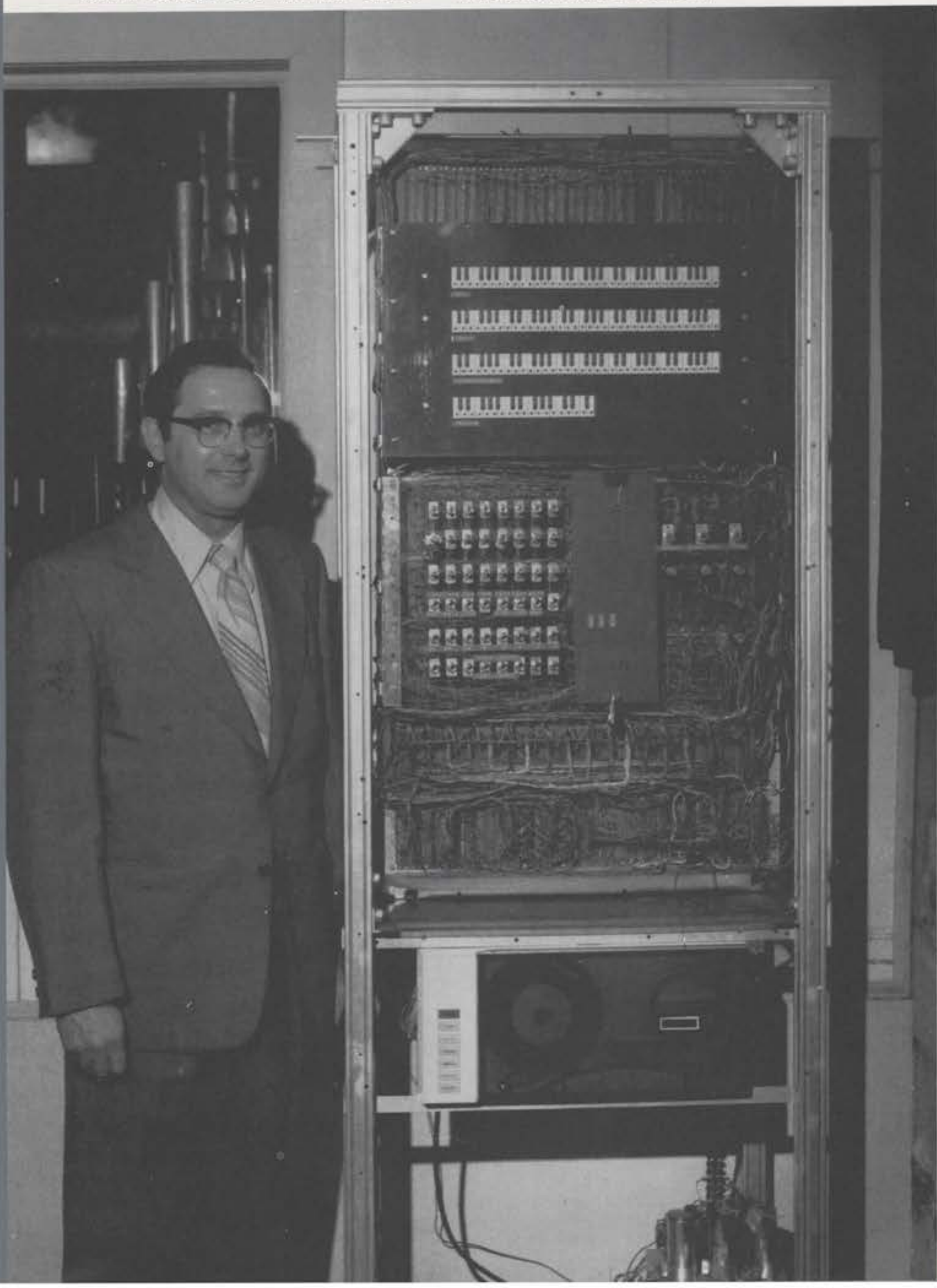
"GENII"

by Marvin Lautzenheiser

Introduction

Today computers are used to do all kinds of things from controlling flights to the moon to keeping records of our charge accounts. It is only natural, then, to try to develop a computer system to play a theatre pipe organ. The GENII System does just that. The music played by GENII is generated from the score itself without copying, mechanically or electronically, an actual performance by a musician. Its capabilities include the playing of any notes on three keyboards and pedalboard, changing stop tabs, controlling the swell shades, and operating the untuned percussion and traps. Up to 40 of these things may be operated simultaneously, giving, in effect, an organist with more than eight hands. It is with more than passing interest that we note that the computers involved in the GENII System are digital. In this system the meaning of the term "unit orchestra" on the Wurlitzer can come close to realization. Inasmuch as GENII is already playing music of an advanced level, the question now is "How *well* can a computer be taught to play the organ?" The remainder of this article will describe the GENII System.

Marvin Lautzenheiser with his "Genii." – (Photo by Richard Neidich.)



Development

The design of GENII began in 1966 with actual construction started in 1968. A multitude of concepts were analyzed and discarded before the current design was adopted. Much of the electronics could be described as "Early American" with many of the parts salvaged from scrapped electronic gear. The MUSICTRAN language has been through three major overall designs leading to a rather generalized, flexible language which combines reasonable ease of use with a thorough control of the resulting music. The MARVEL computer program which

> *The most unusual feature of this summer's convention was GENII, the theatre-organ-playing computer built by Marvin Lautzenheiser. The precision clearing and setting up of the stop tabs invariably triggered an appreciative ripple while the flashing red lights on the keyboard display kept all eyes occupied. Marvin and his GENII received a standing ovation. So many ATOS'ers requested copies of the technical GENII Seminar that it was withheld from the initial convention coverage in order to present the paper in its entirety.*
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> *Editor*

translates the data from punched cards to data on a digital tape has undergone continual modification for over two years.

With all the above work in the past, the task of generating good music via a computer-organist is apparently just beginning. An unbelievably large amount of experimentation has already been mapped out to determine, if possible, some of the mathematical aspects of "good" music.

Items yet to be done include a systematic study of the effects of note timing, overlap, and separation. A special processor is under construction to capture in computer-usable format digital data representing the performance of artists. From this, perhaps a few of the secrets of music may be deduced. Other explorations include the application of orchestra score to the organ via GENII to try to exploit some of the extensive electronic/mechanical skills now available. Of particular interest is the use of GENII to capture, edit, and replay music for making albums. With this capability, an artist may play into GENII, use the GENII computer programs to edit the playing, and replay the music for making the master audio tapes.

GENII Description

The GENII System is made up of six major components:

1. a language (MUSICTRAN) for translating score to data;
2. a computer program (MARVEL) which along with
3. an IBM 370/145 reformats the data;
4. a digital tape reader for reading reformatted data;
5. a controller (GENII) for interpreting reformatted data;
6. a 3/13 Wurlitzer pipe organ for making the music.

A brief description of each of these components follows.

I Musictran

MUSICTRAN is a language developed for the translation of music score into mathematical data for processing by a computer. It deals with seven categories of information:

1. Musical parts (melody, bass, rhythm, etc.)
2. Measures
3. Notes
4. Percussion, toys, and traps
5. Volume
6. Registration (stop tablets)
7. Orchestration (the combinations of all the above items).

Data translated via MUSICTRAN is punched into standard computer cards for processing by the MARVEL program. The translation from music score to punched card data involves the following decisions and operations:

1. Parts

A part is defined by its function such as melody, bass, etc., and is identified by a digit in the range one to nine. During orchestration the part number is used to specify the method of playing the part; that is, the keyboards, octaves, and styles to be used for the part.

2. Measures

A measure generally carries its normal music definition. However, natural measures are often broken into two sections to allow for orchestration changes at more convenient points, such as at the ends of phrases. Measures are identified by a 3-digit number and their sizes are given in computer counts. A normal music beat is defined as 64 computer counts. Thus, a measure in 4/4 time may have a length of 256 counts. Of course, a measure may be of any length required to accommodate the notes and styling to be played in that measure.

Each measure carries with it two metronome settings: the speed as of the beginning of the measure and the speed as of the end of the measure. These are used during data translation to give a smooth decrease or increase in speed throughout the measure. If beginning and ending speeds are the same, of course, no speed changes are recorded within the measure. Occasionally a normal measure will be subdivided into two or more computer measures to allow for several changes of pace within it.

3. Notes

Notes are translated to data by spelling out for each: the measure number to which it belongs, its starting time in the measure, the duration, the relative octave in which it is written, and the name of the note. Starting times and durations are specified in computer counts; thus a quarter note's length could be coded in the range of 56 to 72 with the expected value of 64; its starting time could be any value from one to an upper bound which permits the note to be completed within the measure. Octaves are numbered from one to five (six in the case of top C) and specify the relative octave on the keyboard to be used. The names of the notes are their normal letter designations with 'x' used to denote sharps. Flats are not used as such; the corresponding sharps are substituted.

4. Percussion, Toys, and Traps

The special effects as bass drum, triangle, etc., are translated in the same manner as notes with a 3-character name substitued for the note, octave and name. These are thought of as having their own keyboard and are given a special part designation. Thus the specification of a percussion includes the measure identifier, the part identifier, the starting count, duration, and the effect's name.

5. Volume

The volumes of the two chambers are independently controlled and may be changed at any instant. The range of volumes from completely closed to fully open is designated by a number from zero to nine. The larger the number, the more open the given chamber will be. Only changes in volume need be specified, the GENII System maintains a given swell shade setting until a change occurs. Again, the volume controls are thought of as having their own keyboard and are given a special part designation. To specify a volume setting the user specifies the volume identifier along with the measure number, count within measure at which the change is to occur, the chamber abbreviation and the new setting number in the range zero to nine.

6. Stops

The stops are controlled by GENII by trapping the tablet on the console into the "on" or "off" position. To do this, a very short duration pulse is sent to the appropriate setter action magnet. The specification of the change of a stop includes a special part name; the measure identifier; the count within the measure when the change is to occur; whether the stop is to turn on or off; the keyboard designation (Pedals, Accompaniment, Great, or Solo) and the stop name abbreviation. Unlike a setter action, only stop tabs that are to move need be energized; thus, very few are actuated for normal changes. The trapping of the stop tablets allows an easy, visual identification of those stops in use at any moment and also permits GENII to ignore the stops when no changes are being made. Manual couplers are not actuated by GENII, and they are never used in conjunction with GENII since GENII can provide any and all coupling desired.

7. Orchestration

The orchestration is the most sensitive area of translation in that it really is the point at which the union of music parts and instrument is made. A great flexibility with respect to couplers, attack, speed, etc. is available here to bring out musical variation without modifying the basic data.

The orchestration may be changed between any two measures. It does the following:

a. assigns parts to keyboards
b. assigns parts to octaves
c. assigns transpositions of parts
d. assigns attacks to individual parts
e. assigns overall metronome adjustments
f. defines number of computer counts per beat
g. specifies coupling (a given part may be played on each of several keyboards at several octave levels if so desired)
h. specifies pizzicato touch where desired

II Marvel

The MARVEL computer program is a set of over 1300 instructions which tells an IBM 370 how to translate the MUSICTRAN data cards into information on a digital tape. It does the following:

1. reads cards
2. computes switch numbers for each operation
3. applies couplers as specified in the orchestration cards
4. transposes parts as specified
5. applies parameters for touch (degree of legato, staccato, etc.)
6. calculates start and stop times for all operations
7. sorts data in order of increasing time
8. writes switch numbers and control data on tape in time sequence (A large amount of redundancy is introduced at this point to help insure accurate reproduction of the music.)
9. prints cards for reference
10. prints computed data (optional)

III IBM 370

The MUSICTRAN data is processed at a commercial computer center via the MARVEL program on an IBM 370 using approximately 100,000 bytes of core. The digital tapes are written at a density of 800 bytes (numbers) per inch. Processing time is approximately 20 cards per second. A typical composition may include 500 - 1000 cards taking 25 - 50 seconds to process.

IV Digital Tape Reader

The tapes are read at the Lautzenheiser studio via a PEC digital tape reader. The read rate is 12½ inches per second transferring up to 10,000 pieces of data per second to the GENII processor. A typical composition may run three minutes, use about 200 feet of tape and contain up to two million pieces of data.

V Genii

The GENII processor is a hand built electronic processor which accepts data from a digital tape transport, processes that data, and controls the pipe organ operation. The processor is made up of 152 printed circuit boards containing over 50 integrated circuits, 3000 diodes, 2000 transistors, 5000 resistors, 600 capacitors and a mile of wire. In addition, the cables connecting GENII to the pipe organ contain four miles of wire. The display panel contains over 250 light-emitting diodes. GENII has the following major elements:

1. tape read buffers
2. data checking circuits
3. data decoders
4. organ function memory circuits (512)
5. organ circuit switches (512, electronic)
6. display panel
7. test control circuits

Switching functions are controlled to such a timing accuracy as to become transparent to the music being created. Any operation may be started at the precise moment desired and may be held for any duration. The timing of any one note or operation is completely independent of the timings of the operations of other notes. Up to 40 notes and/or functions may occur simultaneously.

VI Wurlitzer Pipe Organ

The pipe organ controlled by GENII is a 3 manual 13 rank Wurlitzer which is installed in the Lautzenheiser studio in Springfield, Virginia. This organ was originally installed in the Canal Street Theatre in New York City in 1927. In 1931 it was moved to the Loew's Triborough Theatre in Queens, New York City. So far as is known it was last played there in the early 1940's. The Lautzenheisers purchased the organ in 1962 and have been playing it regularly since 1964.

GENII controls the following organ circuits:

1. 215 keys (3 – 61-note keyboards plus the 32-note pedal board)
2. 30 swell shades (2 sets, each having 9 steps)
3. 16 untuned percussions and sound effects
4. 90 stop tabs (using 180 circuits to trap the stop tablets into "on" or "off" positions

This is a total of 429 functions; GENII has room to allow for nearly unlimited expansion in the number of circuits controlled.

Summary

The feasibility of a computer playing an organ has now been demonstrated. Unlike player pianos of the past, GENII has not less, but more, mechanical skill than a human artist. At this point, we have not endowed the computer with any true musical creativity. We have given the musician a new tool that permits him to release his creativity from the slavery of his physical capabilities. Perhaps GENII can be thought of as a new musical instrument, one that responds to digital data instead of digital manipulation of its keyboards. □