THE BELL SYSTEM TECHNICAL JOURNAL
Vol. 51, No. 2, February, 1972
Printed in U.S.A.

Wiring Telephone Apparatus from Computer-Generated Speech

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(Manuscript received October 5, 1971)

Tape-recorded, spoken wiring instructions eliminate the need for a wireman to divert his eyes and hands from the equipment he is fabricating. A computer technique is described for automatically converting printed wire lists to synthetic speech. The technique was used to synthesize spoken wire lists for crossbar-4 equipment, and the result was tested informally on a production line at the Western Electric Company plant in Oklahoma City. No errors were made in wiring crossbar-4 circuitry from the computer-synthesized instructions.

I. INTRODUCTION

In many instances in fabricating and wiring telephone equipment, it is necessary for the wireman to use both hands and to visually "keep his place" in the equipment. Since it is inefficient and time consuming to divert either eyes or hands from the wiring task, a spoken presentation of the wire-list sequence is advantageous.

Tape-recorded, spoken wire lists have been used by Western Electric Company for switchgear wiring and cable forming at the Oklahoma City and Montgomery (Chicago) plants. The wire lists typically are read and recorded by a practiced announcer. The recordings are then checked and edited by another person in a separate listening operation. The final recording is then used in a cassette play-back whose start-stop control is wired to a footswitch. As the wireman needs items of the wiring sequence, he presses the footswitch for a time required to play back each item of the list. Because of the noisy environment he normally listens on an ear-insert earphone. The play-back normally is stopped while each connection is made. A typical wire list includes: lead length; color; beginning point; terminating point; and, sometimes, auxiliary instructions. Studies of the audio technique of wiring show accelerated training time and substantial improvements in quality and efficiency.

Fewer defects are found to occur and less time is needed to repair them.[1]

Wire lists for complex equipment are generally organized on computer cards. The audio technique therefore requires a listing of the card deck in a form convenient for the human announcer. The two human operations [(*i*) recording and (*ii*) editing] offer possibilities for errors to creep in. This sequence of operations is illustrated in the upper half of Fig. 1. Modifications in the wire list—made easily in the card deck and, generally, made often during the life of a typical list—require re-recording and re-editing of the audio tape. Consequently, there is considerable motivation to consider direct and automatic conversion of the card deck into a speech recording. One scheme for a direct and automatic generation of the spoken wire list uses synthetic speech and is illustrated in the lower half of Fig. 1.

II. COMPUTER-SYNTHESIZED INSTRUCTIONS

We recently have devised a computer technique for synthesizing speech from stored, low bit-rate data.[2,3] In its initial form the method has been applied to the synthesis of 7-digit telephone numbers, as might be used in an automatic intercept system. The system is implemented on one of the DDP-516 computers in the Acoustics Research

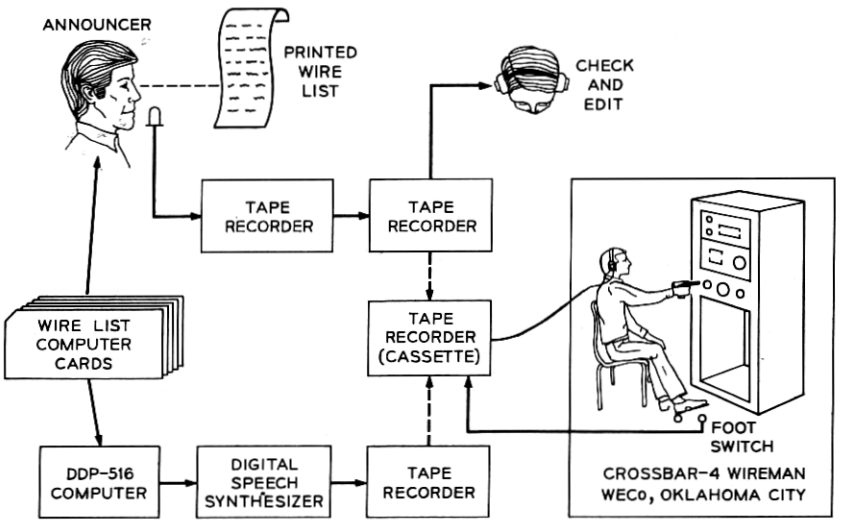

Fig. 1—Human and computer methods of preparing tape-recorded, spoken wiring instructions.

Department, and the major components of the system are shown in Fig. 2.

Individually-spoken words are analyzed in terms of their characteristic (formant) resonances, and the results described by a data rate of 530 bits per second.[2] These data are stored in the fast-access disc of the DDP-516 facility and constitute the vocabulary for the voice-response system. When a word-sequence is demanded by a control (answer-back) program, the formant data for the successive words are accessed from disc and are concatenated "head-to-tail." An analysis is made of the context in which the library words are to appear, and duration and voice pitch data are computed for each word by the synthesis program. The formant data at the boundaries between words are interpolated smoothly by a specially designed algorithm in the synthesis program. Finally, the formant and pitch data calculated for the required utterance are sent to a hardware digital filter whose resonances simulate those of the human vocal tract.[4,5] Digital-to-analog conversion of the filter output yields a synthetic speech signal.

We have used this voice-response system with simplified duration and pitch rules to synthesize wire lists for crossbar-4 switchgear. In this application the card deck comprising the wire list is simply put into the card reader of the DDP-516 and each wiring instruction is synthesized. A computer-controlled analog tape recorder records the output of the D/A converter, and this tape goes directly to the wireman's cassette. The items of the crossbar-4 wire list which were synthesized are shown in Table I. The synthesized list contained a total of 58 complete wire wrap instructions.

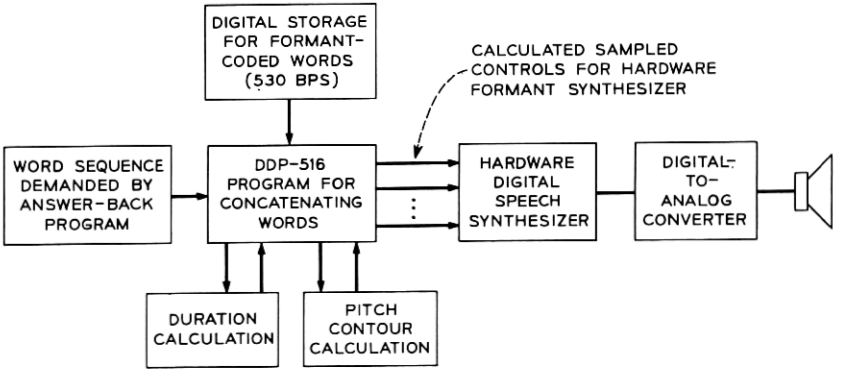

Fig. 2—DDP-516 computer system for automatic synthesis of spoken wiring instructions.

TABLE I—SYNTHESIZED WIRE LIST

SWJ99234T2
issue 7

List combination 1, 2, C, D
Apparatus not otherwise identified shall be considered to be a relay.
Wire colors not otherwise identified shall be green and the length will be in inches.
The sequence of operations will be: wire length, starting terminal and apparatus designation, ending terminal and apparatus designation.

	12	27A terminal strip	6R1
	3	28A terminal strip	2A tube socket
	11	37A terminal strip	4R1
	2	38A terminal strip	6A tube socket
	18	15A terminal strip	1 lower TP
	19	16A terminal strip	1 TP
	20	25A terminal strip	7 break TP
	4-1/2	26A terminal strip	1 top P
	20	35A terminal strip	7 TP
	16	36A terminal strip	2A repeat coil
	11	14A terminal strip	6 make R1
	4-1/2	24A terminal strip	2 top P
	11	33A terminal strip	4 make R1
	19	34A terminal strip	1 upper TP
	11	12A terminal strip	2 R1
	10-1/2	32A terminal strip	upper R1
	3-1/2	1A tube socket	8 top P
	4	5A tube socket	9 top P
	3-1/2	6A tube socket	4 top P
	3	8A tube socket	7 top P
	17	1 top P	6 make TP
	9	2 top P	10 break R1
	10	3 top P	8 make R1
	10	4 top P	top A capacitor
	2-1/2	5 top P	top D capacitor
	9	8 top P	bottom A capacitor
	2-1/2	bottom C2 capacitor	bottom C1 capacitor
	2-1/2	top C2 capacitor	top C1 capacitor
	5	bottom C1 capacitor	8 R1
	3-1/2	top C1 capacitor	top C resistor
	3-1/2	bottom C resistor	10 R1
	5	4 break R1	4A repeat coil
	5	6 break R1	7A repeat coil
	3	bottom A capacitor	8A repeat coil
	4	top A capacitor	3A repeat coil
	7	5A repeat coil	6 TP
	4	1 lower TP	right E capacitor
	4.5	1 upper TP	lower E capacitor
	2	2 lower TP	4 make TP
	3	2 upper TP	4 TP
	3	1A repeat coil	top A resistor
	3.5	6A repeat coil	bottom A resistor
	3.5	bottom A resistor	bottom B capacitor
	3.5	top A resistor	top B
	20	17A terminal strip	5 TP
	20	18A terminal strip	3 TP
	11.5	22A terminal strip	11 R1
	8	6 top P	top R1 upper terminal
	5.5	bottom D capacitor	bottom R1 lower terminal
	7	top R1 upper terminal	5A repeat coil
Red	2.5	11A terminal strip	4A tube socket
Black	3	31A terminal strip	7A tube socket
Black	9.5	7A tube socket	8 break R1
Black	2.5	8 break R1	2 make R1
Black	3	2 make R1	10 make R1
Black	10	10 make R1	top TP terminal

We have made informal experiments at the Western Electric Company plant in Oklahoma City, where we asked the wireman (or, rather, wiregirl) to use the synthetic speech recording to fabricate crossbar-4 equipment. A photograph of the wireman simultaneously wire-wrapping five identical chassis of crossbar-4 equipment is shown in Fig. 3a. The footswitch control of the synthetic speech tape on the cassette is shown in Fig. 3b.

Fig. 3a—Wireman on production line at Western Electric Company plant in Oklahoma City. The wireman is fabricating crossbar-4 equipment from the computer-spoken wire list.

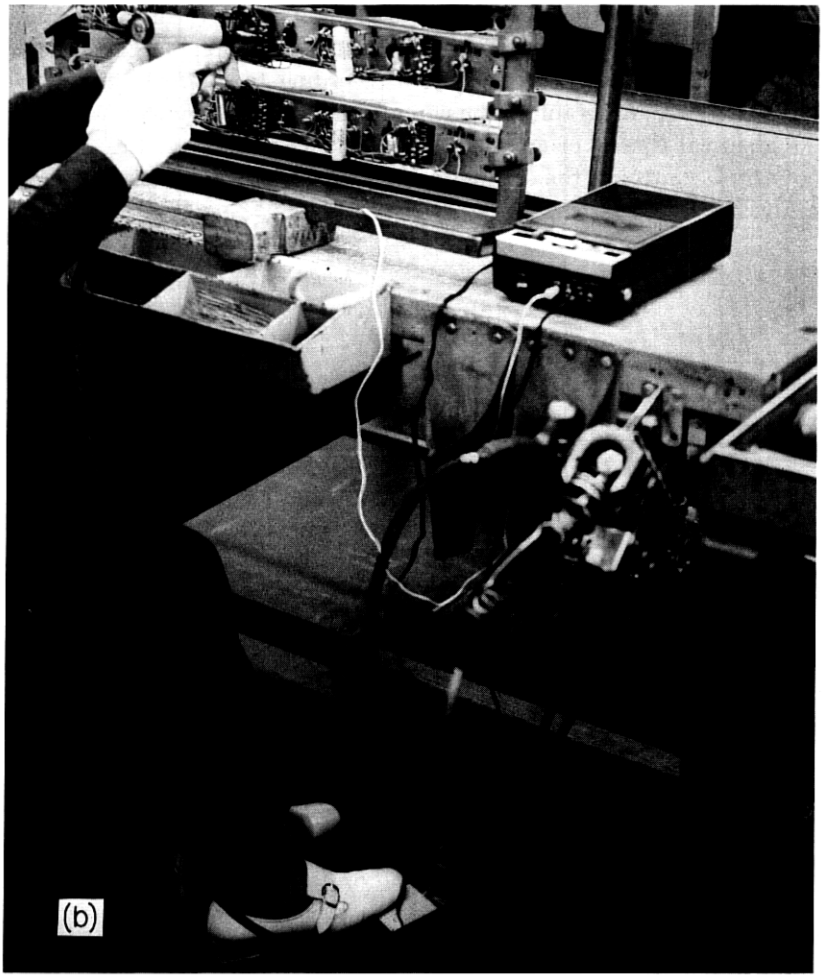

Fig. 3b—Wireman's footswitch to control the computer–synthesized speech tape.

While the quality of the synthetic speech is far from natural, the wireman (who had never heard synthetic speech) experienced no difficulty in using it immediately and, in fact, remarked that the "caricatured" nature of the synthetic signal seemed better for the noisy plant environment than natural speech. About 15 minutes/chassis are needed to wire the equipment shown in Fig. 3, and no wiring errors were made in the informal tests on the five chassis.

For speech material with as small a vocabulary and as rigid a con-

textual format as a wire list, the flexibility and storage economy of the synthesis system is not critically needed. In the case of brief lists, digital recordings of the naturally spoken vocabulary words may be made on the DDP-516 disc and these words can be concatenated automatically by the control program. This simpler approach does not, of course, permit smooth, natural joining of the words into a sentence, but utterances such as the components of a wire list can be rendered reasonably well virtually in isolation. This approach would be exceedingly economical in that no pre-analysis computation of formant data is required to establish the machine vocabulary, and all the advantages of automatic, computer-generation of the spoken instructions are retained.

One final comment may be in order about computer-generation of spoken wire lists. The human-pronounced list which had been in use for the crossbar-4 wiring had a very obvious pausal error throughout. (Look, for example, at the first item in Table I.) The girl announcer who recorded the tapes, and who apparently was unfamiliar with the wiring operation, consistently read the items as "Twelve (pause) Twenty-seven (pause) A terminal strip." The computer, although speaking with a machine accent, never makes this mistake.

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