Presented: National Conference on Computer-based Education,
St. Paul, MN, October 23, 1980.

# AN EFFECTIVE MICROCOMPUTER SYSTEM FOR VERSATILE MUSIC COMPUTER-ASSISTED INSTRUCTION

Rosemary N. Killam
North Texas State University

Richard L. Hamilton
Bell Laboratories

Steven V. Bertsche
University of Wisconsin-Superior

## Introduction

North Texas State University (NTSU) School of Music is developing a versatile microprocessor-based music computer-assisted instruction (CAI) system, supported by a grant from the Apple Education Foundation. The system utilizes the experience NTSU has gained from the development of its ear training CAI lab, which uses eight dedicated terminals on a Hewlett-Packard 2000 Access System (Killam, Bales, Hamilton and Scott, 1979).

## Background

Ear training CAI is approaching the completion of its first decade of development. The first system which accessed sound in a CAI environment was tested at Stanford University in November, 1972; the first use of ear training CAI was by Stanford undergraduate music theory classes in the spring of 1973 (Killam and Lorton, 1974).

Ear training (the development of auditory perception skills in music) is an essential part of the curriculum of all basic music theory and fundamentals courses. Ear training instruction has unique needs, foremost of which is the need for musical sound which can be controlled and repeated by the users: a need which is uniquely met through CAI. The first experiments in ear training CAI have been followed by a number of projects, including those at the University of Delaware, the University of Illinois, the University of Minnesota, the University of Nebraska, the University of Wisconsin and Florida State University, to name a few locations. The International Consortium of Computer-based Music Instruction, a special interest group of the Association for the Development of Computer Instructional Systems, serves as a group central to the development and dissemination of information on music CAI.

In 1977, the NTSU School of Music began its ear training CAI development. An eight-terminal ear training CAI Lab was opened in the School of Music in September, 1979. Since that time, approximately 400 students per semester have registered to use the Lab as an adjunct to their classroom studies. Courseware has been expanded to more than 200 lessons, covering the freshman and sophomore ear training curriculum.

NTSU has received requests from all over the country for information and advice on ear training CAI development. One fact has become increasingly clear: other schools do not need nor can they support a hardware configuration so extensive as NTSU's. One logical solution to this problem is a second generation software system derived from the authoring language developed by Richard Hamilton for NTSU's system.

The Apple Education Foundation has funded a grant for conversion of NTSU's driver from H-P BASIC to PASCAL and for development of a software interface between our driver and two commercially-available sound sources: ALF and Micromusic.

Current CAI Systems Programmer Donald Marshall was responsible for the development of the PASCAL driver. At the outset of the project, he decided that conversion of a BASIC program of the size of the NT CAI package (however well-structured) to the higher level language of PASCAL would take longer than the writing of an entirely new curriculum driver in PASCAL. The new PASCAL driver developed by Mr. Marshall is based on his extensive experience with and responsibilities for the music CAI environment. The driver is complete and has been successfully tested for execution and lesson authoring.

The scope of the current research does not cover conversion of the following areas of the NTSU system:

1. the music graphics presentation, which is dependent on a unique character set developed here and available only on NTSU's CRT terminals (Hamilton and Killam, 1979);
2. the extensive data-keeping system;
3. the courseware, the printout of which now requires over 300 pages.

Each of these three items poses different research and development questions, which we propose to address in subsequent research. However, the scope of our current effort is to produce the necessities for implementation of effective music CAI: a system which allows others to develop their own CAI curricula with readily-available hardware and software.

The system under development provides a clear, economical format for curriculum development and entry, untilizing the powerful music encoding capabilities of Dan W. Scott's code (Hamilton and Scott, 1978), and requiring no additonal programming effort on the part of the developer.

## Method

Our experience with various computer languages has led us to choose PASCAL as the language in which the software is written. The structured nature of PASCAL and its excellent editor and disc operating system have aided our work. Apple PASCAL's string manipulation and linked list structures are a great help with lesson I/O and execution. The anticipated development of music graphics will be aided by the graphics capabilities of PASCAL.

The hardware configuration necessary to support our software is:

48K Apple II computer

Disk II drive with controller

Disk II drive only

High-Speed Serial Interface (required for full functioning of the driver; not required only if no printed output is planned)

Pascal Language Kit

Video Monitor-II (B&W)

Music Synthesizer (ALF or Micromusic)

Monaural amplifier

Headphones or Speaker

Scope and Limitations

Those first considering ear training CAI often assume that representation of traditonal music notation is fundamental to curriculum development. Our experience has shown music notation to be valuable, but not essential. Most of the auditory concepts central to music are traditionally described in alpha-numeric terms, e.g. intervals, chord quality and inversion, and harmonic function in tonal harmony. Presentation of traditional notation of music on a CRT or even on a paper terminal is not difficult, but the design of graphics which can be easily manipulated by the student user in a context similar to traditional paper-and-pencil notation is difficult. Music is written in a form closely resembling a two-dimensional matrix, while CRT's are primarily designed for the sequential input of the printed word. Music perception and translation of that perception into notation compose a complex relationship, on which much more research needs to be done to determine effective sequences of skill development. The problem is best exemplified through a musical fragment, such as that shown in Fig. 1.

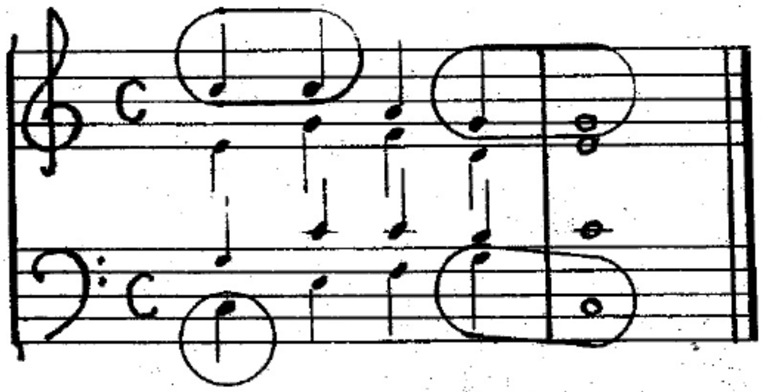

Figure 1. Musical fragment, showing probable first perceptions

The notes circled in Fig. 1 would be those more likely to be perceived first by a beginning music student, although this probability is based upon informal knowledge gained in classroom teaching, not formal experiment. The programming techniques which allow students to enter the notation they perceive first, and the procedures for checking and correcting their first, partial answers are extremely complex. At NTSU, we have been working on these problems since the beginning of our CAI development. Current solutions are beyond the range of moderately-priced hardware and lack formal experimental proof of their effectiveness. Any solution which forces the student to enter notation in a manner which does not reinforce his basic musical perception is of dubious educational value. Therefore, we chose to concentrate on providing an efficient method for teaching and learning the many elements of ear training which do not require notation.

NTSU keeps data on each student by name, student ID number, sex, performing instrument, theory course and section. The students' session times are recorded by minute, hour, and day of year. The transposition of musical examples, students' first and last answers to these examples, and student requests for music repetition are recorded. These data form the basis for a variety of statistical summaries, including weekly reports to teachers of the 30-40 ear training sections, on their students' achievement. Schools with smaller student bodies do not need this amount of record keeping. We decided to postpone implementation of data saving to a subsequent research effort, in order to establish a fully-functional driver in the time frame of the Apple Educational Foundation grant. The competence-based curriculum model was retained, and the curriculum author may specify the percentage of accuracy which students must attain on any lesson to receive a completion message from the driver.

The current research does not include curriculum conversion. NTSU's curriculum is carefully structured and sequenced to reflect our philosophy of theory pedagogy and the profile of our student body. The purpose of this research project is to provide a means by which others can develop ear training curriculum materials which reflect their particular instructional methodology. Recently, several institutions have approached us about conversion of our courseware; we are investigating alternatives for conversion and dissemination of our courseware.

Proposed Population

Our experience has shown that a ratio of approximately one terminal to 75 potential student users allows adequate student access. Thus, schools with a total population of 50-100 students in music fundamentals will probably need only one system. Competence-based curriculum encourages equitable and efficient terminal use; students who master the material quickly free the system to allow more time for slow students. The driver is constructed to give the widest possible latitude to courseware authors and should support ear training CAI development for any age range. The driver will support development of drill and practice courseware in a variety of areas outside of music, but such development and testing is outside the scope of our research.

Results

A. Curriculum driver

The concept of a curriculum driver has evolved slowly in CAI. Even today, much experimental CAI for microprocessors is written with necessary software embedded in each lesson. Specification of a software package supporting curriculum design and use requires detailed knowledge of content, plus teaching and learning strategy. NTSU's curriculum driver has been under continuous development since 1977; a systems programmer maintains and expands the complex of related programs referred to as the "driver". A detailed report on the research which resulted in the PASCAL driver will be presented in a subsequent paper.

Several features give particular support to courseware authors. No prior knowledge of computer languages is required for authoring. Music can be encoded for presentation at specified pitch or by random transposition. Questions can be presented to students by random access or in a predetermined order. Musical examples requiring no response from the student can be interspersed with written text. Figure 2 presents the printout from a sample lesson.

B. Interface with sound generation systems

Interfacing the commercially-produced sound systems to the CAI environment has proved to be no small task. The work is substantially complete, and uses Dan W. Scott's encoding system for music. The encoding system utilizes a variety of default values, economizing on the amount of time required of authors for music encoding. An additional advantage is that a lesson prepared for one sound source can be used on the other, increasing the versatility of courseware prepared on the system.

C. Testing

A small group of NTSU lessons will adapted and converted for the Apple system and tested with a selected student population. These lessons will be selected for their close parallel to previous courseware which has had extensive testing at other sites, so that student performance data may be compared (Hofstetter, 1975). Lesson authoring on the Apple system has proved to be an easy task.

```
C: ADAPTATION OF NT H-P I17 (1980)
C: HARMONIC INTERVALS IN 8VA
C: STARTED 9/25/80, UP ....., RNK
H: MA2 = MAJOR 2ND    MI2 = MINOR 2ND
H: MA3 = MAJOR 3RD    MI3 = MINOR 3RD
H: P4  = PERFECT 4TH P5  = PERFECT 5TH
H: MA6 = MAJOR 6TH    MI6 = MINOR 6TH
H: MA7 = MAJOR 7TH    MI7 = MINOR 7TH
H: P8  = PERFECT 8VA TT  = TRITONE
S:2
CS:
T: $N, THIS LESSON HELPS YOU LEARN--
T: -----HARMONIC INTERVALS.
T: DO YOU WANT INSTRUCTIONS?
T:        (TYPE Y OR N)
A:
M:YES;YE;Y
JN:375
CS:
T: HARMONIC INTERVALS ARE 2 PITCHES--
T: --PLAYED AT THE SAME TIME.
T: I'LL PLAY INTERVALS, AN 8VA OR SMALLER
S:1
L:1
T: MA2 = MAJOR 2ND    MI2 = MINOR 2ND
T: MA3 = MAJOR 3RD    MI3 = MINOR 3RD
T: P4  = PERFECT 4TH P5  = PERFECT 5TH
T: MA6 = MAJOR 6TH    MI6 = MINOR 6TH
T: MA7 = MAJOR 7TH    MI7 = MINOR 7TH
T: P8  = PERFECT 8VA TT  = TRITONE
S:2
L:1
P:5
T: $N, HERE'S A SAMPLE QUESTION--
T: -----(WITH ANSWER)-----
T: $R 4C D-W 4R RQ ?
P:4
T: $N, THE CORRECT ANSWER IS MI2.
P:3
CS:
T: REMEMBER:
T: MI = MINOR   MA = MAJOR
T: P = PERFECT TT = TRITONE
T: TYPE  ?  TO REHEAR THE INTERVAL
T: TYPE  //HINT  TO REVIEW ANSWER FORMS
T: TYPE YOUR ANSWER AFTER THE  *  .
P:5
375 T:
T: LET'S GET STARTED, $N!!
Q:12<D!D!P9/10!3>
<$R 4C D-W 4R RW ?!MI2>
<$R 4C DW 4R RW ?!MA2>
<$R 4C E-W 4R RW ?!MI3>
<$R 4C EW 4R RW ?!MA3>
<$R 4C FW 4R RW ?!P4>
<$R 4C F+W 4R RW ?!TT>
<$R 4C GW 4R RW ?!P5>
```

Figure 2.  Printout of Sample Lesson

Discussion

This paper constitutes the first presentation of research currently underway at NTSU to provide an effective microprocessor system for versatile music CAI. Reasons for the approach selected and limitations of the scope of the research have been presented in detail, so that the reader may better understand the goals of the project.

A decade of research has proved that development of auditory skills in music is effectively approached through CAI (Killam and Lorton, 1976; Hofstetter, 1978). The students' need for musical sound, individualized approach and feedback can be met optimally through CAI. Nationwide, several music CAI systems have been developed (Arenson, 1978). Their effectiveness as learning tools has been documented in the literature.

Our current research has attempted to meet the needs of schools wishing to develop their own CAI programs. The needs of music CAI--hardware and the software to integrate sound into courseware--can be met through the configuration for a stand-alone system described in this paper. The primary thrust of our work has been to integrate commercially-produced and readily-available hardware through complex software development, so that prospective courseware authors can have the advantages of a sophisticated curriculum driver to support their instructional design. The object throughout has been to provide a system with the versatility to meet the widely varying needs of others who wish to participate in the continued development of music CAI.

## Summary and Prospects

The intensity and extent of the research effort described herein present the temptation to proclaim the results as the ideal and ultimate solution to the problem of music CAI needs. However, the original intent never was to solve all the problems attendant on music CAI development. Rather, the intent was the creation of a versatile system, immediately useful for curriculum development and presentation. Three areas of research were, at the outset, excluded from our current research: those areas of screen notation of music, data keeping, and courseware conversion. These areas offer exciting prospects for future enhancement of the current system. The current research is substantially completed; subsequent documentation will detail the technical aspects of the software.

## References

Arenson, Michael A. An Examination of Computer-Based Educational Hardware at Twenty-Eight NCCBMI Member Schools. Journal of Computer Based Instruction. 1978, 5(1 and 2), 38-40.

Hamilton, Richard L. and Rosemary N. Killam. Cost-Effective Implementation of Music Notation on CRT Terminals. Proceedings of the Association for the Development of Computer-based Instructional Systems, San Diego, CA, 1979.

Hamilton, Richard L. and Dan W. Scott. A New Approach to Computer Assisted Instruction in Music Theory. Proceedings of the Ninth Conference on Computers in the Undergraduate Curriculum, Denver, CO, 1978.

Hofstetter, Fred T. GUIDO: An Interactive Computer-based System for Improvement of Instruction and Research in Ear Training. Journal of Computer-Based Instruction. 1975, 1, 100-106.

Hofstetter, Fred T. Computer-Based Recognition of Perceptual Patterns in Harmonic Dictation Exercises. Proceedings of the Association for the Development of Computer-based Instructional Systems, Dallas, TX, 1978.

Killam, Rosemary N., W. Kenton Bales, Richard L. Hamilton and Dan W. Scott. AMUS: The Computer in Music Instruction. Proceedings of the Texas Music Educators Association Conference, Fort Worth, TX, 1979.

Killam, Rosemary N. and Paul V. Lorton Jr. Computer-assisted Instruction in Music. Proceedings of the Fifth Conference on Computers in the Undergraduate Curricula, Pullman, WA, 1974.

Killam, Rosemary N. and Paul V. Lorton, Jr. Performance and Perception: Research and Instruction in CAI-Music. Proceedings of the Seventh Conference on Computers in the Undergraduate Curricula, Binghamton, NY, 1976.