Edit: Mr. Noll, of Bell Telephone Laboratories, Inc., New Jersey, prepared this essay for presentation at the Philadelphia Art Alliance. November 9, 1966. We sent it to England for comment by Ann Hutchinson, founder and Honorary President of the Dance Notation Bureau, and one of the world's foremost scholars of movement notation.

CHOREOGRAPHY AND COMPUTERS by A. Michael Noll

The computer may be potentially as valuable a tool to the arts as it has already proven itself to be in the sciences. I intend here to suggest a few possibilities for the application of computer technology to problems in choreography and dance notation. In recent years the computer has been used in techniques that aid scientists through the evaluation and presentation of visual data, and the same basic principles may be applied to the analysis of shapes and motions in dance.

The first automatic digital computers were built during the early 1940's, and from them have evolved the transistorized marvels that are currently revolutionizing many fields of science and industry. All digital computers are similar in that they manipulate binary numbers under the control of a stored set of instructions called a program. Computers are capable of performing only operations for which they have been programmed and which they have been instructed to perform. However, these machines are incomparably fast in doing their tasks and are also capable of analyzing many factors to make different decisions. This extreme speed coupled with the inherent accuracy of digital calculation explains the desirability of digital computers.

The dance world is currently in the midst of problems concerning dance notation. The problem might be likened to that of a composer who requires a full symphony orchestra at his disposal in order to try different orchestrations as he thinks of them. When the final musical work has been obtained, each musician has to remember his own part. In dance, many choreographers require the full company to be present when creating a new work. And when that work is finished, it remains only in the minds and bodies of those present. Of course, some methods of dance notation are available, but few are used by most choreographers. The best are extremely elaborate and transcription is time consuming and must usually be performed by an expert, and expensive, notator.

The filming of ballets either at rehearsal or at an actual performance has been suggested as a stop-gap solution until dance notation is more widely utilized. Although film is an excellent emergency precaution that will prevent the loss of many of our choreographic masterpieces, it is not, in my opinion, the ultimate solution. This is because film records only one company's particular interpretation of a work. The ballet is a creation of the choreographer, and it is his original conception of the work that must be recorded and preserved. A sound recording of the New York Philharmonic's performance of Stravinsky's *Le Sacre du Printemps* cannot serve as a model for all other orchestras' performances of this work. Similarly a filming of the American Ballet Theatre's performance of *Les Noces* will not suffice. Jerome Robbins' *original* conception of *Les Noces*, and not a *particular* performance of it must be preserved.

Still another problem exists with film. Some portions of the motion of the dancers would be difficult to determine from the film because the dancers in front block those in the rear. Also, film lacks dimensionality, and therefore certain movements would be ambiguous. Of course, multiple filming from different locations would help to reduce, but would not completely solve, these problems.

Another possible solution to the notation problem would be to use a filmed version of the ballet as input to a computer. Equipment has recently become

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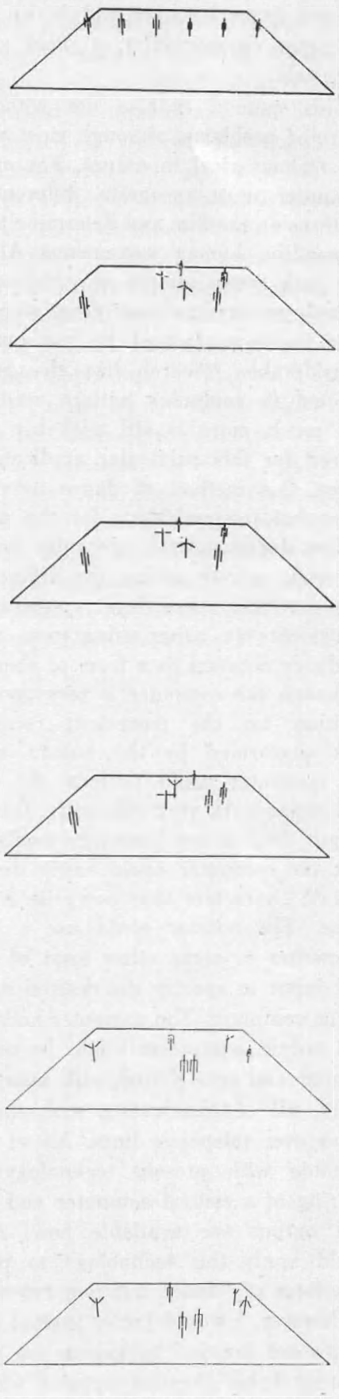

Mr. Noll's three minute movie, from which the shown frames were extracted, was produced by a digital computer under the control of a set of instructions (a program) written by the author. The program consisted of special statements specifying the size and motion of each stick figure. Each frame of the movie was automatically drawn on the face of a cathode ray tube and photographed by a 16mm movie camera all under the control of the computer.

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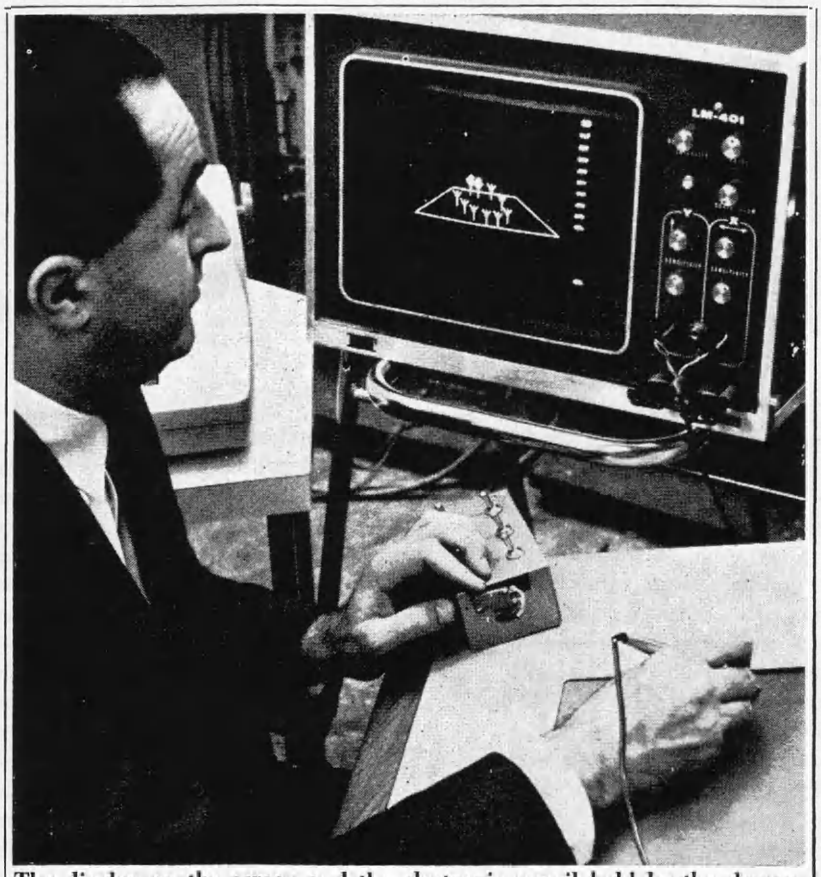
available for converting pictures into a numerical format digestable by computers. However, computers are not yet able to recognize the dancers in the film. The dancers could wear bright lights and perform in a dimly-lit room, and therefore only lines would be obtained on the final film. Different camera positions could be used simultaneously so that the three-dimensional location of the dancers could be calculated by the computer. The films would be analyzed by the computer and converted into motion patterns. These patterns could then be translated into any desired dance notation and drawn by the computer on microfilm or other suitable materials.

This method is also not without its share of problems, although most of them are technological in nature. For one, the computer must recognize different light patterns on the film and determine the corresponding human movements. Although this task seems simple enough, some extremely powerul pattern recognition would have to be performed by the computer. Considerable research has already been devoted to computer pattern recognition but much more would probably be required for this particular application. In effect, this method of dance notation is somewhat too ambitious for the present.

The dance notator presently performs the task of recognizing the different human movements and then transcribes these movements on paper using some method of dance notation as a form of shorthand. Although the computer is very poor competition for the movement recognition task performed by the human notator, the computer could perform the pencil-and-paper work very efficiently. Graphical output devices are presently available so that the computer could easily draw the special characters that comprise a dance score. The notator could use a special typewriter or some other form of graphical input to specify the desired notation to the computer. The computer and graphical output equipment might be centrally located and time-shared with many other users, all communicating with the computer over telephone lines. All of this is possible with present technology; time sharing of a central computer and graphical output are available now. Anyone could apply this technology to produce this form of "dance notation typewriter."

However, I would prefer instead to suggest some drastic changes in the present choreographic creative process which in the long run might be a better solution to many problems including ballet preservation and dance notation.



The display on the screen and the electronic pencil held by the demonstrator are controlled by a digital computer (large metal cabinet containing electronic equipment is seen in part at left). The demonstrator indicates the patterns he wants by writing numerals on an electronically sensitive plate. The computer translates the information to the screen immediately in the form of stick figures. These, says Mr. Noll, can eventually be anatomically more detailed.

Is it necessary for the dancers to be present when the choreographer creates? Is this not wasteful of the dancers' time, which might be better spent in rehearsing and further training? In a way, the traditional method is also restrictive because the resulting work is strongly related to one particular corps of dancers and their abilities. As an alternative to this present approach, assume that the choreographer has a digital computer with some form of visual display at his disposal. The display is produced instantaneously by the computer. Instead of using the dancers as his choreographic instrument, the choreographer interacts with the computer during the creative process. Stick figure representations of the dancers appear in some form of three-dimensional display on the face of an electronic display tube. The choreographer, by manipulating different buttons on the console, controls the movement and progress of the work: Different movements might be stored in the computer's memory and put together at will. Individual movement restrictions for each dancer could even be introduced into the process. Various elements of chance and randomness could be used at the discretion of the choreographer. Scenery and stage props could also be specified by the choreographer and drawn by the computer. In effect, all the different aspects of the work would be under the direct control of the choreographer to manipulate and experiment in a myriad of combinations. When desired, certain portions of the creative process could be filled in by the computer which might be programmed to learn the choreographer's style. All this is a completely new creative process, and might result in new dance forms.

The use of the computer by the choreographer in creating the ballet also solves the dance notation problem. At the completion of the ballet, all the movements of the dancers are stored within the computer in digital form. These movements could then be automatically translated by the computer into any desired form of dance notation. The dance scores would then be given to the individual dancers.

In this manner, the choreographer and dancers would be mutually freed from each other to individually pursue their own tasks.

A movie has already been made with a computer to illustrate very crudely the type of visual display that might be shown to the choreographer. The movie was produced on an automatic plotter consisting of a cathode ray tube (conceptually similar to the picture tube in a television set) and a camera. The cathode ray tube produces pictures on a phosphorescent screen with an electron beam which is electrically deflected across the screen to generate the desired picture. The camera photographs the face of the cathode ray tube. The required signals for deflecting the electron beam and for advancing the film come as instructions from the main computer.

In the movie each stick figure consists of a single line for the body, a single-line shoulder, and the single-line arms. The arm positions are completely variable, and the size of each body element can be individually specified. The whole stick figure can be rotated to any specified angle and located at any position on the stage. In the particular example shown, six figures are used. Three move their arms uniformly up and down. The stage motion is random (any position is equally likely), but only one coordinate changes each time so that the motion is always parallel to the edges of the stage. The motion from position to position is at a uniform rate that is individually specified for each figure. At random times all stage motion ceases, and the three figures with the moving arms make one complete turn. The effect is reminiscent of the motion of atoms in a gas. The stage motion then continues. The movie was generated on the computer using the plotter described previously.

The movie demonstrates the possibilities for introducing controlled combinations of order and randomness. These stick figures are quite simple but do require many detailed specifications. The extension to more elaborate stick figures would require new programming techniques in which movement of the limbs is combined into basic movements which might then be combined on an even higher level. In this way, the most complicated dance motion could be easily specified as a combination of relatively simple movements. Human movement is extremely complex, and obtaining the equations for as simple a motion as walking would be formidable. A better attack on this problem might be for the computer itself to analyze human motion using devices that have just become available for converting pictorial data into machine digestible data. A library of basic movements could be built within the computer, and particular movements could then be put together at will.

Considerable research into special choreographic programming languages would be required before interaction between the computer and the choreographer could be used to completely control very elaborate human-like figures in a visual display. However, the interaction facilities and programming knowledge are available now that might be of assistance to the choreographer in planning and visualizing the stage motions of the dancers in large or complicated ballets. The choreographer might draw the stage positions of the dancers on a visual display tube which then serves as input to the computer. When the choreographer has completed the specification of the stage positions and stage motions of all the dancers for some desired portion of the dance, the computer generates a three-dimensional display of simple stick figures moving about a stage according to the choreographer's instructions. The display would be very similar to the movie described previously. The choreographer could easily make changes in any dancer's position and immediately see the results. Also, the computer could calculate the display for any specified vantage point so that the choreographer could ascertain the impact of the stage motion as seen from any location in the theatre.

These are quite radical proposals, and most certainly not every choreographer would wish to create dance with the supposedly inanimate machine. However, if ballets were specified in computer form much research into the choreographic process and human movement would be possible. Some of the questions to be answered by such investigations include the differences in style and movement used by different choreographers, the relation between music and dance, and the mechanics of human movement.

Presently, any choreographer desiring to use the computer would require a fairly sophisticated knowledge of computer programming. However, special programming languages that closely suit the needs of any particular choreographer could be developed. Special light pens are also available for writing on the face of the visual display tube. Such devices allow the computer user to sit at the console and to interact with the computer to produce a result immediately. It is now even possible to rent a console with a display device and interact with a central computer over distances.

I am a dilettante concerning choreography, and some of my ideas might be altogether completely unacceptable to the dance community. The act of artistic creation is mysteriously nebulous, and any tampering with it should rightfully be viewed with suspicion and carefully assessed. But the stakes are extremely high; the loss of such inspired choreographic masterpieces, that come to my mind, as George Balanchine's *Apollo*, Martha Graham's *Appalachian Spring*, or Jerome Robbins' *Les Noces* would be an artistic catastrophe. Something can be done. Scientific research into the process of human movement notation and choreography should be actively encouraged and supported. As part of this research, I would recommend an investigation of the possibilities of the computer. In the meantime, choreographers and dancers should insist that all new productions should be filmed and notated.