Generalized Skipgrams

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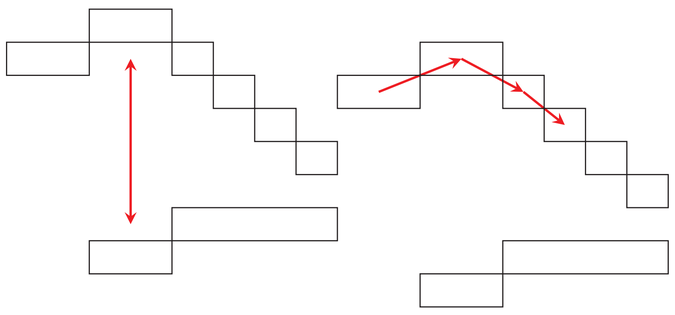
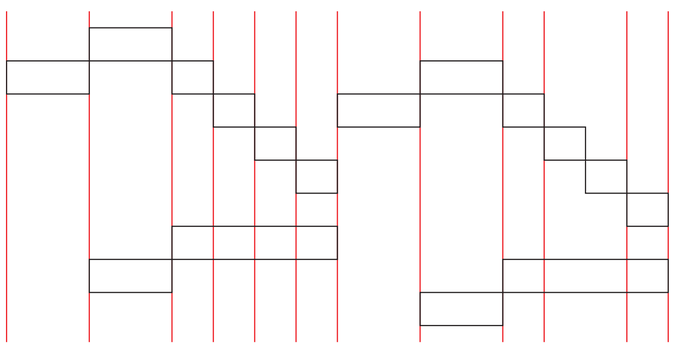
Problem

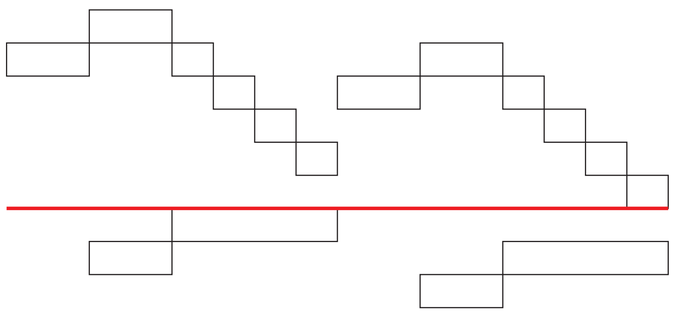
Many aspects of music are oriented **vertically** (harmony), **horizontally** (melody), or both (voice leading). However, the structure of music is neither cleanly vertical nor horizontal, but rather irregular in both dimensions.



Vertical structure is usually enforced by **slicing**. This can be problematic for cutting through notes and in cases where vertically related notes do not overlap (and thus do not have a common slice).

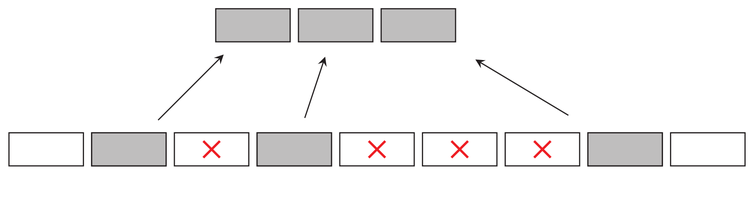


Horizontal structure is often ensured by working on **monophonic voices** or just a single **melody**. This is impractical in the general case, e.g., in piano music.

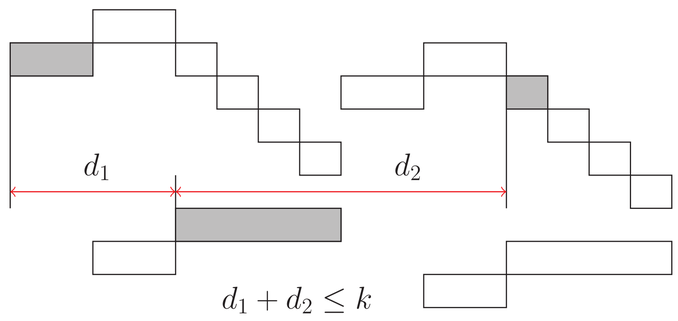


Solution

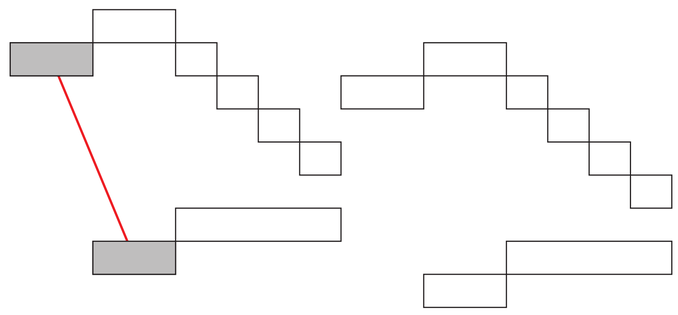
We generalize the **skipgram technique**, well known in linguistics [1] and recently introduced to music research [2]. Skipgrams are similar to n-grams (fixed length subsequences of a sequence) but allow a limited amount of **gaps** between their elements.



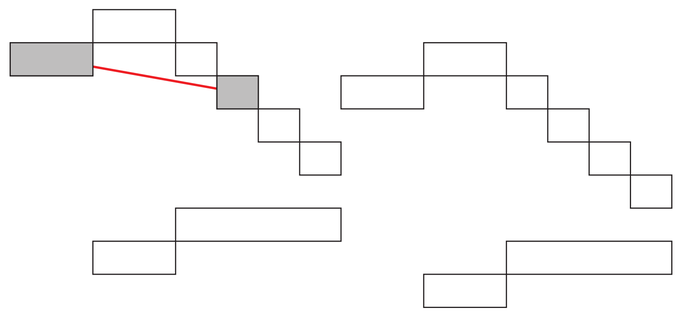
If instead of counting gaps the "amount of skip" is defined by a **skip function**, the technique can be applied to non-sequential structures. The skip function is applied to consecutive elements in the skipgram. The summed skip must not exceed some parameter k.



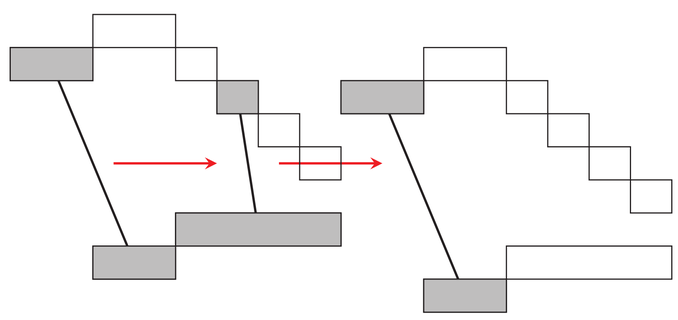
Vertical structure can now be described by **skipgrams over notes** in a piece. An appropriate skip function could be the difference between the notes' onsets. This generates fixed-size groups of notes with **limited** (but possible) **non-simultaneity**.



Horizontal structure can be extracted much like vertical structure. Additionally requiring the notes not to overlap enforces **sequentiality**.



Horizontal and vertical structure can be combined by **recursive application of skipgrams**. A first pass generates vertical structure as skipgrams over notes ("stages"). A second step generates horizontal structure as skipgrams over stages, resulting in a nested, two-dimensional pattern.



Basic Algorithm

The algorithm for enumerating skipgrams takes as input:

- a list L of objects to generate skipgrams over
- a skip function f on pairs of objects
- the skipgram length n
- the skip limit k

The list L must be ordered with respect to the skip function:

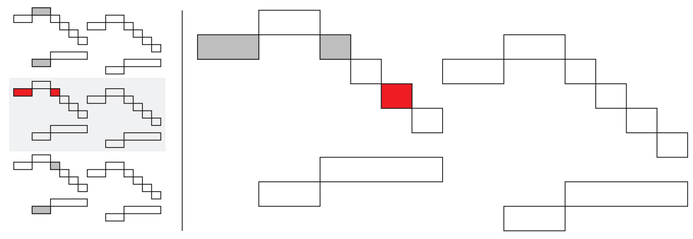
$$\forall i < j < k : f(L_i, L_j) \leq f(L_i, L_z).$$

The algorithm returns all sublists x of L with $|x| = n$ and $\sum_i f(x_i, x_{i+1}) \leq k$.

L is traversed, building up a **list of prefixes** that eventually become complete skipgrams.

For each element e in L:

1. remove old prefixes that cannot be extended with e
2. extend all remaining prefixes with e
3. output all completed prefixes (length n)
4. add all incomplete prefixes to the prefix list
5. add a new prefix $[e]$.



Extensions

Efficient **filtering** can be implemented by **testing a predicate** on every extension of a prefix. If the new prefix does not satisfy the predicate, it is discarded.

Sampling can be implemented efficiently by **flipping a coin** on every prefix extension, deciding whether to keep or to discard the prefix. A prefix is extended $n-1$ times, so keeping each prefix with probability $\sqrt[n-1]{p}$ means keeping the skipgram with probability p.

The output order depends on the last element of each skipgram, because the algorithm outputs skipgrams when they are completed. If the **order of the initial elements** should be retained, completed skipgrams are first entered in a **priority queue**. In each iteration, only those skipgrams are taken from the queue that cannot be preceded by currently active prefixes anymore.

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References

[1] D. Guthrie, B. Allison, W. Liu, L. Guthrie, and Y. Wilks. "A Closer Look at Skip-Gram Modelling". In: *Proc. of the 5th International Conference on Language Resources and Evaluation (LREC-2006)*. European Language Ressources Association, 2006, pp. 1222–1225.

[2] D. R. W. Sears, A. Arzt, H. Frostel, R. Sonnleitner, and G. Widmer. "Modeling Harmony with Skip-Grams". In: *Proc. of the 18th International Society for Music Information Retrieval Conference, ISMIR 2017, Suzhou, China, October 23-27, 2017*. Ed. by S. J. Cunningham, Z. Duan, X. Hu, and D. Turnbull. 2017, pp. 332–338.