



International Business Machines Corporation
Research Division
P.O. Box 218, Yorktown Heights, New York 10598
D. Arvay
Manager of Technical Publicity

CONTACT: Andrea R. Minoff
(914) 945-3167

IBM EXPERT SYSTEM HARMONIZES BACH

YORKTOWN HEIGHTS, N.Y., August 18 . . . With an assist from the music of Johann Sebastian Bach, an IBM researcher has designed an expert system for harmonizing music.

CHORAL, an experimental program developed by Kemal Ebcioglu, adds bass, tenor and alto parts to chorale melodies given as input. It produces four-part scores in conventional music notation that can be read on a computer terminal screen, printed and performed.

Expert systems are complex software programs written for very specific applications. They generally require a large information base and a mainframe computer's power.

Ebcioglu, holder of a master's degree in music composition and a doctorate in computer science, used chorale harmonizations written by 18th-Century German composer J. S. Bach as the primary source for developing the knowledge base of CHORAL. In his lifetime, Bach produced more than 300 chorale harmonizations.

A chorale is a short musical piece meant to be sung by a chorus of male and female voices. Four independent parts (melodies) are sung simultaneously; men sing bass and tenor parts and women sing alto and soprano parts. The soprano part is the main chorale melody with the remaining parts serving as accompaniment.

The harmonization performed by CHORAL is the process of composing bass, tenor and alto parts when the soprano part is given.

The CHORAL expert system contains more than 350 rules. They are divided into groups that observe the chorale from multiple viewpoints, such as the harmonic outline of the chorale and the individual melodic lines of the voices.

Intelligent Backtracking Feature

One of the unique features of the program is an intelligent generate-and-test algorithm that incrementally constructs the harmonization of the melody according to a larger set of rules. These complex rules often "spell out" unique characteristics of the Bach chorale style and are based on Ebcioğlu's study of the Bach chorales and experience with the program.

The harmonization is built stage by stage. CHORAL backtracks and changes notes that it "considers" to be responsible when a dead-end is encountered, just as if it were negotiating a maze and had run into a wall.

Ebcioğlu comments, "It is a well-known fact that rules are not by themselves sufficient for producing beautiful music. Composers use additional knowledge--what we call talent--for choosing among the many possible correct extensions of a partial composition at each stage in the process."

Translating "talent" into an algorithm would be an impossible task. However, Ebcioğlu learned that a large number of precise, style-specific heuristics, or recommendations, could provide a good approximation.

Style Recommendations

CHORAL uses an extensive base of style recommendations about which notes or chords to choose among the many correct possibilities at each stage of the harmonization. Conflicts, such as whether or not to continue a linear progression, are resolved by invoking additional heuristics that assign priorities to the various alternatives.

The program's generate-and-test method of composing is a computation-intensive task. Ebcioğlu designed Backtracking Specification Language (BSL), an efficient logic programming language that reduces the number of instructions and consequently the processing time to complete a chorale harmonization. Using BSL, a chorale harmonization requires about 30 minutes on an IBM mainframe. During this time, the mainframe executes about 23 billion simple instructions.

How good is CHORAL?

While it is unlikely that any expert system could rival Bach, CHORAL would probably receive an above-average to excellent grade in a college composition class, says Ebcioğlu.

"I did not attempt to write a program that would produce only the beautiful chorales that Bach would have written. Instead, I viewed it as a venture into the frontiers of the capabilities of expert systems and as a tool for the more precise understanding of the Bach chorale style," he adds.

"The results have been very encouraging on both counts."

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FROM: IBM Corporation
Research Division
P. O. Box 218
Yorktown Heights, NY 10598

EXPERT SYSTEM IMITATES BACH: IBM Researcher Kemal Ebcioglu explains the harmonization added to Bach's Chorale No. 68 through use of his expert system and the mathematically-expressed rule pictured above the musical notes.

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$(\forall n) (\forall v / \text{bass} \leq v \leq \text{soprano})$
 $[n > 0 \ \& \ \text{mod}(p(n,v) - \text{root}(n), 7) = \text{seventh}] \Rightarrow$
 $p(n-1, v) = p(n, v) \ \& \ a(n-1, v) = a(n, v) \ \checkmark$
 $\text{chordtype}(n) \in \{ \text{dimseventh}, \text{domseventh} \}$

No. 68

