A Novel Representation of Sequence Data based on Structural Information for Effective Music Retrieval

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Outline

- Introduction
- Rule-based Representation
  - Frequent Rule
  - Correlative Rule
- Experimental Results
- Conclusion

Introduction (1/4)

- The growth of **sequence data**
  - *Customer transactions, stock sequences, and music data*
- Application of sequence analysis
  - *Customer behavior analysis, stock price prediction, music classification and retrieval*
- Approaches for sequence analysis

Introduction (2/4)

- Similarity search
  - **Sequence representation** and Similarity measure
- Two types of sequence representation
  - Global representation
  - Local representation

Introduction (3/4)

- Sequential pattern approach

Seq. ID	Sequence	Representation
S_1	<ACGAG>	{<A>, <G>}
S_2	<EAF>	{<A>,<E>,<EA>}
S_3	<BDBDEA>	{<E>, <EA>}
S_4	<GGAGA>	{<A>, <G>}

Frequency threshold = 0.4

Sequential patterns: {<A:0.75>, <E:0.5>, <G:0.5>, <EA:0.5>}

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Introduction (3/4)

- Sequential pattern approach
  - ✓ Losing the characteristics of sequence

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- Sequential pattern approach
  - ✓ Losing the characteristics of sequence
  - ✓ Ignoring sequential relationship

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Introduction (4/4)

- Markov Model approach

Markov model of <ADBECADBC>

	A	B	C	D	E
A	0	0	0	1	0
B	0	0	0.5	0	0.5
C	1	0	0	0	0
D	0	1	0	0	0
E	0	0	1	0	0

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Introduction (4/4)

- Markov Model approach
  - ✓ Losing some subsequences

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Introduction (4/4)

- Markov Model approach
  - ✓ Losing some subsequences
  - ✓ No frequency information

Markov model of <ADBECADBC>

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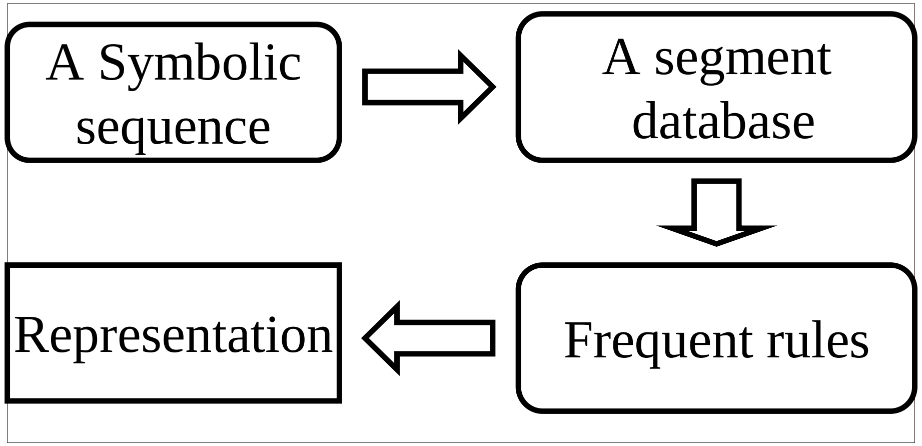
A Rule-based Representation - Overview



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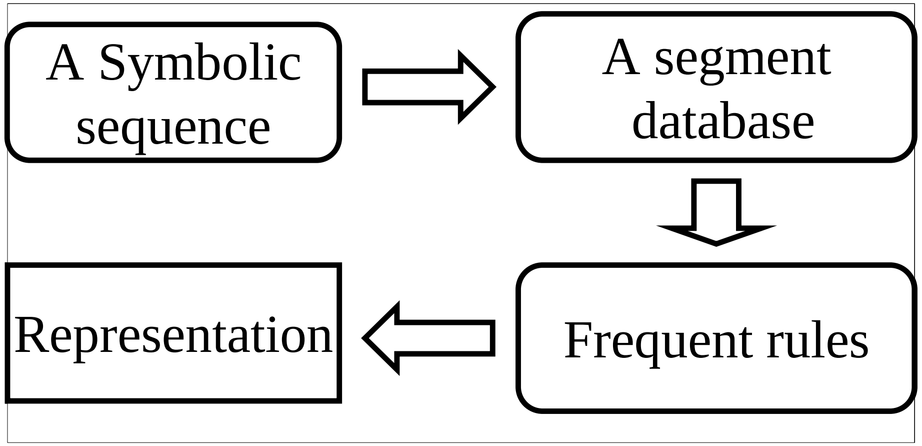

A sequence <BDBCDBCADB>
window size = 4

WID	Window	WID	Window
W_1	BDBC	W_6	BCAD
W_2	DBCD	W_7	CADB
W_3	BCDB	W_8	ADB
W_4	CDBC	W_9	DB
W_5	DBCA	W_{10}	B

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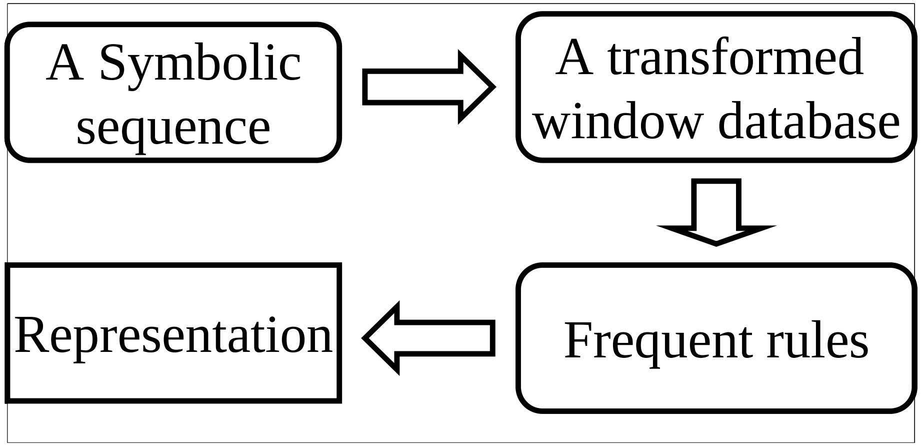

- ✓ Frequent Patterns
  - ✓ subsequences whose first elements are the first elements of windows
  - ✓ satisfy the frequent frequency threshold (minsup = 0.2)
  - ✓ {<B>, <C>, <D>, <BC>...}

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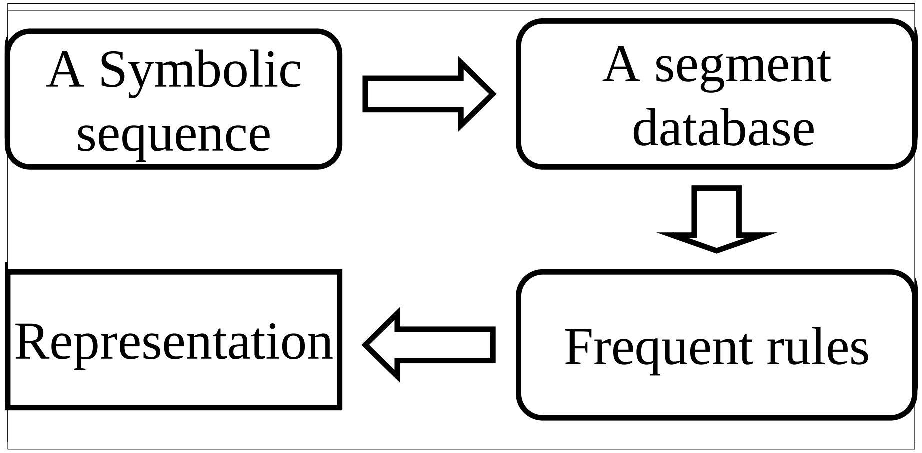

- ✓ Frequent Rules
  - ✓ <X> → <Y>
  - ✓ <XY>, <X> and <Y> must be frequent patterns
  - ✓ <XY>.sup / <X>.sup ≥ minconf (minconf = 0.6)
  - ✓ <B>→<C>, <B> →<D>, ...

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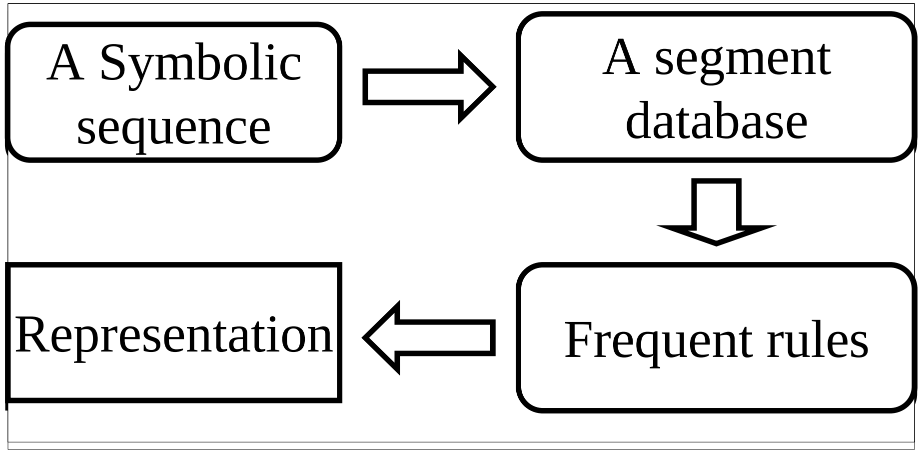

- ✓ Characteristic Matrix
  - ✓ <X> → <Y>
  - ✓ the first row represents the right parts of frequent rules
  - ✓ the first column represents the left parts of frequent rules
  - ✓ a unit represents a rule

	B	C	D
B	0	1	1
C	0	0	1
D	1	1	0

A Rule-based Representation
- Distance Measurement

- Different rules
- The union of rules

M_1	B	C	CD	D
A	1	1	1	1
AC	0	0	0	1
C	1	0	0	1

M_2	B	BC	C
A	1	1	1
AB	0	0	1
B	0	0	1

$$\text{Distance} = \frac{\text{The number of Different Rules}}{\text{The number of Union of Rules}}$$

$$\text{Distance}(M_1, M_2) = \frac{8}{10} = 0.8$$

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The Problems of Rule-based Representation Using Frequent Rules

- Only relationships between frequent patterns
  - E.g. major products {Milk, Juice
    minor products {Jelly, Cookie}
- The relationships between long patterns are hardly derived

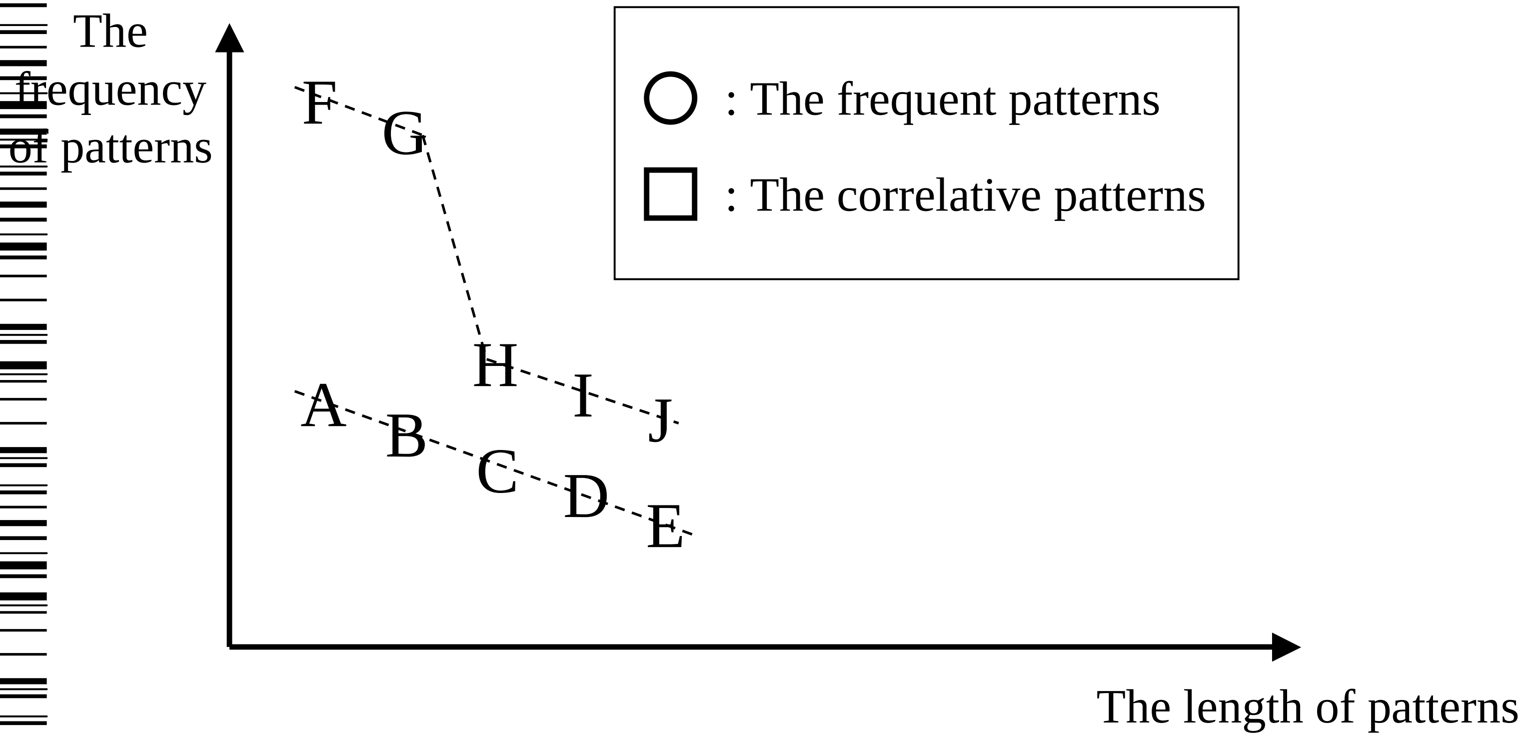
Correlative Patterns and Correlative Rules

- Correlative Patterns
  - Correlative 1-pattern <x>: X.sup ≥ minsup
  - Correlative k-pattern $<a_1a_2...a_k>$: the confidence of $<a_1...a_{k-1}> \rightarrow <a_k> \geq$ minconf
    - <a1...ak>.sup ≥ <a1...ak-1>.sup * minconf
    - Primary rule
- Correlative Rules
  - given a correlative k-pattern $<\beta\gamma>$ where β and γ are patterns, the rule $<\beta> \rightarrow <\gamma>$ the *correlative rule* if its confidence is not below the minconf.

The Proposed Algorithm

- A bottom-up Approach
  - Step 1: Find correlative 1-patterns
  - Step 2: For each correlative (k-1)-pattern X, combine it with each element $Y \in \Sigma$ to generate candidate correlative k-patterns.
  - Step 3: compute the supports of correlative k-patterns
  - Step 4: Extract the correlative k-patterns by testing confidence of the primary rule of each correlative k-pattern

Comparison to the Two Kinds of Patterns



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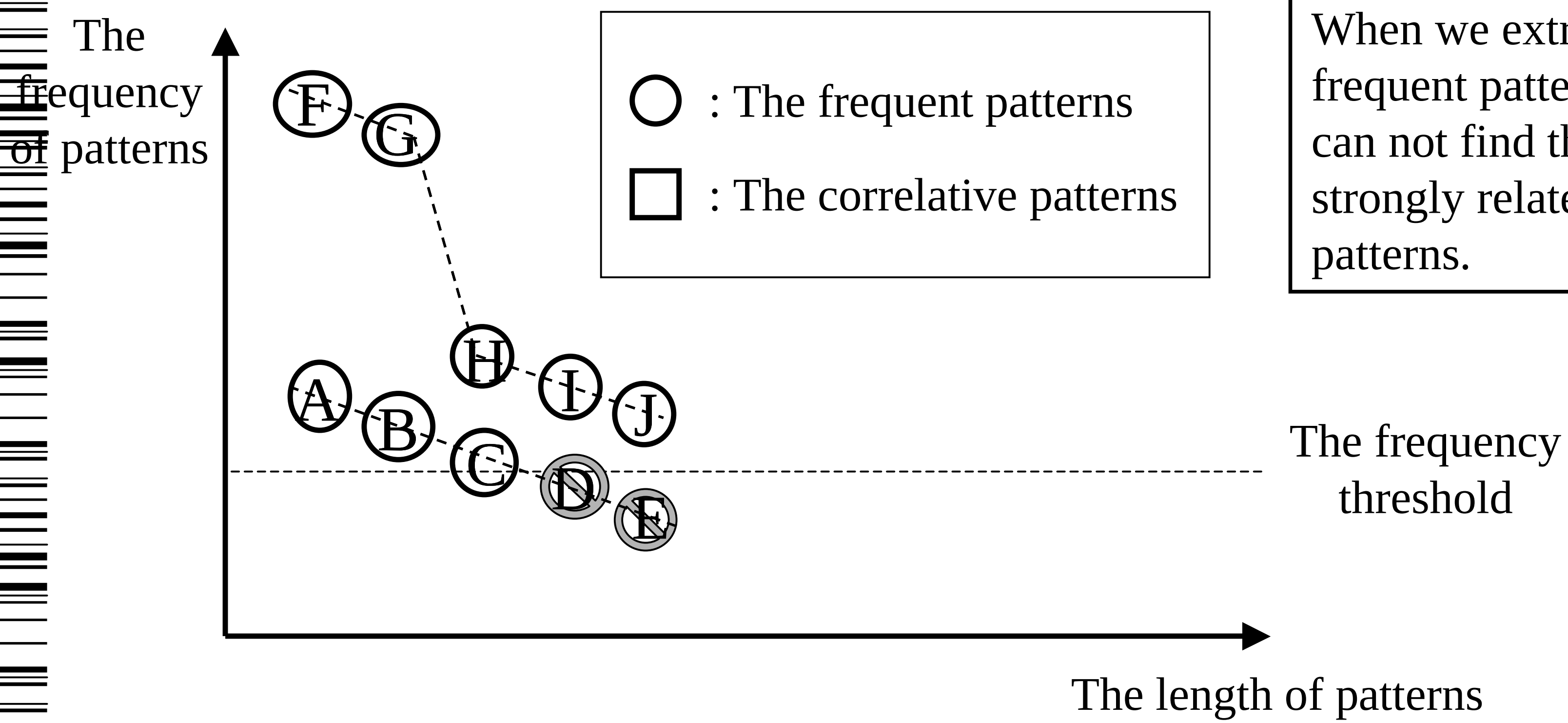
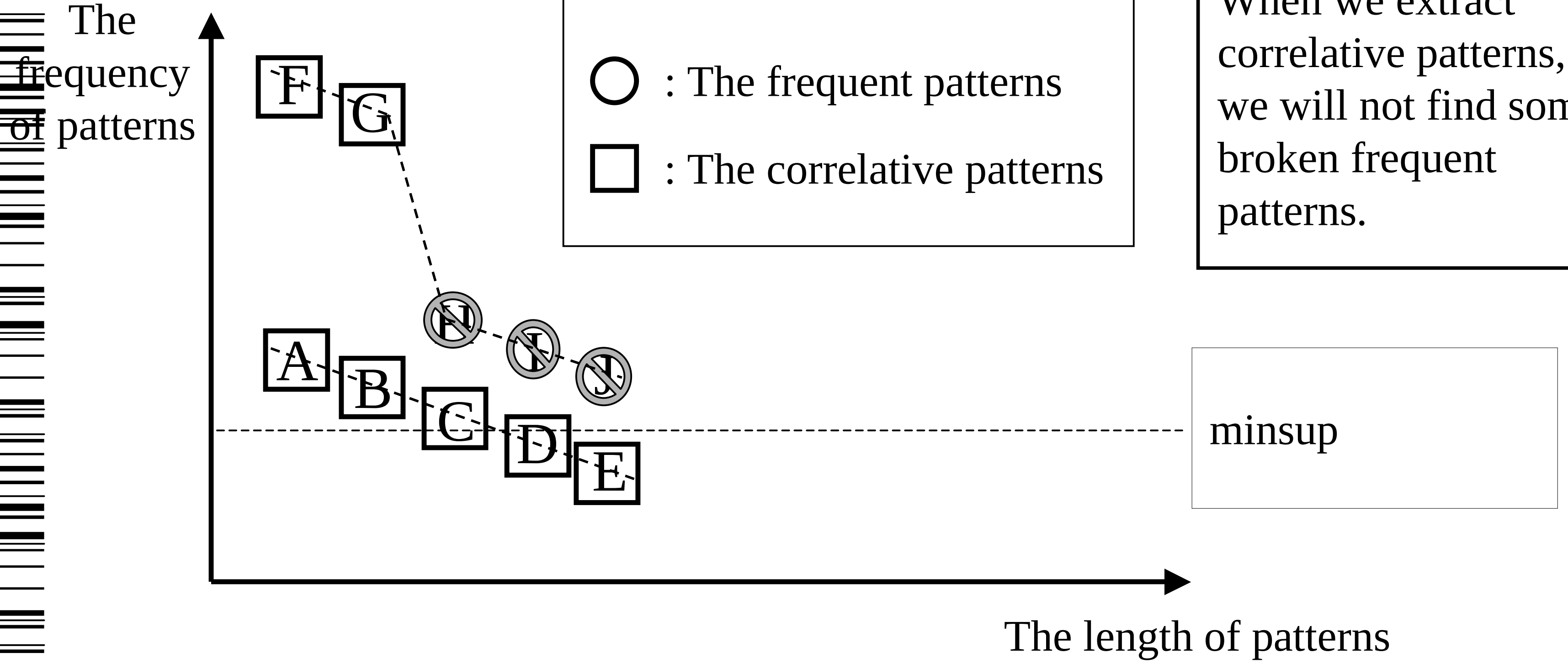


When we extract frequent patterns, we can not find these strongly related patterns.

Comparison to the Two Kinds of Patterns



When we extract correlative patterns, we will not find some broken frequent patterns.

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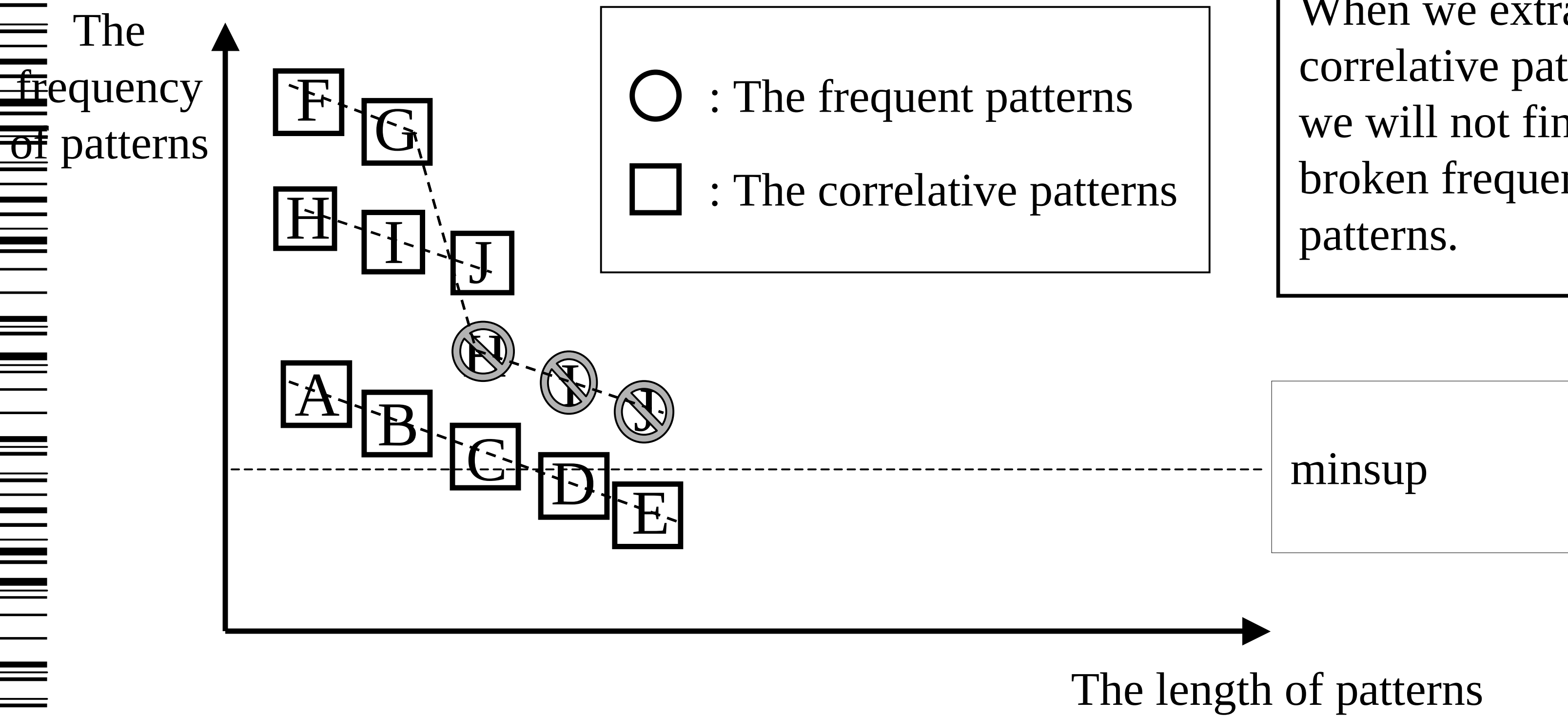


When we extract correlative patterns, we will not find some broken frequent patterns.

Experimental Results (1/7)

- Variation retrieval
  - Dataset: 2866 polyphonic music data that contains

    Twinkle: 26 variations, Lachrimae 22 variations,

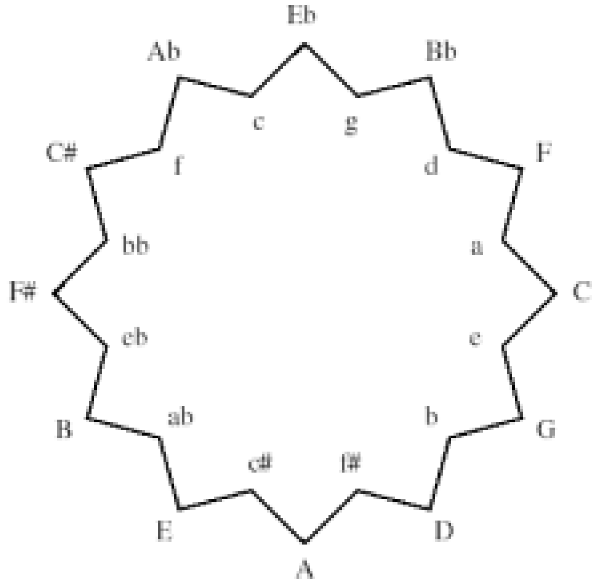
    Folia : 17 variations
  - Relevant results: the variations of query
  - Evaluation: average precision of 11-pt recall/precision

Experimental Results (2/7)

- Harmonic Description ("Harmonic Models for Polyphonic Music Retrieval")[PC02]
  - Chord lexicon
  - 24 major and minor triads

$$Context(s,c) = \sum_{p \in lexicon} \frac{|s \cap p|}{Edist(p,c)+1}$$

  - s: simultaneity,
    c: lexicon chord



Experimental Results (3/7)

- Markov Modeling(MM)

Lexical Chord	Timestep (Simultaneity)				
	1	2	3	4	5
P	0.2	0.1	0.7	0.5	0
Q	0.5	0.1	0.1	0.5	0.1
R	0.3	0.8	0.2	0	0.9

Markov Model			
	P	Q	R
P	0.293	0.287	0.42
Q	0.1417	0.1333	0.725
R	0.5308	0.1615	0.3077

$$
\begin{aligned}
P \to P &= 0.2 * 0.1 = 0.02 \\
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Q \to P &= 0.5 * 0.1 = 0.05 \\
Q \to Q &= 0.5 * 0.1 = 0.05 \\
Q \to R &= 0.5 * 0.8 = 0.4 \\
R \to P &= 0.3 * 0.1 = 0.03 \\
R \to Q &= 0.3 * 0.1 = 0.03 \\
R \to R &= 0.3 * 0.8 = 0.24 \\
\text{TOTAL} &= 1.0
\end{aligned}
$$

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		TOTAL	=	1.0

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Experimental Results (4/7)

- Time Invariant Markov Modeling(TIMM)

Spread	Equivalent Transitions	Transn. Counts	Count Totals	Markov Model
+0	P→P Q→Q R→R	0.44 +0.6 +0.40	=1.00	0.25
+1	P→Q Q→R R→P	0.43 +0.87 0.69	=1.99	0.4975
+2	P→R Q→P R→Q	0.63 0.17 0.21	=1.01	0.2525

Experimental Results (5/7)

- Harmonic Description simplification

	Timestep (Simultaneity)				
Lexical Chord	1	2	3	4	5
P	0.2	0.1	0.7	0.6	0
Q	0.5	0.1	0.1	0.4	0.1
R	0.3	0.8	0.2	0	0.9

⇩

{Q, R, P, P, R}

Experimental Results (6/7)

- Average precision comparison to [PC02]

	MM0	MM1	MM2	MM3	TIMM0	TIMM1	TIMM2
Twinkle Queries	0.1205	0.1094	0.1517	0.1332	0.0414	0.0772	0.1103
Lachrimae Queries	0.2144	0.1429	0.0883	0.1649	0.0967	0.1961	0.1461
Folia Queries	0.5904	0.1669	0.2801	0.2759	0.0286	0.0038	0.0005

Matrix	5-40	6-40	7-40	8-40	9-40	10-40	11-40	12-40
Twinkle Queries	0.13346	0.13252	0.13819	0.13664	0.1344	0.13949	0.141	0.15734
Lachrimae Queries	0.38979	0.33932	0.3419	0.35176	0.3507	0.35789	0.35257	0.31443
Folia Queries	0.50231	0.44275	0.43706	0.43936	0.45056	0.46974	0.48694	0.46566

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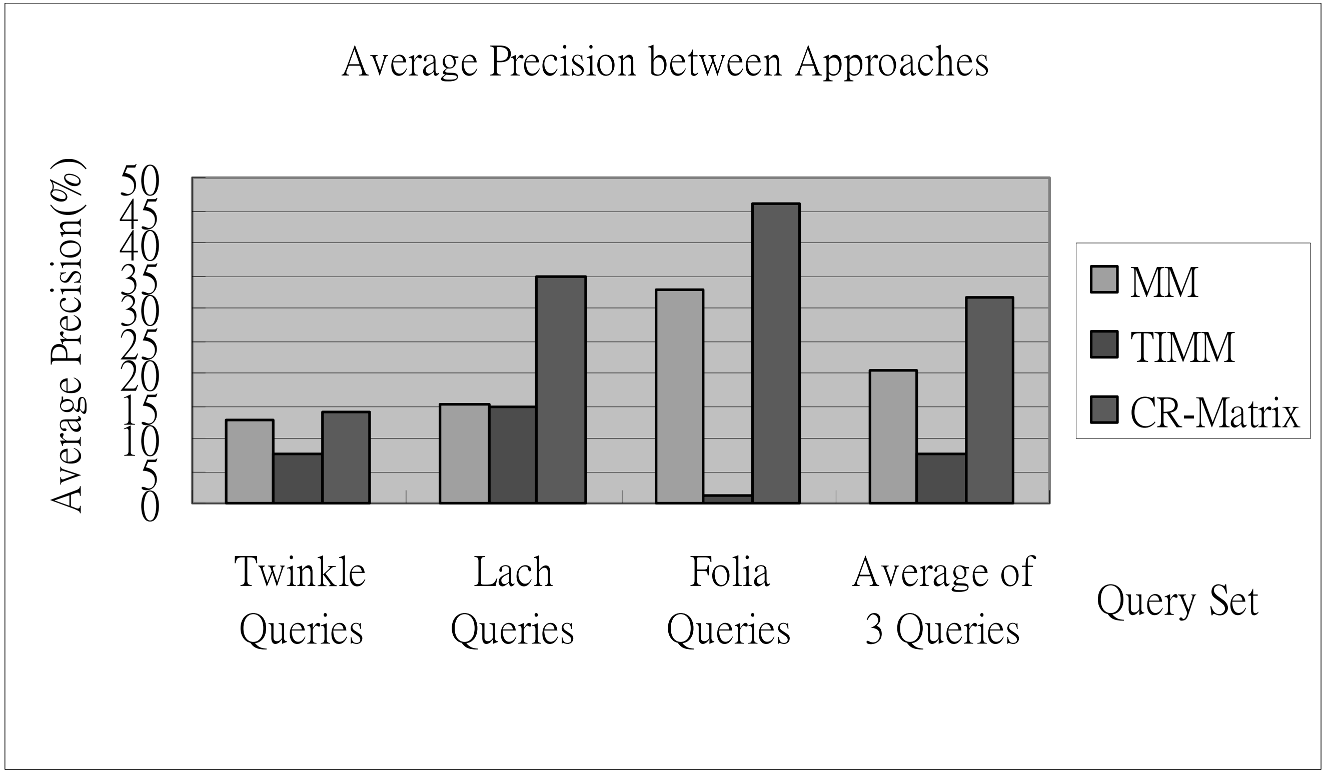

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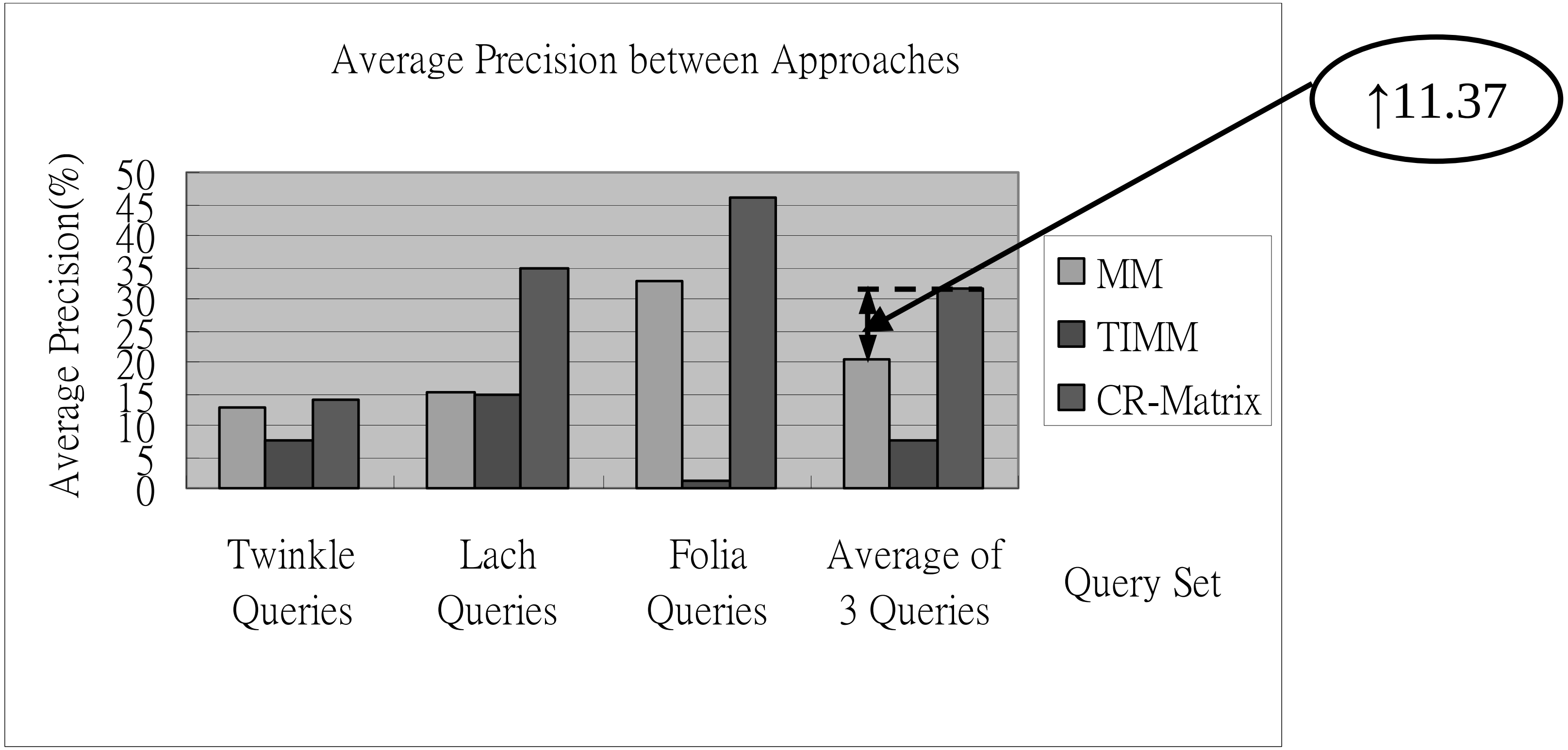

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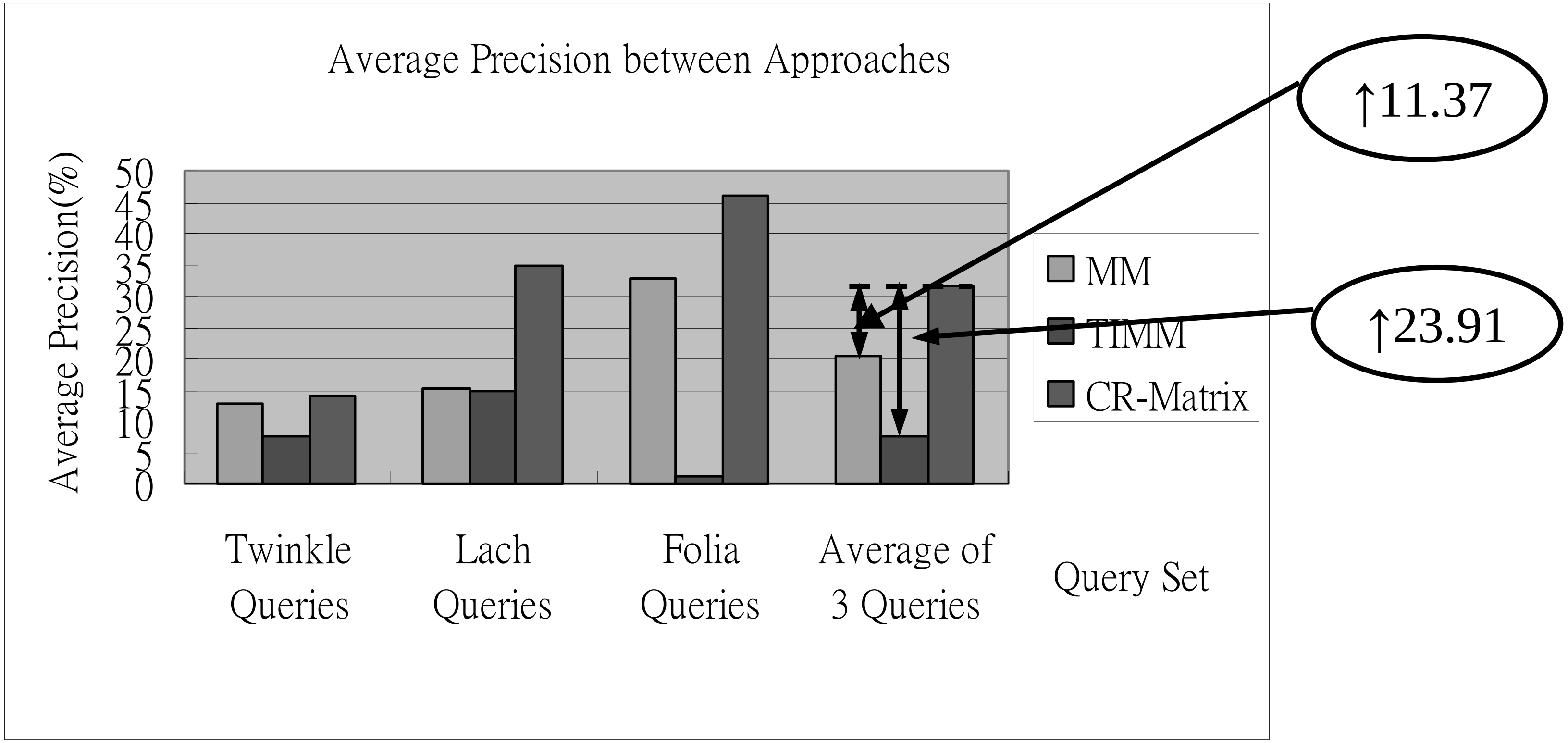

Conclusion

- Rule-based representation
- Correlative patterns (correlative rules)
  - Extract all patterns that strongly relate to the important patterns
  - Long patterns are more easily extracted
- Improved accuracy of variation retrieval
  - 1.56 times of MM precision
  - 4 times of TIMM precision

F.W.

Thanks for your listening!