

Musical Creativity and Conceptual Blending: The *CHAMELEON* melodic harmonisation assistant

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Forms of Creativity



Boden has proposed three forms of creativity:

- Exploratory
- Transformational
- Combinational

Combinational creativity, has proved to be the hardest to describe formally (Boden 1990).

Combinational creativity: “novel ideas (concepts, theories, solutions, works of art) are produced through unfamiliar combinations of familiar ideas.” (iccc2014)

Conceptual Blending



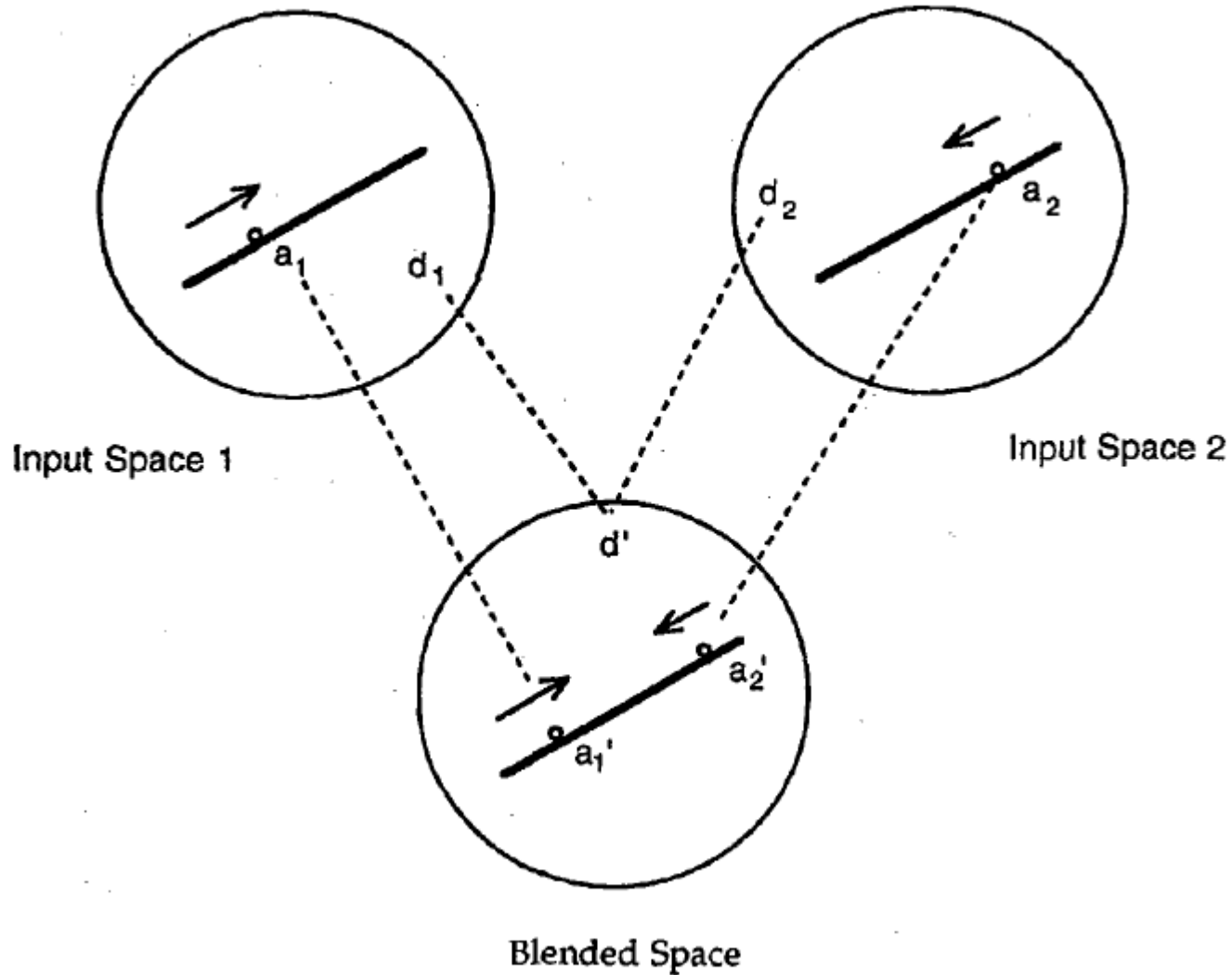
- Conceptual blending is a cognitive theory developed by Fauconnier and Turner (2001)
- Elements from diverse, but structurally-related, mental spaces are ‘blended’ giving rise to new conceptual spaces.
- Such spaces often possess new powerful interpretative properties allowing better understanding of known concepts or the emergence of novel concepts.

Buddhist monk puzzle

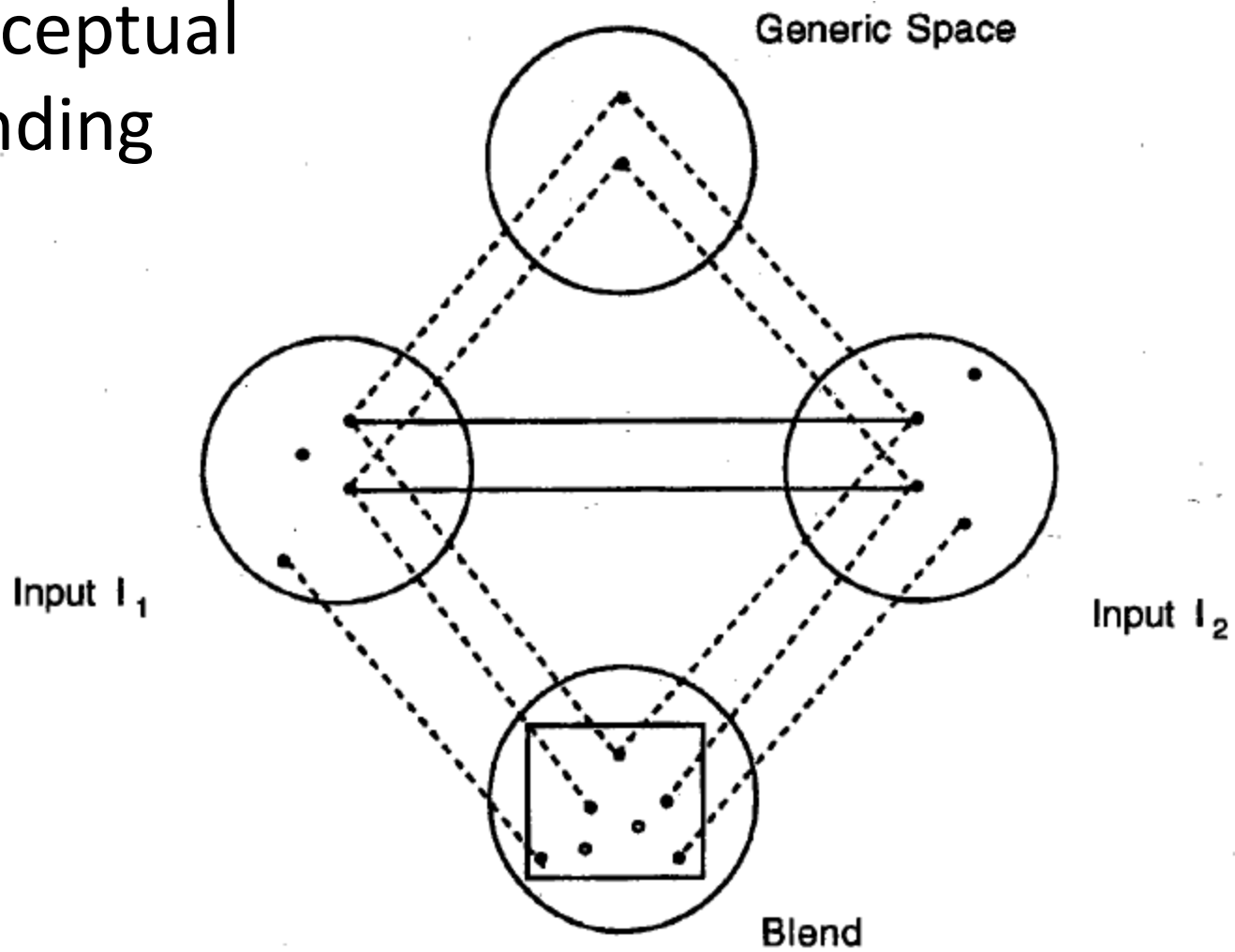


- Consider a classic puzzle of inferential problem-solving (Koestler, 1964):
- A Buddhist monk begins at dawn one day walking up a mountain, reaches the top at sunset, meditates at the top for several days until one dawn when he begins to walk back to the foot of the mountain, which he reaches at sunset. Make no assumptions about his starting or stopping or about his pace during the trips. Riddle: is there a place on the path which he occupies at the same hour of the day on the **two** separate journeys?

Solution: blending the monk's ascent with his descent



Conceptual blending



Coinvent (EU project FP7, 2013-2016)



The overall aim of COINVENT is to develop a computationally feasible, cognitively-inspired formal model of concept creation

- The model draws on Fauconnier and Turner's theory of conceptual blending, and grounds it on a sound mathematical theory of concepts.
- To validate the model, a proof of concept of an autonomous computational creative system are implemented and evaluated by humans in two testbed scenarios:
 - mathematical reasoning
 - melodic harmonization.

Musical Meaning



- structural meaning: arising from structural features/relations of musical contexts/spaces (melodic, harmonic, rhythmic, textural)
- ‘musicogenic’ meaning: arising from physical, gestural, embodied, emotional alignment
- ‘extra’-musical or referential meaning (e.g. text and music, moving image and music, programme music, etc.)

Tripartite Models:

- Intramusical, Extramusical, Musicogenic (Koelsch 2013)
- Formal, Emotional, Referential (Brandt 2009)
- Emotion, Cognition, Kinaesthetics (Kuhl 2007)

Blending in harmony



Focus on creating novel blends (rather than interpreting existing blends)

Emphasis on the creation of new music as a product of *structural* blending.

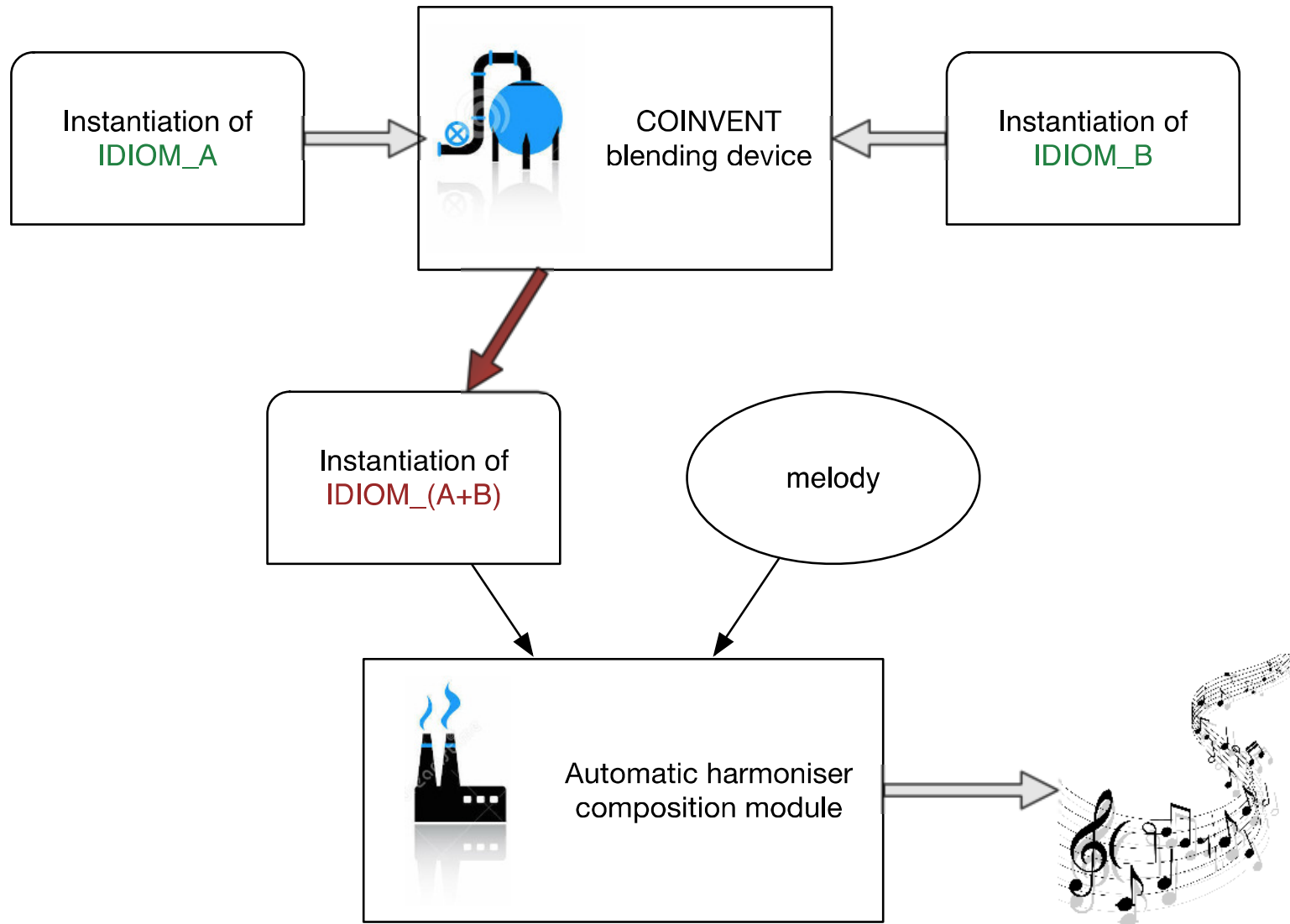


Creative Harmonisation of MELodies via LEarning & bLEnding of ONtologies

- A system that harmonises melodies
- The user inputs a melody
- The output is a harmonised melody
- The produced harmony features **blended** characteristics from different **learned** harmonic idioms.

www.ccm.web.auth.gr/chameleonmain.html

Melodic harmonizer



Dataset and Encoding

Harmonic training dataset

- Over 400 pieces from 7 main domains and several more specific idioms
- Harmonic reduction by experts
- Important harmonic structural info annotated by experts (phrase boundaries – scale info)
- Data extraction tools
- Automatic labelling of chords using the ***General Chord Type (GCT)*** representation

Harmonic Dataset



The dataset comprises seven broad categories of musical idioms, further divided into sub-categories, and presented in the following list:

- Modal harmonisation in the Middle Ages (11th – 14th centuries): includes subcategories of the Medieval harmonic styles of Organum and Fauxbourdon
- Modal harmonisation in the Renaissance (15th – 17th centuries): includes modal music from the 16th – 17th centuries along with modal chorales
- Tonal harmonisation (17th – 19th centuries): includes a set of the Bach Chorales, the Kostka-Payne corpus
- Harmonisation in National Schools (19th – 20th centuries): includes 19th – 20th century harmonisation of folk songs from Norway, Hungary and Greece
- Harmonisation in the 20th century: includes mainly vocal music by Cl. Debussy, P. Hindemith, E. Whitacre, I. Stravinsky, among others. Also, includes 20th-century harmonic concepts extracted from short musical excerpts
- Harmonisation in folk traditions: includes Tango (classical and nuevo styles), Epirus polyphonic songs and Rebetiko songs
- Harmonisation in 20th-century popular music and jazz: includes mainstream jazz, piano pieces by Bill Evans and a collections of songs from The Beatles

Annotated score

Tin Ammo Ammo Pigena



ms_0

P G

R D

Tonality

Grouping

ms_1

P G

R D



The image displays a musical score for the piece 'Tin Ammo Ammo Pigena'. The score is presented in a multi-staff format. The top system includes a vocal line (P G) and a guitar line (R D) for the first measure group (ms_0). The vocal line features a melodic line with eighth and sixteenth notes, while the guitar line provides a rhythmic accompaniment with chords and single notes. Below this, a 'Tonality' staff shows the key signature (one flat) and the time signature (3/8). A 'Grouping' staff indicates the phrasing of the notes. The second system (ms_1) continues the vocal and guitar parts, showing a continuation of the melodic and rhythmic patterns. The guitar line in ms_1 features a more complex chordal structure with some double notes.

GCT representation

It is a representation that is a generalisation of the standard tonal typology, applicable to any type of music.

General Chord Type Algorithm (GCT algorithm)

INPUT:

- Consonant/dissonant interval vector, e.g. [1,0,0,1,1,1,0,1,1,1,0,0]
- Tonality/key

ALGORITHM CORE:

- Reordering of pitch classes (most compact form) such that consonant intervals constitute the 'base' of the chord (left-hand side) & pitches that introduce dissonant intervals in relation to the 'base' are the extension (to the right)

OUTPUT:

- Chord-type and extension
- Root of chord (root-finding)
- Relative root position in current key

Examples of GCT representation

	EXAMPLE
Tonality - key	G: [7, [0, 2, 4, 5, 7, 9, 11]]
Consonance Vector	[1, 0, 0, 1, 1, 1, 0, 1, 1, 1, 0, 0]
Input Pitches	[60, 62, 66, 69, 74]
pc-set	[0, 2, 6, 9]
Maximal subsets	[2, 6, 9]
Narrowest range	[2, 6, 9]
Add extensions	[2, 6, 9, 12]
Lowest is root	2 (note D)
Chord in root position	[2, [0, 4, 7, 10]]
Relative to key	[7, [0, 4, 7, 10]]

[60, 62, 66, 69, 74] → [7,[0,4,7,10]] i.e. dominant seventh in G major

		EXAMPLE 2
Tonality - key		C: [0, [0, 2, 4, 5, 7, 9, 11]]
Cons. Vector		[1, 0, 0, 1, 1, 1, 0, 1, 1, 1, 0, 0]
Input		[50, 60, 62, 65, 69]
pc-set		[0, 2, 5, 9]
Maximal subsets		[2, 5, 9] and [5, 9, 0]
Narrowest range		[2, 5, 9] and [5, 9, 0]
Add extensions		[2, 5, 9, 12] and [5, 9, 0, 14]
Lowest is root		2 and 5 (notes D & F)
Chord in root position		[2, [0, 3, 7, 10]] & [5, [0, 4, 7, 9]]
Relative to key		[2, [0, 3, 7, 10]] & [5, [0, 4, 7, 9]]
Extra	Maximal subset overlap	[2, [0, 3, 7, 10]]

Supertonic II7 or subdominant IV6

Symmetric chords such as diminished sevenths or augmented chord are ambiguous. Context is required for resolution.

Beethoven, Sonata 14, op.27-2 (reduction of first measures)



c: i i2 VI IIN6 V7 i64 V7 i
 0,[0,3,7] 0,[0,3,7,10] 8,[0,4,7] 1,[0,4,7] 7,[0,4,10] 0,[0,3,7] 7,[0,4,7,10] 0,[0,3,7]

G. Gershwin, Rhapsody in Blue (reduction of first five measures)



Bb: I ? V79/IV IV I It6 V7 I
 0,[0,4,7] 8,[0,3,7,9] 0,[0,4,7,10,14] 5,[0,4,7] 0,[0,4,7], 8,[0,4,10] 7,[0,4] 0,[0,4,7]

G. Dufay's Kyrie (reduction) - first phrase in A phrygian mode)



0,[0.7] 0,[0.3,7] 1,[0.4,7] 0,[07] 8,[0.4,7] 0,[0.3,7] 10,[0.3,7] 0,[0.7]

O. Messiaen, Quartet for the End of Time, Quartet VII (reduction of first 6 measures)

GCT- common practice consonance vector	0,[0.4,10,13]	3,[0.4,7,18]	9,[0.3,7,10]	9,[0.4,10,13]	0,[0.4,7,18]	6,[0.3,7,10]
GCT- atonal cons. vector (normal order)	10,[0.2,3,6]	3,[0.4,6,7]	4,[0.3,5,8]	7,[0.2,3,6]	0,[0.4,6,7]	1,[0.3,5,8]

76. Αλημονώ και Χαίρομαι



♩ - 100

Ρίχτης

Ά - λη - σμο - γιο νώ

Ά - λη - σμο - γιο νώ - ο - ο - ε - χε

Γυναίκα

Ά - λη - σμο - γιο νώ

Ά - λη - σμο - νώ

Same 'root' →

0-037	0-03710	0-0310	0-0310	0-037	0-051015	0-035	0-051015	5-07	0-03	0-0	0-010	0-0
0-037	7-0358	10-025	10-025	0-037	10-0257	0-035	10-0257	0-05	0-03	0-0	0-02	0-0

Consonant intervals
345789

Similarity →

Consonant intervals
234578910

Statistical learning of harmonies



The harmoniser is based on a statistical learning approach that combines different learning modules:

- chord types
- chord transitions
- cadences
- bass line voice leading

The training material comprises many diverse musical idioms, annotated by human experts.

Chord learning & generation

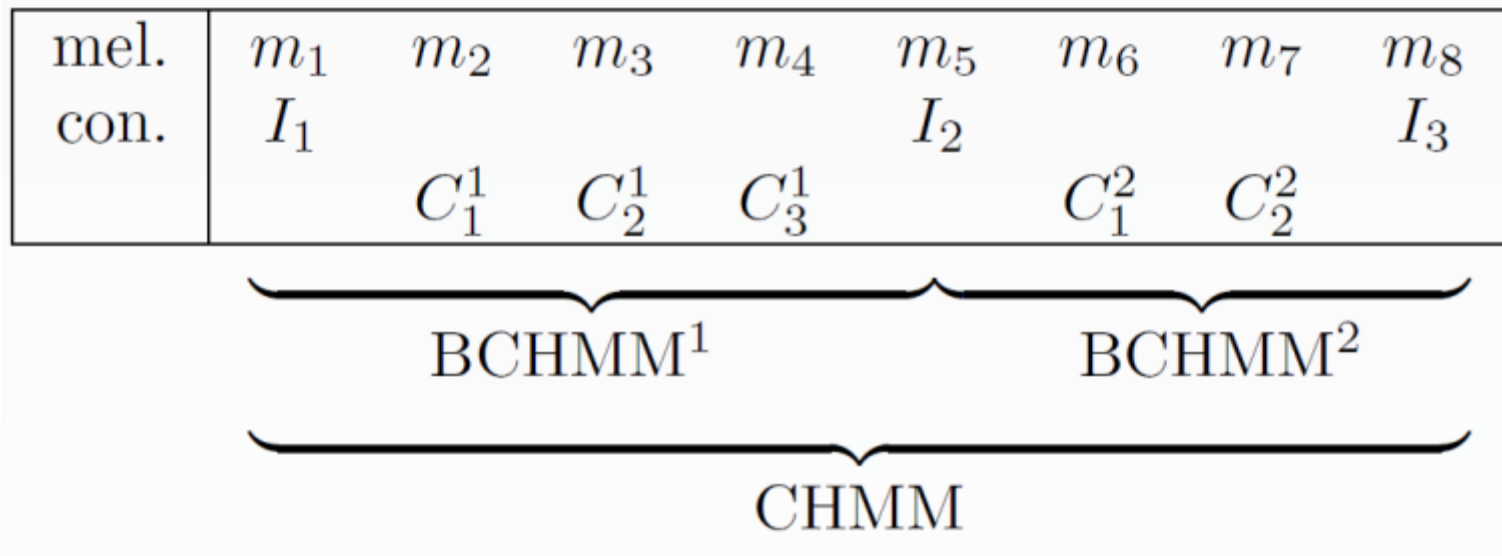


Idiom dependent probabilistic harmonization under chord constraints (**constrained HMM**)

- Chord transitions learned from an idiom
- Novel sequences generated that statistically:
 - preserve the learned characteristics, AND
 - are constrained by fixed 'checkpoint' chords

Bach Chorales: Analysis, Generation

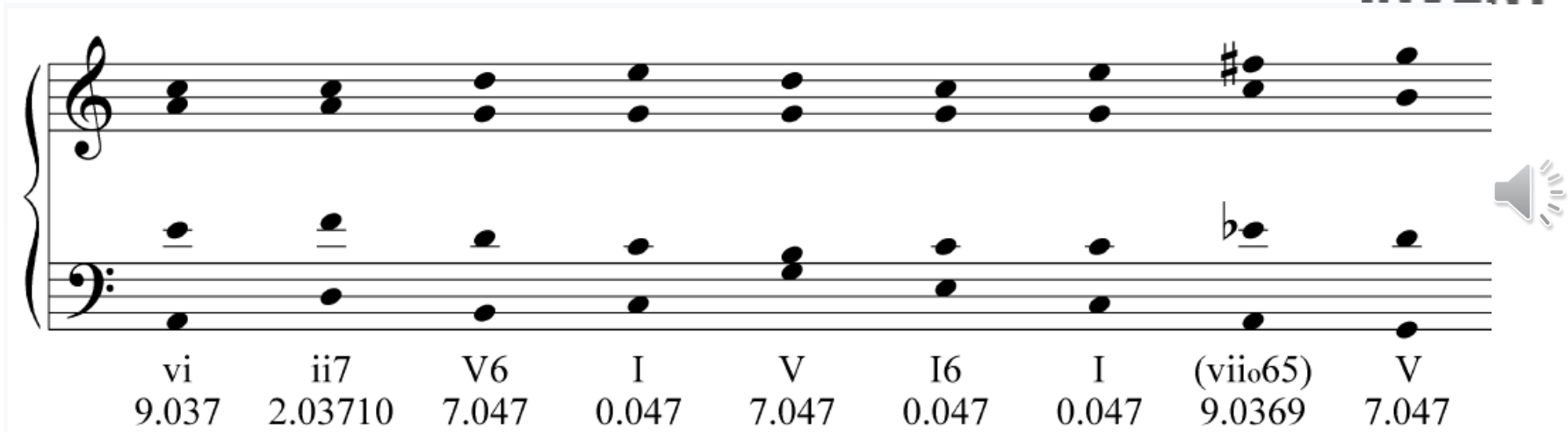
- Statistical learning from GCT Bach Chorale dataset via HMM
- Use of Boundary Constrained HMM



Boundary Constrained HMM (BCHMM)

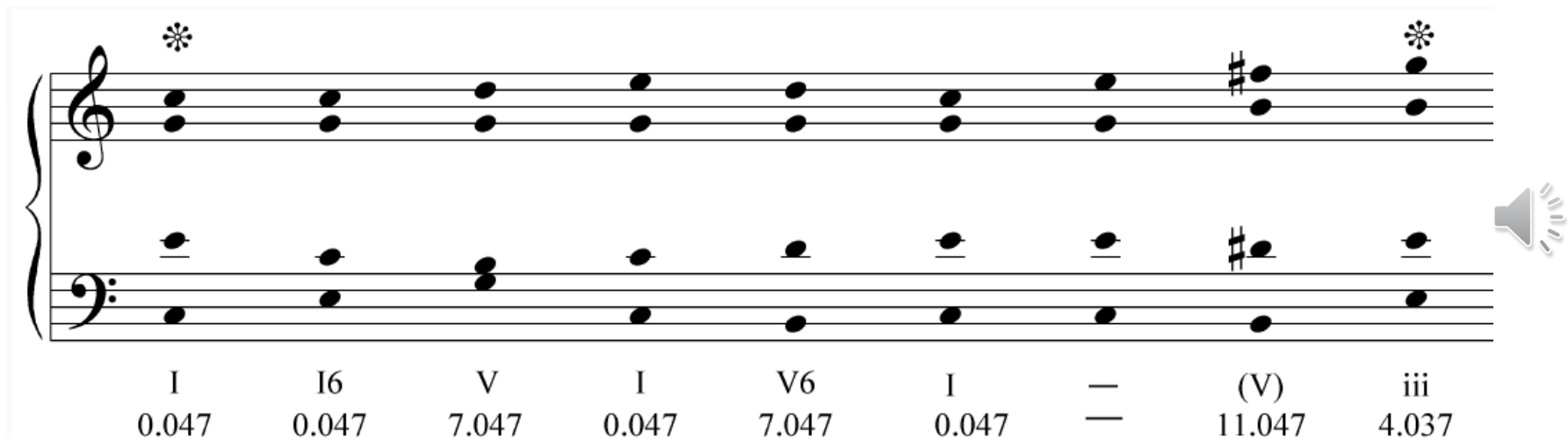
Constrained HMM

Harmonisations with different constraints



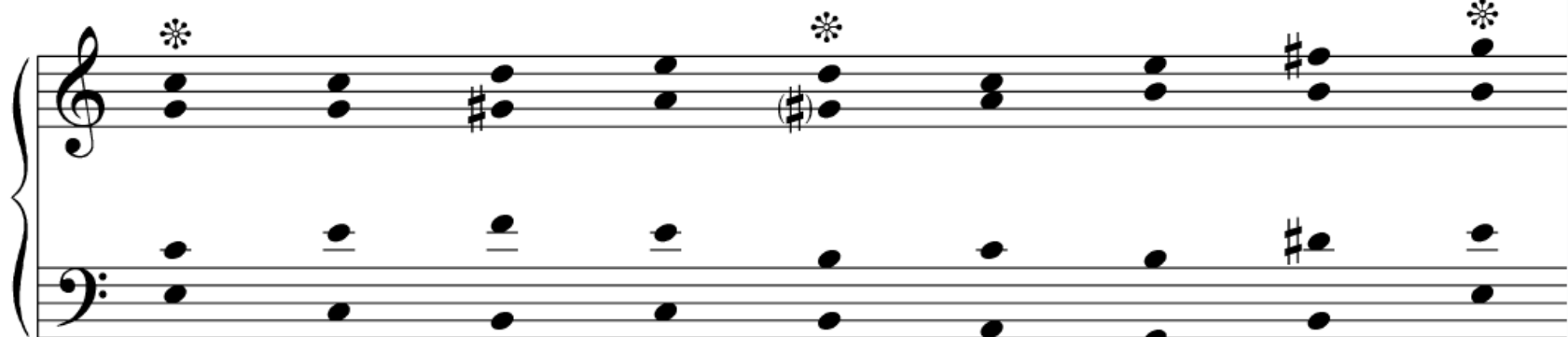
Musical score for the first harmonisation, showing a sequence of chords in treble and bass clefs. The chords are: vi, ii7, V6, I, V, I6, I, (vii°65), V. The notes are: Treble (C4, D4, E4, F4, G4, A4, B4, C5), Bass (C3, D3, E3, F3, G3, A3, B3, C4). The (vii°65) chord has a sharp on the F4 note. The V chord has a flat on the B3 note. A speaker icon is on the right.

vi	ii7	V6	I	V	I6	I	(vii°65)	V
9.037	2.03710	7.047	0.047	7.047	0.047	0.047	9.0369	7.047



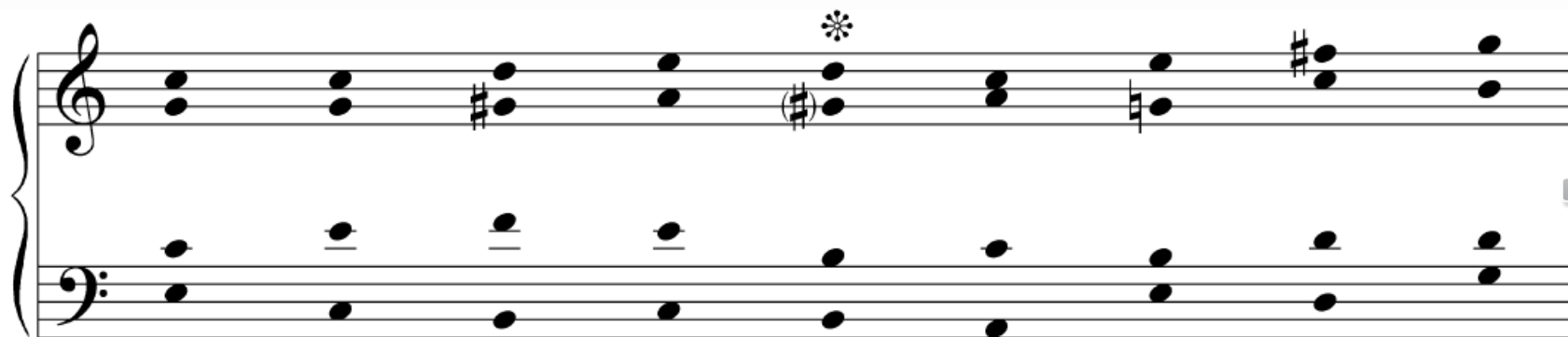
Musical score for the second harmonisation, showing a sequence of chords in treble and bass clefs. The chords are: I, I6, V, I, V6, I, —, (V), iii. The notes are: Treble (C4, D4, E4, F4, G4, A4, B4, C5), Bass (C3, D3, E3, F3, G3, A3, B3, C4). The (V) chord has a sharp on the F4 note. The iii chord has a sharp on the C4 note. Asterisks are above the first and last chords. A speaker icon is on the right.

I	I6	V	I	V6	I	—	(V)	iii
0.047	0.047	7.047	0.047	7.047	0.047	—	11.047	4.037



Musical notation for the first system, showing treble and bass staves with notes and accidentals. Asterisks are placed above the first, fifth, and ninth measures.

I6 0.047 I 0.047 (vii^o6⁵) 11.0369 vi⁶ 9.037 (vii^o6) 8.036 vi 9.03 iii⁶ 4.037 (V) 11.047 iii 4.037

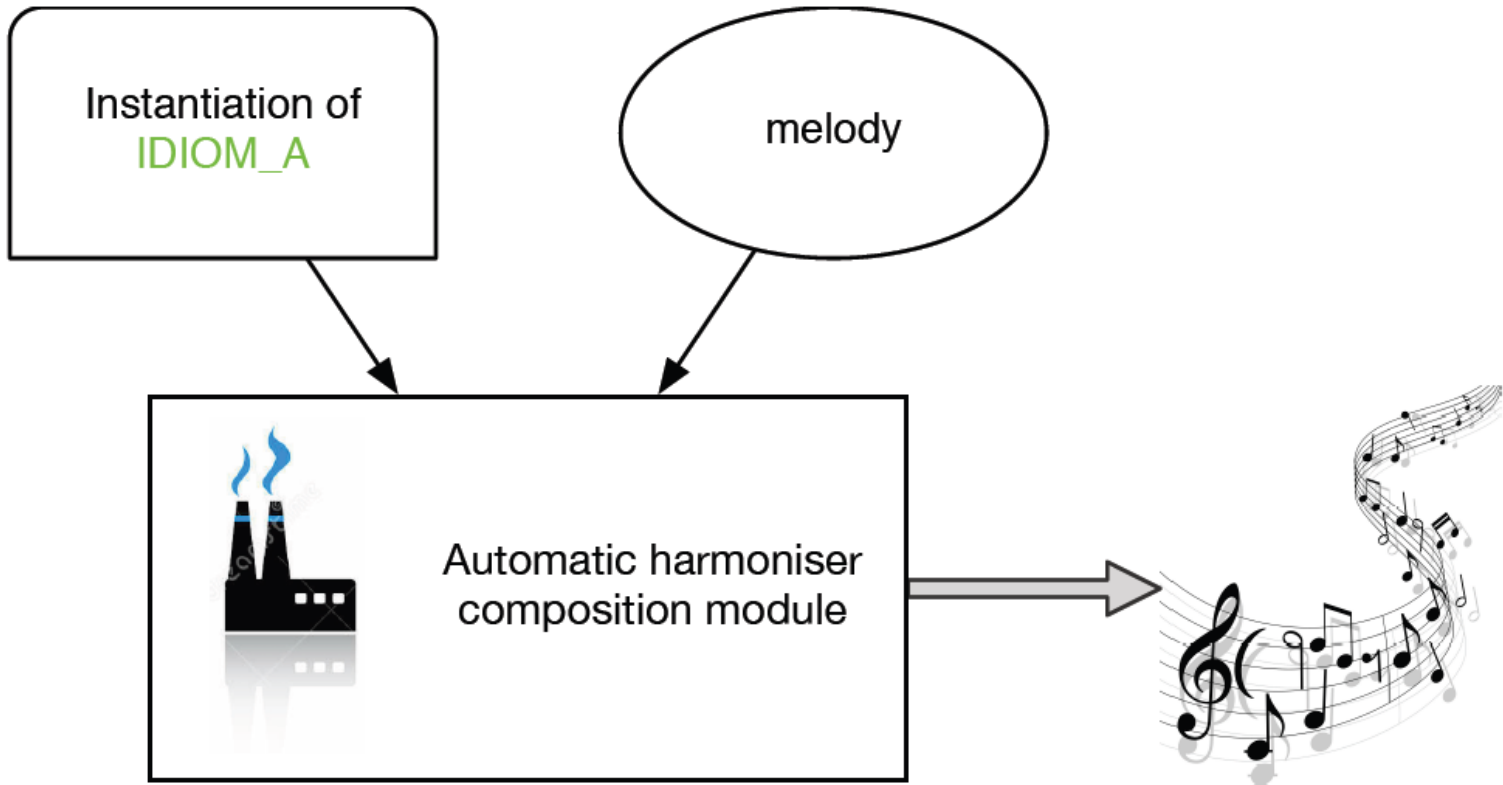



Musical notation for the second system, showing treble and bass staves with notes and accidentals. Asterisks are placed above the fifth and eighth measures.

I6 0.047 I 0.047 (vii^o6⁵) 11.0369 vi⁶ 9.037 (vii^o6) 8.036 vi 9.03 iii 4.037 (V7) 2.0410 V 7.047



Melodic Harmonisation



Blending is relevant in the sense that the implied harmonic space of melody and an appropriate harmonic space are combined.

Melodic Input

At this stage, the input melody is manually annotated by the user as to harmonic rhythm, harmonically important notes, key and phrase structure. The user provides the information and an xml file is produced.

Greek folk song (from Y. Constantinidis "44 miniatures for piano", no. 27)



The image displays a musical score for a Greek folk song, consisting of six staves. The top staff is labeled 'melody' and shows a melodic line in 2/4 time. The second staff, 'harm notes', shows the harmonic notes corresponding to the melody. The third staff, 'harm rhythm', shows the harmonic rhythm. The fourth staff, 'desired chords', shows the chords. The fifth staff, 'tonality', shows the key signature (one sharp, F#) and the tonality. The sixth staff, 'grouping', shows the phrase structure. The score is in 2/4 time and consists of 12 measures.

Diverse Musical Idioms



(a) Traditional melody harmonised in the style of fauxbourdon.



i iv⁶ v⁶ v i v⁶_{5/4} v v i v⁶_{7/II} VII III IV vii⁰⁶_{III} III #vi⁶ v⁷ I

(b) Traditional melody harmonised in the Bach Chorale style.



(c) Traditional melody harmonised in the style of Hindemith.

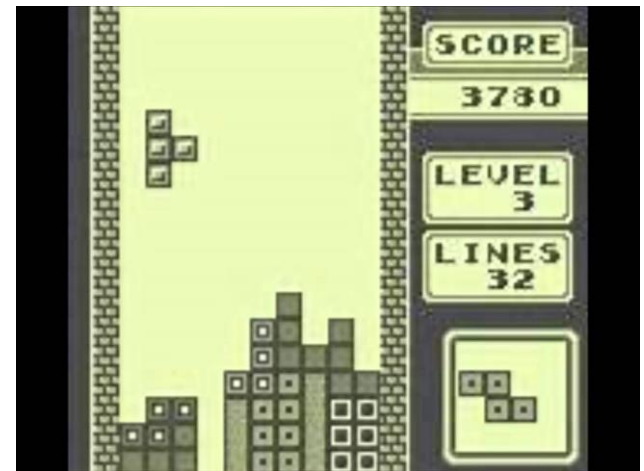


Tetris tune harmonisation

- 🔊 Tetris theme
- 🔊 Korobeneiki (russian folk song)

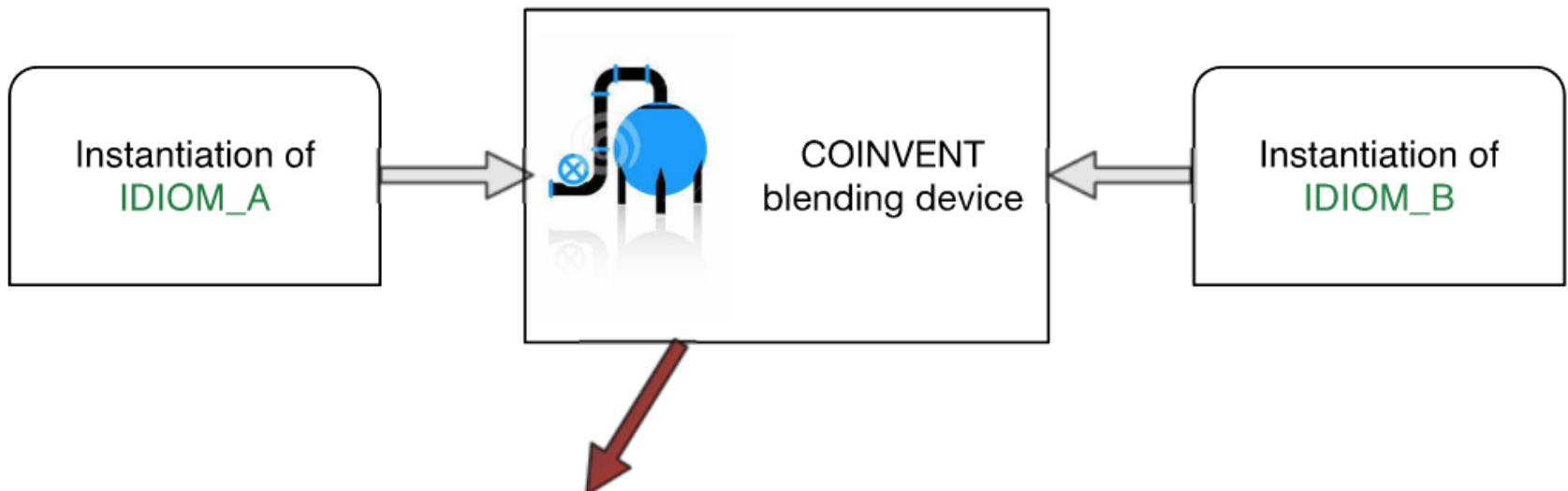
Harmonisations

- 🔊 Bach chorales
- 🔊 Modal chorales
- 🔊 Kostka-Payne
- 🔊 Konstantinidis
- 🔊 Jazz
- 🔊 Hindemith
- 🔊 Epirus folk songs
- 🔊 Organum
- 🔊 Faux Bourdon

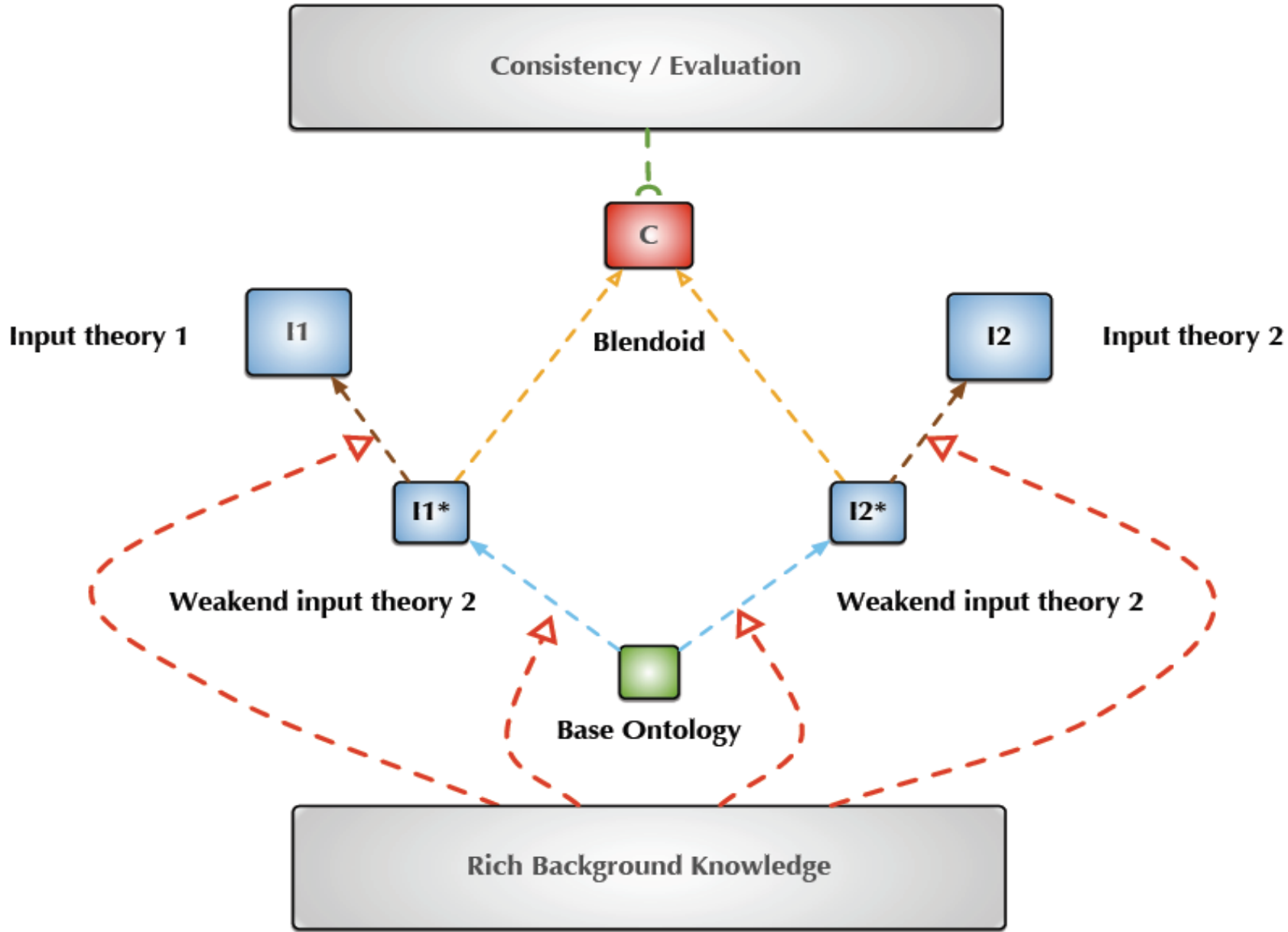


Blending & Harmony

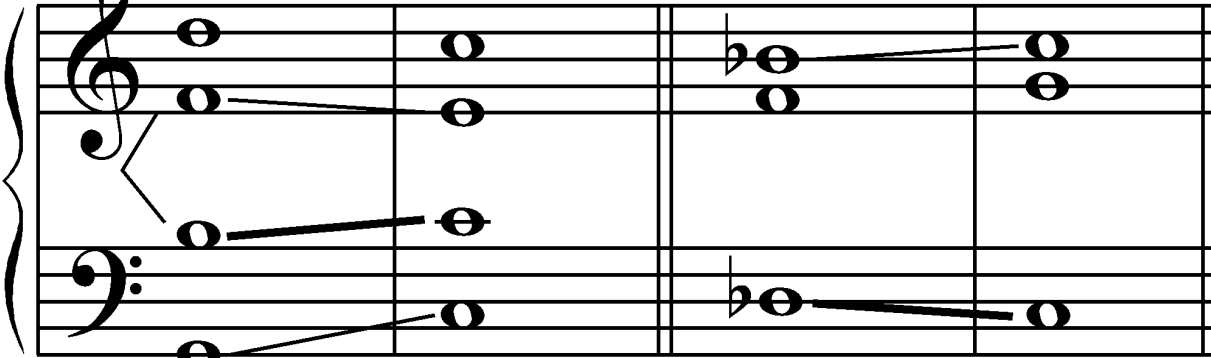


- Chord-level blending
- Chord-sequence level blending
- Harmonic-structure level blending
- Cross-domain level blending



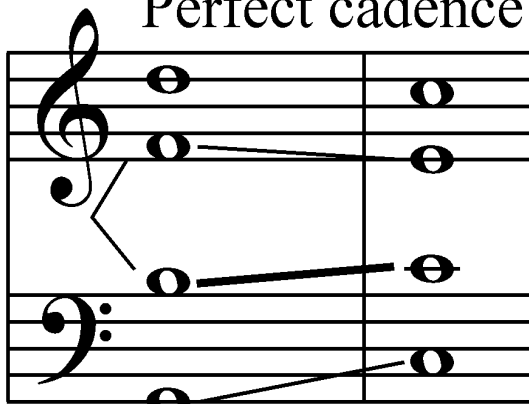
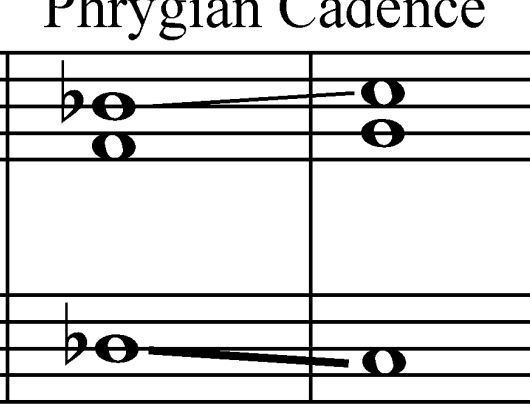
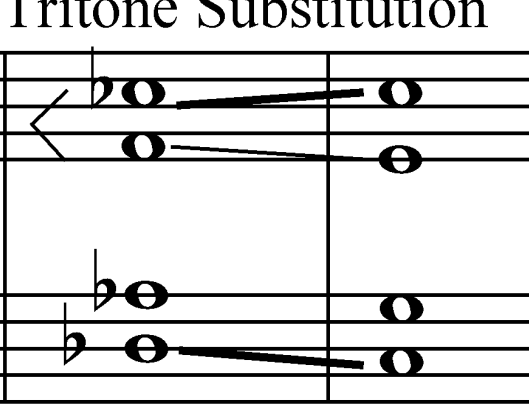
COINVENT blending model



Chord level blending (cadences)

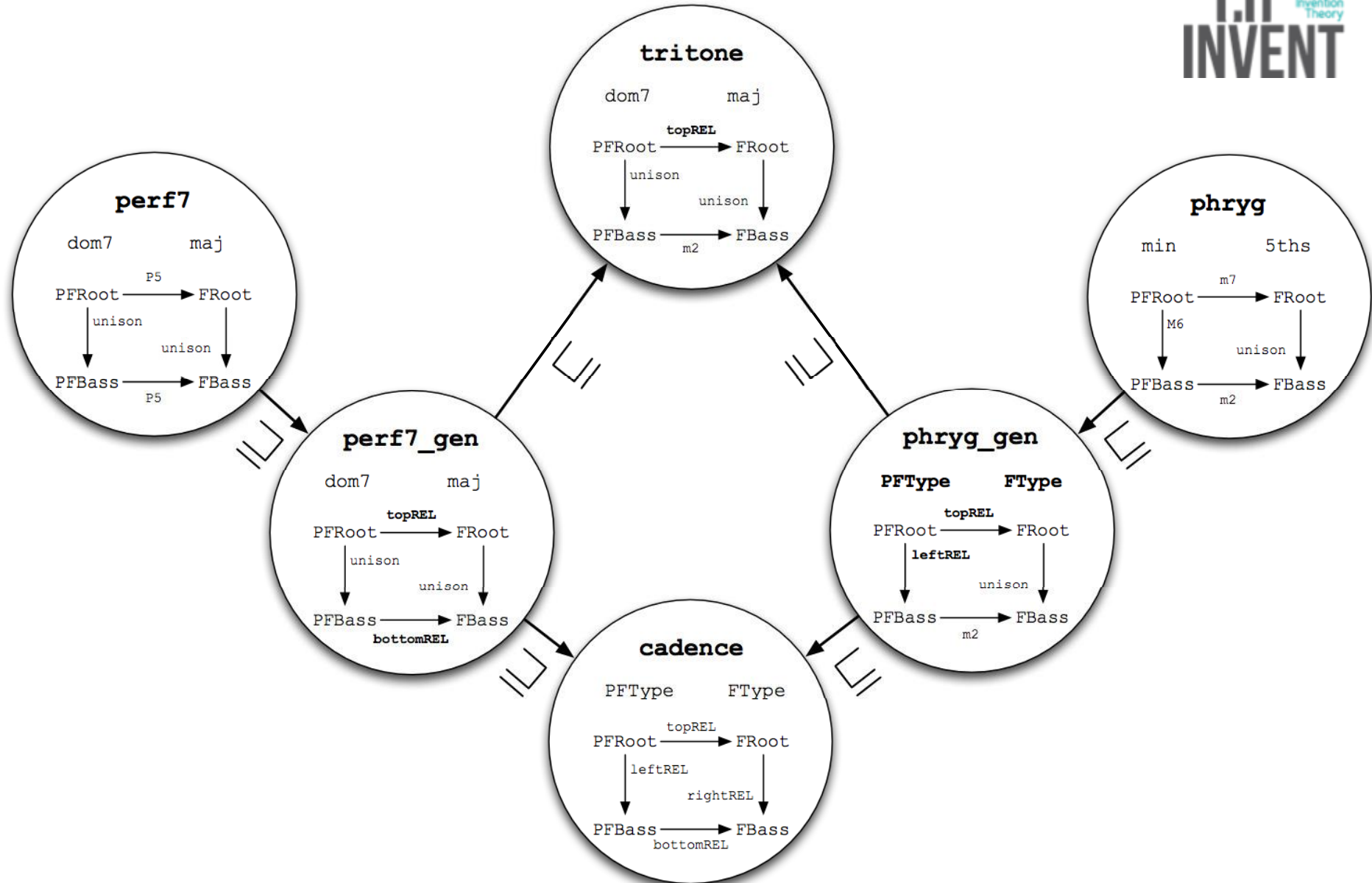
INPUT 1	INPUT 2
Perfect cadence	Phrygian Cadence
 <p>The image shows two musical staves, each with a grand staff (treble and bass clefs). The first staff, labeled 'INPUT 1 Perfect cadence', shows a V chord (C major) in the first measure and an I chord (C major) in the second measure. The second staff, labeled 'INPUT 2 Phrygian Cadence', shows a vii6 chord (C phrygian) in the first measure and an I chord (C major) in the second measure. The notes are connected by lines, showing the movement of each voice part.</p>	
V - I C.major	vii6 - I C.phrygian
	

Chord level blending (cadences)

INPUT 1	INPUT 2	BLEND
Perfect cadence	Phrygian Cadence	Tritone Substitution
		
V - I C.major	vii6 - I C.phrygian	IIb7 - I

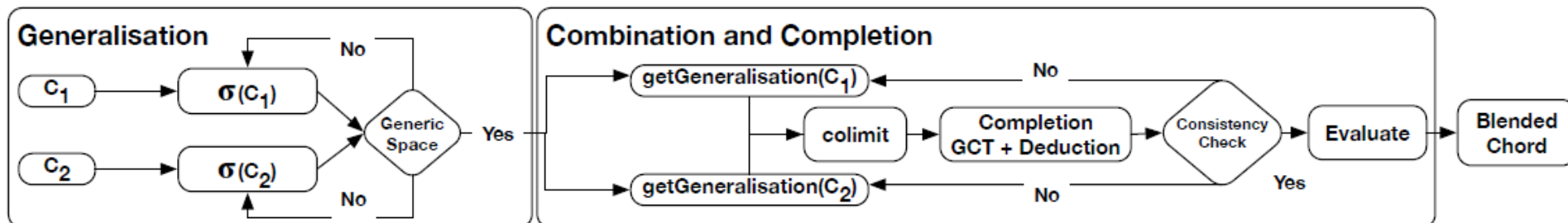


Formalised in the core-model...



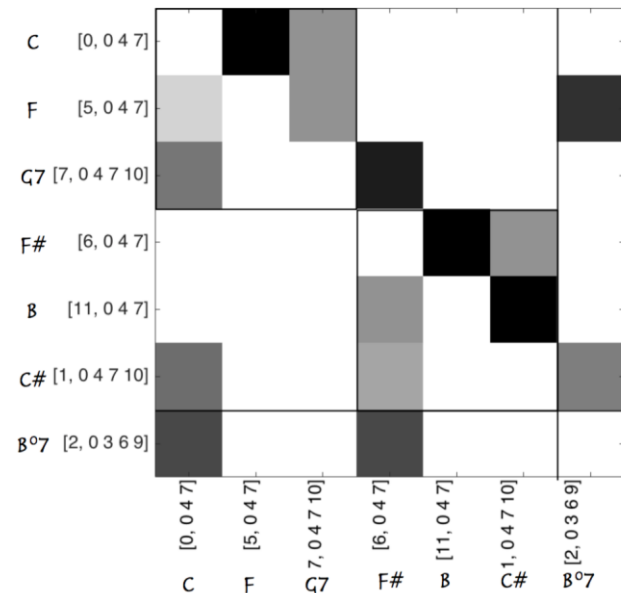
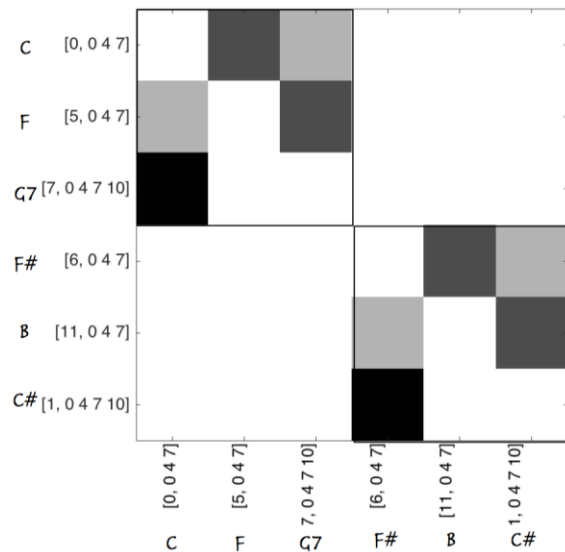
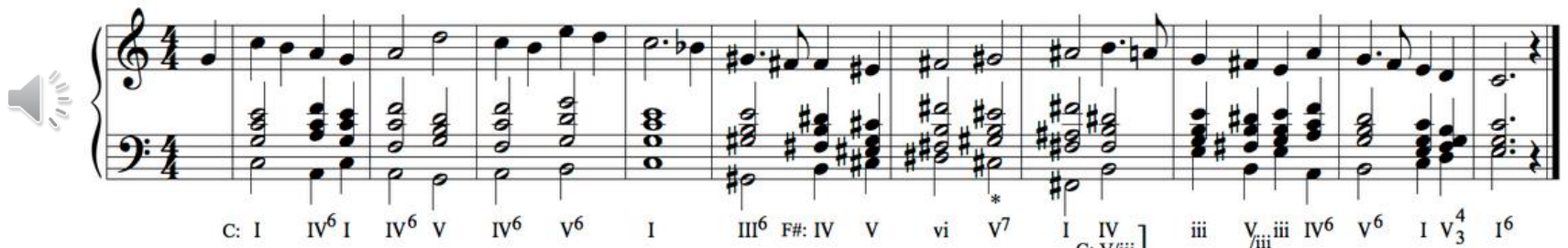
Combination & Completion

- **Generalisation** towards the *generic* space
 - least general generalisation for each input space
 - priorities.
- **Combination:** avoid inconsistencies
 - Balanced generalisation: double-scope blends
- **Completion & elaboration:** enrich composition with background knowledge



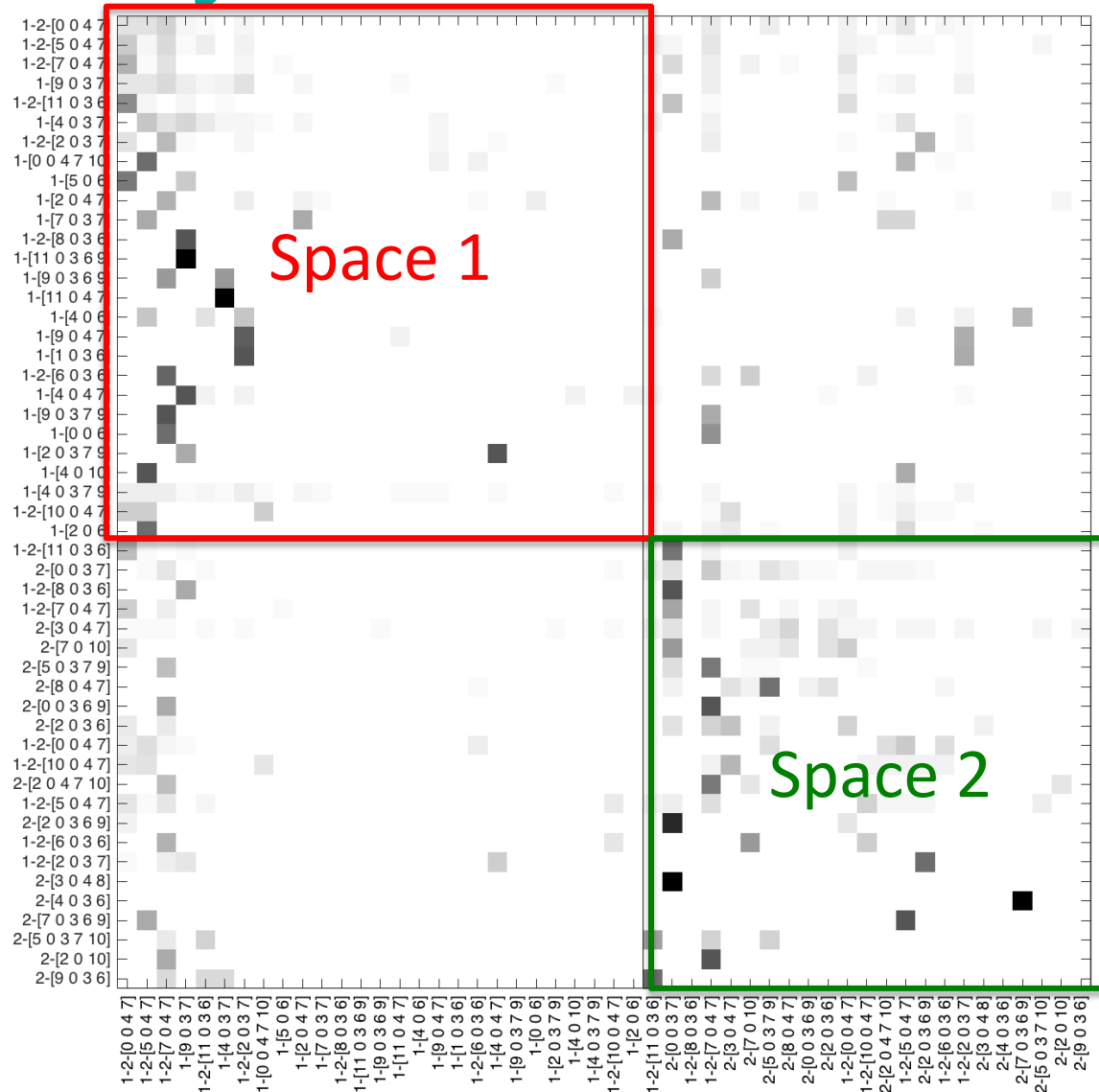
Blending chord transition matrices

- User selects **two idioms** from a list.
- System automatically **blends** the most common transitions
- The ‘best’ resulting blends are integrated in a **compound matrix**.

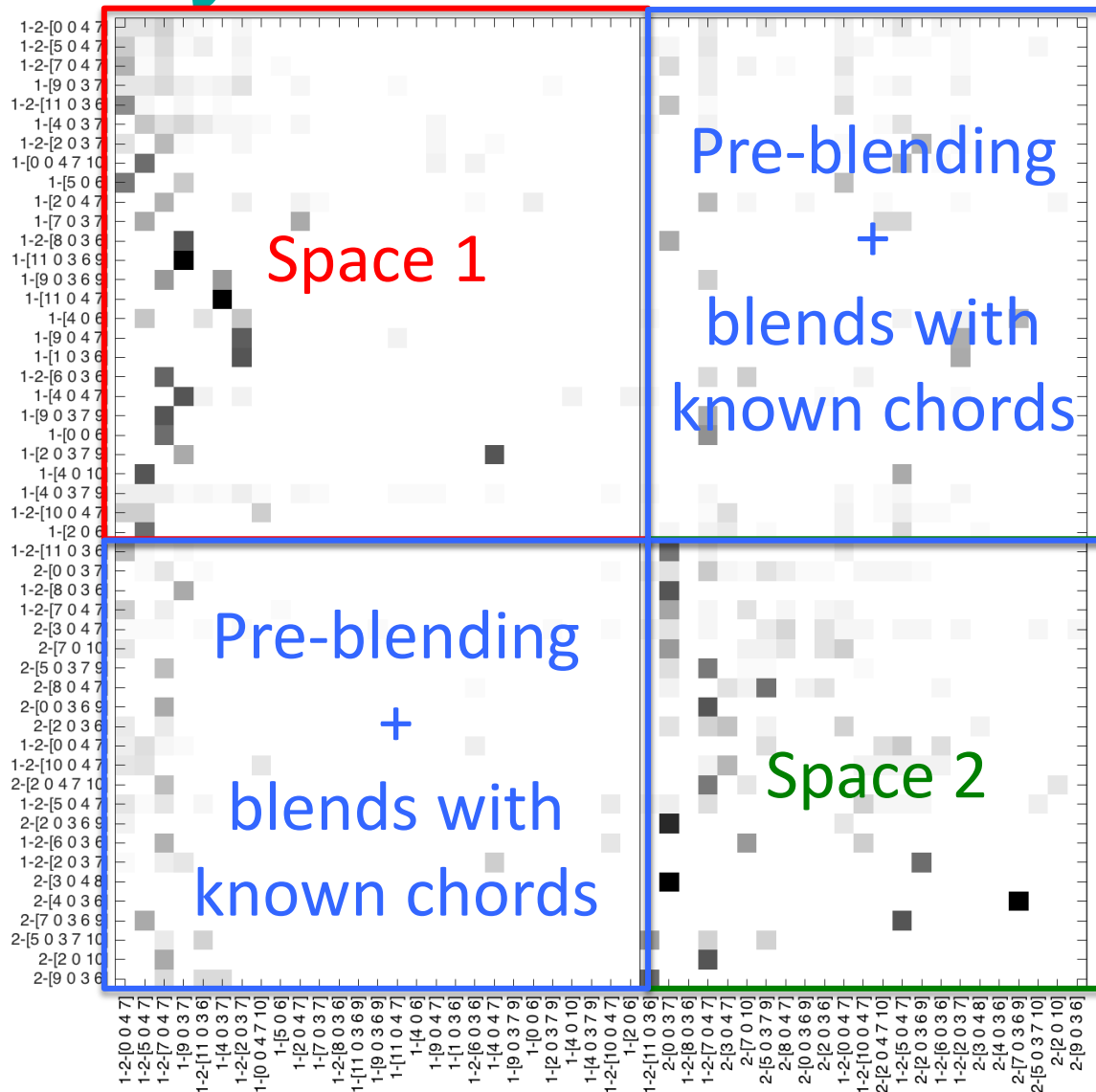



Musical notation for a chord progression in 4/4 time. The notation includes a treble clef and a bass clef. The chords are: C: I, IV⁶I, IV⁶V, IV⁶, V⁶, I, III⁶, F#: IV, V, vi, V⁷, I, C: V/iii, iii, V/iii, iii, IV⁶, V⁶, I V⁴, I⁶. A speaker icon is located to the left of the notation.

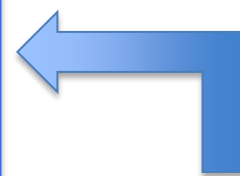
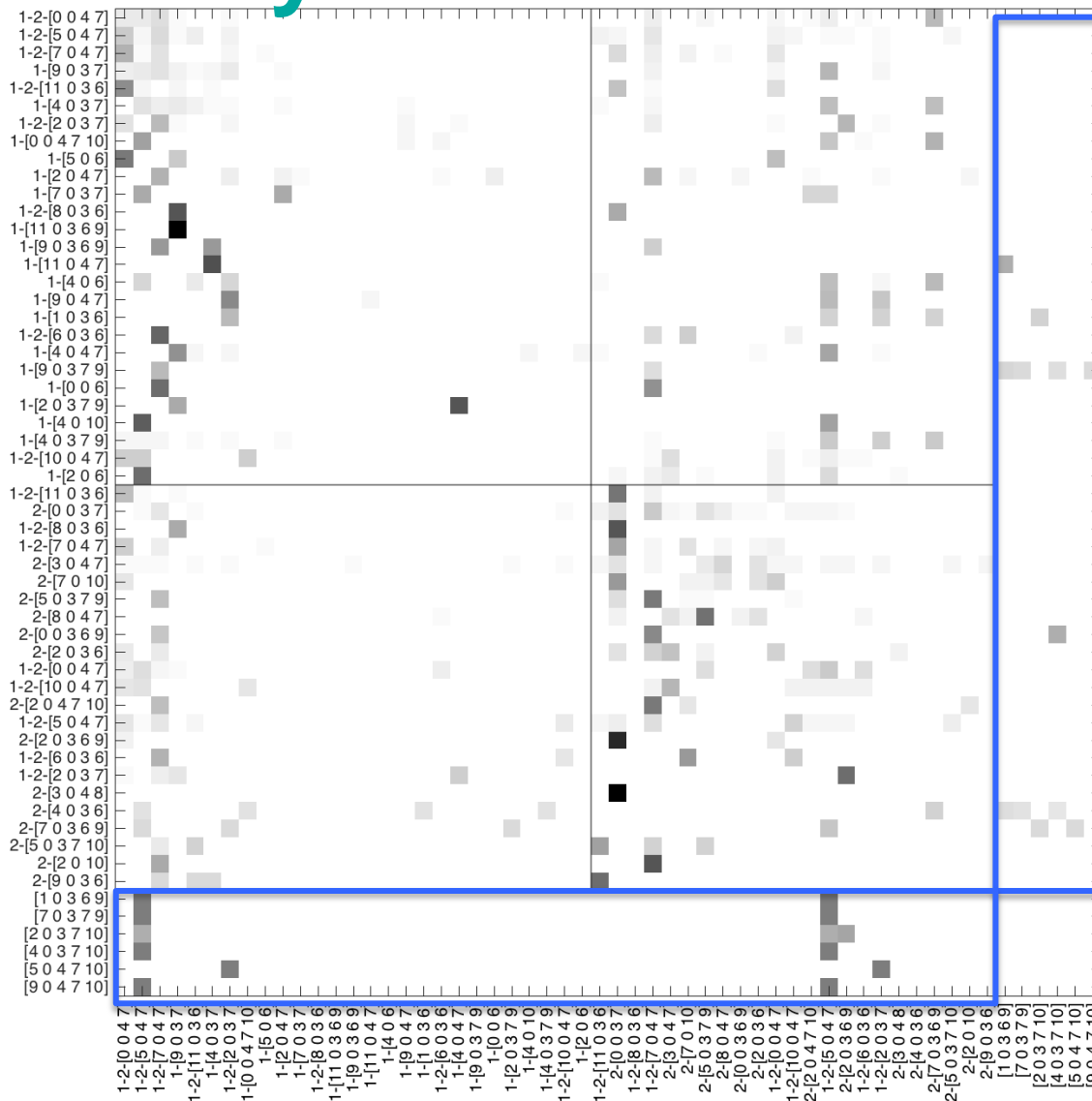
From to transition blends to probability matrices



From to transition blends to probability matrices



From to transition blends to probability matrices



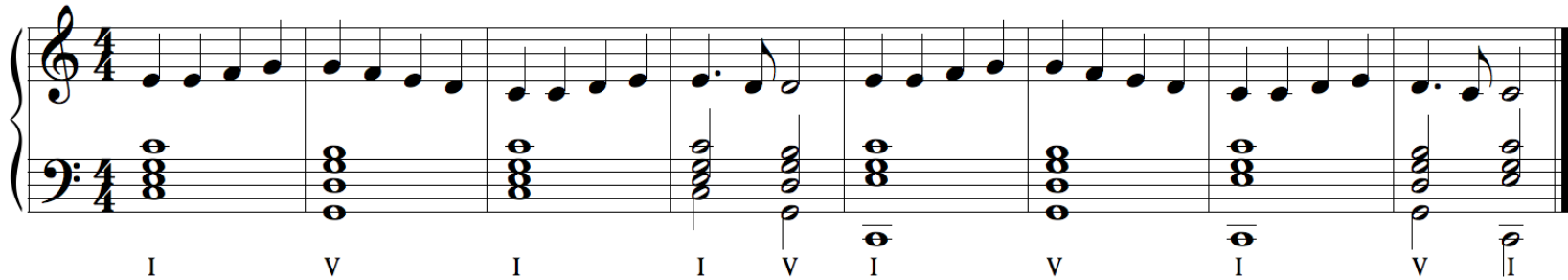
New chords
created through
blending



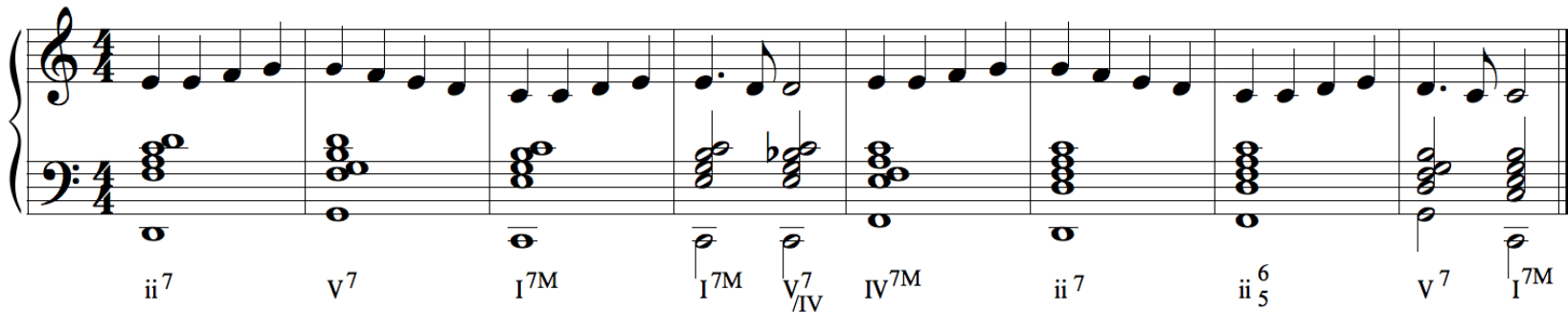
Blending Harmonic Spaces

L.v. Beethoven's "Ode to joy" with three harmonisations:

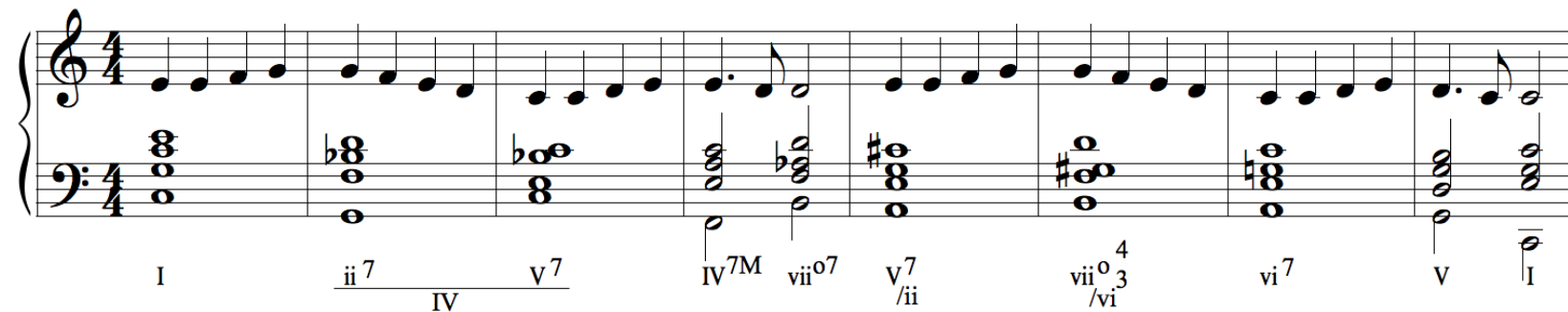
BC major (Bach chorale), JA major (Jazz), Blend of BC major/JA major



BC major (Bach chorale) harmonization. The score shows a treble clef with a melody and a bass clef with block chords. The key signature is one sharp (F#) and the time signature is 4/4. The chords are: I, V, I, I, V, I, V, I, V, I.



JA major (Jazz) harmonization. The score shows a treble clef with a melody and a bass clef with block chords. The key signature is one sharp (F#) and the time signature is 4/4. The chords are: ii⁷, V⁷, I^{7M}, I^{7M}, V⁷/_{IV}, IV^{7M}, ii⁷, ii⁶/₅, V⁷, I^{7M}.



Blend of BC major/JA major harmonization. The score shows a treble clef with a melody and a bass clef with block chords. The key signature is one sharp (F#) and the time signature is 4/4. The chords are: I, ii⁷, V⁷, IV^{7M}, vii⁰⁷, V⁷/_{ii}, vii⁰/₃, vi⁷, V, I.



Blending Harmonic Spaces

The Greek folk song *Apopse ta mesanychta* (Tonight at midnight) with two harmonisations:
Blend of CN/WT and Blend of HM/JA minor



A musical score for the Greek folk song 'Apopse ta mesanychta' in 4/4 time. The score is presented in a grand staff with a treble clef on the upper staff and a bass clef on the lower staff. The melody in the treble clef consists of eighth and quarter notes, starting on a middle C and moving in a generally ascending and then descending pattern. The bass clef accompaniment features a steady eighth-note bass line and chords that blend elements of the Constantinidis style with whole-tone harmony. A speaker icon is located to the right of the score.

Apopse ta mesanychta – Constantinidis/whole-Tone blend



A musical score for the Greek folk song 'Apopse ta mesanychta' in 4/4 time, featuring a different harmonic style. The score is presented in a grand staff with a treble clef on the upper staff and a bass clef on the lower staff. The melody in the treble clef is identical to the first score. The bass clef accompaniment is more complex, incorporating dissonant intervals and chords characteristic of Hindemith and jazz, such as tritones and augmented chords. A speaker icon is located to the right of the score.

Apopse ta mesanychta – Hindemith/Jazz blend



Evaluating CHAMELEON:

Computational creativity evaluation is not trivial

- Artistic creativity – aesthetic value
- Product or process?
- Dimensions: novelty, value, surprise, problem solving ability, originality, divergence (Jourdanous 2012-2016)
- Empirical testing
- User interaction with creative system

Evaluating CHAMELEON: Experiments with students of the School of Music Studies

Passive Evaluation through listening

1. Experiments in harmony class:

Idiom classification, mode classification

2. Experiment in analysis/theory class:

Type of chromaticism classification

Active evaluation through creative/compositional use

3. Creative harmonisation in stylistic composition class

Idiom classification



Melodies used:

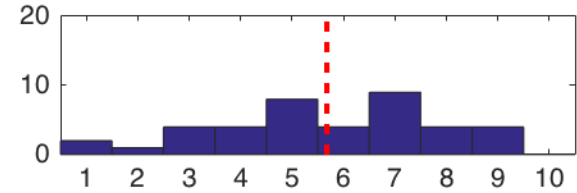
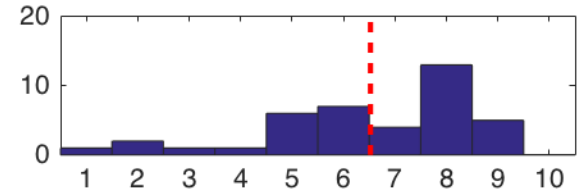
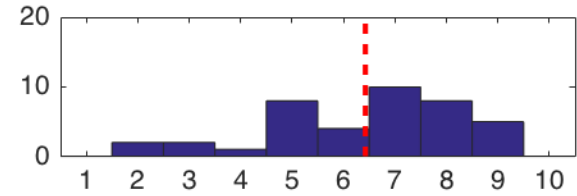
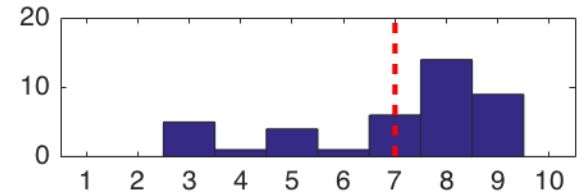
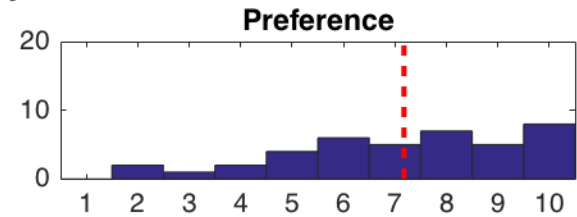
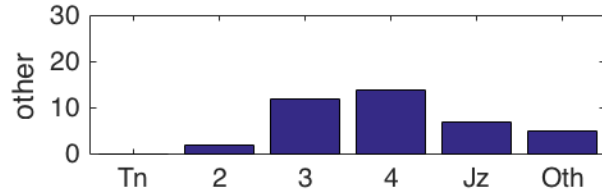
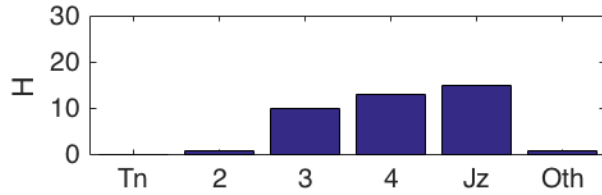
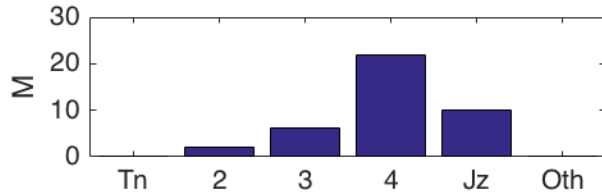
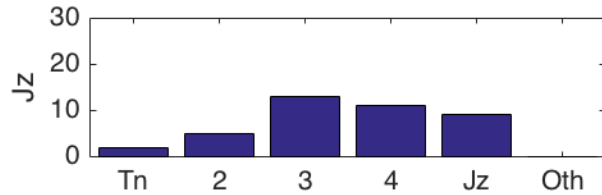
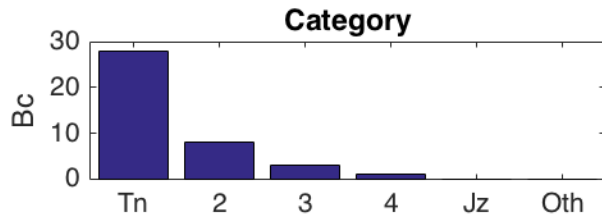
- "Ode to joy", from L.v. Beethoven's 9th Symphony
- "Ah vous dirai-je, maman", French children's song, used as theme in W.A. Mozart's Piano Variations K265
- "Some day my prince will come", by Frank Churchill, soundtrack from Disney's *Snow White and the Seven Dwarfs* (1937)
- "Summertime", by George Gershwin
- "Του Κίτσου η μάνα", Greek folk song

Aim of experiment:

- Assess the extent to which harmonic blending can affect idiom perception.
- Assess preference (i.e., attributed aesthetic value)

Results for "Ode to Joy"

Ode2Joy



Mode classification

Melody used:

- Custom-created melody intentionally lacking the 3rd and 6th melodic degrees, so as to avoid major-minor classification

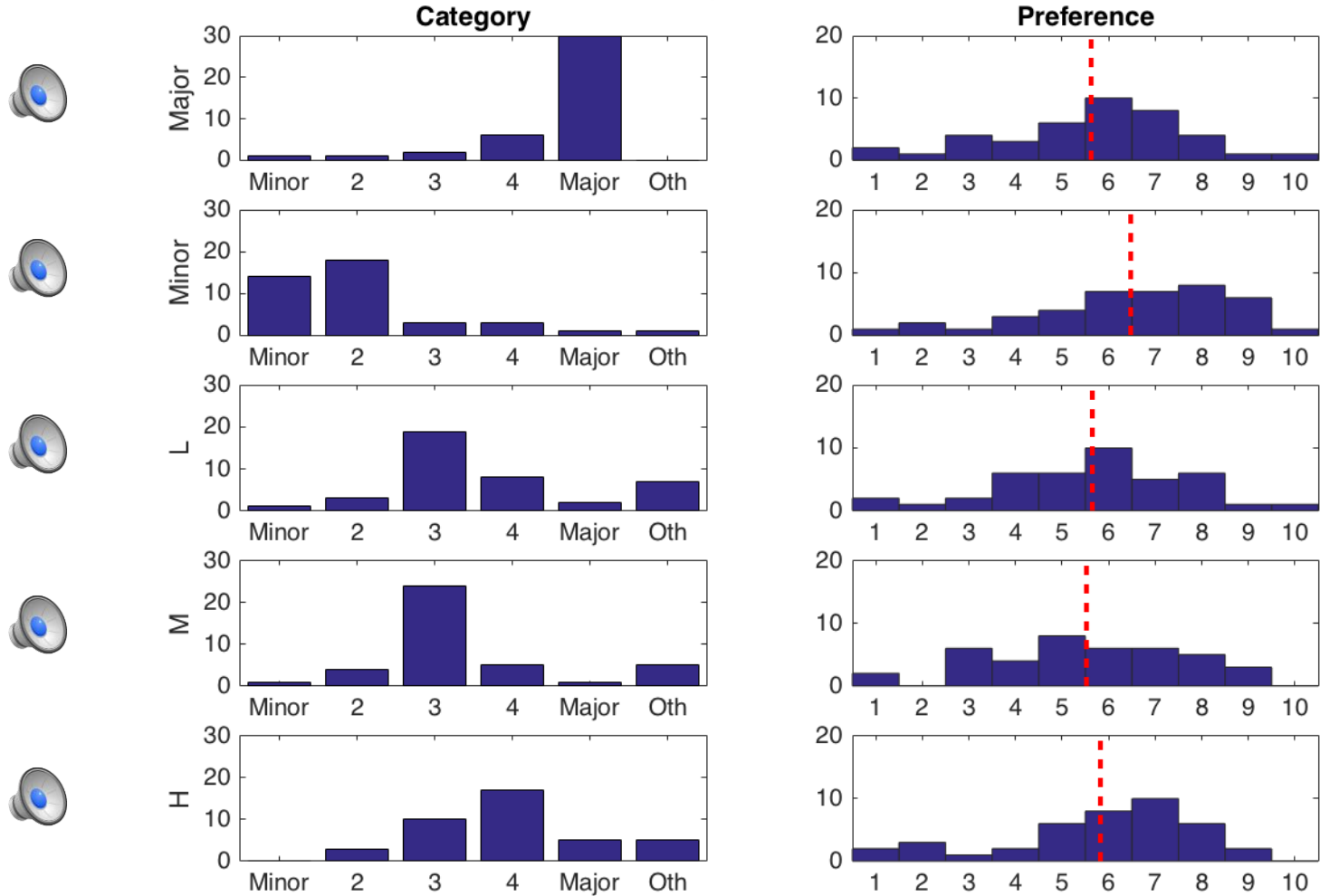


Aim of experiment:

- Assess the extent to which harmonic blending can affect perception of mode.
- Assess preference (i.e., attributed aesthetic value)

Results for "Major-Minor" melody

major-minor



Type of chromaticism classification

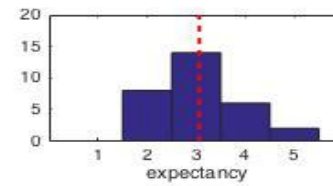
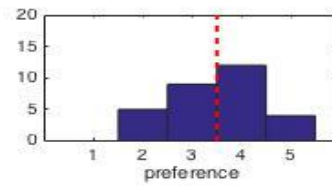
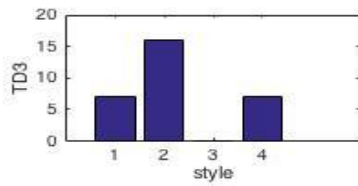
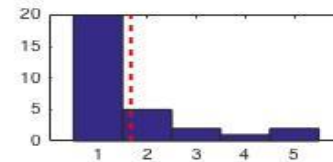
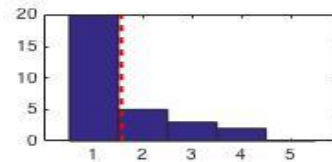
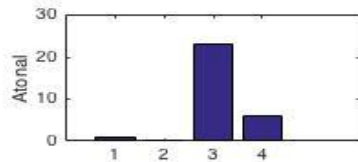
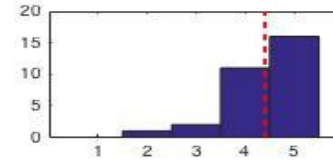
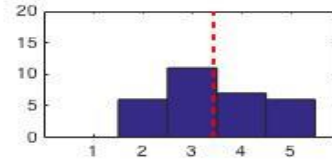
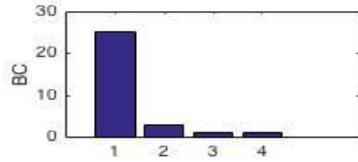
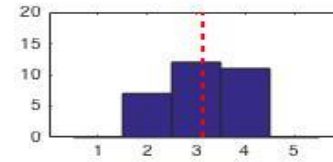
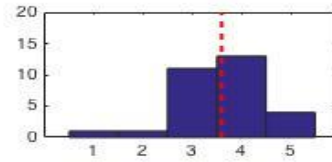
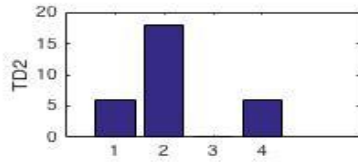
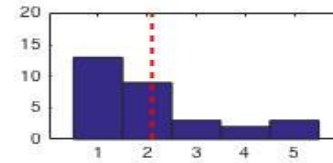
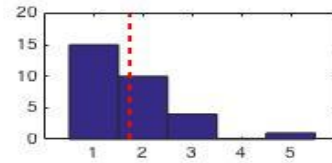
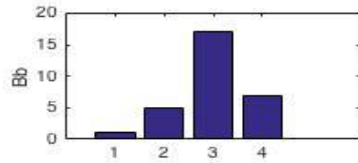
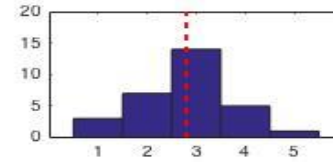
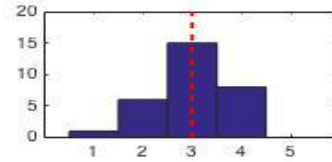
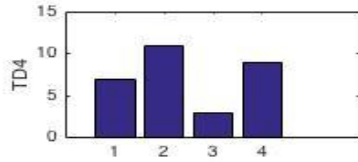
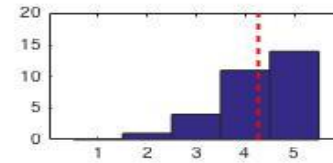
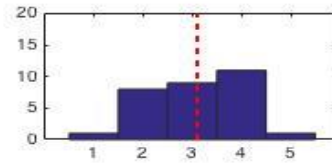
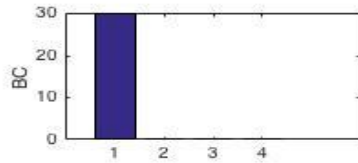


Melody used for harmonisation:

- "Ye banks and braes", Scottish folk song

Aim of experiment:

- Assess the extent to which harmonic blending can affect perception of chromaticism.
- Assess preference (i.e., attributed aesthetic value)
- Assess expectancy (i.e., perceived novelty)



Results for
"Ye banks
and braes"

Creative harmonisation assisted by CHAMELEON



Melodies used for harmonisation and variation:

Three Greek folk songs:

- Είχα μιαν αγάπη (*Eicha mian agapē*, I had a love)
- Απόψε τα μεσάνυχτα (*Apopse ta mesanychta*, Tonight at midnight)
- Μωρή κοντούλα λεμονιά (*Mōrē kontoula lemonia*, Oh short lemon tree)

Aim of experiment:

Creative use of produced CHAMELEON harmonisations (40 for each melody) as a structural harmonic framework for the building of rich musical textures and original variations.

Public Concert

Musical Blender: Artificial Intelligence & Creativity

Presentation and Concert

20:00, 19 Oct 2016

Macedonian Museum of Contemporary Art, Thessaloniki

Seven Piano Miniatures (14') – Fani Karagianni (Piano)

Michalis Goutis: Apopse ta mesanychta

Zesses Seglias: Tonight Midnight

Giorgos Papaoikonomou: Apopse ta mesanychta

Dimitris Maronidis: 7 COnsecutive INVENTions

Lazaros Tsavdaridis: Mōrē kontoula lemonia

Yiannis Sakellaris: Mōrē kontoula lemonia

Stella Dalampira: Mōrē kontoula lemonia

<http://ccm.web.auth.gr/creativeusecomposers.html>

ΤΕΧΝΗΤΗ ΝΟΗΜΟΣΥΝΗ ΚΑΙ ΔΗΜΙΟΥΡΓΙΚΟΤΗΤΑ
ΣΥΜΑΧΙΑ
Φ. ΚΑΡΑΓΙΑΝΝΗ ΤΡΑΝΣ
Α. ΠΑΠΑΔΟΠΟΥΛΟΥ ΒΙΘΩΝ
ΠΑΡΟΥΣΙΑΣΗ ΠΡΟΓΡΑΜΜΑΤΟΣ
CONVENT (FET-PPP)

ΜΟΥΣΕΙΟ ΠΑΙΝΤΕΡΙΚΟ ΤΕΡ

19 ΟΚΤ. 2016 20:00 ΕΙΣΟΔΟΣ ΕΛΕΥΘΕΡΗ
ΜΑΚΕΔΟΝΙΚΟ ΜΟΥΣΕΙΟ ΣΥΓΧΡΟΝΗΣ ΤΕΧΝΗΣ



Selected Publications



- Kaliakatsos-Papakostas, M., Queiroz, M., Tsougras, C., & Cambouropoulos, E. (2017). Conceptual blending of harmonic spaces for creating melodic harmonisation, *Journal of New Music Research*.
- Zacharakis, A., Kaliakatsos-Papakostas, M., Tsougras, C., & Cambouropoulos, E. (2017). Empirical methods for evaluating musical structural blends: A case study on melodic harmonisation, *Musicae Scientiae*, (Forthcoming).
- Zacharakis, A., Kaliakatsos-Papakostas, M., Tsougras, C., & Cambouropoulos, E., (2017). Creating musical cadences via conceptual blending: Empirical evaluation and enhancement of a formal model. *Music Perception*, (Forthcoming).
- Kaliakatsos-Papakostas M., Makris D., Tsougras C., Cambouropoulos E. (2016) Learning and creating novel harmonies in diverse musical idioms: An adaptive modular melodic harmonisation system. *Journal of Creative Music Systems* 1(1).

Thank you!

This work is supported by the COINVENT project
(FET-Open grant number: 611553)
www.coinvent-project.eu

www.ccm.web.auth.gr
www.ccm.web.auth.gr/chameleonmain.html

