

人工知能研究室

指導教員

水谷哲也 講師

学生数

現在 B4:2名, M1:2名, M2:1名

募集人数

1人

水谷は2026年3月定年の予定なので、
大学院志望者はできるだけこの研究室を選ばないでください。

研究内容

人工知能とプログラム理論の融合による知見を用いた音楽情報学の研究

音楽の構造的機能とそれに基づく演奏創造

楽曲の構造的分析と演奏表情との関係

楽曲演奏におけるオンセット情報の抽出 など

単にコンピュータで音楽を演奏するのではありません。

音楽における人間の「知性」と「感性」、「知」と「思」を論理的・数理的に捉えて
モデル化する研究を行います。

なお、特に希望がある場合は、プログラム理論に関する研究、特に

実時間知的プログラムの検証、検証理論の構築

具体例(自動演奏システムなど)への適用・解析

などを行うこともできます。

教員と相談の上、他の興味を持ったテーマを選ぶことは差し支えありません。

演奏表情の自動生成 演奏モデルの作成

どのようにして人間らしい表情豊かな演奏を生成するか
人間らしい演奏のモデルをどのように作成するか

楽曲構造分析

楽曲に内在する緊張, 誘引などの抽出

演奏の解析
(重回帰分析など統計的手法を用いる)

Musical Expression Analysis

- Musical Expression
 - Constructed by
 - note value, pitch, harmony, musical symbols
 - chord progression, melodic motion, progression, etc.
 - repetition of tension and relaxation structures
 - hierarchical tonal tension structures from musical scores [Lerdahl01]
 - Creation of musical rendition models
 - Analyzed by hierarchical tonal tension rules
 - Accurate but very complicated

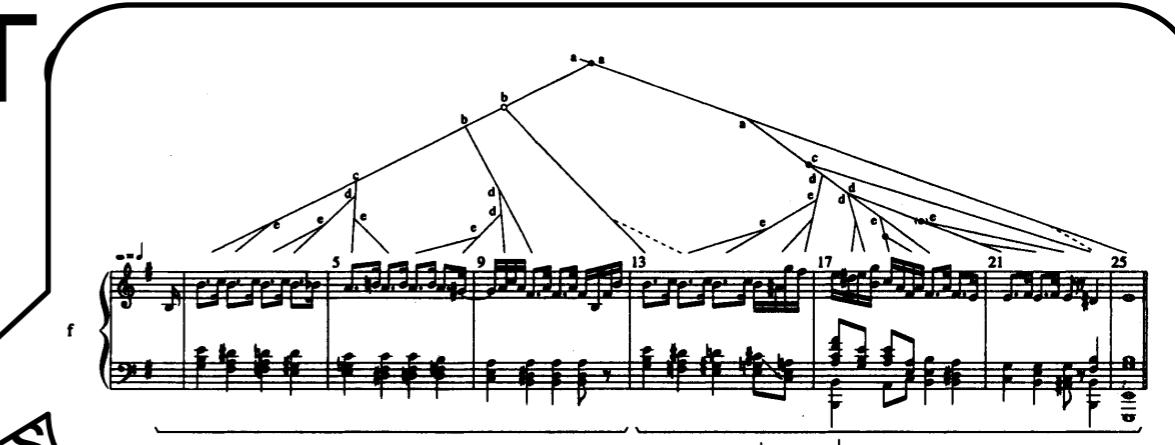
[Lerdahl01] F. Lerdahl, Tonal Pitch Space, Oxford University Press, Oxford, 2001.

Hierarchical Tonal Tension Rules

- Representing of the tension in music score hierarchically
- Assigned value to each chord
- Defined by the prolongational tree and the chord distance
 - The prolongational tree :
 - the hierarchical relationship among events
 - This is very complicated;
 - High level musical knowledge and deep understanding of musical theories are required
 - The chord distance: defined in the cycle of fifth of diatonic scale

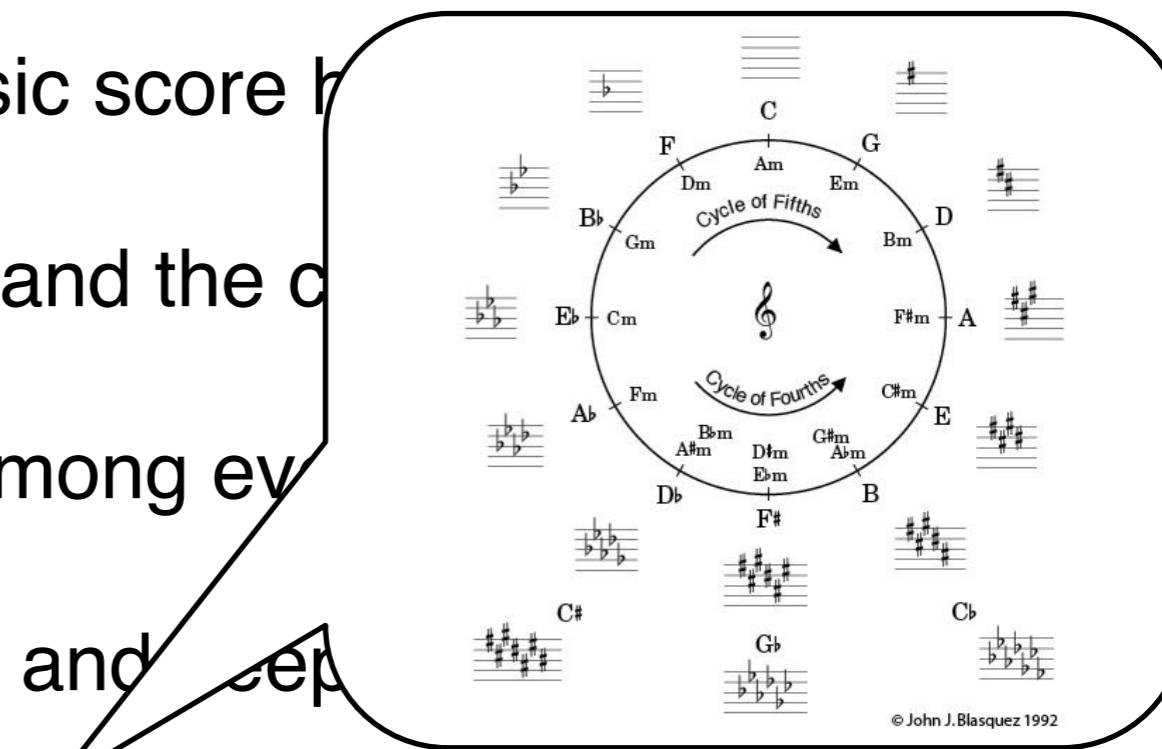
Hierarchical Tonal Theory

- Representing of the tension in musical structures
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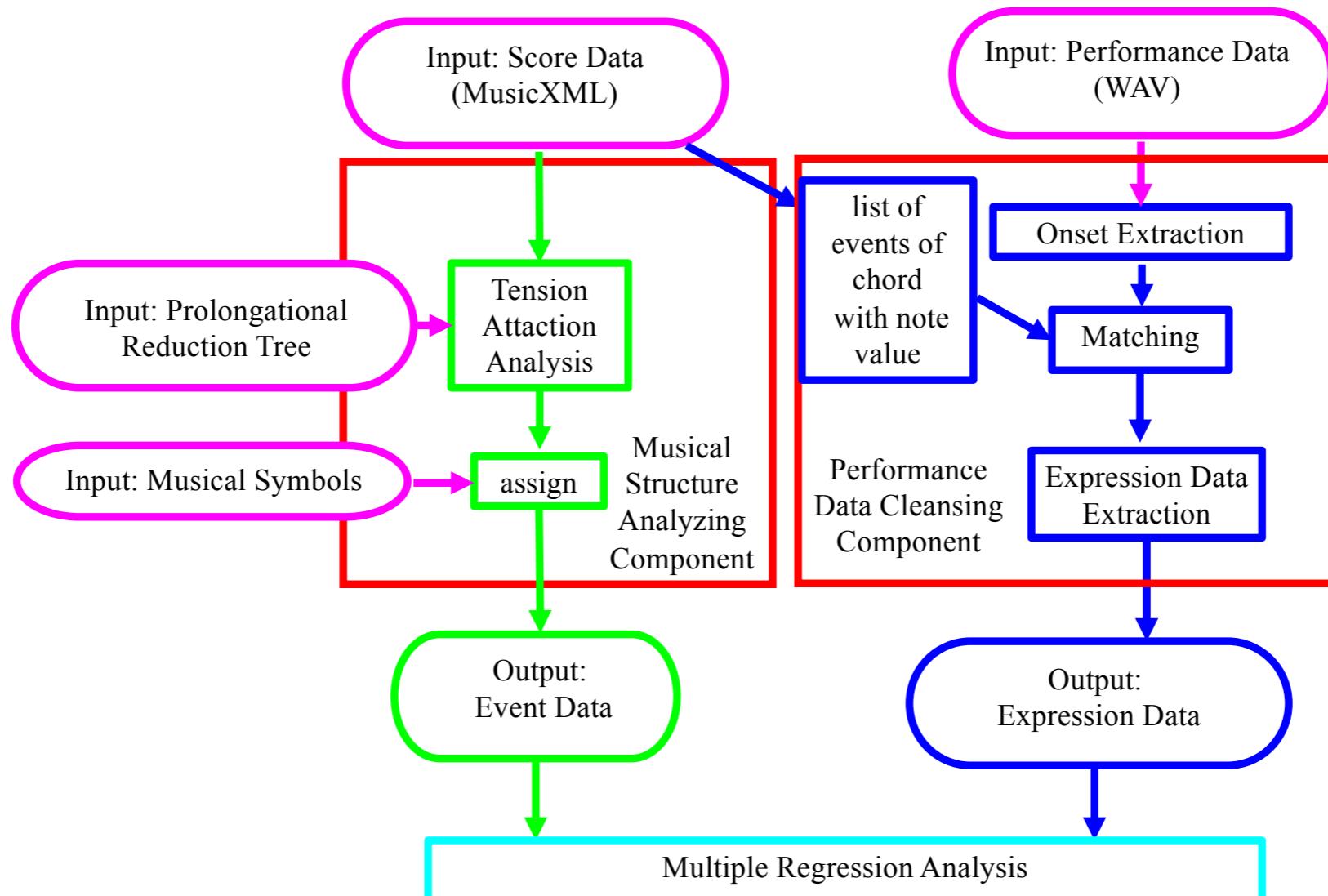


Hierarchical Tonal Tension Rules

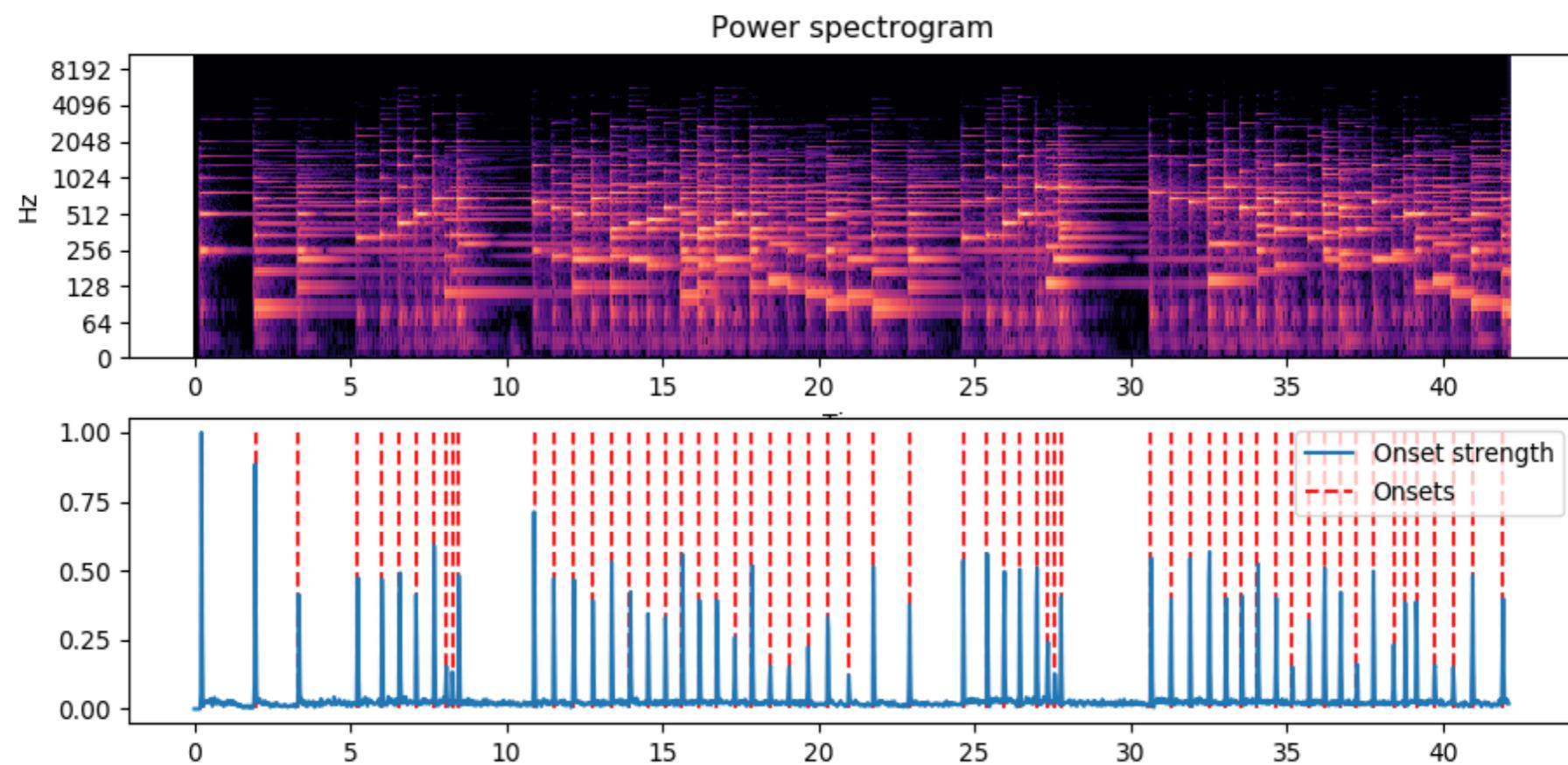
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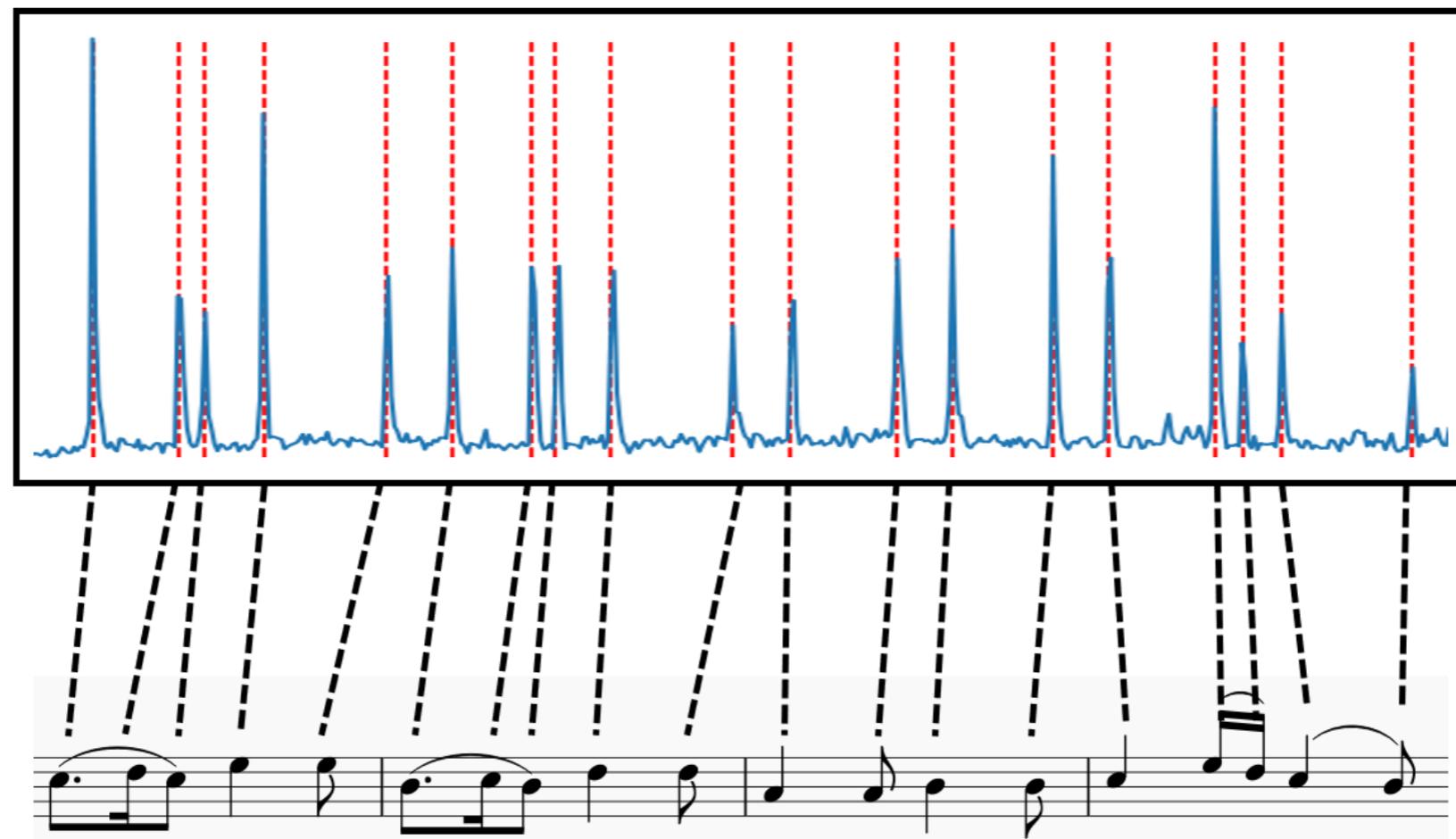
Data Cleansing System



Onset Time Extraction



Matching Onset Times with Events



Analysis of Actual Musical Performances

Musical Data

Composer	Music Title	Pianist
L. v. Beethoven	Piano Sonata No. 8, Op. 13 in C minor, "Sonata Pathétique"	C. Arrau V. D. Ashkenazy W. Backhaus † I. Nakamichi
F.F. Chopin	Nocturne, Op. 9, No. 2 in E-flat major	V.D. Ashkenazy S. S. Bunin V. S. Horowitz M. J. Pires † A. Yokouchi † V. Lisitsa
	Étude Op. 10, No. 3 in E major, "Tristesse"	V. D. Ashkenazy † I. Nakamichi
	Prelude, Op. 28, No. 15 in D-flat Major, "Raindrop"	V. D. Ashkenazy † J. Bolet
R. A. Schumann	Kinderszenen, Op. 15, No. 7 in F major, "Träumerei"	V. D. Ashkenazy I. F. Hemming V. S. Horowitz
M.A. Mozart	Piano Sonata No. 11, K. 331 in A major, Movement I	C. Eschenbach G. H. Gould I. Haebler L. Kraus A. deLarrocha H. Nakamura M. J. Pires N. Shimizu † O. Jegunova † D. Barenboim

†: from YouTube
no mark: from CrestMusePEDB

Analysis Results

Correlation Coefficients vs Change of Tempo

Music	Pianist	vs. tension	vs. attraction
Nocturne	Ashkenazy	-0.253**	0.064
	Pires	-0.160	-0.211**
Tristesse	Ashkenazy	-0.325**	0.189
K.331	Eschenbach	0.296*	0.091
	Pires	0.039	0.274

“**” coefficient is meaningful under the significant level 0.05

“*” coefficient is meaningful under the significant level 0.1

1. Except for K. 331, each music is performed as its tempo tends to faster if the corresponding tension increases.
2. There is no such feature about attraction values.
3. Every coefficient is rather small, i.e. there are only weak correlation.

Analysis Results

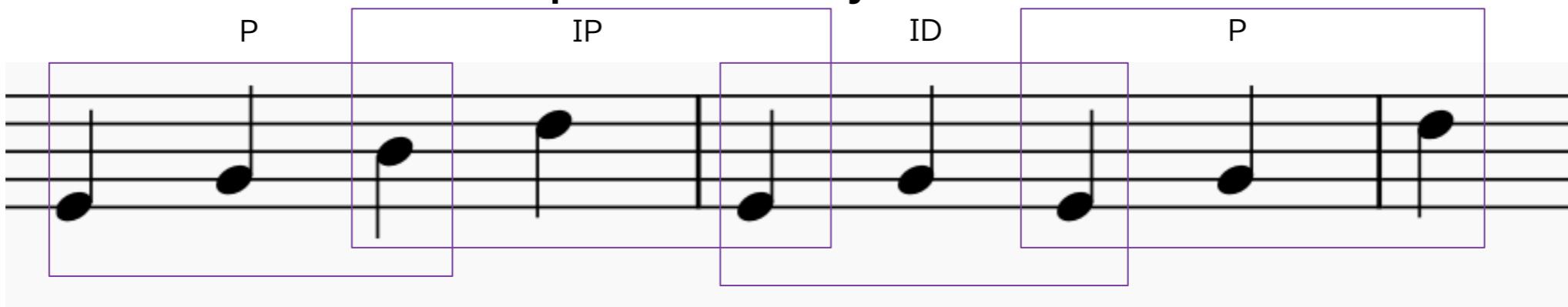
Top 5 Explanatory Variables of Partial Regression Coefficients for change of tempo.

rank	Pathétique	Nocturne	Tristesse	Raindrop	Träumerei	K. 33 I
1	piano_start_M	cre_start_A*	rit_start	graced_M	suc_grace_M	slur_count_M
2	staccato_A	decre_cont_M*	tenuto_M*	suc_grace_M	forte_start_M	sforzando_M
3	staccato_M	piano_start_M	rit_end	piano_start_M	piano_start_M	slur_M
4	slur_start_M*	decre_start_M*	piano_start_M	-	cre_end_M*	piano_start_A
5	slur_end_M	decre_end_M*	accent_M	-	graced_M*	slur_start_M*

4. Almost all music performances are affected by “piano” musical symbol, which is to be played “softly”.
Though most amateur or unnamed pianists often play it as “quietly”, top pianists play it as rather “slowly”.
5. Musical symbols on a melody part affect stronger than that on an accompaniment part. It means that pianists intend to let listeners listen and feel the change of tempo of the melody part rather than the accompaniment part.

Implication-Realization Model

- A melody is divided into some segments by rests or significant changes of consecutive note values.
- A segmented note sequence is abstracted in a sequence of three notes so that one note overlaps with consecutive one and converted into a sequence of symbols.



Symbols of I-R Model

Symbol Name				
D (duplication)				
ID (intervallic duplication)				
P (process)				
IP (intervallic process)				
VP (registral process)				
IR (intervallic reversal)	G4	A4	G4	
R (reversal)	Interval direction changes Large interval and small interval		Realization	Denial
VR (registral reversal)	Interval direction changes Small interval and large interval		Denial	Denial

Analysis

Musical Data from CrestMusePEDB [Crest]

Composer	Music Title	Pianist
L. v. Beethoven	Piano Sonata No. 8, Op. 13 in C minor, “Sonata Pathétique”	C. Arrau W. Backhaus V. D. Ashkenazy
R. A. Schuman	Kinderszenen, Op. 15, No. 7 in F major, “Träumerei”	V. D. Ashkenazy I. F. Hemming V. S. Horowitz
M.A. Mozart	Piano Sonata No. 11, K. 331 in A major, Movement 1 (K331)	N. Shimizu A. de Larrocha C. Eschenbach G. H. Gould L. Haebler L. Kraus H. Nakamura M. J. Pires
F.F. Chopin	Nocturne, Op. 9, No. 2 in E-flat major	V. D. Aashkenazy M. J. Pires S. S. Bunin V. S. Horowitz
	Etude Op. 10, No. 3 in E major Tristesse	V. D. Aashkenazy
	Prelude, Op. 28, No. 15 No. 7 in F major Raindrop	V. D. Aashkenazy

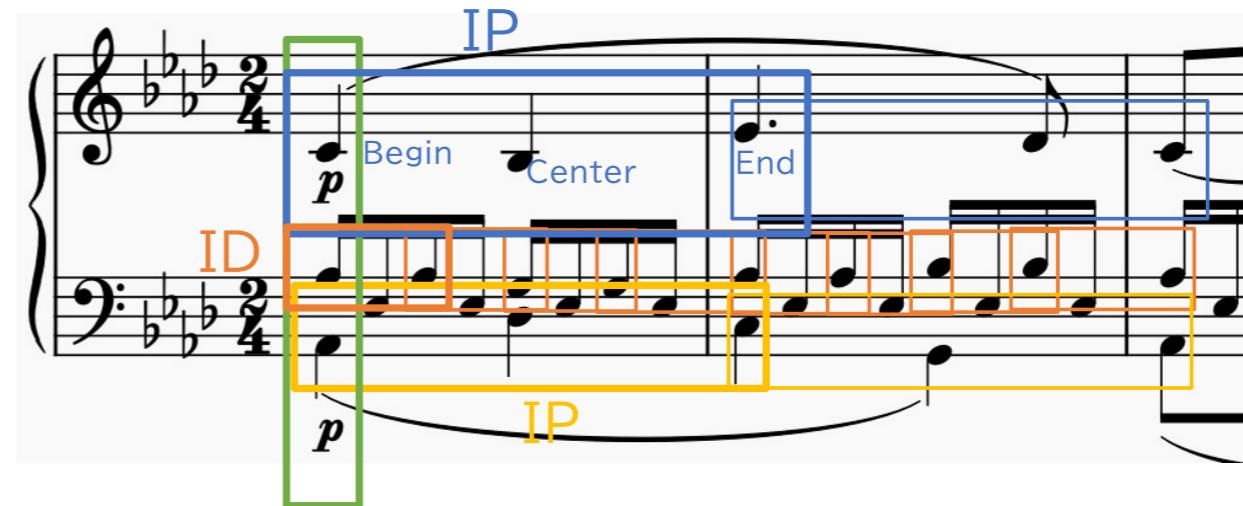
[Crest] CrestMusePEDB. [Online] <http://www.crestmuse.jp/pedb/>

Multiple Regression Analysis

- Objective variable:
 - Local tempo obtained from actual performance
 - Extracting the onset time from the actual performance;
 - Matching to the correponding notes in the score;
 - Then calculating the local tempo of each event of chord
 - Explanatory variables:
 - Number of symbols of the I-R model assigned to event of chord

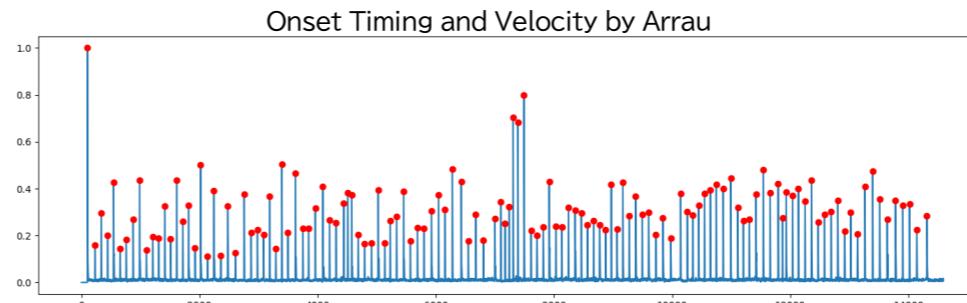
Piano Sonata No. 8,
Op. 13 in C minor,
Sonata Pathétique
by L.v. Beethoven

Symbols:



Explanatory variables:
number of symbols in
events of chords

	Explanatory Variables																							
Event Number	PB	PC	PE	IPB	IPC	IPE	RB	RC	RE	VRB	VRC	VRE	IRB	IRC	IRE	DB	DC	DE	IDB	IDC	IDE	MONAD	DYADB	DYADE
1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
4	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
5	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
8	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
11	1	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
12	1	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
13	1	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
15	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
16	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
17	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	2	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	2	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	2	2	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	2	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0



The objective variable :
the local tempo

Comparison of the Analysis with the Previous Study

Music Title	Pianist	Coefficient of Determination		Correlation Coefficient	
		Previous Study	This Analysis	Previous Study	This Analysis
Sonata Pathétique	Arrau	0.0671	0.1716	0.376	0.570
	Backhaus	0.178	0.1301	0.510	0.539
	Ashkenazy	0.111	0.1207	0.429	0.532
Träumerei	Ashkenazy	0.315	-0.006542	0.818	0.815
	Hemming	0.415	-0.244	0.547	0.480
K331	Shimizu	0.0588	0.2387	0.593	0.577
	deLarrocha	0.382	0.03546	0.557	0.559
	Eschenbach	0.297	0.03569	0.655	0.560
	Gould	-0.0815	0.1357	0.419	0.620
	Haebler	0.667	0.1798	0.560	0.645
	Kraus	0.357	0.1988	0.622	0.655
	Nakamura	-0.0687	0.179	0.362	0.644
	Pires	0.180	0.09949	0.443	0.599
	Aashkenazy	0.594	0.115	0.689	0.315
Nocturne	Pires	0.240	0.0548	0.656	0.423
	Bunin	0.208	-0.008	0.548	0.353
	Horowitz	0.113	-0.0136	0.505	0.346
	Aashkenazy	0.198	-0.03735	0.861	0.474
Etude Raindrop	Aashkenazy	0.594	0.115	0.521	0.348

来年度の予定(希望)

現在の研究のさらなる発展

演奏モデル・演奏ルールの確立

prolongational structureを用いない楽曲・演奏分析方法の確立
演奏データと楽譜情報とのマッチング(特に演奏が不正確のとき)

楽曲演奏におけるオンセット情報の抽出

ゼミの内容, 時間など

ゼミの内容は論文輪講, 研究の進行状況の報告とそれに対するディスカッション
および教員の助言・指導が中心です。

曜日・時間は教官および学生の予定を考慮して定めます。

ゼミはまじめに出席しましょう。ゼミ以外の時間にもこまめに研究室に顔を出して
教員および他の研究室員と非公式のディスカッションを行うことが肝要です。