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Abstract

The VAXONLINE software system, started in late 1984, is now in use at 12 experiments at Fermilab, with at least one VAX or MicroVax. Data acquisition features now provide for the collection and combination of data from one or more sources, via a list-driven Event Builder program. Supported sources include CAMAC, FASTBUS, Front-end PDP-11's, Disk, Tape, DECnet and other processors running VAXONLINE. This paper describes the functionality provided by the VAXONLINE system, gives performance figures and discusses the ongoing program of enhancements.

Background

Since late 1984 the Data Acquisition Software Group at Fermilab has been developing a modular, general purpose data acquisition and analysis system to run on VAX and MicroVAX computers. This VAXONLINE[22] system has been adopted by 12 Fermilab experiments, many of which have been preparing and testing their data acquisition systems for some time, and all of which plan to take 'real' data later this year. One experiment, E735, has used the VAXONLINE online system to record and analyze all its data during its six month run. E735 uses 2 PDP-11s as front-end sub-systems, one which reads data from CAMAC and one which reads data from FASTBUS. The partial events are sent to a VAX-11/750 where the two parts are concatenated together and logged to a single data tape. Several other experiments used the software during their 1985 running period.

What VAXONLINE Provides - Goals

VAXONLINE provides a modular and flexible distributed data acquisition and monitoring system. VAXONLINE configurations at Fermilab range from a single VAX or Microvax to a linked set of 4 PDP-11s, 2 Microvaxes and a VAX 11/780. Data from CAMAC or Fastbus may be acquired either directly into a VAX or MicroVAX or via some other data acquisition sub-system.

VAXONLINE consists of many independent programs and several general software tools provided as subroutine libraries. The programs provided as part of VAXONLINE handle each of the following basic functions of an online system.

- o Acquisition of data (EVENT_BUILDER)
- o Management of a common pool of data (DAQ, BUFFER_MANAGER)
- o Control and coordination of data taking (RUN_CONTROL)
- o Logging of data (OUTPUT)
- o Analysis of data (CONSUMER, VMSMULTI)
- o Display of histograms (DISPLAY)
- o Central reporting of information (COURIER)

Although these programs may be used unchanged by an experiment, they may be augmented by additional user-supplied programs, with the exception of management of the common pool of data (which is central to the system[1]). Extensive software tools and documentation[22] are provided to make construction of user programs both easy and compatible with the rest of the system.

Subroutine Libraries are provided to:

- Enter or access data in the common event pool (DAQ)[1]
- Code a command/menu interface for a program. (MENCOM)[2,3]
- Report errors or other information to the terminal or to a central place (COURIER)[4]
- Enter or access status information in a common dynamic database (Status Manager)[5]
- Access CAMAC or perform data acquisition from CAMAC (CAMAC_VMS.Event Handler)[6]
- Access FASTBUS or perform data acquisition from FASTBUS (FB1821)[7]
- Communicate across a DR11-W link to a VAX, MicroVAX or PDP-11 (CDPACK)[8,33,34]
- Communicate across an RS-232 line to a PDP-11 running RT-11 (RS232)[9]
- Control a PDP-11 running the Fermilab RSX or RT-MULTI Data Acquisition system (RUN_CONTROL)[10]
- Histogram and manipulate data (CERN packages HBOOK, HPLOT, KERNLIB, ZEBRA, ZCEDEX)[11,12,13,14]
- Read back data tapes and disk files written by VAXONLINE (FSLIB.VSLIB)[21]

The final programs which make up the online system of a specific experiment are pulled together into a coherent whole by the use of a uniform user interface (MENCOM) and a program which registers and provides controlled access to programs in the system (Global Menu).[2,16,17]

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The first phase of VAXONLINE concentrated on providing the basic building blocks and subroutine libraries with which to build an online system.

Since then much work has been done to provide a general purpose data acquisition program within the VAXONLINE framework which satisfies the data acquisition needs of the vast majority of experiments (the EVENT_BUILDER). This accomodates hardware configurations from the very simplest to our most complicated consisting of multiple front-end PDP-11's and Fastbus systems, each acquiring partial event data to be concatenated together to form a single event.

Data Acquisition Features

VAXONLINE makes use of an event pool scheme, developed by and for the CDF experiment.[1,18] This scheme provides for any number of programs to act as "producers" of data to be entered into the common data pool. The data can be examined by any number of "consumer" programs, each of which can select the amount and type of data to be examined based on an extensive set of matching and veto criteria.

The Event Builder Program

Event Builder[19] acquires data from one or many different sources and then, acting as an event 'producer', enters that data into the common event pool. Event Builder currently supports high speed acquisition of data from CAMAC (Jorway 411), Fastbus (Lecroy 1821), Disk, Magnetic Tape, DECnet link, data sent over a DR11-W link from another data-collecting computer (either PDP-11 or another VAX/VAXONLINE system), and data sent via Ethernet.[20] Other software packages such as the VMS CAMAC Event Handler[6] or the Fastbus Lecroy 1821 VMS driver[7] may be invoked by Event Builder to actually perform the acquisition of data into a single buffer. 'Foreign' data sources can also be easily supported in Event Builder, with additional coding.

The Event Builder program is able to combine data from several different sources and of several different types. The combination rules are user specifiable. Event Builder interprets certain standard formats of input data and provides a default mapping from the 'type' of the input data to a data type used by the VAXONLINE data pool management software. If the default 'type' mapping is not appropriate then a user mapping routine may be provided for that type of data, in the form of a separate image. This image is dynamically linked into Event Builder at run time without any relinking of the Event Builder program itself. The data sources, data types, relevant parameters such as buffer and event sizes, file names etc., and the rules for building events are specified in a list-like control language.

List Language for Event Builder:

The Event Builder program is controlled via user-written control language programs. The control language program consists of two distinct parts.

a) A declaration part where the nature of all the sources from which data may be acquired is described. The manner in which that data is to be acquired is specified and other parameters relevant to the acquisition are provided as well as classification of the format of the data itself.

b) One or more collection lists which specify how 'events' are to be formed from the data acquired and how the events are to be classified in the common data pool. The criteria of how event fragments are to be examined and matched to a particular collection list are defined. The collection lists allow headers to be inserted into the event at both the overall event level and the sub-event level.

Since several different collection lists are permitted, many different types of data from one or many sources can be constructed, provided the incoming data has itself been tagged sufficiently clearly to ensure that it satisfies only one collection list criterion.

Figure 1 shows a simple Event Builder control program for collecting data from a single CAMAC source.

```
.IDENT  \X01-000\

Event Builder program of VAXONLINE software.


DEFINE_SOURCE   CAMAC

  DEVICE        CJA0:             ; CAMAC device
  DEVICE_TYPE CAMAC,<LAMID=9,LIST=READDATA.EVL,INTERVAL=1>
  DEVICE_MODE   <NOWAIT>          ; Do not wait for each event
  BUFFER_FORMAT BLOCK
  MAPPING_FORMAT VAXJY411         ; Default CAMAC data format
  HEADER        TYPE=TYPE_A       ; Include a 'standard' VAXONLINE
                                  ; header
  BUFFER_SIZE   4000
  BUFFER_COUNT  2                 ; Use 2 buffers for this source

END_SOURCE


Define how the events are to be selected


COLLECT

   EVENT_TYPE   EQUAL,  0         ; Event Type 0 and 1 match this
   EVENT_TYPE   EQUAL,  1         ; list

   TRIGGER_MASK OR,     <^XFFFF> ; Select any trigger mask with
                                  ; one of low 16 bits set

   HEADER       TYPE=   TYPE_A_SINGLE

   SOURCE       <CAMAC>           ; Get events from CAMAC

END_COLLECT


last statement: Do not omit or else!

END_EBL
```

Figure 1

Several experiments use multiple collection lists in their Event Builder control program. This permits events to be formed, for example, either from data arriving on any one of the three links from front-end PDP-11s (to be treated as 'singletons') or from the merging of data from all three links and a Fastbus sub-system (requiring concatenation of all the experiment's sub-events). Although most of the data falls into the latter category, there are sub-system-specific events or pieces of data which also need to be inserted into the data stream.

Other Data Producers:

Any number of user-written event "producers" may co-exist with Event Builder if an experiment needs to gather data from some unsupported source or in some special format.

Multiple Data Streams:

Multiple data streams entered into the common event pool may either be combined together and logged to tape and consumed as a single stream of data, or treated totally separately. Multiple copies of both the Event Builder and the Output (tape logger) program may be run on a single machine, if desired.

Multiple Machine Environment

Although VAXONLINE can provide a full data acquisition and monitoring system on a single VAX or MicroVAX, it is most often used at Fermilab as part of a multiple machine online system.

VAXONLINE provides control functions for stopping and starting runs across either DR11-W links, RS-232 lines or DECnet. The RUN_CONTROL program which provides this is designed to be user modifiable.

All the VAXONLINE software has been designed to provide for communication and coherence across all the DECnet nodes in the online system. A message system allows any VAX program to send messages to the COURIER program for centralised display and logging to a disk file.[4] A common Status Manager[5] database allows any VAX program to either record or inquire the status of any other participating program in the system: a necessary feature for ensuring the orderly execution of programs (at data taking startup for example).

The tape logging program OUTPUT[21] can record data either on tape or in a disk locally or across DECnet, or directly to a DECnet task to task link. It can record in one of several standard formats or if necessary be easily adapted to a user-specific format.

The MENCOM user-interface package, reported in a companion paper at this conference, provides DECnet message passing facilities, permitting one program to control another by sending the appropriate commands to it (just as if an operator had issued the commands).

Data can be passed from the data pool on one machine to that on another using either DECnet logging to the Event Builder program, or a special purpose Buffer Manager program which selectively sends data via a DR11-W link.

Analysis and Display of Data

Experiments generally wish to provide their own programs to analyze their data. VAXONLINE includes an example skeleton analysis program which may be tailored to a particular application with little effort. Histograms filled by the analysis programs are stored either in memory or on disk. While data analysis continues the histograms can be manipulated and examined on any terminal via an interactive DISPLAY program.[23] This system uses the CERN HBOOK/HPLOT and HTV packages and provides graphics output via the Precision Visuals DI3000 system.[24] In addition, a self contained analysis and display package is provided in VMSMULTI.[25] This is a modified version of the Fermilab MULTI analysis system, which many people have used in the past on PDP-11 machines[26,27]

Examples of Use of VAXONLINE and Performance

From the 12 experiments that currently use VAXONLINE, we present three representative examples. Experiment E665 is an example of a large configuration using VAXONLINE. It is shown in Figure 2. We have measured a total throughput for this system of 370 Kbytes per second for logging of data to tape. This is close to the limit imposed by the magnetic tape writing. Figure 3 illustrates the VAX system software components involved in the data acquisition, logging and data distribution process of the configuration shown in Figure 2.

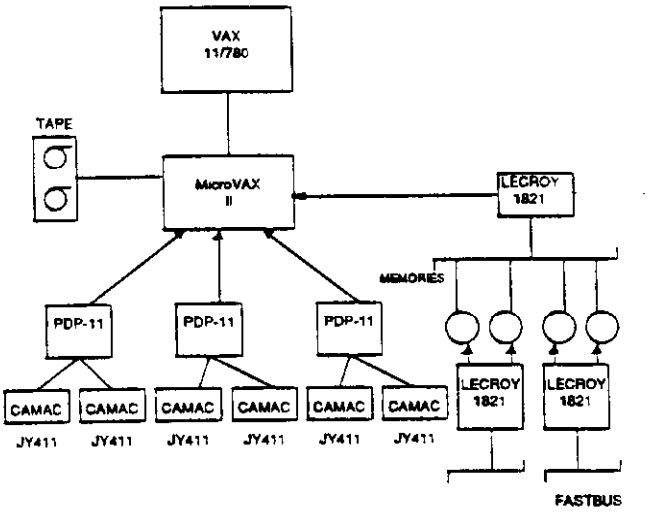

Figure 2: Data Acquisition Configuration of E-665

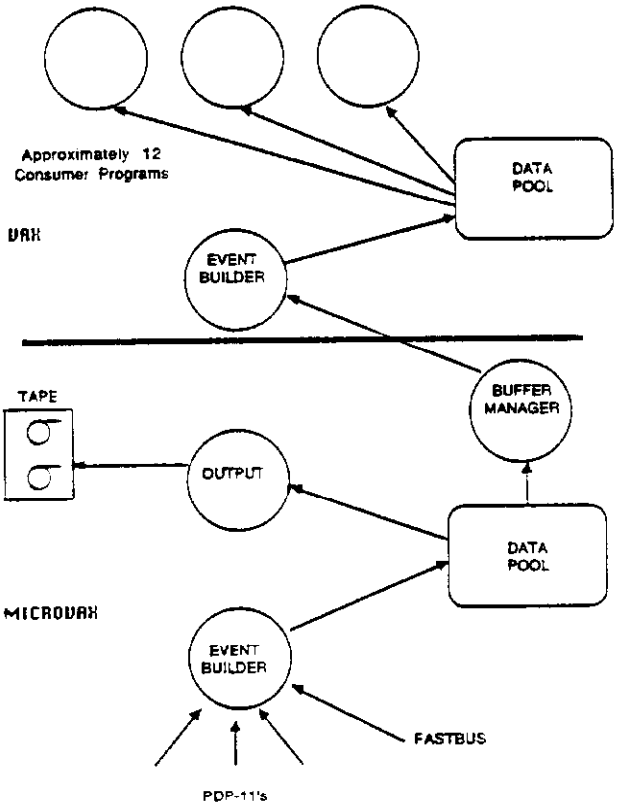

Figure 3: VAX Software Components for Data Acquisition shown in Fig. 2

Experiment E687 uses VAXONLINE on two VMS machines with two event streams filling independent data buffer pools. One performs the experiment control and the analysis of data collected and recorded by a PDP-11 running the Fermilab RT-MULTI system. The other performs data acquisition from CAMAC in between the beam "spills" to provide data to calibration and monitoring programs. Experiment E731 collects and records data on tape from a Fastbus system using the Fermilab RSX-DA data acquisition system.[28] RSX-DA can also send the event data to a MicroVAX for analysis. Since the MicroVAX does not have time to analyze all the events, only some fraction of the data is transmitted, although in principle all of it could be sent.

Ongoing Enhancements - Futures

Upgrades:

The Global Menu program is in the process of being upgraded to fully support access to all programs in the system across DECNET. The menu and command package MENCOM will be extended to support many different types of menu display. The COURIER systems is undergoing major enhancements to dynamically control the routing and display of messages. Distribution of data from one data pool to another will be made more closely in tune with the declared requirements of the CONSUMER programs. The DISPLAY program will be upgraded to use the latest interactive histogram display package from CERN.

Filtering:

The final bottleneck in all the systems currently using VAXONLINE is the magnetic tape recording. Current work with VAXONLINE is in the direction of incorporating further levels of data acquisition subsystems (to provide buffering and/or filtering of the data), leaving the VAX or Microvax as the final destination of the data. Projects include incorporating microprocessors into the Event Building process, in particular to transfer event data directly from Fastbus into 'Farms' of processor boards produced by the Fermilab Advanced Computer Program[29] and to provide a programmable hardware Event Builder module.

Extra Analysis:

The use of VME based 68020 microprocessors to provide additional processing power for analysis programs and their incorporation into VAXONLINE in a transparent way is also being addressed.

Conclusions

The VAXONLINE system has been more widely used and accepted than we ever imagined when we started the project in 1984. Many experiments have chosen to accept the tradeoffs involved in using a standard general purpose software system, with its accompanying documentation and support, as opposed to a private system tailored tightly to their specific needs. Many individuals have been able to do the necessary custom additions and modifications with relative ease.

VAXONLINE has proven to be a useful general purpose data acquisition and analysis system. It can be used by the non-expert with very little work, and also by the knowledgeable who can extend the system as far as their time and expertise will allow.

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