“A Viennese May Breeze” — Twelve-tone theory and the machine

Eamonn Bell
Columbia University
epb2125@columbia.edu
www.columbia.edu/~epb2125

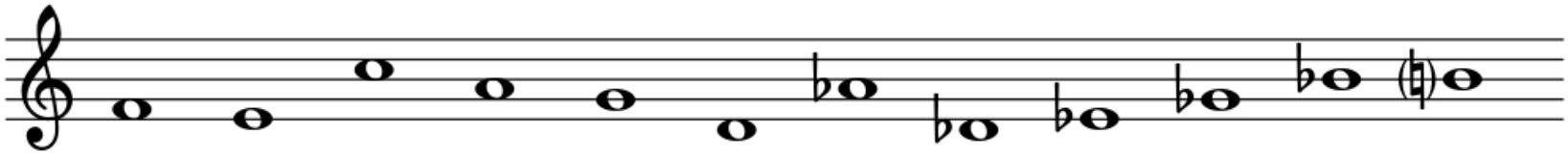
April 15, 2018 (MTSNYS 2018)

Overview

1. The all-interval series problem
   - Herbert Eimert (1964)
2. The place of the problem in the history of music theory
   - Fritz Heinrich Klein (1924, 1925)
   - Ernst Krenek (1937)
3. The Vienna solution
   - Hanns Jelinek (composer) with Heinz Zemanek (engineer) (1959)
4. Aftereffects
   - Zemanek (1992) and Krenek *redux*

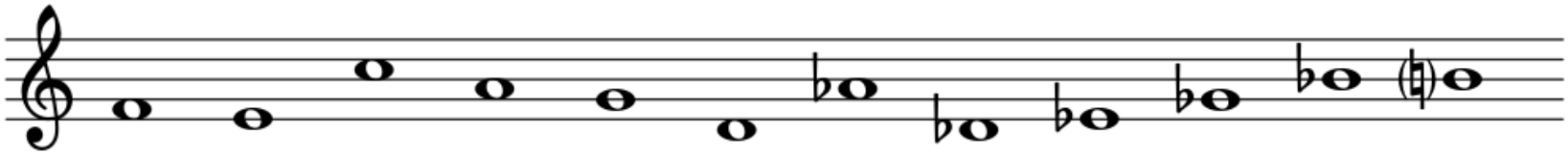
1. The all-interval series problem

The problem



An all-interval twelve-tone series.

The problem

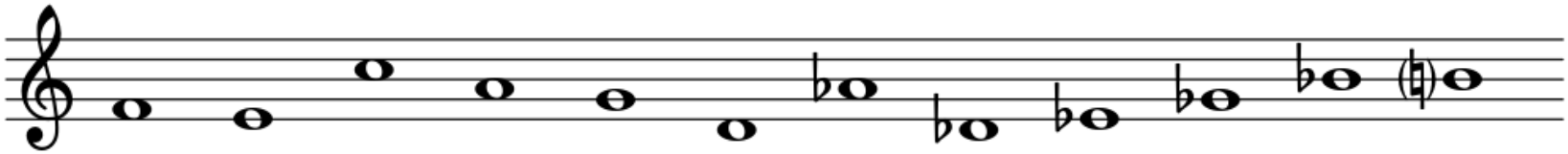


An all-interval twelve-tone series.

I is the sequence of ordered-pitch class intervals between directly successive members of this series.

$I =< 11, 8, 9, 10, 7, 6, 5, 2, 3, 4, 1 >$

The problem



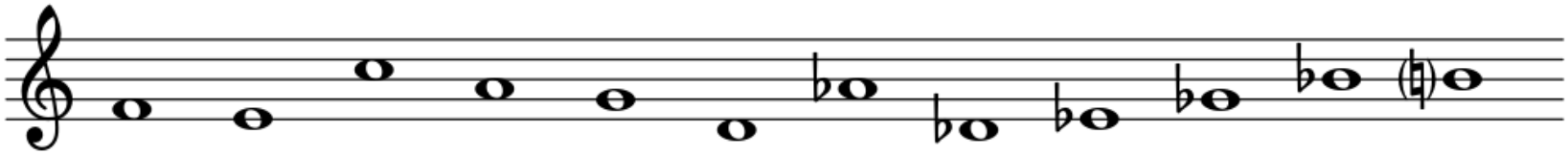
An all-interval twelve-tone series.

I is the sequence of ordered-pitch class intervals between directly successive members of this series.

$I =< 11, 8, 9, 10, 7, 6, 5, 2, 3, 4, 1 >$

I is a sequence of non-zero intervals in which no nonzero, ordered pitch-class interval (i.e. between 1 and 11 *mod* 12) is repeated.

The problem



An all-interval twelve-tone series.

I is the sequence of ordered-pitch class intervals between directly successive members of this series.

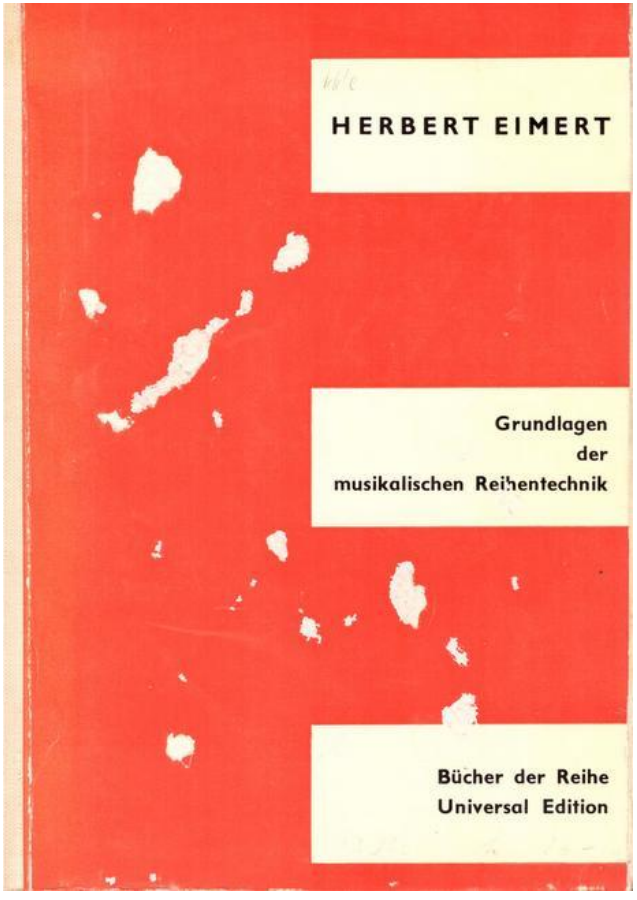
$I =< 11, 8, 9, 10, 7, 6, 5, 2, 3, 4, 1 >$

I is a sequence of non-zero intervals in which no nonzero, ordered pitch-class interval (i.e. between 1 and 11 *mod* 12) is repeated.

Definition: The series is an **all-interval twelve-tone series**.

Which twelve-tone series contain all eleven ordered pitch-class intervals between directly successive pairs of notes?

Herbert Eimert, *Grundlagen der musikalischen Reihentechnik* (1964)

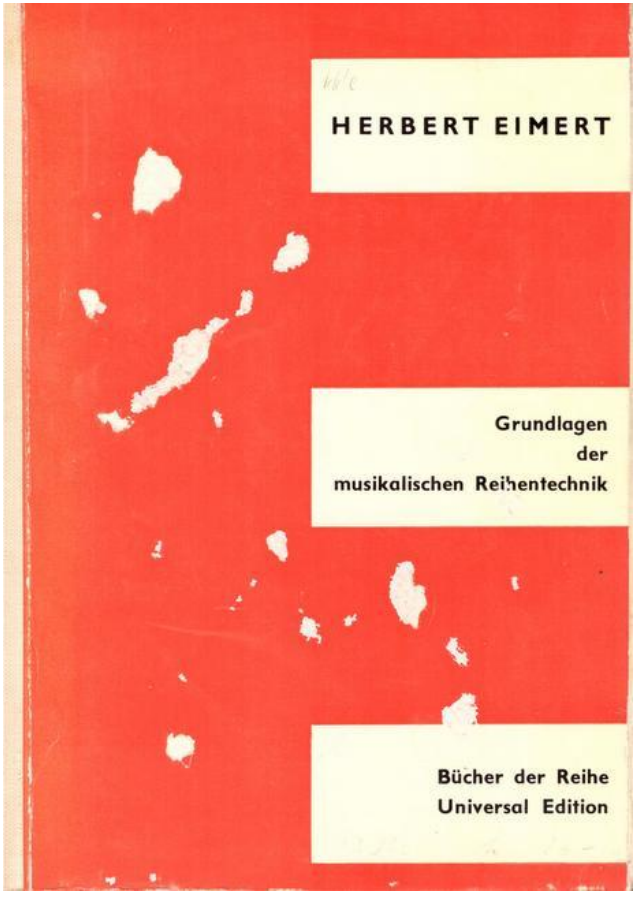


Eimert on the all-interval twelve-tone series problem

Vier Jahrzehnte lang hat diese Reihenfestung jedem Eingriff standgehalten, nur diesen und jenen kleinen Zipfel preisgebend, und nun liegt sie geöffnet vor einem wie die verbotene Frucht vom Baum der Erkenntnis.

For four decades, this serial fortress has resisted every encroachment, only disclosing this or that little corner, and now it is open before us like the forbidden fruit from the Tree of Knowledge.

(Eimert (1964), p. 45. All translations are my own, unless otherwise indicated.)

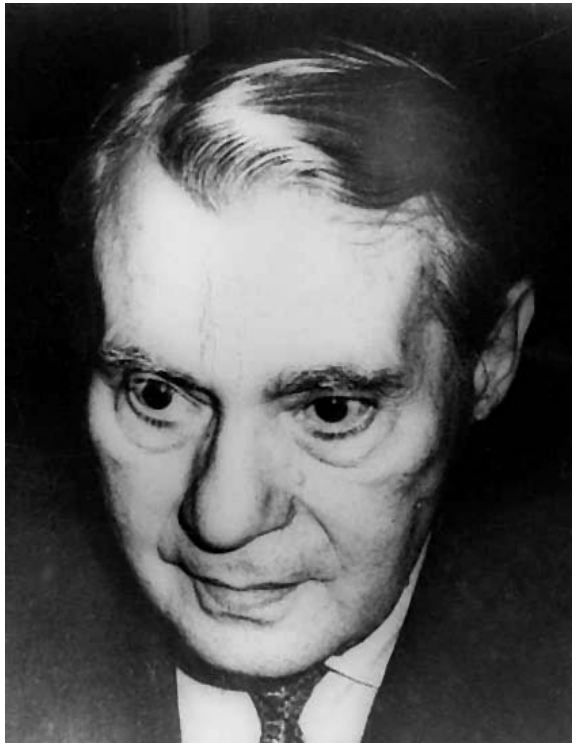


Computer-generated all-interval series catalogs (1959–1965)

Authors	Year	Location	Computer
Jelinek and Zemanek	**1959**	**TU Vienna (Austria)**	***Mailüfterl***
Schmitz and Wirtz	1961	Remington-Rand *Rechnungszentrum* (Cologne, Germany)	Remington-Rand UNIVAC (probably)
Riotte	1963	CÉTIS/EURATOM (Ispra, Italy)	IBM 7094 (probably)
Bauer-Mengelberg and Ferentz	1965	IBM New York (Systems Research Institute)	IBM 7094

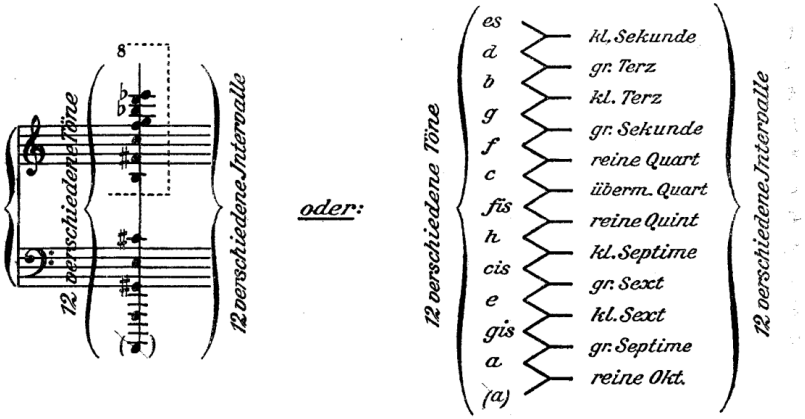
2. The place of the problem

Fritz Heinrich Klein (1892–1977)



FHK. Undated photograph, *Oesterreichisches Musiklexikon online*.

- Klein, “Die Grenze der Halbtonwelt” in *Archiv für Musikwissenschaft* (1925)



Klein’s presentation of his *Mutterakkord* (all-interval twelve-tone series).

Musikstatistik: Klein, Preface to op. 14 (1924)

Da in meiner Musikstatistik alle Akkorde vom schlichten Dreiklang bis zum Komplizierten Mutterakkord gleichberechtigt Bürger eines Klangstaates sind (einwig ***gerechte*** *Wertung!) sind auch deren* ***Konsequenzen****, nämlich die Tonalität und Extonalität als* ***gleichberechtigte*** *Ausdrucksarten zu betrachten [...] Gerade meine "Musikstatistik" hat micht gelehrt, mit gleicher Liebe und Demut* alle *Erscheinungen der Musik zu behandeln; sie dab mir den Mutterakkord geschenkt, so darf ich auch den Dreiklang nicht verachten. Dies ist meine* ***Überzeugung*** *und dieses Überzeugung gibt mir Kraft und Muß zu einem* ***allumfassenden freien Schaffen****!*[1]

Since in my statistics of music all chords, from the simple triad to the complex *Mutterakkord*, are equal citizens in a realm of tones (the only **fair** estimation!), their **consequences**, namely tonality and extonality, are also to be considered **equal** manners of expression. [...] My "statistics of music" has taught me exactly this, to treat all manifestations of music with the same love and humility; it has given me the *Mutterakkord*, so neither can I scorn the triad. This my **conviction**, and this conviction strengthens me toward **all-encompassing, free creation!**[2]

---

[1] Klein, 12. Fax in Ashby.

[2] Ashby (1995), 265. Ashby's translation. Emphasis is Klein's.

Rufer trans. Searle, *Composition with Twelve Tones* (1954)

Emancipation means the guaranteeing of equal rights and equal entitlements. The moment one note claims rights equal to those of all the other notes, it no longer recognises the domination of any other note.[3]

[3] Rufer (1954), 50–51.

Krenek on the all-interval series problem

- [1936] Lectures on contemporary music in Vienna…

Krenek on the all-interval series problem

- [1936] Lectures on contemporary music in Vienna…
- [1937] …collected and published as *Über neue Musik*

Krenek on the all-interval series problem

- [1936] Lectures on contemporary music in Vienna…
- [1937] …collected and published as *Über neue Musik*
- [1939] …revised and translated by Fles as *Music Here and Now*

Krenek on the all-interval series problem

- [1936] Lectures on contemporary music in Vienna…
- [1937] …collected and published as *Über neue Musik*
- [1939] …revised and translated by Fles as *Music Here and Now*
- …in which the chapter corresponding to “Musik und Mathematik” (originally Lecture 5) omits the discussion of all-interval series.

Krenek, “Musik und Mathematik” in *Über neue Musik* (1936/7)

Die gesuchte Formel ist tatsächlich noch nicht gefunden; mathematische Autoritäten, denen das Problem vorgelegt wurde, verwiesen auf den Weg des Probierens, wozu Professor Duschek (Wien) eine sehr praktische Anregung gab, die man freilich zuerst besser an einem System von weniger als zwölf Elementen versucht.[4]

In fact, the sought-after formula is not yet found. Mathematical authorities to whom the problem was presented pointed to the way of trial-and-error [brute force], for which Professor Duschek (Vienna) gave a very practical proposal, which is of course, best tried first on a system of less than twelve elements.[5]

[4] Krenek (1937), 74–75.

[5] Krenek (1937), p. 75

Krenek, “Musik und Mathematik” in *Über neue Musik* (1936/7)

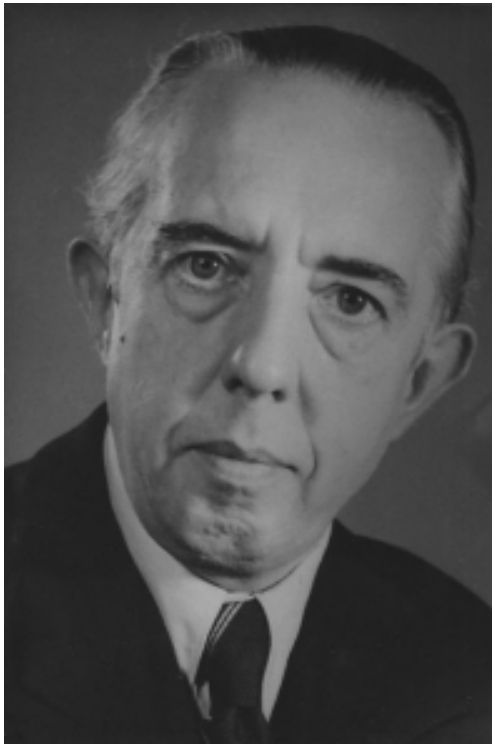
Eine Eigenart dieses mathematischen Gebietes besteht aber bekanntlich darin, daß auch bei geringen Vermehrungen der Elemente die Zahl der Möglichkeiten beängstigend steigt.[6]

A characteristic of this mathematical domain, however, is—as is well known—the fact that the number of possibilities increases alarmingly, even in the case of small increases in the number of elements.

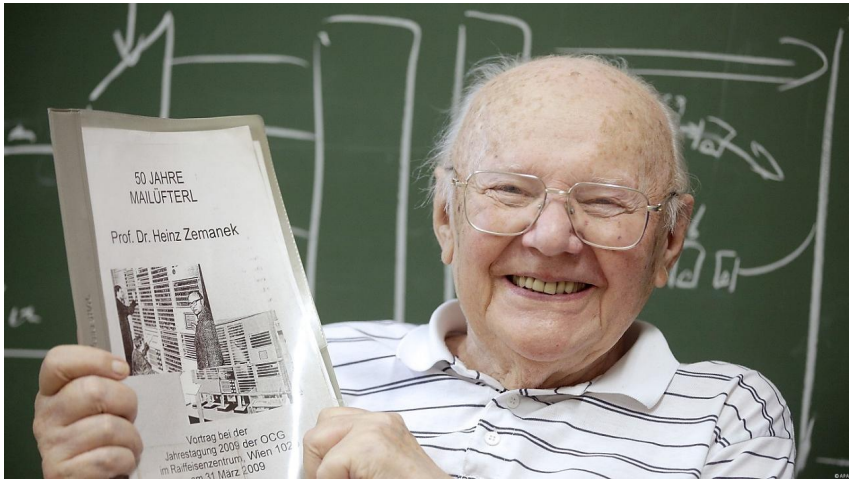
[6] Krenek (1937), 76.

3. The Vienna solution

The Vienna solution collaborators

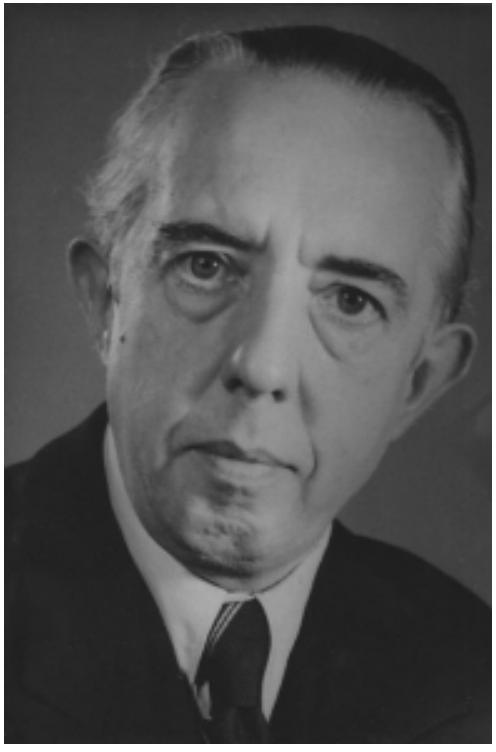


Hanns Jelinek (1901–1969). Photograph, 1947. *Wiener Stadt- und Landesarchiv* (CC BY-NC-ND 4.0)



Heinz Zemanek (1920–2014). Photograph, c. 2008. © *Austria Presse Agentur*

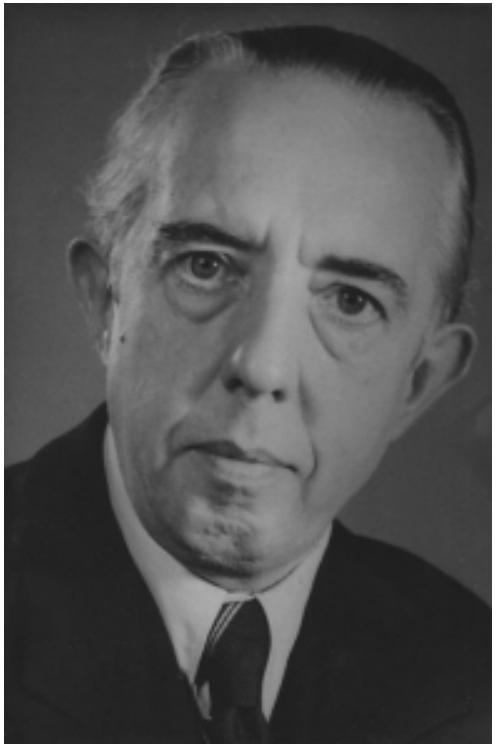
Jelinek's publications



Hanns Jelinek (1901–1969). Photograph, 1947. *Wiener Stadt- und Landesarchiv* (CC BY-NC-ND 4.0)

- [1951] *Zwölftonwerk*, op. 15 for multiple instruments

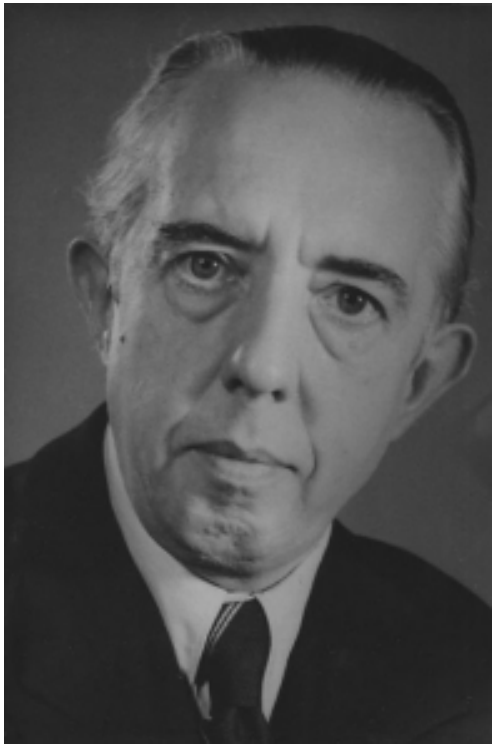
Jelinek's publications



Hanns Jelinek (1901–1969). Photograph, 1947. *Wiener Stadt- und Landesarchiv* (CC BY-NC-ND 4.0)

- [1951] *Zwölftonwerk*, op. 15 for multiple instruments
- [1952/8] …and its two-part companion treatise *Anleitung zur Zwölftonkomposition*

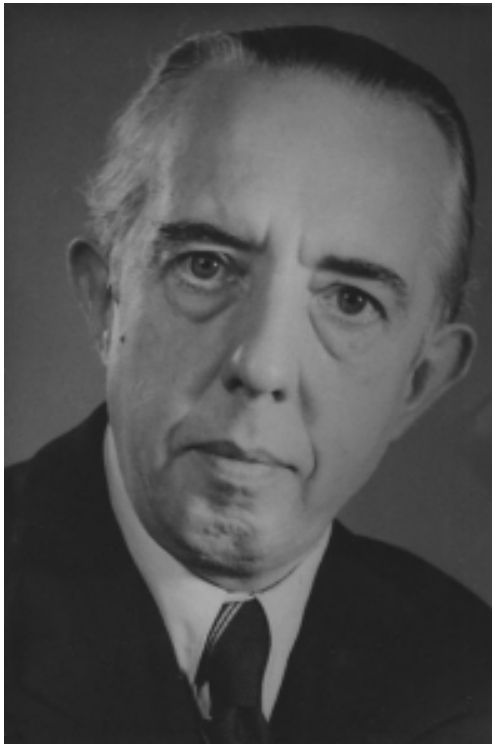
Jelinek's publications



Hanns Jelinek (1901–1969). Photograph, 1947. *Wiener Stadt- und Landesarchiv* (CC BY-NC-ND 4.0)

- [1951] *Zwölftonwerk*, op. 15 for multiple instruments
- [1952/8] …and its two-part companion treatise *Anleitung zur Zwölftonkomposition*
- [1961] "Die krebsgleichen Allintervallreihen" (article)

Jelinek's publications



Hanns Jelinek (1901–1969). Photograph, 1947. *Wiener Stadt- und Landesarchiv* (CC BY-NC-ND 4.0)

- [1951] *Zwölftonwerk*, op. 15 for multiple instruments
- [1952/8] …and its two-part companion treatise *Anleitung zur Zwölftonkomposition*
- [1961] "Die krebsgleichen Allintervallreihen" (article)
- …drew on draft materials for forthcoming *Systematik zur Zwölftonreihen* (unpub.)

Jelinek on the all-interval series [*Allintervallreihen*] problem (I)

Im Laufe meiner Befassung mit den Zwölftonreihen traten manche Probleme an mich heran, deren erschöpfende Behandlung in meiner Anleitung zur Zwölftonkomposition *sich aus verschiedenen Gründen als unzulässig erwies: sei es, daß ihre gründliche Durchforschung eher den Wissenschafter interessierte als den Komponisten, für den doch die* Anleitung *in erster Linie bestimmt ist, sei es, daß ihre vollständige Darstellung einen verhältnismäßig größeren Raum beansprucht hätte, als ihr in einer* Anleitung *zugestanden werden konnte.*[7]

During the course of my engagement with twelve-tone series many problems offered themselves to me, the exhaustive treatment of which in my *Anleitung zur Zwölftonkomposition* proved to me unacceptable for several reasons: whether it be that their thorough investigation was more interesting to the scientist than to the composer, for whom the *Anleitung* was primarily intended; or that their complete presentation would have consumed comparatively larger space than could be allowed for in a manual [*Anleitung*].

[7] Jelinek (1961), 115.

Jelinek on the all-interval series [*Allintervallreihen*] problem (II)

Daß es für die AIR im allgemeinen und für K=AIR [krebsgleichen Allintervallreihen] im besonderen eine solche einfache Herstellungsanweisung nicht gibt, hatte ich längst vermutet und fand ich nun bestätigt. […] Wolle ich diese lösen, blieb mir keine andere Möglichkeit, als alle derartigen Reihen aufzufinden und entsprechend geordnet ("katalogisiert") wiederzugeben.[8]

The fact that there is no such simple preparation for the all-interval series in general, and for retrograde-symmetrical all-interval series in particular, had long been suspected by me, and I now found this to be confirmed. […] If I wanted to solve this, I had no other option than to find all such series and reproduce them in an orderly fashion (a "catalog").

[8] Jelinek (1961), 116.

Mailüfterl (operational 1958)

= “May-breeze” (cf. “Whirlwind”, operational at MIT 1951)

Mailüfterl control panel detail

Mailüfterl (now at *Technisches Museum* Wien)

Zemanek on Jelinek's "logical idea" (Oral history interview, 1987)

He came already with a kind of program, not an elaborated program, but a logical idea for it. He had also computed one block. We transformed his idea into a real *Mailüfterl* program, and we started by doing the first block. To our satisfaction, there were, like on his sheet, thirteen results. Only, it turned out after the first glory that there were mistakes in it. Of course, it was not machine mistakes [*sic*]. Doing it by hand, he was bound to make mistakes: he had one series twice and didn't see it. And he lacked one and he didn't see it.[9]

[9] Aspray (1987), 37.

4. Aftereffects

Zemanek's molecular metaphor (1992)

Man wählt also ein Feld der Kunst aus und sucht dort die Atome, die Töne (Grundschwingungen) der Musik, die Farbpunkte eines Gemäldes, die Grundbewegungen des Tanzes und so fort. […] In der Musik sind die Zwölftonserien ein sehr typisches Beispiel: Sie werden wie Moleküle verstanden, mit denen man die Komposition aufbaut, mit Methoden der Informationsverarbeitung.[10]

Thus, one chooses a field of art and looks there for atoms: the tones (the fundamental frequencies) of music, the points of color of a painting, the basic movements of dance, and so so. […] If one masters atoms and regularities, then one can move on to the corresponding technologies of production. If this is done with the help of the computer, then nothing stands in the way of computer-generated art any more […] In music, the twelve-tone series are a very typical example: they are to be understood to as molecules, with which a composition is built, using the methods of information processing.

[10] Zemanek (1992), 251–252.

Krenek, “Musik und Mathematik” in *Über neue Musik* (1936/7)

[…] wenn wir eine Formel suchen, die uns Anzahl und Bildungsmöglichkeiten der All-Intervall-Reihe angeben könnte, wenn wir die Beziehungen der Grundreihe und der von ihr abgeleiteten Fünfer- oder Siebenerreihe untersuchen, so sind das Fragestellungen, die unserer Gesamtauffassung nach darum für das Komponieren von viel wesentlicherer Bedeutung sein müssen als die zahlenmäßig meßbaren Qualitäten des Einzeltons, ***weil wir von der Anschauung ausgehen, daß das Musikwerk nicht Ergebnis einer auf Grund der Beschaffenheit seiner Atome durchgeführten Summierung solcher Atome ist, sonder von der Ganzheitskonzeption des musikalischen Gedankens geschaffen wird.***

[…] whether we look for a formula which could indicate the number and possibilities of formation of the all-interval series, or whether we examine the relations of the basic series and the series derived by [interval] multiplication from it, such are the questions which, according to our general conception, must be of much greater importance for composing than the numerically measurable qualities of the single tone because we proceed from the intuition that the musical work is not the result of a summation of such atoms, carried out on the basis of the nature of its atoms, but is created by a holistic conception of musical thought.

Outline

- How many all-interval twelve-tone series are there?
  - This problem is refactory to manual computation
  - Generate-and-test (brute force) prevailed
  - Several researchers got there, apparently independently, between (1958–1965) using the digital computer
- The earliest computational solution to the all-interval twelve-tone series problem is Jelinek–Zemanek with the help of *Mailüfterl* (c. 1959)
  - Jelinek came up with a systematic description of the problem
  - Zemanek and team converted this to a working program
  - Serial composition emerges as species of “information processing” (*Informationsverarbeitung*)
- Implications for the history of twentieth-century theory
  - Search for “AIR” is part of a liberatory technique of *Musikstatistik* (Klein, 1925)
  - …and furthers non-traditional agenda for relationship between math and music (Krenek, 1937)

Outline

- How many all-interval twelve-tone series are there?
  - This problem is refactory to manual computation
  - Generate-and-test (brute force) prevailed
  - Several researchers got there, apparently independently, between (1958–1965) using the digital computer
- The earliest computational solution to the all-interval twelve-tone series problem is Jelinek–Zemanek with the help of *Mailüfterl* (c. 1959)
  - Jelinek came up with a systematic description of the problem
  - Zemanek and team converted this to a working program
  - Serial composition emerges as species of "information processing" (*Informationsverarbeitung*)
- Implications for the history of twentieth-century theory
  - Search for "AIR" is part of a liberatory technique of *Musikstatistik* (Klein, 1925)
  - …and furthers non-traditional agenda for relationship between math and music (Krenek, 1937)

A turn to computation and enumeration reconfigures the objects—or, in a mood inspired by Klein's turn of phrase, statistical "subjects"—of a mathematized music theory

Select Bibliography I

Ashby, Arved. 1995. “The Development of Berg’s Twelve-Tone Aesthetic as Seen in the Lyric Suite and Its Sources.” PhD diss., Yale University.

Aspray, William. 1987. “Oral History Interview with Heinz Zemanek (1987).” http://conservancy.umn.edu/handle/11299/107723.

Bernard, Jonathan W. 1997. “Chord, Collection, and Set in Twentieth-Century Theory.” In *Music Theory in Concept and Practice*, edited by James M. Baker, David W. Beach, and Jonathan W Bernard. Rochester, NY: University Rochester Press.

Eimert, Herbert. 1952. *Lehrbuch der zwölftontechnik*. Weisbaden: Breitkopf und Härtel.

———. 1964. *Grundlagen der musikalischen Reihentechnik*. Bücher der Reihe 1. Wien: Universal Edition.

Fripertinger, Harald, and Peter Lackner. 2015. “Tone Rows and Tropes.” *Journal of Mathematics and Music* 9 (2):111–72. https://doi.org/10.1080/17459737.2015.1070088.

Hacking, Ian. 2006. *The Emergence of Probability: A Philosophical Study of Early Ideas About Probability, Induction and Statistical Inference*. 2nd ed. Cambridge; New York: Cambridge University Press.

Headlam, Dave. 1992. “Fritz Heinrich Klein’s ’Die Grenze Der Halbtonwelt’ and Die Maschine.” *Theoria* 6:55–96.

Hofstetter, Günther. 1988. *Fritz Heinrich Klein: Leben und Werk*. n.p.

Select Bibliography II

Jelinek, Hanns. 1952–1958. *Anleitung zur Zwölftonkomposition: nebst allerlei Paralipomena*. 2 vols. Vienna: Universal Edition.

———. 1961. “Die krebsgleichen Allintervallreihen.” *Archiv für Musikwissenschaft* 18 (2):115–25. https://doi.org/10.2307/930340.

Kirchmeyer, Helmut. 1998. *Kleine Monographie über Herbert Eimert*. Vols. Bd. 75, H. 6. 75. Leipzig: Verlag der Sächsischen Akademie der Wissenschaften.

Klein, Fritz Heinrich. 1925. “Die Grenze der Halbtonwelt.” *Die Musik* 17 (January):281–86.

Krenek, Ernst. 1937. *Über neue Musik: Sechs Vorlesungen zur Einführung in die theoretischen Grundlagen*. Wien: Ringbuchhandlung.

Noell, Marion. 1998. *Hanns Jelineks kompositorischer Weg zur Zwölftontechnik in seinem Ersten Streichquartett op. 10: archivalische, biographische und analytische Untersuchungen*. KulturReihe aktuell, Bd. 1. Kiel: Vauk.

Nolan, C. 2003. “Combinatorial Space in Nineteenth- and Early Twentieth-Century Music Theory.” *Music Theory Spectrum* 25 (2):205–41. https://doi.org/10.1525/mts.2003.25.2.205.

Rufer, Josef. 1954. *Composition with Twelve Tones*. Translated by Humphrey Searle. New York: MacMillan.

Zemanek, Heinz. 1983. “‘Mailüfterl’ - Eine Retrospektive.” *Elektronische Rechenanlagen* 6 (December).

Select Bibliography III

———. 1992. *Das geistige Umfeld der Informationstechnik*. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-76828-6.