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• 1. Automatic Improvisation.

• 2. Sub-model Interpolation.

• 3. Combining knowledge and context.

• 4. Belief Propagation.
Factor Oracle

- Structure representing the evolution of an improvisation on a local context
- One-dimensional data
- Heuristics and control parameters: continuity, leap choices, loops, taboo...
Music is multidimensional

Pitch, harmony, rhythm, dynamics, timbre, orchestration...

Dimensions are correlated and style-dependent => Difficult to model

Oleo - Sonny Rollins
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Sub-model interpolation

P(M_t | X_{1:t})

melody at time t  music from times 1 to t

High dimensional. Can not be used in practice.

P(M_t | X_{1:t}) = \sum_i \lambda_i P_i(M_t | Z_{i,t})

global model  sub-models

Z_{i,t} \subset X_{1:t}

\sum_i \lambda_i = 1 \quad \lambda_i \geq 0 \ \forall i
Using probabilistic sub-models to represent correlation between dimensions.

\[ P(M_t \mid M_{t-1}, \ldots, M_{t-n}) \]

\[ P(M_t \mid C_t) \]

\[ P(C_t \mid C_{t-1}) \]

\[ \ldots \]
Smoothing techniques

- Training corpora are small.
- Smoothing techniques help avoiding zero-valued probabilities and overfitting.
- Additive smoothing: every possible event appears $\delta$ times more than it actually appears in the corpus.
- Back-off smoothing: interpolation with a lower order model.

$$P(X \mid Y) = \lambda P(X \mid Y) + (1-\lambda) P(X \mid Z), \text{ with } Z \subset Y$$
Experimental Results

(B) \( P(M_t | X_{1:t}) = P(M_t | M_{t-1}) \)

(M) \( P(M_t | X_{1:t}) = P(M_t | C_t) \)

\[ P(M_t | X_{1:t}) = \alpha P(M_t) + \beta U(M_t) + \lambda_1 P(M_t | M_{t-1}) + \lambda_2 P(M_t | C_t) \]

Training on Charlie Parker’s Omnibook (50 tunes with improvisation):

- Training corpus: 40 tunes and improvisations to train the sub-models
- Validation corpus: 5 tunes and improvisations to train the interpolation and smoothing coefficients
- Test corpus: 5 tunes and improvisations
Experimental Results

\( P(M_t | X_{1:t}) = P(M_t | M_{t-1}) \)

\( P(M_t | X_{1:t}) = P(M_t | C_t) \)

\[
P(M_t | X_{1:t}) = \alpha P(M_t) + \beta U(M_t) + \lambda_1 P(M_t | M_{t-1}) + \lambda_2 P(M_t | C_t)
\]

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(B) \(P(M_t | X_{1:t}) = P(M_t | M_{t-1})\)

(M) \(P(M_t | X_{1:t}) = P(M_t | C_t)\)
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“The development of a motive should be done in a logical, organic way, not haphazardly (improvisation as spontaneous composition) - not, however, in a preconceived way - rather in a way based on intuition enriched with knowledge (from all the study, playing, listening, exposure to various musical styles, etc., that have occurred through a lifetime including all life experiences); the result is a personal musical vocabulary.”

–Marylin Crispell, Elements of Improvisation.
Combining probabilistic models with the factor oracle

- Interpolated models represent the system’s knowledge
- The Factor Oracle represents the local context
  - Acts as a constraint for the probabilistic model.
  - Enables the system to take into consideration a longer context.
- Navigation in the Factor Oracle is now guided by previous knowledge.
Experimental Results

• Generated improvisations on Charlie Parker’s music following 3 methods (15 improvisations per method over 3 tunes):

  • OMax without any probabilistic module.

  • OMax with a probabilistic module trained on the Omnibook (50 improvised tunes).

  • Omax with a probabilistic module trained on a classical music corpus (850 non improvised tunes).
Improvisation on Donna Lee

Ab  F7  Bb7  %  Bb-  Eb7  Ab  Eb- Ab7 Db  Gb7  Ab
   7th  5th  3rd    3rd   5th   9th   5th
F7  Bb7  %  Bb-
   7th  5th  13th

... 

other examples on members.loria.fr/evincent/files/smc16
Experimental Results

\[
P(M_t \mid M_{t-1}) \\
P(M_t \mid C_t) \\
P(C_t \mid C_{t-1})
\]

- Informal listening

- When using a probabilistic module:
  - Better harmonic stability.
  - Charlie Parker’s musical language a bit faded when trained on classical music.
  - Improvisations are more “diverse, fluid and creative”. The combination of dimensions and the smoothing provide escape mechanisms.
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Cluster graph

\[ \phi_1(A, B, C), \phi_2(B, C), \phi_3(B, D), \phi_4(B, E), \phi_5(D, E), \phi_6(B, D), \phi_7(B, D, F) \]

\[ \psi_1 = \phi_1 \]

\[ \psi_2 = \phi_2 \cdot \phi_3 \]

\[ \psi_3 = \phi_4 \]

\[ \psi_4 = \phi_5 \]

\[ \psi_5 = \phi_6 \cdot \phi_7 \]

- \( \phi_i \) : factors ; \( \Psi_i \) : initial potentials
- \( C_i \) : Clusters ; \( S_{i,j} \subseteq C_i \cap C_j \) : Sepsets
Belief Propagation

• Message passed from cluster $i$ to cluster $j$:

$$
\delta_{i \rightarrow j}(S_{i,j}) = \sum_{C_i = S_{i,j}} \psi_i \prod_{k \in (N_i - \{j\})} \delta_{k \rightarrow i}
$$

• Belief Propagation algorithm:

1. Assign each factor $\phi_k$ to a cluster.
2. Construct initial potentials of each cluster (product of assigned factors).
3. Initialise all messages to be 1.
4. Repeat message passing.
5. Compute final beliefs:

$$
\beta_i(C_i) = \psi_i \prod_{k \in N_i} \delta_{k \rightarrow i}
$$
Application to the factor oracle and sub-models

- Sub-models are factors for the cluster graph.
- A subset of clusters represents the oracles.
- Oracles communicate via the cluster graph through messages.
Coda

• What about the multi-scale organisation?

• How to combine dimensions evolving on different time scales?

• How can we extend the concept of scenario used in ImproTek? (inference of scenario)
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