

# Book: Fundamentals of Music Processing



#### Meinard Müller

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Accompanying website: www.music-processing.de

# Dissertation: Tonality-Based Style Analysis

Christof Weiß Computational Methods for Tonality-Based Style Analysis of Classical Music Audio Recordings Dissertation, Ilmenau University of Technology, 2017

Chapter 7: Clustering and Analysis of Musical Styles Chapter 8: Subgenre Classification for Western Classical Music





#### **Recall: Chroma Features**







- Better categories?
- Musical style
- Independent from instrumentation
- $\rightarrow$  Tonality / Harmony





### **Classification Scenario**

- Dataset: CrossEraDB (Historical Periods)
  - Balanced Piano (p) Orchestra (o)
  - Each 200 pieces  $\rightarrow$  1600 in total



# **Classification Scenario**



#### **Classification Features**

MFCC	16	Interval cat.	6 x 4		
OSC	14	Triad types	4 x 4 7 x 4		
ZCR	1	Complexity			
ASE	16	Chord progr.	11 x 5		
SFM	16				
SCF	16				
SC	16				
LogLoud	12				
NormLoud	12				
Sum	119	Sum	123 x 2		
Mean & Std	x 2	Mean & Std			
Total	238	Total	246		

#### **Dimensionality Reduction**

- Reduce feature space to few dimensions (prevent curse of dimensionality)
- Maximize separation of classes with Linear Discriminant Analysis (LDA)
- Using standard features (MFCC, spectral envelope, ...)



# **Dimensionality Reduction**

- Reduce feature space to few dimensions
- Maximize separation of classes with Linear Discriminant Analysis (LDA)
- Using tonal features (interval, triad types, tonal complexity, ... 4 time scales)





# **Classification methods**

k Nearest Neighbours (kNN)



#### **Classification methods**

Decision Trees (DT)



# **Classification methods**

k Nearest Neighbours (kNN)



# **Classification methods**

Random Forests (RF)





# **Classification methods**

Support Vector Machines (SVM)



# **Classification methods**

Deep Neural Networks (DNN)



#### **Classification methods**

Gaussian Mixture Models (GMM)



# **Classification methods**

Deep Neural Networks (DNN)



# **Classification Results**

Gaussian Mixture Model (GMM) classifier, LDA reduction, 3-fold cross validation

	Full Dataset	Piano	Orchestra
Standard features	87 %	88 %	85 %
Tonal features	84 %	84 %	86 %
Combined	92 %	86 %	80 %

Weiss / Mauch / Dixon, Timbre-Invariant Audio Features for Style Analysis of Classical Music, ICMC / SMC 2014

## **Classification Results**

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Overfitting???

Weiss / Mauch / Dixon, Timbre-Invariant Audio Features for Style Analysis of Classical Music, ICMC / SMC 2014

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Flexer, A Closer Look on Artist Filters for Musical Genre Classification, ISMIR 2007

## **Classification Results**

GMM classifier, LDA reduction, 3-fold cross validation

No	composer	filter
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	Full Dataset	Piano	Orchestra	
Standard feature	s 87 %	88 %	85 %	
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ing composer filter				
ing composer filter	Full Dataset	Piano	Orchestra	
ing composer filter Standard feature	Full Datasets54 %	<b>Piano</b> 36 %	Orchestra 70 %	
ing composer filter Standard feature Tonal features	Full Dataset   s 54 %   73 %	<b>Piano</b> 36 % 70 %	<b>Orchestra</b> 70 % 78 %	
ing composer filter Standard feature Tonal features Combined	Full Dataset       s     54 %       73 %     68 %	<b>Piano</b> 36 % 70 % <b>44 %</b>	Orchestra 70 % 78 % 68 %	

Weiss / Müller, Tonal Complexity Features for Style Classification of Classical Music, ICASSP 2015

# Classification Results

- GMM classifier, LDA reduction, 3-fold cross validation
- No composer filter

	Full Dataset	Piano	Orchestra	
Standard features	87 %	88 %	85 %	
Tonal features	84 %	84 %	86 % 80 % Orchestra	
Combined	92 %	86 %		
ng composer filter	Full Dataset	Piano	Orchestra	
ng composer filter Standard features	Full Dataset	Piano 36 %	Orchestra 70 %	
ng composer filter Standard features Tonal features	<b>Full Dataset</b> 54 % 73 %	Piano 36 % 70 %	<b>Orchestra</b> 70 % 78 %	
ng composer filter Standard features Tonal features Combined	Full Dataset       54 %       73 %       68 %	Piano 36 % 70 % 44 %	Orchestra 70 % 78 % 68 %	

Weiss / Müller, Tonal Complexity Features for Style Classification of Classical Music, ICASSP 2015

#### **Classification Results**

- What is actually learned?
- Pay attention to:
- Overfitting
- "Curse of dimensionality" use dimensionality reduction techniques
- Artist / album effects
- Evaluation: "Figures of merit":
- Confusion matrix
- Error examples: Consistently misclassified itemsListening tests
- Evaluation on unseen data (no cross validation)

Bob Sturm, Classification Accuracy is not enough, Journal of Intelligent Information Systems, 2013

# **Classification Results - Confusion Matrix**

- 80 tonal features, GMM with 1 Gaussian, LDA, composer filtering
- Full dataset
- Mean accuracy: 75 %
- Inter-class standard deviation: 6.7 %



# Classification Results: Error Examples

- 80 tonal features, GMM with 1 Gaussian, LDA
- Look at consistently and persistently misclassified items

Class	Composer	Piece	Classified
Baroque	Bach, J. S.	Well-Tempered Piano 1, Prelude in E>minor BWV 853	Romantic
Baroque	Bach, J. S.	Well-Tempered Piano 1, Prelude in F major BWV 856	Romantic
Baroque	Bach, J. S.	Well-Tempered Piano 1, Prelude in A minor BWV 865	Romantic
Baroque	Bach, J. S.	Well-Tempered Piano 1, Prelude in B <sup>5</sup> major BWV 866	Romantic
Baroque	Bach, J. S.	Well-Tempered Piano 1, Prelude in B <sup>\$</sup> minor BWV 867	Romantic
Baroque	Bach, J. S.	English Suite No. 3 in G minor BWV 808, Sarabande	Romantic
Baroque	Bach, J. S.	Brandenburg Conc. No. 1 in F major BWV 1046, Adagio	Romantic 🕨
Baroque	Bach, J. S.	Overture No. 2 in B minor BWV 1067, Badinerie	Romantic
Baroque	Bach, J. S.	Overture No. 3 in D major BWV 1068, Gigue	Romantic
Baroque	Couperin, F.	27 Ordres, Huitième ordre, IX. Rondeau passacaille	Romantic
Baroque	Corelli, A.	Concerto grosso op. 6 No. 2, III. Grave – Andante largo	Romantic
Baroque	Lully, JB.	Ballet de Xerces LWV 12, Gavotte en rondeau	Romantic
Baroque	Purcell, H.	Opera "Dido and Aeneas" Z. 626, Overture	Romantic
Baroque	Vivaldi, A.	"The Four Seasons," RV 293 "Autumn," Adagio molto	Romantic
Romantic	Schumann, R.	Kinderszenen op. 15, "Haschemann"	Baroque
Romantic	Grieg, E.	Holberg suite op. 40, Gavotte	Baroque 🕨
Romantic	Mendelssohn, F.	Symphony No. 4 in A major, IV. Saltarello, presto	Baroque
Modern	Shostakovich, D.	Preludes & Fugues op. 87 Fugue No. 1 in C major	Baroque
Modern	Shostakovich, D.	Preludes & Fugues op. 87 Fugue No. 5 in D major	Baroque

# Musical Style Analysis



# Musical Style Analysis - Complexity



# **Clustering: Pieces**





# **Clustering: Years**

- Features: Interval, complexity, chord progressions
- Dimensional reduction with Principal Component Analysis (PCA)
- k-means clustering with different number of clusters k

1	Г													8		
2						b							а			
3						b					c				а	
4	Г				8				c	b			d		8	
X 5		с			b			а				e		d		
ater		ſ			b			а		e		d			0	
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Z 11		6	k		f		h	1		b	j	g		8	c	d
12	d	h	f		i		1	j		с	а	k		0	ь	9
13	k	а	h		e		d	j		c	f	m	i	1	b	9
14	j	1	а		9	d	h	h b		k	f	e	m	0	n	i.
15	0	0	i.		9	d	1	k	b	c	m	а	n	h	1	f
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# **Clustering: Composers**





# Clustering: Composers



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1900 1950 2000

1850