



*Polifonia: a digital harmoniser for musical heritage knowledge,
H2020*

D3.1: Software Tools for Pattern Extraction (V1.0)

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Project Information

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POLIFONIA Consortium

No.	Short name	Institution name	Country
1	UNIBO	ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA	Italy
2	OU	THE OPEN UNIVERSITY	United Kingdom
3	KCL	KING'S COLLEGE LONDON	United Kingdom
4	NUI GALWAY	NATIONAL UNIVERSITY OF IRELAND GALWAY	Ireland
5	MiC	MINISTERO DELLA CULTURA	Italy
6	CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	France
	SORBONNE	SORBONNE UNIVERSITE (LinkedTP)	France
7	CNAM	CONSERVATOIRE NATIONAL DES ARTS ET METIERS	France
8	NISV	STICHTING NEDERLANDS INSTITUUT VOOR BEELD EN GELUID	Netherlands
9	KNAW	KONINKLIJKE NEDERLANDSE AKADEMIE VAN WETENSCHAPPEN	Netherlands
10	DP	DIGITAL PATHS	Italy

Project Summary

European musical heritage is a dynamic historical flow of experiences, leaving heterogeneous traces that are difficult to capture, connect, access, interpret, and valorise. Computing technologies have the potential to shed a light on this wealth of resources by extracting, materialising and linking new knowledge from heterogeneous sources, hence revealing facts and experiences from hidden voices of the past. Polifonia makes this happen by building novel ways of inspecting, representing, and interacting with digital content. Memory institutions, scholars, and citizens will be able to navigate, explore, and discover multiple perspectives and stories about European Musical Heritage.

Polifonia focuses on European Musical Heritage, intended as musical contents and artefacts - or music objects - (tunes, scores, melodies, notations, etc.) along with relevant knowledge about them such as: their links to tangible objects (theatres, conservatoires, churches, etc.), their cultural and historical contexts, opinions and stories told by people having diverse social and artistic roles (scholars, writers, students, intellectuals, musicians, politicians, journalists, etc), and facts expressed in different styles and disciplines (memoire, reportage, news, biographies, reviews), different languages (English, Italian, French, Spanish, and German), and across centuries.

The overall goal of the project is to realise an ecosystem of computational methods and tools supporting discovery, extraction, encoding, interlinking, classification, exploration of, and access to, musical heritage knowledge on the Web. An equally important objective is to demonstrate that these tools improve the state of the art of Social Science and Humanities (SSH) methodologies. Hence their development is guided by, and continuously intertwined with, experiments and validations performed in real-world settings, identified by musical heritage stakeholders (both belonging to the Consortium and external supporters) such as cultural institutes and collection owners, historians of music, anthropologists and ethnomusicologists, linguists, etc.

Executive Summary

Deliverable D3.1 is titled: *Software Tools for Pattern Extraction*. It is due month 12, and linked to Task 1 of WP3: *Pattern Extraction*. The task leader is KNAW (Meertens Institute) and the participants are: UNIBO, OU, NUIG, IREMUS, KCL, and CNAM. This deliverable and task are strongly linked with D3.2 *Pattern recognition and definition in monodic and polyphonic music*. This deliverable includes the software components that are described in detail in deliverable D3.2.

Document History

Version	Release date	Summary of changes	Author(s) - Institution
V0.1	15/11/2021	Version for internal review	Danny Diamond (NUIG) and Abdul Sahid (NUIG), and Jacopo de Berardinis (KCL) and Andrea Poltronieri (UNIBO) and Peter van Kranenburg (KNAW)
V0.2	10/12/2021	Updated version for final internal review based on the reviewer's remarks	Danny Diamond (NUIG) and Abdul Sahid (NUIG), and Jacopo de Berardinis (KCL) and Andrea Poltronieri (UNIBO) and Peter van Kranenburg (KNAW)
V1.0	22/12/2021	Final version submitted to EU	UNIBO

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1 Introduction

This deliverable consists of four components which are part of the Polifonia ecosystem: a software component implementing similarity measures for folk songs based on n-gram models (FONN), a data set component containing a corpus of midi representations of Irish instrumental music, a software component that implements a key finding algorithm, and a software component that implements a harmonic similarity measure based on local similarities. The program code and corresponding documentation are accessible from repositories hosted at github.com. In this document, for each component, we present a summary, including a description and links to the code or data. Furthermore, we discuss the exploitability and the plans for future work.

2 Component: FONN - FOlk N-gram aNalysis

2.1 Summary

ID	
Type	Software
Title	FONN - FOlk N-gram aNalysis
Credits	Danny Diamond (NUIG), and James McDermott (NUIG), and Abdul Shahid Khattak (NUIG), and Mathieu d'Aquin (NUIG)
Description	<p>Detection of similarity between pieces of folk music is a key tool in the exploration of structure, function and meaning of folk music across cultural, geographic and temporal boundaries. It has been an area of study since the early 20th century, and is an integral task in the toolkit for exploration of shared European cultural resources, under development through the Polifonia project.</p> <p>FONN is a set of software tools for detecting, compiling and analysing patterns in monophonic MIDI music corpora, with the ultimate goal of detection of melodic similarity via frequent pattern similarity. Current work is based on identification of similar pitch class patterns across multiple pieces of music via edit distance.</p> <p>The validity of such pattern similarity as an indicator of melodic similarity between musical pieces in the corpus is currently being explored, and testing of the methodology is ongoing using the Ceol Rince na hÉireann (CRÉ) corpus. Evaluation of results will be central to the next phase of work: this will be achieved by comparing FONN similarity results with existing academically-identified 'tune families', and by scaling up from the CRÉ corpus to the crowd-sourced Irish traditional music resource thesession.org, which holds a significant corpus of 40,000+ melodies.</p>
Source Code	https://github.com/polifonia-project/folk_ngram_analysis
Documentation	README.md
Release	v0.4-dev
Licence	CC BY 4.0
Running Instance	Demo.ipynb
Bibliography	
Related Deliverables	Polifonia deliverable D3.2

2.2 Exploitability

The FONN code contributes to overall Polifonia goals, in particular it provides a concrete implementation of patterns suited to monophonic folk music (specialised to Irish traditional music). This concrete implementation allows the user to identify important patterns in tunes, or across a corpus; and to identify possible “filial” relationships among tunes in a corpus due to similarity in their patterns. FONN has been created by NUIG but is available to other partners. In particular, we hope to apply FONN tools to Dutch folk corpora in collaboration with KNAW, and eventually to use FONN as a component in a web-accessible pattern dashboard with multiple folk corpora.

2.3 Future Work

An immediate priority is testing the existing FONN tools and methodology on the thesession.org's corpus of 40,000+ Irish tunes. This corpus contains in-built crowd-sourced groupings of similar melodies, along with academically-identified ‘tune families’: we plan to use these resources as ground truths, against which we can compare FONN’s melodic similarity results.

Other planned work includes:

- Integration of Root Note Detection component into FONN to allow accurate root note assignment for large corpora.
- Exploration of alternative methods to derive representative pattern(s) from a single melody for use as search terms in FONN’s melodic similarity search. Currently we extract top patterns as ranked by tf-idf but pattern clustering options will also be explored as alternatives.
- Detection of frequent patterns in features other than pitch class, and application of similarity search to these patterns.
- Testing on additional corpora within the Polifonia consortium.
- Addition of results visualisation tools.
- Addition of CLI and GUI interfaces.
- Publication and dissemination of research to date.

3 Component: Ceol Rince na hÉireann MIDI corpus

3.1 Summary

ID	
Type	Data
Title	Ceol Rince na hÉireann MIDI corpus
Credits	Danny Diamond (NUIG)
Description	<p>For development and testing of FONN's pattern extraction and similarity methods, a test corpus of Irish instrumental music was required. The <i>Ceol Rince na hÉireann (CRÉ)</i> corpus was chosen. <i>CRÉ</i> is a canonical collection in the Irish tradition, featuring accurate transcriptions and a high degree of internal consistency; it is also freely available in an existing machine-readable format via music researcher Bill Black's personal music repository website, capeirish.com.</p> <p>Our work involved cleaning, annotating and converting the ABC Notation corpus to MIDI. This new version of the corpus is provided here as a data component for Polifonia deliverable 3.1. More information on the background and history of the corpus, and on our changes to the existing ABC version are detailed in Polifonia D3.2 and in the corpus README.md file below.</p> <p>The corpus has been a valuable resource for preliminary exploration and proof-of-concept testing, but its limited size makes it less useful for rigorous testing and validation of results, and the next phase of FONN will move to thesession.org's corpus of 40,000+ Irish melodies. It is hoped that the MIDI CRÉ corpus will be of use for other researchers both within and outside the Polifonia consortium.</p>
Source Code	https://github.com/polifonia-project/folk_ngram_analysis/corpus
Documentation	README.md
Release	v0.4-dev
Licence	CC BY 4.0
Running Instance	Jupyter Notebook
Bibliography	
Related Deliverables	Polifonia deliverable D3.2

3.2 Exploitability

The CRÉ corpus contributes to Polifonia objectives by providing an open and “cleaned” corpus of folk music, suitable for musicological research. It is already exploited by the FONN component for initial results. It can be exploited by other aspects of Polifonia including WP2 by converting to a knowledge graph.

3.3 Future Work

Work on the CRÉ corpus is complete: the MIDI version of the corpus has been created, documented, and used for informal small-scale testing of FONN work-in-progress. We intend to apply the workflow developed for CRÉ to extract a MIDI version of thesession.org's Irish corpus, but no further active work on the CRÉ corpus is planned.

4 Component: Root Note Detection

4.1 Summary

ID	
Type	Software
Title	Root Note Detection
Credits	Abdul Shahid (NUIG), and Danny Diamond (NUIG), and James McDermott (NUIG), and Mathieu d'Aquin (NUIG)
Description	<p>Determination of the root note of each piece of music in the corpus under investigation is a key foundational step in FONN. Accurate root note data allows reliable calculation of key-invariant chromatic pitch class sequences, which have been the primary input for our pattern analysis and melodic similarity work.</p> <p>For the CRÉ corpus, transcriber-assigned root data was available but its accuracy was determined to be 86%; and due to the modal nature of much of the music under study, existing pitch detection algorithms produced accuracy under 80%.</p> <p>Given the above, we began to explore use of multiple root determination metrics ranging from key detection algorithms to simple statistics, as detailed in Polifonia D3.2 report. Work-in-progress involves using the results of these metrics as ensemble inputs to decision tree and random forest algorithms, which aggregate and improve the root detection results.</p> <p>While further formal evaluation is required to verify and refine the work, initial informal testing has indicated a high degree of accuracy in the output,. Work-in-progress involves testing on our Polifonia partner Meertens Instituut's MTC-ANN corpus, and further evaluation work will be carried out on thesession.org Irish corpus.</p>
Source Code	https://github.com/polifonia-project/fonn/root_note_detection
Documentation	README.md
Release	v0.4-dev
Licence	CC BY 4.0
Running Instance	Jupyter Notebook
Bibliography	
Related Deliverables	Polifonia deliverable D3.2

4.2 Exploitability

Correct identification of root notes is foundational for our n -gram pattern approach as used in the FONN component. We do not currently envisage exploitability by other Polifonia partners. In some corpora, a root note annotation is provided, for example in the Dutch folk song database, and then a machine learning approach is not needed. The exploitability of the root note detection component may be limited unless new corpora are proposed which lack such annotations.

4.3 Future Work

Future work will involve refining the methodology, working towards a root detection algorithm model with a high degree of accuracy, which can automatically populate root note values for corpora where root data does not exist, where manual assignment of is impractical, or where accuracy of existing root data is potentially low.

The effectiveness of various combinations of ensemble input metrics will be evaluated, as will alternative parameters in the decision tree and random forest algorithms.

The root detection work will be tested and evaluated on additional corpora: the ground-truth annotated Meertens Instituut [MTC-ANN](#) corpus of Dutch folk song melodies, which is available within the Polifonia consortium; and also thesession.org Irish tune corpus.

On completion, the tool produced by this work will allow FONN automatically assign key-invariant pitch class values with a high degree of accuracy as a fundamental step before pitch-class based pattern analysis and similarity searching.

5 Component: Local Harmonic Agreement based on Recurrent Patterns (LHARP)

5.1 Summary

ID	
Type	Software
Title	Local Harmonic Agreement based on Recurrent Patterns (LHARP)
Credits	Jacopo de Berardinis (KCL) and Andrea Poltronieri (UNIBO)
Description	A method for computing harmonic similarity from symbolic sequences, based on shared recurring harmonic structures. This method emphasises shared repeated patterns among symbolic chord sequences, to accommodate a wide set of applications. Compared to other harmonic similarity methods on symbolic music, LHARP enables more explorative studies, as it can establish links when local harmonic patterns are found repeated in both sequences, while retaining global information to a lesser extent. This software component is also complemented with “ <i>The Harmonic Network</i> ” – a computational tool allowing users to explore music collections by visualising harmonic similarities among tracks and interacting with the resulting graph to discover nontrivial relationships among authors, composers, and pieces.
Source Code	https://github.com/polifonia-project/harmonic-similarity
Documentation	Readme
Release	LHARP v1.0.0
Licence	CC-BY-NC 4.0
Running Instance	https://polifonia-project.github.io/musilar-preview/
Bibliography	J. de Berardinis, A. Meroño-Peñuela, A. Poltronieri, V. Presutti, <i>A local harmonic similarity function based on shared repeated chord structures</i> (manuscript under review).
Related Deliverables	N.A.

5.2 Exploitability

LHARP proposes an approach for analysing the harmonic similarity between two pieces. Unlike the approaches proposed in literature, LHARP proposes to consider harmonic similarity on a local level, rather than on the entire song. Through this approach, it is not only possible to cal-

culate the harmonic similarity value between two different pieces, but also to know which are the similar harmonic sub-sequences between the two pieces and their temporal location within the piece. Moreover, the proposed similarity function can be extended to other fields of application, and used to calculate similarities between melodic and rhythmic elements as well as harmonics. Furthermore, this method will be used for the INTERLINK pilot, as it allows connections between musical objects to be established at the level of musical content.

5.3 Future Work

Future work involving HARP includes revising the similarity function so that it also takes into account the duration of the musical objects under consideration, thus providing a similarity value that more closely approximates similarity from a perceptual point of view. Another aim is to extend the chord encoding methods used, in order to take into account different chord annotations, the notes that constitute them, as well as different interpretations provided by different annotators. Finally, the aim is to expand the proposed model in order to use it for the analysis of similarity between melodic and rhythmic sequences.



The Polifonia project

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Polifonia-D3.1-V1.0

Horizon 2020

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