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Concepts for Computing Patterns in 15th Century Korean Music

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SOONGSIL UNIVERSITY 1897

1872 PRIFYSGOL ABERYSTWYTH UNIVERSITY

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Presenter: Jacqueline Daykin

- Jackie [PhD, CMath CSci FIMA], Sêr Cymru II Fellow in the Department of Computer Science, Aberystwyth University, Wales, and Research Fellow in the Department of Information Science, Stellenbosch University, South Africa. She was a Lecturer in Computer Science at the Aberystwyth University Mauritius campus [2016-2019] and previously a visiting Lecturer at the University of London (Royal Holloway & King's) while raising a family

- Jackie's research area is stringology algorithmics both in theory and practice. Current interests include designing and applying string algorithms and methods in bioinformatics for tackling infectious diseases and also in musicology analysis

- Jackie has participated in PATTERNS committees since 2013; she has also served the conferences: WALCOM, SPIN, CUBE, IWOCA

Classical Korean music ⟹ Stringology

- King Sejong, fourth king of the Joseon Dynasty, ruled [1418–1450] according to Neo-Confucianism teaching. For this he invented 'yeack' ideology of courtesy and music plus a music score:

1. Neo-Confucianism structured music score
2. Two notation patterns for recording the music

- We propose applying stringology (study of strings of data) to analyze these music scores computationally
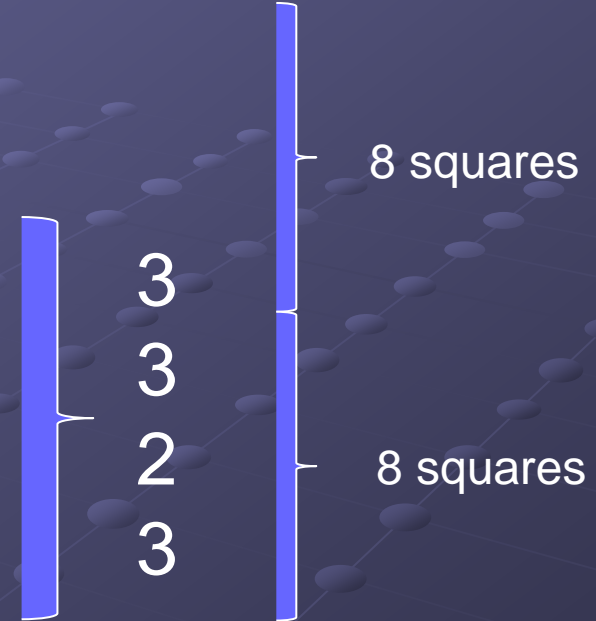
Structure of a music score
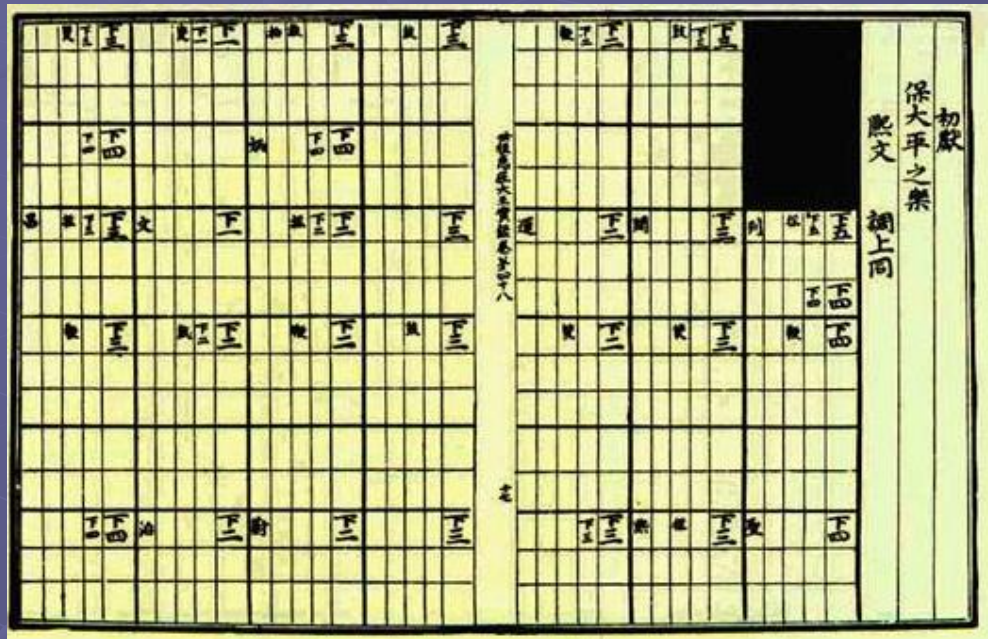
read

6 daegangs

3 squares 2 squares
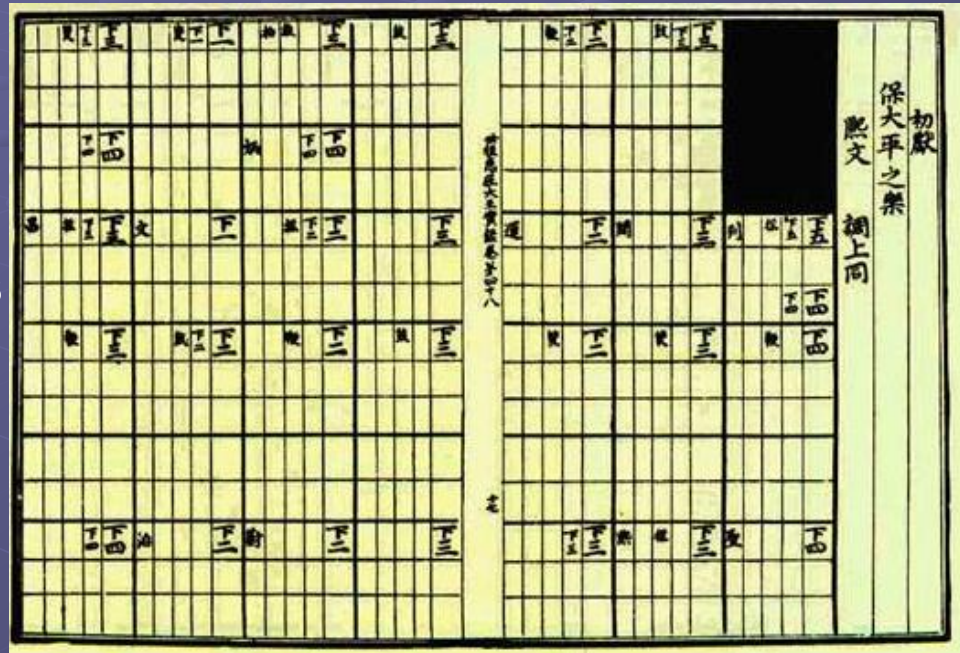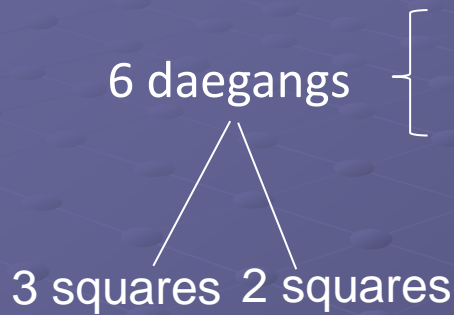
jeonggan

haeng

The Joseon Dynasty [1392–1897] music score was first improved by King Sejong's son, King Sejo, then evolved until now. The score notates lyrics, instruments, one-third and one-fourth beats

Structure of score Ctd.

8 squares

3
3
2
3

8 squares

5 set

This jeongganbo music score has the pattern
$(3\ 3\ 2\ 3)^5(3\ 2\ 3\ 3\ 2\ 3)^5(3\ 2\ 3\ 3\ 2\ 3)^5 \cdots$

Jeongganbo music column set

- A full score where five columns make one column set:

Lyric	Percussion instrument 2	Percussion instrument 1	Wind instrument	String instrument (melody)
Column 5	Column 4	Column 3	Column 2	Column 1

percussion is notated by symbols of strokes

melody is notated by a pitch name

Neo-Confucian meaning of the structure of the music score

year											
music						music					
8 diagrams spring			8 diagrams summer			8 diagrams fall			8 diagrams winter		
heaven	human	earth	heaven	human	earth	heaven	human	earth	heaven	human	earth
3	2	3	3	2	3	3	2	3	3	2	3

King Sejong's version: 32 square haeng means 1 year

King Sejo's version: 16 square haeng means music

Interpreting the rhythm of the music score

- Theories on interpreting this music rhythm [1950 -]:

1. H. Lee interpreted one square as the unit of beat - *musical rhythm was strange and couldn't be played*
2. J. Hwang and J. Lee generalised to each square having the same length in rhythm - *musical rhythm was strange*
3. J. Condit proposed theories - *these did not reflect the characteristics of Korean music*
4. J. Hong proposed theories - *did not reflect Korean music*
5. S. Moon proposed promising new theory (examples later)

   Implications for computational processing!

15th Century Joseon music

- Two types of music:

1. Dangak - music from China, with lyric written in Chinese characters

2. Hyangak - indigenous music of Korea, with lyric written in the Korean language

- Music was recorded in the score with 2 notation patterns

Pattern 1	Pattern 2
Melody, percussion, and lyric are notated in the unit: 8 squares	Melody, percussion, and lyric are notated in the unit: 5 squares & 3 squares
Dangak	Hyangak

Notation pattern 1: Rhythm with binary subdivision of a beat
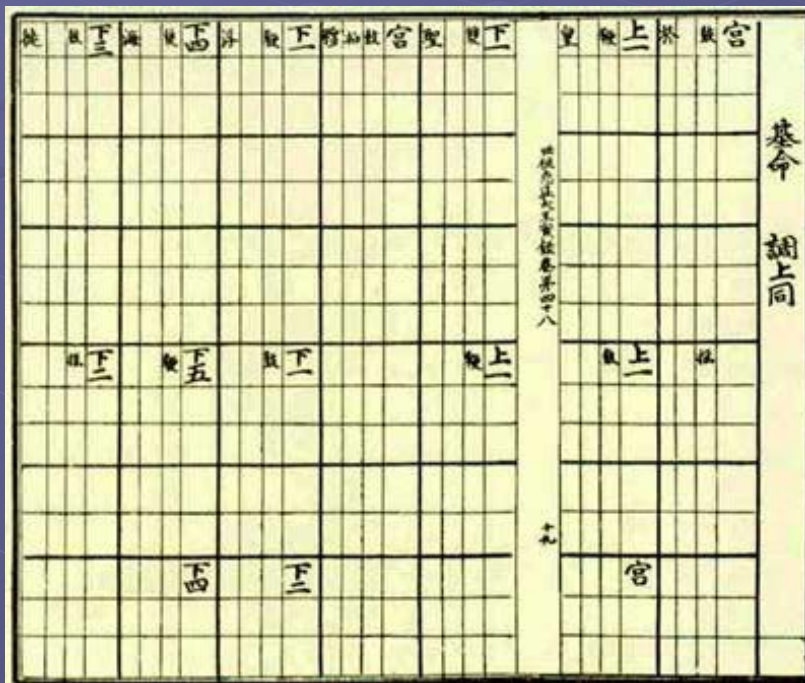
Music passage: Dangak, Gimyeong (基命)

Notation pattern 2: Rhythm with ternary subdivision of a beat

one-third beats:

Music passage: Hyangak, Cheongsanbyeolgok (青山別曲)

Computer Science: Stringology

- A *string* is a sequence of symbols over an alphabet Σ eg text, DNA (A,C,G,T), music (A, B, C, D, E, F, G)
- A *degenerate* string is a sequence of nonempty subsets of letters over Σ, eg {3,1,7}{4}{9,1,6,5}{4}

- Korean music score patterns:
1. 3323 is a string over the integers with *border* 3 (3323)
2. 323323 is a *palindrome* with a *proper suffix* 3323 (323323)

- Korean music score rhythms:
1. the string $((212)(111)(212)(111))^n$ is a *repetition*

Lyndon words

Definition. (Lyndon, 1954) A string over an ordered alphabet is a *Lyndon word* if it is the unique minimal in lexicographic order $<_{IL}$ amongst its cyclic rotations

Example: aabc is a Lyndon word over $\Sigma = \{a < b < \ldots < z\}$

<u>Lyndon</u>
border
century
fourth

aabc
caab
bcaa
abca

<u>Not Lyndon</u>
patterns
conference
lyric

Lyndon properties: border-free, primitive (not a repetition)

V-order $<_V$

- Strehl, Winkelmann 1981; Dahn, D. Daykin 1996
- Total order over an ordered alphabet - keep deleting 'V' elements then apply reversed lexicographic order

$$x = 9199566 \qquad y = 9199665$$

$$y <_V x$$

Definition. A string is a *V-word* if it is the unique minimum in *V*-order amongst its cyclic rotations

Applications of stringology to musicology

- Compare lexicographic $<_L$ and *V*-order $<_V$:

  beat $<_{lL}$ rhythm   musicology $<_{lL}$ pattern

  beat $<_V$ rhythm   pattern $<_V$ musicology

Any string can be factored into Lyndon or *V*-words in linear time

- Primitive Lyndon words have been used to analyse musical repetition in traditional African repertoires [M. Chemillier]:

1. harp melodic canons played by Nzakara people from CAR
2. asymmetric rhythmic patterns in central African cultures

- The rhythmic pattern 3 2 2 2 2 3 2 2 2 2 2 occurring in Aka Pygmies music forms a *V*-word

Research avenues

- Apply analysis and processing of Korean music:

  - Automated Korean music classification
  - Pattern matching techniques optimized for Korean music retrieval tasks
  - Apply degenerate strings to pattern matching tasks for finding chords and analysing chord progressions
  - Apply string factoring techniques to pattern inference of meaningful musical sequences
  - Investigate palindromes, repetitions, borders etc in Korean music
  - Enumerate periodic Korean musical structures using Lyndon or *V*-words

- *Methods transfer to other music cultures & genres*

Acknowledgements & Thanks

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- Original music score books predate copyright; see Proceedings for source of images

- References in Proceedings

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