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RECOGNITION OF STATES OF MORE THAN ONE EMITTER IN REAL TIME

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Abstract—The problems are considered of detecting and processing wave process signals in real time so that a feedback loop can be introduced to control the experimental setup and the process under study. A practical implementation of the respective procedures within a two-processor set is described along with the associated hardware and software. The potential applications of the system are illustrated by evaluating the contributions of individual sources to the total emission from the source domain and by identifying the states of the domain.

In studying any system which processes waves it is desirable that the experimental setup and the workpiece should be controlled during the experiment, especially when a changing behaviour of wave processes is involved. A control feedback loop (Fig. 1) enables the experimenter to maintain, depending on the object behaviour, the best experimental regimes which reveal the specific features of the process.

In order to control an experiment it is required above all that the available data processing rate should exceed the rate of data arrival from the transducers, i.e. the data should be processes in real time. Otherwise there will be a bottleneck in real time processing associated with the means of recording and processing of wave-process data. Therefore the response time of the measurement–processing–control chain must be sufficiently small. This goal may be achieved by parallel processing of data acquisition and employing computationally simple but efficient analytical algorithms.

With the above principles in mind we developed an automated system based on a SM-4 minicomputer and a CAMAC crate for coupling the computer with the process under study. The minicomputer includes a 16-bit wordlength SM 2104 processor (one register-to-register operation takes 1.2 μs), a 256 Kbyte main memory, two magnetic disc stores of 10 Mbyte total capacity, four SM 7200 displays, three D100 microprocessor printers, an SM 7103 keyboard printer and a puncher/punched-tape reader.

The display and printers allow multiuser operation. The puncher encodes the researcher–computer dialog for subsequent analysis and logging of an experiment.

The CAMAC modules include a 106A crate controller (general control of modules), an auxiliary 181A microprocessor (20 K RAM, 12 K EPROM), two 10-bit digital to analog converters wired in one SDAC-10 module, a 058A voltage converter (248/12V), a relay control register, five RAM units (4 Kbytes of 24-bit words), three ROM units (32 Kbytes of 24-bit words), a 1-μs real-time clock, a 730V timer (from 1 MHz to 1 Hz in decade steps), four analog-to-digital converters (10-bit word, 25 μs conversion time), a unit of 10-kHz bandfilters, a time/pulse counter and a dataway display.

The N306 plotter is connected via 2DAC-10 and relay control register modules.

The service modules comprise a manual controller with step-operation, one-operation, and cycle functions, a unibus indicator, a 730V timer, a 24-bit word generator and an extender. These modules are responsible for the control and adjustment of the functional modules.

This automated system is basic, for it will solve a very wide class of design problems. It can be readily expanded if needed. For example, 32-channel multiplexers can be added to increase the number of input channels, a 560 colour TV interface can be connected to enlarge the graphic possibilities, and so on.

The system includes a number of function subsystems such as wave process modeling, experimental design, transducer signal reception and logging, synthesis of diagnostic features, numerical data processing, control action generation, monitoring, and testing. Each subsystem is equipped with the requisite hardware and software facilities.

The system software is built around a real-time operating system with wide functional capabilities:

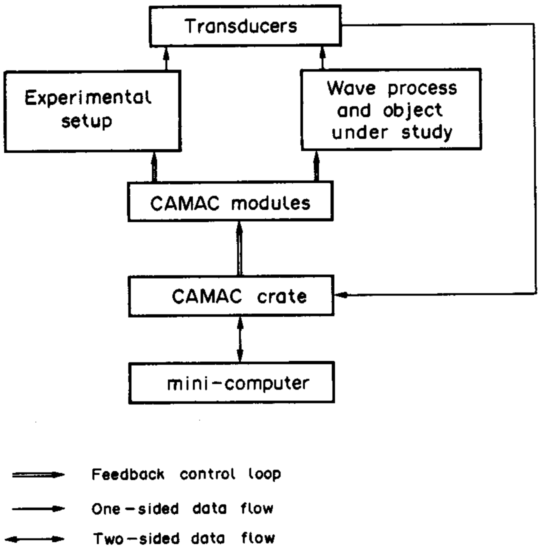

Fig. 1. Block diagram of the automated system.

a 2048 Kbyte RAM unit, up to 20 supported terminals, resident file protection, organization of resident libraries, diagnostic routines for the hardware and software and database control systems.

The application programs are integrated in a single software complex with common information and logical links. This complex realizes a data processing network based on an original procedure.

The automated system offers the following capabilities:

- — up to 102 input channels,
- — input signal quantization frequency up to 170 kHz,
- — 60 dB dynamic range,
- — input signal bandwidth (with a videotape recorder as an intermediate carrier) up to 1.7 MHz,
- — up to 10 simultaneously processed data sets,
- — data type: byte, integer, real,
- — multiple use of data for a single input,
- — data correcting operations: shift, permutation, zeroing, replacement with a given value in the interval or range,
- — estimation of data sets by the minimum, maximum or mean value,
- — interactive user–computer operation,
- — basic set of processing procedures: normalization, integration, smoothing, amplitude, spectrum, spectrum analysis and pattern recognition,
- — imagery of data and results, as a whole or by parts,
- — scaling (uniform, logarithmic) of coordinates, rotation of plots, overlapping and labeling of curves, construction of 3-D sections, lettering of graphs, etc.

One of the problems in analysis of wave processes that had to be tackled is formulated as follows. A certain domain of an elastic medium, small compared to the distance to the receiver, contains sources of waves with distinct parameters. The receiver is a piezoelectric transducer that is set on the surface of the medium to sense the resultant wave and convert its energy into an electrical signal. The number of sources and the frequency spectra of each source are known. It is required to determine from the resultant radiation the proportion $(P_i, i = 1, \ldots, n; \sum P_i = 1)$ contributed by each source, recognize one of m states of the radiant domain, and compute the control action $U = (u_1, u_2)$ with two controls, u_1 for the experimental setup and u_2 for the elastic medium.

We select n frequencies, f_j, $j = 1, 2, \ldots, n$, such that the sets of amplitudes of the source spectra do not coincide completely (partial coincidence is allowed) for any two sources and are linearly independent. We shall use these amplitudes as the primary diagnostic features and denote them by $W_i^{(j)}$ (Fig. 2), i standing for the number of the source, and j for the number of the frequency component.

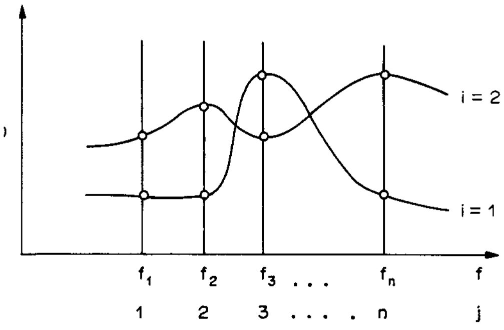

Fig. 2. Primary diagnostic features.

Attenuation in the medium brings about the relation

$$\tilde{W}_i^{(j)} = W_i^{(j)} e^{-ar},$$

where $\tilde{W}_i^{(j)}$ is the amplitude of the frequency component near the detector, $W_i^{(j)}$ is the amplitude of the frequency component near the source, a is the attenuation coefficient and r is the source-sink spacing.

According to the principle of superposition, the received wave is a linear combination of component waves

$$W_d^{(j)} = \sum_{i=1}^{n} \alpha_i \tilde{W}_i^{(j)} = e^{-ar} \sum_{i=1}^{n} \alpha_i W_i^{(j)},$$

where $W_d^{(j)}$ is the detected amplitude of a frequency component, and α_i is the coefficient reflecting the source intensity.

In order to eliminate the multiplicative interference due to attenuation, we normalize the amplitudes in relation to their sum, namely,

$$W_{\text{norm}}^{(j)} = \frac{W_d^{(j)}}{\sum_{j=1}^{n} W_d^{(j)}} = \frac{e^{-ar} \sum_{i=1}^{n} \alpha_i W_i^{(j)}}{\sum_{i,j=1}^{n} e^{-ar} \alpha_i W_i^{(j)}} = \sum_{i=1}^{n} \tilde{\alpha}_i W_i^{(j)},$$

$$\sum_{j=1}^{n} W_{\text{norm}}^{(j)} = 1,$$

$$\tilde{\alpha}_i = \alpha_i \Big/ \sum_{i,j=1}^{n} \alpha_i W_i^{(j)}.$$

The sets $W_i = \{W_i^{(j)}, j = 1, \ldots, n\}$ are linearly independent, therefore we may treat them as the basis vectors of the linear spaces R^n, and $W_{\text{norm}} = \{W_{\text{norm}}^{(j)}, j = 1, \ldots, n\}$ as a vector in this space. Then $\tilde{\alpha}_i$ may be defined as the projections of the vector on the coordinate axes (Fig. 3). If we know $\tilde{\alpha}_i$, then the proportions of source contributions (secondary diagnostic parameters) can be readily determined as

$$P_i = \frac{\alpha_i}{\sum_{i=1}^{n} \alpha_i} = \frac{\alpha_i \Big/ \sum_{i,j=1}^{n} \alpha_i W_i^{(j)}}{\sum_{i=1}^{n} \left(\alpha_i \Big/ \sum_{i,j=1}^{n} \alpha_i W_i^{(j)} \right)} = \frac{\tilde{\alpha}_i}{\sum_{i=1}^{n} \alpha_i}.$$

The distribution of P_i characterizes the state of the radiant domain. By one of the methods of pattern recognition (polylinear decision rules) the feasible region of P_i is separated by hyperplanes into m subspaces (Fig. 4). The state of the sources varies with time and their P_i vary accordingly. The values of the contributions P_i form some trajectory whose intersection with one of the separating

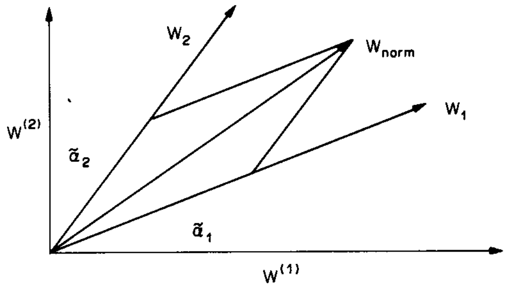

Fig. 3. Definition of α_i in a two-dimensional case.

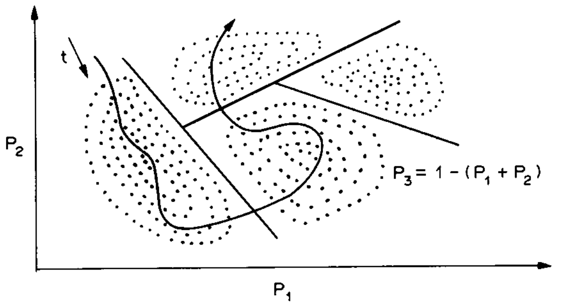

Fig. 4. Dividing the space of secondary diagnostic parameters in three dimensions.

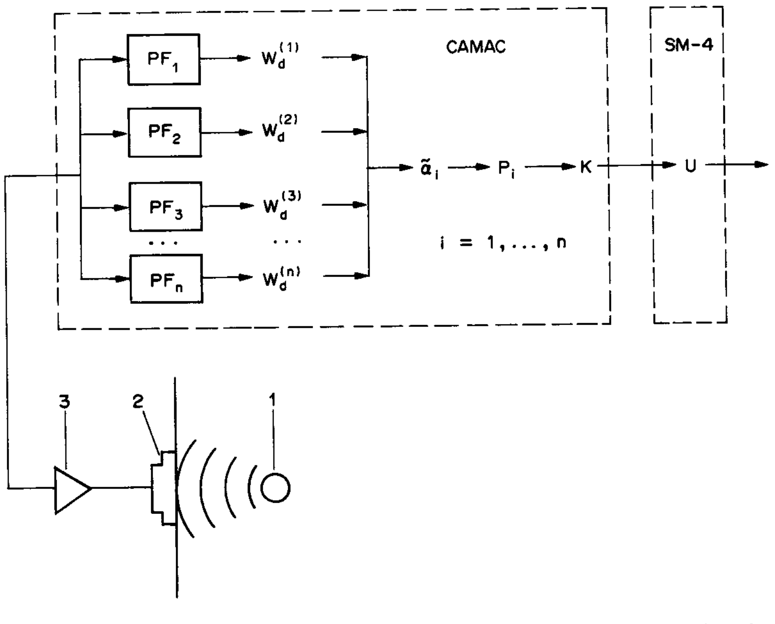

Fig. 5. Schematic diagram of wave process detection and analysis. 1, emitting domain; 2, piezoelectric transducer; 3, preamplifier; PF, passband filters.

hyperplanes implies that the source domain changes its state. At this instant the system generates the controls u_1 and u_2.

The piezoelectric transducer (Fig. 5) converts the detected vibrations into an electrical signal which upon amplification in a preamplifier arrives at the input to the block of passband filters incorporated in the CAMAC unit. The filters single out the narrowband components $W_d^{(j)}$ out of the arriving wideband (up to 1 MHz) signal. These primary features are fed into the CAMAC processor to compute the secondary parameters P_i that are used to determine the number K

$(K = 1, \ldots, m)$ of the state of the emitting domain. This value of K is conveyed to the minicomputer that computes the necessary control actions.

The automated system described in this paper is being used for analysis of elastic waves in solid bodies.

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