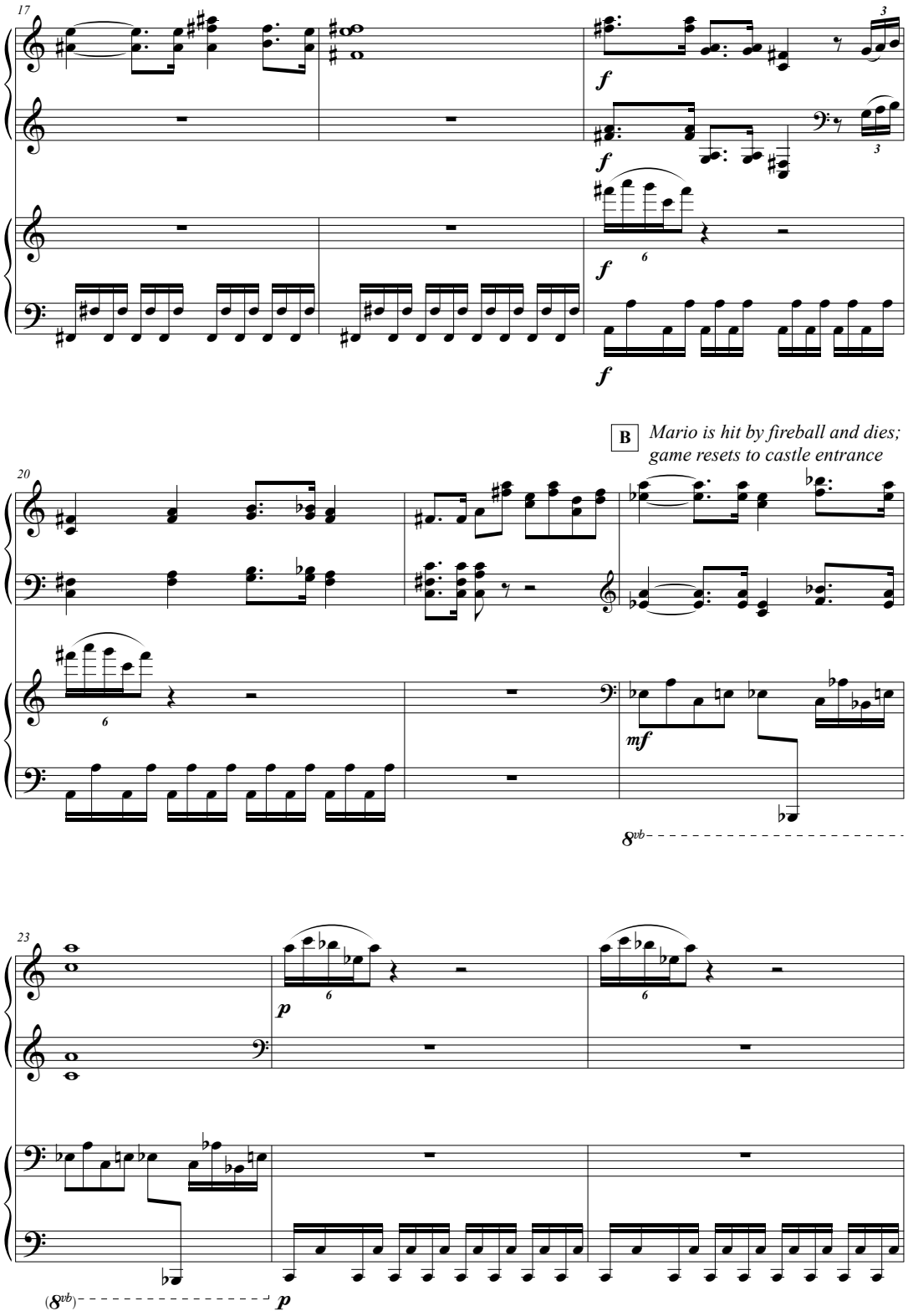

94
94
94
94

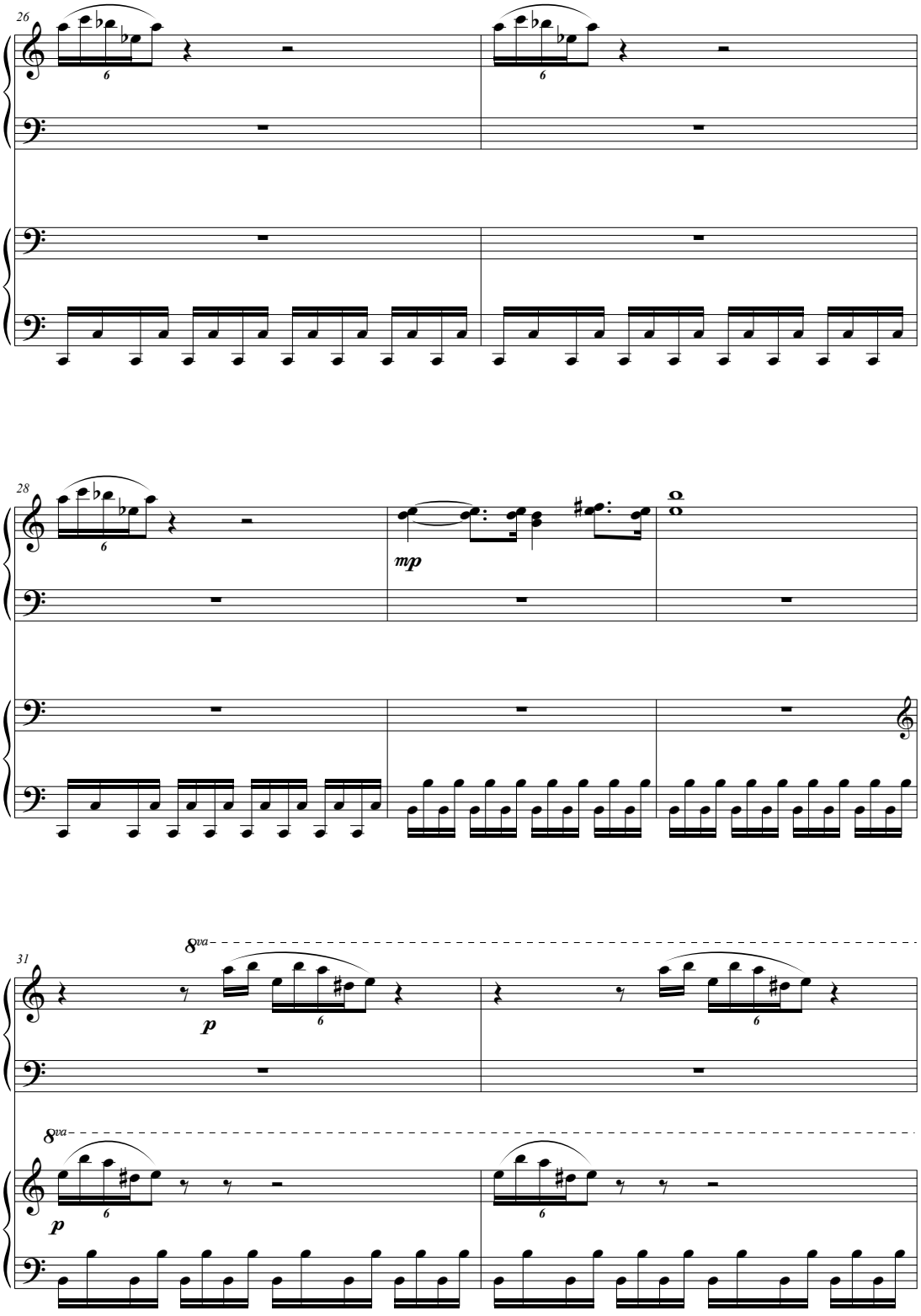
III. BOWSER'S CASTLE

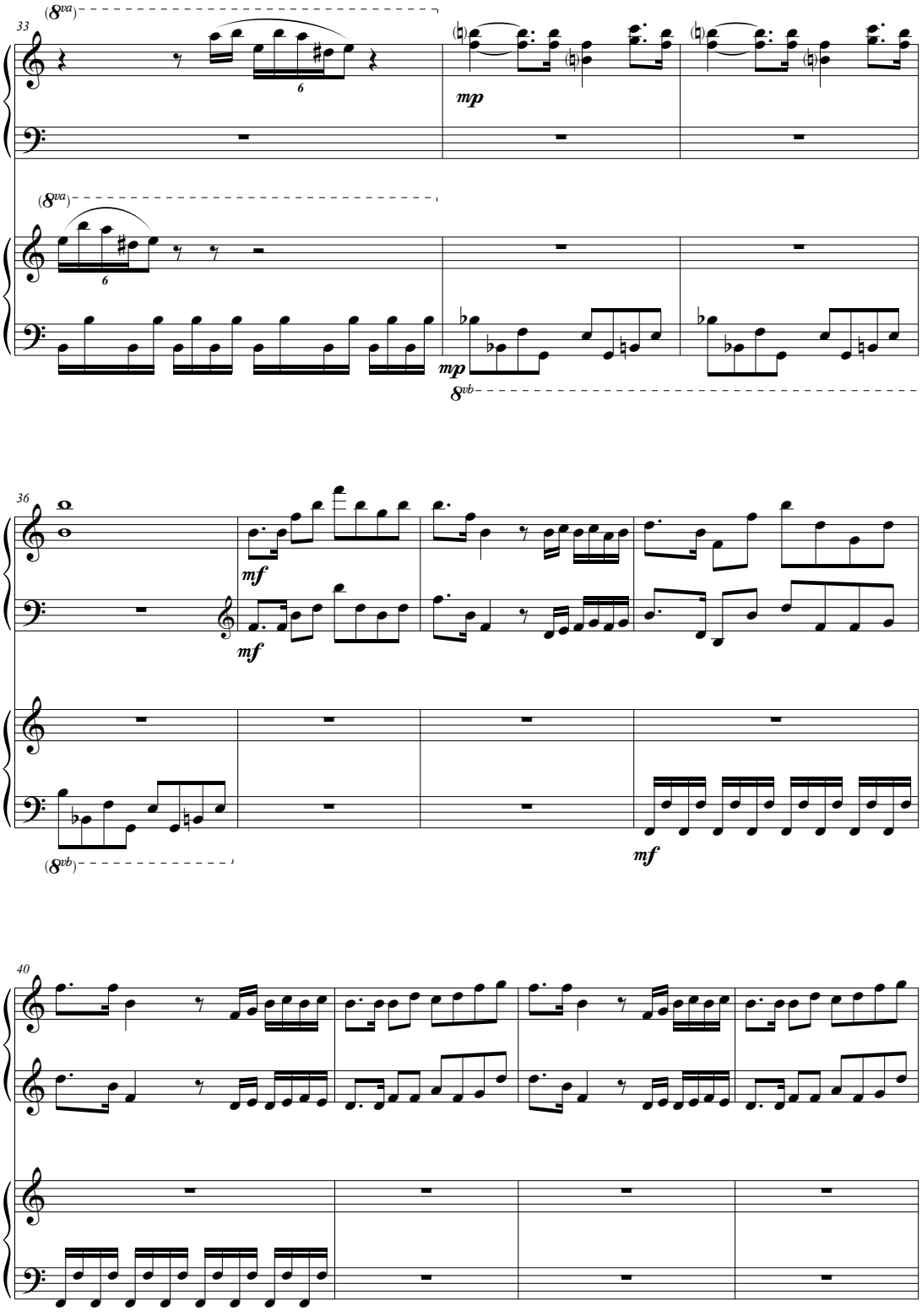


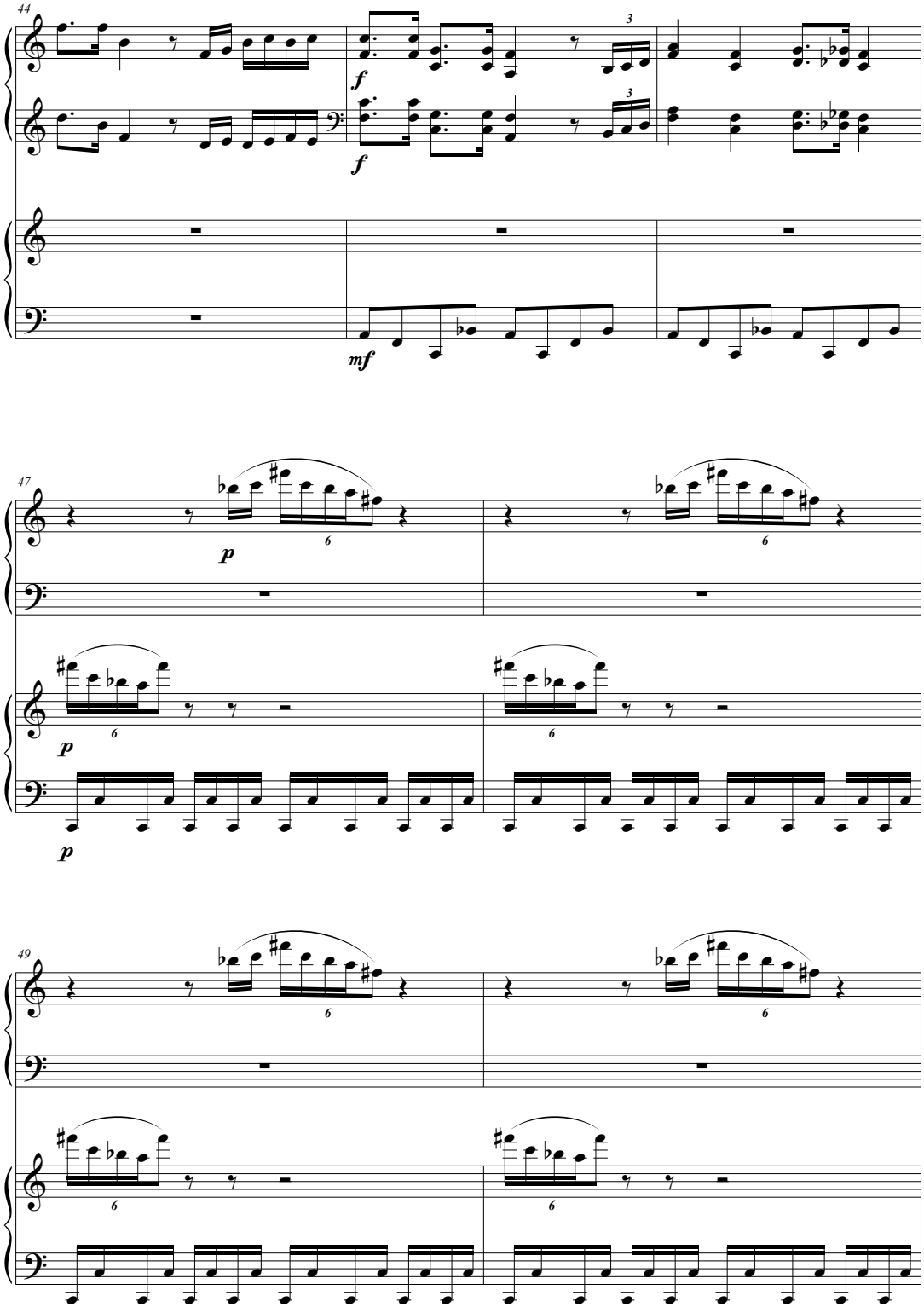


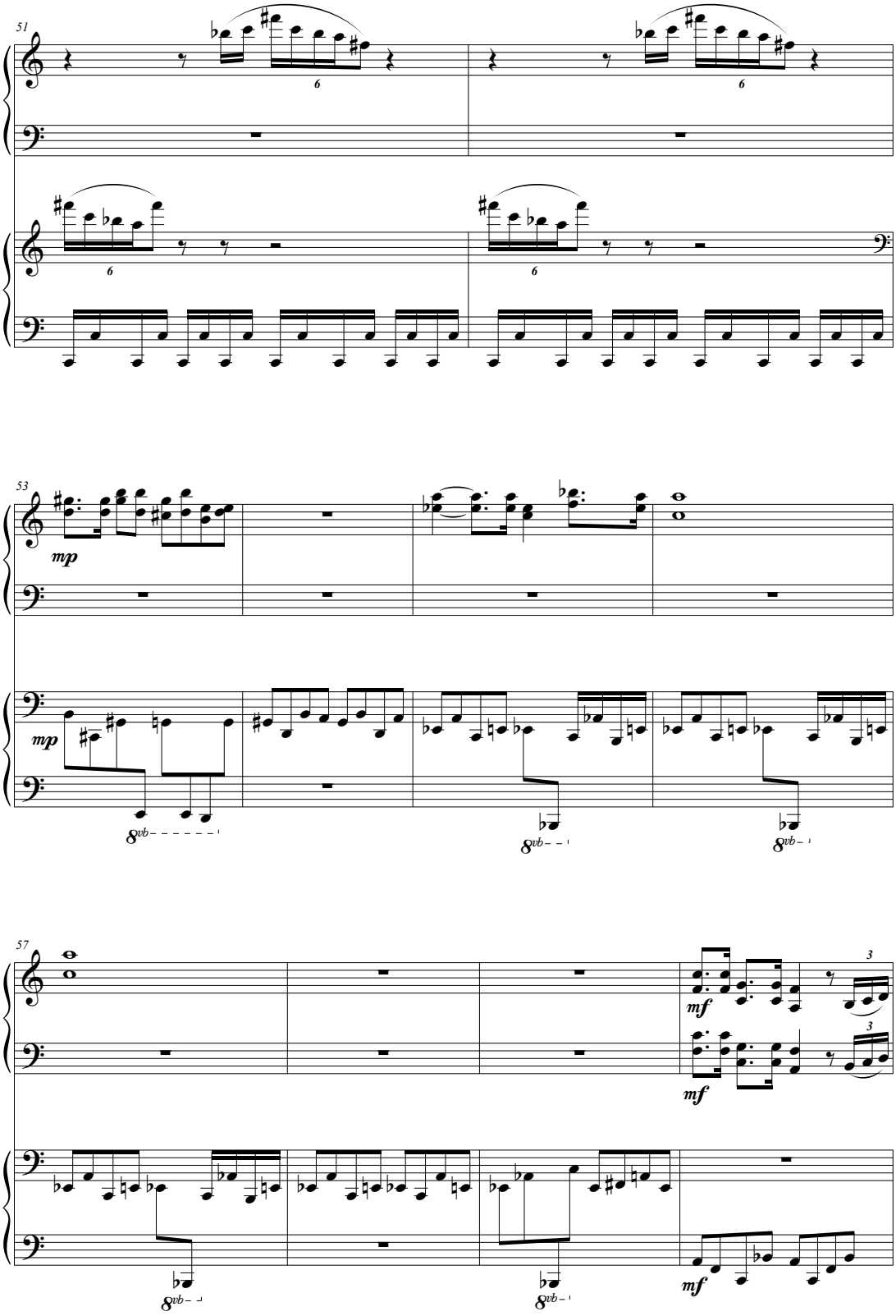

A
Mario enters castle
9
mp
p
12
p
15
mf

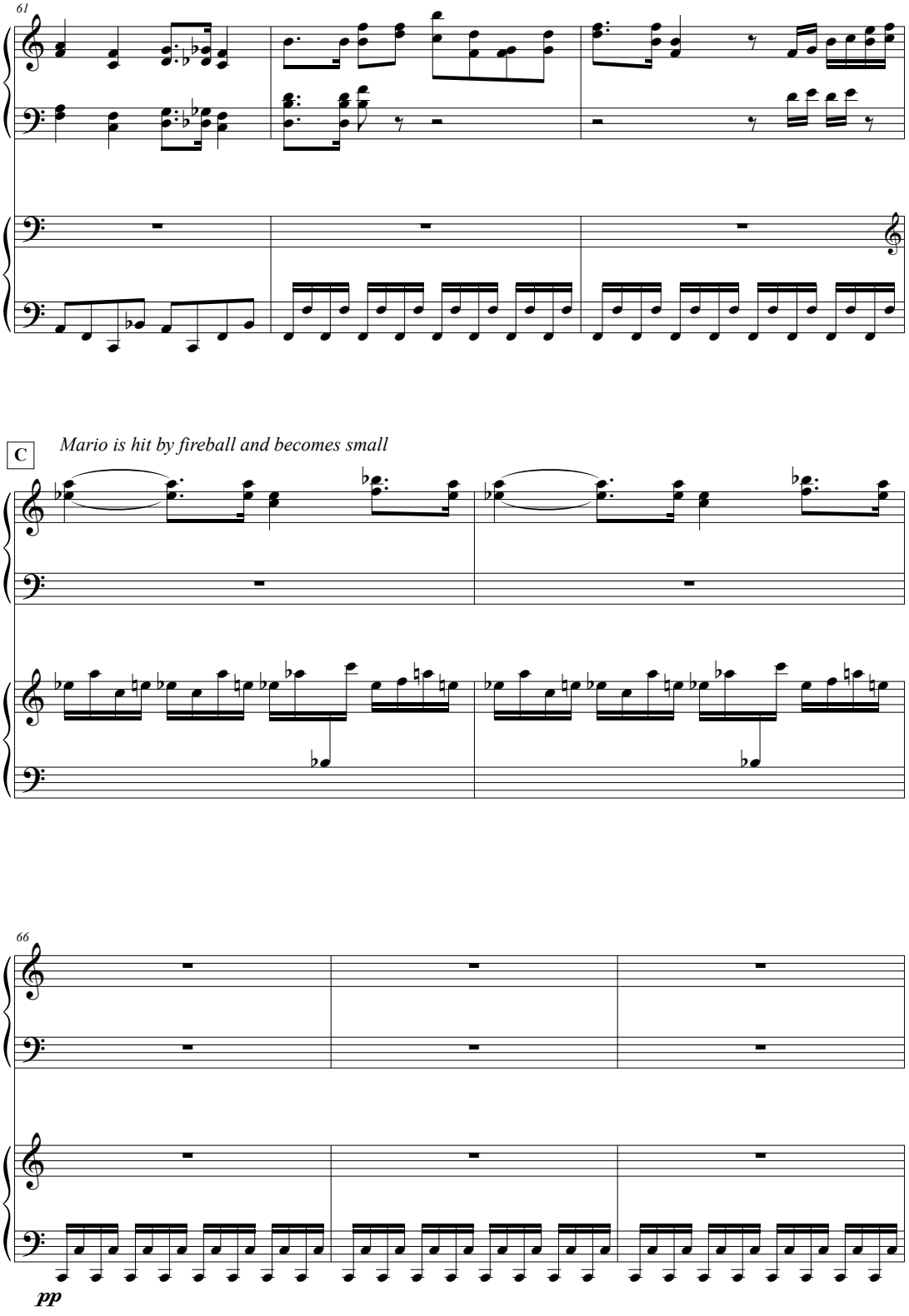

17
f
f
f
f
B
Mario is hit by fireball and dies;
game resets to castle entrance
20
mf
8vb
23
p
p
(8vb)

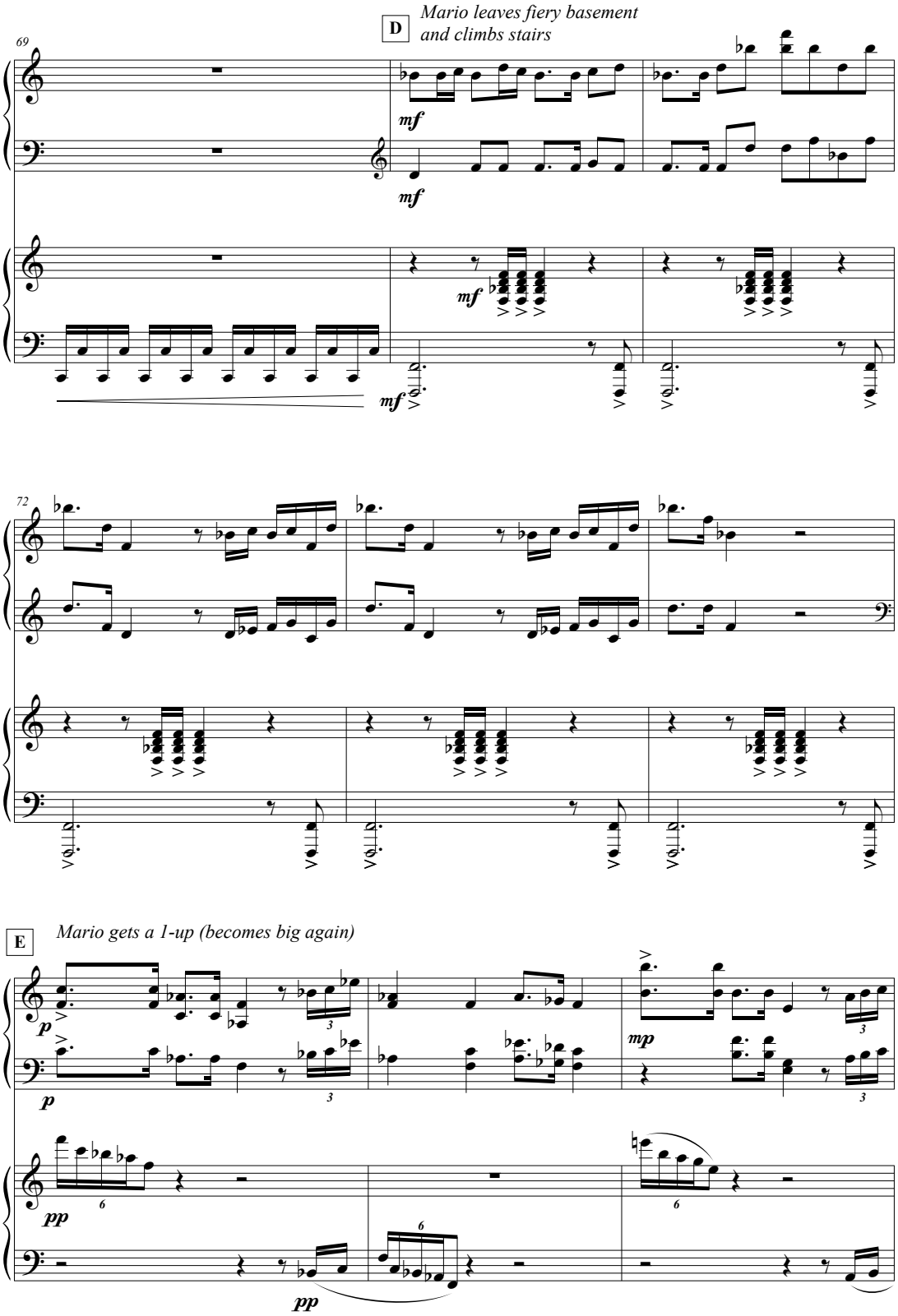

26
28
mp
31
8va
p
8va
p

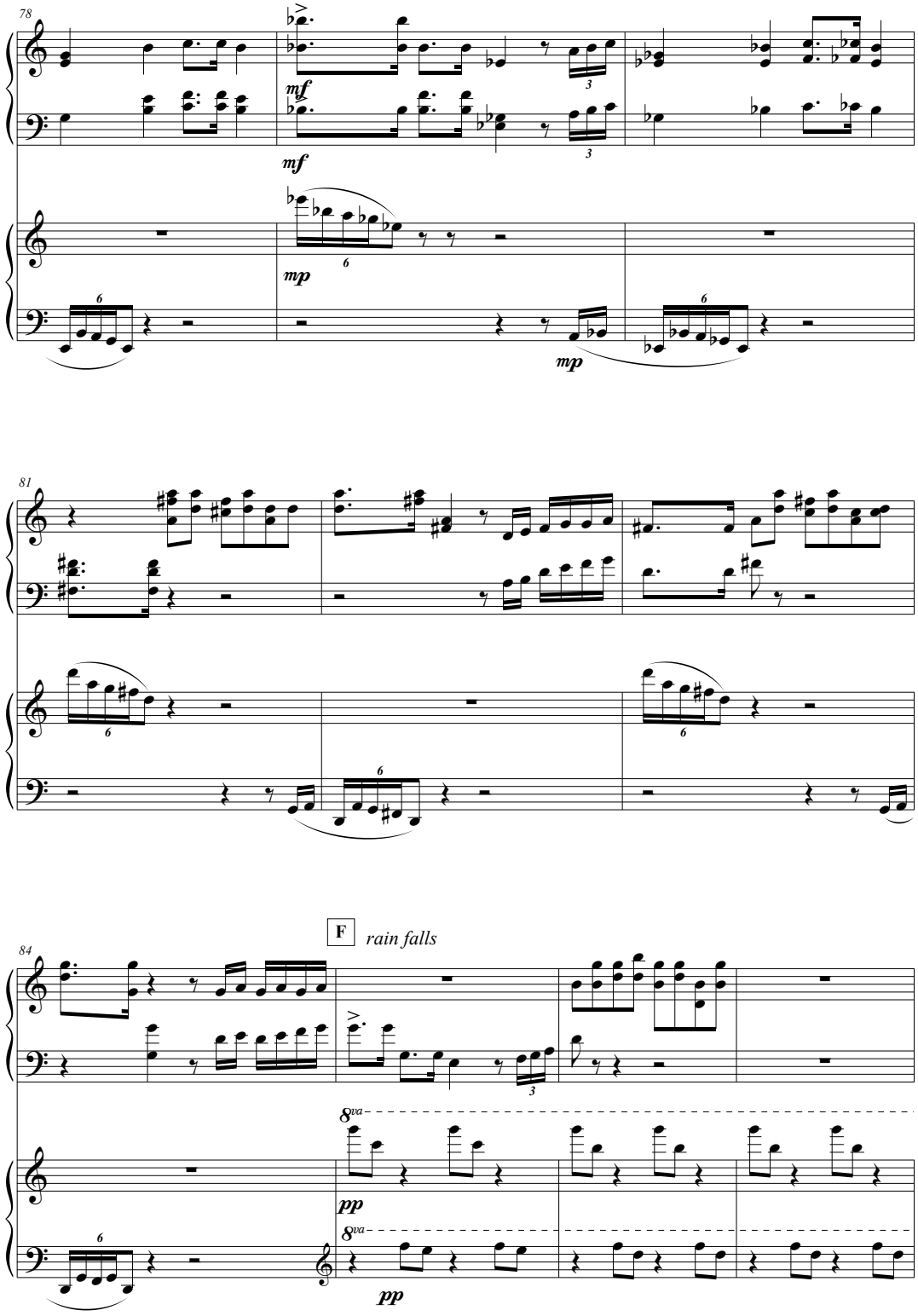

33
(8va)
6
mp
(8va)
6
mp
8vb
36
mf
mf
(8vb)
mf
40

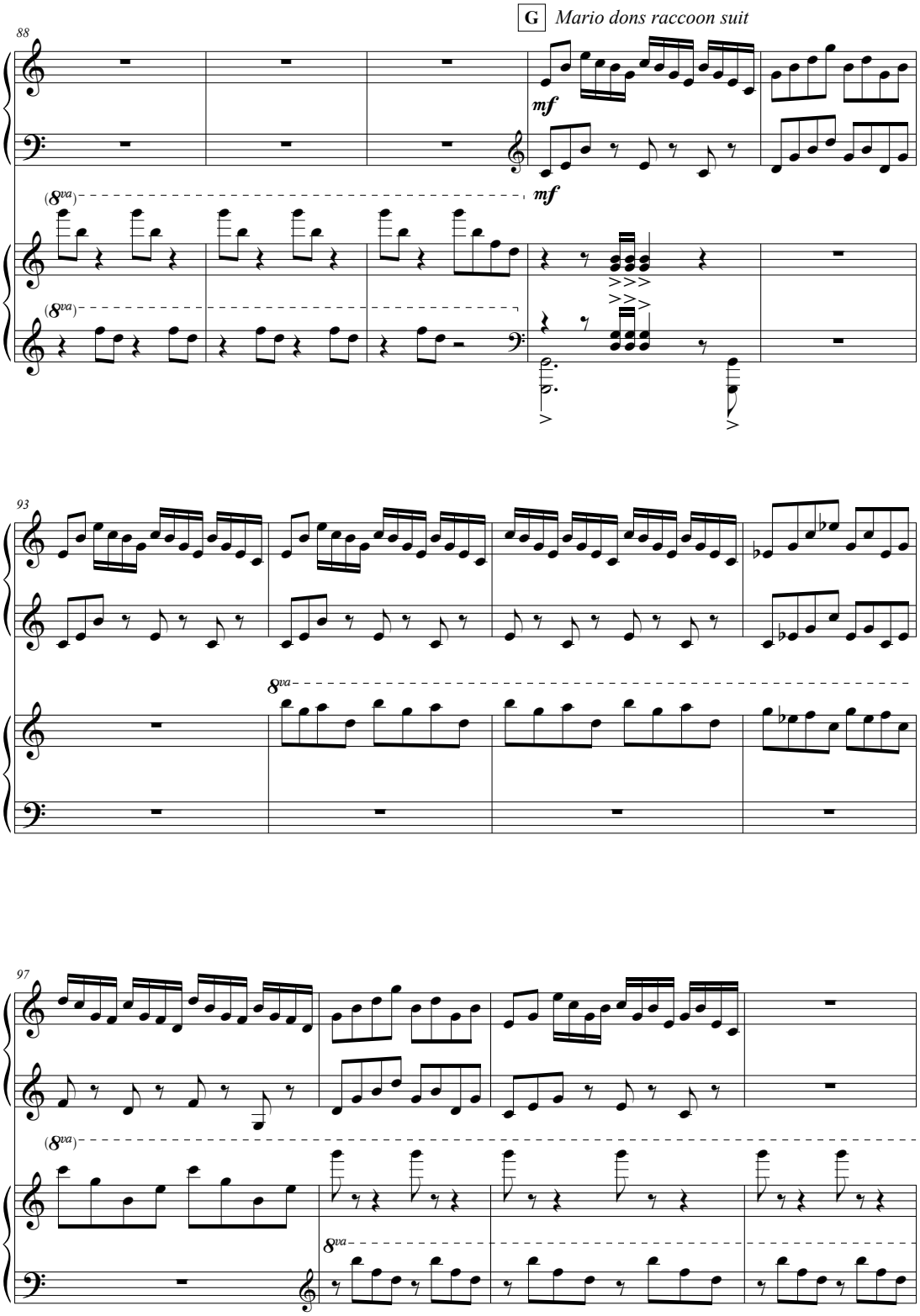

44
f
f
3
3
mf
47
p
6
p
6
p
49
6
6
6
6

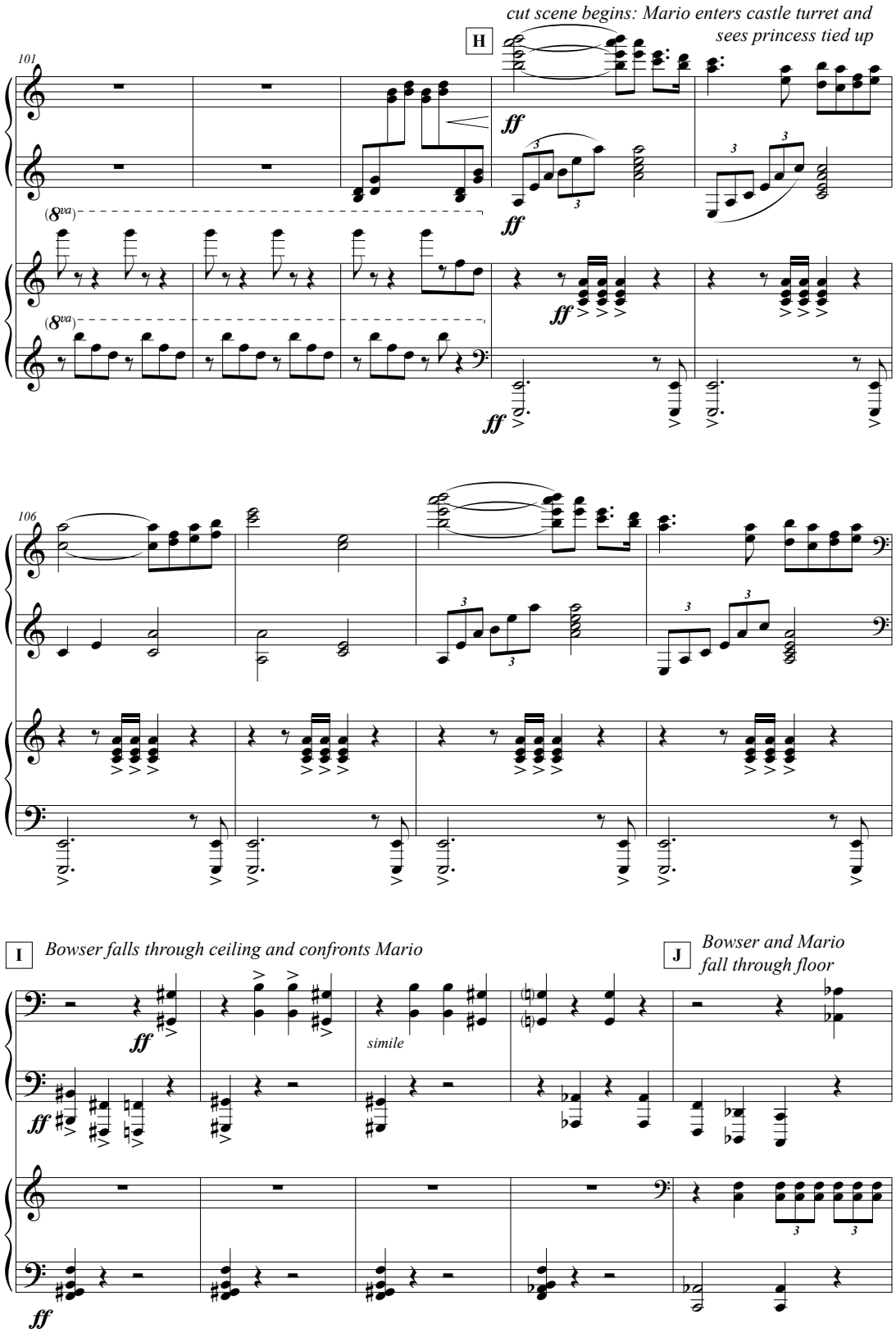

51
6
6
6
6
53
mp
mp
8vb
8vb
8vb
57
3
mf
3
mf
8vb
8vb
mf

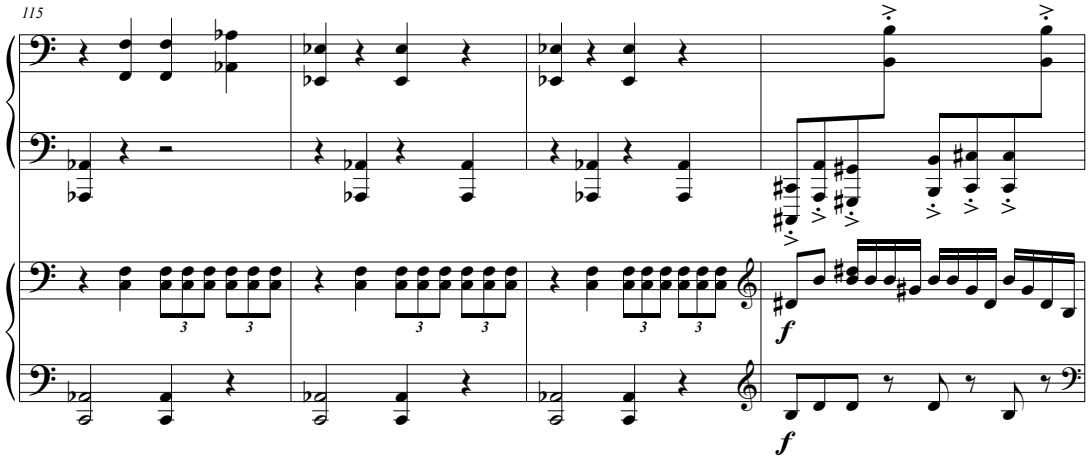

61
C
Mario is hit by fireball and becomes small
66
pp


D
Mario leaves fiery basement
and climbs stairs
69
mf
mf
mf
mf
72
E
Mario gets a 1-up (becomes big again)
p
p
mp
pp
pp

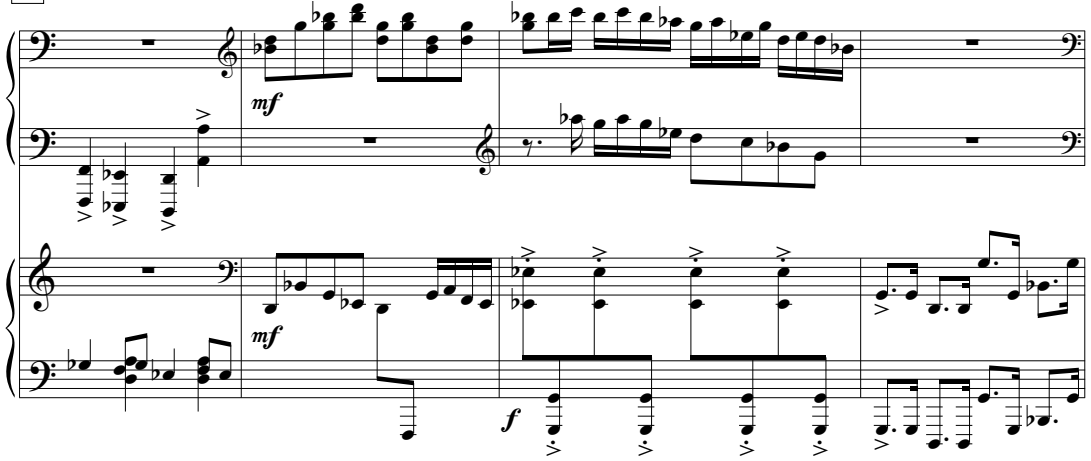

78
mf
mf
mp
mp
81
F
rain falls
84
8va
pp
8va
pp

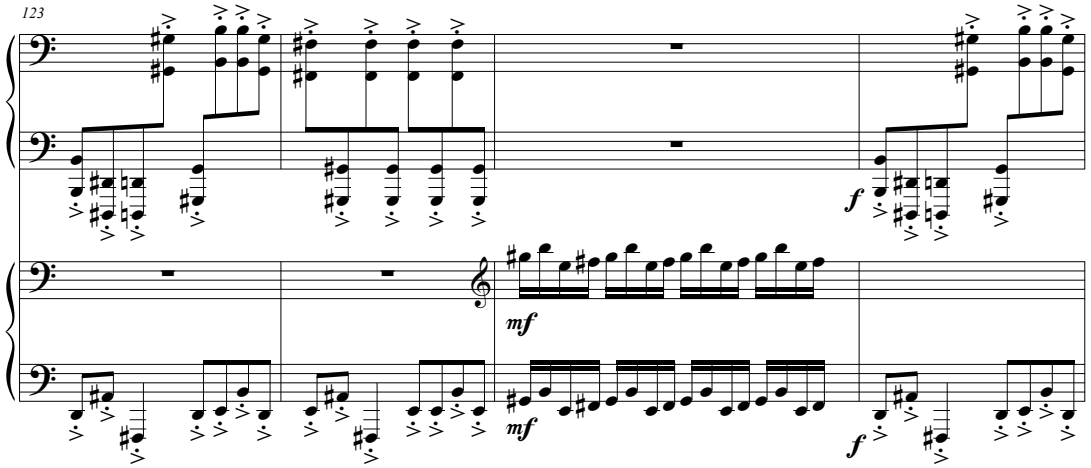

G
Mario dons raccoon suit
88
mf
mf
(8va)
(8va)
93
8va
97
(8va)
8va

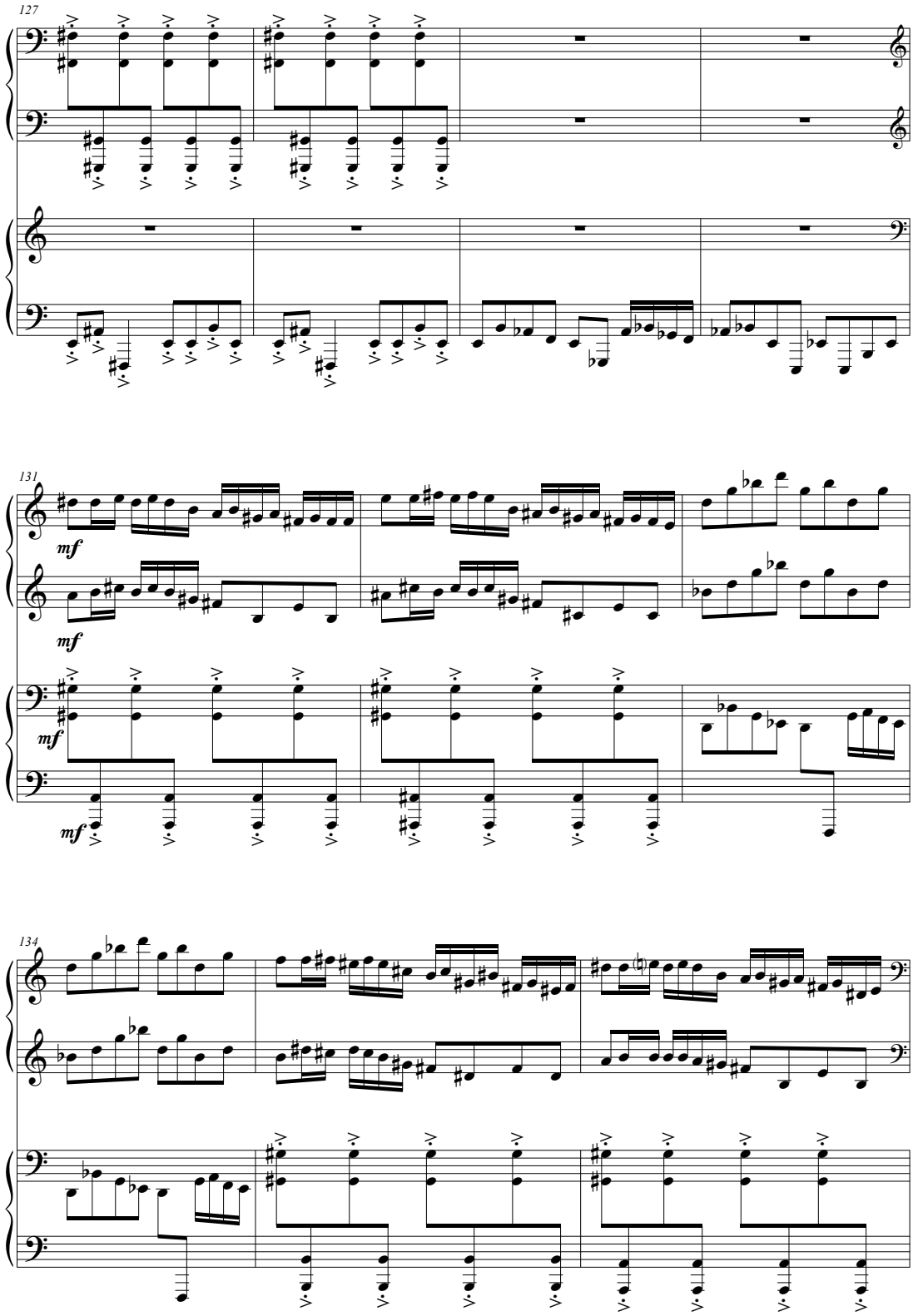

cut scene begins: Mario enters castle turret and sees princess tied up
H
101
106
I
Bowser falls through ceiling and confronts Mario
J
Bowser and Mario fall through floor
simile

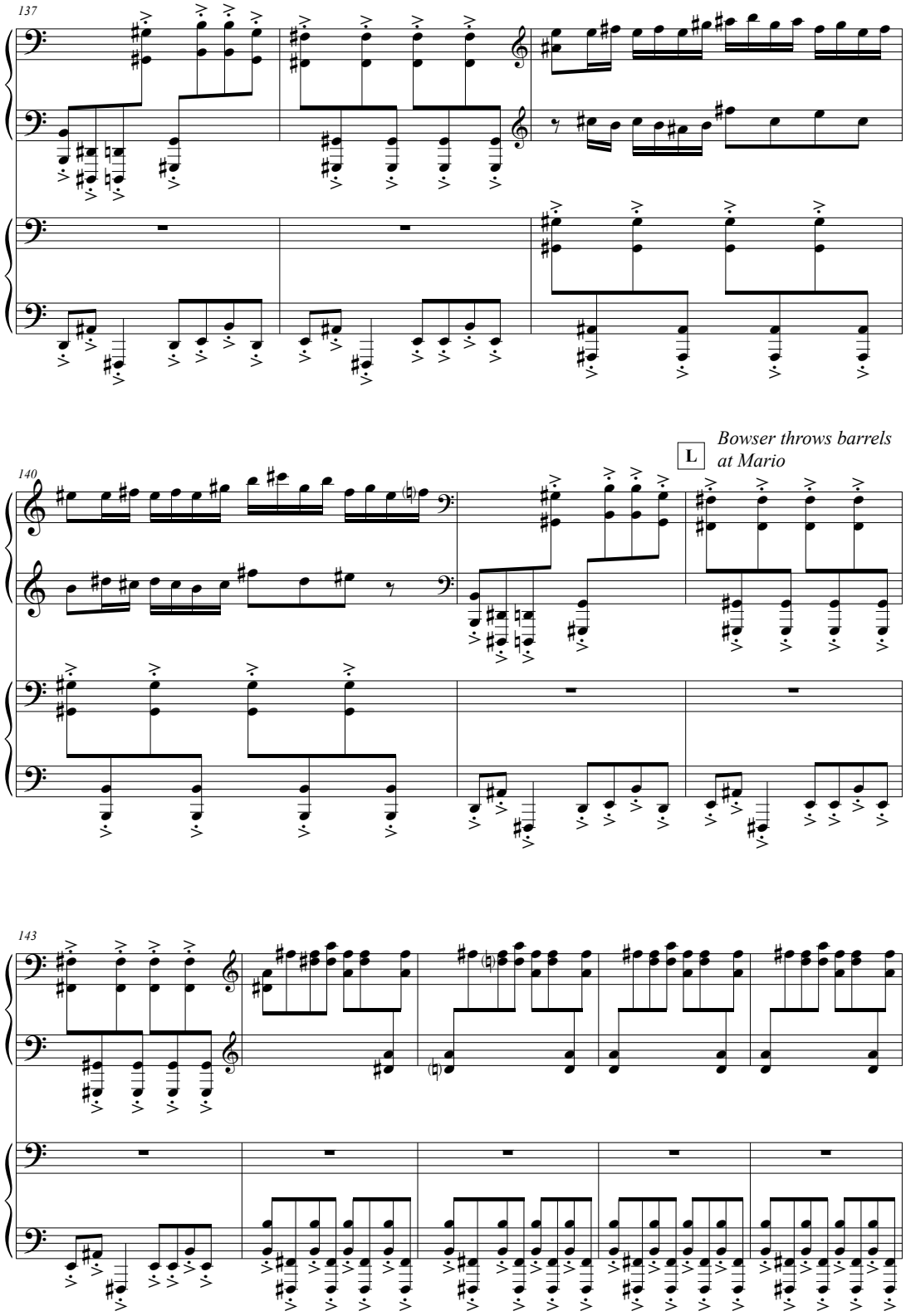


K *cut scene ends: Mario (in raccoon suit) begins battling Bowser while ascending stairs*

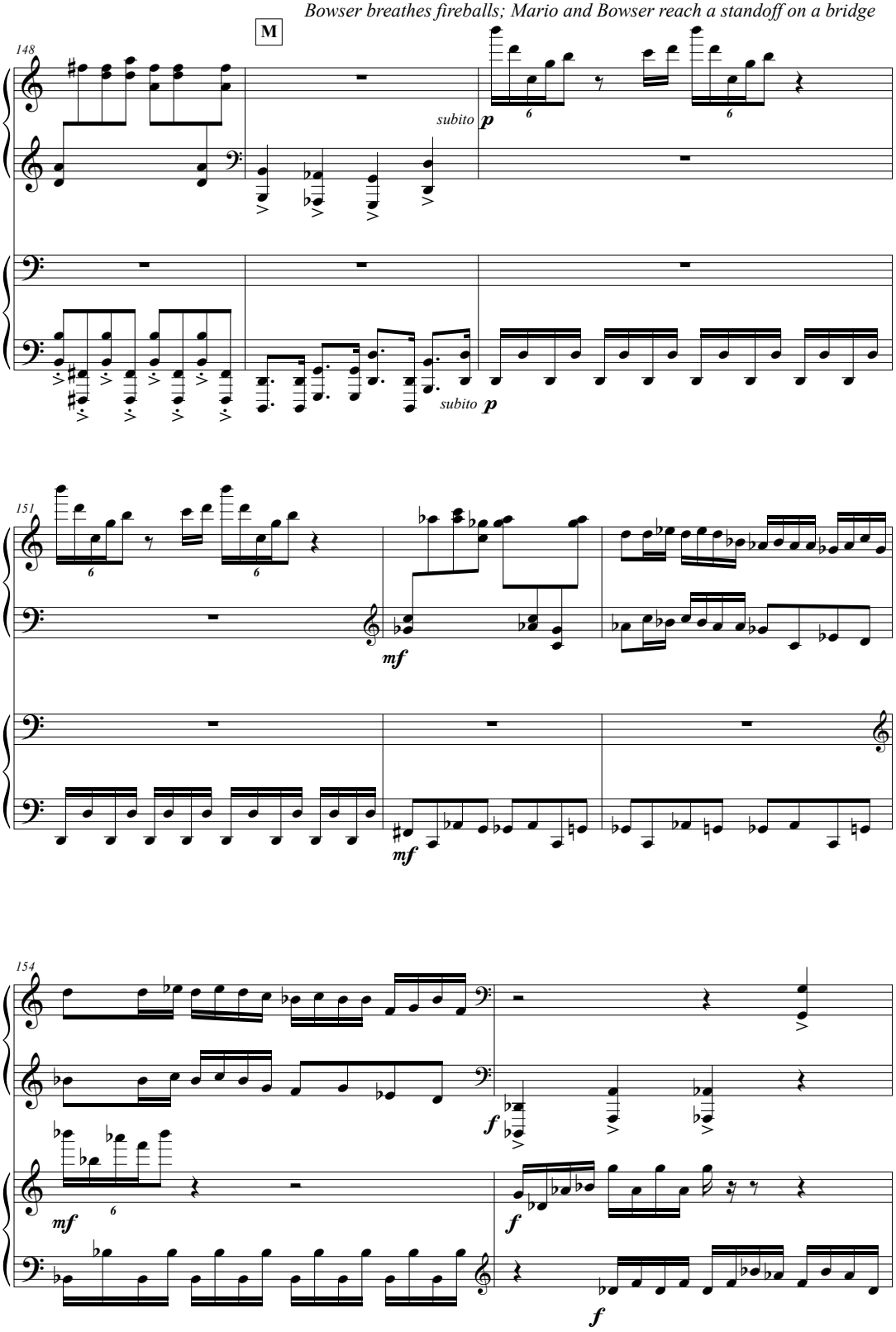


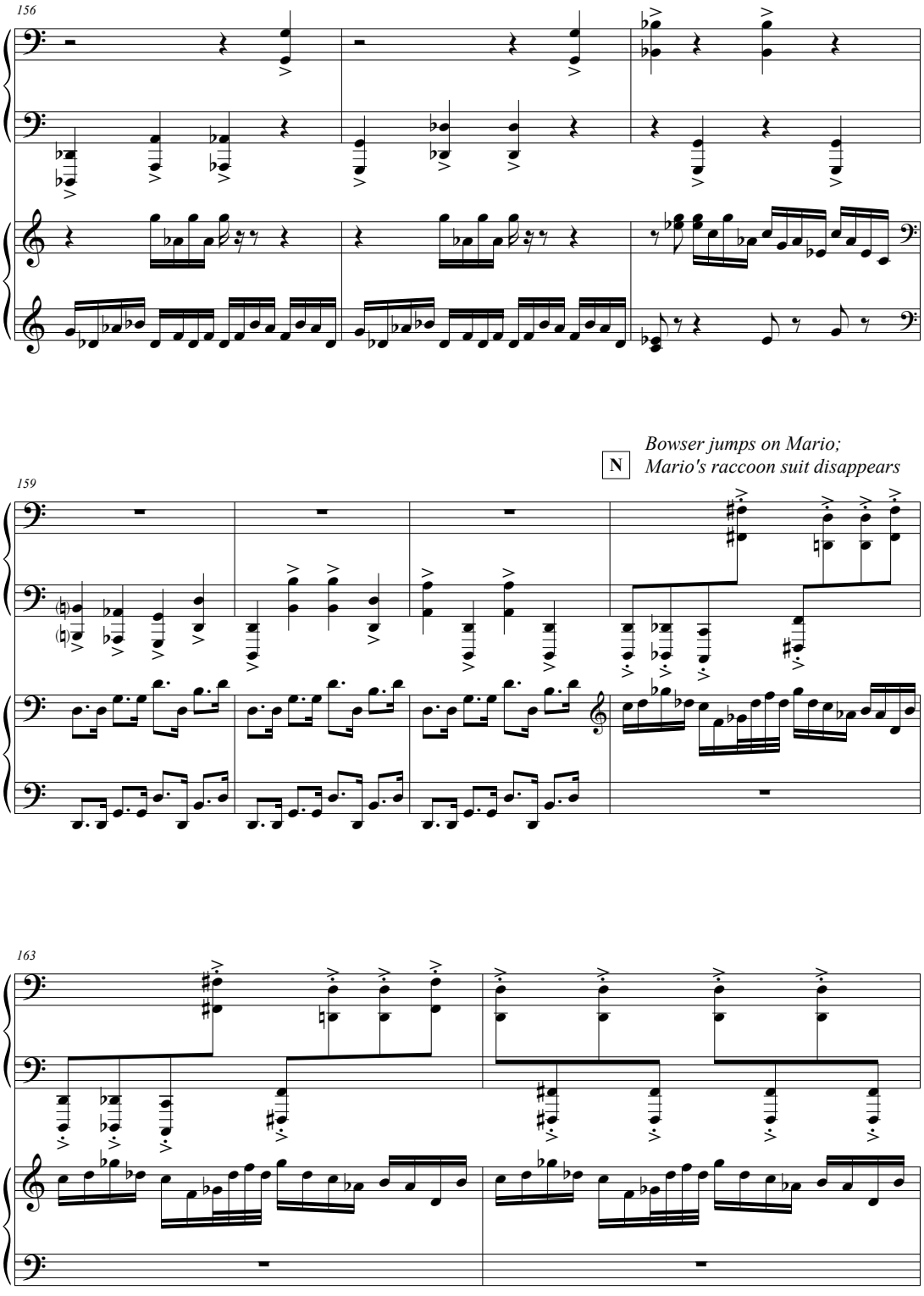


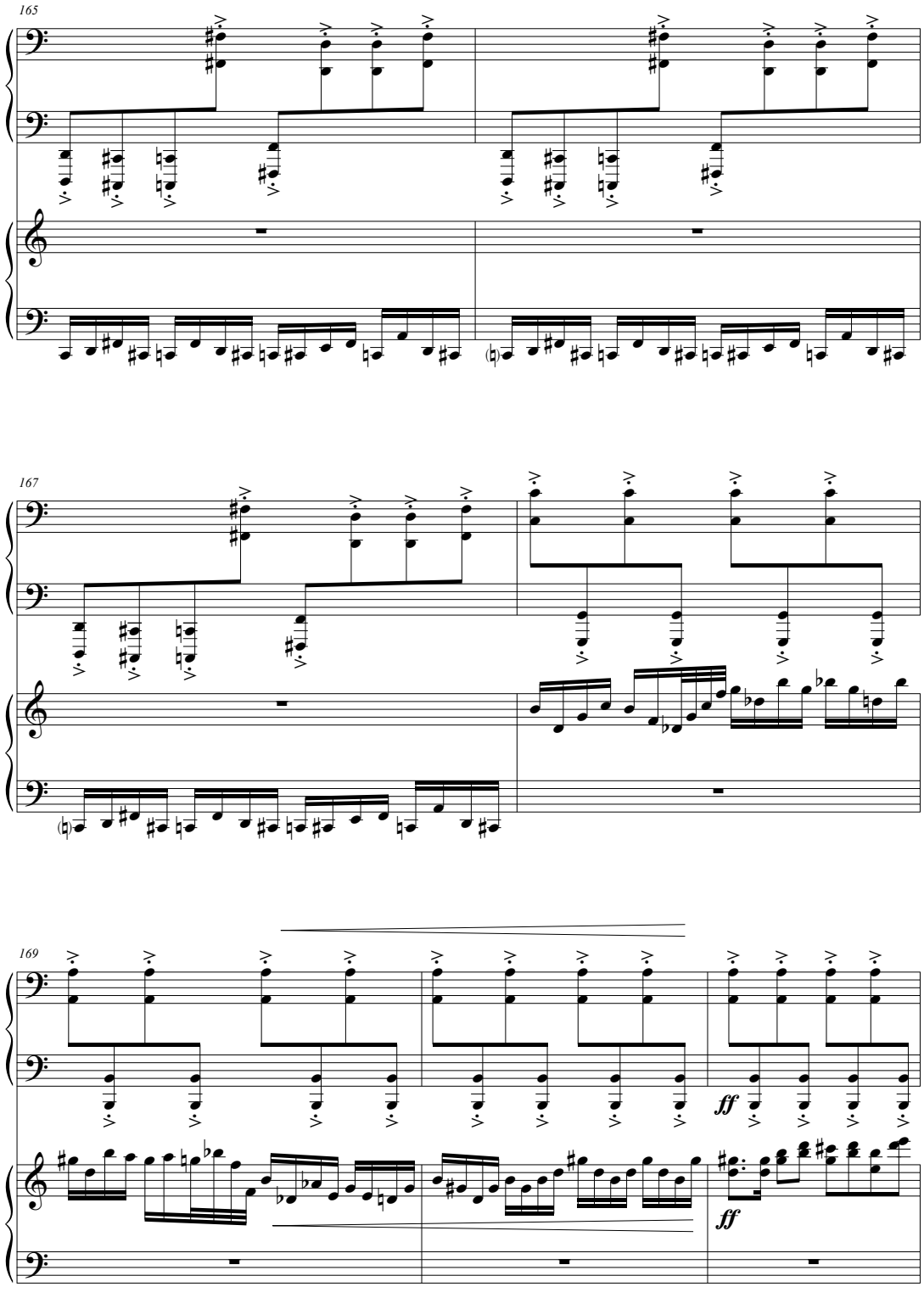

127
131
mf
mf
mf
mf
134

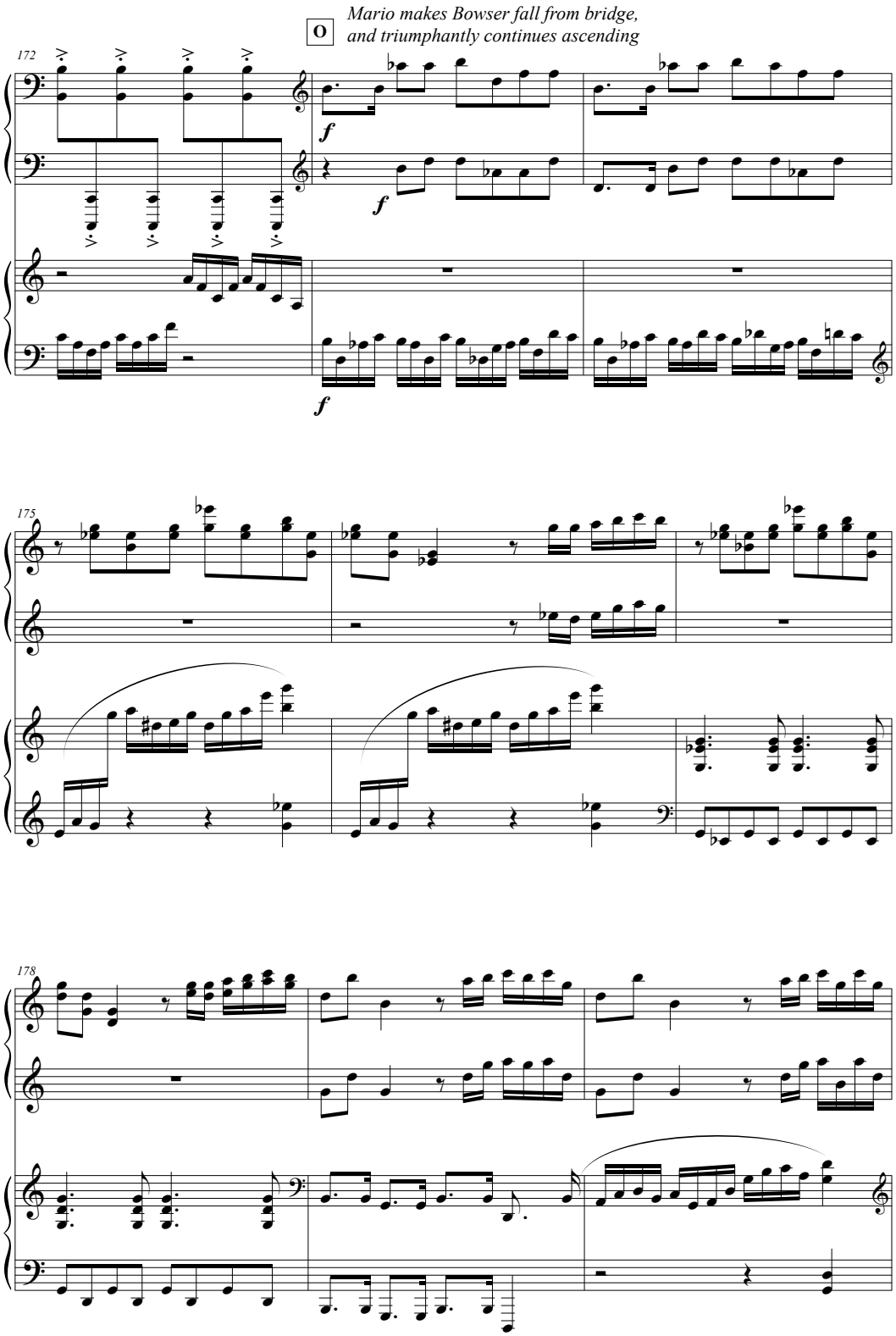

137
140
L
Bowser throws barrels at Mario
143

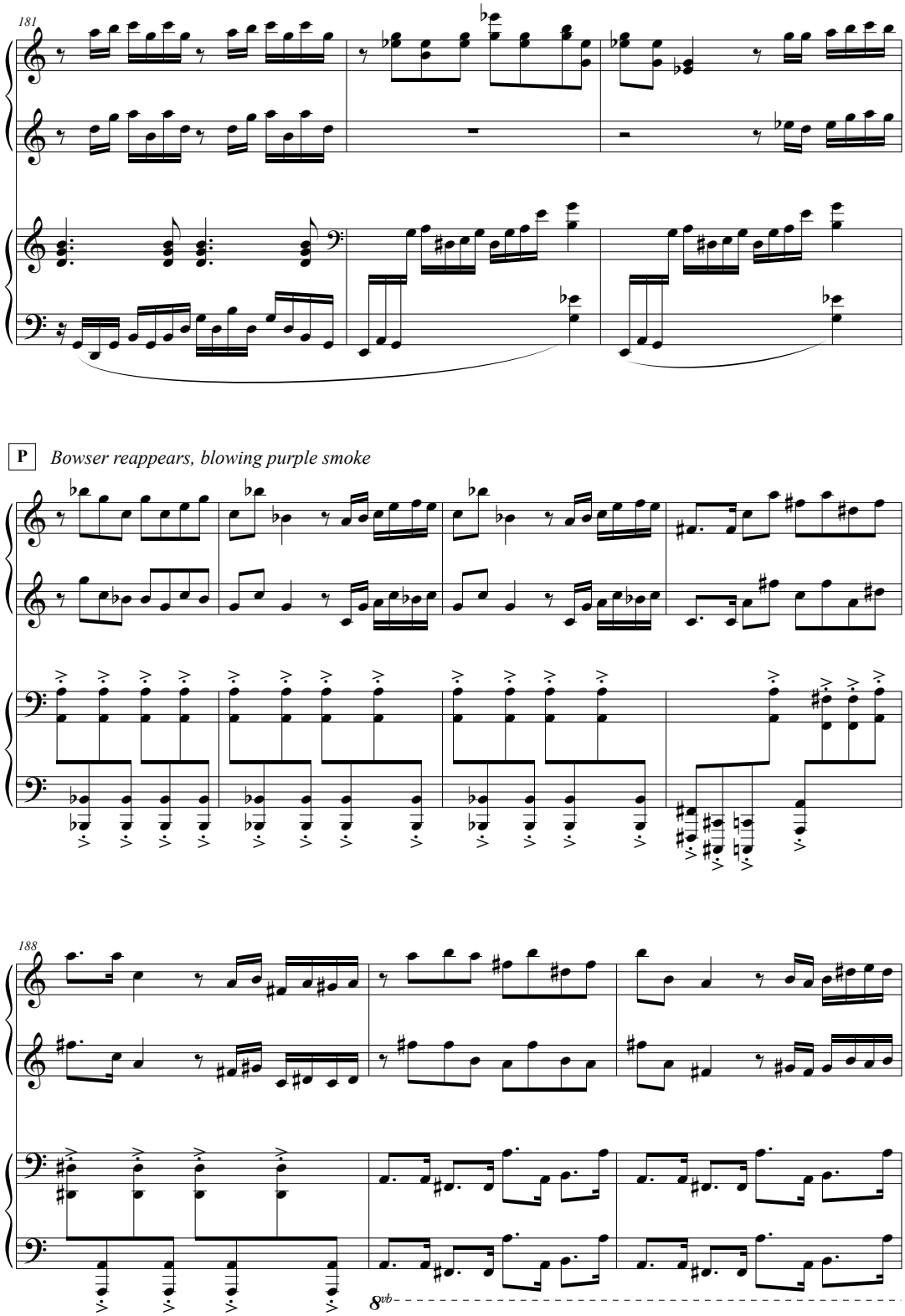
Bowser breathes fireballs; Mario and Bowser reach a standoff on a bridge

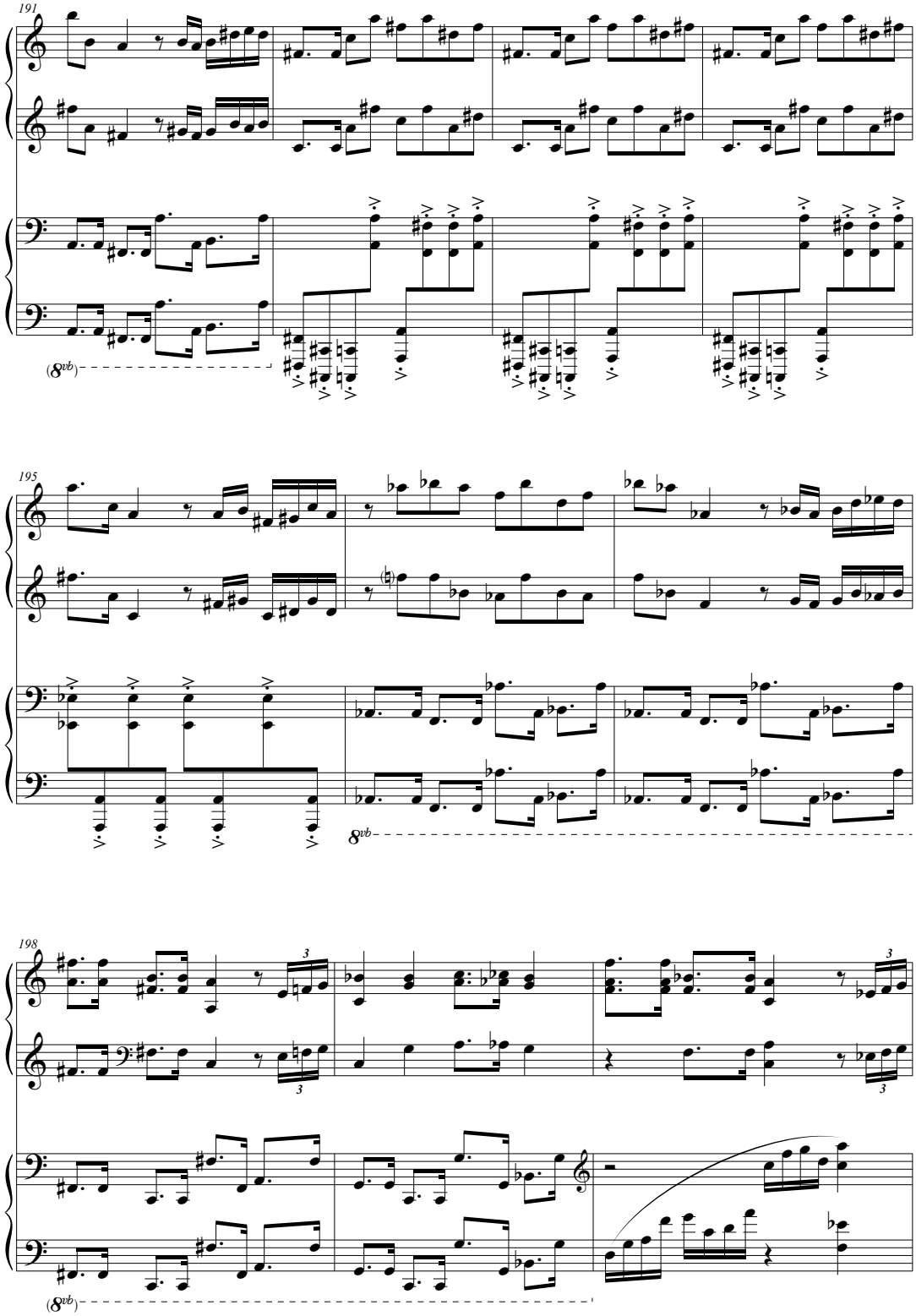


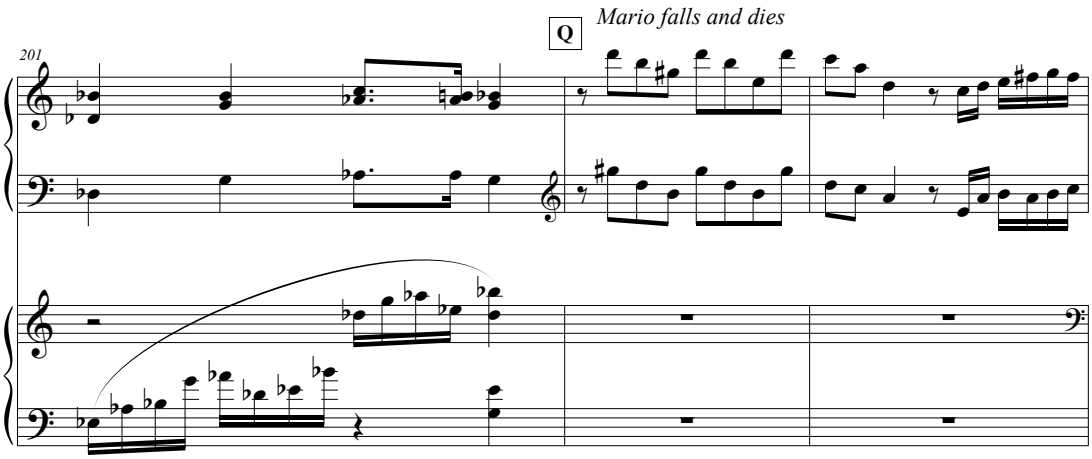

156
N
Bowser jumps on Mario;
Mario's raccoon suit disappears
159
163

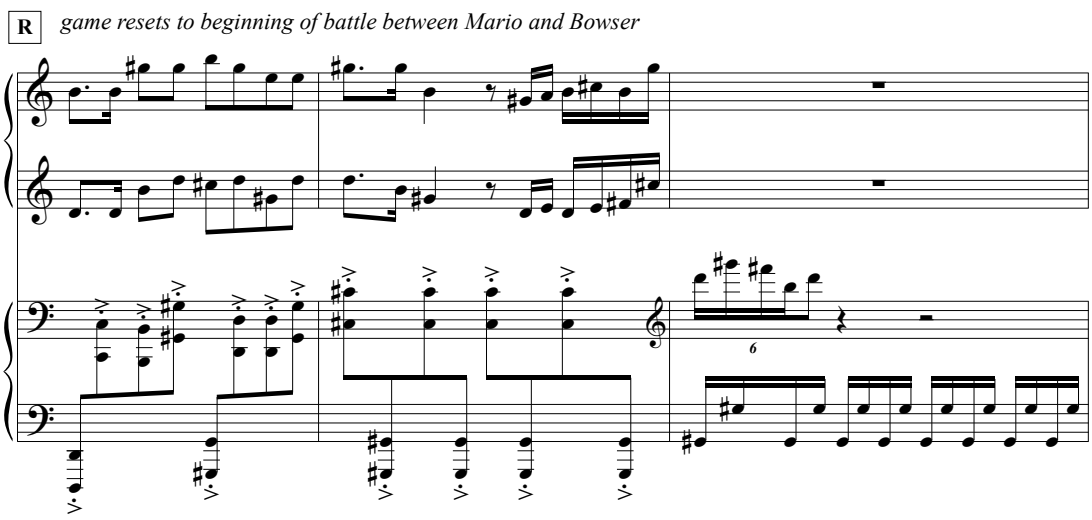

165
167
169
ff
ff

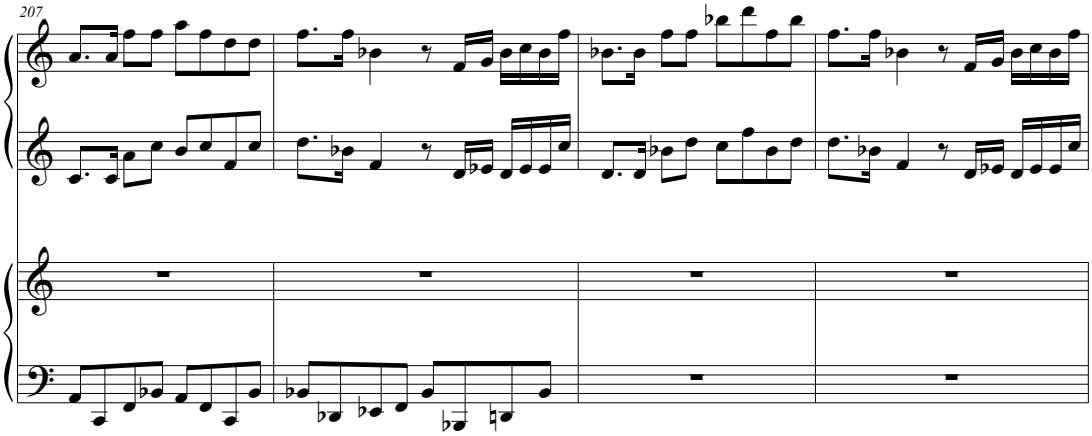

O
Mario makes Bowser fall from bridge,
and triumphantly continues ascending
172
175
178

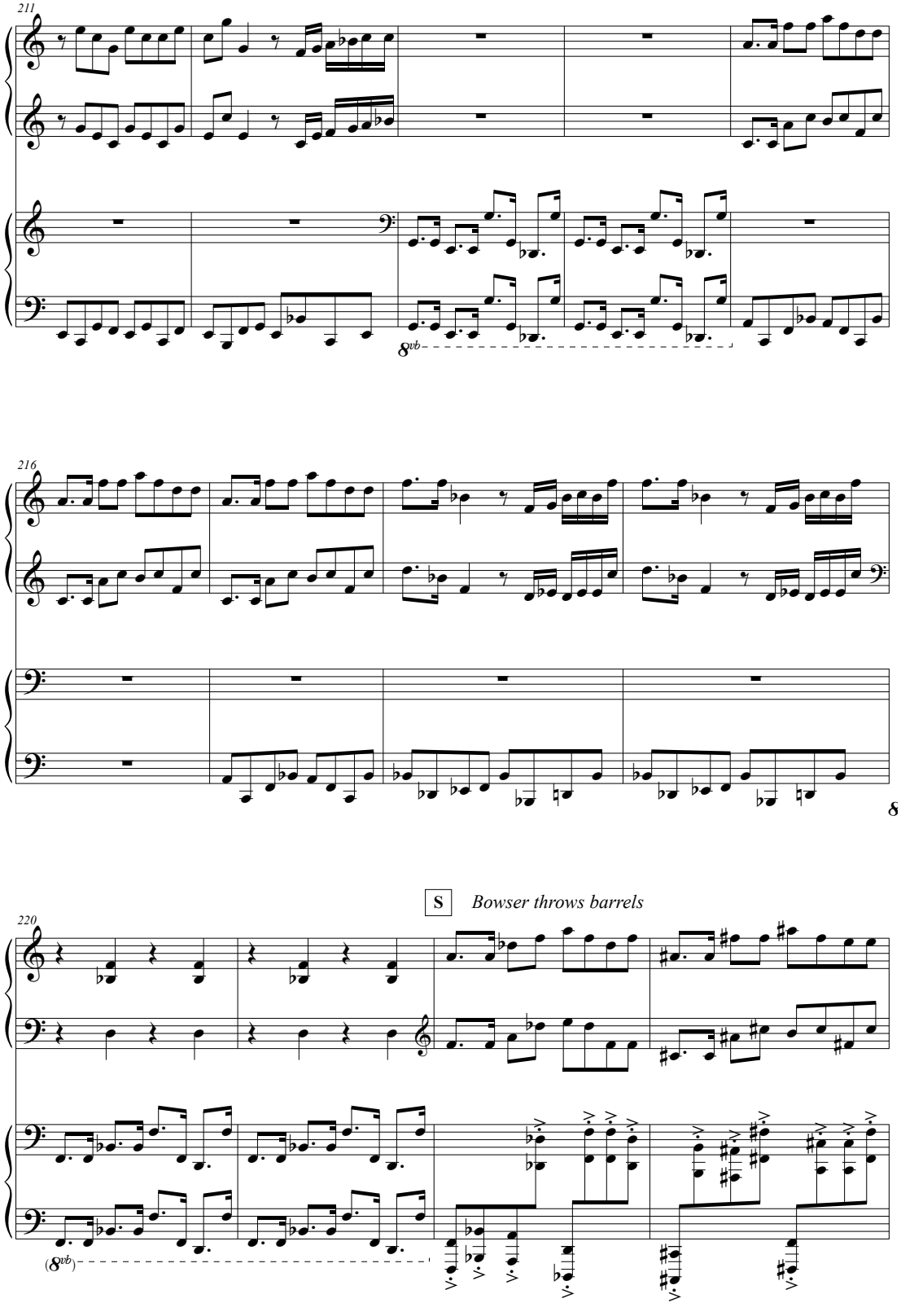

181
P
Bowser reappears, blowing purple smoke
188
8vb

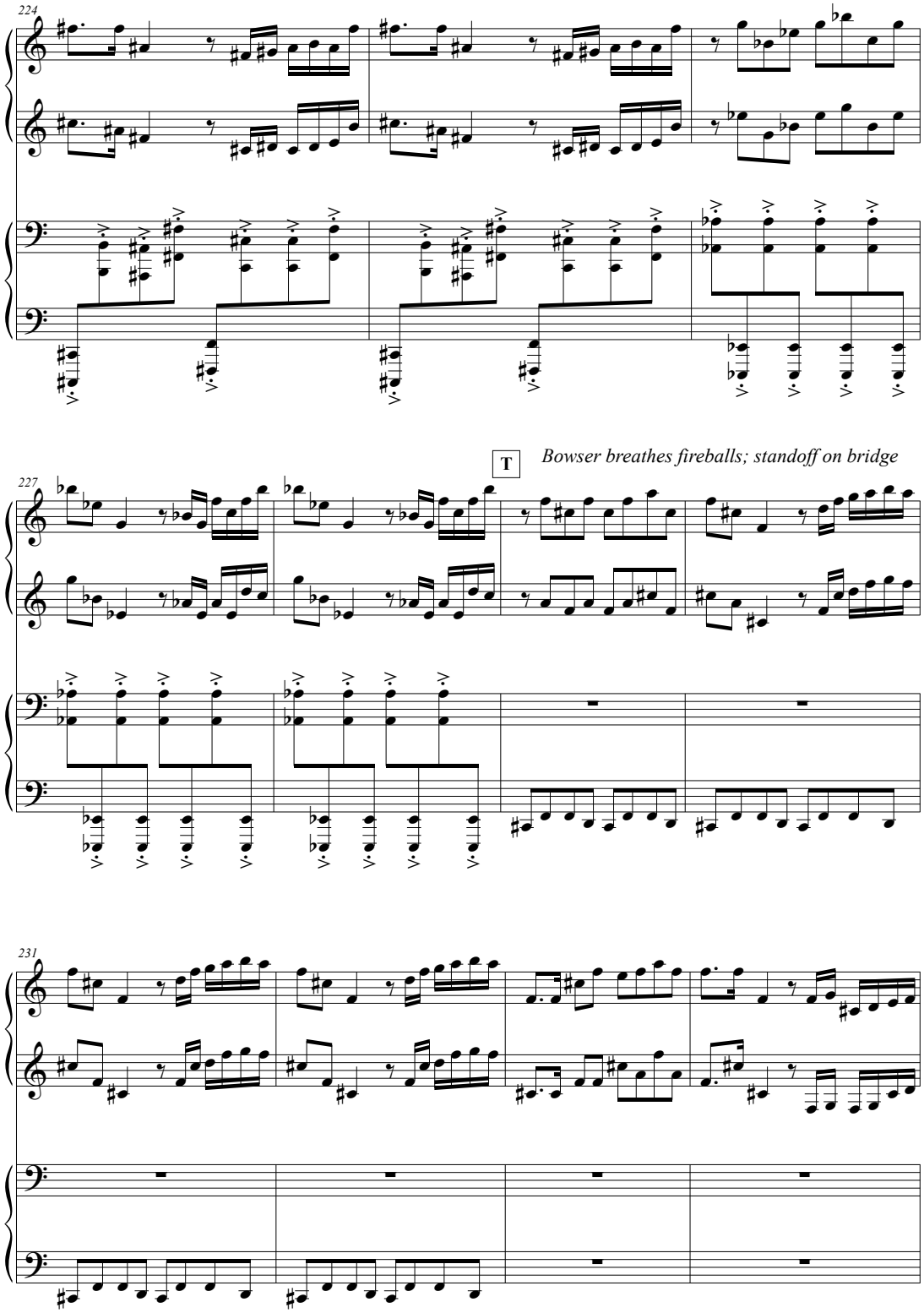

191
(8vb)
195
8vb
198
(8vb)


Q
Mario falls and dies
201

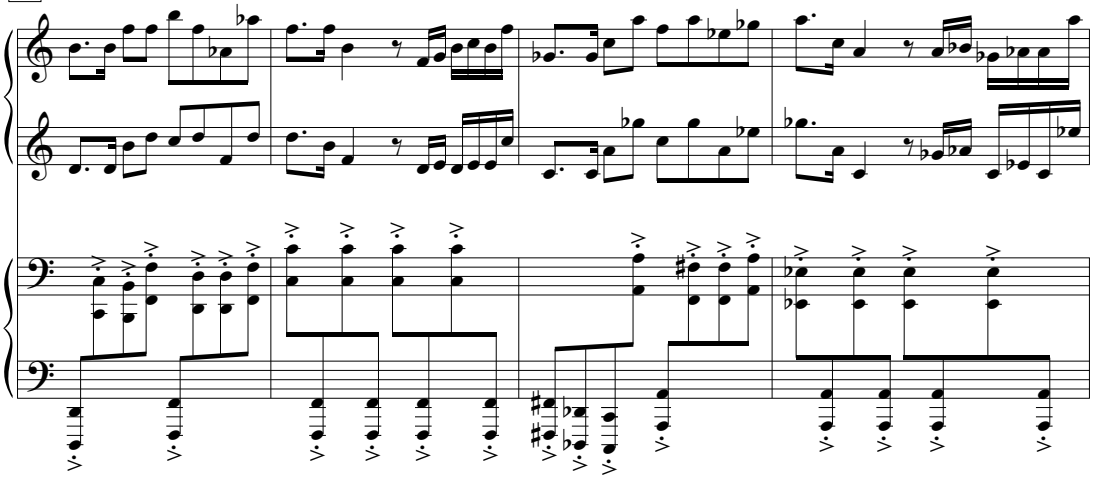

R
game resets to beginning of battle between Mario and Bowser
6


207

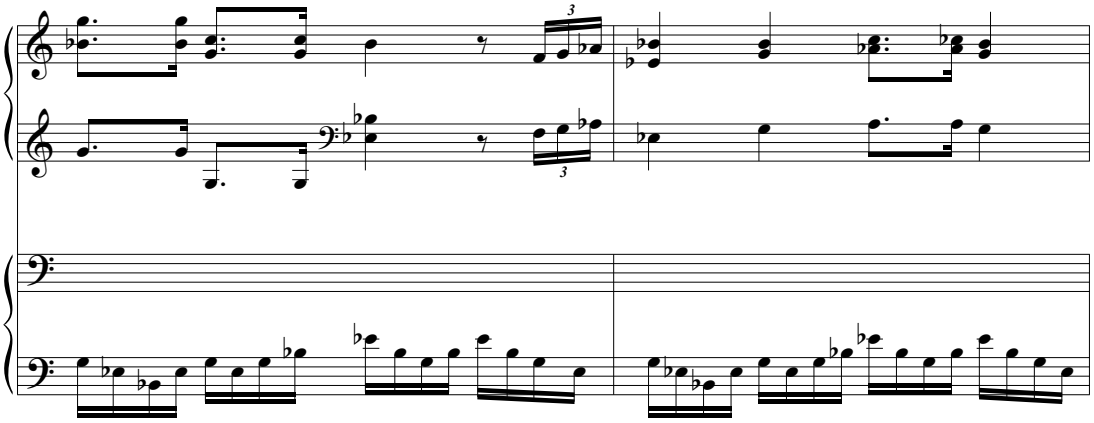

211
8vb
216
8
S
Bowser throws barrels
220
(8vb)

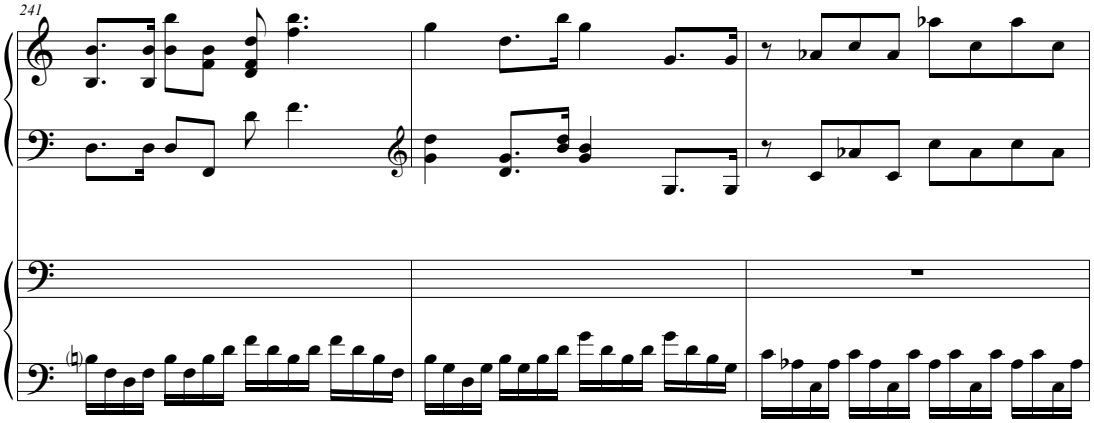

224
227
T
Bowser breathes fireballs; standoff on bridge
231

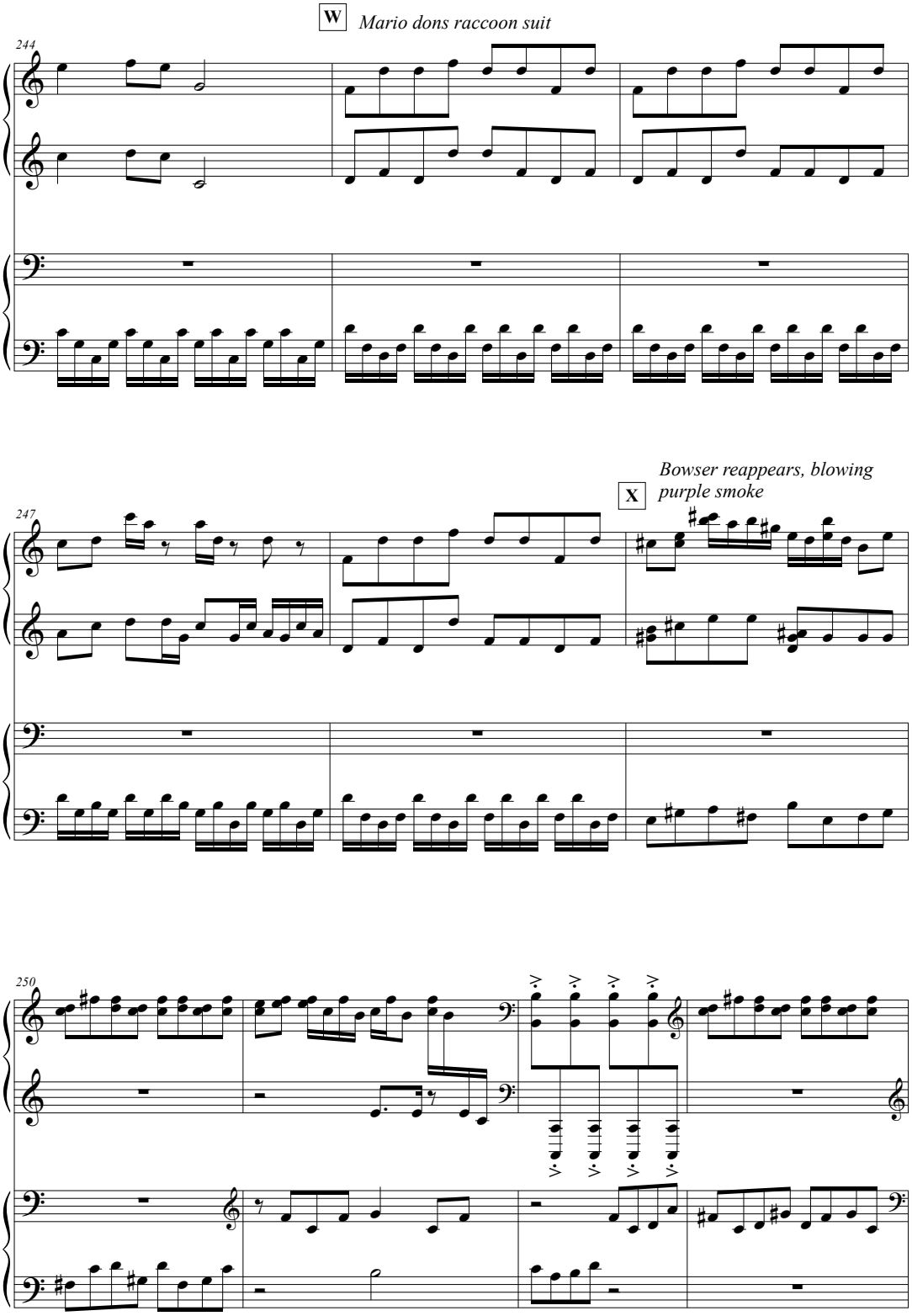
U *Bowser injures Mario*

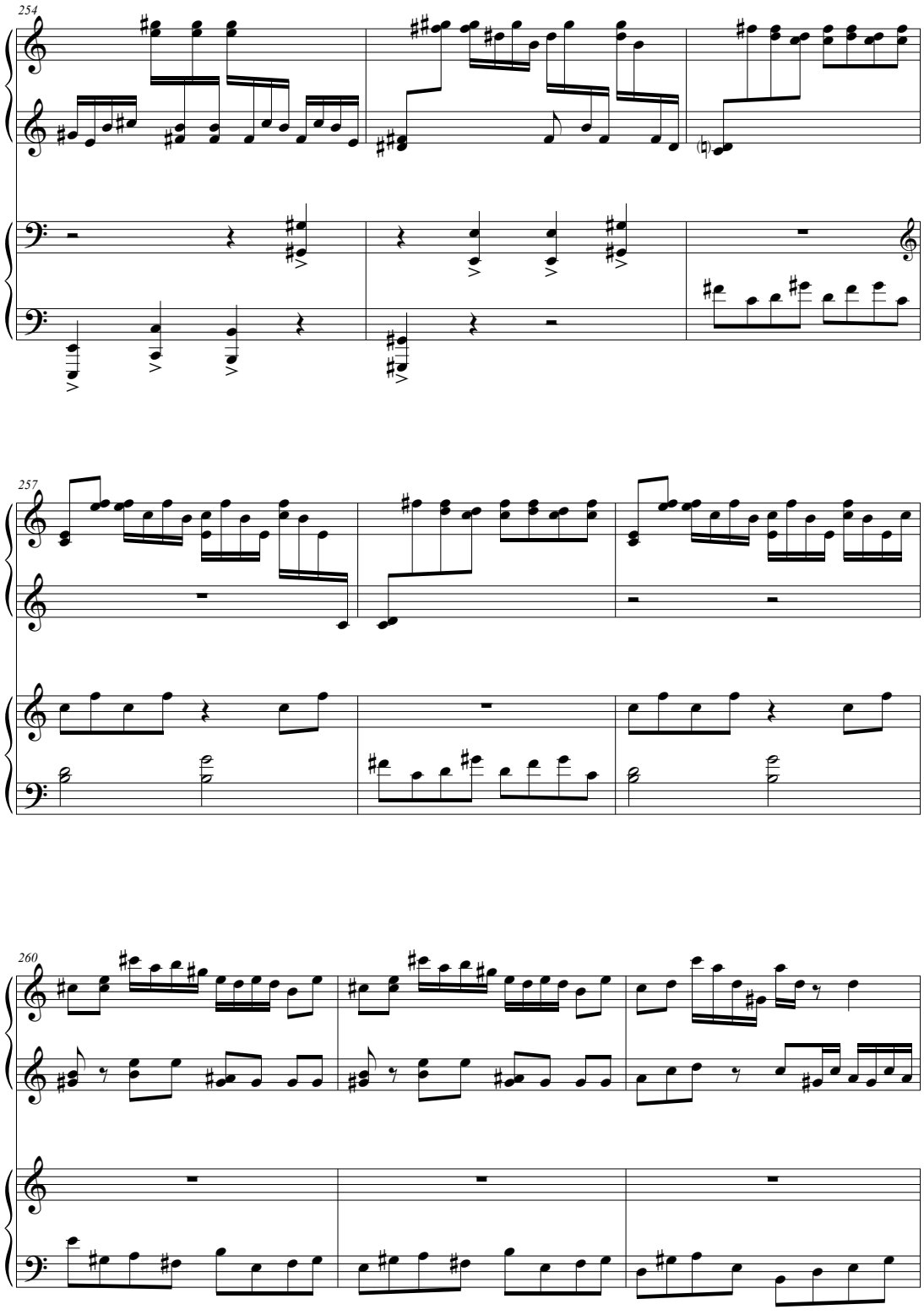


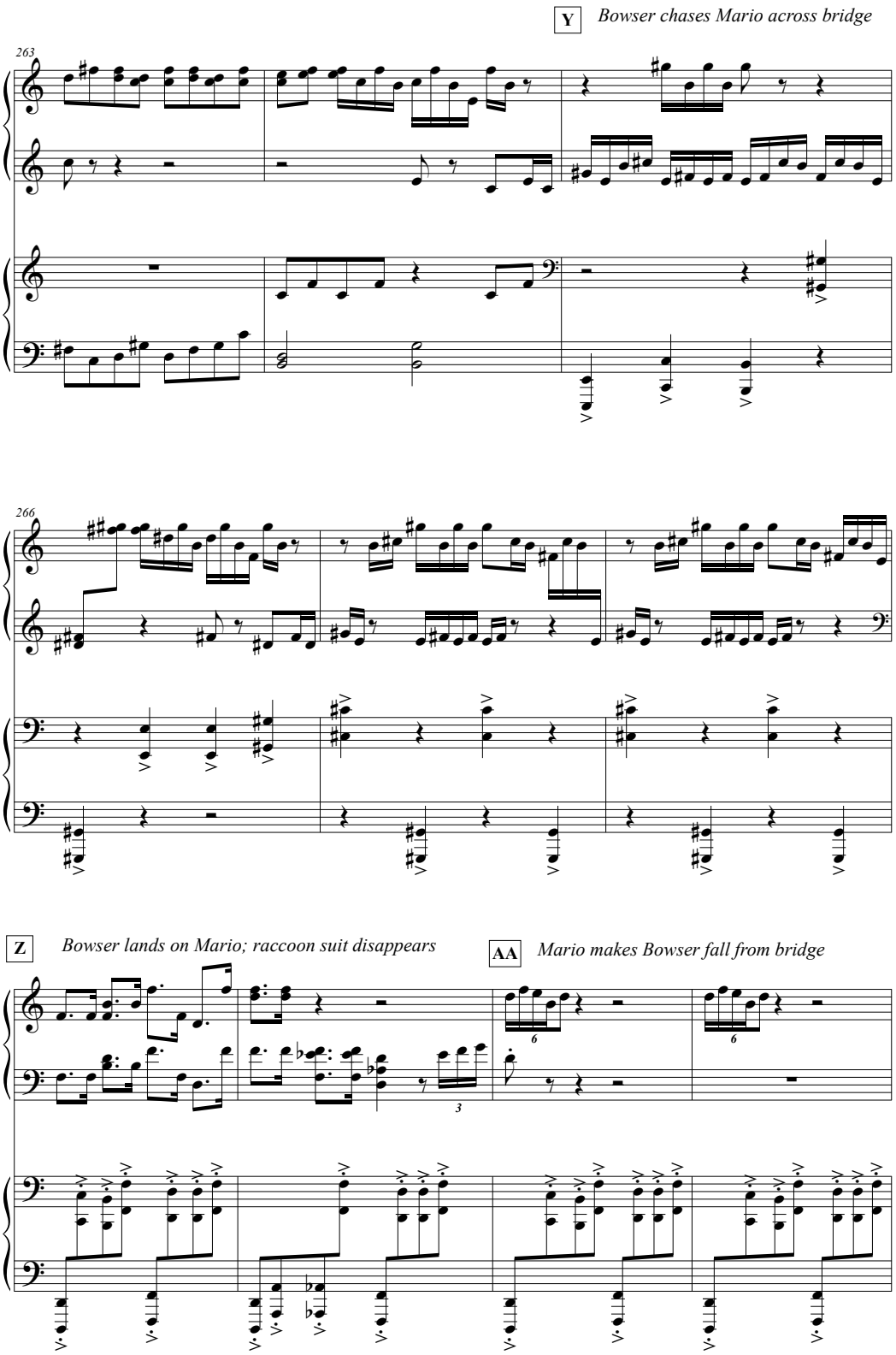
V *Mario knocks Bowser off bridge and triumphantly ascends stairs*



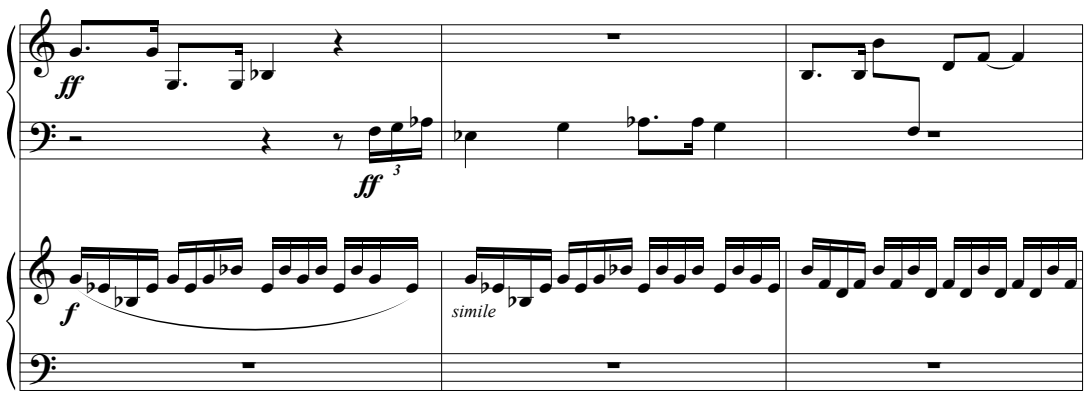


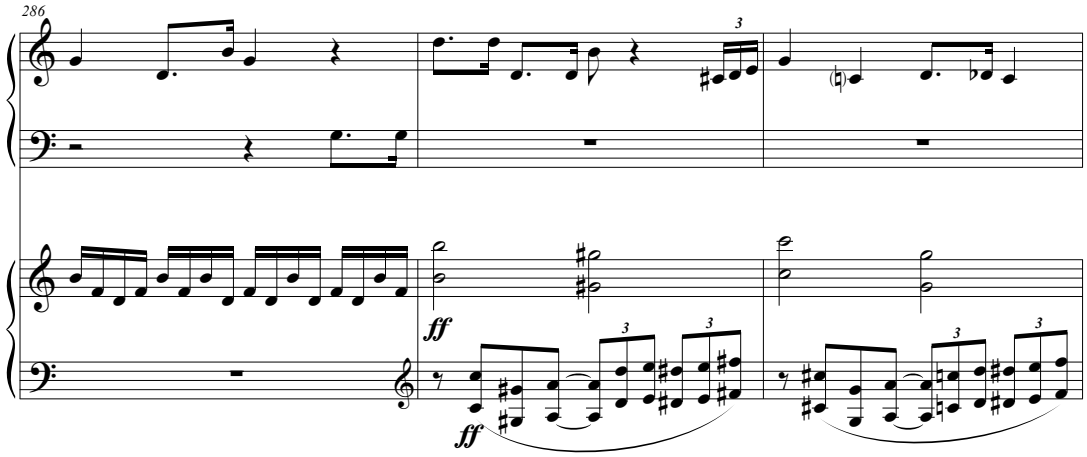

W
Mario dons raccoon suit
244
Bowser reappears, blowing
purple smoke
X
247
250

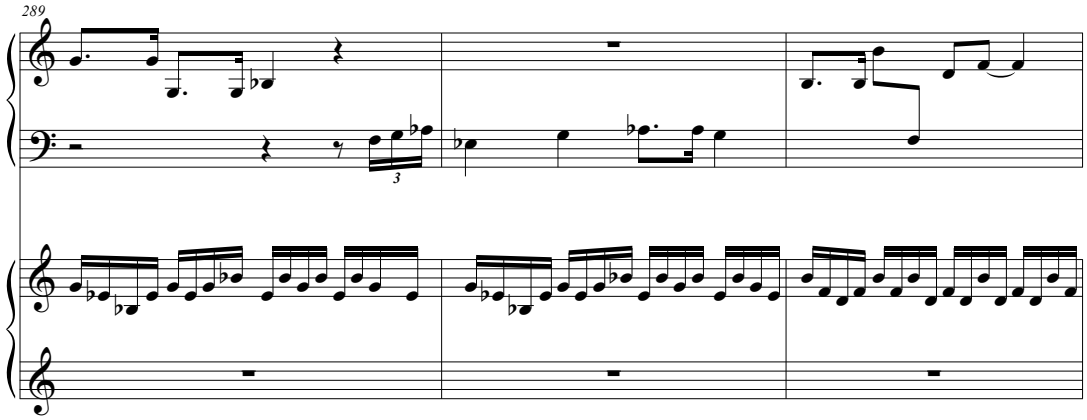

254
257
260

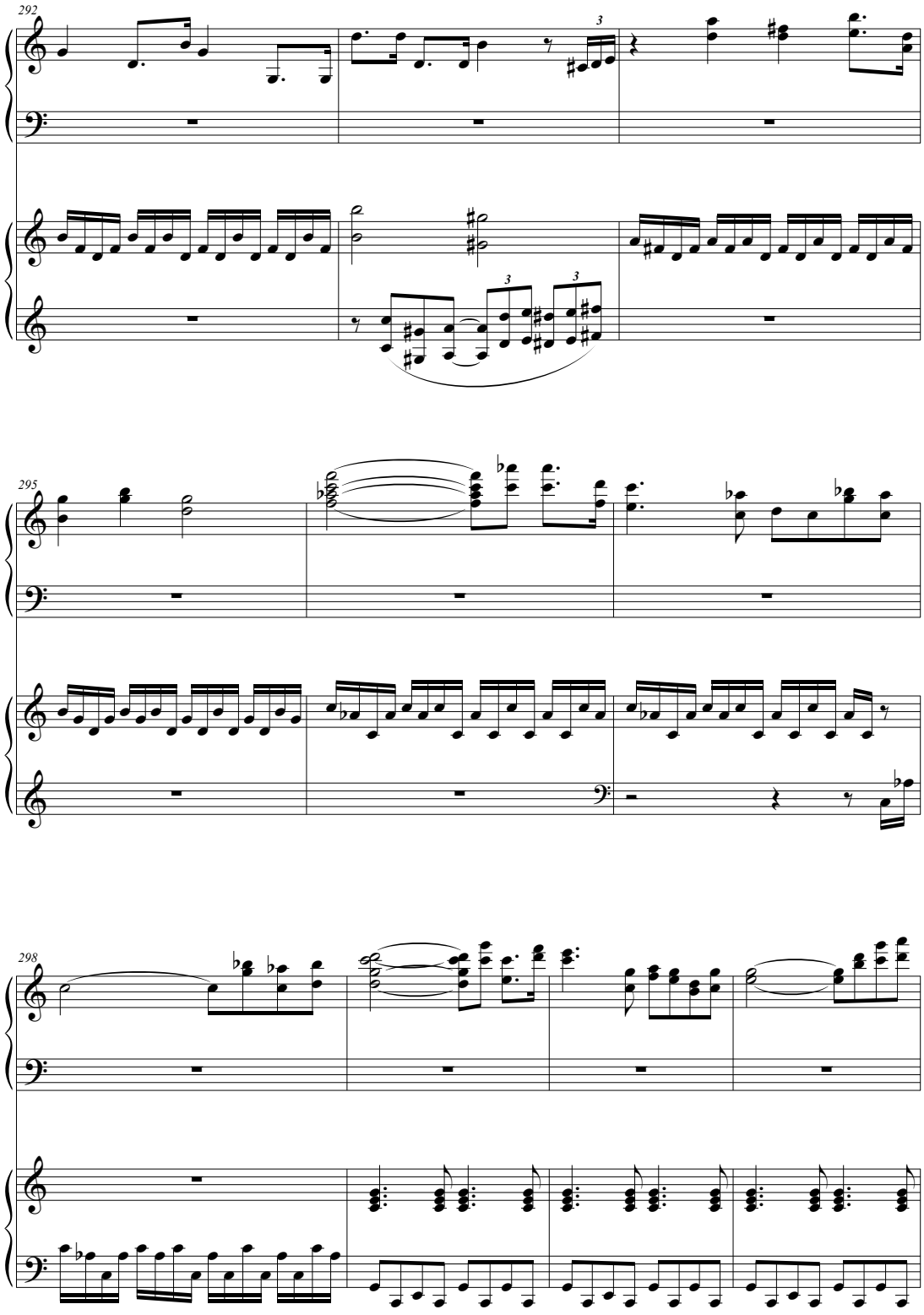

Y
Bowser chases Mario across bridge
263
266
Z
Bowser lands on Mario; raccoon suit disappears
AA
Mario makes Bowser fall from bridge

BB *Mario triumphantly ascends to highest turret, where he finds princess tied up*



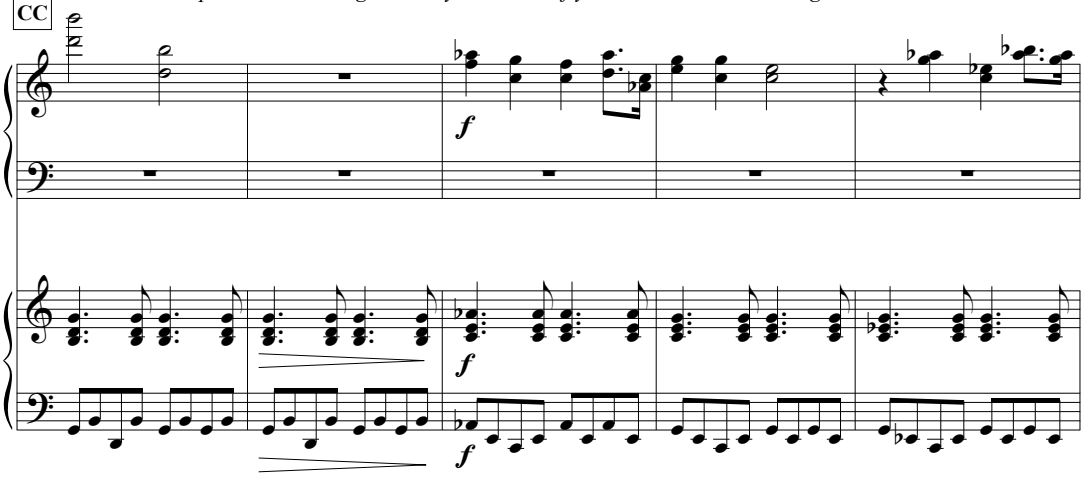





292
3
3
3
295
298

Mario unties princess, rescuing her; they dance and fly around while credits begin

CC



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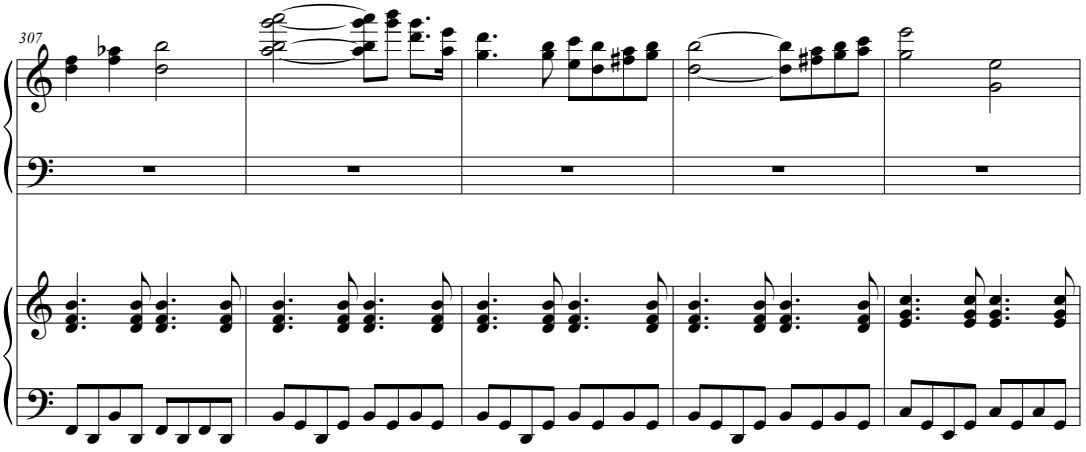

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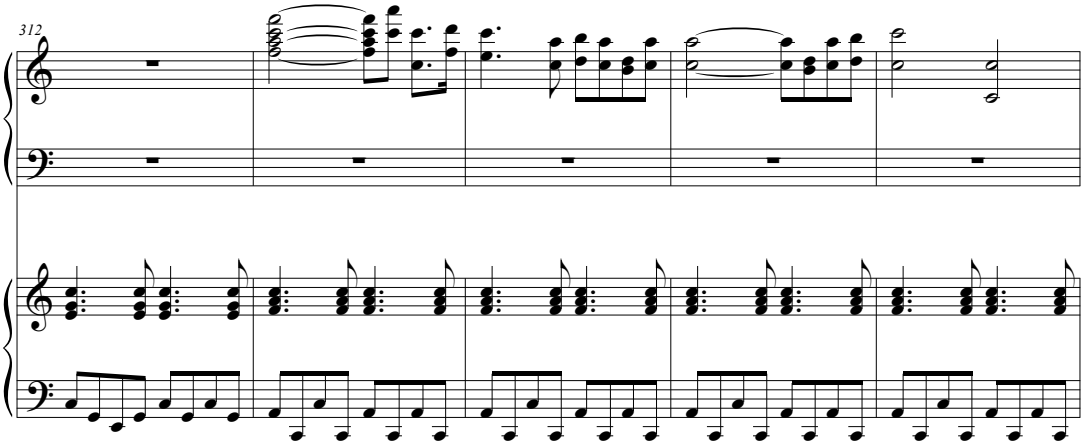
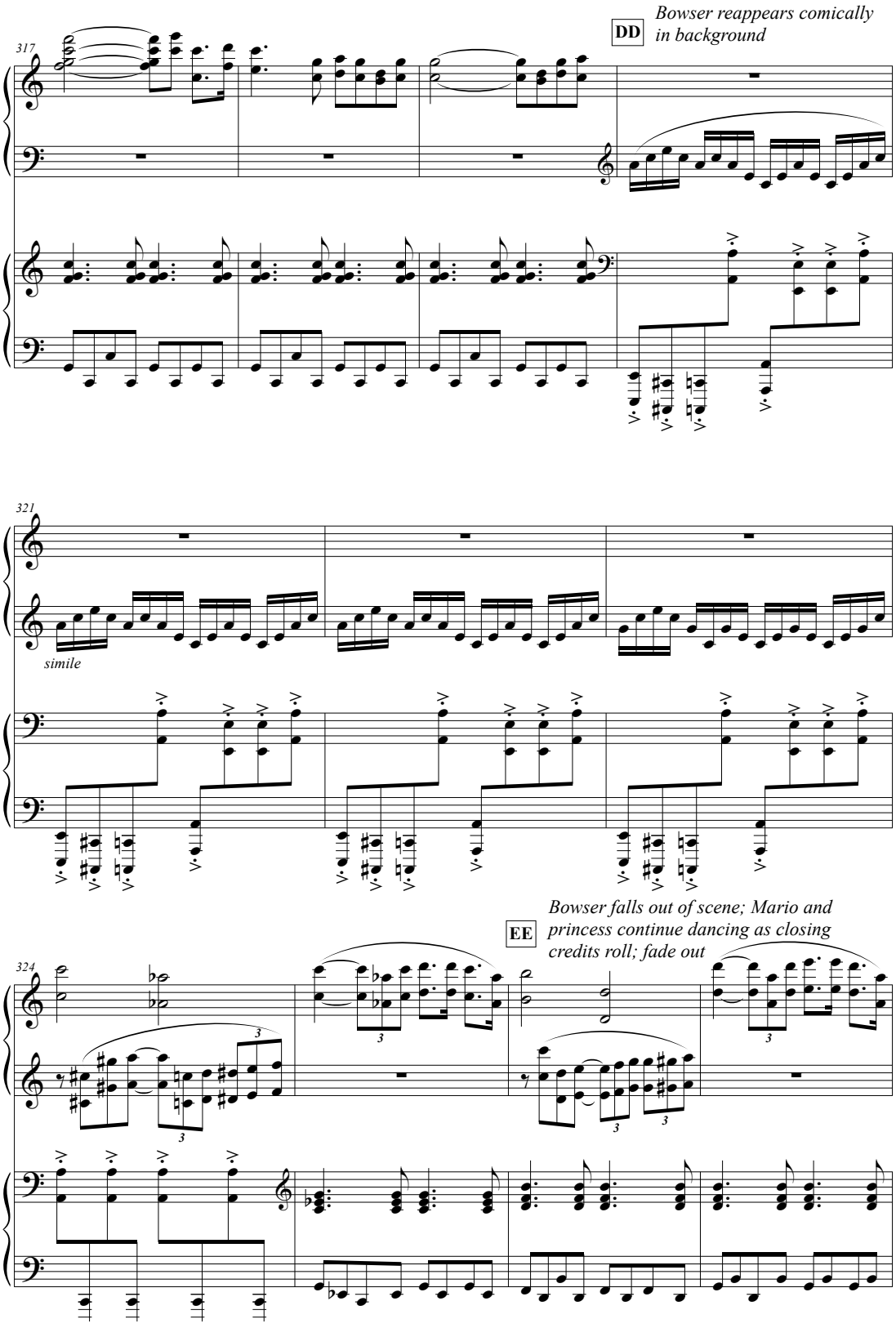
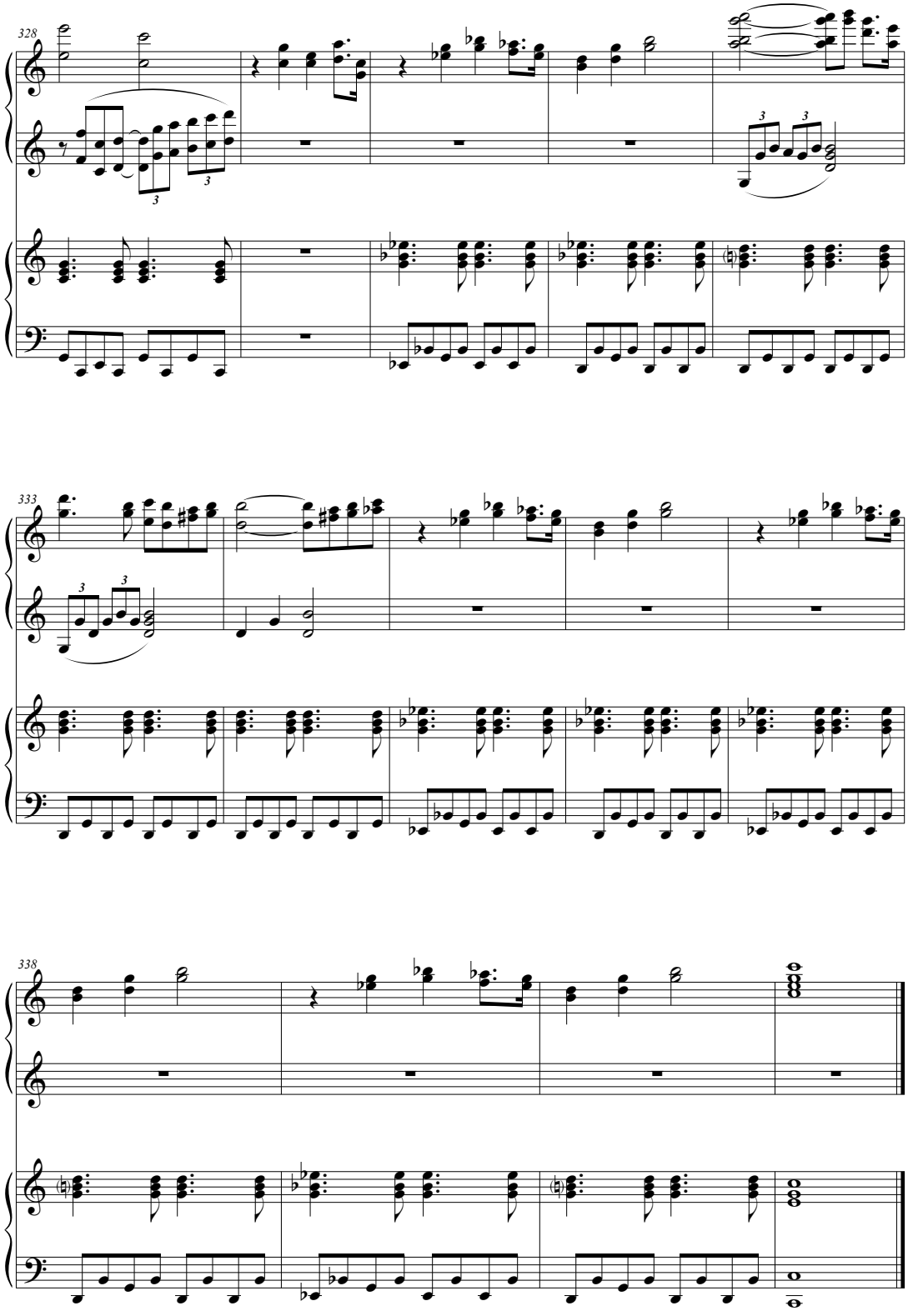



317
DD
Bowser reappears comically in background
321
simile
324
EE
Bowser falls out of scene; Mario and princess continue dancing as closing credits roll; fade out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Part II

Words

Chapter 1 Introduction

Computer gaming has grown over the last decade from simple entertainment to high-level art form. Today, more and more computer games have intricate plots, interesting characters, and sophisticated narratives. It is for this genre of game that I have created a computer program, called *Mezzo*, that procedurally composes music to accompany gameplay. Procedural music is not a common feature in computer games today, but it is a growing field of interest, and several popular games over the past two decades have used various types of procedurally generated or manipulated music for their soundtracks (Collins). By composing game music procedurally, there are two problems that *Mezzo* addresses. First, how to keep music from becoming repetitious, as prerecorded, looped music often becomes when a game experience stretches on for long periods of time. Second, how to computationally define and compose music that evokes the narrative states occurring in a game, and to change from one state to another as the game changes.

It turns out that addressing the second question in fact provides a solution to the first. Repetition of material is certainly an essential element to most music. At the heart of *Mezzo*'s design is the idea that repetition is more than just a necessary means of extending musical material over time. Patterns of repetition actually have signifying functions; they express a wealth of musical states. Even repetitiousness

itself has a signifying function: Berlioz' repeating strophes have been associated with obsession or neurosis (Rodgers 5). Minimalism champions repetition as a means of generating a kind of transcendence of temporality. The problem with looped music is thus not that repetitiousness is always undesirable; rather, that it only signifies a very narrow range of meanings. The polarity between repetitiousness and non-repetitiousness can be subsumed into a multi-dimensional structure of semiotically related states that are evinced by different patterns of musical repetition. These patterns, applied to different musical elements, and changed appropriately over the course of a game, effectively evoke elements in a game story and direct the listener's focus and even sympathy toward various characters. The structure of these semiotic relations as they are represented in *Mezzo*, and the factors by which these relations are determined, will be discussed in this dissertation and illustrated with examples from *Mezzo*'s output.

Narrative in Music and Computer Games

Narrative is a problematic concept in reference to both games and instrumental music, albeit for different reasons. So far, game narrativity and musical narrativity have been studied as unrelated fields. The overlap in the methodology of narrative ludologists and narrative musicologists is substantial, though; research in both fields borrows from a common pool of structuralist concepts that was first introduced by Vladimir Propp and then expanded by Barthes, Greimas, Jacobson, and

Levi-Strauss, among others, during the middle of the 20th century. The lack of contact between scholars in the two fields is not surprising; computer games are a young art form, and the technical limitations on generating music for a game have until very recently been severe. Also, the focus of narrative research in each field differs. Research into the narrative capability of a computer game is motivated, arguably, by a creative impulse, rather than an analytical one, a desire to enrich the experience of gameplay by designing plots and characters that are both interesting and interactive. Music, as an art form, is disproportionately older than the computer game; for this reason, perhaps, research in musical narrative is mostly analytic, positing different ways of hearing and thinking of extant works. Narrative conceptions of music are in these cases conceived as analytical methods resulting from cultural and stylistic intuitions, not as bases for compositional algorithms[1].

It is beyond the scope of this dissertation to discuss the complex problem of generating a narrative in a game and maintaining its coherence while recognizing unexpected changes in the story created by a player's actions. *Mezzo* does not need to know anything about the design of this aspect of a game's architecture; its role is not to produce stories, but to reinforce their discourse through music (although its integration with a game's story generator could foreseeably increase *Mezzo*'s functionality). For *Mezzo* to compose for a game, though, it does assume a model of narrative used today in game design, in which stories are represented as discrete steps

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[1] Robert Hatten, however, suggests that the formal novelty of Beethoven's late-period works was due to a conscious manipulation of degrees of musical discourse and the signification this would create (175).

leading from an initial situation to a final, desired outcome (Riedl and Young 48). Furthermore, these steps must come from an inventory of story segments recognizable to the player/listener. The existence of such an inventory was first illustrated by Vladimir Propp, in his *Morphology of the Folktale*, which put forth the idea that all folktales have a similar structure which can be described in terms of a sequence of episodes. While the surface details differ across folktales, the underlying structure is more or less the same, with some additions and deletions and reordering allowed.

According to Márta Grabócz, following a musical narrative means following the "succession of functions, that is, the…sequence of 'spheres of musical action.'" (*Musique, narrativité, signification* 98) These functions correspond to changes of 'character,' and not necessarily to thematic developments or harmonic movement, although they can. The question that arises when equating a Proppian, text-based collection of story functions with a collection of musical 'spheres of action' is how closely the two correspond. Which story functions can music represent, and to what extent, and how?

Structural Semiotics and Schemata

A discussion of narrative in instrumental music is usually introduced by acknowledging instrumental music's representational incapability, and hence its inability to depict specific characters, actions, and settings: "It is not within the

semiological capabilities of music to link a subject to a predicate," writes Nattiez (257). These elements being inextricable from the traditional model of the narrative—the written or spoken tale—their absence implies a limited musical capacity to convey a story, unaccompanied by words. But people *do* attach interpretations to musical passages and works: while music doesn't represent, it would be hard to argue that it doesn't *express* (Tucker 30). Furthermore, these interpretations commonly take the form of stories.

While it is impossible to attach a universally accepted interpretation to a work of instrumental music, it is reasonable to make generalities about the interpretive strategies that listeners acquainted with a style of music will make in reference to a work. Robert Hatten makes the distinction between 'interpretations' and 'correlations.' Interpretations are the individual, hermeneutic acts of composers and listeners in reference to a work of music, which undoubtedly vary from person to person. Correlations are ideas or expressive states which are mapped onto opposing musical elements within a style: major vs. minor, fast vs. slow, repetitive vs. diffuse, etc. These mappings occur within a cultural context through what Hatten refers to as a "constructive dialectic … [in which] a listener learns a style in terms of generalizations from works, and whose strategic interpretation of works is in turn guided by an emerging stylistic competency" (30). Furthermore, in making such mappings, listeners attach values to these oppositions. This "valuation given to difference" is defined as 'markedness,' a semiotic concept borrowed from linguistics, in which a "*marked* term asserts the presence of a particular feature, and an unmarked

term negates that assertion" (Hatten 34; Battistella 2). The unmarked term represents the normative, while the marked term is defined only in opposition to the unmarked term, and represents deviation or exception from the norm. Furthermore, Byron Almén writes that narrative involves not only the articulation of conflicting elements, but their temporal engagement in shifts of hierarchical emphasis as well (47). While degrees of markedness distinguish musical elements in terms of their relationships in a network of oppositions, and the values in a hierarchy that listeners afford these oppositions, it is the perception of these relationships changing over time that leads to a narrative, as opposed to merely expressive, interpretation of a work.

The compositional process in *Mezzo* is based on the way these concepts from structuralist semiotics are manifested in the music of the Romantic Era. Many works from the Romantic Era have been associated with a program, which is either explicit (Berlioz), or secret (Mahler), or attributed later through a conventional collective interpretation that the composer was reluctant to sanction (Beethoven). These works didn't adhere to any previous models of musical form: they were long, torturous sequences of musical episodes. The attribution of a program or narrative was a way of understanding or explaining how these episodes were organized. By the Romantic Era, there was a rich and well-defined vocabulary of musical correlations from the recent past that had become conventionalized. A culturally informed listener would recognize these conventions and associate them with particular expressive or formal functions. This allowed composers to play with the significations of these conventions (Kramer 189; Skowron 254). For instance, at the very beginning of a

sonata-allegro movement, a listener would expect certain things like a repeated melody with very little development, a stable tonic harmony, and a symmetrical phrase structure; that is, *unmarked* musical qualities. These are qualities that became conventionally associated with the beginning of a sonata-allegro. Due to the prevalence of the sonata, it can be said that these qualities became furthermore associated the general notion of a beginning (Agawu 51-61).

This is an association between musical events and extra-musical events: 'to begin' does not just mean to begin a piece of music; it is a deeper cognitive notion that humans relate to a variety of experiences. In cognitive science, this is called a *schema* (or a frame), an underlying structure that a listener/reader/audience member associates with a certain experience/meaning/affect. In this respect, Grabócz's 'spheres of musical action' are musical events which a listener interprets by comparing them to an internal repertory of schemata. Moving from one set of musical events to another suggests movement from one schema to another, and this movement can have a narrative structure in the Proppian sense. Schemata have semantic webs surrounding them, so a 'beginning' schema, evoked by the musical features listed above, can suggest departure, or the state just before departure, a state of familiarity, stability, contentment—in general, unmarkedness, a state against which subsequent states will be contrasted.

Schemata were conveyed in the Romantic Era with recognizable topics, such as the march or the pastoral, but also more subtly by employing or withholding normative patterns of formal organization conventionalized in the Classical Era. The

recognition of normative patterns, and the correlation between them and unmarked states allowed Romantic composers to subvert traditional musical forms in favor of successions of musical sections that passed through varying states of markedness and unmarkedness, producing various trajectories of expectation and fulfillment, tension and release. The sequence of musical episodes correlates with a sequence of schemata that makes up the deep structure of a story, the characters and conflicts of which can vary from listener to listener, but the general trajectory of which still evokes some kind of narrative. A 'beginning' section, for instance, appearing in the middle of a drawn-out sequence of middle sections, can suggest, say, temporary regaining of the initial state, or a cyclical return, or a nostalgia for the lost initial state.

Functional Musical Features

Mezzo uses three musical features as vehicles for conveying markedness, which will be referred to in this dissertation as harmonic tension, formal regularity, and energy. They are the functional musical features in the program's compositional process: that is, the qualities that *Mezzo* is constantly adjusting in order to musically express a narrative. The specific operational details of each of these features will be defined in later chapters, but their general meanings are intuitively understandable. Of the three functional features, energy is the simplest one to implement computationally, and will not be given a full chapter's discussion. It simply refers to the number of musical events occurring within a given period of time; in *Mezzo*, high

energy loosely corresponds with marked states, although this is modulated by the other two functional aspects, harmony and repetition. In terms of harmony, markedness is equated with a high degree of tension, as evinced by, say, a dominant harmony, which conveys a displacement from and a drive back toward the unmarked harmonic state of a tonic triad. This quality and how it is controlled is defined quantitatively in chapter 3.

Formal regularity is the notion upon which *Mezzo*'s design is largely based. Its definition is multifaceted, and will be presented gradually throughout this dissertation. Broadly, *Mezzo* is designed on the idea that certain patterns of melodic repetition combined with harmonic function became conventionalized in the Classical Era as normative forms: the sentence, period, and sequence. These forms exist in the middleground of a musical work, each comprising one or several phrase repetitions, one or a small number of harmonic cadences, and at a moderate tempo last between ten seconds and a minute. They constitute, to a large degree, the rhetorical character of a composition—how the flow of the passage of time is conveyed to the listener.Much excellent research has been done on musical *Formenlehre* in the past two centuries, by Schoenberg, Ratz, Caplin, and Koch, to name but the most influential. *Mezzo* is an algorithmic application of their theories to 21st-century interactive composition. Each musical form has a normative structure, and various ways in which it can be deformed. Regularity refers to how close an instance of such a form adheres to its normative structure. Forms that deviate from their normative structures have various levels of irregularity (the means of measuring this will be

given in detail) and hence markedness. This is how *Mezzo* implements the idea introduced at the beginning of this chapter, that repetition is a functional feature of musical expression. However, this implementation is problematic in the context of game music. Merely constructing a method of composing forms with normative structures and a system of deforming them does not address the problem of playing these forms over an arbitrary long period of time. A normative form repeated indefinitely will quickly cease to sound normative: the periodicity resulting from exact repetitions, which creates balance in small temporal proportions, draws attention to itself and sounds unbalanced. The identification of periodicity with normativity does not survive the mapping from closed-time to open-time composition.

To resolve this problem, *Mezzo* applies deformations stochastically to composed forms during playback. This stochastic model, described in chapter 5, is a generalization of the methods of deformation used by Classical and Romantic composers, and attempts to maintain continuity with their procedures while projecting them into a modern, interactive context.

There is an analogy here with the development of non-Euclidean geometry, which was developed by removing one of Euclid's axioms on which traditional geometry had been based (the parallel postulate[2]), and exploring the resulting system by redefining or generalizing Euclidean ideas, and developing new ones. In this case,

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[2] If a line segment intersects two straight lines forming two interior angles on the same side that sum to less than two right angles, then the two lines, if extended indefinitely, meet on that side on which the angles sum to less than two right angles (Heath 309).

the axiom being removed is that *the temporal proportions in a work of music are fixed in advance*. The elements that are immediately affected by this removal are the ideas about musical expectation codified by authors like Meyer and Narmour. Periodicity and symmetry over an arbitrarily long time become repetitious and no longer satisfy a listener's expectations. However, these features are not meaningless in interactive music; only in need of modification to fit the context of radically new and as yet undefined musical forms.

Implementations and Architecture

Together, the features of harmonic tension, formal regularity, and energy produce various levels of markedness that evoke general qualities of story schemata like stability, accumulation, velocity, dissolution, disorientation, and urgency (Guck 210). *Mezzo* attempts to define a set of schemata used in a game story, write rules for generating musical episodes that evoke them, and then, when a specific schema is asked for during gameplay, produce it on demand. The game aspect further motivates *Mezzo*'s of a Romantic-Era vocabulary: conventions from that period are still familiar, due to their use in film and game soundtracks, so listeners recognize them and can attest to how well the program works.

Furthermore, a dominating quality of this musical style and its lineage is melodic thematicism. Melodies and motives are foregrounded and identifiable, and changes in melodies announce changes in the musical narrative. There seems to be a

predilection in human perception to associate a melody or motive with a character, either one that is specifically named, as in a Strauss tone-poem or a Wagner opera, or one that is a general archetype, like the 'hero' in a Beethoven symphony. This is the means by which *Mezzo* conveys changing schemata in a game. Characters and important objects are given *Leitmotivs* (input by the user). At any point in the game, any *Leitmotiv* can be mapped to a combination of the three functional musical qualities, melodic regularity, harmonic tension, and energy, to express various levels and types of markedness or unmarkedness which correspond to the state of that character in the game. The actual motive or melody which constitutes the *Leitmotiv* lets the listener identify the character or object being depicted musically. The melodic content of a motive—its contour, rhythm, and texture—is not altered by the program, except for fragmentation. In this way, it remains recognizable. The program maps motives onto different combinations of the three functional features listed above. These mappings express different states of the character or object being depicted melodically.

Motives are thus associated with characters, and mappings with conditions. These two independent associations allow each coupling of a motive with a mapping to be interpreted as a pair of coordinates in a state space, where various regions of the space correspond to different expressive musical qualities. This can be depicted geometrically by a semiotic square, a model first developed by Greimas.

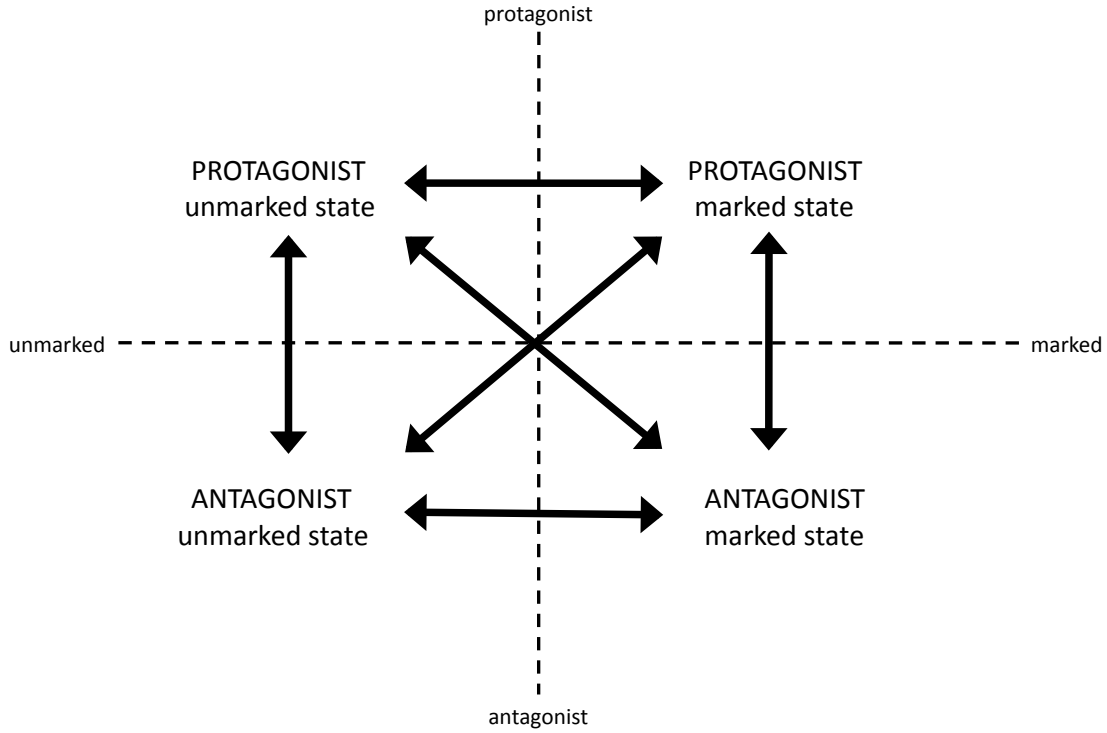


Figure 1.1: Semiotic Square

The semiotic square in the above diagram presupposes the existence of two oppositionally related motives: one representing a protagonist, and the other an antagonist. This is, in fact, a common state of affairs in a computer game, and so this distinction is very useful in *Mezzo*'s compositional process. The four quadrants are in the square represent different states of hierarchical emphasis, and the arrows between them different paths by which these states change. In fact, this four-part diagram is an oversimplification of the various narrative states that *Mezzo* expresses musically: within the half-plane of 'marked states,' there are many qualitatively distinct regions. The means by which these regions are distinguished computationally forms the basis of the rest of this dissertation.

From its focus on middleground levels comes the name *Mezzo*, as well as its role as an intermediary in the interpretation and conveyance of the discourse of the game. It does not create the narrative elements that occur; it receives these as signals from the game, and then tries to reinforce and amplify them with appropriate music, just as a pianist in a silent-movie house did.

Composition in *Mezzo* essentially occurs in two steps. First, motives and harmonies are organized into basic formal units with normative structures. Then, stochastic deformations are applied to these forms. Both of these processes are directed by various features of the game's state; each time the state changes in a way that affects the music, *Mezzo* composes new musical material or modifies the current material.

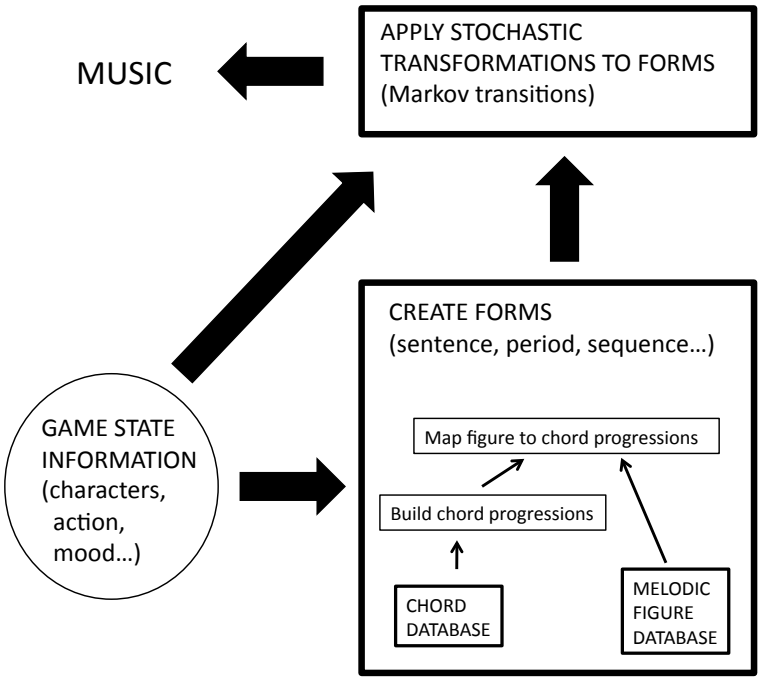


Figure 1.2: Flowchart of *Mezzo*'s architecture

Mezzo consists of about 4,000 lines of Python code that do all the computation, and a few Max patches that act as an interface, sending game signals to the Python code, receiving musical data, and handling playback. Communication between Python and Max is implemented using Open Sound Control protocol.

Chapter Organization

The next chapter introduces and defines the three basic formal patterns *Mezzo* uses. Chapter 3 describes the process by which harmonic and melodic material is combined to compose them. Chapter 4 introduces the notion of formal regularity and its correlation with expressive and narrative function. Chapter 5 describes how this notion of regularity is defined and implemented stochastically by *Mezzo*. In chapter 6, the way in which *Mezzo* uses all of the elements of the preceding chapters to compose music during a game is detailed, and chapter 7 illustrates this process with a detailed formal analysis of 'By Sweat and Toil,' an accompaniment composed in real-time for a game-play experience. Chapter 8 describes, in less detail, the composition of the other two pieces, '$(SW^2)^2$,' and 'Bowser's Castle.' Chapter 9 contemplates further research into the concepts introduced by this dissertation, and how it could be integrated into *Mezzo*'s design.

Chapter 2 Basic Forms

Mezzo composes music by taking precomposed melodic motives and phrases, writing chord progressions for them, and then structuring their repetition in specific ways. There is a handful of musical formal groupings *Mezzo* uses that relate harmonic progression and type and amount of melodic repetition. These are middle-level formal groupings, meaning they are just larger than the phrase level: each one consists of several melodic phrases (in some limiting cases, a single phrase), and one or two cadential progressions.

Three formal units appear in *Mezzo*'s compositions: the sentence, the period, and the sequence. Each of these three forms is historically defined in terms of its normative structure, the structure in which it is said to most commonly appear in the literature. However, this structure allows various deformations, and it is the elastic quality of these formal units allows for a variety of rhetorical gestures and control of the temporal motion within a work of music.

Formal groupings in *Mezzo* are represented by a hierarchy of Python class objects. The levels in the hierarchy are as follows:

Form ⊃ *Section* ⊃ *Phrase* ⊃ *Measure*

The three formal groupings discussed in this chapter are all of the class *Form*. Different forms have different types of sections, which are distinguished both

harmonically and melodically. Harmonically, they are distinguished by cadence type—perfect authentic (PAC), imperfect authentic (IAC), or half (HC). Melodically, they are distinguished by the number of motivic repetitions, whether the motive used is a cadential or non-cadential motive (i.e. character, environment, or action—this will be discussed in the next chapter), and whether the motive is complete or fragmented ('split').

Each of these forms and its specific section types will be discussed below. Mezzo composes a form section by section; building a section means mapping one or several phrases to a harmonic progression. Phrases are the basic building blocks of Mezzo's musical construction process, and, except for one special case concerning cadences, phrases aren't categorized as different types, as sections and forms are—there is only one kind of phrase. Phrases are themselves made up of measures, which correspond to the traditional musical definition of measures. Measures bear no actual structural import; they are groupings used to regulate playback and notation.

Because the program treats cadential melodic material in a special way, forms that use such material must be composed slightly differently than their analogs that do not use cadential material. Each form class thus has a double, which specifies that it uses cadential material: *CadentialPeriod, CadentialSentence,* and *CadentialSequence.* The modifier "Cadential" does not here refer to the harmonic closure of a form, but rather whether the form uses cadential melodic material. All sections of forms, in fact, are mapped to progressions with harmonic cadences, as will be discussed in the next chapter.

The structure of each of the three forms will now be defined.

SENTENCE

The sentence form is ubiquitous in music of the Classical Era, although it was only first labeled and analyzed by Schoenberg (114). It is normatively an eight-measure grouping divided into three smaller groups, in the proportions 4 + 2 + 2 (in terms of measures). These three groups are labeled differently by various theorists, but the different labellings convey the same sense of their functions. Agawu calls them the *beginning, middle,* and *end* (151); Caplin uses *presentation*, *continuation*, and *cadence* (10-11). I will use Caplin's terms.

The presentation is made up of a two-measure melodic idea and its immediate repetition, over a harmonic progression that prolongs the tonic. According to Caplin,

> The presentation functions to create a solid structural beginning for the theme by establishing its melodic-motivic content in a stable harmonic-tonal environment. The initial statement of the basic idea sets forth the fundamental material of the theme, and the immediate repetition of the idea fully "presents" it as such to the listener. The tonic prolongational progression provides the requisite harmonic stability (35-36).

The continuation is characterized by four qualities which distinguish it from the preceding presentation section: (1) melodic fragmentation, (2) acceleration in

harmonic rhythm, (3) increase in surface rhythmic activity, and (4) sequential harmonic movement (Caplin 41). The cadence contains a cadential harmonic progression, and either a further fragmentation of the melodic material, or conventional cadential melodic material.

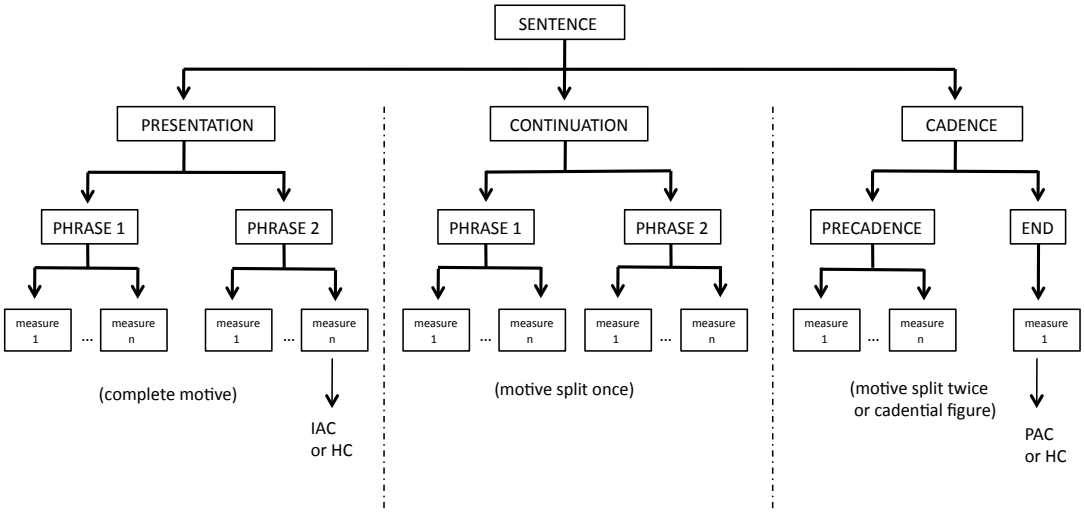
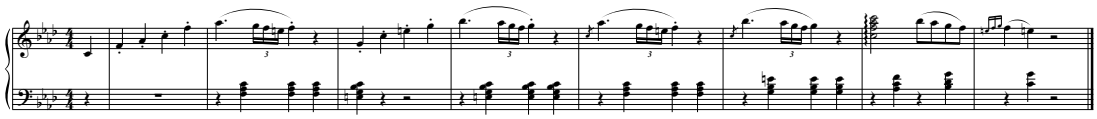


Figure 2.1: Sentence Structure



Example 2.1: Sentence from Beethoven, Op. 2, No. 1, mvt. 1, mm. 1-8

In *Mezzo*, the presentation uses either an HC or an IAC (chosen at random by the program). Each motive repetition is saved as an instance of a *Phrase* object; this section thus consists of two phrases, each consisting of one entire statement of a motive.

The continuation and cadence sections share a single harmonic progression. The continuation takes up the first part of the progression, and consists of two repetitions of a fragment of the motive (which is creating by calling the *split* method: see the discussion of motives in the next chapter). Each of these repetitions is saved as a phrase. The cadence section falls over the second part of the progression, and consists of two phrases, labeled the 'Precadence' and the 'End.' The 'End' is just the final measure of the cadence; the term 'phrase' here refers to its role as a data structure in a hierarchy, and not as a musical phrase. The 'Precadence' consists of everything after the continuation and before the 'End;' it is possible that there is no such material, and this phrase is empty. The distinction between the final measure and the rest of the cadence allows the program to expand or elide the cadence. The context and means for doing this will be discussed later.

The motivic material in the cadence section either consists of a further fragmentation of the original motive—that is, the motive fragment that was created for the continuation by splitting the presentation's motive is now split again—repeated twice, or a single cadential motive. The harmonic closure is either a PAC or an HC. Which cadence type it will be depends on the state of the game; this will be discussed in Chapter 6.

The sentence contains a high degree of symmetry in its melodic repetition, and establishes and sustains a stable harmonic region. For these reasons, it was commonly used in sections meant to evoke stability. Its proportions were often doubled; a four-measure melodic phrase would generate a 16-measure sentence with

the proportions 8 + 4 + 4. However, the structure of the sentence allows for substantial deformations. Both the continuation and the cadence sections of sentences undergo expansions and contractions in terms of their measure length throughout the musical literature of the Classical Era. Deformed sentences appear as commonly as normative ones; this fact is interesting, considering that the qualities of symmetry and proportion are invoked as characteristics of music from this period. While large-scale forms like the sonata, rondo, and ternary form may have simple, symmetrical structures, the middle-level musical layer of this era was full of unevenness.

PERIOD

The period is normatively an eight-measure structure, divided symmetrically into two four-measure phrases. The first phrase is labeled the *antecedent*, and the second the *consequent*. Harmonically, both antecedent and consequent end on cadences. The consequent's cadence must be stronger than the antecedent's; usually, it ends with a PAC. There are typically two melodic motives used in a period form, and there are several ways in which they are distributed. In a typical eight-measure period, according to Caplin, the antecedent starts with two measures of a *basic idea* and then follows it with two measures of a *contrasting idea* (49). The consequent begins with the basic idea, and either follows it with the contrasting idea, or some cadential melodic material. The antecedent ends either on an HC or IAC, and the consequent ends with a PAC. The consequent section functions similarly to the

cadence section of a sentence; it closes off a form, acting cadentially, and can be elided or expanded in the same way a cadence section can.

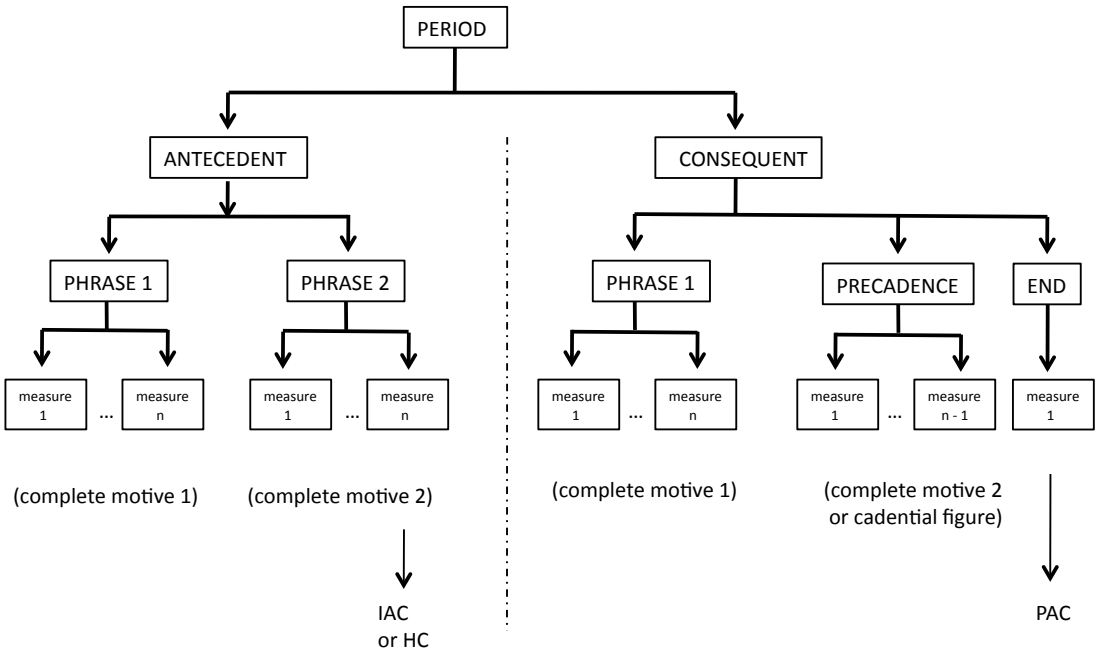


Figure 2.2: Period structure

The symmetry and harmonic closure of the period form has been associated by theorists with balance and stability. The period allows less substantial deformation; Goetschius illustrates periods in which either the antecedent or consequent is repeated, or in which one of the sections is expanded by interjecting measures of melodic material, but the proportions of each sections do not expand and contract to the extent that the sections of sentence forms throughout Classical and Romantic literature do (72-87). Due to its balanced structure, the period was

commonly correlated with lyric or picturesque sections in Romantic music (Monelle 110): descriptive music in which the experience of the flow of time was supposed to be minimized, or eliminated altogether.

SEQUENCE

A sequence consists of repetitions of a melodic phrase, motive, or figure. Each repetition is successively transposed by a certain interval. It can stay within a key, moving to different scale degrees while retaining a harmonic progression within the key, or it can modulate. *Mezzo* defines a sequence as *three modulating* repetitions of a melodic passage. In practice, sequences were often made up of exactly three repetitions; this number is probably as close to a normative description as possible. *Mezzo* only uses modulating progressions because I haven't yet found a good way to computationally transpose chromatic harmonies while staying within a single key; the intervallic mapping becomes very complex. Simply modulating the entire progression is computationally much easier, and the resulting music is still appropriate to the style of the Romantic Era, in which chromatic modulations were common.

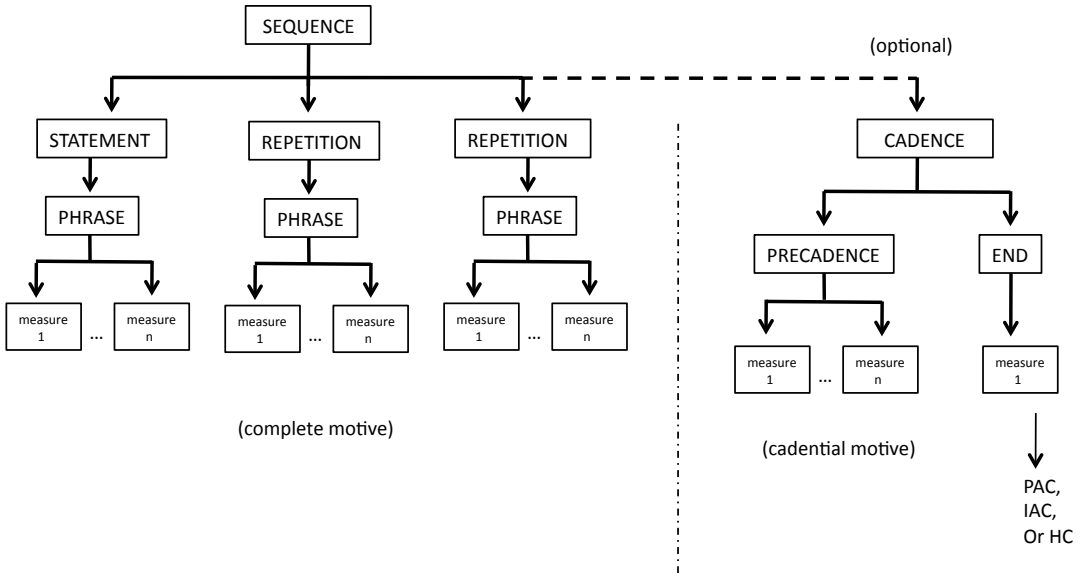


Figure 2.3: Sequence Structure

The sequence consists of a single phrase repeated three times, each time in a different key. The interval distance between the tonic of each repetition's key is fixed, and is chosen depending on the current state of the game. A sequence is composed by choosing a harmonic progression that would fit a presentation section; that is, a progression over which two repetitions of the motive would be mapped. From this progression, only the first half—the part that harmonizes the first statement of the motive—is chosen; the second repetition and its harmonic cadence is discarded. The motive is mapped over this half-progression, then the half-progression is twice transposed up or down the interval distance specified, and the motive is mapped over it each time, to produce three phrases. The best voice leading is chosen between the last chord of one phrase and the first chord of the next, transposed phrase, in the manner described in the next chapter. This can result in a

new permutation of the voices; the melody can possibly occur in a different voice in the next phrase after the voice leading is effected. Sequences can optionally finish with cadences. In this case, the original harmonic cadence from the progression taken from the database is added to the third, final phrase, transposed to the key this phrase is now in.

Caplin does not include the sequence as one of his formal groups. Instead, he refers to "model-sequence technique," a process by which the formal organization of a section of music is loosened; that is, by which symmetry and regularity of pacing is broken. Historically, no normative form for the sequence has been agreed upon by theorists. Joseph Riepel described the *Gang*, a term meaning "walk, movement, course, progress, development," in his *Anfangsgründe zur musicalischen Setzkunst* of 1754 (Monelle 104), and this term also appeared in A.B. Marx's *Die Lehre von der musikalischen Komposition* of 1837, the treatise in which most of the basic notions of Classical form were first comprehensively analyzed and labeled. Marx's definition of the *Gang* as "a tone pattern, that is deprived of...a close" (24) imparts little information; it is from the examples he gives that the idea of a sequence as a chain of repetitions of a melodic passage comes. The aspect of the sequence on which all the theorists mentioned here agree is that it creates a sense of movement, as opposed to rest. A sequence has a transitional formal function; it is thus correlated with states of movement, or instability. The interval of transposition of repetitions and the length of the melody being repeated correlate with specific expressive qualities, as well; these will be discussed in chapter 6. It is for this reason that sequences occur largely in

transitions and development sections; indeed, many Classical development sections consist entirely of sequences.

The next chapter details the process by which these three forms are created.

Chapter 3 Composing Forms

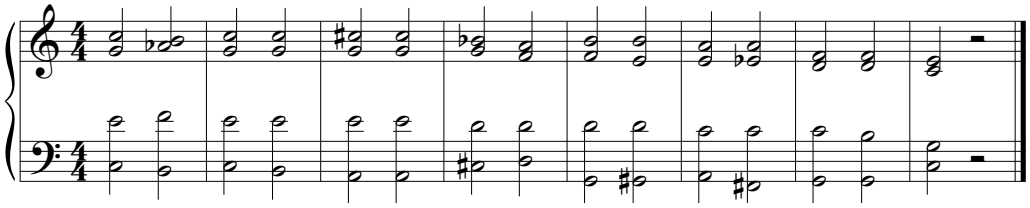
Mezzo builds sentences, periods, and sequences by writing chord progressions and then mapping motives to them. Every form is composed according to its normative structure; after composition, forms are associated with stochastic variables that deform them during playback. This chapter describes the initial process of form composition; form deformation will be described in the next two chapters.

Chord databases

Mezzo builds chord progressions from databases of chords that are loaded by the user. To load a chord database, the user inputs a MIDI file of any number of chord progressions. These chord progressions are in standard, textbook-style format: unornamented quarter- or half-note progressions on two piano staves. For each composition included in this dissertation, I reduced compositions from a particular composer (Chopin, Wagner, Liszt) to make a database. Chords can have any number of voices; I have used four-part progressions. Each progression is analyzed in terms of a single major key, the tonic of which is given to the database along with the phrase. In the case of progressions that rove, such as in Wagner, the association of a progression with a single key is probably analytically unsound, but for the

compositional purposes of the program, it works. Progressions in the MIDI file are separated by measures of rest; each progression is analyzed by the program as a single harmonic phrase. From each phrase, a variety of information is extracted which is used to create new progressions for the game composition.

The chord database is a Python dictionary object. The pc-multiset in normal form of each chord in the progression is calculated; this serves as the key for looking up chords in the dictionary. Associated with each key are the pitches in the chord (represented as MIDI values) and the voice-leading motions between it and the chord that follows it in the progression.



A B C D E F G H

Key (pc-set)	Pitches	Voice-leading motions
(0 0 4 7)	(48 64 67 72)	(-1 -1 +1 +1)
	(48 55 60 64)	(-1 +0 +0 +0)
(2 5 7 11)	(43 62 65 71)	(+0 -1 +1 +0)
	(42 59 62 65)	(-2 -1 +5 -4)

Example 3.1: a progression being loaded into a chord database

The example above shows a progression (taken from Chopin, Op. 9, No. 2) which has three chords, labeled A, C, and H, which share the pc-multiset (0 0 4 7), and two chords, labeled E and G, which share the pc-set (2 5 7 11). In the database, the pitch collections of A, C, and H are stored under the key '(0 0 4 7),' and the pitch collections of E and G are stored under the key '(2 5 7 11).' The voice-leading motions from A to B, C to D, E to F, and G to H are associated with the pc-sets of the first chord in each pair (not the pitch sets) and are represented as vectors. These vectors are constructed with the following algorithm.

Let pc_i be the number in the ith place in the pitch-class set S. Find the pitch p in the set of pitches that has this pitch class. If there is more than one number equal to pc_i in S (i.e. S is a multiset), and pc_i is the first instance of this number in S, pick the lowest pitch in the chord that has this pitch class. If it is the second instance, pick the second lowest pitch, and so on. Take the number of semitones between p and the note in the following chord that it moves to (i.e., the note in the same voice as p). Add parity: if the movement is down, this number is negative, and if it moves up, the number is positive. This number vl_i is the ith entry in the voice-leading vector.

In the example above, A and C have the same pitches, but move to different chords. The voice-leading vector associated with A is formed by first looking at the lowest pitch with pitch class zero—the C in the bass voice, MIDI value 48. It moves down one semitone to the bass B in chord B; its voice-leading entry is thus -1. The next lowest pitch with pitch class zero is in the soprano; it also moves down a half-step (Chopin was definitely more lax with his parallel octaves than Bach). The tenor

voice in chord A has pitch class 4, and the alto pitch class 7. The resulting voice-leading vector from chord A is thus (-1 -1 +1 +1). Because the last chord, chord H, does not move to another chord, it offers no voice-leading vector. There are thus two pitch-set entries associated with pitch-class set (0 0 4 7) from this progression, and two voice-leading vectors. There is one important point to add: the voice-leading vectors and the pitch sets, once stored in a dictionary, are no longer associated with one another.

In addition to storing each individual chord's information, a chord database stores the last two chords of each phrase as one of two types of cadence: "Authentic" or "Half." An authentic cadence in this case is defined as a pair of chords taken from the end of an input progression in which the second of the pair has a bass note which is the tonic. A half cadence is defined as a pair of chords taken from the end of an input progression in which the second of the pair has a bass note which is not the tonic. The reason for not differentiating further between perfect and imperfect cadences will be seen below. Each cadential pair is saved in one of the two cadence categories in the database.

Constructing chord progressions

Composing a chord progression is a highly constrained problem. In *Mezzo*, a progression must voice lead well, be harmonically well-formed, have a desired cadence, and have a desired average harmonic tension. Because of the complexity of

this problem, I have opted to use a genetic algorithm to create chord progressions, rather than a constructive algorithm, as Cope uses (*Experiments* 151-187; *CMMC* 237-243). This method has the benefit of generating many acceptable chord progressions relatively quickly; in a real-time situation, this emphasis on speed and a slightly lower tolerance for mistakes is practical. As of the writing of this dissertation, the genetic algorithm still takes a bit too long to be used in real-time, and because of this, *Mezzo* generates all its progressions before the game begins and saves them in categorized databases. However, the genetic approach is still more useful than the constructive approach, as it creates a wide variety of good progressions that can be used during the game, and the time it takes to do so is reasonable enough (under a minute) that it can be done while a game is initially being loaded.

The structure of a genetic algorithm is given in Holland and in Goldberg. In *Mezzo*, genomes are strings of pitch-class sets drawn from the chord database. To begin, the constraints that a progression must satisfy are given to the program, as well as a constraint on the range of values a genome's length must be in. This length constraint is an interval, representing the minimum and maximum length; I generally use [2, 9]. A certain number (I start with 100) of different strings of random chords is then generated; each string is made up of some number of pc-sets. To bias the selection and speed up the process, the last two chords of each string are taken from the appropriate cadence category in the database—this means that all progressions made have a good likelihood of having the proper cadential ending, although the

proper root motions might be destroyed in the course of genomic evolution, due to voice-leading (this will be discussed below).

Each string of chords is given a score in terms of the four constraints listed above. Except for the cadential constraint, each of these constraints has a quantitative measure by which it is judged.

Voice Leading

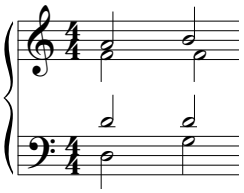
Given a pc-set in a genome, the program measures its voice-leading as follows. Call the set being judged X and its succeeding set Y. First, all possible motions from any pitch class in X to any pitch class in Y are calculated. If the cardinality of both X and Y is n, this gives a list of $n!$ voice-leading vectors, although if either is a multi-set, some of these vectors will be duplicates. Call this list V. Each of these vectors is measured against each of the voice-leading vectors stored under X in the chord database. To compare voice-leading vectors, *Mezzo* uses a simple measure. Let $A = < a_1\ a_2\ ...\ a_n >$ and $B = < b_1\ b_2\ ...\ b_n >$. Then

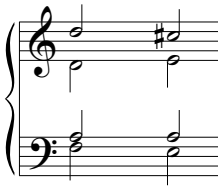
$$A - B = \sum_{i=1}^{n} | a_i - b_i |$$

Equation 3.1: Voice-leading difference

The vector in set *V* for whom the equation above is the smallest is chosen as the voice-leading to use to go from *X* to *Y*. (If there is more than one such choice, one of them is chosen at random.) In this process, "good" voice leading is thus defined as voice-leading that is close to voice-leading taken from the progressions input into the database, meaning the sum above is as close to zero as possible. This captures the harmonic sensibilities in some sense of the composer who wrote the progression. For instance, example 2.1 illustrated a case of parallel octaves in Chopin; similar voice-leadings that arise in the process of the genetic algorithm will thus be chosen, favoring instances of parallel octaves more than a database taken from Bach chorales would.

Voice leadings in database:





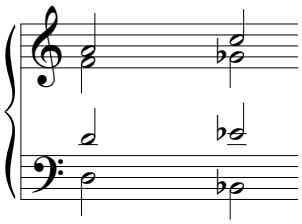
Pc-set	voice leadings
(2 2 5 9)	(+5 +0 +0 +2)
	(+2 -1 -1 +0)

Voice leading being measured: (2 2 5 9) ⟶ (0 3 6 10)

All permutations of second chord's pc-set, and resulting voice leadings:

([0, 3, 6, 10], [-2, 1, 1, 1]), ([0, 3, 10, 6], [-2, 1, 5, -3]), ([0, 6, 3, 10], [-2, 4, -2, 1]), ([0, 6, 10, 3], [-2, 4, 5, -6]), ([0, 10, 3, 6], [-2, 8, -2, -3]), ([0, 10, 6, 3], [-2, 8, 1, -6]), ([3, 0, 6, 10], [1, -2, 1, 1]), ([3, 0, 10, 6], [1, -2, 5, -3]), ([3, 6, 0, 10], [1, 4, -5, 1]), ([3, 6, 10, 0], [1, 4, 5, -9]), ([3, 10, 0, 6], [1, 8, -5, -3]), ([3, 10, 6, 0], [1, 8, 1, -9]), ([6, 0, 3, 10], [4, -2, -2, 1]), ([6, 0, 10, 3], [4, -2, 5, -6]), ([6, 3, 0, 10], [4, 1, -5, 1]), ([6, 3, 10, 0], [4, 1, 5, -9]), ([6, 10, 0, 3], [4, 8, -5, -6]), ([6, 10, 3, 0], [4, 8, -2, -9]), ([10, 0, 3, 6], [8, -2, -2, -3]), ([10, 0, 6, 3], [8, -2, 1, -6]), ([10, 3, 0, 6], [8, 1, -5, -3]), ([10, 3, 6, 0], [8, 1, 1, -9]), ([10, 6, 0, 3], [8, 4, -5, -6]), ([10, 6, 3, 0], [8, 4, -2, -9])

Best choice (lowest score): [10, 3, 6, 0]
Score = 6



Example 3.2: voice-leading measurement

When voice-leadings between all pairs of adjacent pc-sets in a progression have been chosen, the progression is actually voice-led. To do this, the first pc-set in the progression must be associated, when random strings are first constructed, with

one of its pitch sets taken from the database. Starting from this chord, then, the voice leadings are propagated forward until the end of the progression.

Cadence

Since the voice leading is propagated from the beginning of a progression, the last two chords may or may not maintain the proper bass motion that befits a cadence. While this could be avoided by propagating voice leading backward from the last chord, there is a benefit to leaving the final chord possibilities open. Cadences in the database, as mentioned, are divided into authentic and half cadences, distinguished in terms of the final chord's bass pitch. By creating different pitch sets for the final chord in a progression through different voice-leading, the program can change the quality of perfection in an authentic cadence, creating perfect cadences out of imperfect cadences in the database, and imperfect ones out of perfect ones. This bias toward variety over restriction allows the chord progressions the program writes to be more distinct from those the database analyzes, while maintaining similarity in voice leading. It also allows progressions of different cadential types to be generated from a small set of input progressions.

Harmonic Tension

The harmonic tension of a chord is measured according to formulas developed by David Cope, based on theories of Paul Hindemith. Since they are discussed extensively in Cope (*CMMC* 221-237), I will not go into too much detail here. The tension of a chord in a progression in *Mezzo* is a function of two variable types: the types of intervals and their placement in the chord, and the root motion to the chord from the preceding chord. Cope includes two more aspects that factor into harmonic tension, the metric placement of a chord and its duration. During *Mezzo*'s progression-building process, however, chords are not timed. When they are finally associated with durations and meter, at a later stage in the program, their movement is relatively uniform and slow—a chord either lasts one quarter note, two quarter notes, or one or several measures, and there is little variation among the durations (this will be discussed later). Because of this, the duration and metric placement formulas add negligible amounts to a chord's harmonic tension, and can be discarded in the interest of speeding up the algorithm.

In *Mezzo*, the harmonic tension of a progression is the average value of its chords' harmonic tensions (Cope uses the sum, not the average). The harmonic tension constraint is given to the genetic algorithm as one of five levels: 'very low,' 'low,' 'medium,' 'high', and 'very high.' Each of these levels defines a range of harmonic tension values. These are calculated from the chords in the database. The harmonic tension of each pitch set associated with a chord is measured in terms of its

interval weights, with the root-motion weight excluded. All of the resulting chord weights define the range of harmonic tension levels that a progression can have; the difference between the lightest and the tensest chords in the database is divided into five parts, and these parts are associated with each of the levels given above. A progression whose harmonic tension is "very low" will thus have an average value close to the lightest single chord in the database; a progression whose tension is "very high" will have an average tension close to or higher than the heaviest chord.

Harmonic Function

Harmonic tension also allows the harmonic function of a progression to be measured. The idea of harmonic function is that a group of contiguous chords in a progression can be perceived as a single unit, similar to the linguistic sense in which a noun phrase functions as a noun, or a verb phrase a verb. This was computationally implemented first by David Cope's 'SPEAC' model, and he has already written about at length (CMMC 237-250); I will therefore only briefly allude to it here. In *Mezzo*, I use a harmonic grammar that is much more lightweight than *SPEAC*, for the sake of algorithmic speed; since harmonic function derives from a hierarchical grammar, determining whether a given string can be generated from such a grammar is not a linear-time procedure. My grammar uses only two classes, instead of Cope's five: *S*, statement; and *A*, antecedent. A chord is a statement if its tension is equal to or less

than the average tension of a progression; otherwise, it is an antecedent. The grammatical decompositions of statements and antecedents is as follows:

$S \rightarrow (A\ S)\ ,\ (S\ S)$

$A \rightarrow (A\ A)$

Figure 3.1: *Mezzo*'s harmonic function grammar

The genetic algorithm gives each progression a score based on each of the four constraints just described: voice-leading, harmonic function, harmonic tension, and cadence. The first two constraints are aspects any progression must have; every progression should voice lead well and make sense harmonically. The last two constraints are context-based. For each type of cadence (PAC, IAC, HC), it evolves a list of progressions in each of the five harmonic tension categories, and loads these progressions into a database of chord progressions. The result is fifteen categories of progressions, each containing progressions of various lengths. Typically there are between 3 and 40 progressions in each category. This is an ample assortment of harmonic possibilities for *Mezzo* to draw from during real-time composition.

Motives

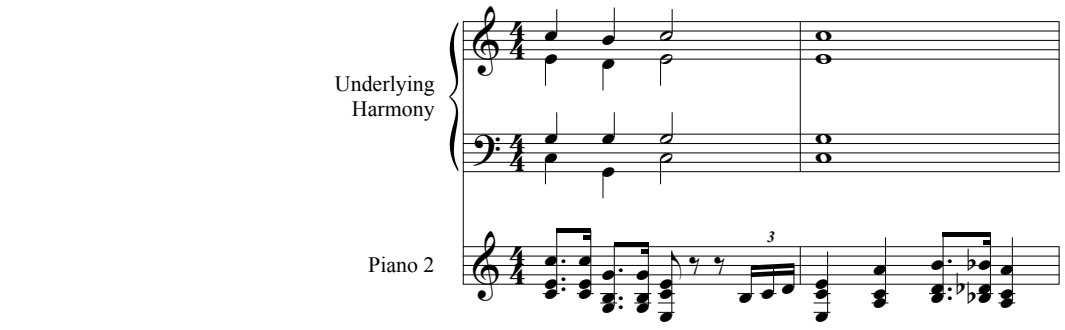
Motives are also stored in databases which are loaded from MIDI files. Each topic must be loaded along with an underlying harmonic progression and its tonic.

This is so that each note in the motive can be encoded in terms of its relation to a structural harmonic pitch; the motive can then be mapped to different harmonies in the course of composition, while maintaining this relation.

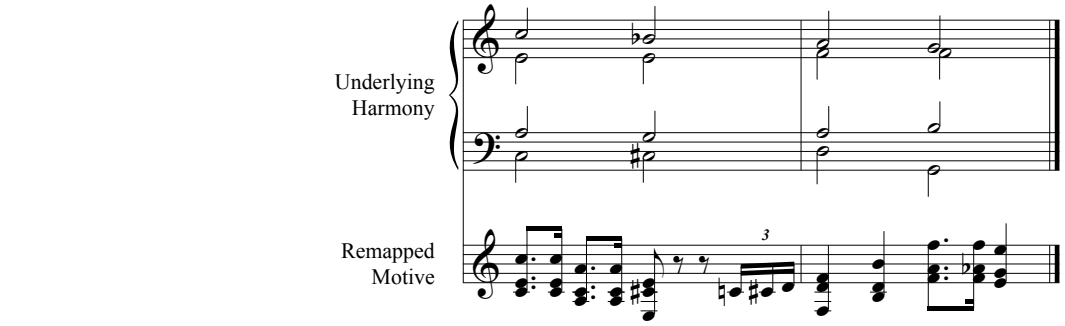
When a motive is entered into the database, the meter and the downbeat time is given as well. Each note's ontime and duration is recorded as a fraction of a quarter-note. The downbeat time is necessary in case the motive has an anacrusis; in this case, the ontimes of the notes in the anacrusis are negative. A note's pitch in a motive is recorded in four variables. As mentioned, a harmonic progression is given along with each motive. This means that each note has an underlying chord associated with it. Each note's pitch class's distance in semitones from the nearest pitch class in the underlying chord is calculated. If this distance is zero, the note is part of the underlying harmony. If it is non-zero, it is a non-harmonic tone, and can either be part of the chord's underlying scale, or it can be a chromatic non-harmonic tone. If the pitch is part of this scale, it is flagged as "scalar;" if not, it is flagged as "chromatic." Determining the underlying scale for a given chord is a problem without an obvious solution; I have experimented with various algorithms to do this, and am yet to find one with which I am satisfied.

The four variables associated with each pitch are its register, its nearest harmonic pitch, its distance from the harmonic pitch, and the distance type (scalar or chromatic). The distance type determines what scale will be used when a non-harmonic pitch is remapped to a different chord; if it is scalar, the "distance" variable refers to the number of scale steps away it lies from the nearest harmonic pitch. If it

is chromatic, the distance variable simply refers to the number of semitones away it lies.



STRUCTURAL HARMONIC PITCH INDEX (SHPI):	0	1	1	1	2		1	1	1	2	1	0	0	1
	2	2	3	3	0					1	0	0	0	0
	0	1	1	1	2					2	1	0	0	1
DISTANCE FROM SHPI:	0	0	0	0	0		-1	0	1	0	1	-1	-2	1
	0	0	0	0	0					0	0	1	1	1
	0	0	0	0	0		-1	0	1	0	1	-1	-2	1
INTERVAL TYPE:							S		S		S	S	C	S
							S		S		S	S	C	S
REGISTER:	5	5	4	4	4		3	4	4	4	4	4	4	4
	4	4	3	3	3					4	4	4	4	4
	4	4	3	3	3					3	3	3	3	3



Example 3.3: Motive storage and remapping

Motives are stored in separate database regions according to the elements of the game they are to be associated with. In *Mezzo*, a motive can be associated with a character, a physical aspect of the environment, or a quality of action: "battle," "quest," "triumph," etc. A further set of cadential motives can also be loaded into the database. These are melodic figures that are associated with the ends of phrases, and are not associated with any particular game aspect. The type of motivic association determines how the motive will be used in composition. Motives associated with characters will be primarily used as melodies when those characters are present, and motives associated with environments and action will primarily be used as ostinati, although character motives are occasionally used for ostinati, and environment/action motives as primary melodies. Cadential motives will only be used in cadential sections, which will be discussed below.

Each motive is stored as an instance of a *Motive* class object, which has several attributes and methods attached to it that are used for mapping the motive to harmonic progressions. Upon loading, a motive's *energy* and *thickness* are recorded. *Energy* is a function of the average number of distinct attack times per measure in the motive and the amount of rests in the motive. The first aspect is intuitive—a motive consisting of a steady stream of 16^{th}-notes, for instance, should have a high energy. However, the second aspect, the amount of rests in the motive, is also important; for instance, a motive consisting of a single downbeat should have a low energy, and this energy should not increase too much if this downbeat is preceded by a short ornament

made up of eight grace notes. Factoring in the amount of rest time in the motive makes the calculation conform to intuition:

$$motive\ energy = (d - r) \times a$$

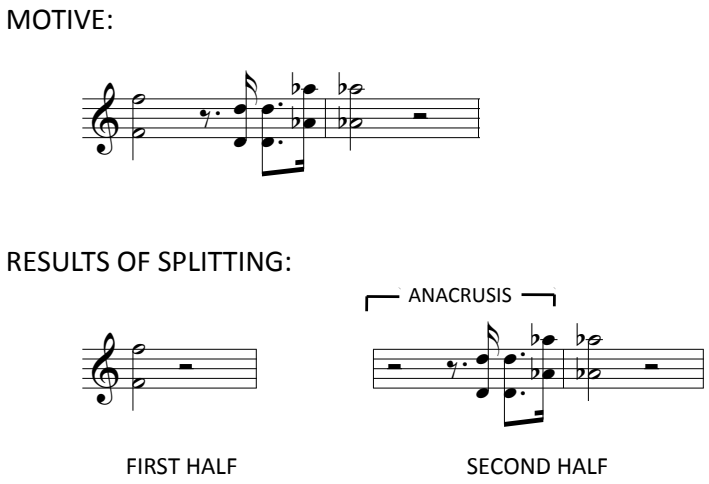
where d = *motive duration*

r = *total duration of rests in motive*

a = *number of attacks in motive*

A motive also has a *thickness* attribute, which simply measures the average number of pitches per attack time in the motive. Motives made up of chords have higher thickness than motives made of single lines. The thickness attribute is used during composition primarily when choosing ostinati and cadential material. When changing ostinato motives, or when moving from a character's motive to a cadential motive, the program tries to match the thickness of the new motive with that of the previous one, to create a smooth transition.

The most important motive method is the *split* method: a motive can break itself into two halves, returning a list of two new motive fragments. This is essential for the creation of different formal sections, primarily continuations. Splitting a motive isn't always as simple as just dividing it in half; it's possible that notes in the first half should be grouped with the second half, as an anacrusis.



Example 3.4: Splitting a motive / second half acquires an anacrusis

Determining which notes in the first half should be grouped into the anacrusis to the second half is not always apparent. *Mezzo* uses the following algorithm. Suppose a note n_i is the ith note in the first half of the motive; n_i is considered part of the second half's anacrusis if

1. it does not occur on the downbeat of the first half
2. the average inter-onset time between any two notes n_j and n_j, for $j, k \geq i$, is smaller than the inter-onset time between n_{i-1} and n_i.

Timing Progressions

Progressions in the database are not timed; that is, their chords are not associated with any durations. After choosing a database progression to which to

map a motive, the program calculates appropriate durations for each chord in the progression based on the duration of the motive being mapped, so that the progression will fit the mapping. The term 'mapping' here refers to the total number of all motivic repetitions being mapped to the progression. So, for a presentation section, the mapping consists of two motives. The continuation and cadence section of a sentence share a progression, so the mapping refers to two repetitions of a (split) motive for the continuation, plus either a single cadential motive or two repetitions of the motive split in half twice for the cadence.

The final chord of each progression is the chord of cadential arrival, and so it should fall on a strong beat. If the mapping has a duration of longer than one measure, the final chord is given a duration of one measure. If the mapping's duration is equal to one measure, the final chord is timed to fall on the second strongest beat in the last measure (the downbeat is the strongest); so far, everything *Mezzo* has composed is in 4/4 time, so the second strongest beat of a measure is the third beat.

Once the final chord has been timed, there remains a certain number of chords that must be fit to the remainder of the mapping's duration. *Mezzo* uses a method that allows a progression of any length to be fit to this duration. If there are as many chords as measures in the mapping, the timing is trivial: each chord is given a duration of one measure. If this is not the case, though, different durations must be given to chords in order that their sum equals the appropriate duration. One of two formulas are used for calculating the sequence of durations the chords in a

progression will have, depending on if there are more chords than measures, or fewer. I derived these formulas based on the idea that an increase in harmonic rhythm is typical of motion toward a cadence; thus, durations in a progression should get progressively shorter as they approach the last chord. The formulas are given below.

Let the mapping duration (minus the piece of the mapping that occurs over the final chord—recall that this has already been mapped) be c measures long, where c is some multiple of .5 (this is one of *Mezzo's* constraints; it does not work with motives of less than half of a measure). Let n be the number of chords in the progression (minus the final chord), and d_i, $0 \leq i < n$, be the duration of the ith chord in the progression.

If $n < c$, then, letting $\varepsilon = \log_2(c/n)$:

$$d_i = 2^{\text{ceil}(\varepsilon)} \quad \text{for } i < n\text{-}1$$

$$\text{and} \quad d_{n-1} = 2^{\text{ceil}(\varepsilon)} - (2^{\text{ceil}(\varepsilon) - \varepsilon} - 1)c$$

If $n > c$, then, letting $\theta = \log_2(n/c)$:

$$d_i = 2^{1-\text{ceil}(\theta)} \quad \text{for } i < c2^{\text{ceil}(\theta)} - n$$

$$\text{and} \quad d_i = 2^{-\text{ceil}(\theta)} \quad \text{for } i \geq c2^{\text{ceil}(\theta)} - n$$

where 'ceil' represents the ceiling function. These two formulas can be proven by summing the resulting durations.

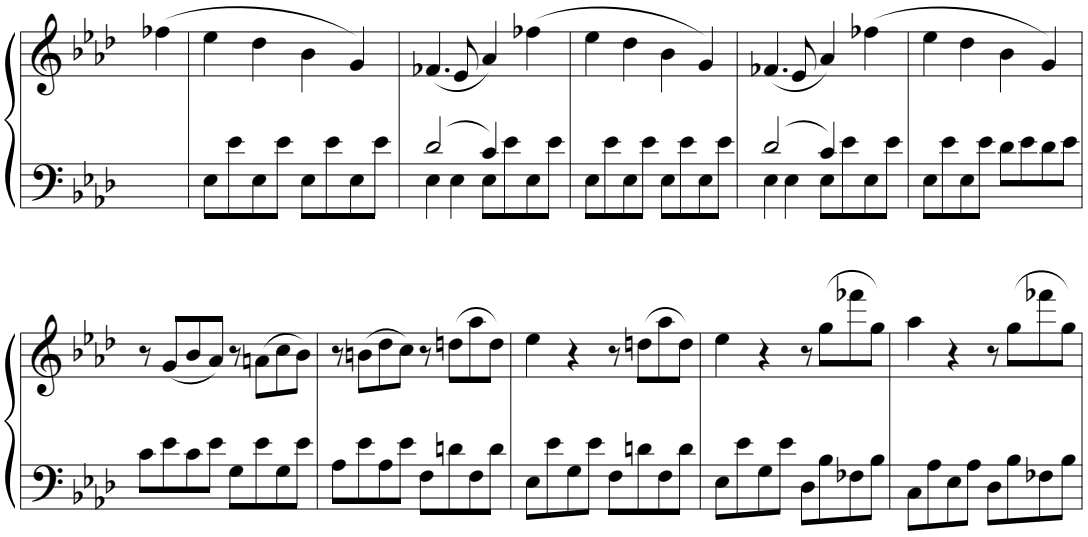
Chapter 4 Formal Regularity and Markedness

The previous chapter described how harmonic tension is measured, and how progressions with a desired level of harmonic tension are created and fit into forms. At this stage of composition, every form created has a normative structure. Next comes the procedure described in this chapter and the next, the process of deforming each form according to various expressive demands—that is, applying the parameters that govern how the melodic material within each form is repeated. The last chapter remarked upon some correspondences between certain forms and certain expressive functions. In the next two chapters, this notion will be extended: form deformation will be defined as a function of several variables, and different values of these variables will be shown to produce various levels of markedness which lend themselves to particular interpretations.

Formal Regularity and Markedness

Caplin makes the distinction between what he calls "tight-knit" and "loose" melodic themes, pointing out that most initial sonata themes are of the former

category, while second themes tend to be in the latter. That is, the second theme, besides being harmonically removed from the tonic key, is often more irregular in terms of its formal organization (99). While a second theme displays the sections of a basic form, elements may be repeated, left out, or reordered. The following example, the second theme of the exposition of the first movement of Beethoven's First Piano Sonata, is an example of a 'loose' theme.



Example 4.1: Second Theme of Beethoven's First Piano Sonata

This identification of initial themes as 'tight-knit' and secondary themes as 'loose' is revealing. To distinguish between large-scale sections of a piece, changes in key, texture, and motivic material are typically cited. In fact, a change in the regularity of formal organization typically corresponds to the introduction of a new structural section in a composition as well.

As was remarked in Chapter 1, narratives or programs became attached to the sonata form during the Classical Era. The common program attached to many of Beethoven's sonata forms is that of a heroic figure (often considered Beethoven himself) overcoming obstacles or problems tossed at him by the hands of Fate. This program is suggested by the sonata-allegro form: the hero is introduced by the first theme of the exposition, the obstacle by the second theme. The development evokes the hero striving to overcome his problem, and the recapitulation evokes his success in this endeavour. This ordering of events recalls Propp's taxonomy and ordering of episodes in Russian folktales.

Within the tripartite form of the Classical sonata, Grabócz has discerned an embedded four-part structure corresponding to the quadrants of a semiotic square as illustrated in chapter 1, in which the quadrants are defined as binary combinations of melodic themes and markedness values, and the presentations, transitions, and developments of these themes signal passages between quadrants (*Musique, narrativité, signification* 111-130). In this respect, the opposition between "tight-knit" initial themes vs. "loose" secondary themes in a sonata exposition is a markedness relation that is exploited later in the development and recapitulation. Passage through different regions of markedness in a musical semiotic square correspond, according to Grabócz, with the narrative interpretations given to the succession of formal sections in a sonata-allegro movement. A motive introduced with a high degree of formal symmetry is identified as proper, heroic, desired. It establishes the initial situation as one of equilibrium, and frames the entire movement

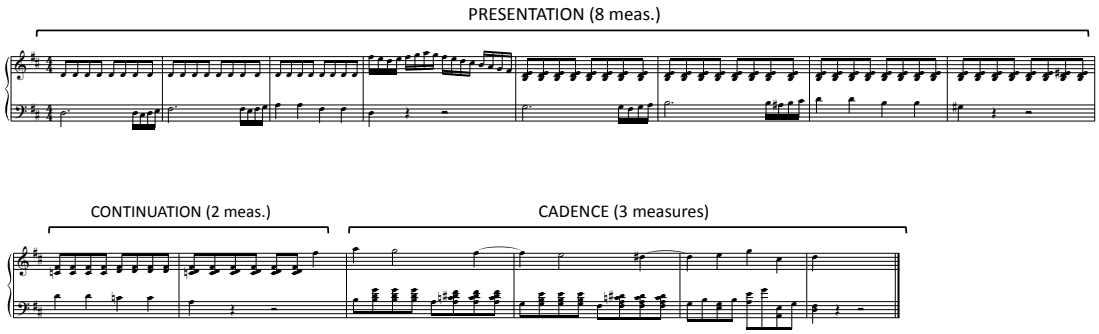
as a sequence of states which are interpreted in terms of their distance or reference to this initial state. When a second motive is introduced with irregular repetition and an asymmetrical organization, it is identified as improper, deviant, lacking: the gesture is seen as a motion out of the initial state of equilibrium. The new musical character is thus confronting the main character, not just following it in time; it brings about a subversion of the initial state of affairs, a subversion that must be rectified.

The formal organizations of the development and recapitulation sections also reinforce Propp's narrative morphology. Organization of development sections has a high variability across works and composers which does not allow a 'development form' to be classified as precisely as the form of an exposition or recapitulation. Developments use sequences abundantly, and the number of repetitions in a sequence varies, creating a high level of asymmetry. Motives from the exposition are often fragmented and their ordering is not specified by a set of norms. These qualities have led the development section to be identified with a quest or struggle, one whose goal is to regain the state of equilibrium introduce at the beginning of the movement. In the recapitulation, the achievement of this goal is evoked with a high degree of formal regularity; the motives from the exposition are presented again, one or often both with high degrees of regularity. These changes in formal regularity work along with the harmonic and textural cues to delineate the sections of the movement and to motivate their order.

Levels of Regularity

At the heart of *Mezzo*'s design is the idea that there are different perceptible levels of formal irregularity that can be quantitatively measured, and that these different levels convey different levels of markedness. This imbues the necessary process of repeating musical material with expressive capability, and provides a system for distinguishing expressive states through varying levels of irregularity. Furthermore, it suggests that if a small amount of irregularity can be heard as less marked than a large amount, it can even suggest a state of normativity, without itself being completely normative. That is, an 'almost-unmarked' state, in certain contexts, can be identified as 'unmarked.'

This notion is essential for effective procedural game music. In Classical- and Romantic-Era music, completely normative formal structures could be used to evoke unmarked states. This is not possible in a game, where the temporal proportions of sections are not known in advance. A symmetrical eight-measure sentence repeated more than a couple of times will quickly cease to express normativity and will instead become repetitious. Consider, however, the following example, the first theme of Beethoven's 2nd Symphony, 1st movement (the beginning of the sonata-allegro movement proper, after the Andante introduction):



Example 4.2: Beethoven, Symphony 2 theme

This is a highly irregular sentence. An eight-measure presentation section sets up an expectation for a four-measure continuation and a four-measure cadence. Instead, the continuation proceeds only halfway—one statement of the initial melody, fragmented—before cadential material interrupts it. This cadential material lasts, then, for three measures, before arriving at its goal, a perfect authentic cadence which elides with the beginning of the next theme. The proportions of this sentence are thus 8 + 2 + 3, resembling neither an eight- nor a 16-measure normative instance.

That this is the initial statement of the first phrase of an exposition in a relatively conservative symphony—a position conventionally representing stability and straightforwardness—attests to the sentence form's mutability, and to the fact that it can represent states of normativity associated with symmetry and regularity even without being symmetrical or regular. This example can be said to have a low, albeit non-zero, degree of regularity, which is perceived as conveying a similar quality and level of unmarkedness as a completely regular form.

Stochastic Irregularity

Mezzo creates irregularity by adding or omitting repetitions of musical material in a form it has constructed, the same way Beethoven did in the example above. Furthermore, it extends this concept to function in the open-ended setting of a game. When a set of forms is composed at a given point in the game, each form is associated with a number of stochastic variables that govern its playback. When a form is chosen to be played, different parts of the form are repeated or omitted with certain probabilities, as prescribed by the stochastic variables. Thus, each time the form is played, it will, with some probability, be organized differently from the previous time, and there will be no pattern to the way the organization changes from statement to statement. However, this randomness is controlled by the stochastic variables, so that a certain quality of irregular formal organization will always be met. This quality of irregularity is calculated by the program to give the melodic material a certain amount of markedness that appropriately reflects the state of the game narrative. From a small set of normative forms, then, a variety of musical events can be generated, and prolonged for an indefinite period of time, until a new narrative state occurs, without becoming repetitive.

The stochastic variables applied to a form dictate both the *type* and the *amount* of irregularity appropriate to the current state of the game requires. The *type* of irregularity in repetition refers to the level of the formal hierarchy—measure, phrase, or section—at which extra repetitions or omissions take place. The *amount* of

irregularity refers to how far from the normative structure of a form its deformation deviates, which is measured stochastically by the program. The means by which game state is mapped to these stochastic variables and then implemented will be given in detail in the next chapter.

Different combinations of types and amounts of irregularity have different levels of markedness. Specifically, *Mezzo* operates on the hypothesis that the lower the hierarchical level at which the irregularity occurs, the greater the degree of markedness perceived. Repeating or omitting measures within a phrase conveys a stronger sense of asymmetry than repeating or omitting entire phrases or sections. It is for this reason that example 4.1 can be said to be more irregular (Caplin's term is 'looser'), and hence more semiotically appropriate as a second theme, than that of example 4.1. In the latter, an entire statement of a motive is missing, the second fragmentation of the initial motive that should occur in a continuation section. In the former, an unexpected third repetition of the initial motive is added to the first two, only to be cut off in mid-statement by the continutation. The irregularity here occurs *within* a motivic statement as well as in terms of the repetition of statements. Both of these themes have irregular cadential sections, but, as will be discussed in the next chapter, cadences allow a degree of expansion and contraction, without disrupting the musical motion. The cadential irregularity in these themes does not have the functional role that the other types of irregular in them do; it is the latter which distinguishes one as more marked than the other.

In the 20th century, irregular repetition within phrases became a signature of

Stravinsky. Adorno found this level of irregularity so disturbing as to be philosophically repugnant, reflecting "the element of mimicry, of clowning—of constantly busying himself with something important that turns out to be nothing at all." Stravinsky, according to Adorno, 'mockingly distorts, dislocates, and provides with caustic little additions…the sections he strings together may not be identical and yet may never be anything qualitatively different. This is why there is damage instead of development" (153). Adorno's reaction to Stravinsky's repetition suggests the high degree of markedness that this level of irregularity evokes.

Applying stochastic irregularity to various hierarchical levels of a form has a very significant result. Normativity is no longer defined by whether a single statement of a form adheres to a normative structure, but whether it has a high probability of doing so, and, furthermore, if it does deviate, at what level of the formal hierarchy the deviation occurs. Or, to put it another way, the amount of markedness an arbitrarily long stretch of music has results from how much, on average, the formal groupings in the music deviate from their normative structures, and how they do so. The consequence is that regions of markedness can be defined by the type and amount of irregularity applied probabilistically to a succession of forms. High levels of markedness come from giving the material within phrases high degrees of irregularity. Conversely, a low level of markedness can be perceived even if forms are irregular, as long as the amount of irregularity is low, and it is applied to higher levels of the formal hierarchy (entire phrases or sections). From this difference a spectrum of regions of regularity is constructible, producing a structure

of signification in which formal regularity correlates to narrative function.

Furthermore, unmarkedness need not be evoked through complete regularity but can still be conveyed if the music has a very low level of irregularity; the region evoking 'unmarkedness' is wide enough to contain both completely regular and slightly irregular musical states. This means that *Mezzo* can express normative states musically for indefinite periods of time, with music that is varied enough not to become repetitious.

It must be said here that these notions arise from my own intuitions about music of the Classical and Romantic Eras, as well as other musics, based on my own familiarity and experience. It conforms well to cognitive notions like those of Meyer, Narmour, and Lerdahl and Jackendoff, and, furthermore, I believe that it is supported often by the musical literature. I cannot attest, however, that this idea comes from a careful analysis across many works: it does not. I have not undertaken such a study (although designing this program has prompted in me an interest in doing so). Instead, it is my hope that the output of *Mezzo* attests to the validity of this hypothesis, if not as an analytical generalization of extant works, then as a useful creative principle for composing new works.

Chapter 5 Form Deformation

Composition in *Mezzo* is a two-step process: first build forms, then deform them according to stochastic constraints. Chapter 3 described the first step of this process. This chapter describes the second. Both of these processes generate expressive features in the music being composed. The form-building stage described in chapter 3 contributes the harmonic tension, and also chooses forms which correspond to the given state of the game—periods, for instance, if a state of stability should be evoked, or sequences for a state of instability or striving, say. In the second stage, each form that has been composed is mapped to a data structure that sets the stochastic constraints on its regularity, as described in the last chapter, determining which, if any, sections or phrases or measures will be repeated or omitted, and to what extent.

The 'Form,' 'Section,' and 'Phrase' classes in *Mezzo* that encode the different formal groupings described in chapter 2 are all inherited from a class called *MarkovPlayer*. This class is itself inherited from Python's *list* class, but it overwrites the list class's iteration function so that it traverses its contents according to, as the name implies, a Markov transition matrix. The transition probabilities in the matrix are calculated according to variables which reflect the desired types and amounts of regularity a formal grouping should have. This allows the regularity to be changed in

very specific ways, to reflect the nature of the action, characters, and environment currently onstage in the game. Since these classes are nested, many different types of stochastic behavior can be created, as will be illustrated below.

For a MarkovPlayer with n states, the transition matrix will be a square (n+2) × (n+2) matrix. A 'start' and 'stop' state, which are not manifested musically in any way, are added to the n states; they determine where a Markov chain generated by the matrix will begin and end. A player that is completely regular has a transition matrix $M = [\, p_{i,j} \,]$ consisting of all zeroes except for the entries $p_{i,i+1}$. For instance, a completely regular MarkovPlayer with three states will have the following matrix:

	START	State 1	State 2	State 3	STOP
START	0	1	0	0	0
State 1	0	0	1	0	0
State 2	0	0	0	1	0
State 3	0	0	0	0	1
STOP	0	0	0	0	1

Figure 5.1: Completely regular matrix

The Player always begins in the top row, the 'start state' row, and chooses the first musical state to go to from the probabilities listed; in the example above, it will

always choose the first state in the list. Each musical state will, with probability one, move to the next musical state, until the last state, which will move to the 'stop state,' represented by the bottom row. At this point, the MarkovPlayer will stop returning states.

The 'states' in a formal class are all instances of classes one level down in the hierarchy: a Form class's states are Section classes, a Section class's states are Phrase classes, and a Phrase class's states are Measure classes. There are thus three hierarchical levels in a Form class to which Markov chains are attached. An example will illustrate this. Example 5.2 shows a sentence from *By Sweat and Toil.* Below it are listed the Markov chains for each type of formal class that will ensure it is always played in its normative structure.

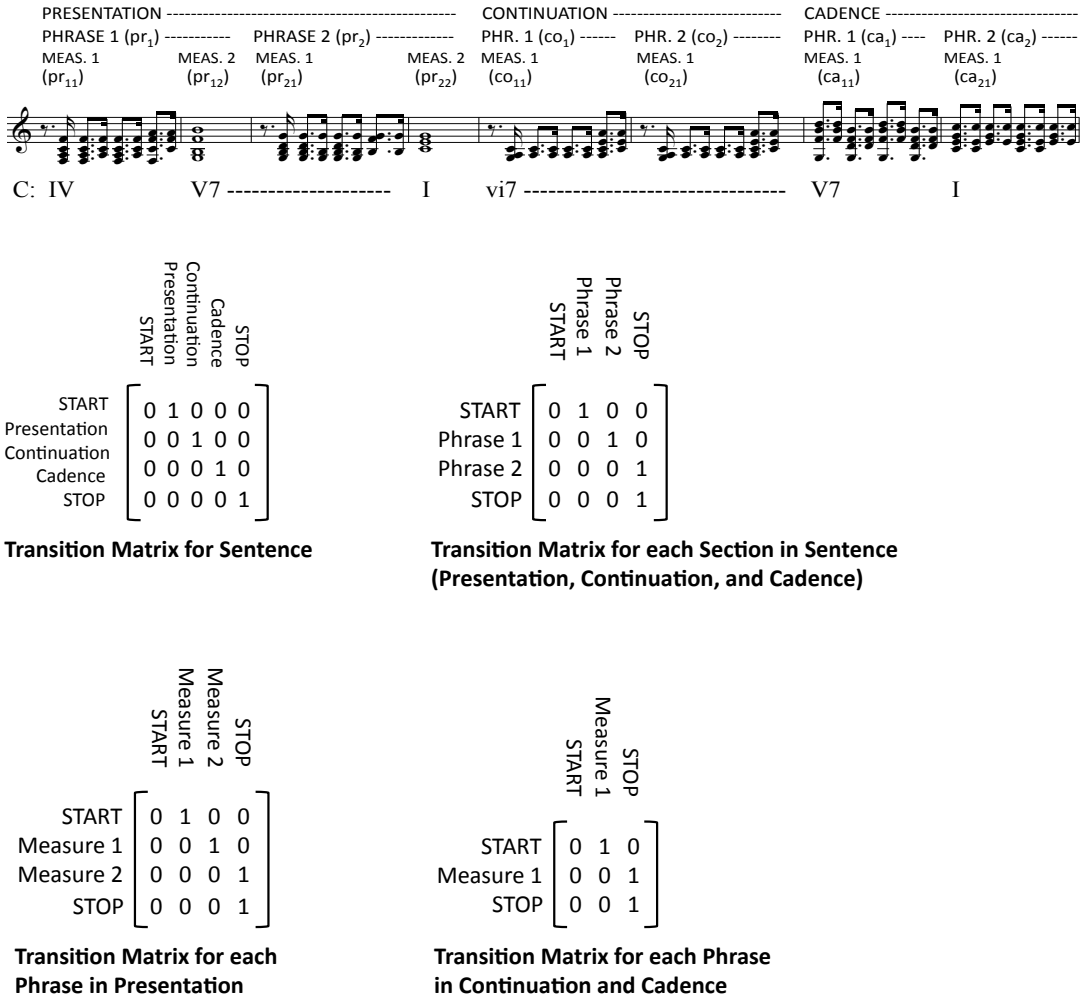


Figure 5.2: Normative sentence with associated Markov matrices

There is one top-level matrix, the sentence's, whose states are the presentation, continuation, and cadence sections. Each of these sections has a matrix containing two states, its phrases. Phrases in the presentation are made up of two measures, so each of them has a two-state matrix; in the continuation and cadence, each phrase has only one measure, and so all of their matrices are trivial, one-state matrices.

A Form class is played by iterating recursively through each hierarchical level, according to the probabilities in the Markov chains. Iteration begins in the 'start' state of the form's top-level matrix. From here, it chooses the first section to play; in the case of the example above, this will, with probability one, be the presentation. The program thus starts in the 'start' state of the presentation section, and chooses the first phrase in it to play; here it will be the first phrase. The program then begins in the start state of this phrase and chooses the first measure to play. This is the level at which actual musical material is returned: the phrase returns the first measure, then moves probabilistically on to the next, and so on, until it reaches the 'stop' state. At this point, the program moves back up one level of the hierarchy, and probabilistically chooses the next phrase in the presentation to play. Similarly, once all the phrases in the presentation have been played, and the presentation reaches its own 'stop' state, the program will move up another level of the hierarchy and choose the next section to be played. This will continue until the top-level matrix reaches its 'stop' state.

The diagram below illustrates this movement through the various hierarchical levels of the sentence given above, according to the Markov chains also given above.

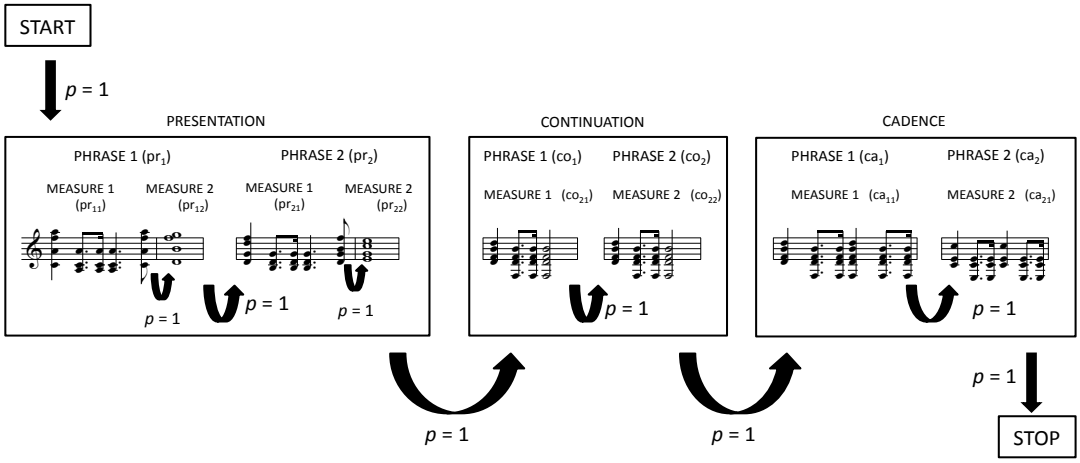


Figure 5.3: Completely regular sentence with transitions

Mezzo uses three variables to control the regularity of repetition in a MarkovPlayer: a 'repeat state' probability *r*, an 'early cut-off' probability *c*, and a 'wrong start state' probability *w*. These variables act as weights on the entries in a transition matrix. They are passed to a MarkovPlayer class as a vector (in Python, a 'tuplet'): ‹ *r , c , w* ›, where each variable *r, c, w* is between zero and one, inclusive.

If a 'repeat state' probability r , $0 \leq r \leq 1$, is added to the above matrix, the result will be the following:

$$\begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & r & 1-r & 0 & 0 \\ 0 & 0 & r & 1-r & 0 \\ 0 & 0 & 0 & r & 1-r \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Figure 5.4: Matrix with 'repeat state' probabilities added

With some small probability r, each musical state in the matrix will repeat before moving on to the next state.

If an 'early cut-off' probability c, $0 < c < 1$, is added to Example 5.1, the result will be the following matrix:

$$\begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1-c & 0 & c \\ 0 & 0 & 0 & 1-c & c \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Figure 5.5: Matrix with 'early cut-off' probabilities added

With some small probability c, the stop state will follow state 1 or state 2; that is, the Markov chain will end with one of them, and leave out any following states.

If a 'wrong start state' probability w, $0 < w < 1$, is added to Example 5.1, the result will be the following:

$$\begin{bmatrix} 0 & 1-w & w/2 & w/2 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Figure 5.6: Matrix with 'wrong start state' probabilities added

With some probability *w*, a Markov chain will begin not with state 1 but with state 2 or 3.

To set the entire regularity of a form, three vectors, each containing an *r, c,* and *w* value, are given to the form. One vector adds the appropriate weights to the matrix governing section iteration; another, to each section's matrix, which govern phrase iteration; and a third to each phrase's matrix, which governs measure iteration. Every class at one level of the formal hierarchy thus has the same matrix, but the matrices may differ between hierarchical levels. The matrices in example 5.2 would thus be passed the following vectors:

	r c w
SECTION:	**(0, 0, 0)**
PHRASE:	**(0, 0, 0)**
MEASURE:	**(0, 0, 0)**

Figure 5.7: Vectors generating a completely regular form

I have chosen certain settings which I believe are perceptually significant and musically logical for the style of music *Mezzo* composes. To create irregularity within phrases, the program adds a repeat-state and/or an early-cut-off probability; it thus ensures that a phrase always begins on its first measure, so that it is recognizable when it is introduced. Repeating measures within a phrase does not destroy the voice-leading, so harmonic continuity at this level is not sacrificed for the sake of irregular repetition. This kind of irregularity is used in conjunction with a character's

motive, to evoke the state of the character, as discussed in the previous chapter. If the character is in a stable or unmarked state, its measure-level regularity will be very high; that is, there will be no weights attached to its phrase matrices (recall that each formal class's matrix controls the repetition of the form class below it, so a phrase matrix governs measure-level regularity). If the character is in a marked state—suffering, unsound, striving, or is an antagonist, say—its phrase matrices will be weighted toward irregularity.

In *Mezzo*, a form or a section can be made irregular by adding any of the three variables to its transition matrix. This will make entire phrases within a section be repeated, or the section not begin on its first phrase (for instance, a sentence may skip its presentation and begin on its continuation), or the section cut off before finishing.

Mezzo uses five levels of formal irregularity, defined by different combinations of the values of *r*, *c*, and *w* passed to each hierarchy level in a form:

REGULARITY:	MEASURE	PHRASE	SECTION
	(*r c w*)	(*r c w*)	(*r c w*)
VERY LOW:	*q q* 0	*q q q*	*q q* 0
LOW:	*q* 0 0	*q* 0 *q*	0 0 *q*
MEDIUM:	0 0 0	*q* 0 0	0 0 *q*
HIGH:	0 0 0	*q* 0 0	0 0 0
VERY HIGH:	0 0 0	0 0 0	0 0 0

where $0 < q < 1$.

Figure 5.8: Regularity vectors in *Mezzo*

For the three accompanying pieces in the score, q is equal to .2.

Formal (non-stochastic) methods of increasing irregularity

In addition to these Markov operations, *Mezzo* uses four formal methods of introducing irregularity: eliding a cadence, expanding a cadence, interrupting a form with a phrase, or adding measures of rests between phrases ('dilution'). These four methods will be described in turn.

Cadential Elision

This occurs when a cadence section's 'End' phrase (which only consists of one measure—recall Chapter 2) is about to be played, and when the corresponding harmonic cadence is a PAC. When this happens, the program can instead skip this measure and go directly to the beginning of another formal grouping.

Cadential Expansion

This occurs when the cadence section of a sentence or the consequent section of a period uses a cadential figure and a PAC. The cadential figure from this section is then used as the motive for a new sentence, which is substituted for the original

cadence section. The figure is played twice over a new presentation progression, two fragments are played over a continuation section, and then it ends on a PAC with either more fragmentation or another cadential figure. Since the new sentence ends with a PAC and cadential material, its end can be further expanded into another cadential sentence; this can occur indefinitely. Cadential expansion is a common musical device, used to stretch out a musical idea, although in a narrative context it cannot occur indiscriminately. Because it extends a single form, it has the effect of focusing attention on the form and what it is evoking, and increasing the expectation of a salient and complete end to the form. This is appropriate in contexts where a character is approaching the successful achievement of a goal.

Interruption

This occurs when a phrase is interjected between two successive phrases in a form. This interjecting phrase typically uses a different motive from the phrases it is interrupting. This device serves to break up the continuity of the music, signifying a state of affairs that is not at equilibrium.

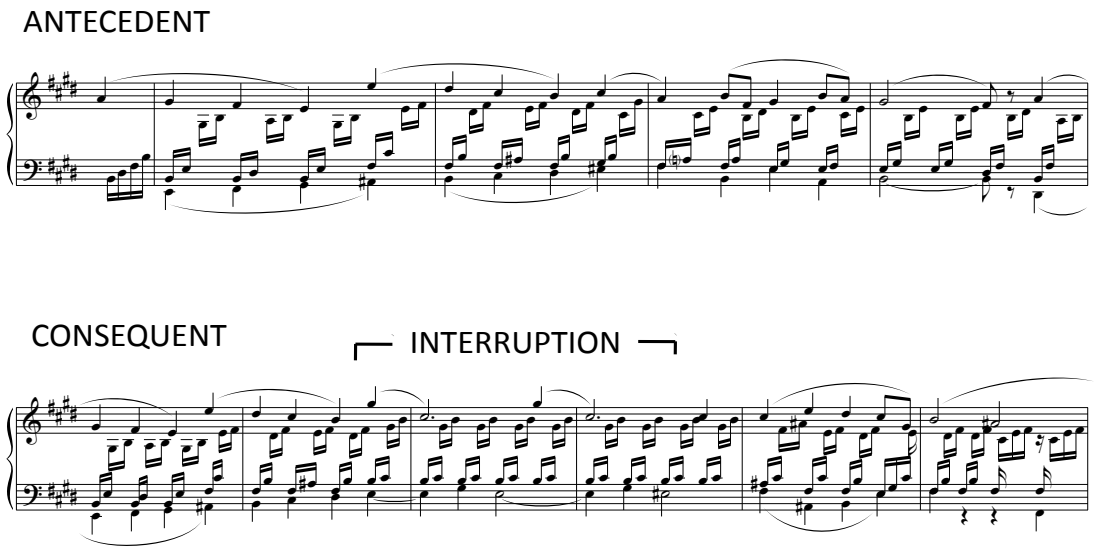
Dilution

This term simply refers to the insertion of some number of rests between phrases. During these rests, *Mezzo* plays an ostinato figure, mapped to the final chord

in the previous phrase. Whether measures of rest will be inserted before a phrase, and what the number of measures will be, are both controlled with stochastic variables. The decision to rest is made according to a probability threshold, and the number of rests is controlled by a Poisson distribution. *Mezzo* has a setting called 'density,' which sets the mean of the Poisson distribution; a very high density will have a mean near zero, meaning that rests are very improbable, while a very low density will have a mean around four, meaning that phrases will be separated by an average of four measures of rest.

These four devices are used throughout Western musical literature, and produce different levels of irregularity. The elided and expanded cadence, for instance, do little to disrupt the sense of proportion or continuity. Their effects are subtle, adding or subtracting musical information in order to keep the proportions of the musical phrasing from becoming too obviously periodic, but doing so in concord with the overall motion of the form in which they occur. That is, the sense of an 'ending' is still suggested when the 'ending' section is elided or expanded. In the first case, it is not perceived as omitted but rather identified as the beginning of a new section. In the second case, the motion toward the final conclusion, already inherent in the cadence, is prolonged.

Interrupting a form with a phrase tends to produce a more salient feeling of disruption, as the following example illustrates.



Example 5.1: Mendelssohn, Lieder Ohner Worten, Op. 19, No. 1

The injected figure and its repetition in the sixth through eighth measures jumps out because it is new material, and because it disrupts the symmetry of the period form in which it occurs. The motion toward the cadence is halted temporarily. In this example, the formal irregularity interacts with the pastoral topic to evoke nostalgia or melancholy—marked emotional states. This kind of form deformation produces a level of markedness that expanding or eliding a cadence does not; it can be considered 'more irregular' because it disrupts the motivic unity of the music.

Mezzo uses these four formal methods in combination with stochastic deformations to create various behavior. The possibility of each method occurring is governed by a probability threshold, which changes according to the game state. For instance, if the overall regularity is low (a context which will be described in the next

chapter), the probability of an interruption occurring will be high. If the regularity is high, this probability will be low, although the probabilities of cadential elision and expansion will remain relatively high, since these don't contribute as much perceived irregularity to formal organization. Dilution is governed, as described above, by a 'density' variable; the interaction of different density values with different levels of irregularity produces a variety of marked states, as the analyses later in this dissertation will show.

Chapter 7 will illustrate the computations described in this chapter, by presenting a detailed analysis of how irregularity is applied to forms in each section of *By Sweat and Toil*.

Chapter 6 Composition with *Mezzo*

Mezzo is designed to make all the compositional choices during a game: the music changes according to how the program perceives the action of the game changing. However, someone using *Mezzo* to provide the music for a game has choices influencing what kind of music will be created, and how the program will react to game state information. The first part of this chapter describes how *Mezzo* composes during a game. The second part specifies the input the program needs from a user to operate, and the authorial choices afforded the user.

Composition during Gameplay

To compose music for a game, *Mezzo* takes in a number of variables describing the current game state. These variables describe aspects of the characters onstage, their actions, and elements of the environment. When any of these aspects is changed, its variable is updated. Depending on the nature of the change, *Mezzo* will either compose new music for the new game state, or will change the stochastic controls on the playback of its current music.

The composition of new music corresponds to one or more of three possibilities: the entrance or exit of a character, a change in the action, or a change in the harmonic tension. A new ensemble of characters means that new motives must be selected and then mapped to forms. A change in the action requires different forms to be created from the existing motives, since certain forms are associated with certain types of action (see chapter 3; the associations *Mezzo* uses are discussed below). A change in the overall harmonic tension requires different progressions to be chosen to map existing motives to. This typically occurs when the action changes as well, but can also reflect an increase or decrease in urgency, if, say, the action involves battling or questing.

Mezzo uses a class called a *Beat* to contain all the information and music for a particular scene. This term is used in the dramatic sense, not the musical sense: a 'beat' refers to the smallest element of dramatic structure, any set of actions which, as an ensemble, convey a single narrative function (McKee 37). *Mezzo* determines that a new beat in the story has begun when one of the three changes listed above occurs. At this time, it chooses a number of appropriate forms to create based on the action and characters involved, and composes them, using progressions with the appropriate harmonic tension from the database. All the forms for a beat are composed at the instance the beat is created. The appropriate transition matrices for each form, its sections, and its phrases are then calculated, based on the regularity of the characters whose motives the form uses, and the probabilities of cadential elision, cadential expansion, interruption, and dilution are calculated.

Certain changes do not require the composition of new material. For instance, if the desired density of forms is increased from low to high, the variable governing the number of rests between phrases is changed (its mean is decreased), but all the forms stored in the beat, and the transition probabilities between them, stay the same. Similarly, changing the regularity, energy, or environment does not require new composition. These features will be discussed in more detail below.

A beat contains its own Markov transition matrix, which determines the sequence by which forms are played during the beat. Each state in a beat's transition matrix is a form. This matrix differs from those in a MarkovPlayer class in that it has no stop state; it will continue to move from form to form until a new beat is created. This is as close to looping pre-composed music as *Mezzo* gets. To this effect, the program is insensitive to individual character actions in a game; if a character is fighting, the music will reflect a state of battle through harmony and form, but will not write a specific musical gesture to line up with a character's gesture. Composing all the music for a beat at the beat's creation gives the beat a musical identity, as specific harmonies, motives, and forms will be repeated during its course, and will thus be associated with this particular scene. This is a desirable aspect; it imparts an episodic quality to the accompanying music.

Forms are composed in their normative structures, and they are also stored that way. When a form is chosen by the beat to be played, it gives a phrase to the playback engine by iterating recursively through its sections, phrases, and measures, according to each class's transition matrix, as described in the last chapter. Also,

when a phrase is given to the game to be played, an accompaniment is added to it. This accompaniment is made up of motives associated with environmental features, if there are any such motives, or with actions, or with other characters. The analysis of 'Bowser's Castle' in chapter 8 illustrates in detail the matching of accompaniments to motives.

There are two types of information that *Mezzo* uses to compose forms and deform them: character information and information about the state of the world. The specific aspects of each type of information that *Mezzo* is able to interpret are discussed now in turn.

Characters

Mezzo contains a list of all characters involved in the game. With each character is associated a *presence* variable, which tells the program if the character is onstage or not, a *regularity* variable, which determines its formal regularity (described in the previous chapter), and a *thickness* variable, which determines the thickness of the character's motive to be used. The energy of a character's motive is not considered; changes in energy are handled by choosing an appropriate ostinato motive.

Worldstate

Mezzo has several variables to represent the type of music that should be written for a scene:

Energy

This variable determines the amount of energy an accompaniment or ostinato motive should have. There are five values this variable can have: 'very low,' 'low,' 'medium,' 'high,' and 'very high.' If no motive with the appropriate energy level can be found, the program chooses one that is close.

Regularity

This does not refer to the regularity of each character's formal repetition, which is determined by the character's own 'regularity' variable. Instead it governs the probability of interrupting one phrase with another form's phrase (see last chapter).

Symmetry

This applies to periods and sentences, and determines if the form's first half will be as long as its second half; that is, if a period's antecedent and consequent will be the same length, and if a sentence's presentation will be the same length as its continuation and cadence combined. The length of a section depends on the size of

the motive being mapped to it. There are three values for this variable: 'high,' which means the first and second half are exactly the same length; 'medium,' which means that they are nearly the same length; and 'low,' which means that their lengths differ greatly. A low level of symmetry contributes to a highly repetitive sound. A high level creates a sense of severe disproportion, even when forms are played back with high regularity.

Motive Size

This determines the duration of motives chosen. For now, *Mezzo* only uses motives that are one, two, or four measures long. Shorter motives will mean that the music composed moves from form to form more quickly, and can thus produce a sense of motion or urgency.

Harmonic Tension

This determines the desired level of harmonic tension in a progression to be chosen from the progression database (see chapter 3).

Density

This sets the probability that phrases will be separated by measures of rests (with ostinati), and the mean of the Poisson distribution that governs the amount of measures that will occur.

Motive Number

This determines how many motives per character will be chosen. Each motive chosen will be mapped to some form. For beats that seem like they will be quite long, this variable is high—say, three motives per character. This way, repetition is further avoided by using a large variety of different melodic material (see any symphony by Mahler). If the beat seems like it will be short, or if one specific character or aspect of the scene demands focus, only one motive per character will be chosen. This is illustrated in the middle of 'Bowser's Castle,' when the music accompanies the cut scene of Mario approaching the princess and being ambushed by Bowser. The discovery of the princess, and Bowser's entrance, are both very short, and the focus of the game is clearly on each character's entrance into the scene. Therefore, only one motive per character is chosen, so that that motive will be saliently identifiable with the character it represents.

Thickness

This determines the thickness of the accompaniment motive, not the melodic motive (whose thickness is determined by the motive's character's thickness variable).

Environment

Elements in the environment can have motives attached to them, *Leitmotiv*-style, if the user wishes. For 'Bowser's Castle,' I associated melodic material with

fire, rain, ascent, questing, and triumphing, because these aspects are particularly salient in the game. 'By Sweat and Toil,' on the other hand, uses only two environment motives, signifying the countryside and a train. Environment elements are only used for accompaniments and ostinati; when an environment variable changes, then, new forms don't have to be composed. This is an effective musical device—a character's motive can play continuously, while underneath it the accompaniment changes to evoke the character passing into a new environment.

Action

Mezzo also uses an 'action' variable, which has (so far) seven different values: *Stable (Pastoral), Stable (Dramatic), Encounter, Quest*, *Battle, Triumph, Approach,* and *Defeat*. It would seem, at first, that this variable is superfluous; these states could be evoked through proper combinations of the variables described above. For instance, a battle could be evoked with high energy, high harmonic tension, low regularity, and low motive size. These are, in fact, important elements in evoking a battle; but they don't specify the forms to be composed for such a scene. As was illustrated in chapter 4, certain forms correlate with certain types of expression.

Periods are used if the action state is 'Stable (Pastoral).' In this case, the motives used for the basic idea and contrasting idea are both taken from the same character (or cadential material is used for the consequent). Periods are also used if there are two characters engaged in the action state 'Battle.' In this case, a motive from one character is used for the basic idea, and a motive from the other for the

contrasting idea; no cadential material is used. When used in conjunction with a low motive size, this form produces a fast volley between the two characters' motives, creating a sense of focus quickly shifting from one character to the next.

Sequences are used if the action state is an unstable one; that is, 'Quest,' 'Battle,' or 'Defeat.' Sequential transpositions differ in affect according to the direction and interval distance. Instead of specifying the interval by which to transpose the initial phrase, *Mezzo* uses three classes of intervals: *step* (1 or 2 half-steps), *skip* (3 or 4 half-steps), and *leap* (5 or 6 half-steps). Specifying intervals by range allows for more possible voice-leading options, which may result in better voice-leadings. For 'Quest' states, sequences that move up or down in skips or leaps are chosen; this covers circle-of-fifths progressions (5 half-steps), as well as chromatic modulations that occur in Romantic music. These progressions suspend the tonality, and reinforce the sense of wandering, without a clear goal in sight. 'Battle' states use sequences of any type; along with a heightened energy level and high harmonic tension, sequential modulation creates a sense of uncertainty and suspense in a battle scene.

'Defeat' and 'Approach' states use sequences that move down or up in steps, respectively. These are musical clichés, due to the perceptual salience of the intervallic transposition. Moving an entire phrase down in steps consecutively is a bit of tone-painting, reflecting a fall. Moving the phrase up in steps is the device used in musical theater and Wagner's operas to inject a quick boost in excitement.

Sentences, because of their structural malleability and their ubiquity in all kinds of musical settings from the Romantic Period, can be used in any action state. The harmonic cadence of a sentence, however, is determined according to the action state. If the action is stable, sentences with authentic cadences are chosen; if not, half cadences are preferred.

Authoring a Musical Experience with *Mezzo*

Mezzo's compositional process involves combining and arranging small musical motives to make large musical sections. It does not create the melodic material it uses; this must be supplied by the user. The user thus has the ultimate authorial control over the melodic content of everything *Mezzo* composes. This control comprises determining which elements and characters will have motives associated with them; what, how many, and how long they will be; and what musical topics they will express. In addition, the ostinato material is also supplied by the user.

Choosing the characters that will have associated musical motives means determining how salient a character's presence will be in a game. When a character has a motive attached to it, every time this character is present onscreen its motive will be played as part of the musical texture. While it will likely not be played continuously, it will be one of the motives that is arranged into one or more forms, and will thus occur with frequency. It will undergo the musical modifications described in this chapter and previous chapters that evoke changing states of the

character. Hence, associating a character with musical material in *Mezzo*'s motive database will ensure that that character's condition is musically underscored as a significant element of the game narrative.

If a motive is attached to a character, object, or idea, but this motive is stored as a 'worldstate' variable, it will be heard when that character, object, or idea is depicted onscreen, but it will not be musically foregrounded. That is, it will be used as an ostinato motive; it will not be arranged into a formal unit, and its repetitions will not occur with any particular formal organization, other than being mapped to the harmony. Rather, it will be repeated without change as an ostinato underneath phrases containing characters' motives, or heard over a static chord during rests. The lack of formal operations on worldstate motives—that is, the patterns of motivic fragmentation and contrast manifested by sentences and periods—mitigates their perceptual salience, and any changes in the condition of a worldstate element cannot be evoked musically by *Mezzo*.

Authoring a musical experience in a game with *Mezzo* thus requires the user or developer to decide which game elements should be evoked with music, and, of these, which ones are functional in the game narrative. In *By Sweat and Toil*, the accompaniment to a level in *Red Dead Redemption,* I chose only two 'characters' to be associated with character motives: the player's cowboy character, and the herd of cattle as a collective 'character.' I chose two elements to associated with 'worldstate' motives: the countryside, and the train. There were other elements I could have associated with motives: the cowboy who accompanies the player's character, the

outlaws attempting to hold up the train, the people riding the train, the horses, even individual cows. Because of the choices I made, the piece composed for this scene has a very homogenous quality: only a few themes are circulated throughout it. This was done in order to musically draw the focus onto the condition of the player's character and the herd of cattle; in the narrative that is consequently suggested by the music, it is not the experience of a variety of situations that is highlighted, but rather the changing levels of control the player's cowboy has over his charge as these situations occur.

Writing the musical motives means determining their topics as well. The user must thus decide how she wants the piece to sound: if it will be topically homogenous, or if it will be comprised of several topics. The topical content of each motive will influence how the character or element it is associated with in a game will be interpreted. In *Bowser's Castle*, for instance, Bowser, the antagonist, has a heavy, obsessive motive that I felt evoked both his monstrous and his villainous natures. The antagonists in *By Sweat and Toil*, however, are not, in my interpretation, the train robbers, but rather the cattle being herded. Their antagonism is not intentional or threatening, but a result of the difficulty their mindlessly intractable behavior presents the player, who must guide the unwieldy herd out to pasture. The motive I chose to represent the cattle was a scherzo motive that contains small ornamental chromatic alterations; this, I feel, expresses a sense of disorder and wild playfulness that contrasts with the player's character's 'heroic' motives.

The harmonic material must also be supplied by the user in the form of progressions, as described in chapter 3, although these progressions are only used by the program to write new ones in a similar style. Still, this allows a user to determine the harmonic palette the music will have, without explicitly dictating how various chords will be used.

While the musical aspects listed earlier in this chapter are designed to correspond broadly with various types of actions and states, the way in which these actions and states are communicated to *Mezzo* is not defined. In this respect, it is up to the user to determine how the energy level in, say, a battle scene should be interpreted and mapped to various values of *Mezzo*'s musical variables. The next two chapters will illustrate how I chose to interpret game states in terms of *Mezzo*'s settings. Ultimately, this is an area in which much more experimentation needs to be done.

Chapter 7 Analysis of Formal Regularity in *By Sweat and Toil*

This chapter presents a beat-by-beat analysis of the formal irregularity in *By Sweat and Toil*, the first work in the accompanying score, *Années de Chômage*. The aim of this analysis is to clarify through illustration the way in which *Mezzo* translates the characters' conditions and actions into musical material that appropriately evokes this state. It will also serve to specify various distinct states of markedness and unmarkedness that arise in a computer game narrative, and how the various types and amounts of irregular repetition, combined with appropriate harmonic tension and energy, convey these states.

Because *Mezzo* was not at this time connected to any game engine, I used 'walkthroughs' to make the three pieces in the score: screen captures of peoples' gameplays. To simulate actual gameplay, I made a list of cues in each walkthrough at which the action or mood changed, and for each of these cues I established the value of each action, character, and worldstate variable that I thought would be passed to

Mezzo at this time. A small Max patch held each of these sets of values as a preset, which was triggered at the point in time at which these values would be passed to the program. Each piece was then written by the program in real time, as I played the corresponding video and ran the Max patch that triggered the associated cues.

I arranged the pieces for two pianos, from the four MIDI channels of data the program produced. The only changes that I made to the actual music were to change the register of certain notes that I felt had been mapped poorly, and to change the pitches of a few non-harmonic tones that didn't fit (*Mezzo*'s non-harmonic tone-mapping algorithm is not as intelligent as it should be.)

By Sweat and Toil accompanies a walkthrough from the game *Red Dead Redemption* (Rockstar Games). The title of the piece comes from the title of the level in the game. There are two characters associated with motives in this piece: the cowboy, and the cattle herd (which is interpreted as a single 'character'). The cowboy has four motives, all of which evoke a similar 'heroic' topic with dotted-eighth/sixteenth-note rhythms, block chords, and melodies which arpeggiate the harmony. Motive 4 is a fragment of motive 1, and was included in the database so that forms of different lengths could be constructed.

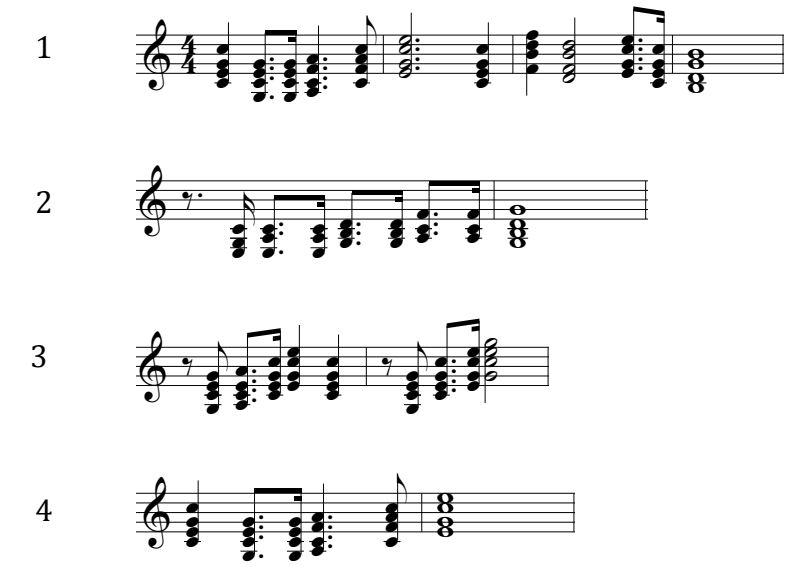


Figure 7.1: Cowboy motives in 'By Sweat and Toil'

The 'cattle' motive is a two-measure phrase taken from Liszt's *Gnome Dance,* the second piece in his Two Concert Études, S. 145. I chose this motive because of its scherzo character, suggesting the frenzy of a herd of cattle running across open pastures:

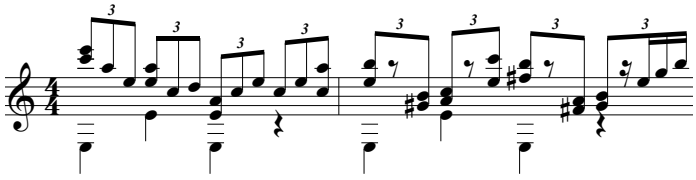


Figure 7.2: Cattle motive

The formal organization of the piece follows the events that occur during the game walkthrough. Each dramatic beat is delineated in the score by a rehearsal letter. The overall story line, in terms of beats, is as follows.

Rehearsal Letter	Measures	Description of Action
	1 – 16	cowboy introduced; mounts horse
A	17 – 51	cattle introduced; cowboy rides into herd and begins driving them
B	52 – 76	explosion on horizon; cowboy rides toward it
C	77 – 88	cowboy encounters train robbery in progress
D	89 – 108	gunfight between cowboy and train robbers
E	109 – 129	cowboy's horse shot; cowboy looks for another horse; train robbers flee
F	130 – 146	cowboy mounts new horse and bids farewell to train passengers he rescued from robbers
G	147 – 175	cowboy attempts to marshal cattle that have scattered during commotion of train robbery
H	176 – 191	cowboy tries to corral errant cow back to herd; gives up and rides off with remaining cattle
I	192 – 214	the herd, minus one cow, reach the sought-after pasture and begin grazing happily
J	215 – 255	cowboy rides home, mostly successful

What follows is a detailed analysis of the forms composed for each beat, the stochastic values attached to them to determine their formal regularity, and the resulting musical structure.

Beginning (mm. 1 – 17): Introduction of cowboy (player's character)

At the beginning of the piece, two forms were constructed from cowboy motives, a sentence and a period. Because this scene simply introduces the cowboy, each of these forms is completely regular. This means that the values of *r*, *c*, and *w*, the repeat-state, early-cut-off, and wrong-start-state probabilities, respectively, are all zero, and the Markov matrices produced are the same as those in example 5.2. Hence, both of these forms will be played according to their normative structures. Form B, however, is not heard to completion, because the action changes in the middle of it, and so a new beat is composed, whose first measure breaks in in the middle of the form's statement. Therefore only its first phrase is ever heard; the example below hence does not give its full form.

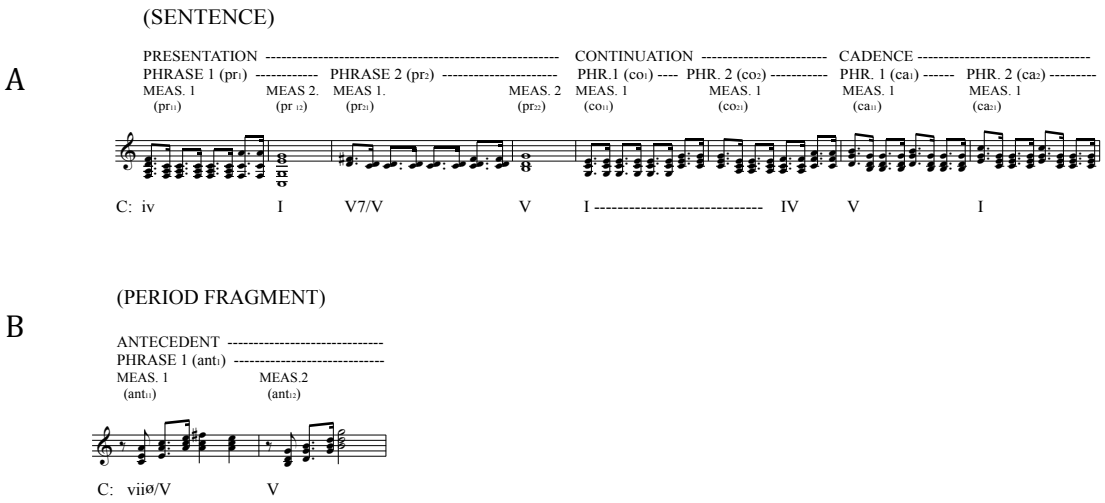
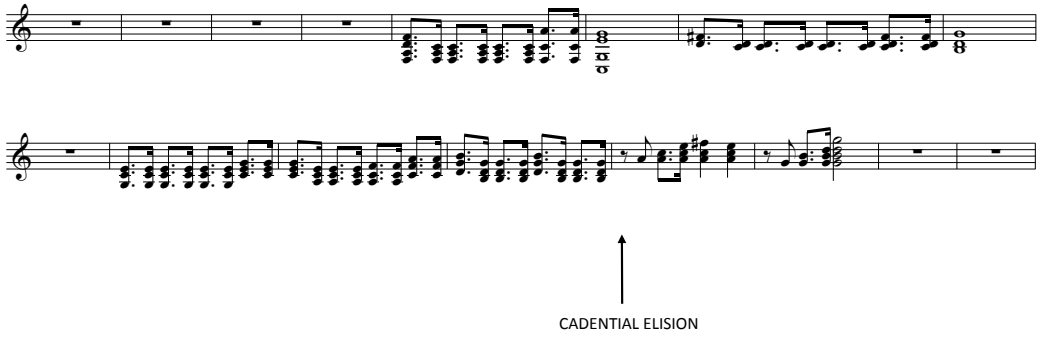


Figure 7.3: Forms made for beginning of 'By Sweat and Toil'



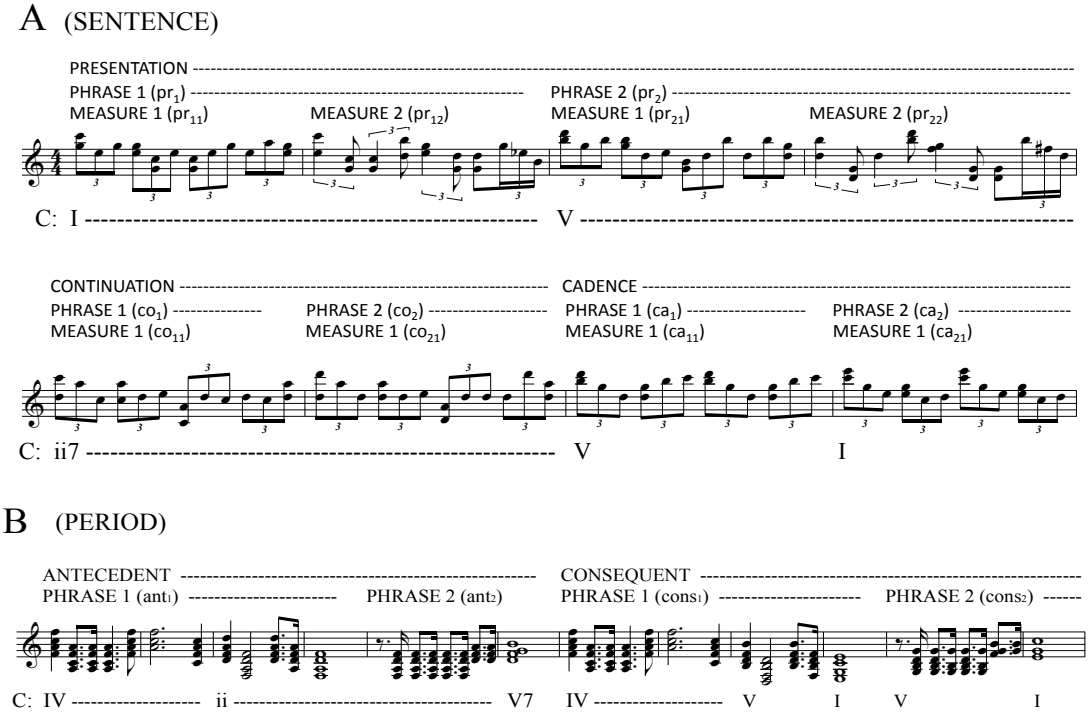
Example 7.1: Beginning of 'By Sweat and Toil'

The 'density' setting during this part of the scene is set to 'medium,' which means that some measures of rests occur between phrases, creating a sense of low urgency with which to begin the gameplay. A cadential elision occurs at measure 13;

this means that the final measure of form A is replaced with the first measure of form B.

RL A (mm. 17 - 51): cattle introduced; cowboy rides into herd, begins driving them

The cowboy opens the pen where the cows are kept at measure 17, and begins herding them out to pasture. Here occurs the introduction of instability. For this part of the game, the program composed one cow form and two cowboy forms:



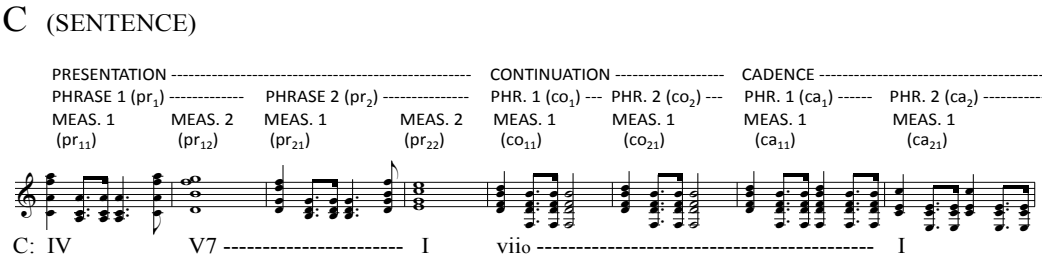


Figure 7.4: Normative cow form (A) and cowboy forms (B and C) at rehearsal letter A

Form A, the cow form, is a sentence, as is cowboy form C. Form B is a period which uses different cowboy motives; this form is chosen because the overall action state is set to 'Stable (Pastoral).' At this point in the game, the player's task has just been introduced: the cows are difficult to manage, and must be led to pasture without any of them going astray. There is a problem to be solved, but no specific complications have yet arisen. The cows present an element of antagonism and instability, although a mild one. To evoke this, the regularity of each of the forms in this section is set to 'medium.' This means that, according to figure 7.5, a small 'repeat-state' probability is added to the matrix in each section (presentation, continuation, and cadence) that governs phrase transitions, and a 'wrong-start-section' probability is added to the top-level matrix governing section transitions. Harmonically, progressions with low tension are chosen.

Form regularity = MEDIUM

Regularity vectors:

	r	*c*	*w*
SECTION:	**(0,**	**0,**	**.2)**
PHRASE:	**(.2,**	**0,**	**0)**
MEASURE:	**(0,**	**0,**	**0)**

Example 7.5: regularity vectors for all forms at rehearsal letter A

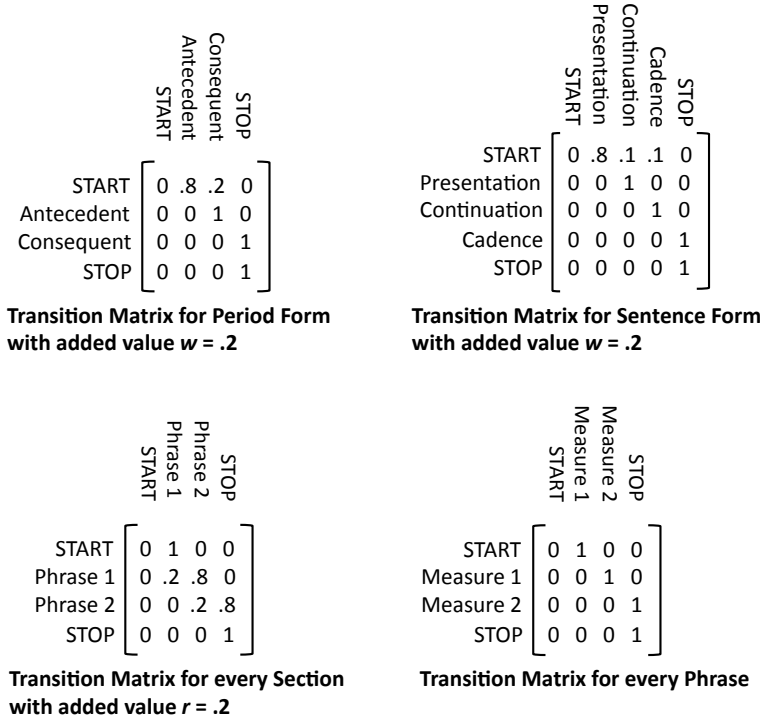


Figure 7.6: Resulting transition matrices for cowboy period at rehearsal letter A

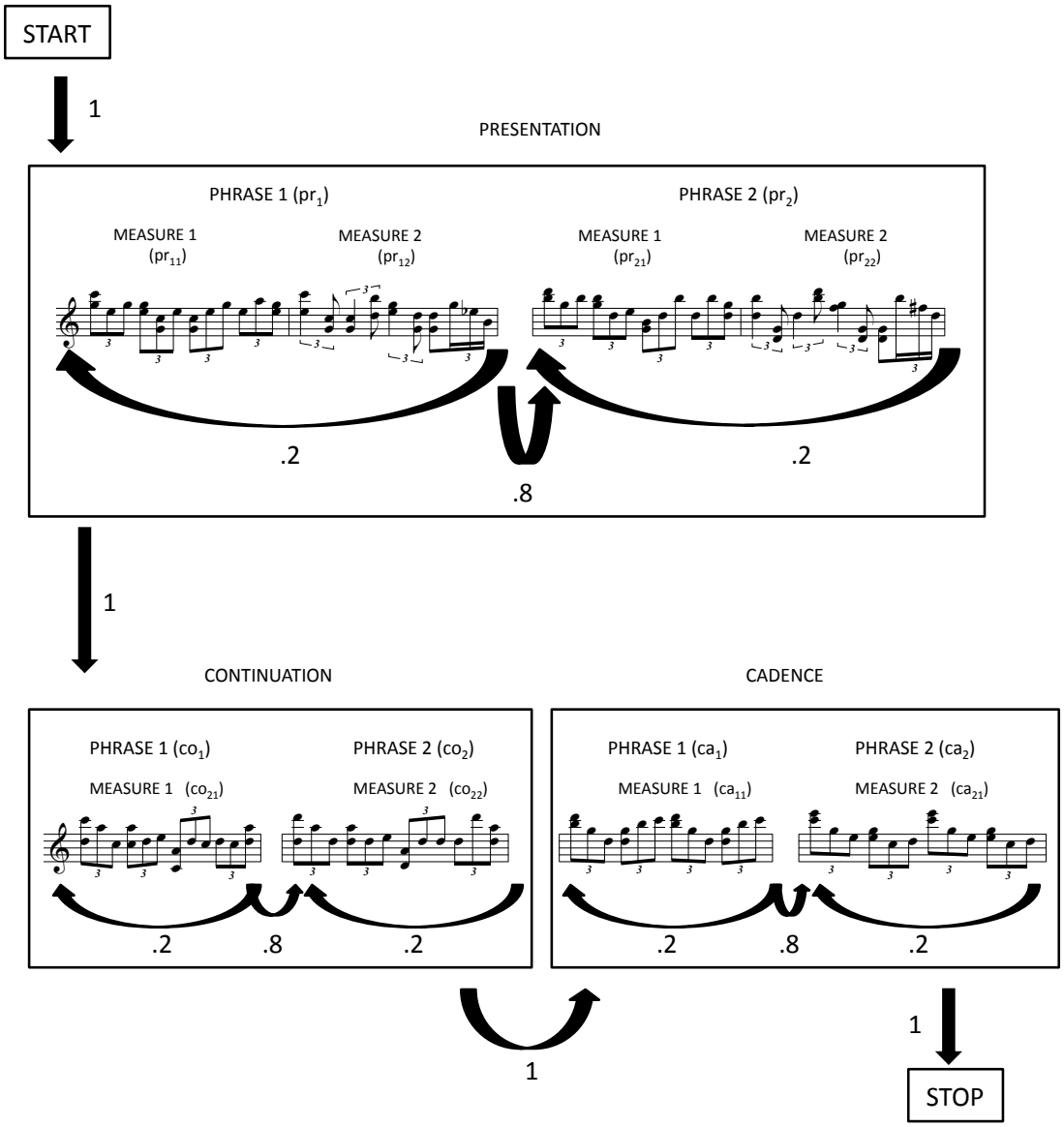
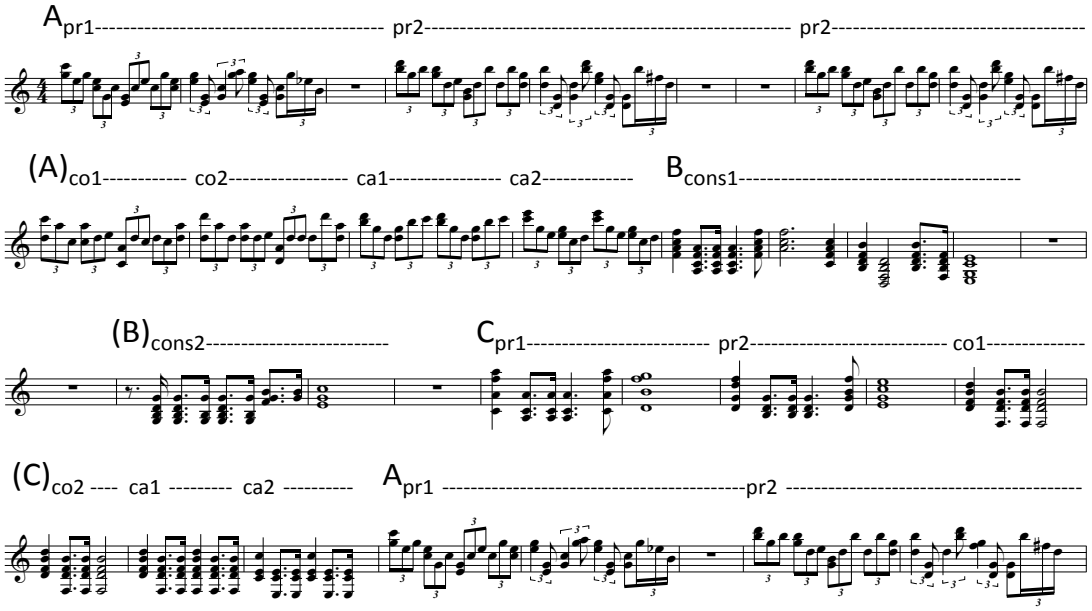


Figure 7.7: resulting transition probabilities in cow form at rehearsal letter A



Example 7.2: resulting music at rehearsal letter A

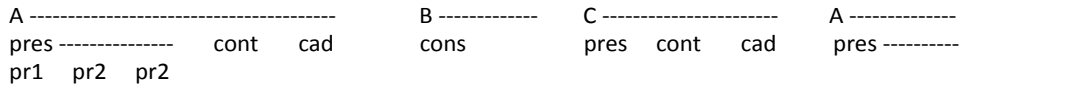


Figure 7.8: formal repetition at rehearsal letter A

The cow form A and cowboy form C are both normatively sentences of equal length (eight measures). The cow form, though, due to the added $r = .2$ value in its sections' phrase-repetition matrices, repeats occasional phrases. Cowboy form B, due to the added $w = .2$ value, skips its antecedent section and only plays its consequent. The result is not drastic; a small amount of irregularity is introduced. During form A's presentation section, the second phrase is repeated an extra time (mm. 20-25)

before progressing to the continuation and cadence sections. At m. 30, form B comes in, but skips its antecedent phrase and begins on the consequent, due to the added value *w* = .2. After this, at m. 39, a complete, normative statement of form C occurs, followed by the beginning of a complete statement of form A again, which is interrupted by the beat change that occurs at m. 52.

RL B (mm. 52-76): explosion seen on horizon; cowboy rides toward it

At rehearsal letter B (m. 52), there is the first hint of real difficulty: an explosion in the near distance that riles the herd and threatens trouble ahead. This begins a new dramatic beat: two new forms are composed, and new regularities are calculated.

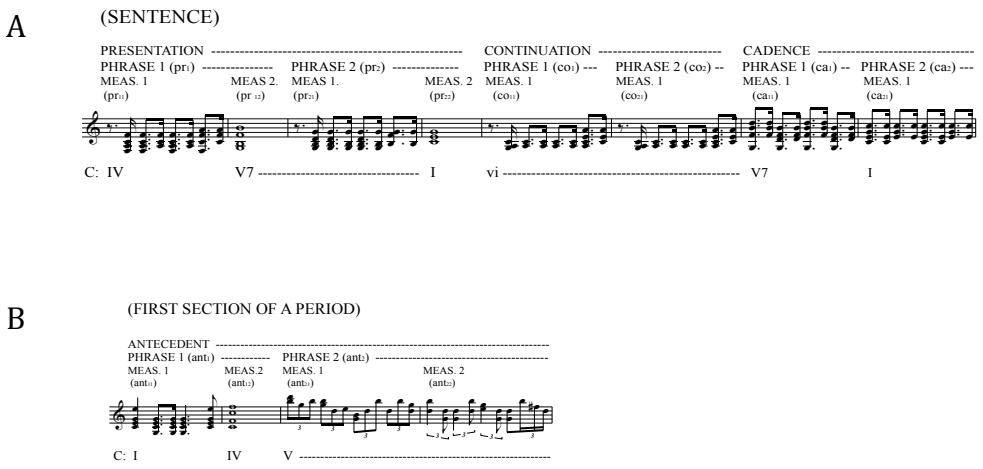


Figure 7.9 forms created for rehearsal letter B

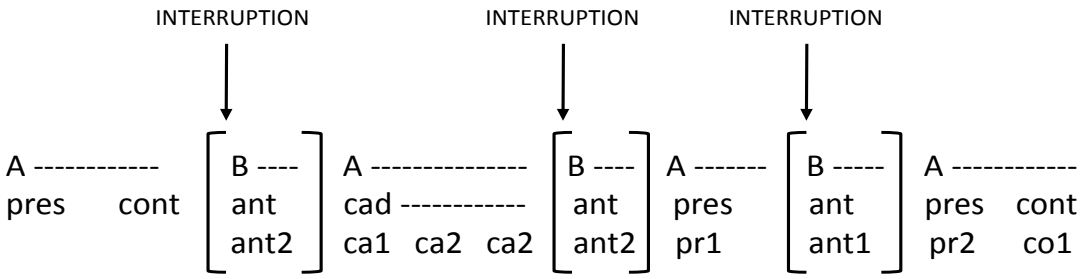


Figure 7.10: Formal organization at B

Form A is a sentence made from one of the cowboy's motives. Form B is a period in which the basic idea is made from a cowboy motive and the contrasting idea from the cattle motive; musically, this period form built of opposing characters' motives shifts focus quickly back and forth between the characters, creating a sense of tension. Since this form is never heard in its entirety during this beat, only the part that is heard —the antecedent—has been listed above.

The characters' regularities are the same as in the previous beat, but the worldstate regularity is decreased, which results in a tendency for forms to be interrupted by a single phrase from another form before they can finish. The entire beat consists of two statements of form A, which are interrupted three times by a statement of form B. First, at m. 58, form B interrupts between form A's continuation and cadence sections. Second, at m. 63, a new statement of form A is about to start when form B breaks in again for two measures. Third, at m. 69, form B interrupts between the two phrases in form A's presentation section. Since the value of *w* for each character equals .2, there is a probability that each form will not begin with its proper beginning section. This is manifested by form B, but not by form A:

the first two times form B interrupts, it begins on its second phrase; the third time, it begins on its first phrase.

The increased irregularity in this beat, combined with a moderate density that injects small periods of rests between statements, reflects the cowboy questing: he is not under duress, but his goal is yet to be obtained. The musical forms are thus not in a state of completion; they have a slight markedness.

RL C (mm. 77-88): cowboy and cattle encounter train robbery in progress

The scene is chaotic when the cowboy rides up to the train robbery in progress: the cows, addled by the gunfire and the noise of the train, begin running amok. The levels of irregularity in the characters' forms and the worldstate reflect both this sense of chaos and the determination of the cowboy who rode into the fray instead of avoiding it. The cows' form (A) is a sentence, and the cowboy's form (B) is a period, although only the first phrase of the presentation section of the former, and the first section (the antecedent) of the latter are actually heard.

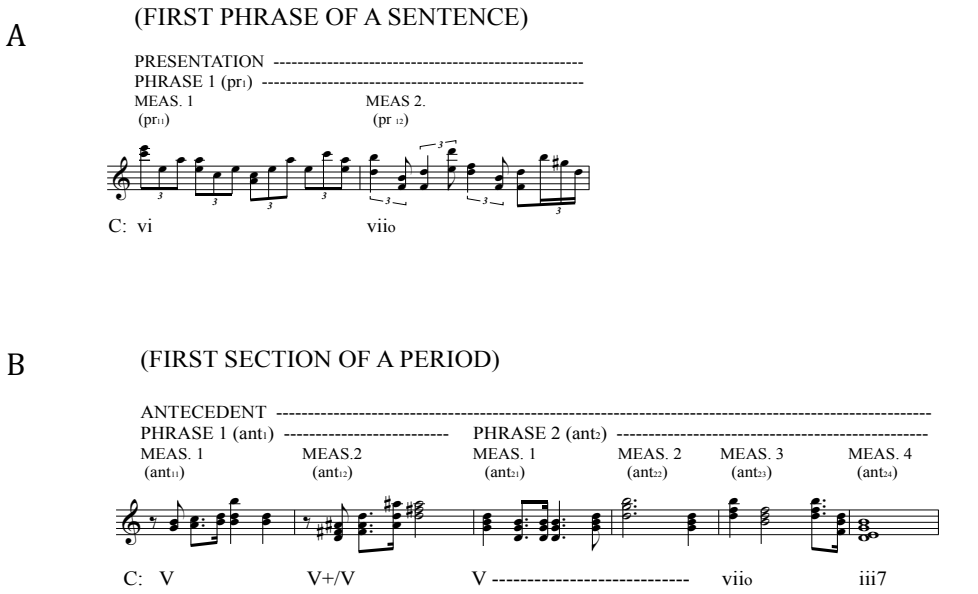


Figure 7.11 forms created for rehearsal letter C

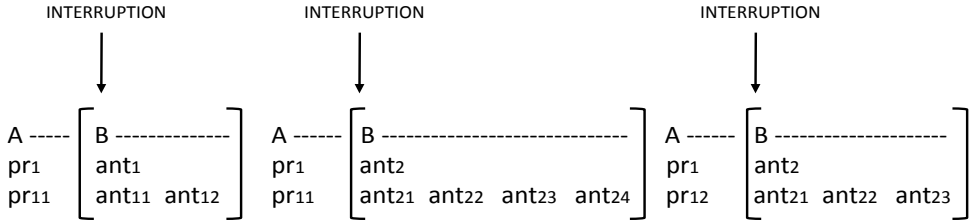


Figure 7.12: Formal organization at C

The cow form's regularity is low, which means that the following types of deformation will all occur with a .2 probability: repetition of individual measures, repetition of entire phrases, sections beginning after their proper beginning phrases, and the whole sentence form beginning after its proper beginning section.

Cow Form regularity = LOW

Regularity vectors:

	r	*c*	*w*
SECTION:	**(0,**	**0,**	**.2)**
PHRASE:	**(.2,**	**0,**	**.2)**
MEASURE:	**(.2,**	**0,**	**0)**

Figure 7.13: Cow form regularity at rehearsal letter C

Furthermore, the worldstate regularity is low, which means that, with a high likelihood, form statements will be interrupted by individual phrases. The resulting music is diagrammed in figure 7.12; it is essentially the beginning of one statement of form A, which is constantly being interrupted by form B. Leaving out the three interrupting statements of form B, the figure contains the first phrase of form A's presentation section (pr_1), in which the first measure (pr_{11}) is repeated twice, due to the added $r = .2$ value at the measure level, before progressing on to the second measure (pr_{12}). The irregularity at the measure level reflects a high degree of markedness among the cattle. However, the interruptions of form B convey the cowboy's resolve: his regularity is high, meaning the only deformations that can occur in cowboy forms are the repetition of entire phrases. This is seen in the progression of his interruptions: the first interruption consists of the entire first phrase of the antecedent; the second, the entire second phrase. The third interruption repeats the second phrase again, and would consist of a complete statement, except that it is

interrupted by the creation of a new beat. The music at rehearsal letter C can be heard as two interleaved forms, the cattle's and the cowboy's. The former of is highly irregular, or marked, and the latter is highly regular, or unmarked. The harmonic tension setting is 'high,' resulting in diminished chords and an augmented secondary dominant.

RL D (mm. 89-108): gunfight between cowboy and train robbers

A gunfight ensues between the cowboy and the train robbers; the cows are briefly forgotten in the fighting. For this beat, two cowboy forms are composed, including, for the first time in the piece, a sequence. It is built from a four-measure cowboy motive over a single chord with a high harmonic tension (vii half-diminished), which is twice transposed down a whole step.

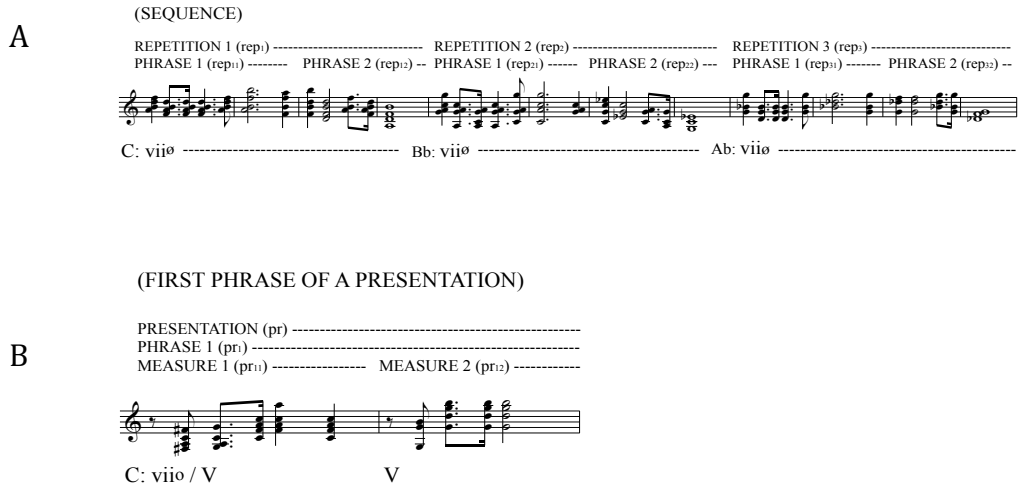


Figure 7.14 forms created for rehearsal letter D

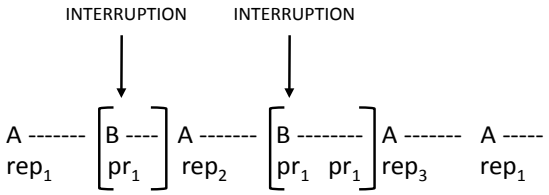


Figure 7.15: Formal organization at D

The cowboy's regularity is now medium, to reflect his plight. However, *Mezzo* does not allow sequences to be affected by irregularity; that is, they are never deformed, in order to preserve their strong sense of directed melodic and harmonic motion. The resulting music is thus one statement of the sequence, interrupted between each chromatic modulation by the first phrase of form B's presentation section. The second interruption, due to the cowboy's irregularity, repeats the first phrase twice. After the sequence ends, it begins again, now in the new key of Ab, and would continue modulating down in whole steps were it not interrupted by an abrupt change in the cowboy's condtion: his horse is shot and killed, and crumbles underneath him. A new beat begins.

RL E (mm. 109-129): cowboy's horse shot; he looks for another horse; train robbers flee

At this beat, the cowboy suddenly finds himself in real distress. He is without a horse, and spends 20 measures searching for a new one. The music reflects this with a high level of markedness, manifested through several features. Two forms are

created from cowboy motives, a period and a sentence, although only the first section of the former and the first phrase of the latter are played (figure 7.14) The regularity of both forms is set to 'very low,' which means the maximum amount of deformation will be applied to the forms' playback. The worldstate irregularity is low, which means that forms have a high likelihood of being interrupted. The harmonic tension is set to 'very high,' and the density is set to 'low.' The music that results is a series of individual phrase fragments, broken apart by several measures of rest, over a harmony centered around the dominant. These phrase fragments are repeated obsessively, conveying the cowboy's desperation.

Cowboy Form regularity = VERY LOW

Regularity vectors:

	r	***c***	***w***
SECTION:	**(.2,**	**.2,**	**0)**
PHRASE:	**(.2,**	**.2,**	**.2)**
MEASURE:	**(.2,**	**.2,**	**0)**

Figure 7.16 Cowboy Form regularity at rehearsal letter E

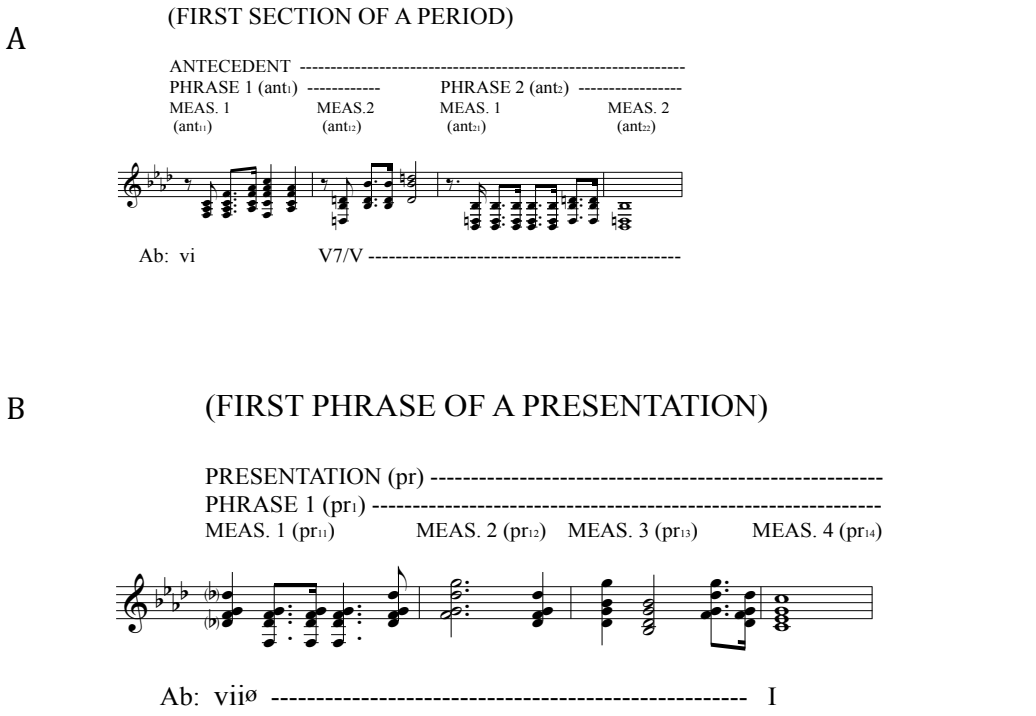


Figure 7.17: Forms created for rehearsal letter E

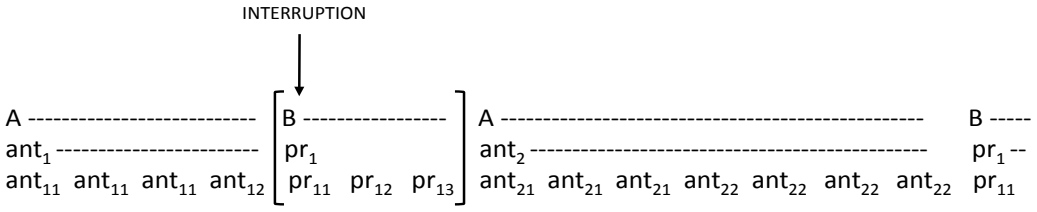


Figure 7.18: Formal organization at E

RL F (mm. 130–146): cowboy mounts new horse and bids farewell to train passengers he rescued from robbers

Having found a new horse, the cowboy mounts it and finds that the train robbers have fled. He has emerged from this episode victorious; the irregularity of the two forms composed from his motives now rises to 'medium,' conveying that he has not yet achieved his ultimate goal of safely herding the cattle to pasture, but he has successfully chased away the train robbers, and thus is in a relatively unmarked state, though not a completely unmarked one. The formal organization at this dramatic beat is much more normative than in the previous one. Two sentences are composed for this beat; only the presentation section of the first is played, and only the first phrase of the second's presentation. Form A is interrupted by form B after stating its entire presentation, and then after this interruption repeats its presentation's second phrase once more. It then cuts off and states its entire presentation again.

Cowboy Form regularity = MEDIUM

Regularity vectors:

	r	***c***	***w***
SECTION:	**(.2,**	**0,**	**.2)**
PHRASE:	**(.2,**	**0,**	**0)**
MEASURE:	**(0,**	**0,**	**0)**

Figure 7.19: Cowboy form regularity at rehearsal letter F

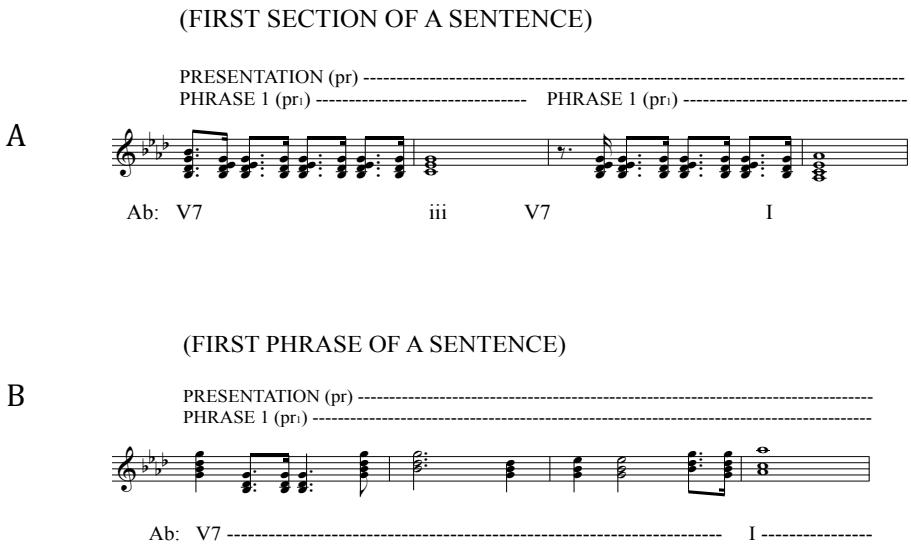


Figure 7.20: Forms created for rehearsal letter F

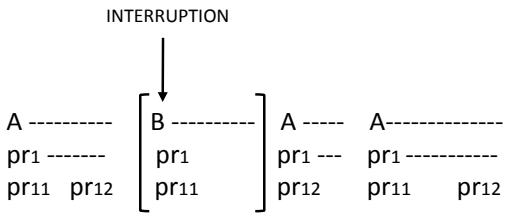


Figure 7.21: Formal organization at F

RL G (mm. 147 – 175): cowboy attempts to marshal cattle that have scattered during the commotion of the train robbery

The game now turns back to the cowboy's goal of rounding up the cattle and driving them to pasture. The cows are in a state of severe confusion, having been frightened by the train robbery, and the reintroduced cattle motive reflects this. Two forms are composed, both sentences based on the cattle motive. Of these, only one (form B), is heard in its completion (although it is highly altered). From the other,

form A, only the continuation section is heard. This is due to the 'very low' regularity: the cattle forms' stochastic settings designate that will be played with as much irregularity as possible, and it will occur at all levels of the formal hierarchy. At the measure level, this means that measures can be repeated, and phrases can cut off before reaching their proper last measures (*r* and *c* = .2). At the section and phrase level, all three types of stochastic irregularity can occur (*r*, *c*, and *w* = .2). The positive *w* and *c* values at the section level are what cause only the continuation of form A to be played.

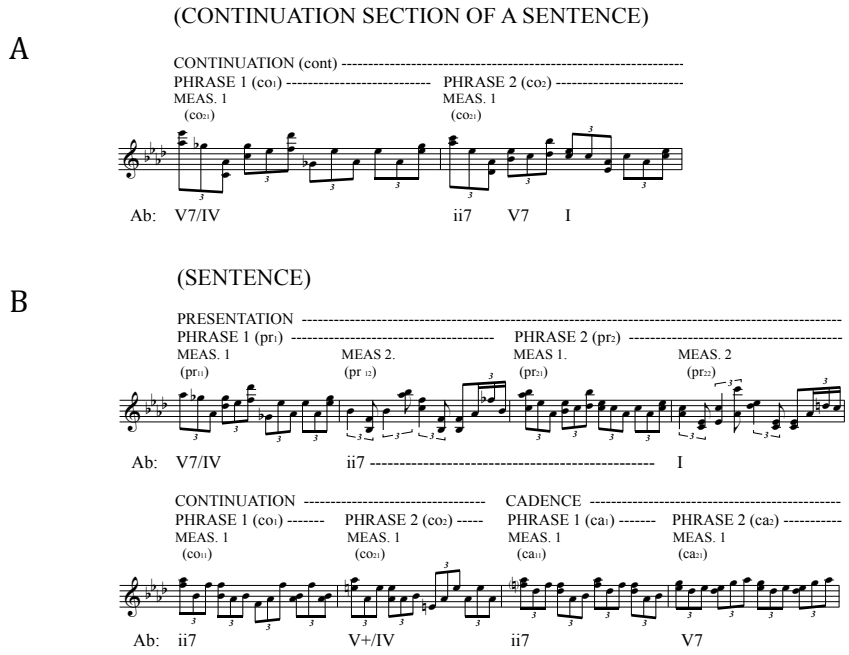


Figure 7.22: Forms created for rehearsal letter G

Cow Form regularity = VERY LOW

Regularity vectors:

r c w

SECTION: (.2, .2, .2)

PHRASE: (.2, .2, .2)

MEASURE: (.2, .2, 0)

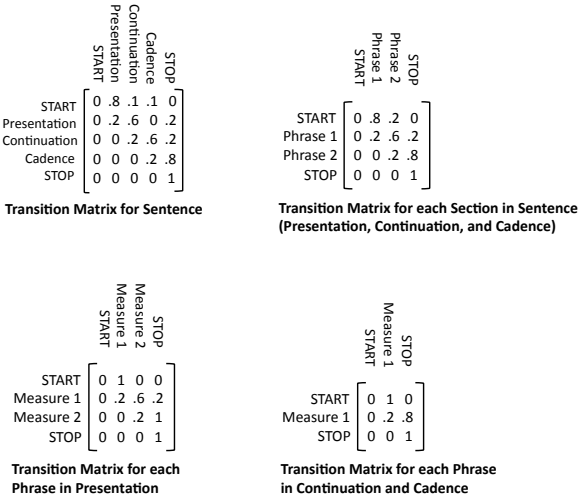


Figure 7.23: Regularity vectors and resulting transition matrices for cow form at G

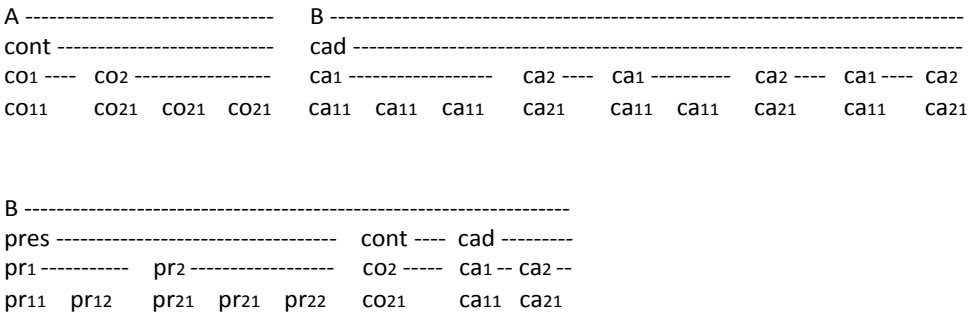


Figure 7.24: Formal organization at G

RL H (mm. 176 – 191): cowboy tries to corral one errant cow back to the herd; finally gives up and rides off with the remaining cattle

The cowboy has successfully rounded up all but one of the cows, and now rides around searching for it. Upon finding it, he struggles to direct it back toward its colleagues, but the lone cow is recalcitrant, and so the cowboy cuts his losses and leaves it behind. A period was composed for this beat, with a cowboy motive as its basic idea and the cow motive for its contrasting idea; this highlights the struggle between the two characters. In addition, a sentence was composed from a cowboy motive. The regularity is not at its lowest, as in the previous beat, but is now at 'medium,' reflecting the cowboy's struggle, but general completion of his task (all but one cow is errant). The resulting music plays the beginnings of each form, with phrase repetitions.

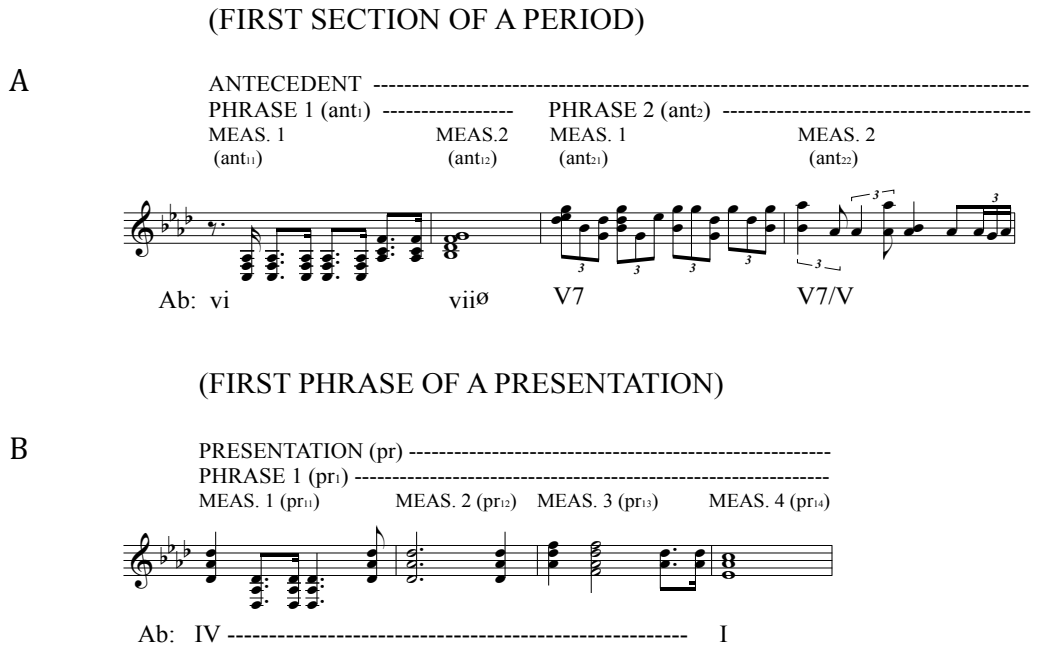


Figure 7.25: Forms created for rehearsal letter H

A			B	
ant			pres	
ant1	ant2	ant1	pr1	pr1

Figure 7.26: Formal organization at H

RL I (mm. 192 – 214): the herd, minus one cow, reach the sought-after pasture and begin grazing happily

Finally, the cowboy succeeds in leading the herd, minus one, to the desired pasture. The goal has been attained. To reflect this, both the cows' and the cowboy's regularities are set to 'high,' meaning the only possible stochastic deformation is the

repetition of entire phrases. Two forms are composed, a period using both cow and cowboy motives, and a sentence on the cow motive. Form A is heard straight through, and complete, and then begins to repeat its consequent when it is interrupted by form B. This statement of form B is heard in completion, except for a cadential elision: the last measure of form B is replaced by the beginning of the next phrase in form A which it has interrupted, and to which the music now returns.

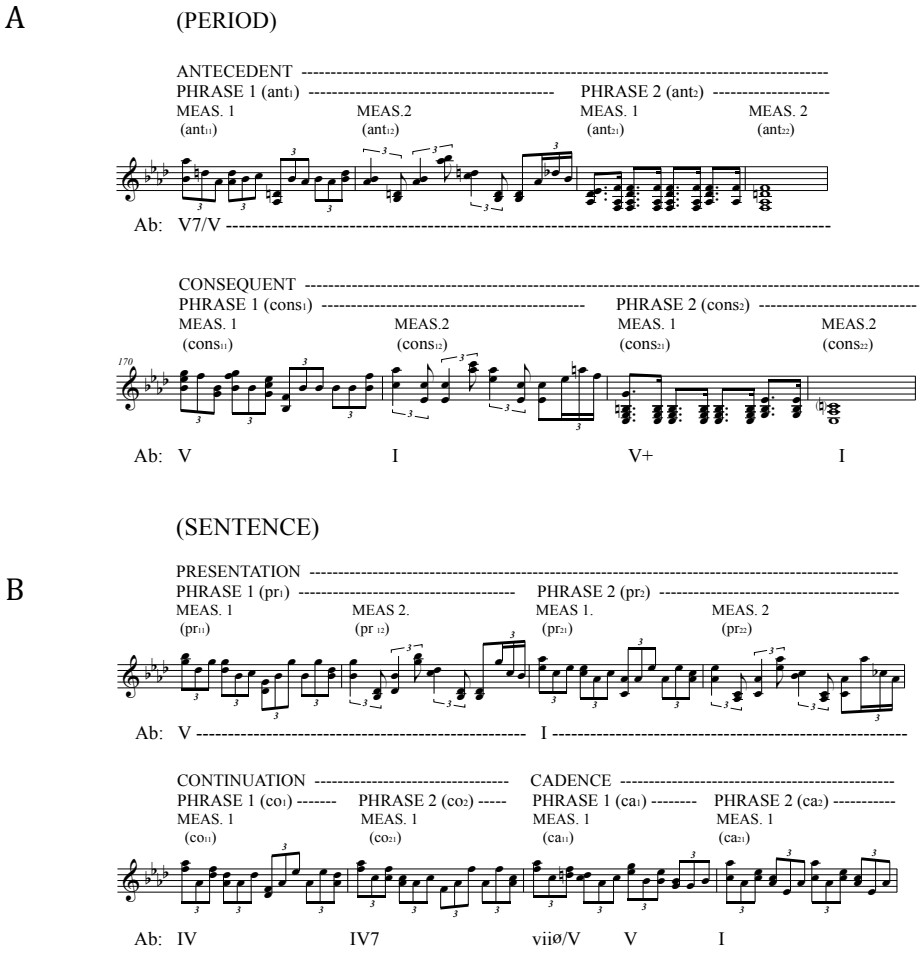


Figure 7.27: Forms created for rehearsal letter I

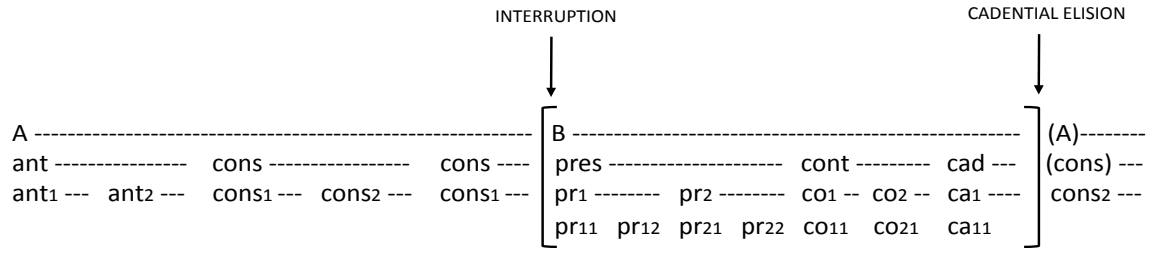


Figure 7.28: Formal organization at I

RL J (mm. 215 – 255): the cowboy rides home, mostly successful

Leaving the cows to graze, the cowboy returns home. Two forms are composed, and the regularity is 'very high.' The cowboy, having completed his tasks, is back in his initial, unmarked state. The resulting music presents both forms in their normative structures, with one interruption.

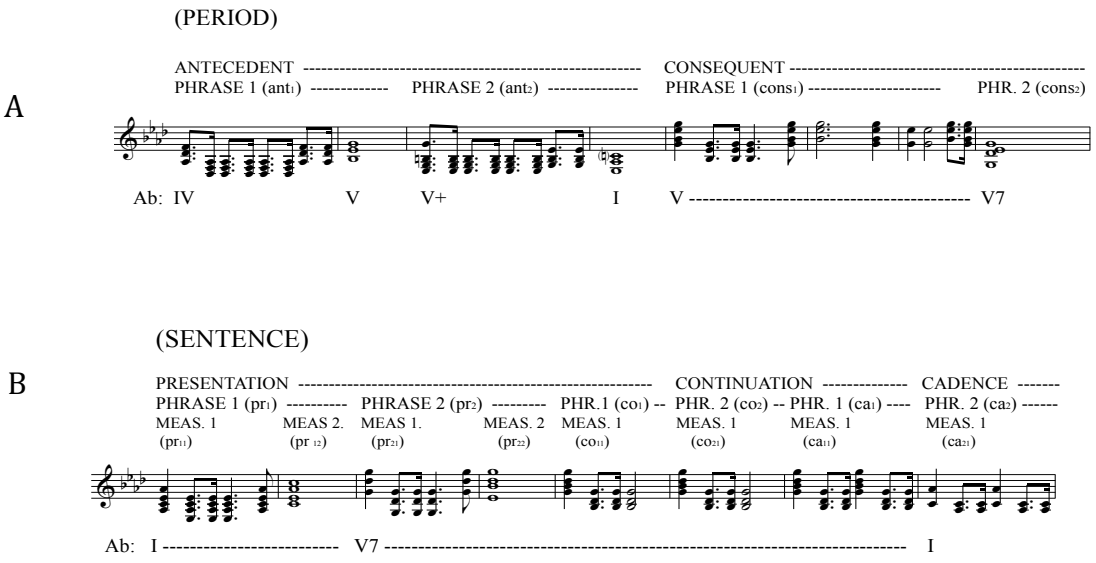


Figure 7.29: Forms created for rehearsal letter J

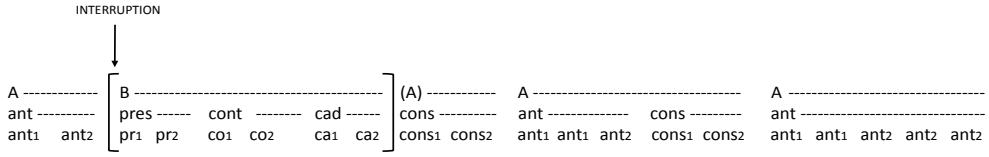


Figure 7.30: Formal organization at J

The overall form of the resulting piece for this game scene walkthrough can be seen by plotting each rehearsal letter against two axes, creating a semiotic square like the one introduced in chapter 1. One axis (the vertical in the figure below) represents whether the music is bringing focus to the cowboy or to the cattle (based on the motives being used), and the other (the horizontal), on how much markedness, evinced by irregularity of repetition and harmonic tension, the character in focus displays. In the figure below, the solid arrows follow the primary focal character at each beat, and the dotted arrows the secondary character. Though the resulting path is circuitous, it has a clear overall trajectory. It begins with the cowboy in an unmarked state, introduces markedness with the cattle, then sends the cowboy into various degrees of markedness. After a brief respite (at F), the cattle are sent into different states of markedness, until finally they pass back into unmarkedness along with the cowboy. This form thus moves through each of the four quadrants of a semiotic square and returns to its initial unmarked quadrant.

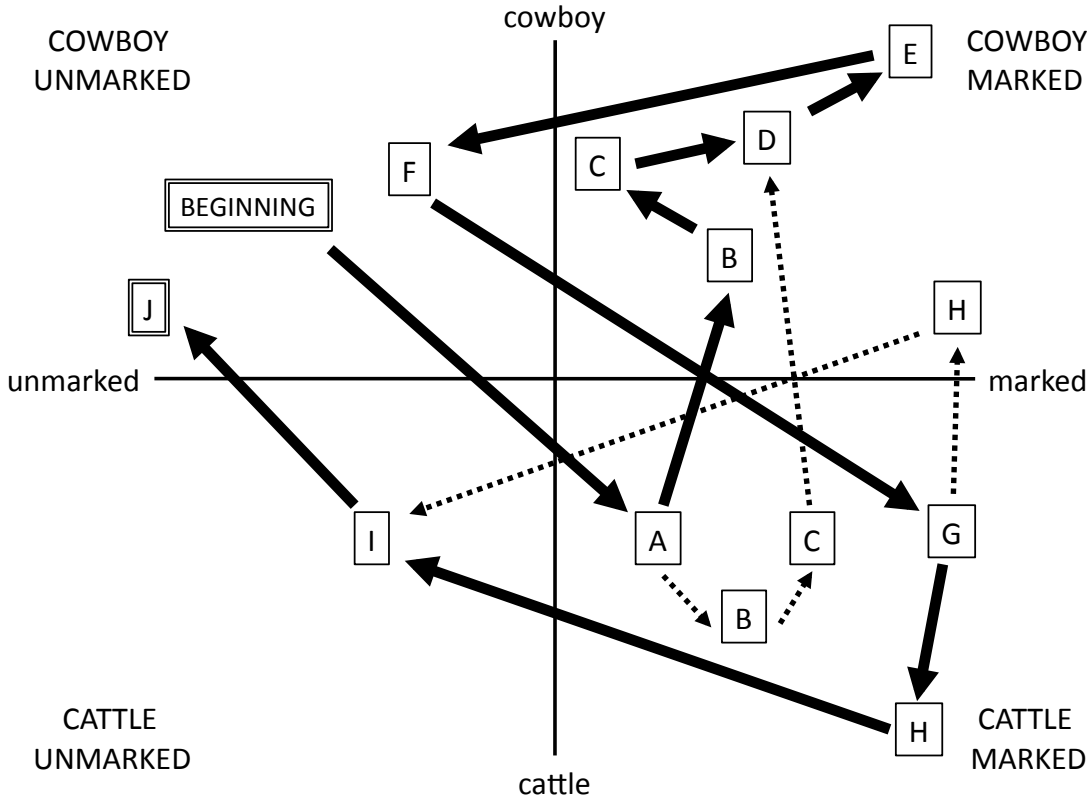


Figure 7.31: Narrative path through semiotic square in 'By Sweat and Toil'

Chapter 8 Analyses of *$(SW^2)^2$* and *Bowser's Castle*

After the detailed analysis of *Mezzo*'s compositional process and its results in the last chapter, I present here a briefer description of the other two pieces from *Années de Chômage*, in order to further illustrate the narrative possibilities for accompanimental music composed by the program.

$\mathbf{(SW^2)^2}$

$(SW^2)^2$ (Song Without Words: Star Wars Walkthrough) was written by *Mezzo* as an accompaniment for a walkthrough of a scene from *Star Wars: The Old Republic* (Bioware), a game in which much of the storyline is generated from conversations the player has with other characters in the game. The scene this piece accompanies is a love scene. In it, the player's character, a Jedi Knight, approaches the alien Vette, for whom he has romantic feelings. Acting upon such feelings is forbidden by the Jedi code, and the intrigue in this scene is generated from the player's decisions about whether to act or not act upon these feelings. The walkthrough begins with the Jedi entering the building in which Vette awaits, and bringing up the nature of their

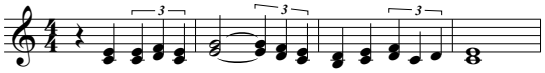
relationship to her. During the conversation between the player's character and Vette, various opportunities occur in which the Jedi can address or sidestep his feelings; in this particular walkthrough, they are addressed, generating a slow rise in sexual tension that finally culminates in a kiss. Immediately after this climactic event, the scene cuts to the Jedi and Vette in a bedroom, having fulfilled their desires, discussing what they should now do about their forbidden love. They agree to conceal it, and the Jedi leaves to meet with a hologram display of his sergeant, during which he confesses to his dalliance and swears that it will not deter him from his duties as a Jedi. The sergeant thanks him for his candor, warns him not to let it happen again, and gives him a new assignment. There are seven dramatic beats that the music responds to; they are listed below.

Rehearsal Letter	**Measures**	**Description of Action**
	1 – 5	Jedi enters matriarch's building
A	6 – 19	Jedi encounters Vette
B	20 – 28	Jedi expresses feelings to Vette
C	29 – 32	Jedi and Vette kiss
D	33 – 46	post-coitus
E	47 – 64	Jedi talks to sergeant over hologram
F	65 – 95	sergeant gives Jedi marching orders

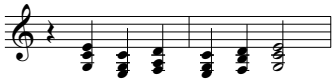
For this scene, there are two themes signifying desire, another signifying desire's attainment, and two signifying the soldierly duty of the Jedi (here labeled 'Battle'). In addition, there are two cadential motives that are used to end forms.

DESIRE MOTIVES:

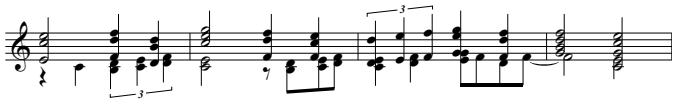
A



B

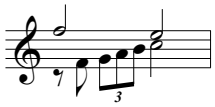


ATTAINMENT MOTIVE:

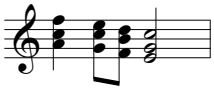


CADENTIAL MOTIVES:

A

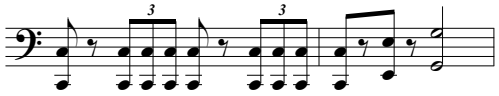


B



BATTLE MOTIVES:

A



B

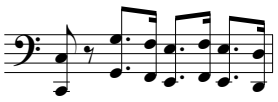


Figure 8.1: Motives in *(SW²)²*

The scene begins with a brief introduction combining battle motive A, as an ostinato, with desire motive A, as the Jedi approaches the 'Matriarch's Building' in which Vette awaits. Upon entering, the conversation between the Jedi and Vette begins at rehearsal letter A. During this conversation, the desire motives are heard at a low level of regularity and a medium density; they are thus relatively small fragments, suggesting the uncertainty with which the Jedi is approaching the situation. As he begins opening up to Vette with more forthrightness, the regularity increases to medium (RL B). The attainment motive is introduced with medium regularity at RL C, where the kiss occurs. After this, at rehearsal letter D, the desire motive returns, with a low regularity, to suggest that their brief furtive affair has now filled them with concern for its consequences. At letter E, the Jedi has left Vette and begun speaking to his sergeant; the 'battle' motive reflects this. At F, he leaves the meeting with his sergeant to go off on his next mission, the desire motive still floating longingly over the battle motive in the ostinato, as it was in the beginning.

The regularity in the motives never ventures into the high range during this piece, in order to suggest that the player has never really achieved a state of contentedness. Despite achieving a romantic encounter with the alien of his desires, the Jedi must now face remorse and possible punishment for acting on his desires. A sense of markedness pervades the entire scene, and hence the music as well, although the levels of markedness vary in small amounts. The overall form, seen as a path through a semiotic square, is illustrated below.

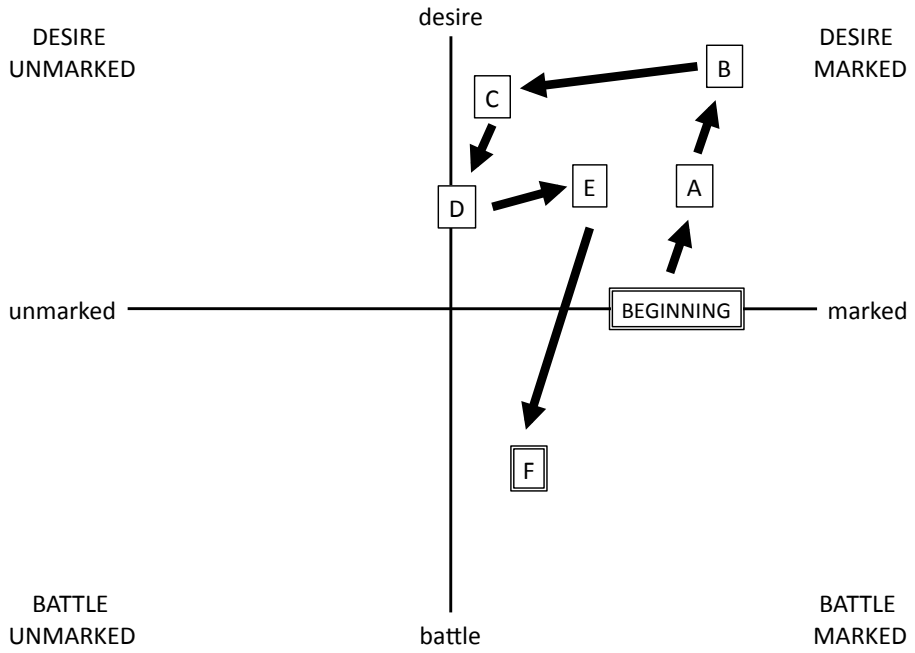


Figure 8.2: Narrative path through semiotic square in $(SW^2)^2$

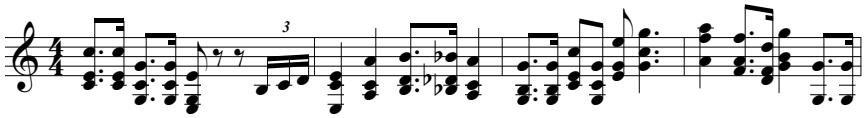
Bowser's Castle

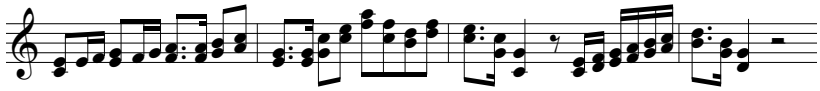
Bowser's Castle was written by *Mezzo* to accompany the final scene of *Super Mario 3D* (Nintendo). The scene involves Mario climbing through the various levels of Bowser's castle in order to rescue the princess whom Bowser has kidnapped and tied up on the highest turret of the castle. Upon entering the castle, Mario must traverse a labyrinth whose floor is a sea of fire. After successfully finding his way out, he begins ascending the castle's turrets in a rainstorm. He briefly discovers the princess, only to be ambushed by Bowser. At this, a protracted fight scene begins. Mario leaps from stone block to stone block, the castle having, for some reason, exploded into pieces which hang frozen in the air, providing a treacherous, if

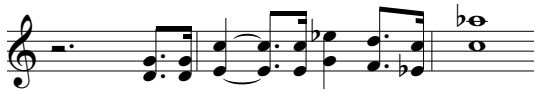
phantasmagorical, staircase to ascend. While he does this, Bowser constantly tries to knock him over the edge, by blowing fire and smoke and hurling barrels. During this scene, Mario occasionally finds a magical raccoon suit which, when he puts it on, increases his speed and agility. Finally, after several minutes of fighting, Mario destroys a bridge upon which Bowser is standing, and the beast falls into the sea of fire miles below them. Mario then finishes his ascent, finds the princess, unties her, and they dance a pas de deux in midair while the credits roll.

The overblown, hallucinatory, and incredibly entertaining imagery in the story had too many associations with Wotan's imprisoning and Siegfried's rescue of Brunnhilde in *Valkyrie* and *Siegfiried* for me to resist, and so I peppered the motive databases with melodies, and loaded the chord database with progressions, taken from these operas. Each character has one or more *Leitmotivs* associated with it, as do three environmental features which I thought were salient: fire, rain, and the abstract notion *ascent*. All of these *Leitmotivs* are listed here, and labeled for reference in the formal discussion that follows.

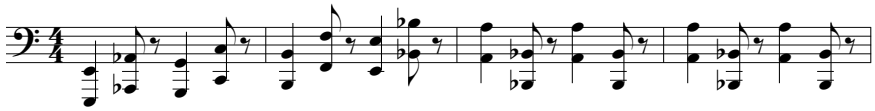
Mario:

M_1 

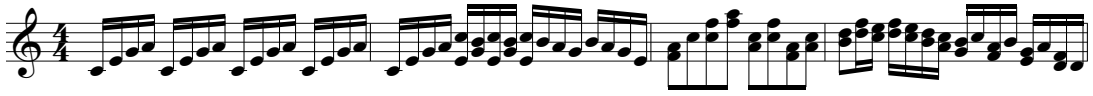
M_2 

M_3 

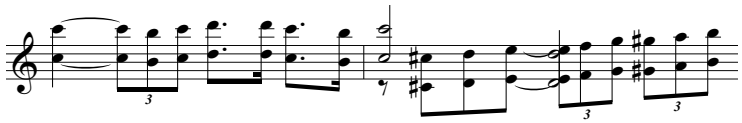
Bowser:

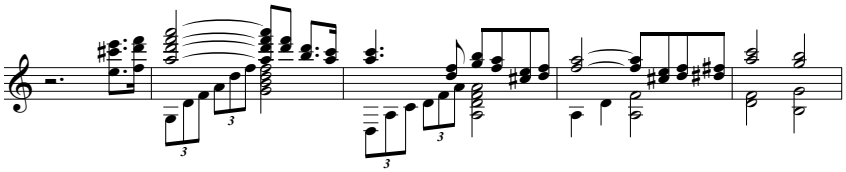


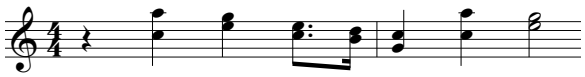
Raccoon:



Princess:

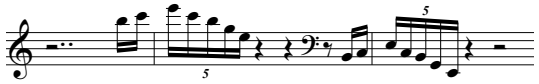
P_1 

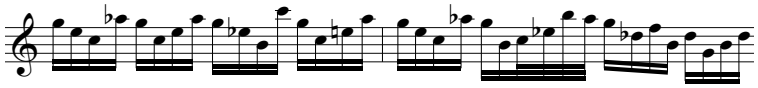
P_2 

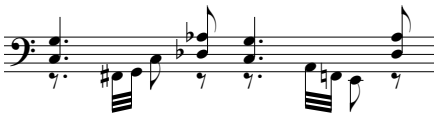
P_3 

Environment motives:

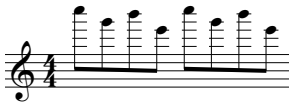
Fire:

F_1 

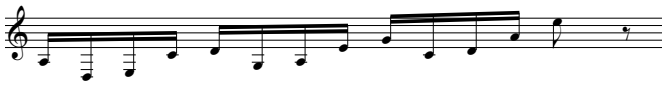
F_2 

F_3 

Rain:



Ascent:



The following is not a comprehensive analysis of the music composed for this scene, but a description of the most interesting and illustrative aspects of *Mezzo*'s compositional process. A list of each beat, its character and worldstate settings, and the forms composed for it can be found in Appendix A. In the score, every rehearsal letter corresponds to the beginning of a new beat.

The scene begins with Mario standing outside the castle, preparing to enter. He is introduced with a sequence; the heroic M_1 melody is repeated twice, completely regularly, transposed up an augmented fourth with each repetition. The harmonic tension is high, so the melody is harmonized over a string of dominant seventh chords: E7-D7 for the first phrase, followed by their transpositions Bb7-Ab7. Due to the voice-leading, the melody stays at the same pitch across the transposition, enharmonically reinterpreting the third of E7 with the seventh of Bb7; this clever harmonic reinterpretation is a fortunate result of *Mezzo*'s voice-leading algorithm.

The third repetition of the sequence begins, only to be interrupted suddenly by a statement of M_3. This coincides with Mario's entrance into the castle (RL A), at which point the regularity of the first nine measures' material immediately breaks down. For the next 65 measures, Mario's regularity is low, meaning that phrases

containing his motives will repeat measures or cut off abruptly, and sections will repeat phrases or cut off abruptly. Furthermore, the worldstate regularity is also low. This means that this section consists of various phrases using each of his motives that interrupt each other, and cut off irregularly. The density is medium, which means that many phrases are isolated by measures of rest, during which the 'fire' motive F_1 can be heard as an ostinato (mm. 24-28, 30-33, 47-52). The relatively thin, highly irregular repetition of a single character's motives conveys the sense that he is under duress, unsatisfied, struggling to achieve his goals of staying alive and finding the princess.

At measure 75 (RL E), Mario's regularity increases to medium, to convey the sense that he is succeeding. The M_1 melody is repeated three times in a sequence, each time transposed down a half-step (mm. 75-80). The harmony during rehearsal letter D suggests a pedal on the dominant of Eb; this would make the first chord of m. 75 the ii of Eb, which, due to its sequential mapping in mm. 75-80, begins to sound like the i of f minor, mapped up to the i of f# minor, then the i of g minor. 81 begins on the dominant of g minor, but ends with a PAC in G major. This section, from 81 until 84 is the presentation of a new sentence; it is completely regular, because Mario has now escaped the infernal basement and is now ascending the stairs into the open air. The sentence form would continue regularly, moving into a continuation and a cadence, except that Mario has encountered a new obstacle: he must now begin his ascent up the castle's walls. The triumph suggested by a completely regular statement of a sentence must be withheld until later.

At measure 91 (RL G), Mario finds and dons the raccoon suit; accordingly, the raccoon theme is now substituted for the Mario themes heard up till now. This theme, a very active theme which represents the raccoon suit's endowment of speed, is heard in a single long (nine-measure), highly irregular phrase; measures and phrases are repeated, over a harmony centered around C major/minor, and accompanied by the 'rain' theme.

Measure 113 (RL H) begins a 'cut scene,' a pre-animated, cinematic sequence in which the player cannot control the characters. Here, Mario enters a turret and sees the princess. Her P_2 comes in a completely regular sentence, only to be interrupted in mid-stride when Bowser crashes through the ceiling (RL I). His melody is highly irregular, reflecting his role as an antagonist, a destroyer of equilibrium and normativity. At I, he and Mario crash through the crumbling floor together, and prepare to begin their final long battle; the segue is made smoothly here by introducing a militant ostinato under Bowser's melody.

The cut scene ends at measure 119 (rehearsal letter J), and what follows is 164 measures of fight music. The density is high, the regularity of both characters is low, and several environmental elements come and go as ostinati: when Bowser blows fireballs, the 'fire' themes recur, and the 'ascent' theme also turns up frequently. The musical result is frantic and kaleidoscopic. Several times, the two characters' themes are heard in counterpoint: in mm. 131-140, Bowser's theme becomes a low, angular ostinato against the raccoon's frenetic 16^{th}-notes. The harmony, whose tension is high throughout this section and is made more piquant with an abundance of

chromatic non-harmonic tones in the fire themes, roves through the keys of Eb, ab, F, and C.

Halfway through this section, at measure 202 (RL Q), Mario is killed, and must return at the beginning of the battle scene. This is a clear illustration of how the music *Mezzo* composes for a scene changes each time the scene takes place. Rehearsal letters R-V involve generally the same action as rehearsal letters K-O, although Mario is no longer in his raccoon suit (he lost it when he died and was resurrected, as these things go in many games). Of course, the actual individual sequence of player actions is not the same each time, but the arc of the story remains the same: Mario fights Bowser in the same places, perpetually ascending to the top of the castle. The music, though, as well as using Mario's themes instead of the raccoon's themes, is formally completely different, while still conveying the sense of battle appropriate to the scene.

At measure 271 (RL AA), Mario finally knocks Bowser into the fiery pit, and proceeds triumphantly upward to the princess. His regularity is now raised, but is still relatively irregular, as he has not yet completed his quest. The harmonic tension is finally low. At measure 287, the princess' theme enters underneath Mario's theme, as a counterpoint. It continues, slightly broken and separated with rests, until Mario finally rescues her, at which time its regularity becomes very high, signifying the successful realization of Mario's quest. The finale of the piece lingers on the princess' themes over an energetic ostinato with low harmonic tension; the only interjection is a comical reentrance by Bowser in the background while the credits are

rolling and Mario and the princess are spinning through the air. This occurs at measure 320 (RL DD), and continues irregularly until it is abruptly extinguished by the princess' themes again.

A detailed trajectory through a semiotic structure would be very complicated to show graphically, since there are four characters, each of which pass through varying states of markedness. The general movement through the piece, given in terms of Mario and Bowser, and the rehearsal letters at which the markedness changes drastically, is given below.

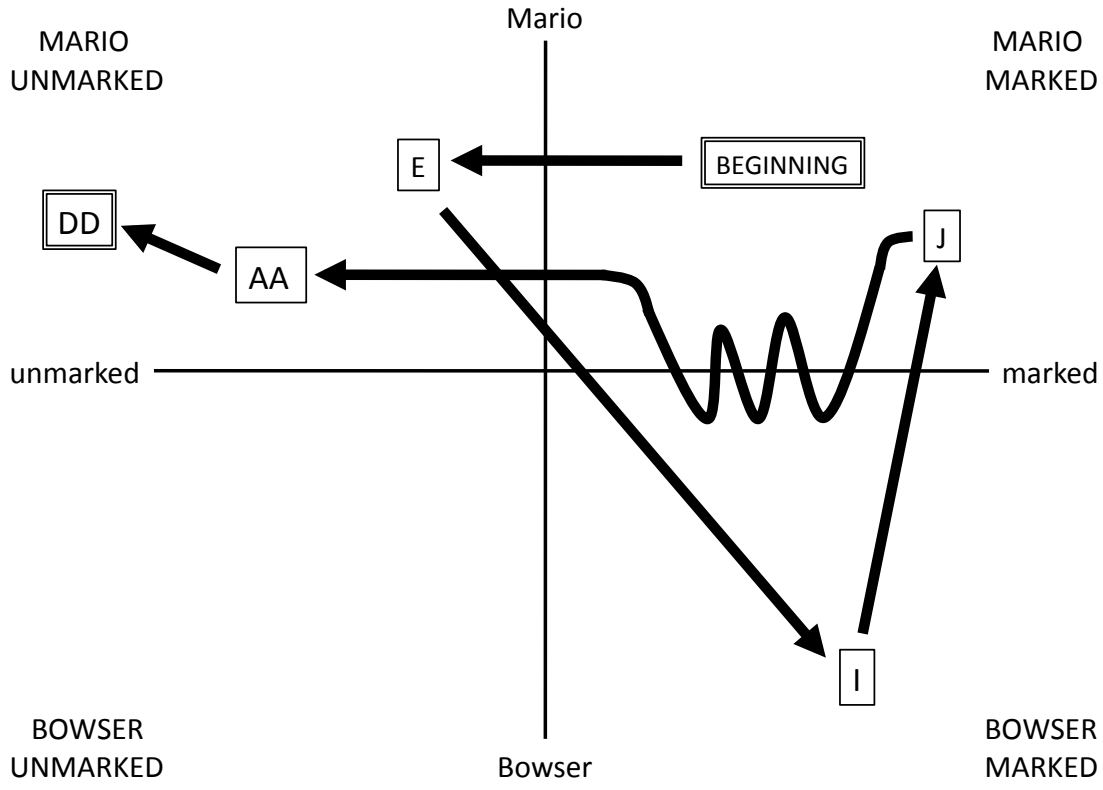


Figure 8.4: Narrative path through semiotic square for 'Bowser's Castle'

Chapter 9 Avenues for Further Research

This dissertation has illustrated in detail *Mezzo*'s use of two musical features that can be varied to produce different amounts of markedness, harmonic tension and formal regularity, and has also mentioned other features like energy, density, and thickness that contribute to the music's expressivity. The first two, which demand most of the program's computational effort, are syntactic elements. They generate expression by organizing musical motives, but *Mezzo* needs these motives to be given to it in advance by the user; it doesn't write them itself. Users must explicitly define the musical topics that will occur in a game accompaniment, and these topics are the only topics that will occur. The choices of ostinato based on a desired level of energy, and a melody with a desired thickness, operate on the level of content, as opposed to syntax, although the musical material to be chosen from must again be input by the user.

While the formal organization of musical material is a critical aspect of composing, and one which this dissertation argues contributes to narrative and expressive function, musical topic contributes just as much or more, and is perhaps

more immediately salient to the listener. The capacity to map melodic material into various topics would create a much more versatile version of the current program. It is, however, a difficult problem to design an algorithm that would undertake such mappings. On top of this, the interaction between topic and form in terms of expressive potential is a broad and complex subject in music analysis; there is not a straightforward method of implementing this multidimensional interaction. But while this is a complex subject, it is not inscrutable, and attempting to add this level of functionality to *Mezzo* would provide a method of empirical inquiry into the interaction of form and content in Romantic music, as well as vastly enriching *Mezzo*'s output.

The music included with this dissertation was output as general MIDI piano sounds, with no control over expressive aspects of performance like tempo fluctuations or dynamics. Since *Mezzo*'s function is not merely to write music, but to perform it as it is composed in real-time, this is a severe limitation on its effectiveness. For this reason, examples of games that are action-oriented, like *Super Mario 3D* and *Red Dead Redemption* were chosen as models for *Mezzo*'s accompaniment; they lend themselves to high-energy soundtracks by an instrument whose sound envelope has a high attack and a low sustain, like a general MIDI piano. I was pleasantly surprised, however, by *Mezzo*'s ability to compose in a more delicate texture, as it did for *Star Wars: The Old Republic*. Nevertheless, incorporating expressive playback into *Mezzo*'s design is critical, and this can be done to varying degrees of complexity. Changes in tempo and dynamics have conventional

expressive interpretations that could be assimilated relatively easily as further functional features in the program. 'Human-playback' algorithms that introduce small amounts of randomness in attack time and envelope would produce a more pleasing performance. The expressivity of performance, however, ultimately cannot be treated as an independent dimension of *Mezzo*'s output. Just as topic interacts with form to create a sense of musical function, so can performative qualities evoke various levels of markedness. Since the performance occurs at the time of composition, and must change along with the gameplay just as the compositional demands must constantly change, there is no interval for weighing interpretive performance strategies, as a human performer learning a piece can do. Therefore, expressive performance aspects must be a factor in *Mezzo*'s compositional process, not just in its performance process.

Ultimately, I believe that the model presented in this dissertation must integrate both topic composition and expressive performance into its design. That is, in addition to manipulating levels of musical markedness through the formal features described in the previous chapters, *Mezzo* needs an expanded vocabulary of formal, topical, and performative elements, all of which interact. Composing music for a given dramatic beat, then, would involve not just choosing the proper motives, fitting them to appropriate forms, and giving them ostinati with the appropriate energy. It would instead be a process in which the musical motives themselves were written, including all of their sonic qualities: instrumentation, ornamentation, tempi, dynamics, etc. These would then be placed in forms that not only satisfied the overall

expressive demands of the music, but fit the intrinsic qualities of the motives themselves.

The influence of the expanded sonic spectrum of the Romantic-Era orchestra on musical form is widely remarked. The composition process propounded in the previous paragraph would need an orchestrational module that worked in conjunction with the composing and organizing algorithms. While this conjectural program would be quite large and complex, it should also offer some respite to the amount of music *Mezzo* must compose for a game in its present incarnation: a few sustained string or horn tones would be a favorable substitute for a thousand notes in a repeating piano ostinato, for instance. *Mezzo*'s inability to compose its own thematic material or play it back expressively means that all the expressive functionality is pushed to the forces of formal organization. On one hand, I believe that experimenting with the expressive aspects of form, independent of content or performance, as *Mezzo* has done, illustrates just how much capacity for expression this musical dimension has. However, it remains quite limited in its scope of expression, due to the deficient aspects listed here. I cite these deficiencies with optimism, though, because I believe that *Mezzo* offers a strong foundation on which other compositional processes can be built and integrated with one another and the preexisting structure, as well as motivation to do so, in order to produce more expressive and interesting music for interactive settings.

APPENDIX: LIST OF BEATS IN 'BOWSER'S CASTLE'

What follows is a list of the information passed to Mezzo at the beginning of each dramatic beat in *Bowser's Castle* (delineated by rehearsal letters; see the score for descriptions of the action at each letter). The final column lists the forms, associated characters, and the cadences that Mezzo found to choose from that properly reflect the input information at each beat.

BEAT	RL	CHARACTERS	WORLDSTATE	APPLICABLE FORMS
1		Mario cadential: no regularity: very high thickness: medium type: protagonist	symmetry: medium density: very high energy: low harmonic tension: very high thickness: medium regularity: very high motivesize: medium action: questing environment features: fire	Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario]
2	A	Mario cadential: no regularity: low thickness: medium	symmetry: very high density: low energy: high ht: very high thickness: low regularity: low motivesize: low action: questing environment features: fire	Sentence - IAC or PAC, [Mario] Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario]
3	B	Mario cadential: no regularity: very low thickness: medium type: protagonist	symmetry: very high density: medium energy: high harmonic tension: high thickness: medium regularity: high motivesize: low action: questing environment features: fire	Sentence - IAC or PAC, [Mario] Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario]
4	C	Mario cadential: no regularity: low thickness: medium	symmetry: very high density: low energy: high ht: very high thickness: low regularity: low motivesize: low action: questing environment features: fire	Sentence - IAC or PAC, [Mario] Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario]

BEAT	RL	CHARACTERS	WORLDSTATE	APPLICABLE FORMS
5	D	Mario cadential: no regularity: medium thickness: medium	symmetry: very high density: low energy: very high ht: very high thickness: medium regularity: very high motivesize: low action: questing environment features: fire	Sentence - IAC or PAC, [Mario] Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario]
6	E	Mario cadential: no regularity: very high thickness: medium	symmetry: very high density: very high energy: low ht: high thickness: medium regularity: very high motivesize: low action: questing environment features: fire	Sentence - IAC or PAC, [Mario] Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario]
7	F	Mario cadential: no regularity: medium thickness: low	mood: None symmetry: medium density: medium energy: high ht: low thickness: medium regularity: medium motivesize: high action: questing environment features: rain	Sentence - IAC or PAC, [Mario] Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario]
8	G	Raccoon cadential: no regularity: very low thickness: medium type: protagonist	symmetry: medium density: low energy: high ht: low thickness: medium regularity: high motivesize: medium action: questing environment features: rain	Sentence - IAC or PAC, [Raccoon] Sentence - HC, [Raccoon] Sequence, [Raccoon] Sequence, [Raccoon]
9	H	Princess cadential: no regularity: very high thickness: medium type: desired	symmetry: medium density: very high energy: low ht: low thickness: medium regularity: very low motivesize: high action: questing environment features: None	Sentence - IAC or PAC, [Princess] Sentence - HC, [Princess] Sequence, [Princess] Sequence, [Princess]

BEAT	RL	CHARACTERS	WORLDSTATE	APPLICABLE FORMS
10	I	Bowser cadential: no regularity: very low thickness: low type: antagonist	symmetry: medium density: very high energy: very low ht: very high thickness: medium regularity: very low motivesize: high action: questing environment features: None	Sentence - IAC or PAC, [Bowser] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]
11	J	Raccoon cadential: no regularity: very low thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: low type: antagonist	symmetry: medium density: very high energy: medium ht: very high thickness: medium regularity: very low motivesize: low action: battling environment features: None	Sentence - HC, [Raccoon] Sequence, [Raccoon] Sequence, [Raccoon] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]
12	K	Raccoon cadential: no regularity: very low thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: low type: antagonist	symmetry: high density: high energy: high ht: high thickness: medium regularity: low motivesize: low action: battling environment features: fire, ascent	Sentence - HC, [Raccoon] Sequence, [Raccoon] Sequence, [Raccoon] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]
13	L	Raccoon cadential: no regularity: very low thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: low type: antagonist	symmetry: high density: high energy: high ht: high thickness: medium regularity: low motivesize: low action: battling environment features: ascent	Sentence - HC, [Raccoon] Sequence, [Raccoon] Sequence, [Raccoon] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]

BEAT	RL	CHARACTERS	WORLDSTATE	APPLICABLE FORMS
14	M	Raccoon cadential: no regularity: very low thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: low type: antagonist	symmetry: high density: high energy: high ht: high thickness: medium regularity: low motivesize: low action: battling environment features: fire, ascent	Sentence - HC, [Raccoon] Sequence, [Raccoon] Sequence, [Raccoon] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]
15	N	Mario cadential: no regularity: very low thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: medium type: antagonist	symmetry: high density: very high energy: very high ht: very high thickness: medium regularity: very high motivesize: low action: triumphant environment features: fire, ascent	Sentence - IAC or PAC, [Mario] Sentence - IAC or PAC, [Bowser]
16	O	Mario cadential: no regularity: very high thickness: medium type: protagonist	symmetry: high density: very high energy: high ht: low thickness: medium regularity: very high motivesize: low action: triumphant environment features: ascent	Sentence - IAC or PAC, [Mario]
17	P	Mario cadential: no regularity: medium thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: medium type: antagonist	symmetry: high density: very high energy: high ht: very high thickness: medium regularity: low motivesize: low action: battling environment features: ascent	Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]
18	Q	Mario cadential: no regularity: very low thickness: medium type: protagonist	symmetry: high density: very high energy: very low ht: very high thickness: medium regularity: low motivesize: low action: defeated environment features: None	Sentence - IAC or PAC, [Mario] Sentence - HC, [Mario]

BEAT	RL	CHARACTERS	WORLDSTATE	APPLICABLE FORMS
19	R	Mario cadential: no regularity: very low thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: medium type: antagonist	symmetry: low density: high energy: high ht: very high thickness: medium regularity: low motivesize: low action: battling environment features: fire	Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]
20	S	Mario cadential: no regularity: very low thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: medium type: antagonist	symmetry: low density: high energy: high ht: very high thickness: medium regularity: low motivesize: low action: battling environment features: fire	Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]
21	T	Mario cadential: no regularity: very low thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: medium type: antagonist	symmetry: low density: high energy: high ht: very high thickness: medium regularity: low motivesize: low action: battling environment features: None	Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]
22	U	Mario cadential: no regularity: very low thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: medium type: antagonist	symmetry: low density: high energy: high ht: very high thickness: medium regularity: low motivesize: low action: battling environment features: fire	Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]

BEAT	RL	CHARACTERS	WORLDSTATE	APPLICABLE FORMS
23	V	Mario cadential: no regularity: very high thickness: medium type: protagonist	symmetry: high density: very high energy: very high ht: very low thickness: medium regularity: very high motivesize: medium action: triumphant environment features: ascent	Perf. Pd., [Mario,Mario] ImPerf. Pd., [Mario,Mario] Sentence - IAC or PAC, [Mario]
24	W	Raccoon cadential: no regularity: very low thickness: medium type: protagonist	symmetry: high density: high energy: very high ht: very low thickness: medium regularity: very high motivesize: medium action: triumphant environment features: ascent	Perf. Pd., [Raccoon ,Raccoon] ImPerf. Pd., [Raccoon ,Raccoon] Sentence - IAC or PAC, [Raccoon]
25	X	Raccoon cadential: no regularity: very low thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: medium type: antagonist	symmetry: high density: very high energy: very high ht: very high thickness: medium regularity: low motivesize: medium action: battling environment features: ascent	Perf. Pd., [Raccoon ,Bowser] ImPerf. Pd., [Raccoon ,Bowser] Perf. Pd., [Raccoon ,Bowser] Sentence - HC, [Raccoon] Sequence, [Raccoon] Sequence, [Raccoon] Perf. Pd., [Raccoon ,Bowser] ImPerf. Pd., [Raccoon ,Bowser] Perf. Pd., [Raccoon ,Bowser] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]
26	Y	Raccoon cadential: no regularity: very low thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: medium type: antagonist	symmetry: high density: very high energy: very high ht: very high thickness: medium regularity: low motivesize: low action: battling environment features: None	Sentence - HC, [Raccoon] Sequence, [Raccoon] Sequence, [Raccoon] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]

BEAT	RL	CHARACTERS	WORLDSTATE	APPLICABLE FORMS
27	Z	Mario cadential: no regularity: ((0.2, 0, 0 thickness: medium type: protagonist Bowser cadential: no regularity: very low thickness: medium type: antagonist	symmetry: high density: very high energy: very high ht: very high thickness: medium regularity: low motivesize: low action: battling environment features: None	Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario] Sentence - HC, [Bowser] Sequence, [Bowser] Sequence, [Bowser]
28	AA	Bowser cadential: no regularity: very low thickness: medium type: antagonist	symmetry: high density: very high energy: low ht: very high thickness: medium regularity: low motivesize: low action: defeated environment features: fire	Sentence - IAC or PAC, [Bowser] Sentence - HC, [Bowser]
29	BB	Mario cadential: no regularity: ((0, 0, 0), thickness: medium type: protagonist Princess cadential: no regularity: ((0, 0, 0), thickness: medium type: desired	symmetry: high density: high energy: high ht: low thickness: medium regularity: high motivesize: medium action: questing environment features: None	Sentence - IAC or PAC, [Mario] Sentence - HC, [Mario] Sequence, [Mario] Sequence, [Mario] Sentence - IAC or PAC, [Princess] Sentence - HC, [Princess] Sequence, [Princess] Sequence, [Princess]
30	CC	Mario cadential: no regularity: ((0, 0, 0), thickness: low type: protagonist Princess cadential: no regularity: very low thickness: medium type: desired	symmetry: high density: very high energy: very high ht: very low thickness: medium regularity: very high motivesize: medium action: triumphant environment features: None	Perf. Pd., [Mario ,Mario] ImPerf. Pd., [Mario ,Mario] Sentence - IAC or PAC, [Mario] Perf. Pd., [Princess ,Princess] ImPerf. Pd., [Princess ,Princess] Sentence - IAC or PAC, [Princess]

BEAT	RL	CHARACTERS	WORLDSTATE	APPLICABLE FORMS
31	DD	Bowser	symmetry: high	Sentence - IAC or PAC, [Bowser]
		cadential: no	density: very high	Perf. Pd., [Princess ,Princess]
		regularity: very low	energy: very high	ImPerf. Pd., [Princess ,Princess]
		thickness: medium	ht: very low	Sentence - IAC or PAC, [Princess]
		type: antagonist	thickness: medium	
		Princess	regularity: very high	
		cadential: no	motivesize: medium	
		regularity: very low	action: triumphant	
		thickness: medium	environment features: None	
		type: desired		
32	EE	Princess	symmetry: high	Perf. Pd., [Princess ,Princess]
		cadential: no	density: high	ImPerf. Pd., [Princess ,Princess]
		regularity: very high	energy: low	Sentence - IAC or PAC, [Princess]
		thickness: medium	ht: low	
		type: desired	thickness: medium	
			regularity: very high	
			motivesize: medium	
			action: triumphant	
			environment features: None	
		thickness: medium	ht: low	
		type: desired	thickness: medium	
			regularity: very high	
			motivesize: medium	
			action: triumphant	
			environment features: None	
			environment features: None	

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