Melody Characterization by a Fuzzy Rule System

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Introduction

What’s a melody?

Melody is a somewhat **elusive** musical term that often refers to a **central part of a music piece** that **catches most of the listener’s attention**, and which the rest of music parts are subordinated to.

Motivation

- Objective of this work:
  - To describe with readable linguistic labels what a melody is
    - And learn it automatically from a dataset

Related previous works

- Some authors give descriptions of what a melody is for other given objective:
  - Polyphonic to monophonic reduction
  - Extraction of melody from a polyphonic audio source
  - From a MIDI file, select a track as the melody track

- Ponce de León et. al. [ISMIR'07]: melody characterization by automatically induced rules

  `AvgPitch>=65 and TrackOccupationRate>=0.51 and ….`

  - Rules induced by a Random Forest classifier
  - Rules expressed in numerical terms difficult to read
  - Crisp decisions: what happens if AvgPitch = 64?

Methodology

Metholodogy overview

1st.

Extract statistical **descriptors**

2nd.

Induce set of **crisp rules** set to describe the term "melody"

3rd.

Transform the numerical based **rules in linguistic** label based rules that avoid crisp logic

By means of fuzzy logic and genetic algorithms
(Genetic Fuzzy System - GFS)

1st step: track description

- Set of statistics on properties of note streams:

Category	Descriptors
Track info	Normalized duration, Number of notes, Occupation rate, Polyphony rate
Pitch	Highest, Lowest, Mean, Standard deviation
Pitch intervals	Number of distinct intervals, Largest, Smallest, Mean, Mode, Standard deviation
Note durations	Longest, Shortest, Mean, Standard deviation
Syncopation	Number of syncopated notes
Class	Melody, accompaniment

2nd step: crisp rule induction

- Ripper algorithm (Cohen, 1995):
  - Sequential covering: generate rules one at a time until all positive examples are covered
  - Conditions are added to a rule:
    - to maximize an information gain measure.
    - until it covers no negative example.

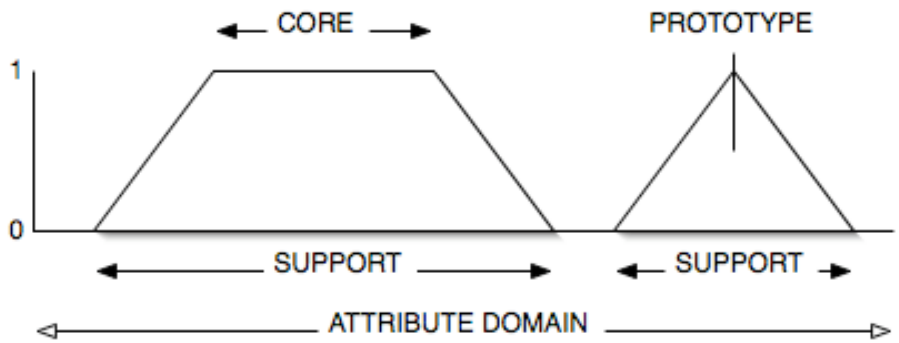
3rd step: from crisp rules to fuzzy rules

- Data representation (descriptors)
  - Crisp descriptor (e.g. avgPitch) → fuzzy variable
  - Fuzzy variable membership function parameters are optimized using a Genetic Fuzzy System
    - Fuzzy Inference System (FIS) + Genetic Algorithm (GA)
- Rules
  - *Fuzzify* antecedents:

    $(x > a) \rightarrow (x \text{ IS } term_1) \text{ OR } (x \text{ IS } term_2) \ldots$

3.1 Descriptor *fuzzification*

- Transform descriptors ➔ fuzzy variables + linguistic terms
  - $X \in \Re$ ➔ $X \in \{$ low, average, high $\}$
- λ Each linguistic term (low, high,…) has its own <u>membership function</u> (fuzzy set) for each fuzzy variable
  - λ Indicates to what extent *'x' IS 'term'*
  - λ *Fuzzy set* definition
    - λ Select a shape (trapezoidal, triangular, gaussian,…)
    - λ Adjust shape parameters

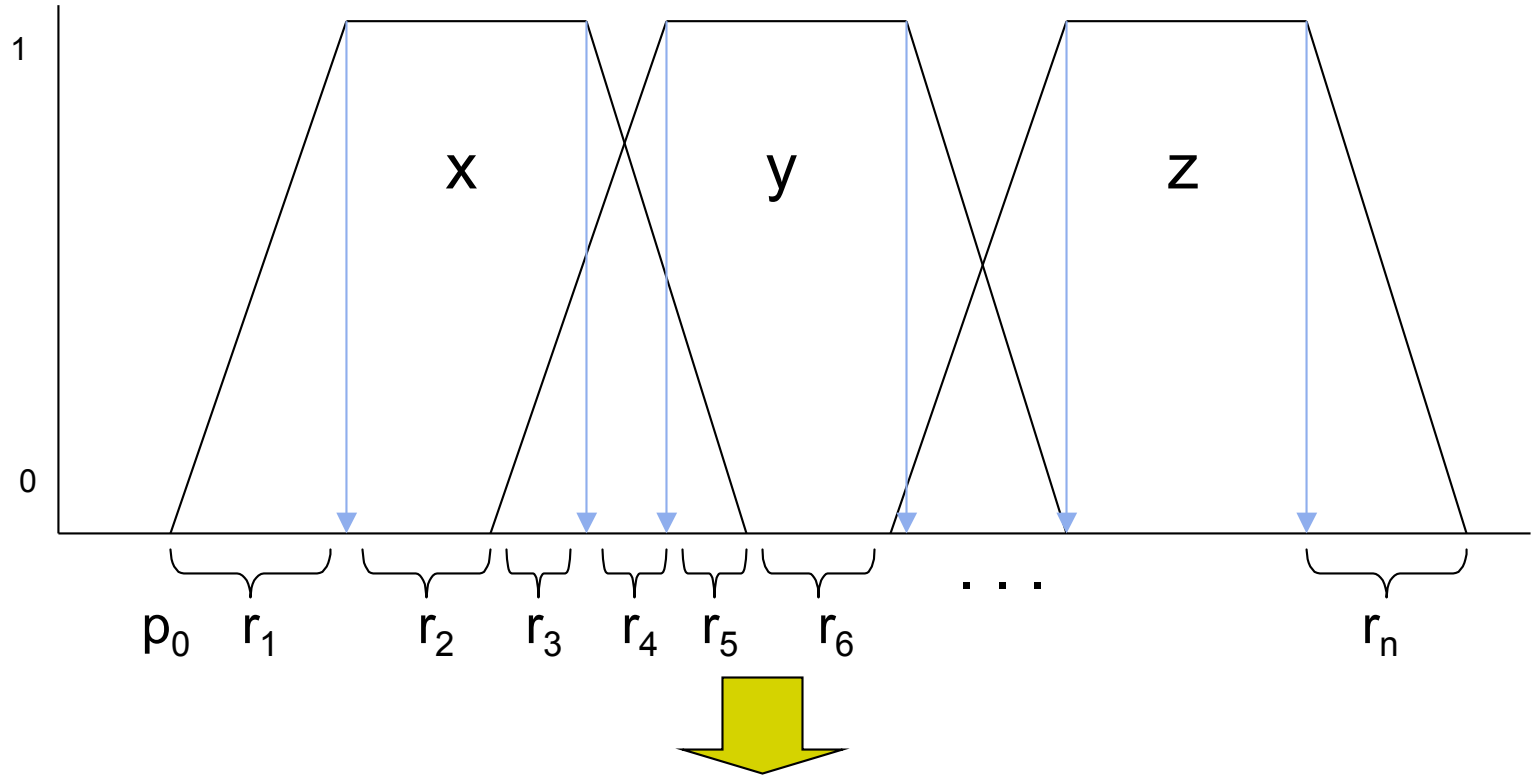


3.1 Descriptor *fuzzification*

- Most frequently used fuzzy variables: 5 terms
  - E.g. *TrackPolyphonyRate* $\in$ *{none, low, average, high, all}*
- Other: 3 terms
  - E.g. *DistincIntervals* $\in$ *{ few, average, alot }*
- Fuzzy set shape: trapezoidal (degenerate to triangular)
- Fuzzy set parameters
  - Adjusted by a Genetic Fuzzy System

3.2 Fuzzy set parameter optimization: encoding

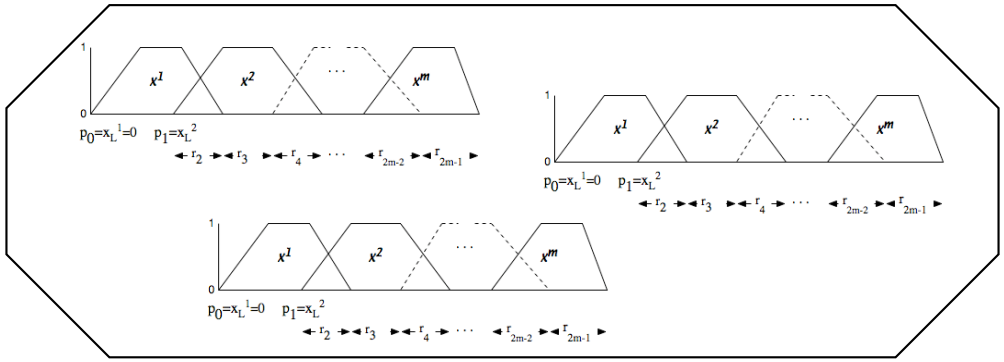
- Only fuzzy set <u>support points</u> considered for optimization
  - the relative values of the vertices are encoded into genes



Gene = $\{p_0, r_1, r_2, r_3, \ldots r_n\}$

3.2 Fuzzy set parameter optimization: encoding

Fuzzy variables



Chromosome

3.2 GA fitness function

Chromosome

⇩

Build fuzzy sets from chromosome

⇩

Fitness measure: test quality of fuzzy rules system with training corpus:

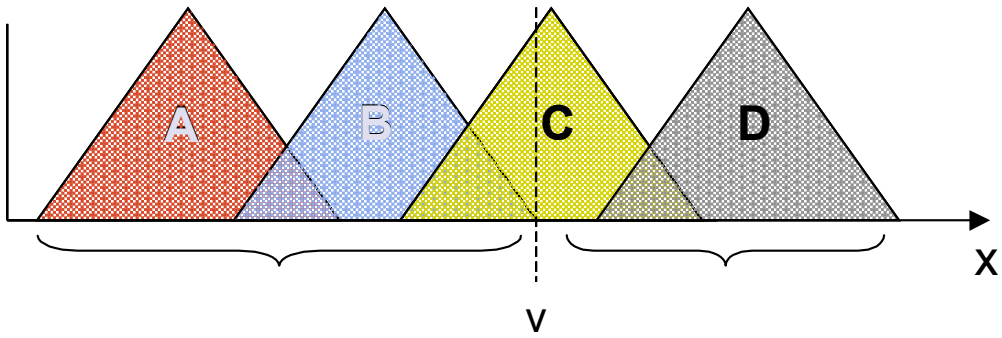
Two possible quality measurements:

a) Number of hits: num. of tracks correctly classified by the FIS

b) F-measure for class ‘IsMelody=true’

3.3 Crisp Rule *fuzzification*

- *Fuzzify* antecedents: keep the sets whose support holds the inequality



(x < v) ➔ (x IS C) OR (x IS B) OR (x IS A)

(x > v) ➔ (x IS C) OR (x IS D)

Crisp → Fuzzy

```
if (AvgPitch >= 65.4)
and (TrackNumNotes >= 284)
and (ShortestNormalizedDuration <= 0.001)
and (ShortestDuration >= 0.02)
and (NormalizedDistinctIntervals >= 1)
then IsMelody=true
```

```
IF (AvgPitch IS high OR AvgPitch IS veryHigh)
AND (TrackNumNotes IS high)
AND (LowestNormalizedDuration IS shortest)
AND (ShortestDuration IS NOT low)
AND (NormalizedDistinctIntervals IS highest)
THEN IsMelody IS true
```

Experiments and results

Corpora

- Manually tagged
  - Class: {melody | accompaniment}

Dataset	Tracks	Songs	Melody tracks
SMALL	2775	600	554
LARGE	15168	2513	2337
AJP	3732	762	760
RWC-G	311	48	44

Experimental setup

TRAIN

Induce CRISP Rules with SMALL Dataset

↓

Fuzzify rules

↓

Optimize fuzzy sets with SMALL Dataset (GFS)

System output = fuzzy system parameters ↓

TEST

Use the fuzzy rules based on the optimized fuzzy sets

Tested Corpora: LARGE, RWC-G, AJP

FIS optimization parameters

Experiment parameter	Values
GA population size	100,500,1000
GA no. of generations	100,500,1000
GA mutation ratio	none, 0.05, 0.1
GA selection strategy	Best one, Best 10%, Best 20%
GA fitness metric	Hit count, F-measure
Defuzzification threshold	0.5,0.6, 0.7

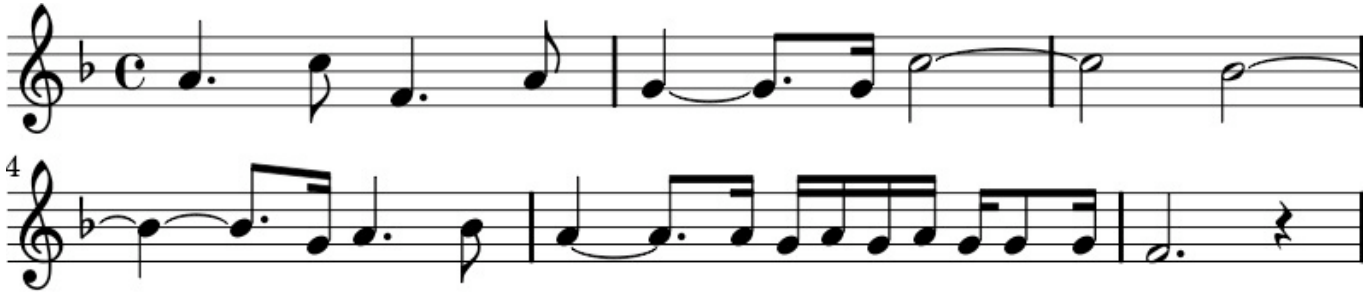
Results

System parameters learnt with SMALL dataset

Dataset	Precision	Recall	F	Error rate
LARGE (crisp)	0.79	0.80	0.80	0.06
LARGE (fuzzy)	0.70	0.74	0.72	0.09
RWC-G (crisp)	0.54	0.77	0.64	0.13
RWC-G (fuzzy)	0.43	0.43	0.43	0.16
AJP (crisp)	0.88	0.89	0.88	0.05
AJP (fuzzy)	0.88	0.83	0.86	0.06

Melody description example (I)

- Air In F, Watermusic, Handel (Baroque)
  - Melody

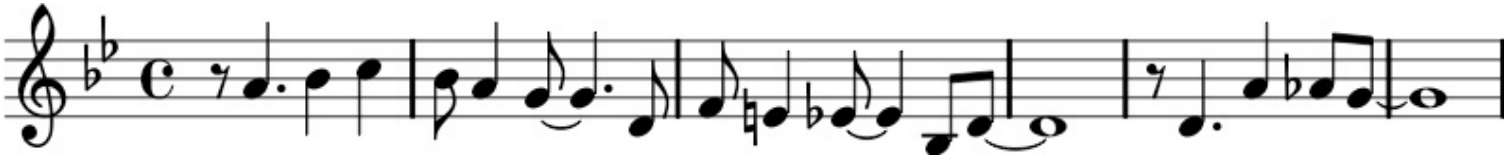


Most fired rule:

(**AvgPitch** IS NOT **veryLow**) AND
(**AvgAbsInterval** IS NOT **high**) AND
(**AvgAbsInterval** IS NOT **third**) AND (**AvgAbsInterval** IS NOT fourth) AND
(**TrackSyncopation** IS **alot**) AND
(**TrackOccupationRate** IS NOT **low**) AND
(**LowestNormalizedPitch** IS NOT **low**) AND
(**DistinctIntervals** IS **alot**) AND
(**TrackNormalizedDuration** IS **largest**)

Melody description example (II)

- There Is No Greater Love, I. Jones (pre-Bop Jazz)
  - Melody



Most fired rule:

(**AvgPitch** IS NOT **veryLow**) AND
(**AvgAbsInterval** IS NOT **high**) AND
(**AvgAbsInterval** IS NOT **third**) AND (**AvgAbsInterval** IS NOT fourth) AND
(**TrackSyncopation** IS **alot**) AND
(**TrackOccupationRate** IS NOT **low**) AND
(**LowestNormalizedPitch** IS NOT **low**) AND
(**DistinctIntervals** IS **alot**) AND
(**TrackNormalizedDuration** IS **largest**)

Conclusions

Conclusions

- A melody fuzzy description system that is automatically induced from examples has been built
- The accuracy of this system is lower than that of the crisp rule system
- The readability of the rules have been improved
- We plan to improve the fuzzy rule system by:
  - modifying the way it is optimized
  - exploring different alternatives for rule fuzzification