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AUDIO SIGNAL EXAMINATION USING A COMPUTER SYSTEM

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1.0 Abstract

To obtain the maximum information from a tape recording, a number of examination techniques is required. One possibility is to digitise the signal and examine it in various ways in the digital domain. Here, the development of a minicomputer system with suitable devices for interactive audio-visual examination of the digitised signal is discussed.

2.0 Introduction

A digital signal processing facility based on a minicomputer was set up 6 years ago at the Home Office Scientific Research and Development Branch for research and development in the processing of audio data. One of the main research areas is the examination and enhancement of poor quality tape recordings. An operational audio tape laboratory was established 4 years ago, for the authentication and enhancement of tape recordings received or obtained by the police. Tape Laboratory staff spend a large proportion of their time in the authentication of tapes, which requires intensive examination of the tapes and of their signal contents. A separate computer system has been created for operational work with similar components to the development system and running the same software. The current systems are described below together with some possible future developments.

3.0 Computer System

The system is based on a Digital Equipment PDP11 16 bit minicomputer. A simple single user operating system, Digital's RT11, is used. This is capable of supporting real time operations such as recording and playback, and imposes very little overhead on computationally intensive processes. The development system is based on a PDP 11/60 and the operational system on a PDP 11/34. Both development and operational systems include the devices shown in figure 1.

3.1 Array Processor

The Analogic AP400 array processor is a specialised unit for executing rapid computations (8 million instructions per second) on arrays of numbers. It is under the control of the host computer. Calculation-intensive operations are up to 100 times faster on the array processor than they would be if executed on the PDP 11. This is very important for the production of spectrograms, which requires many Fourier transform calculations.

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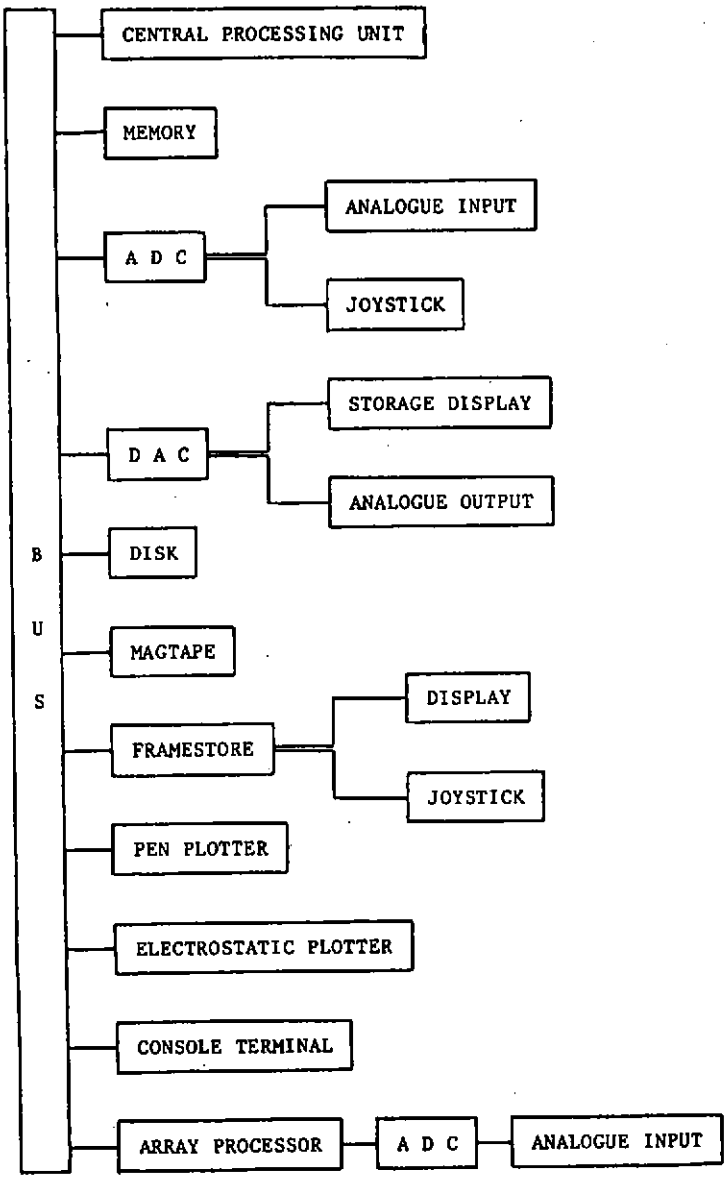

Figure 1. Schematic block diagram of the computer system

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3.2 Digital to analogue (dac) and analogue to digital (adc) converters

The adc provides digital recording and the dac allows playback of digitally recorded signals. Analogue signals are sent from tape recorders or microphones via amplifiers and low-pass anti-aliasing filters to the adc where they are converted to digital form. Digital signals are converted to analogue form by the dac, after which they are sent to loudspeakers or tape recorders via low pass filters and amplifiers. The DEC AD11 adc allows up to 15 kHz sampling rate, giving a signal bandwidth of 7.5 kHz. Recently an adc which inputs to the array processor has been obtained, which is capable of up to 50 kHz sampling rate. The DEC AA11 dac has been enhanced so that it can replay at up to 20 kHz. The data are digitised into 12 bits giving 72 db dynamic range, and a 10 kHz sampling rate is usually used.

3.3 Mass Storage

The digitised signal is stored on computer disk or tape. The development system has 400 Mbyte of hard disk and a magtape drive, while the operational system has 160 mbyte of removable hard disk. At 10 kHz sampling rate, 1 minute of signal requires 1.2 Mbytes of storage, the length of recording being inversely proportional to the sampling rate used. Because of various software constraints the maximum continuous recording which can be made is 55.9 minutes at 10 kHz.

3.4 Display devices

Both systems have a storage display screen (Tektronix 613 or 618). This analogue device has good resolution and is capable of rapid line drawing, but cannot scroll the display across the screen or selectively erase parts of the display and has no internal character generator for display annotation. A joystick is used for positioning cursors on the screen. A frame store with raster display and joystick (AED 512) has just been installed on the development system, which is capable of displaying 256 colours or grey levels, and has a resolution of 512 by 512 pixels. Data can be scrolled and any part of the display can be erased. Characters and simple geometric figures can be internally generated. It has a DMA parallel interface to the host computer for rapid data transfer (0.5 Mband).

3.5 Hardcopy plotting devices

Both systems have an eight-colour pen plotter (Tektronix 4662) and an electrostatic plotter (Versatek V80). The pen plotter has a resolution of 4096 x 3124, and uses cut sheet paper. The electrostatic plotter has horizontal and vertical resolutions of 200 points per inch, and uses roll paper so that continuous plots can be produced. The greyscale plots have about 16 levels of grey.

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4.0 Signal Examination Software

The software has been developed in-house, most of which is written in FORTRAN with the exception of some time-critical operations which are written in assembly language. It was initially used to assist in development of signal enhancement algorithms. The importance of signal examination in its own right was realised later, as a result of operational workload. Spectra are calculated on the array processor using the fast Fourier transform algorithm.

4.1 Recording and playback software

As a first step, the data must be digitally recorded on computer disk. Any sampling rate up to 50 kHz may be selected. A program has been written to emulate a tape recorder which permits recording, record level check, and playback. Complex sequences of playing back sections of the signal in loops are possible because of the rapid and accurate addressability of the data on computer disk. Assembly language is used for the record and playback routines.

4.2 Interactive examination software package

This software allows the user to view waveforms, play back sections of signal, display instantaneous or average spectra, zoom in on areas of interest, plot sections of waveform and spectra, make accurate measurements and save the waveforms and spectra of areas of interest. It can also be used to carry out simple interactive processing such as scaling the data and removing sharp transient peaks. Control is by commands typed in at the console terminal and use of a joystick. The storage display screen is used for display, but a version of the software has been written to use the framestore on the development system. The pen plotter is used for hardcopy plots.

4.3 Hardcopy plotting programs

Waveforms can be plotted continuously or in sections on the electrostatic plotter and in sections on the pen plotter, with various scalings and formats (figure 2). Spectra can be plotted on the pen plotter.

4.4 Spectrogram software

The spectrogram is a very useful representation of a signal. It is a plot of freqency against time, with magnitude as a third dimension. Two methods of showing this information exist: the magnitude can be shown as grey level or colour at a point (with time and frequency as the x and y axes) or an isometric ('mountain range') plot can be made. Programs exist to display or hard copy plot both of these formats. The isometric plot requires only line drawing and can be done on any of the display or plotting devices (figure 3). Greyscale spectrograms can be produced using the display screens, the frame store and the electrostatic plotter (figure 4). The frame store can also

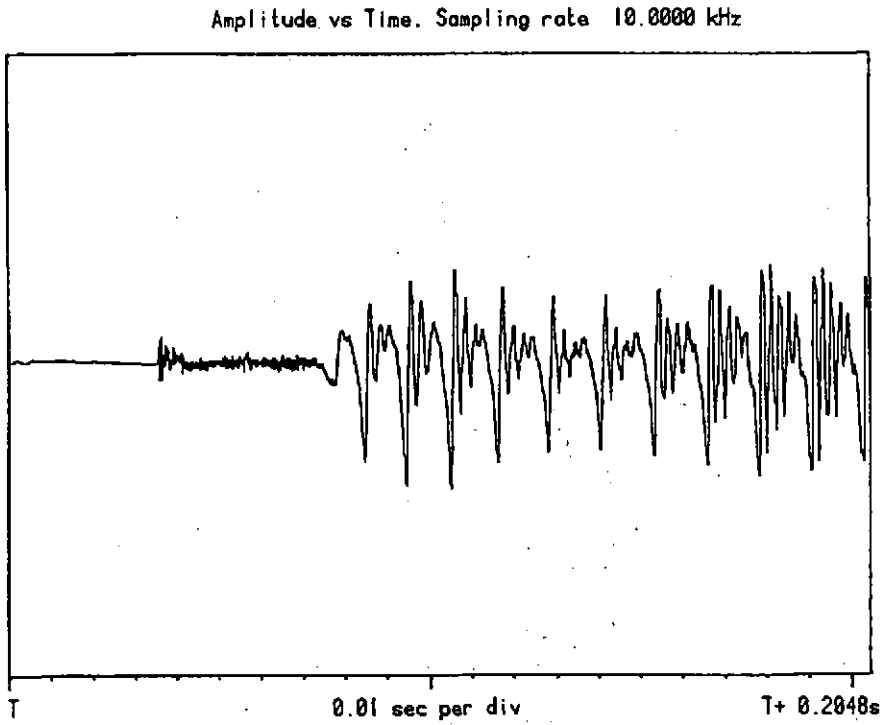

Figure 2. Waveform plot on the pen plotter. Represents 0.2048 seconds of high quality speech.

generate false colour spectrograms. In all cases, a linear or log magnitude display may be produced, with a choice of dynamic range, and a speech weighting filter may be applied to the data. The user can select the data window overlap and an analysis bandwidth in the range 20 to 625 Hz.

5.0 Advantages of the computer system

Before the computer system was available for operational work, signal examination was carried out using a variety of equipment such as tape recorders, a spectrum analyser with a plotter, and a chart recorder. These devices are still used and are more suitable than the computer for some tasks. In general, however, the computer system has a number of advantages as listed below.

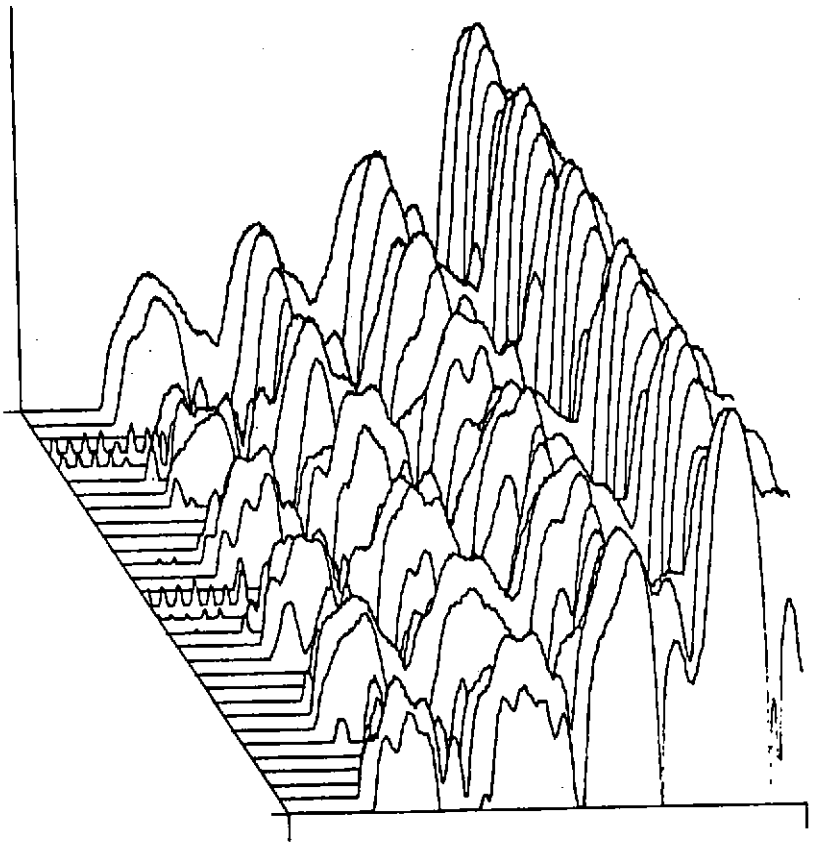

Figure 3. Isometric spectrogram plot on the pen plotter. Analysis bandwidth 300 Hz. 75% overlapped data windows. 0.04 seconds from the word 'day'.

5.1 Versatility

Once the data have been digitised, various operations can be carried out in any order, any number of times. The user can interactively set parameters such as waveform scaling, dynamic range of spectrograms, angle of view of isometric spectrograms, length of signal replayed in a continuous loop and so on. The user can switch the system between functions easily and quickly.

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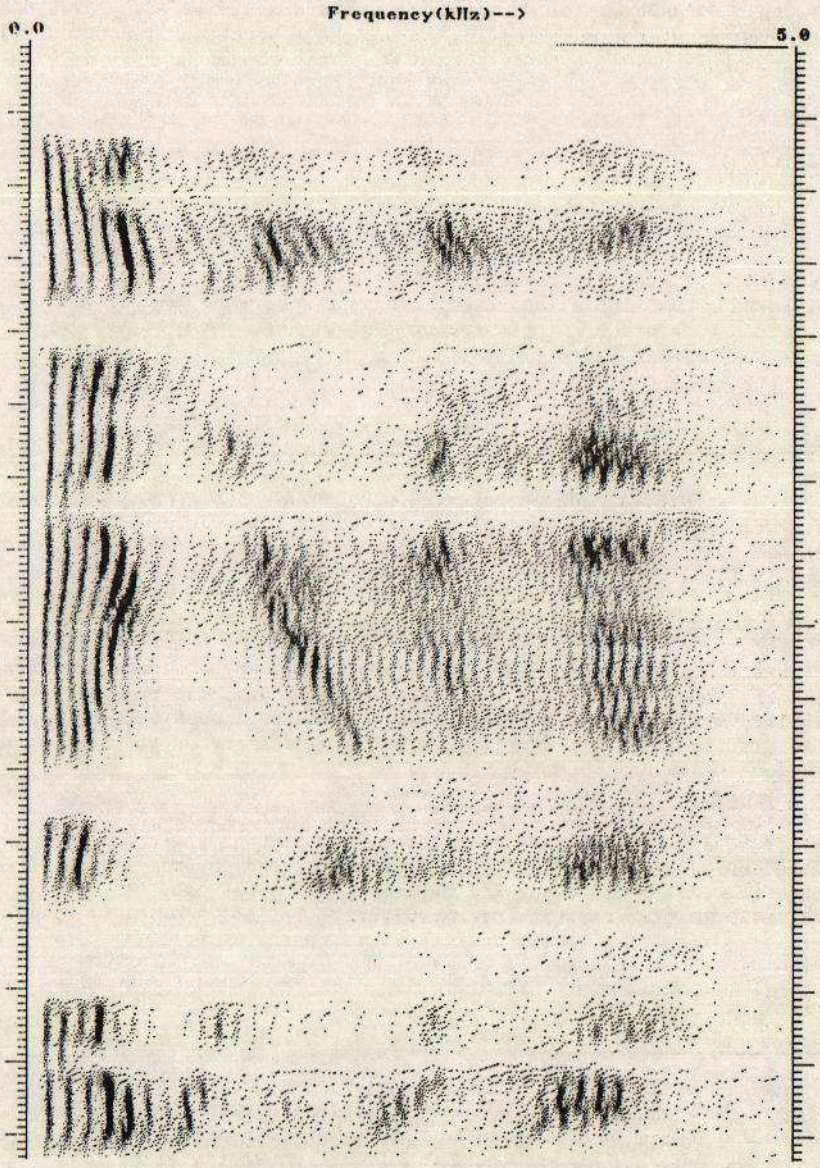

Figure 4. Greyscale spectrogram plot on the electrostatic plotter. Analysis bandwidth 40 Hz. 98% overlapped data windows. 1.5 seconds of high quality speech.

For example, a signal can be recorded, its waveform displayed, played back, a five second passage identified and saved, and a spectrogram plotted while the user remains at the computer terminal. This can be done interactively, meaning that the system is fast enough to execute each stage of a task while the user waits.

5.2 Additional Functions

The SRDB had no capability for producing spectrograms in any form before the computer system was available. Dedicated devices for producing spectrograms are commercially available, but are less versatile and offer the user less control over plotting parameters than the computer. The spectrogram is an important tool for signal examination, giving more useful information than either a waveform or single spectrum plots for some purposes.

5.3 No signal degradation

The dynamic range of the computer system is wider than that of a tape recorder, and a signal bandwidth of up to 25 kHz can be used. Digitally recorded signals are not subject to degradations such as additive noise, tape wear or stretching due to repeated playback. In the computer system the data remain digital throughout all processes, whereas a device such as a spectrum analyser can only receive signals in analogue form even if they were originally stored on a digital tape recorder.

5.4 Precision and repeatability of measurement and calculations

Measurement of time duration and signal amplitude can be accurately made, and calculation of signal energy and frequency spectra can be accurate and repeatable. For example, time measurements can be accurate to one sample (0.1 millisecond at 10 kHz sampling rate) using cursors on the display screen.

5.5 Random access and location of events

As data from disk can be randomly accessed any part of the signal can be instantly found, and examined for as long as desired. Frames of data can be viewed in any order, and it is not necessary to capture the required display as it scrolls past as on a spectrum analyser. The position of an event can be accurately noted for future reference, to repeat an operation for example.

6.0 Future Developments

6.1 Interactive examination software package

The framestore will provide extra features such as scrolling, multiple display windows, highlighting with colour, and more interactive control of the display. A hard copy unit can be connected to obtain a colour print of the screen display. The interactive examination software package will be replaced by a program which exploits the extra features of the framestore.

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6.2 Real time spectrogram display

Using the array processor and frame store it may be possible to calculate and display spectrograms in real time. The signal would be played from a tape recorder at normal speed via the adc into the array processor. Spectral cross sections of blocks of the signal would be calculated and sent to the frame store to be displayed in greyscale or false colour. This would remove the need to record all the data digitally before examining it. Large amounts of data could be examined in real time, with just the passages of interest recorded on computer disk for more detailed study.

6.3 Maintenance

Because the system is now used regularly by the operational staff, faults and unsatisfactory characteristics are being shown up and areas for improvement identified. Feedback from the operational work is carefully documented and studied. Modifications to rectify faults and make minor improvements are continuously made and major improvements can be considered for future programs.