University of Antwerp
Operations Research Group
ANT/OR

FuX, an Android app that generates counterpoint

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CI for Creativity and Affective Computing

Overview

Computer Aided Composing

Quantifying Counterpoint Quality

VNS

Android Implementation

Conclusion

Computer aided composing (CAC)

Composing music = combinatorial optimization problem

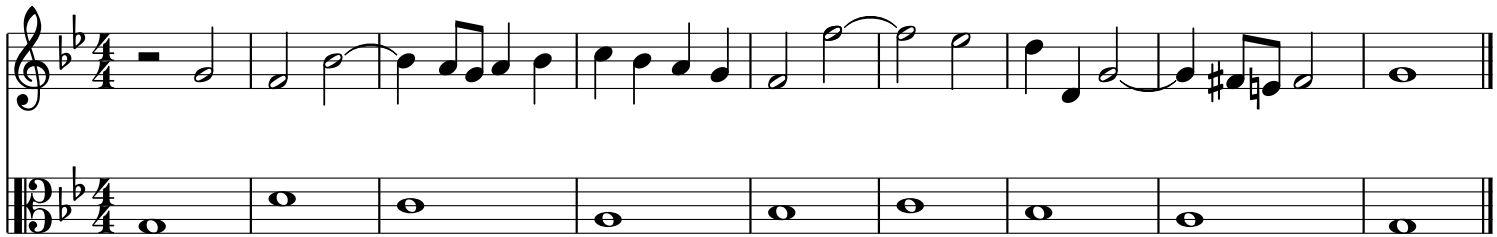
- Music $\rightarrow$ combination of notes
- "Good" music $\rightarrow$ fits a style as well as possible
- Formalized and quantified "rules" of a style $\rightarrow$ objective function

Counterpoint

- Polyphonic baroque music
- Inspired Bach, Haydn,. . .
- One of the most formally defined musical styles
  $\rightarrow$ Rules written by Fux in 1725

5th species counterpoint

- Counterpoint & Cantus firmus



- Represented as a vector of note objects, each with:
  - Pitch: midi value
  - Duration
  - Beat number
  - Measure number
  - Tied?

Quantifying musical quality

Examples of rules:

- Each large leap should be followed by stepwise motion in the opposite direction
- Half notes should always be consonant on the first beat, unless they are suspended and continued stepwise and downward
- All perfect intervals should be approached by contrary or oblique motion

$\rightarrow$ 19 vertical and 19 horizontal subscores between 0 and 1

Quantifying musical quality

- Eight notes (8ths) must move in step.

$$subscore_1^H(s) = \frac{\#\text{8ths not preceded by step} + \text{8ths not left by step}}{\#\text{8ths} \times 2} \tag{1}$$

- Whole notes should always be vertically consonant.

$$subscore_1^V(s) = \frac{\#\text{dissonant whole notes}}{\#\text{whole notes}} \tag{2}$$

Quantifying musical quality

$$f_{cf}(s) = \underbrace{\sum_{i=0}^{19} a_i.\text{subscore\_cf}_i^H(s)}_{\text{horizontal aspect}} \tag{3}$$

$$f_{cp}(s) = \underbrace{\sum_{i=0}^{19} a_i.\text{subscore\_cp}_i^H(s)}_{\text{horizontal aspect}} + \underbrace{\sum_{j=0}^{19} b_j.\text{subscore}_j^V(s)}_{\text{vertical aspect}} \tag{4}$$

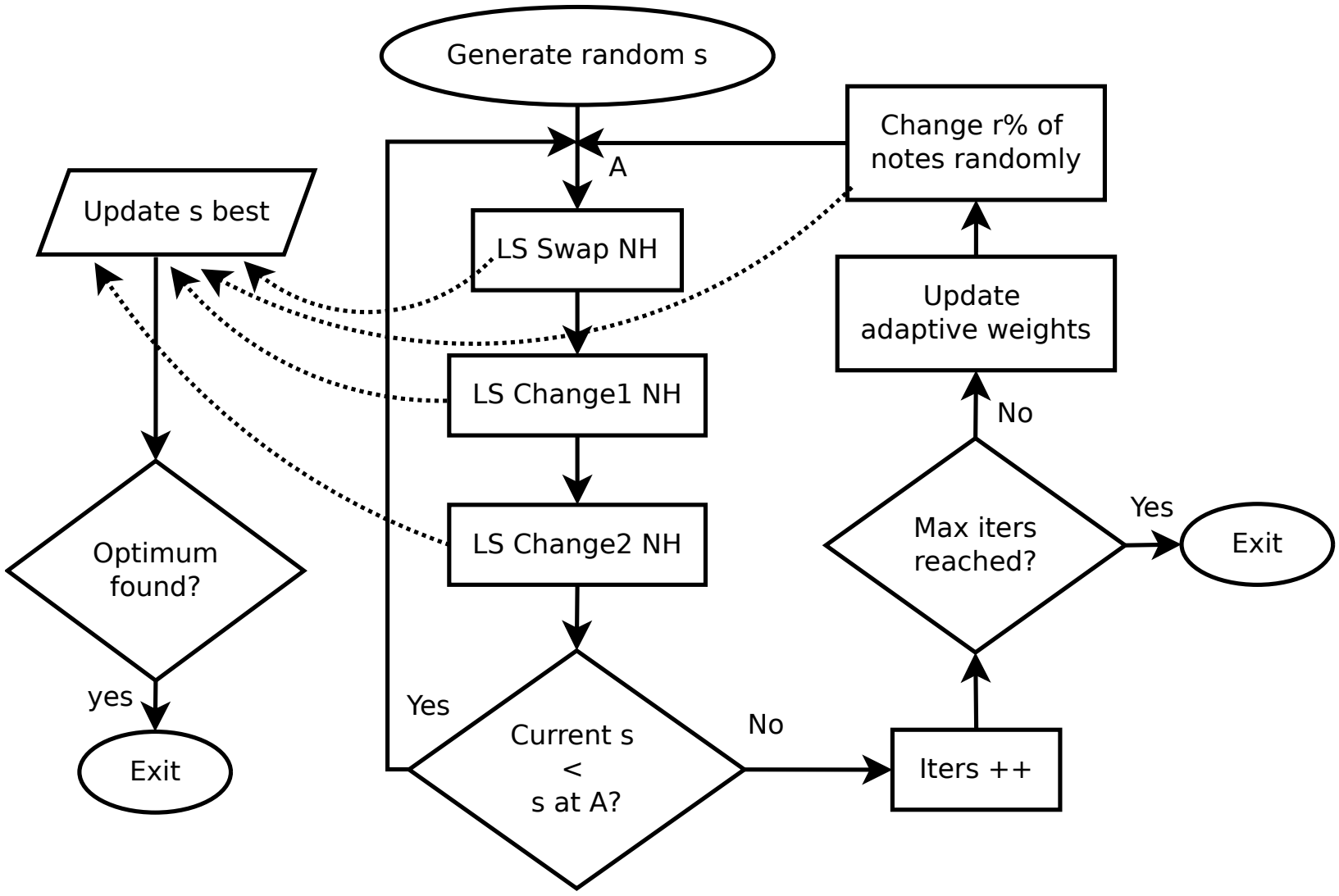
Variable Neigborhood Search

- Local search with 3 neighborhoods
- Selection: steepest descent

N_i	Name	Description
N_{sw}	Swap	Swap two notes
N_{c1}	Change1	Change one note
N_{c2}	Change2	Change two notes

Variable Neigborhood Search

- Excluded framents
  - Tabu list
  - Infeasible
- Perturbation
  - Change r% of the notes randomly
- Adaptive weights mechanism
  - Increase weight of subscore with highest value
  - Keeps the search in the right direction


Generate random s
A
Update s best
LS Swap NH
LS Change1 NH
LS Change2 NH
Optimum found?
yes
Exit
Yes
Current s < s at A?
No
Iters ++
Max iters reached?
Yes
Exit
No
Update adaptive weights
Change r% of notes randomly

Experiments & Results

- Full factorial experiment, n=2304

Parameter	Values	Nr. of levels
N_{sw} - Swap	on with tt_{sw}=0, $tt_{sw}=\frac{1}{16}$, $tt_{sw}=\frac{1}{8}$, off	4
N_{c1} - Change1	on with tt_{c1}=0, $tt_{c1}=\frac{1}{16}$, $tt_{c1}=\frac{1}{8}$, off	4
N_{c2} - Change2	on with tt_{c2}=0, $tt_{c2}=\frac{1}{16}$, $tt_{c2}=\frac{1}{8}$, off	4
Random move	$\frac{1}{4}$ changed, $\frac{1}{8}$ changed, off	3
Adaptive weights	on, off	2
Max. iterations	5, 20, 50	3
Length of music	16, 32 measures	2

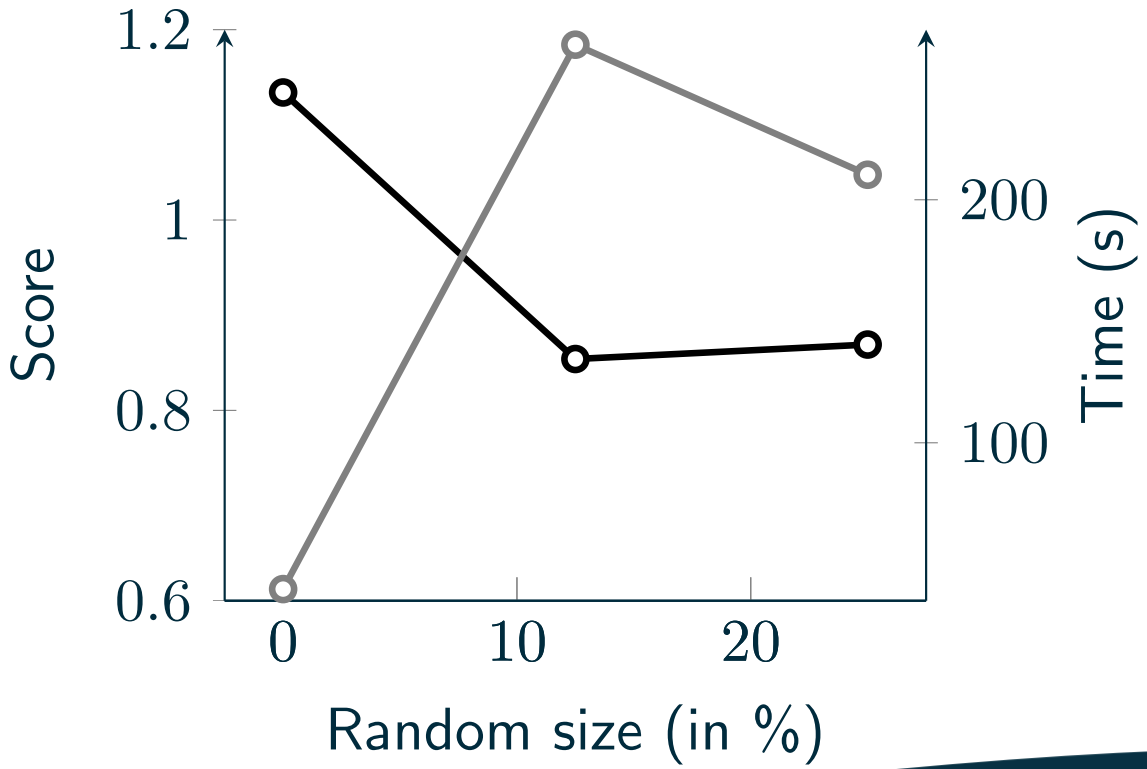
Experiments & Results

- Multi-Way ANOVA model with interaction effects, using R
- $R^2 = 0.98$

Parameter	Df	F value	Prob $(> F)$
N_{c1}	1	9886.2323	$< 2.2e^{-16}$
N_{c2}	1	15690.7234	$< 2.2e^{-16}$
N_{sw}	1	3909.2959	$< 2.2e^{-16}$
randsize	2	1110.1724	$< 2.2e^{-16}$
maxiters	2	322.6488	$< 2.2e^{-16}$
length	1	165.6053	$< 2.2e^{-16}$
adj. weights	1	4.0298	0.0448367
tt_{c1}	2	2.2575	0.1048791
tt_{c2}	2	8.271	0.0002646
tt_{sw}	2	3.2447	0.0391833

Experiments & Results

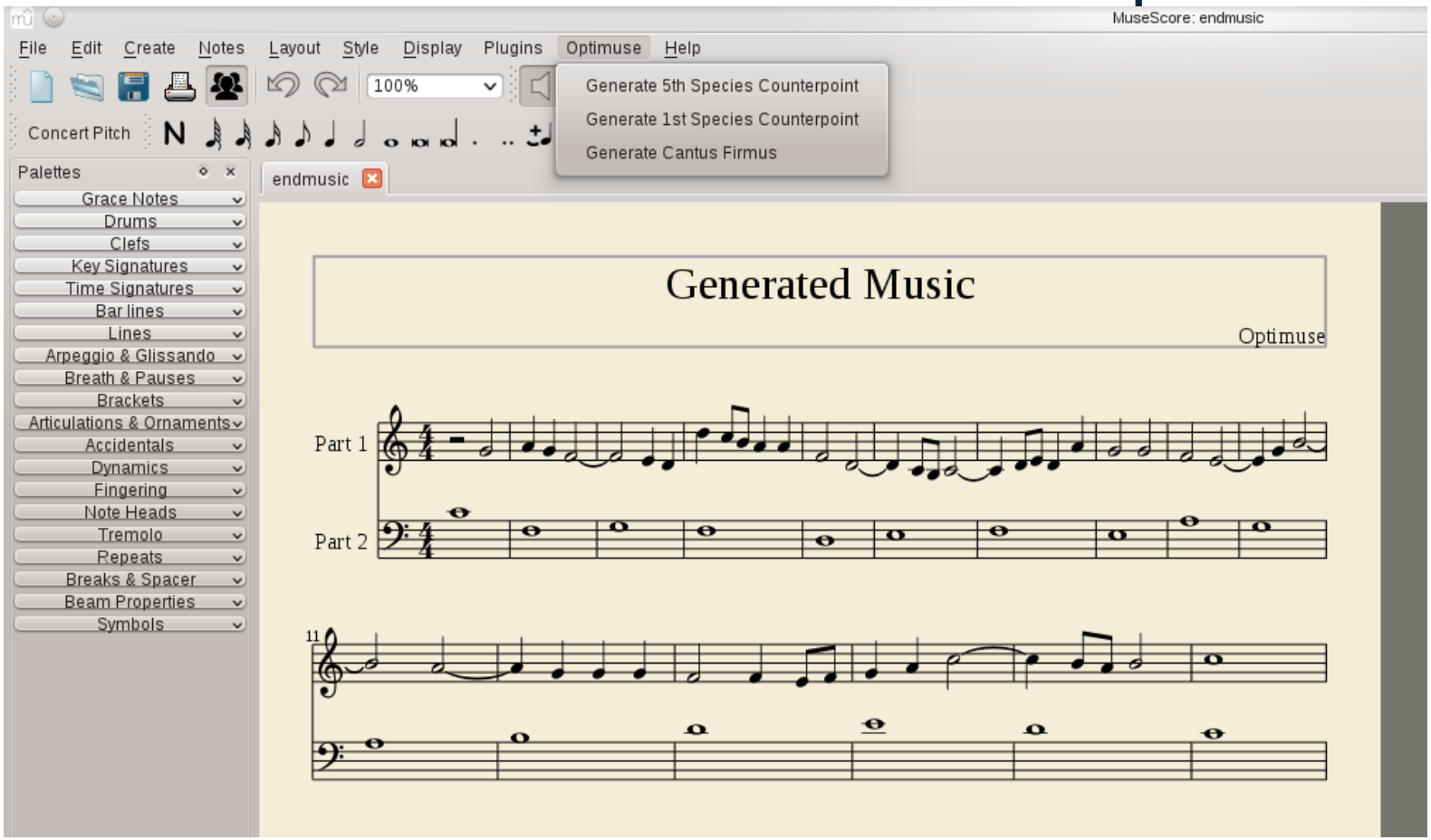
- Mean plot for the size of the random jump



Optimal parameter settings

Parameter	Value
N_{sw}	on with $tt_{sw} = \frac{1}{16}$
N_{c1}	on with $tt_{c1} = \frac{1}{16}$
N_{c2}	on with $tt_{c2} = \frac{1}{16}$
Random move	$\frac{1}{8}$ changed
Adaptive weights	on
Max. number of iterations	50

C++ Implementation



Android App - FuX

- Software toolkit for mobile devices
- Dalvik Virtual Machine $\rightarrow$ Java
- VNS is computationally expensive
  $\rightarrow$ Native C++ (jni) with java NDK
- Midi files (Android-Midi-Lib & Mediaplayer)

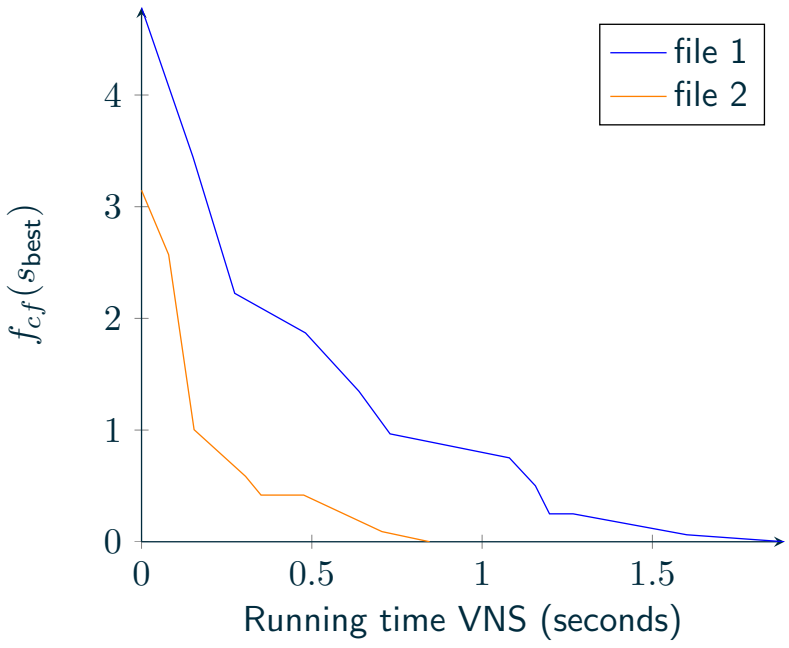
$\Rightarrow$ Continuous stream of music (multitreading)

Android App - FuX

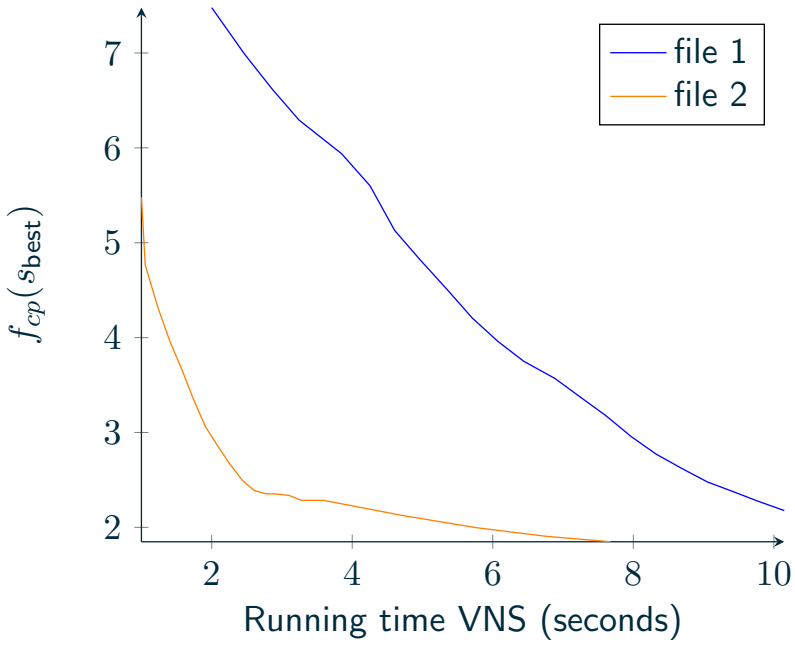
Time	Generate	Playback
-1	16 measures (file 1)	
0s	8 measures (file 2)	file 1
16s	8 measures (file 3)	file 2
24s	8 measures (file 4)	file 3
...	...	...

$\rightarrow$ Evaluation based on last 16 measures

Results over time



(a) Cantus firmus



(b) Counterpoint

Evolution of the objective function over time

FuX

dorien

INSTALLED

This app is compatible with your Proximus HTC HTC One V.

Description

Are you a composer looking for ideas? Or do you just enjoy listening to music? Fux lets you listen to an endless stream of continuously generated counterpoint music.
FuX uses a Variable Neighbourhood Search algorithm (VNS) to generate a continuous stream of fifth species counterpoint.

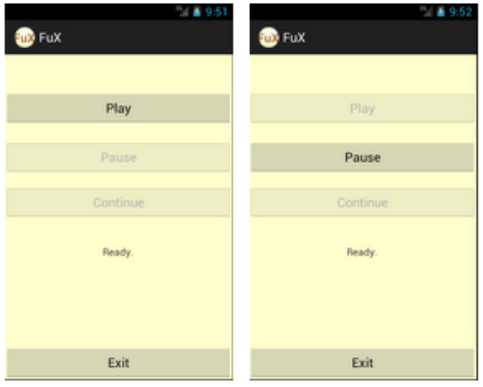
Strict counterpoint is a formally defined musical style that originates in the 16th century. The rules of this style were written down by Fux in his book "Gradus Ad Parnassum" in 1725. This app generates a continuous stream of music that adheres to these rules as well as possible.

The VNS algorithm used in FuX takes into account 19 melodic and 19 harmonic rules when

MORE

Visit Developer's Website › Email Developer ›

App Screenshots



ABOUT THIS APP

RATING:

UPDATED:
November 14, 2012

CURRENT VERSION:
1.0

REQUIRES ANDROID:
2.3.3 and up

CATEGORY:
Music & Audio

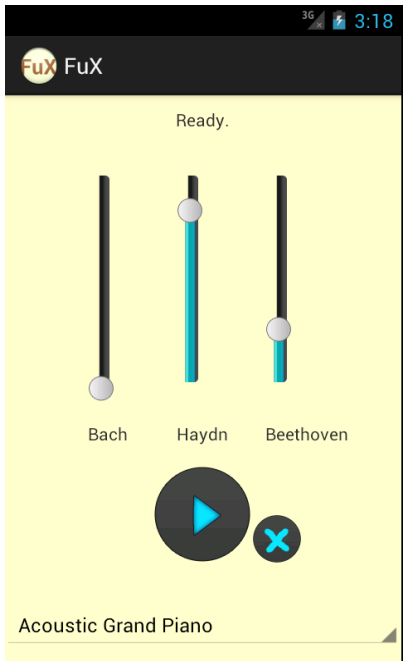
SIZE:
349k

PRICE:
Free

CONTENT RATING:
Everyone

Composer specific music - FuX 2.0

- Analyzed existing music (Bach, Beethoven, Haydn)
- 3 composer classification models
- Incorporated in objective function



Conclusion

An efficient VNS has been developed and implemented as an Android app. The resulting app can play a continuous stream of counterpoint music on any Android phone or tablet.

Future research:

- More complex music:
  - Different styles
  - More parts
  - Theme
- Improved sound quality
- Bugfixes for multitude of devices
- Hit song prediction

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