Functional Generation of Harmony and Melody

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Functional Art, Music, Modeling and Design 2014

6 September 2014

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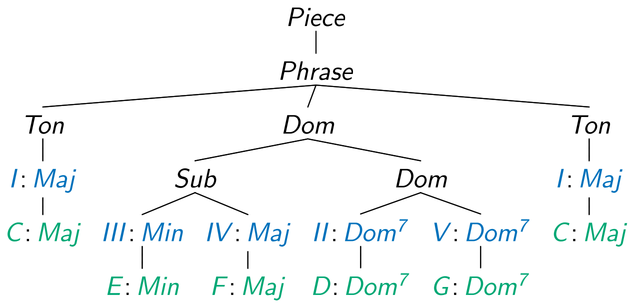
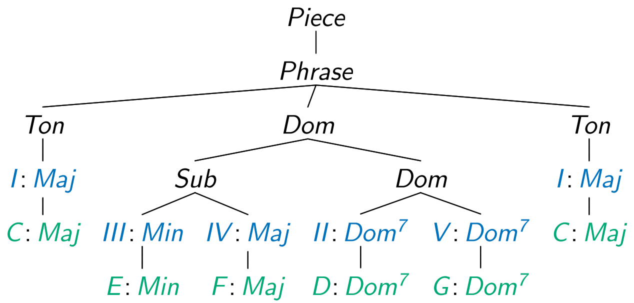
- A system for automatic melody harmonisation (FARM 2013);
- FComp: a system for automatic generation of harmony and accompanying melody (this talk).

An example: visualising harmonic structure



You can see this tree as having been produced by taking the chords in green as input. . .

An example: generating harmonic structure



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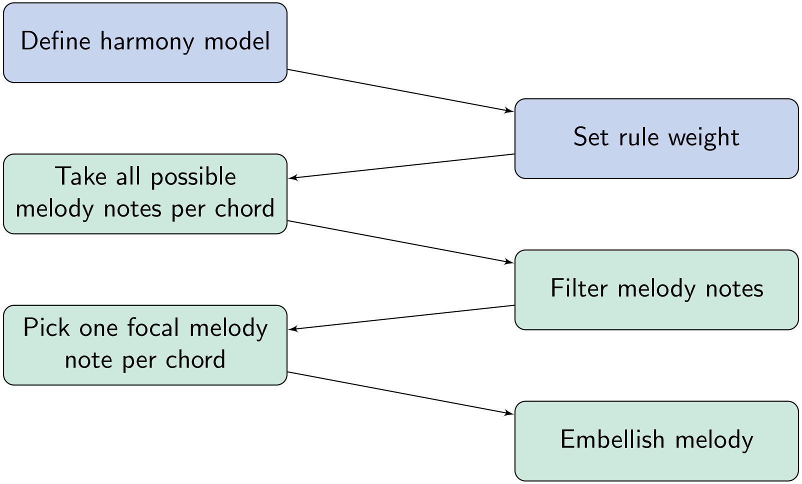
System structure


Define harmony model
Set rule weight
Take all possible melody notes per chord
Filter melody notes
Pick one focal melody note per chord
Embellish melody

A functional model of harmony

$$\mathit{Piece}_{\mathfrak{M}} \rightarrow [\mathit{Phrase}_{\mathfrak{M}}] \qquad (\mathfrak{M} \in \{\mathsf{Maj}, \mathsf{Min}\})$$

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Simple, but enough for now, *and easy to extend*.

Now in Haskell—I

A GADT encoding musical harmony:

$\textbf{data}\ \mathit{Mode} = \mathit{Maj}_{\mathit{Mode}} \mid \mathit{Min}_{\mathit{Mode}}$

$\textbf{data}\ \mathit{Piece} = \forall \mu :: \mathit{Mode}.\mathit{Piece}\ [\ \mathit{Phrase}\ \mu\ ]$

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$$\begin{aligned}
&\textbf{data}\ \mathit{Phrase}\ (\mu :: \mathit{Mode})\ \textbf{where}\\
&\quad \mathit{Phrase}_{IVI} :: \mathit{Ton}\ \mu \to \mathit{Dom}\ \mu \to \mathit{Ton}\ \mu \to \mathit{Phrase}\ \mu\\
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$$\begin{array}{l}
\textbf{data}\ \mathit{Ton}\ (\mu :: \mathit{Mode})\ \textbf{where} \\
\quad \mathit{Ton}_{\mathit{Maj}} :: \mathit{SD}\ \mathit{I}\ \mathit{Maj} \to \mathit{Ton}\ \mathit{Maj}_{\mathit{Mode}} \\
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\end{array}$$

Now in Haskell—I

A GADT encoding musical harmony:

```
data Mode = Maj_Mode | Min_Mode
data Piece = ∀μ :: Mode.Piece [Phrase μ]

data Phrase (μ :: Mode) where
  Phrase_IVI :: Ton μ → Dom μ → Ton μ → Phrase μ
  Phrase_VI  ::         Dom μ → Ton μ → Phrase μ

data Ton (μ :: Mode) where
  Ton_Maj :: SD I Maj → Ton Maj_Mode
  Ton_Min :: SD I Min → Ton Min_Mode

data Dom (μ :: Mode) where
  Dom_1 :: SD V   Dom^7 → Dom μ
  Dom_2 :: SD V   Maj   → Dom μ
  Dom_3 :: SD VII Dim   → Dom μ
  Dom_4 :: SDom μ → Dom μ → Dom μ
  Dom_5 :: SD II Dom^7 → SD V Dom^7 → Dom μ
```

Now in Haskell—II

Scale degrees are the leaves of our hierarchical structure:

$$\begin{aligned}
&\textbf{data}\ \mathit{DiatonicDegree} = \mathit{I} \mid \mathit{II} \mid \mathit{III} \mid \mathit{IV} \mid \mathit{V} \mid \mathit{VI} \mid \mathit{VII}\\
&\textbf{data}\ \mathit{Quality} \qquad\quad\ = \mathit{Maj} \mid \mathit{Min} \mid \mathit{Dom}^{7} \mid \mathit{Dim}
\end{aligned}$$

$$\begin{aligned}
&\textbf{data}\ \mathit{SD}\ (\delta :: \mathit{DiatonicDegree})\ (\gamma :: \mathit{Quality})\ \textbf{where}\\
&\quad \mathit{SurfaceChord} :: \mathit{ChordDegree} \to \mathit{SD}\ \delta\ \gamma
\end{aligned}$$

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$$\mathit{gen} :: (\mathit{Representable}\ \alpha, \mathit{Generate}\ (\mathit{Rep}\ \alpha)) \Rightarrow [(\mathit{String}, \mathit{Int})] \rightarrow \mathit{Gen}\ \alpha$$

Examples of harmony generation—I

$$
\begin{aligned}
&\mathit{testGen} :: \mathit{Gen}\ (\mathit{Phrase}\ \mathit{Maj}_{\mathit{Mode}})\\
&\mathit{testGen} = \mathit{gen}\ [(\texttt{"Dom4"}, 3), (\texttt{"Dom5"}, 4)]\\
&\mathit{example} :: \mathit{IO}\ ()\\
&\mathit{example} = \mathbf{let}\ k = \mathit{Key}\ (\mathit{Note}\ \natural\ C)\ \mathit{Maj}_{\mathit{Mode}}\\
&\qquad\qquad\quad \mathbf{in}\ \mathit{sample}'\ \mathit{testGen} \ggg \mathit{mapM}\_\ (\mathit{printOnKey}\ k)\\
&\mathit{printOnKey} :: \mathit{Key} \rightarrow \mathit{Phrase}\ \mathit{Maj}_{\mathit{Mode}} \rightarrow \mathit{IO}\ \mathit{String}
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$$\begin{aligned}
&> \mathit{example}\\
&[C{:}\ \mathit{Maj}, D{:}\ \mathit{Dom}^7, G{:}\ \mathit{Dom}^7, C{:}\ \mathit{Maj}]\\
&[C{:}\ \mathit{Maj}, G{:}\ \mathit{Dom}^7, C{:}\ \mathit{Maj}]\\
&[C{:}\ \mathit{Maj}, E{:}\ \mathit{Min}, F{:}\ \mathit{Maj}, G{:}\ \mathit{Maj}, C{:}\ \mathit{Maj}]\\
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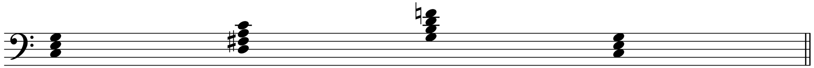
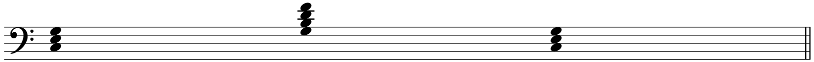
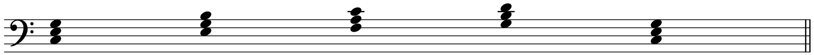
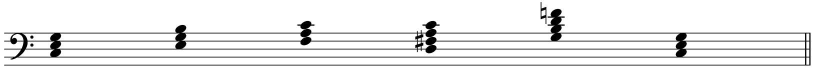
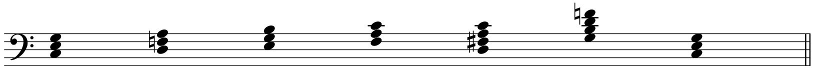
Examples of harmony generation—II











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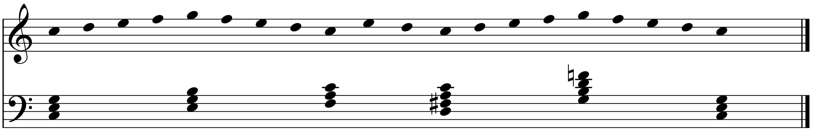
1. Generate a list of candidate melody notes per chord;
2. Refine the candidates by filtering out obviously bad candidates;
3. Pick one focal candidate melody note per chord;
4. Embellish the candidate notes to produce a final melody.

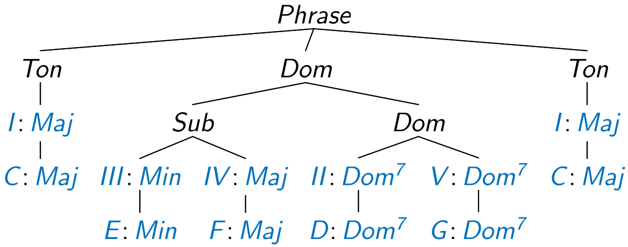
These four steps combine naturally using plain monadic bind:

$$
\begin{aligned}
&\mathit{melody} :: \mathit{Key} \rightarrow \mathit{State\ MyState\ Song}\\
&\mathit{melody}\ k\ =\ \mathit{genCandidates} \ggg\!= \mathit{refine} \ggg\!= \mathit{pickOne} \ggg\!= \mathit{embellish}\\
&\qquad\qquad \ggg\!= \mathit{return} \circ \mathit{Song}\ k
\end{aligned}
$$

More details in the paper!

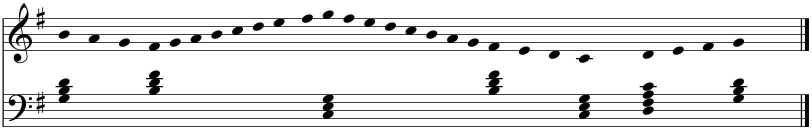
Example I

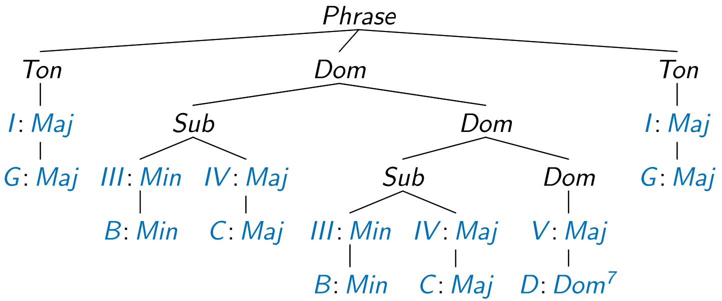




Phrase
Ton
Dom
Ton
I: Maj
Sub
Dom
I: Maj
C: Maj
III: Min
IV: Maj
II: Dom7
V: Dom7
C: Maj
E: Min
F: Maj
D: Dom7
G: Dom7

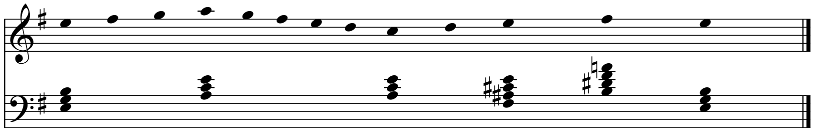
Example II

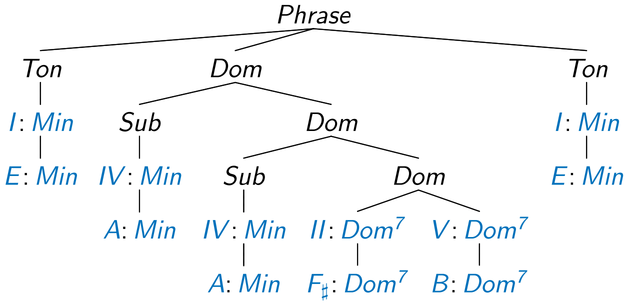




Phrase
Ton
Dom
Ton
I: Maj
Sub
Dom
I: Maj
G: Maj
III: Min
IV: Maj
Sub
Dom
G: Maj
B: Min
C: Maj
III: Min
IV: Maj
V: Maj
B: Min
C: Maj
D: Dom7

Example III





Phrase
Ton
Dom
Ton
I: Min
Sub
Dom
I: Min
E: Min
IV: Min
Sub
Dom
E: Min
A: Min
IV: Min
II: Dom7
V: Dom7
A: Min
F♯: Dom7
B: Dom7

Conclusion

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Lots of room for improvement:

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Thank you for your attention!