MUSICAL ARTICULATION IN THE ORGAN

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ABSTRACT

In organ playing the only musical parameters immediately available for expression are changes of the tone onsets and offsets. While interonset intervals (IOIs) have been studied extensively in performances on several instruments, the offset timings are largely unknown. For analysis of musical articulation the extractions of onsets as well as offsets are required.

In this study, the tone onsets and offsets were measured in seven monophonic Bach organ fugue openings, each of which was played by three, four, or five organists sampled from commercially available recordings. The articulation for each tone was defined as the ratio between the tone duration and the IOI. The articulations, IOIs, and relative IOIs of all tones were calculated, as well as a number of inter- and intrapersonal correlation coefficients. The relative IOI is a measure of the local tempo deviation. Articulatory strategies were analysed using an explorative (not hypothesis-driven) approach.

Quantitatively, the mean articulation was 0.86, with an average standard deviation of 0.15. The mean correlation coefficient between performers' articulation in the same piece was 0.44, which is almost as high as for the relative IOI (0.46). The mean correlation between articulation and relative IOI was –0.26 (95% CI –0.37 - –0.16). In the studied material lengthening of relative IOI thus typically coincides with shorter (more staccato-like) articulation.

Qualitatively, some performances were articulated binarily, i.e. each tone is long or short but not intermediate. Other articulation strategies enhance the inherent phrasing or matrical structure. Different articulation strategies may well be mutually contradictory. Therefore, possible rules in a model for musical articulation should not be applied indiscriminately, but should be applied in groups falling under different overall strategies.

1. INTRODUCTION

1.1. Musical articulation

In a dissertation on the interpretation of J. S. Bach's organ works, written by the Finnish organist and musicologist Enzio Forsblom, one reads: "By articulation we here refer to the tying or separation of the tones, through which the expression of the melodic line can be affected. In opposition to this, the phrasing slurs unite the tones belonging together in a phrase and mark the phrases off from one another" [1] (my translation from Swedish). This catches two important features of what is generally meant by "musical articulation".

First, articulation has to do with the *individual tone* and its relation to the neighbouring tones (Similar opinions can be found in, e.g., [2] and [3] Chew (2001), p. 86). Thus, *staccato* and *legato* are said to be manifestations of articulation. Secondly, Forsblom touches upon the ability of articulation to affect the musical expression. This is hardly surprising. Musical interpretation does indeed convey emotions; this has surely been known for a long time, though it has been scientifically scrutinized only recently; for a comprehensive review, see [4]. For example, when performers are asked to play a piece first in a neutral way and then in a specified expressive way (e.g. "happy" or "sad"), the articulation is changed, as are many other factors.

The German musicologist Hermann Keller is an important person in this area. In 1925 he published *Die musikalische Artikulation insbesondere bei Joh. Seb. Bach* ("Musical Articulation, Especially in Joh. Seb. Bach", no English translation available) [5]. Thirty years later, he completely rewrote the book and published it with the title *Phrasierung und Artikulation* (*Phrasing and Articulation*, English translation 1965). As for the distinction between articulation and phrasing – sometimes used synonymously by musicians and musicologists – Keller was clear-cut: "[T]he words 'phrasing' and 'articulation' have basically different meanings: *phrasing* is much like the subdivision of thought; its function is to link together subdivisions of musical thought (phrases) and to set them off from one another; it thus has the same function as punctuation marks in language. (…) The function of musical *articulation*, on the other hand, is the binding together or the separation of the individual notes; it leaves the intellectual content of a melody line inviolable, but it determines its expression" [6].

It is important to recognize that there is a variety of strategies for making adjacent tones belong together or for making them seem separated. Tones can be played longer or shorter than their nominal duration. Furthermore, tones can be played with different sound levels, or with different vibrato, or with different tone attacks, etc. Adjustment of the amount of rest between the tones – the most obvious articulation strategy – is far from the only possibility.

In this paper I will only deal with methods involving the timing of the tones. There are two such methods. The first is to alter the relative length of the rest, i.e. what is normally called *legato* vs. *staccato*. If one note ends exactly when the following note starts, the articulation ratio is 1 (one). If one note lasts for only half the time between its onset and the onset of the next tone, the articulation ratio is 0.5. In other words the articulation ratio for tone n is $(\text{offset}_n - \text{onset}_n)/\text{IOI}_n$, where IOI is the *interonset interval* (see e.g. [7]), defined as the time interval between the onset of a given tone and the onset of the immediately following tone, i.e. $\text{IOI}_n = \text{onset}_{n+1} - \text{onset}_n$. For simplicity, I will use the word "articulation" for "articulation ratio" as defined above.

It should be noted, incidentally, that the term "IOI" is well-established from earlier studies, whereas "articulation" in the specified sense "(offset – onset)/IOI" perhaps is not. Some researchers, e.g. [8], use the terms "key overlap time" (KOT) and "key detached time" (KDT) in discussing legato and staccato in piano playing. The word "articulation" covers them both, being also applicable in other musical instruments.

The second method is to play the tones (or, more to the point, their IOI's) longer or shorter than their nominal duration. In other words the tempo is altered locally. This can be expressed in terms of relative IOI. A relative IOI of 1 (one) means that the duration of the tone is exactly what is to be expected from the nominal (notated) length given the mean tempo of the piece. For example, if a piece is performed at the mean tempo 120 quarter-notes per minute, we would expect an eighth-note to last for 0.25 s. A certain eighth-note with a duration of 0.30 s then has the relative IOI 0.30/0.25 = 1.2.

1.2. Earlier studies

Bolzinger studied the influence of different acoustical qualities of performance venues on piano playing [9]. He concluded firstly that the acoustic feedback clearly influenced the playing intensity, so that "in most cases, a dull concert hall will require a greater physical effort from the interpreter" (p. 136; my translation). Secondly, however, even though all interpreters reacted to changes in the acoustic feedback, the reactions were very diverse, depending on the interpreter, the style of the music and its technical characteristics, and even on the general situation. This diverse conclusion, abounding with reservations, is typical of the subject. Although not investigated by Bolzinger, we should also remember that instruments change over time. An appropriate *Hammerklavier* articulation might not be suitable for a *grand piano* performance, not even for the same piece of music.

Gabrielsson studied the timings in five performances of the opening Andante theme of Mozart's A major piano sonata, K. 331 [10]. He could demonstrate that most pianists showed similarities in tempo deviations.

On articulation, Gabrielsson writes that "[a]lmost all the present performances are of the legato type" (p. 99). He discusses some exceptions to this observation, but there is no evidence that he actually measured the tone offsets.

Repp made a very large study of "temporal commonalities and differences" in piano playing [11]. Repp measured the IOIs in no less than 28 recorded performances of Schumann's "Träumerei". His focus is on the behaviours such as *ritardandi* of structures called "melodic gestures" (two to seven notes long). Repp's paper contains many interesting observations. Again, it has nothing to report on articulation, since only the tone onsets were measured. The introductory part (p. 2546–2548) gives a valuable overview of earlier research.

In three subsequent papers, Repp specifically studied legato and staccato articulation in the piano [12], [13], [14]. However, the data material for these works were scales, arpeggios, and simple sequences, not "real" music as in the earlier study [11]. In all three papers the pianists were explicitely asked to play legato or staccato. Repp's findings were, for example: KOTs (key overlap times) for successive tones judged to be optimally legato were greater for high than for low tones [12], [13]; note durations increased significantly as tempo decreased in both perception and production of staccato [14]. As indicated by the article titles, one of Repp's main concerns has been the relationship between perception and production of different articulations. He claims, e.g., that produced staccato is not necessarily percepted as staccato [14].

One interesting study on piano playing was made by Battel and Fimbianti [15]. They studied the first 16 bars of the Andante movement of Mozart's G Major Sonata, K. 545. Five near-professional pianists played the piece nine times each. First they were asked to play it in an "optimal" (preferred) way, then in eight ways characterized by four pairs of expressive adjectives (bright vs. dark, light vs. heavy, hard vs. soft, and passionate vs. flat). The researchers performed several statistical tests relating the tone timings to the different adjectives ("intentions"). As for the articulation, they stated: "A close survey proves that the staccato/legato degree in each version depends on [harmonic] tension. Particularly, the DRO average of all performance notes depends on the expressive intention while, for each note, local value depends directly on the harmonic structure. The performer increases the slur degree when the harmonic tension increases in each different intention, no matter the global value" (p. 69f). The DRO is explained to be "the ratio between the note value (key on/off) and the IOI" (p. 69), which appears to be identical to articulation in the present work. (This is confusing, since DRO in other papers on music performance stands for the *pause* duration, not the tone duration.) In other words, Battel and Fimbianti claim that the average articulation is affected by the overall intention, but also that the individual values are dependent on the harmonic tension of each note. We are told that the tension for each note was calculated according to a theory due to Lerdahl. This result sounds very interesting, but since no details are given it is hard to assess the quality of the finding.

Bresin and Battel [8] used the same material for further analysis. They concentrated more on articulation matters. They found that legato was played with a key overlap ratio which depended on the IOI.

When both onsets and offsets have been measured, as in some of the above studies, the material has been either scales and arpeggios or music where the composer has already added some phrasing and articulatory marks. The comprehensive reviews by Alf Gabrielsson [16], [17] confirm this picture; in studies of performance timing only the onsets seem to have been extracted in most cases.

2. AIM OF PRESENT STUDY

The present study aims at a rough description of the articulation in one-part melodies played on the organ. I will report some basic findings. In particular I will investigate the following questions: What is "normal" articulation in one-part music lacking notated articulation marks, i.e. what is its mean and standard deviation? How large differences are there between performers in the same piece? Is there any detectable relationship between articulation and IOI? Between articulation and relative IOI? If so, how could these be explained?

It seems that no one has investigated these questions before, at least not in a quantitative manner. There are some studies on how to play a predetermined articulation type, as indicated in the preceding section. For example, Battel and Bresin [8] reports that a typical *staccato* in the pianoforte has an articulation ratio of approximately 0.4 (independent of absolute IOI). Repp [12] reports that a legato in the piano has an articulation ratio of about 1.2. However, there are no reports on the articulation of music without notated articulation marks. I will also devote some space to finding out whether specific articulation strategies are present in the pieces analysed.

The reason for analysing organ recordings rather than, say, violin recordings is that the articulation is straight-forward in the organ; it is only a matter of measuring the onset and offset of each tone. Furthermore, the organ tone is steady, being (very nearly) equally loud from onset to offset. A possibly complicating factor is that there is no standard organ. For example, organs might be mechanical or electro-pneumatic. Different organs do not respond in the same way to a given touch. These things have been ignored in this work. The rationale for this is the assumption that a skilful organist can produce an intended articulation on almost any organ (or at least on the organs of the analysed recordings). Some of the preliminary results of this study have been summarised in [18].

3. METHOD

The material in this study is seven Bach fugue openings for the organ. The material is from BWVs 537, 538, 542, 544, 548, 564, and 578. By "opening" I mean from the beginning of the fugue (*dux*) to the entrance of the second voice (*comes*) or even shorter; the material is thus monophonic. Scores of the fugue themes are presented in Figure 1. These scores were redrawn from [5]. In BWV 538 the trill of the tone *e* has been excluded from analysis. The same is true for the trill *f sharp* in BWV 548. In both cases the articulation ratios are ascribed the value 1 (one). There are notated pauses in BWV 564. Here, notes immediately preceding pauses have been excluded from analysis. This is necessary because it is impossible to calculate their tempo deviations, and hence their relative IOIs.

Figure 1: *The seven analysed fugue openings: a) BWV 537, b) BWV 538, c) BWV 542, d) BWV 544, e) BWV 548, f) BWV 564, g) BWV 578.*

Each piece is played by three, four, or five organists that were sampled from commercially available recordings. In all, 28 recordings were used. The organists are Hans Fagius, Peter Hurford, Wolfgang Rübsam, Helmuth Rilling, and Ton Koopman. See Table 1 for details.

The onset and offset of each tone were estimated through spectrogram inspections. The programs WaveSurfer 1.4.5 [19] and Soundswell 4.0 [20] were used to supply spectrograms. Because of the very reverberant (and very different) recording conditions it was not possible to use an automatic procedure to establish the onset and offset timings, e.g. by defining them as the moment when the sound level exceeds or falls below a fixed number. The extraction of timings has thus been made manually, through ocular inspection combined with repeated playbacks. For each performance the onset/offset timings were input to Matlab files calculating the articulation of each tone, the relative IOI and some statistical parameters.

As for the search for specific articulation strategies, an explorative approach will be used. This means that I do not test any predetermined hypotheses, but try to find patterns in the articulation. For example, if I analyse a piece with this passage appearing in the printed notes, , finding that one performer articulates like this, , I would guess that it was intentionally done, because it seems musically reasonable. Therefore it would qualify as a “pattern”. But finding such patterns is, of course, a risky project, since I might attribute intentions to the performers originating, in reality, from my fantasy.

BWV	Performer	Recording	Year
537	Hans Fagius	BIS 397/398	c. 1988
537	Peter Hurford	Decca 443485-2	1979
537	Wolfgang Rübsam	Naxos 8553150	1988
537	Ton Koopman	Teldec 0630-13155-2	1996
538	Hans Fagius	BIS 439/440	1989
538	Peter Hurford	Decca 443485-2	1979
538	Wolfgang Rübsam	Naxos 8553150	1988
538	Ton Koopman	Archiv 410999-2	1983
542	Hans Fagius	BIS 308/309	c. 1985
542	Peter Hurford	Decca 443485-2	1978
542	Wolfgang Rübsam	Naxos 8550652	1989
542	Helmuth Rilling	Denon 38C37-7039	1974
542	Ton Koopman	Hänssler 98182	1986
544	Hans Fagius	BIS 397/398	1988
544	Wolfgang Rübsam	Naxos 8550652	1989
544	Helmuth Rilling	Denon 38C37-7039	1974
544	Ton Koopman	Teldec 4509-94458-2	1994
548	Hans Fagius	BIS 397/398	1988
548	Peter Hurford	Decca 421337-2	1981
548	Wolfgang Rübsam	Naxos 8550184	1988
564	Hans Fagius	BIS 343/344	1986
564	Peter Hurford	Decca 443485-2	1981
564	Wolfgang Rübsam	Naxos 8550901	1993
564	Ton Koopman	Archiv 410999-2	1983
578	Hans Fagius	BIS 439/440	1989
578	Wolfgang Rübsam	Naxos 8553135	1995
578	Helmuth Rilling	Denon 38C37-7039	1974
578	Ton Koopman	Teldec 4509-94458-2	1994

Table 1: *Recordings used for analysis.*

4. RESULTS

4.1. Tempos

Table 2 shows the tempos chosen by the organists in all performances.

BWV	Performer	Tempo (BPM)
537	Fagius	𝅗𝅥 = 61
537	Hurford	𝅗𝅥 = 73
537	Rübsam	𝅗𝅥 = 58
537	Koopman	𝅗𝅥 = 70
538	Fagius	𝅗𝅥 = 63
538	Hurford	𝅗𝅥 = 52
538	Rübsam	𝅗𝅥 = 54
538	Koopman	𝅗𝅥 = 64
542	Fagius	♩ = 77
542	Hurford	♩ = 79
542	Rübsam	♩ = 61
542	Rilling	♩ = 65
542	Koopman	♩ = 89
544	Fagius	♩ = 58
544	Rübsam	♩ = 50
544	Rilling	♩ = 60
544	Koopman	♩ = 56
548	Fagius	𝅗𝅥 = 63
548	Hurford	𝅗𝅥 = 58
548	Rübsam	𝅗𝅥 = 53
564	Fagius	♩. = 54
564	Hurford	♩. = 65
564	Rübsam	♩. = 54
564	Koopman	♩. = 66
578	Fagius	♩. = 69
578	Rübsam	♩. = 66
578	Rilling	♩. = 62
578	Koopman	♩. = 73

Table 2: Mean tempos of analysed performances.

4.2. Articulation

The mean articulation, for all pieces and all performances, was 0.86, with an average standard deviation of about 0.15. The results for each performance are presented in Table 3. As can be seen, there are some differences between pieces, which is quite expected because different pieces seem to invite the performers to articulate differently. Two piece mean values stand out. In BWV 544 the mean value is high, with a small standard deviation, whereas in BWV 564 the mean value is low, with a high standard deviation.

BWV	Performer	Mean art. ± SD	Piece mean ± SD
537	Fagius	0.93 ± 0.13	0.85 ± 0.17
537	Hurford	0.89 ± 0.18	
537	Rübsam	0.90 ± 0.13	
537	Koopman	0.67 ± 0.23	
538	Fagius	0.87 ± 0.15	0.88 ± 0.12
538	Hurford	0.98 ± 0.06	
538	Rübsam	0.93 ± 0.10	
538	Koopman	0.75 ± 0.17	
542	Fagius	0.83 ± 0.14	0.86 ± 0.17
542	Hurford	0.96 ± 0.15	
542	Rübsam	0.88 ± 0.11	
542	Rilling	0.93 ± 0.23	
542	Koopman	0.70 ± 0.21	
544	Fagius	0.94 ± 0.07	0.97 ± 0.07
544	Rübsam	0.98 ± 0.04	
544	Rilling	1.01 ± 0.12	
544	Koopman	0.96 ± 0.05	
548	Fagius	0.68 ± 0.16	0.83 ± 0.12
548	Hurford	0.86 ± 0.11	
548	Rübsam	0.95 ± 0.08	
564	Fagius	0.73 ± 0.23	0.73 ± 0.23
564	Hurford	0.66 ± 0.27	
564	Rübsam	0.86 ± 0.18	
564	Koopman	0.65 ± 0.23	
578	Fagius	0.91 ± 0.11	0.90 ± 0.14
578	Rübsam	0.88 ± 0.16	
578	Rilling	0.98 ± 0.13	
578	Koopman	0.84 ± 0.16	

Table 3. Mean articulations and standard deviations.

4.2.1. Articulation correlations

A rough measure of the articulation similarities between performers is the mean value of all pairwise correlations. For example, there are six performer combinations for BWV 537: Fagius-Hurford, Fagius-Rübsam, Fagius-Koopman, Hurford-Rübsam, Hurford-Koopman, and Rübsam-Koopman. This mean value, for all seven fugues (43 performer pairs), was 0.44. An approximate 95% confidence interval is 0.37-0.51. The full results are presented in Table 4.

BWV	Pair of performers	Art. corr.	Piece mean
537	Fagius-Hurford	0.31	0.50
537	Fagius-Rübsam	0.70	
537	Fagius-Koopman	0.71	
537	Hurford-Rübsam	0.32	
537	Hurford-Koopman	0.59	
537	Rübsam-Koopman	0.38	
538	Fagius-Hurford	0.93	0.63
538	Fagius-Rübsam	0.54	
538	Fagius-Koopman	0.84	
538	Hurford-Rübsam	0.31	
538	Hurford-Koopman	0.82	
538	Rübsam-Koopman	0.36	
542	Fagius-Hurford	0.22	0.36
542	Fagius-Rübsam	0.51	
542	Fagius-Rilling	0.34	
542	Fagius-Koopman	0.63	
542	Hurford-Rübsam	0.12	
542	Hurford-Rilling	–0.14	
542	Hurford-Koopman	–0.01	
542	Rübsam-Rilling	0.54	
542	Rübsam-Koopman	0.61	
542	Rilling-Koopman	0.76	
544	Fagius-Rübsam	0.20	0.30
544	Fagius-Rilling	0.89	
544	Fagius-Koopman	0.01	
544	Rübsam-Rilling	0.42	
544	Rübsam-Koopman	0.14	
544	Rilling-Koopman	0.17	
548	Fagius-Hurford	–0.07	0.13
548	Fagius-Rübsam	0.34	
548	Hurford-Rübsam	0.11	
564	Hurford-Koopman	0.60	0.73
564	Hurford-Rübsam	0.52	
564	Hurford-Fagius	0.71	
564	Koopman-Rübsam	0.83	
564	Koopman-Fagius	0.82	
564	Rübsam-Fagius	0.90	
578	Fagius-Rübsam	0.40	0.33
578	Fagius-Rilling	0.22	
578	Fagius-Koopman	0.50	
578	Rübsam-Rilling	0.18	
578	Rübsam-Koopman	0.16	
578	Rilling-Koopman	0.51	

Table 4. Articulation correlations between all performer pairs.

4.2.2. Articulation and IOI

The IOI (or, for clarity, absolute IOI) is the duration of the tone, including the following pause (if any) before the next tone. The IOI is straightforward to perceive. Relative IOI, on the other hand, is cognitively much more complicated, since it reflects the deviation from a notated duration, the existence of which the listener must deduce from the relative values only. Let us therefore first investigate whether we can find any interesting correlation coefficients when comparing absolute IOI and articulation values. Table 5 shows the correlations between articulation and absolute IOI for each performance.

BWV	**Performer**	**Corr. art.-IOI**
537	Fagius	–0.20
537	Hurford	0.19
537	Rübsam	–0.07
537	Koopman	0.09
538	Fagius	0.71
538	Hurford	0.60
538	Rübsam	0.49
538	Koopman	0.55
542	Fagius	–0.44
542	Hurford	0.15
542	Rübsam	–0.61
542	Rilling	–0.94
542	Koopman	–0.88
544	Fagius	–0.58
544	Rübsam	0.07
544	Rilling	–0.51 (o)
544	Koopman	0.06
548	Fagius	0.52 (o)
548	Hurford	0.19 (o)
548	Rübsam	0.00 (o)
564	Hurford	–0.23
564	Koopman	–0.65
564	Rübsam	–0.90
564	Fagius	–0.75
578	Fagius	–0.04
578	Rübsam	–0.31
578	Rilling	–0.15
578	Koopman	0.01

Table 5. Correlations between articulation and absolute IOI for all performances. (o) = value should be interpreted with care due to presence of outliers.

It should be noted immediately that the correlation coefficient is sensitive to outliers. In a few cases, individual data points affected the correlation coefficients considerably. These are marked '(o)' in Table 5.

The overall average for all pieces is –0.20, which is not very interesting given the wide range of both positive and negative values. Let us look at the extremes. The most negative correlations are found in BWV 542 and BWV 564. Obviously, for all other performers except Hurford a negative correlation between articulation and IOI is preferred. Why BWV 542 and BWV 564? The reason might be that both themes consist entirely of only two notated note lengths, namely eighth-notes and sixteenth-notes. If the longer notes are generally given another articulation (here: shorter) than the short notes, the correlation can easily be very significant, because the notes are divided into two distinct groups along both the IOI and articulation dimensions.

The most positive correlations are found in BWV 538. Here, too, long and short notes are articulated differently, but the other way around; long notes are played more legato, and short notes more staccato. Why? I think the reason is that the short notes (quarter-notes) generally occur on weak beats and are followed by leaps. They therefore function as up-beats.

For reference, all data are presented in Figure 3.

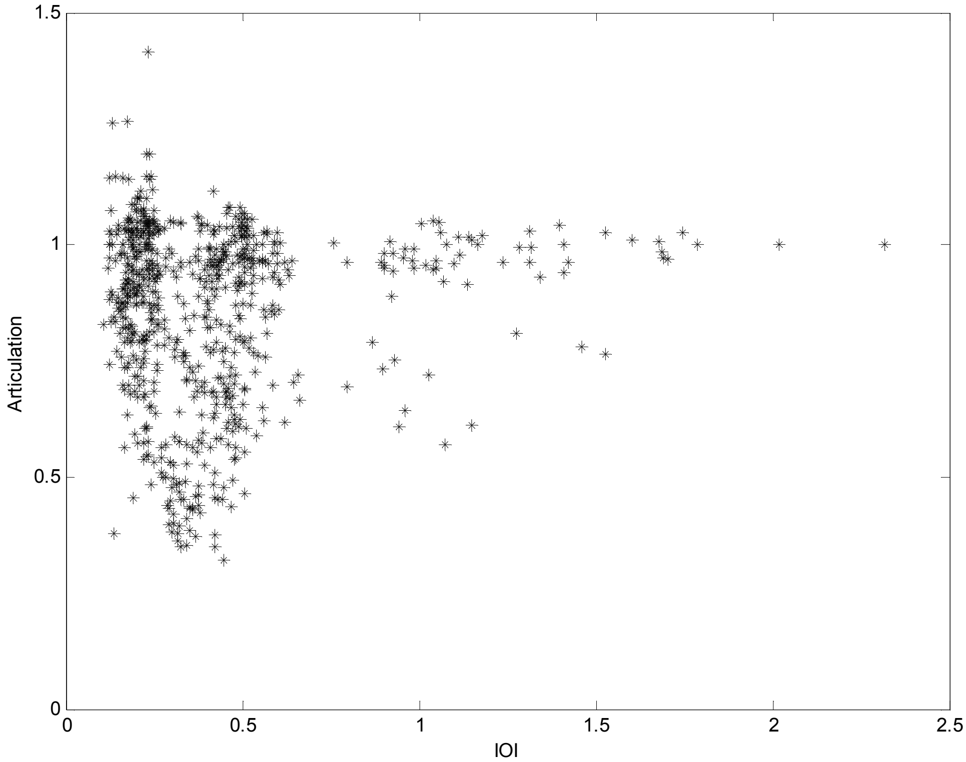

Figure 3. IOI vs. articulation for all data, i.e. all performances of all pieces. IOI is measured in seconds.

4.2.3. Articulation and relative IOI

Change of articulation ratio and adjustment of relative IOI are the two temporal strategies for joining or separating adjacent tones. The relative IOI consistency, measured as the mean correlation between performers (43 performer pairs), was 0.46. An approximate 95% confidence interval is 0.40-0.53. The value is only slightly higher than the mean correlation for articulation between performers.

Relative IOI deviations have been studied fairly extensively. To find a relationship between relative IOI and articulation would therefore be helpful, since it could provide a shortcut in simulations of realistic articulation in computer music. Should we expect such a relationship? A negative correlation might seem obvious: if a tone is given a fixed duration, then prolonging its IOI would mean adding time to the following rest, thereby reducing its articulation. This would mean that longer IOI's are more likely to be associated with shorter (more *staccato*-like) articulation. But *a priori*, one could as well argue that the opposite could be true: perhaps shorter tones must be articulated more clearly (i.e. more *staccato*) to be heard in their own right, whereas longer tones do not need such clarification. If so, longer IOI's are more likely to be associated with longer (more *legato*-like) articulation. Or maybe none of these alternatives is true.

In this study, the mean correlation between articulation and relative IOI for all performances was negative, –0.26. An approximate 95% confidence interval is –0.37 - –0.16. The full results are presented in Table 6.

There were no great differences between pieces, except that BWV 564 stands out with an unussualy negative mean.

BWV	Performer	Corr. art.-rel. IOI	Piece mean
537	Fagius	–0.36	–0.11
537	Hurford	0.21	
537	Rübsam	–0.34	
537	Koopman	0.07	
538	Fagius	–0.28	–0.22
538	Hurford	0.14	
538	Rübsam	–0.63	
538	Koopman	–0.11	
542	Fagius	–0.53	–0.34
542	Hurford	–0.02	
542	Rübsam	–0.51	
542	Rilling	–0.02	
542	Koopman	–0.61	
544	Fagius	–0.58	–0.24
544	Rübsam	0.07	
544	Rilling	–0.51	
544	Koopman	0.06	
548	Fagius	0.09	–0.20
548	Hurford	–0.24	
548	Rübsam	–0.44	
564	Fagius	–0.66	–0.50
564	Hurford	–0.08	
564	Rübsam	–0.74	
564	Koopman	–0.52	
578	Fagius	–0.26	–0.19
578	Rübsam	–0.47	
578	Rilling	–0.04	
578	Koopman	0.03	

Table 6. Correlations between articulation and relative IOI for all performances.

Another way of handling this material is to look at the mean value for each performer. Table 7 shows the correlations from Table 6 averaged for each performer.

Performer (no. of performan-ces)	**Mean correlation art.-rel. IOI**
Fagius (7)	–0.37
Hurford (5)	0.00
Rübsam (7)	–0.44
Rilling (3)	–0.19
Koopman (6)	–0.18

Table 7. Mean value for correlations between articulation and relative IOI for all performers.

Table 7 is interesting information. Of course, the data set is too little to establish the calculated values as "typical" for these performers (this is especially true for Rilling, with only three performances). But the set is sufficient for the assessment that there seems to be a variability in the articulation/relative IOI correlation between performers.

The whole material is presented in Figure 4.

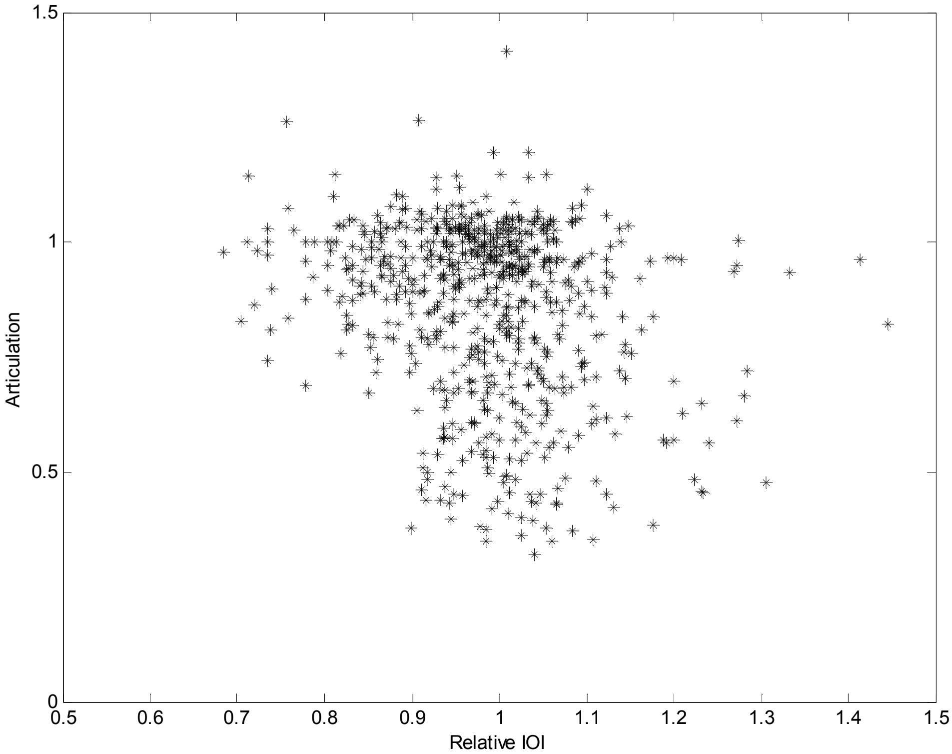

Figure 4. Relative IOI vs. articulation for all data, i.e. all performances of all pieces.

4.3. Articulation patterns in different pieces

In this section I will sketch some of the the articulatory patterns in each piece, as revealed by the data for articulation and relative IOI. For each piece, all the data will also be presented graphically.

4.3.1. BWV 537

Plotting Fagius' articulation vs. Rübsam's reveals a fairly linear relationship (Figure 5). It is reasonable to say that Fagius uses a binary type of articulation, either short or long. In Fagius no tones have articulations between 0.8 and 0.9. For Rübsam the pattern is not equally clear. His articulation values are more evenly spread. However, adopting 0.8 as the boundary between short and long articulation for both performers, only two eighth-notes at the end of the theme are disputed.

Koopman's articulation is similar to Fagius' and Rübsam's. Actually, Koopman's articulation is identical to Rübsam's if we only distinguish two types of articulation, long and short. Koopman's average articulation is, however, much lower than Fagius' and Rübsam's (see Table 3), so his boundary between staccato and legato is 0.5, not 0.8. Figure 6 shows in musical notes the articulations of Fagius, Rübsam, and Koopman.

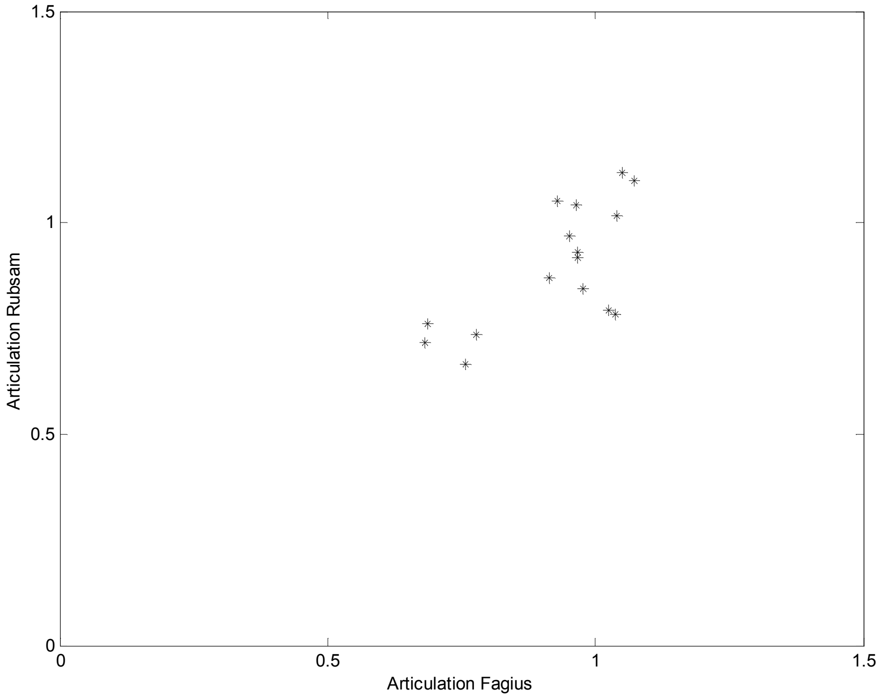

Figure 5. Articulation in BWV 537 for Fagius and Rübsam. The two outliers closest to the bottom right corner are the two disputed eighth-notes *D* and *E flat* at the end of the theme.

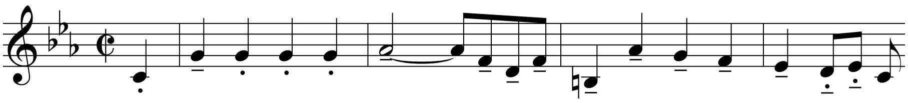

Figure 6. Articulation in BWV 537 for Fagius, Rübsam, and Koopman. Tones for which the articulation is less than 0.8 (for Fagius and Rübsam) or less than 0.5 (for Koopman) are marked staccato, other notes are marked portato. The two tones marked both ways were played staccato by Rübsam but legato by Fagius and Koopman.

Hurford uses roughly the same articulation, but he is more extreme, reaching articulations below 0.6 on three occations. At the same time he plays with the most stable tempo of the three performers, his relative IOI never exceeding ±10% (see Figure 8, top). It seems resonable to say that Hurford compensates his moderate tempo deviations with more expressive articulation; but this can only be an intelligent guess given the small data sample. Figure 7 shows Hurford's articulation in musical notes.

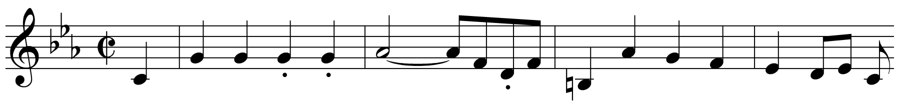

Figure 7. Hurford's articulation in BWV 537. Staccato dots indicate articulations of below 0.6. All other tones have articulations above 0.9.

Figure 8 shows all data for articulation and relative IOI.

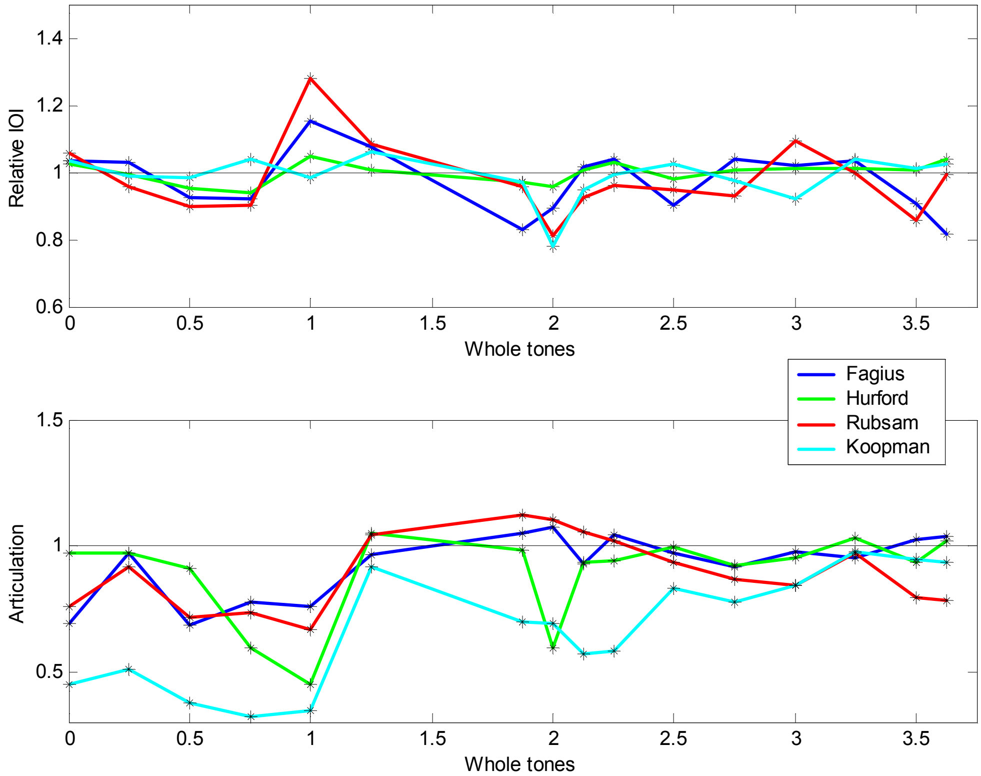

Figure 8: Relative IOI (top) and articulation (bottom) for all four performances of BWV 537.

4.3.2. BWV 538

BWV 538 has been discussed briefly under "Articulation and IOI," above, and there is little more to add. Generally, long notes are played more legato, and short notes more staccato. I believe this is due to the up-beat quality of the short notes. There are great similarities in articulation between performances.

Figure 9 shows all data.

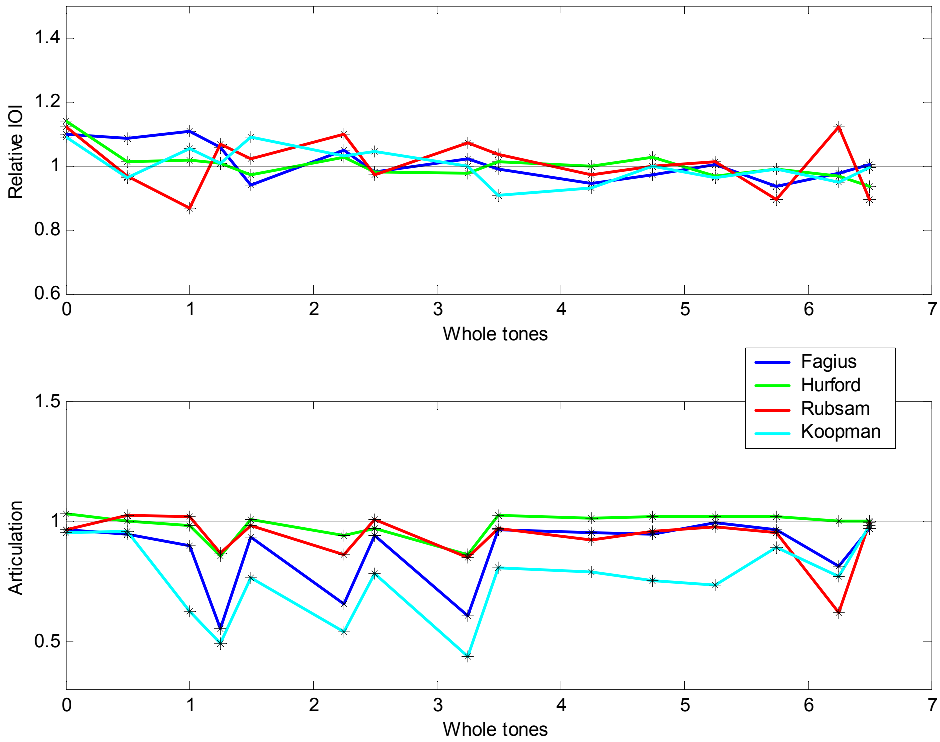

Figure 9: Relative IOI (top) and articulation (bottom) for all four performances of BWV 538.

4.3.3. BWV 542

The great g minor Fantasia and Fugue BWV 542 is one of Bach's most well-known organ pieces. The fugue is quite fast, with only eighth-notes and sixteenth-notes intermingling.

As can be seen in Figure 13, Fagius' articulation is in no way distinguished; for many notes it comes close to the average articulation of the other three organists. Still, it is hard to find patterns. In Figure 10 three different articulations have been indicated, but the boundaries between them are quite arbitrary. There is a tendency of shortening notes immediately preceding the beats, but this seems to be fully explained by corresponding lengthenings of the relative IOI's. In this way Fagius has emphasized the metrical structure, but he has not used any specific articulation strategy separable from simply adjusting the relative IOI's.

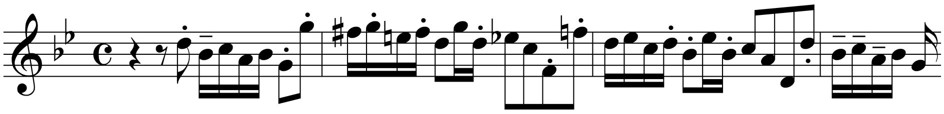

Figure 10. Articulation in BWV 542 for Fagius. Staccato dots indicate articulations of 0.56–0.79, portato strokes indicate articulations of 1.03–1.05, neither dots nor strokes indicate articulations of 0.81–0.98.

Turning to Hurford, it is not as easy to find distinct articulation types. Almost all articulation ratios are between 0.86 and 1.15. Four notes have articulation values below 0.76. These four notes are marked with staccato dots in Figure 11. They are not randomly scattered but are the last two notes in a recurrent group of four. All other notes have articulation values of 0.86 or more.

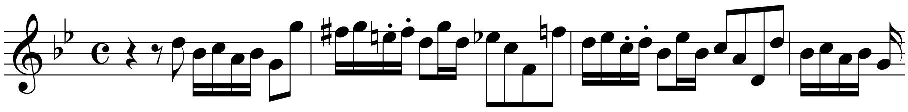

Figure 11. Articulation in BWV 542 for Hurford. Staccato dots indicate articulations of less than 0.76. All other notes have articulations of 0.86 or more.

According to Table 3, in Koopman has a mean articulation of 0.70, whereas Rilling has 0.93. Still, their articulation profiles are very similar, as shown in Figure 12. They have both adopted a binary type of articulation; either short (for Koopman 0.37–0.57, for Rilling 0.57–0.75) or long (for Koopman 0.73–1.04, for Rilling 1.02–1.20). Since they have chosen the same type of articulation for all tones, with only one or two exceptions, the points in Figure 12 are gathered in two distinct groups. What is the explanation of the striking similarity found in Koopman and Rilling? The answer is simple: All long notes (eighth-notes) are played short, while all short notes (sixteenth-notes) are played long (note the highly negative correlations for Koopman and Rilling in BWV 542 in Table 5).

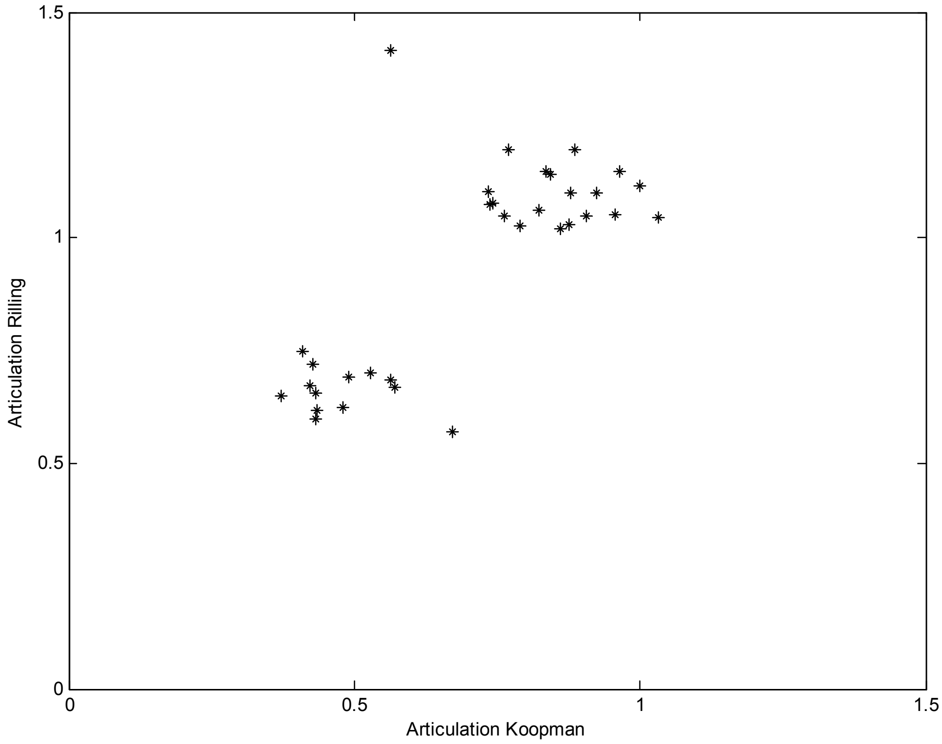

Figure 12. Articulation in BWV 542 for Koopman and Rilling. The binary character is clear in both performers, but it is most accentuated in Rilling.

Rübsam's articulation is less distinct. Nonetheless, looking at Figure 13 (lower panel), Rübsam uses approximately the same articulation as Koopman and Rilling, the difference being that Rübsam's is not binary but more blurred.

All data are shown in Figure 13.

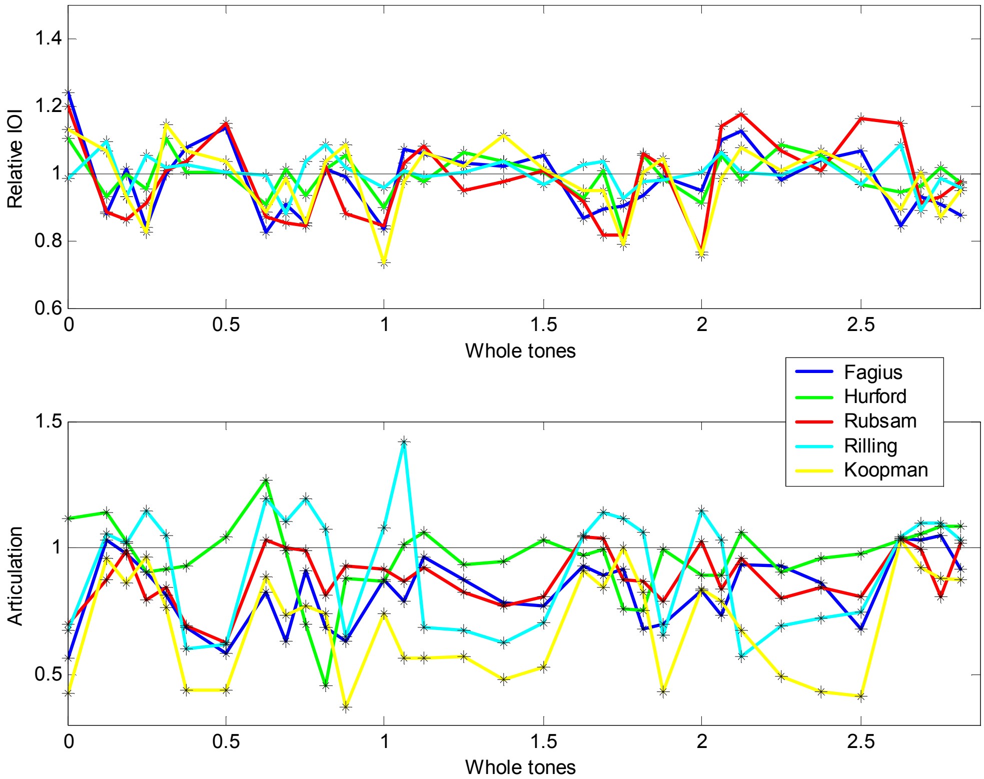

Figure 13: Relative IOI (top) and articulation (bottom) for all five performances of BWV 542.

4.3.4. BWV 544

BWV 544 turned out not to be very interesting. The theme consists entirely of eighth-notes, progressing stepwise (no leaps). All performers played legato (or almost so) all the way.

Figure 14 shows all data.

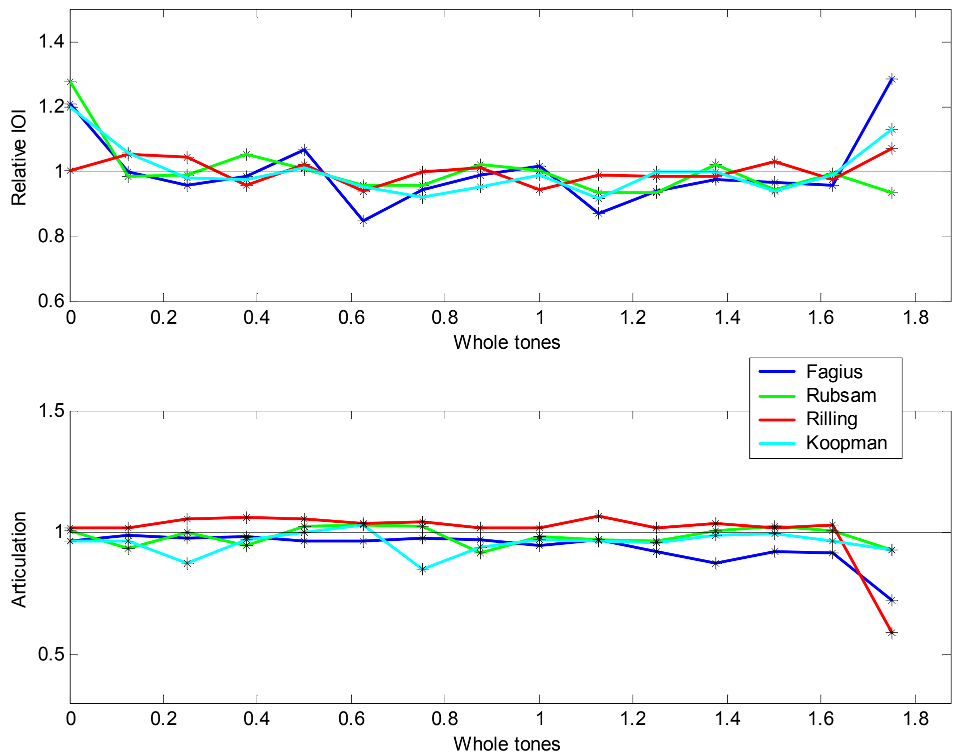

Figure 14: Relative IOI (top) and articulation (bottom) for all four performances of BWV 544.

4.3.5. BWV 548

The BWV 548 fugue, sometimes called 'the wedge' because of the shape of the subject, is an example of two melodic lines being compressed into one voice.

The up-beat is played short by all performers. In Fagius there is a tendency of playing the first eighth-note in each group of four notes longer than the second tone, which is a little longer than the third tone, which is a little longer than the fourth tone. However, the differences are not very conspicuous. In Hurford and Rübsam no articulatory patterns are found in the eighth-tone sequences.

All data are found in Figure 15.

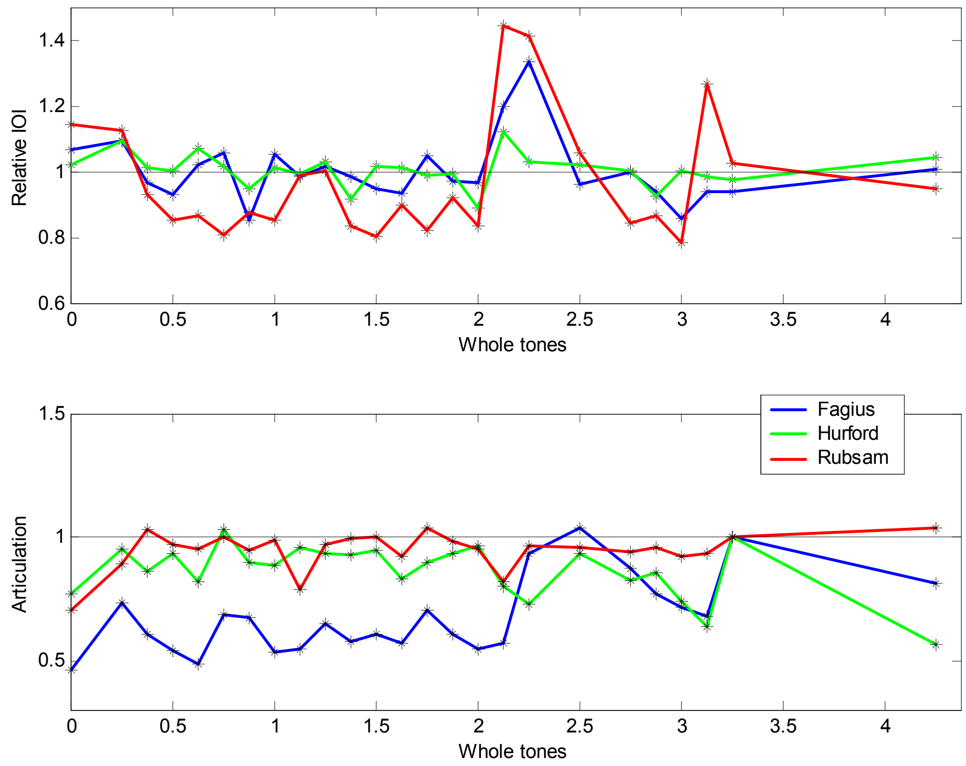

Figure 15: Relative IOI (top) and articulation (bottom) for all three performances of BWV 548. The trill has been assigned the articulation 1 (one) in all performances.

4.3.6. BWV 564

In BWV 564 there are notated pauses in the theme. Please observe that notes preceding pauses have been excluded from analysis.

Hurford and Fagius show a clear pattern relating articulation and metrical structure: Notes coinciding with strong beats are played legato, others are played staccato. In 6/8 time, strong beats are on the first and fourth eighth-notes of each bar; the other notes are weak. See Figure 16.

Figure 16. Articulation in BWV 564 for Hurford and Fagius. Staccato dots indicate articulations below 0.5 (for Hurford) or below 0.65 (for Fagius). Two tones are disputed.

Koopman's and Rübsam's articulations are similar to Hurford's and Fagius', but with even more tones made staccato. In particular, the fourth beat of each bar is played staccato. This was not the case with Hurford and Fagius. Koopman and Rübsam have very different "standard articulation" levels, their average articulation values being 0.65 and 0.86, respectively. Still, we see here another example of great similarities found in performers with very different average articulations. Figure 17 shows their articulations plotted against one another, Figure 18 shows the notated result.

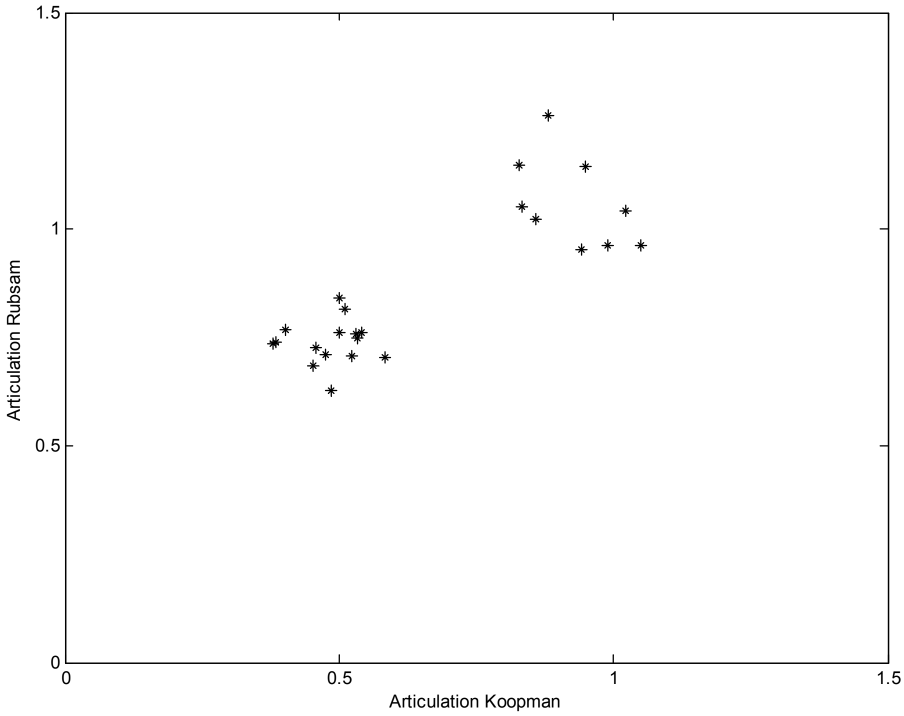

Figure 17. Articulation in BWV 564 for Koopman and Rübsam.

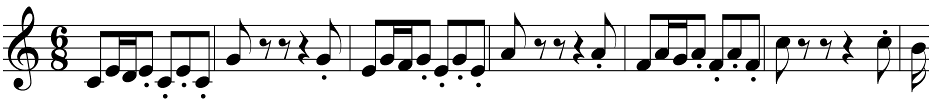

Figure 18. Articulation in BWV 564 for Koopman and Rübsam. Staccato dots indicate articulations below 0.6 (for Koopman) or below 0.85 (for Rübsam).

Figure 19 shows all data.

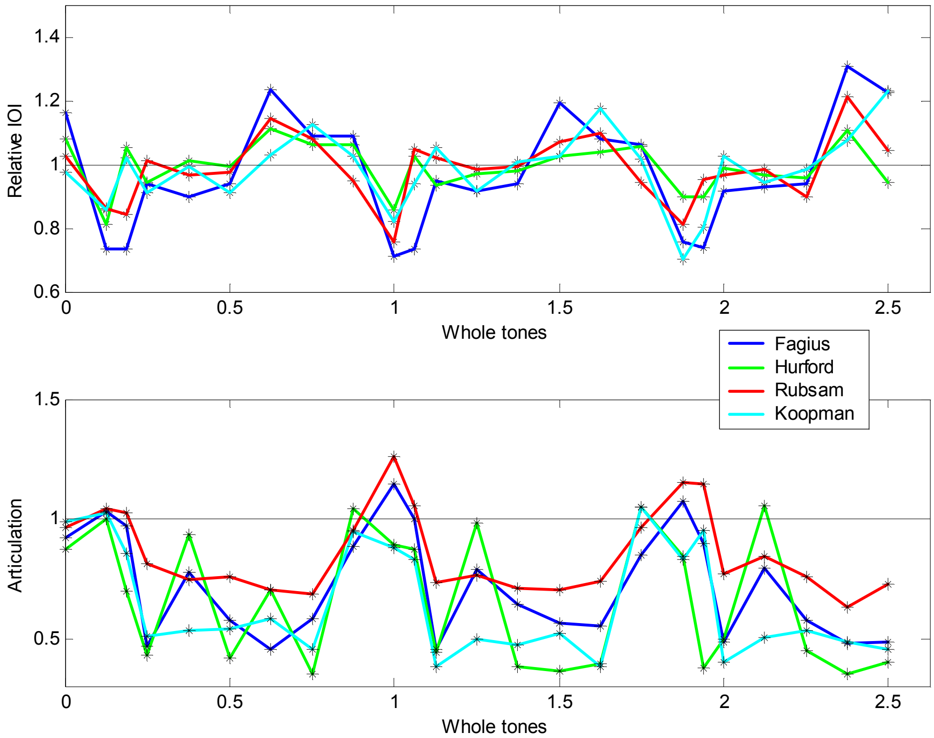

Figure 19: Relative IOI (top) and articulation (bottom) for all four performances of BWV 564. Please observe that notes followed by pauses have been excluded.

4.3.7. BWV 578

The BWV 578 theme is both rhythmically and melodically, but perhaps not harmonically, varied. It includes several leaps greater than or equal to a fourth.

In both Fagius and Rübsam, many staccato notes are metrically weak. They appear, for example, on the last eighth-note or on the last sixteenth-note of each beat (the theme is in common time, so there are four beats in each bar). In other words, they do not appear on the beats at all. This behaviour is very evident in Rübsam, although he also plays some other tones staccato. In Fagius, all staccato tones are of this kind, with only two exceptions (the D in the second bar, and the G in the fourth bar). So even though I have marked 21 notes staccato in Rübsam, but only 10 notes in Fagius, I would say that they share an overall strategy, shortening the articulation on metrically weak notes. Figures 20 and 21 show the notated result.

Figure 20. Articulation in BWV 578 for Rübsam. Staccato dots indicate articulation below 0.9.

Figure 21. Articulation in BWV 578 for Fagius. Staccato dots indicate articulation below 0.85

Rilling shows an almost uniform legato articulation throughout the excerpt. Scrutinizing his few staccato tones reveals that they appear at the end of bars 2 and 3. I believe this is Rilling's way of marking the phrase ends; he thus sees bars 1-2 as one phrase, bar 3 as one phrase, and bars 4-5 (or possibly even longer) as one phrase. Figure 22 shows Rilling's articulation in musical notes.

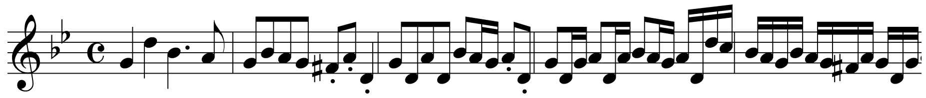

Figure 22. Articulation in BWV 578 for Rilling. Staccato dots indicate articulation below 0.8.

Koopman's articulation is crisper. He plays staccato on all eighth-notes followed by leaps, plus the last note of the second bar. See Figure 23.

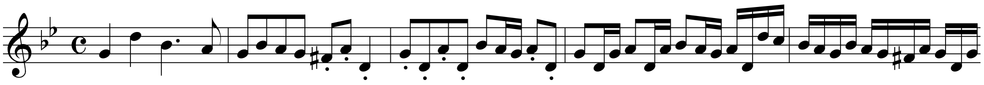

Figure 23. Articulation in BWV 578 for Koopman. Staccato dots indicate articulation below 0.715.

Figure 24 shows all data.

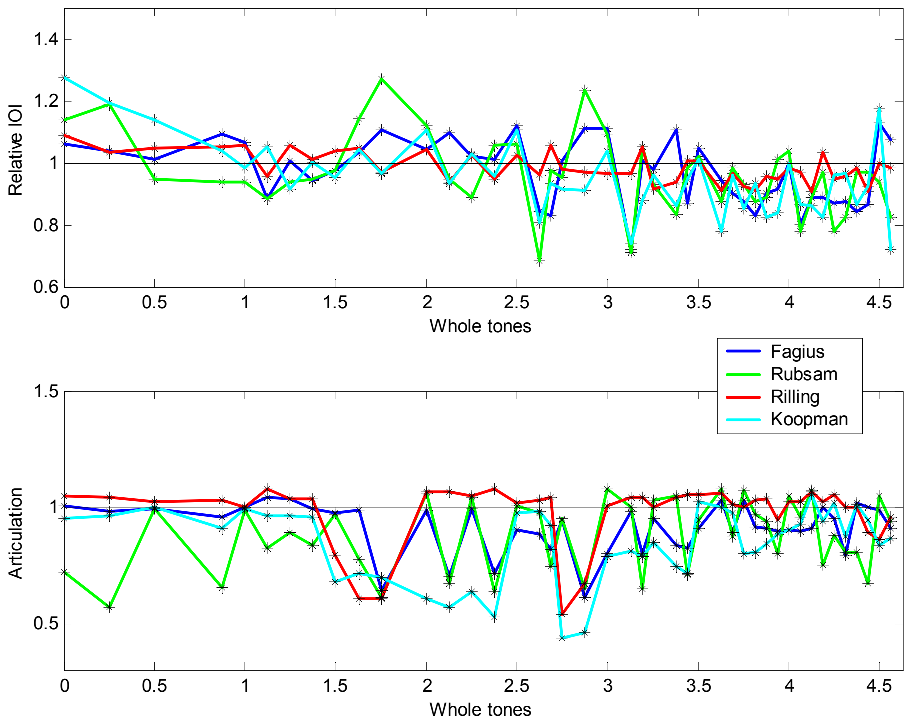

Figure 24: Relative IOI (top) and articulation (bottom) for all four performances of BWV 578.

5. DISCUSSION AND CONCLUSIONS

This investigation has given some quantitative results. First, the mean articulation was 0.86, with a standard deviation of 0.15 across the whole material. It is not easy to know how strongly influenced is the result from the type of instrument (organ) or from the type of music (Bach fugue openings). Articulation similarity between performers of the same piece was almost as high (mean correlation 0.44) as the relative IOI similarity (mean correlation 0.46). The difference is too small to be statistically significant, but if it is real I believe it can be explained by the relative IOI being not only an articulation strategy, but most of all a phrasing strategy. Relative IOI adjustments act also on a larger scale, making them more robust.

Secondly, in most performances, the correlation was negative between articulation and relative IOI. Although there were differences between pieces (Table 6, right column), they were not greater than those between performers (Table 7). Therefore, as an approximation of the first order, we could say that articulation and relative IOI are inversely related, roughly speaking.

A general result of more qualitative character is that performers may have different average articulation but still share the same articulatory strategy. Thus an articulation of 0.75 could be staccato for one performer, but legato for another. This might perhaps not be surprising, but it is nevertheless a basic result to keep in mind in all discussions on articulation.

Up-beat tones are often played short in the studied material. It is possible that this is a rule that applies to a vast majority of all cases.

Another result is the occurence of binary articulation. This term means that the performer articulated each tone either short or long. The most clear examples were found in BWV 542 and BWV 564. Both these themes are rather fast and are made out of only two note-values. The existence of binary articulation is interesting from a computer-control point of view, for it could facilitate successful simulation of realistic articulation. It would only be a matter of determining for each tone whether it is short or long. Within the two articulation groups the exact articulation values could be computed by adding or subtracting small random values so that not all tones in the same group (short or long) will get exactly the same articulation.

Other articulation strategies enhance the phrasing or the metrical structure (with more staccato on weak beats). Some strategies seem to be mutually exclusive.

All in all, we have ended up with a bundle of diverse results. To be fair, they do point at any clearly dominant factor always determining the articulation.

Therefore, when modelling musical articulation, e.g. in order to implement a rule system for computers, one should probably not try to apply all conceivable rules at the same time. Instead, one should implement a collection of rules belonging to one overall strategy. Although I can not tell, at present, how many such strategies there could be, three candidates are binary articulation, articulation enhancing phrasing, and articulation enhancing metrical structure. If the relative IOIs are computed from some other rules (as in, e.g. Director Musices [21]), indications of a reasonable articulation could be given by using an inverse relationship between relative IOI and articulation, even without applying any particular articulation strategy.

In conclusion, even though musical articulation might be hard to model, it is well worth trying. The present study suggests that performers often articulate in comprehensible ways, but it is difficult to tell which strategy is to be chosen in a particular piece. Some of the strategies are mutually exclusive. Still the mean intraperformer correlation is almost as high for articulation as for relative IOI, the variations of which have been studied and modelled by many researchers. Articulation seems to be no more random than, say, phrasing, but it is certainly more complex.

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