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Use of On-Line Computers in Environmental Research

by

Wayne V. Burt

Final Report to Office of Naval Research on Contract N00014-68-A-0148, NR 083-230

Reference 73-18

October 1973

School of Oceanography
Oregon State University
Corvallis, Oregon 97331

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John V. Byrne
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ABSTRACT

A real-time data acquisition/central system has been developed for environmental monitoring and research. The basic elements of the system are a large instrumented spar buoy, a computer which controls data acquisition through a telemetry link and simultaneously files and analyzes the data, and the investigator who prescribes appropriate sets of computer operations. The system has particular advantages for real-time operational decision making and for nonstandard environmental investigations.

INTRODUCTION

The research reported here has been directed toward real-time computer applications to oceanic and atmospheric data gathering, processing and analysis. Four primary elements are included in this research: a) source of measurements, b) real-time transmission to and from a computer facility, c) a computer facility, and d) software that produces readily usable outputs. Fundamentally, these elements constitute a closed-loop measurement/analysis system which includes a man who can make decisions that influence further measurements and analyses.

Sources of measurements are the Totem spar buoys; they are 160 feet long, can support a 2000 lb. load above water and are moored by a four-point system. The paramenters measured include wind speed and direction, air and water temperatures, atmospheric pressure, rainfall, wave height, current speed and direction and solar radiation.

The full-duplex digital transmission system is conventional and uses off-the-shelf components, plus a computer interface. The computer facility includes a DEC PDP-15 computer with added core storage and peripheral equipment. The software library includes programs for statistics, time series analyses and graphical display, as well as software for data acquisition and system control.

BUOY STRUCTURE AND SCIENTIFIC INSTRUMENTATION

The Totem buoy structure is a quasi-cylindrical spar 160 feet long and 6 feet in diameter. The buoy is towed to station horizontally, erected by flooding ballast tanks, and moored by a four point system. Details of Totem structure, mooring and deployment are subjects of separate reports (Dominguez and Nath, 1969; Young and Neshyba, 1970). Adequate room for power supplies, navigational aids and data acquisition and telemetry equipment is provided by a two-story shelter on top of the spar. Freeboard of one-sixth the spar length provides a stable platform for scientific instrumentation. Atop a tower ten feet above the shelter roof and forty feet above sea level are the meteorological instruments which monitor air temperature, barometric pressure, solar radiation, rainfall and wind speed and direction. At the mean water level sea surface temperature and elevation (wave staff) are monitored. Water temperature and current speed and direction are monitored by boom mounted instruments at depths of 7, 15, and 36 meters below mean water level. A Yo-Yo system was installed (but did not become operational) that would allow, by command from the data center, profiles of temperature, conductivity and current speed and direction to be obtained.

DATA ACQUISITION - TELEMETRY SYSTEM

Data acquisition is controlled by a PDP-15/30 computer under the direction of the investigating scientist. The link between the data center and buoy, a distance of some 90 miles, is via a 600 bit per second VHF/UHF radio data link. The available band width of this link limits the data acquisition rate to 40 samples per second using 12 bit data words. The computer will sample any desired parameter at a rate specified by the investigator and store the data in the computer system or graphically display it if the scientist desires to examine it. The PDP-15/30 computer, a foreground-background machine, can also simultaneously process the raw data through mathematical or statistical routines into a form desired by the scientist. The results of analysis can thus be presented to the scientist in any format desired in seconds after the observations are made. This real time control/analysis/display enables the scientist to adjust his sampling rate to meet existing conditions; it thereby removes the constraint of having to guess the needed sampling rate and then having to wait until the experiment is terminated to learn if the experimental design was appropriate. Also, as the status of the data collection system is known in real time, malfunctions can be rapidly corrected so as to minimize data loss.

The data acquisition system has 64 analog data channels which are digitized at the buoy, 32 digital input channels, 32 command channels and 3 continuous analog channels. These data acquisition subsystems are described below.

The analog data subsystem has 64 analog inputs which are multiplexed to a 12 bit 0 to 10 volt analog-to-digital converter. Each input to the system is conditioned in a separate integrated circuit board located internally in the system, conditioning the input signal into the format needed by the analog-to-digital converter. Changing the function of any one of the 64 channels thus simply involves replacing a circuit board.

The digital input subsystem has 32 digital inputs which accept words 12 bits in length. Eight of the 32 channels are permanently assigned to the Yo-Yo which is a winch-lowered sensor probe.

The command subsystem acts as the control center for the buoy system. It decodes 32 computer commands into properly sequenced control signals to control the buoy sub units. Among the devices controlled are the Yo-Yo winch, motor-generator, system power, and the buoy transmitter.

The three analog channels are for continuous transmission of data and have a cutoff of approximately 2 Hz. These channels were included in the system to obtain long data records without bogging down the remaining system, thus enabling simultaneous experiments. These channels can operate simultaneously with the higher speed data acquisition system.

The system's design is modular, permitting investigators to attach an instrument to the system by inserting a printed circuit board. It should be noted that all components of the system can operate simultaneously and an optional voice link exists for system maintenance and check out.

COMPUTER FACILITY

The computer facility serves two functions; data acquisition and system control, and data reduction and anlysis.

Data gathering and system control require less than 0.1% of the computer's time. To alleviate this waste of computer power the machine is so programmed that it can run a data reduction or an analysis program simultaneously with the data acquisition system. The computer "jumps" in and out of the data acquisition program portion upon receiving an external interrupt once every second. Because of data acquisition program takes so little of the computer's time, the scientist who is running a data reduction or analysis program never realizes that the buoy data acquisition system is running simultaneously. The computer automatically interrogates the buoy system at standard intervals (ten minutes) and approximately one-half month of this routine data can be stored on a single DEC tape. The scientist can initiate a sequence of special buoy functions or observations by typing in an initial time for the initial function or observation and the desired time interval between functions or observations. For example, the scientist can follow wave development during a storm by automatically taking wave staff measurements every three hours at one-tenth second intervals for ten minutes. He would obtain wave statistics and spectral plots within minutes after collecting each data set. To delete a buoy function or observation the initial time is set to 400 days, thus effectively deleting it as the system runs on the standard 365-6 day year. Thus the scientist has absolute control of the buoy via the computer.

Available output devices to the scientist for displaying the data include teletypes, a high speed paper tape punch, 4 DEC tape drives, a line printer, and a Tektronix 4002 graphic display terminal.

SOFTWARE

Software functions include: computer peripheral hardware control, buoy control, system checks, data acquisition-filing and data analysis. Standard data analysis programs for statistics, spectral analyses and graphical displays were developed. The basic spectral analyses routines detrend and filter time series and compute Fourier transforms, correlation functions and complex demodulates, as well as compute auto, cross and multivariate spectral density estimates (Ochs, et al, 1970 & 1971). These spectral routines are in modular form and have simplified the process of developing specialized routines for computation of ratary spectra, time-variable spectra, air-sea transfer functions, spectra of gappy series and stochastic predictions.

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