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A PROGRAMMED PARAMETRIC SYNTHESIZER

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The synthesizer described generates signals with a duration of the pitch period, which follow the waveform of the respective segments of a natural speech signal. Parameters of each segment are determined on the basis of digital data using a computer. Some of these data are used to generate the constituents of a signal in digital to analogue convertors and some to shape the waveform obtained. The paper also gives the range of the available parameters of the sounds generated and also some examples of programmes.

1. Introduction

The main purpose of the construction of the synthesizer was to obtain a system, which would make it possible to shape a wide range of synthetic speech signals, so that while using it the analytical results, which define phonetically and acoustically the identifiable properties of speech sounds, could be verified. The principle on which it was based was that of a representation of the elementary waveform of a natural speech signal, without reference to the vocal tract transmission.

The parameters of the waveform generated by the synthesizer are determined by digital data from a computer. These data serve to generate a signal in the time domain corresponding to the pitch period.

From the technical point of view the synthesizer system is a specialized output computer device.

2. The performance of the synthesizer and its design

The synthesizer system consists of two independent tracts: one to generate sounds of harmonic (formant) structure, the other to generate signals with the character of noise. To generate the signal of the formant structure, four inde-

pendent systems of sound generation corresponding to the successive formants: $F1$, $F2$, $F3$, $F4$, which were later summed, were used.

2.1. The principle of formant signal generation

The generation of the formant signal with a waveform defined by the digital input data occurs in a digital to analogue converter system of a special type in which, in addition to the generation of a sinusoidal signal, it is modulated in amplitude at the same time, according to the analogue signal supplied by the envelope shaping system. This system is also a form of a digital to analogue converter. In both digital to analogue converters the signal generation consists in decoding the counter, to which the signal from the pulse generator is supplied. Subsequently each decoded value (in the range of 0 to 15) is reduced to a relevant analogue value for which, when the waveform corresponding to a specific formant is generated, the series of analogue values forms a sinusoidal variation, and for which, when the envelope signal is generated, it can have an essentially arbitrary shape, defined by the system. Fig. 1 shows schematically the relationships between the input signals and the resultant formant signal.

2.2. Generation of signals with the character of noise

The generator of white noise, whose signal is controlled simultaneously by 12 selective amplifiers, is used to generate a signal with a predetermined

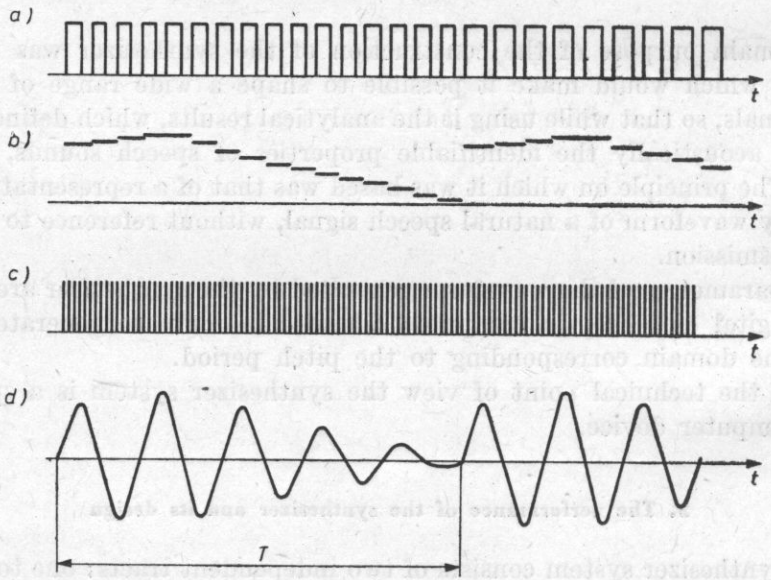

Fig. 1. An example of forming a formant signal: a) a signal from a pulse generator; b) an envelope shaping signal; c) a signal from a pulse generator F_n; d) a formant signal

spectral characteristic. The amplifiers are controlled by a digital signal, and the output signal is the sum of the outputs of the amplifiers.

2.3. The performance of the synthesizer and its block diagram

A block diagram of the synthesizer is shown in Fig. 2. The main units of the system are the following: a control unit, 8 input registers, 8 operative registers,

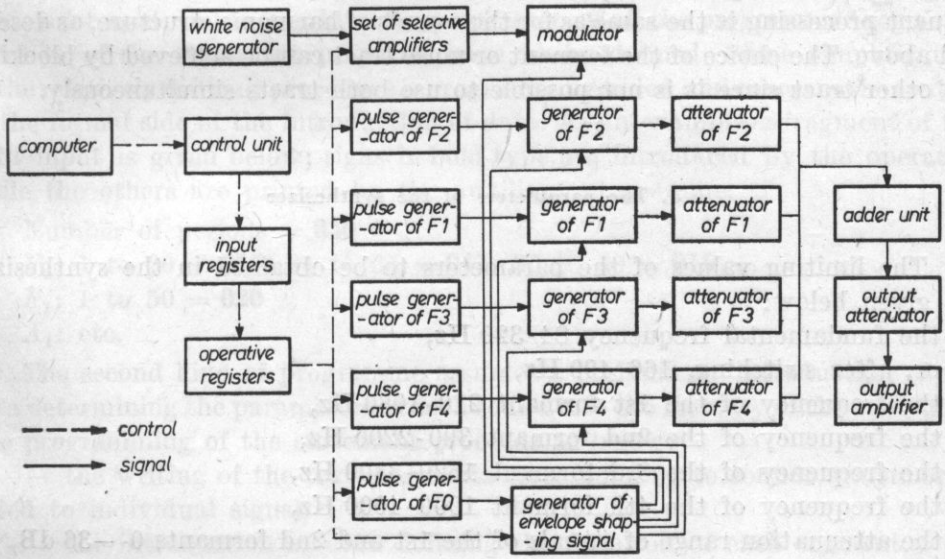

Fig. 2. A block diagram of the synthesizer system

a white noise generator, a pulse generator in the pitch circuit, a digital to analogue converter system for envelope shaping, 4 pulse generators in the formant circuits, 4 digital to analogue converters for modulating the formant circuits, 12 selective amplifiers, a modulator in the noise circuit, 4 attenuators of the formant signals, an adder, an output attenuator, an output amplifier.

The synthesizer functions in the following way: a series of 8 commands of 8 bits, defining the parameters of the signal, is sent from the computer. The end of each segment (period) is followed by a transcription of the contents of the input registers to the operative registers whose state defines the parameters of the signal for the ongoing segment whose duration is determined by 16 pulses from the F_0 pulse generator. In the case of the generation of sounds with a harmonic structure, the signals, each of which has an independent frequency, level and envelope shape, are generated by formant generators. The formant signals are amplitude modulated in the digitally controlled attenuators, and subsequently added in the adder system. The output signal is attenuated in the

output attenuator, which is also digitally controlled. This attenuator can be used to shape the envelopes of the segments which have a duration longer than the pitch period. An amplifier was used at the output of the system in order to achieve an output signal level of the order of a fraction of a volt.

A modulator, which is controlled from the envelope shaping system with a signal of the fundamental frequency is included in the noise tract. Without the modulating signal the signal from the outputs of the selective amplifiers does not change at the output of the modulator. The shaped noise signal is supplied to the input of the attenuator of the second formant and its subsequent processing is the same as for the sounds of harmonic structure, as described above. The choice of the formant or noise tract can be achieved by blocking the other tract since it is not possible to use both tracts simultaneously.

3. The parameters of the synthesizer

The limiting values of the parameters to be obtained in the synthesizer are given below:

- the fundamental frequency 84-320 Hz,
  or, after switching, 166-490 Hz,
- the frequency of the 1st formant 210-1080 Hz,
- the frequency of the 2nd formant 390-2200 Hz,
- the frequency of the 3rd formant 1620-3300 Hz,
- the frequency of the 4th formant 1900-4000 Hz,
- the attenuation range of signals of the 1st and 2nd formants 0- —36 dB,
- the attenuation range of signals of the 3rd and 4th formants 0- —26 dB,
- the attenuation range of the output signal 0- —23 dB,
- the number of the envelope shapes available without switching 7,
- the available levels at the outputs of the selective amplifiers 0, —8, —16 dB, no signal,
- the frequency range transmitted by the selective amplification unit 1-5 kHz,
- the relative width of the selective amplification bandwidth about 0.14.

The synthesizer was built on 4 boards of 300 ×300 dimensions and TTL technique was used in the digital systems.

4. Controlling the performance of the synthesizer

The performance of the synthesizer depends on the computer programme which defines parameters for each segment of period T_0. In order to define the parameters of the signal the following should be given

- the mode of structure: harmonic-noise,

– the fundamental frequency F_0,
– the frequencies of the four formants,
– the level of the four formants,
– the shape of the envelope of the waveform of the formant within the pitch period,
– the attenuation level of the resultant signal.

When data is introduced into the memory of a computer it has the form of three numerical values and is presented in a coded form.

In the use of the synthesizer two kinds of controlling programmes have been so far used. In the first kind the parameters of all the programmed segments (periods) of the statement prepared have to be defined. Some simplification of the relatively difficult procedure is programming-aided and concerns the control of the formal side of the introduction of data. As an example, a fragment of the data input is given below; signs in bold type are introduced by the operator, while the others are printed by the auxiliary programme.

Number of periods = **050**
F_0: 1 to 20 = **015**, 21 to 35 = **017**, 35 to 50 = **016**
F_1: 1 to 50 = **020**
A_1: etc.

The second kind of programme assumes a preliminary introduction of the data determining the parameters of each sound into the memory of the computer. The programming of the statement proceeds as below:
– the writing of the text (segments corresponding to sounds are subordinated to individual signs),
– the introduction of data defining the duration of each segment,
– the introduction of data defining the intonation curve,
– the definition the value of the fundamental frequency.

The introduction of the data is also assisted by the programme; the duration of the sound segments is given in a coded form as a single digit number each time after the given sign has been printed by the programme. The intonation is defined on the basis of the data introduced as a number of musical half-tones preceded by a sign (+ or –), or possibly 0 after a bracket printed after the sign of the segment and the number of periods (16 ms) defining the duration of the segment. The closing bracket is interpreted by the programme as a lack of change until the end of a given segment.

An example of programming: signs in bold type are introduced by the operator

janek text
j5a7n5e5 4 k3 duration
j06(**+1 +2**)a12(**+1 +1**)n05()e06(**–200** –2)04()*k*03() intonation
sf0 = **0.14.**

In view of the limited range of the use of the synthesizer to date it has not been necessary to use other controlling programmes which are easier to use if a more detailed definition of data is required than in the example presented above. The possibility of influencing the applying of a signal generated for short time intervals is considered by the users of the synthesizer as a characteristic meeting the initial assumptions and a useful application of the synthesizer.

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