Astronomical Data Analysis Software and Systems IV
ASP Conference Series, Vol. 77, 1995
R. A. Shaw, H. E. Payne, and J. J. E. Hayes, eds.

The Array Limited Infrared Control Environment

P. N. Daly and A. Bridger

Joint Astronomy Centre, 660 N. A'ohōkū Place, Hilo HI 96720

D. A. Pickup and M. J. Paterson

Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, Scotland

Abstract. This paper describes the recently commissioned Array Limited Infrared Control Environment (ALICE), used to control a new 256^2 array imager, IRCAM3, on UKIRT. Future plans, including the delivery of a second ALICE to upgrade the UKIRT long-slit spectrometer, CGS4, are also discussed.

1. Introduction

Infrared astronomy was revolutionized in the 1980s by the advent of array detectors. One of the first such imaging cameras in regular operation was IRCAM (McLean et al. 1986), followed by the array spectrometer CGS4 (Mountain et al. 1990), both of which were commissioned onto the 3.8 m United Kingdom Infrared Telescope (UKIRT) on Mauna Kea, Hawaii. The control electronics of both these systems, however, were geared to driving the smaller SBRC 62×58 InSb array. What was needed was a flexible *and* extensible system capable of driving the new generation of arrays to the limits of their performance, hence the term *Array Limited Infrared Control Environment* (ALICE).

Built at the Royal Observatory in Edinburgh (ROE), ALICE forms the backbone of the program to upgrade both IRCAM and CGS4 to SBRC 256^2 InSb arrays. The ALICE design allows it to operate under a wide range of conditions such as high resolution low background near infrared spectroscopy, real-time shift-and-add image sharpening, and broad-band thermal imaging. To date, the first ALICE has been commissioned on the telescope and the new instrument, IRCAM3, saw first light on 1994 April 8 UT.

2. The Array Control System

The array control system (Pickup et al. 1993) applies well defined, and well controlled, bias and clock voltages to the array, and is also responsible for clocking the appropriate waveform to trigger read, reset, or read-reset operations. It also obtains time stamps from the UKIRT satellite clock and is able to control the secondary mirror in synchronization with the observations. All of these operations may be manipulated under software control from the user interface, thus giving the system considerable flexibility.

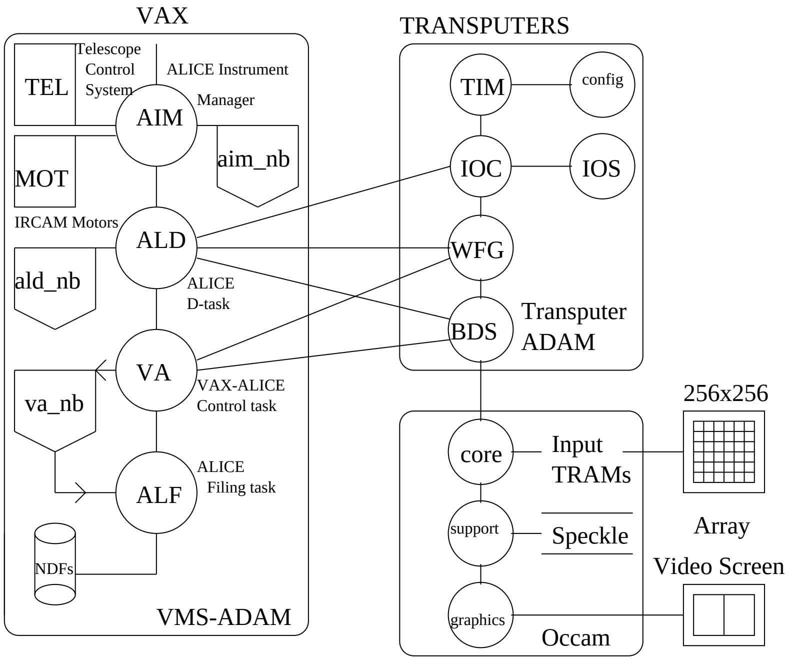

Figure 1. The ALICE Software Map.

The array control system software operates under the transputer ADAM environment (Kelly et al. 1993), and was originally written in parallel FORTRAN, although this will be replaced by a C version when the second ALICE is commissioned. The tasks comprise the time stamping process (TIM), the I/O controllers (IOC and IOS), and the waveform generator (WFG), as shown in Figure 1. The WFG is initialized with full frame read, reset, and read-reset waveforms—other waveforms, for sub-array reads and so forth, are downloaded as required.

The waveform generator hardware includes an Inmos T805-25 transputer with 16 MB of DRAM. The waveform memory has 16 banks of 256k $\times$ 32-bit field memory. Each of the 32 bits of the waveform handles one clock signal (three of which are reserved for system use). Moreover, any of the 16 banks can hold a single waveform sufficient to drive a full 256^2 array. Banks can also be read out seamlessly so that, if necessary, a waveform can be loaded across several banks. In this fashion, larger arrays should easily be accommodated as they become available.

3. The Bulk Data System

The bulk data system (BDS) supports the bi-directional transfer of data between ALICE and the host system at $\sim$50 kB s^{-1}. Thus a full 256^2 4-bytes pixel^{-1} frame takes $\sim$5 s to transfer. Four MB of on-board RAM are used to buffer the data to allow asynchronous acquisition of new data.

The bi-directional nature of the data transfer allows data to be passed up to the host computer and, for example, bad pixel masks, color tables, or background frames to be passed down to the transputer sub-system when required by the video display system. The BDS also handles the downloading of waveforms to the WFG when required to trigger different reads of the array and the transputer ADAM messaging traffic. Messages between the host computer (a VAX in the present application), are routed through a B300 TCP-linkbox (ethernet gateway).

4. The Data Acquisition System

The data acquisition system controls the analog conditioning of signals from the array, conversion to digital inputs for the INMOS link adaptors via ADCs (14-bit, 2 mega-samples s^{-1}), and for the collection and re-assembly of the full 256^2 image via a transputer network. Several frames may be coadded to form an integration before transmission to a host computer or local disk. There is also a video display system that updates at $\sim$2 Hz, that can show either the current integration or both the current integration and the coadded image side by side, along with some simple image analysis (peak pixel in x, y, brightness, etc.).

ALICE makes extensive use of transputers ($>$ 24), mainly T805s with 2 MB of memory each. The 16 input processors are hardwired as a pipeline on the motherboard so each processor, during normal operation, sees every 16th pixel from the array. The "core" process running on a single transputer acquires the data from the pipeline and re-assembles the data into full frames. A speckle option has recently been introduced using fiber-optic TRAMs that can "spurt" the data to a local (SCSI) disk directly for (very) fast acquisition. The transputer data acquisition sub-system is programmed in Occam and the bootable may be downloaded from either a Sun or a VAX.

5. Performance

Laboratory tests have shown that ALICE is capable of sustaining data rates for $256^2 \times 4$ bytes pixel^{-1} frames of $\sim$115 Hz for destructive reads and $\sim$85 Hz for non-destructive reads (Chapman et al. 1990). Real-time, post-detection image sharpening via a shift-and-add algorithm keyed on the brightest pixel in a sub-area, can be driven on the full array at $\sim$35 Hz. Unfortunately, the IRCAM3 array cannot be driven at these rates (Puxley et al. 1994). Table 1 summarizes the available ALICE/IRCAM3 observing modes. The ALICE/IRCAM3 observing regimes include STARE, ND_STARE, CHOP, ND_CHOP, and Shift-and-Add, presented to the observer via Starlink's SMS user interface.

6. Future Plans

The immediate plan is to install and commission the second ALICE as part of the CGS4 upgrade beginning in 1994 November. The major parts of this program are modifications to the CGS4 instrument (hardware) to handle the smaller pixel size in the larger array (30 μm as opposed to 76 μm), the introduction of

Table 1. IRCAM3/ALICE Observing Modes

Observing Mode	80% Well Depth	Readout Area	Exp$_{min}$[a] (ms)	M$_{sat}$[b] J	K	L
Standard	80,000 e^-	256^2	120	8.6	7.8	7.4
(JHK)	(13,500 DN)	128^2	35	7.3	6.5	6.2
		64^2	12.5	6.2	5.4	5.0
Fast	80,000 e^-	256^2	72	8.1	7.3	6.9
(Shift and Add)	(13,500 DN)	128^2	20	6.7	5.9	5.5
		64^2	6.5	5.5	4.6	4.3
Deep Well	144,000 e^-	256^2	72	7.4	6.6	6.3
(nbL, L', nbM)	(24,000 DN)	128^2	20	6.1	5.2	4.9
		64^2	6.5	4.8	4.0	3.7

[a]Minimum exposure time in this mode.
[b]Saturation magnitude for Exp$_{min}$ ($0.''3$ pixel^{-1})

algorithms into the automated data reduction system to compensate for curved slits and so forth, and the upgrade of the ALICE software to C. Another ALICE has been built for use with IRCAM2 on the 4.2 m William Herschel Telescope on La Palma in the Canary Islands. A second-generation ALICE is being built at the ROE to drive the mid-infrared imager/spectrometer (Michelle). Given the modularity of the ALICE design, new components such as faster ADCs or T9000 TRAMs should easily be accommodated, improving performance by a factor of $\sim$10 each.

References

McLean, I. S., Chuter, T. C., McCaughrean, M. J., & Rayner, J. T. 1986, in Instrumentation in Astronomy VI, Proc. SPIE, Vol. 627, ed. D. L. Crawford (Bellingham, SPIE), p. 430

Mountain, C. M., Robertson, D. J., Lee, T. J., & Wade, R. 1990, in Instrumentation in Astronomy VII, Proc. SPIE, Vol. 1235, ed. D. L. Crawford (Bellingham, SPIE), p. 25

Pickup, D. A., Sylvester, J., Paterson, M. J., Puxley, P. J., Beard, S. M., & Laird, D. C. 1993, in Infrared Detectors and Instrumentation, Proc. SPIE, Vol. 1946, ed. A. M. Fowler (Bellingham, SPIE), p. 558

Kelly, B. D., McNally, B. V., & Stewart, J. M. 1993, in Astronomical Data Analysis Software and Systems II, ASP Conf. Ser., Vol. 52, eds. R. J. Hanisch, R. J. V. Brissenden, & J. Barnes (San Francisco, ASP), p. 305

Chapman, A. R., Beard, S. M., Mountain, C. M., Pettie, D. G., Pickup, D. A., & Wade, R. 1990, in Instrumentation in Astronomy VII, Proc. SPIE, Vol. 1235, ed. D. L. Crawford (Bellingham, SPIE), p. 25

Puxley, P. J., Sylvester, J., Pickup, D. A., Paterson, M. J., Laird, D. C., & Atad, E. 1994, in Instrumentation in Astronomy VIII, Proc. SPIE, Vol. 2198, ed. D. L. Crawford (Bellingham, SPIE), p. 350