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The Software for the LRIS on the Keck 10-Meter Telescope

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Abstract. We discuss the software for the Low Resolution and Imaging Spectrograph, one of the first light instruments built for the Keck 10–meter telescope. Details of the CCD detector readout scheme, the motor control system, the user interface, the astrometric preparatory software, etc., are given.

1. Introduction

The Low Resolution and Imaging Spectrograph (LRIS) for the Keck telescope is an effort under the direction of Bev Oke, principal investigator, (now retired from the California Institute of Technology), Judy Cohen, deputy principal investigator, and a team of engineers and technicians at Caltech. The software, computer interfacing, etc., was the responsibility of J.Cohen. The spectrograph provides direct imaging and multi-slit and long slit low and moderate resolution spectroscopy over a field of view 6 x 8 arc-minutes in size at the Cassegrain focus of the ten–meter Keck telescope.

2. Functions of the LRIS Software (as Specified in 1988)

To read out the detector using multiple amplifiers possibly on multiple CCDs (i.e., to allow for the possibility of a mosaic of CCDs) as rapidly as possible (The formal requirement is to read out and store in the disks of the main instrument computer a 2048 x 2048 image in less than 2 minutes.); to control the remotely operated mechanical mechanisms in a safe yet efficient manner; to support quick look analysis, and to provide the astrometric capabilities needed to make multi-slit masks under various circumstances (i.e., via externally generated coordinate lists or generating a coordinate list from a LRIS image).

All this is to be done through code which is easy to use, with a simple yet powerful user interface, easy to maintain, easy to modify and upgrade (i.e., adding a new motorized stage), and well documented.

The detector used in LRIS is a 2048 x 2048 pixel thinned Tektronix CCD. The only other optical instrument planned for first light at the Keck telescope is HIRES (a high resolution echelle spectrograph located at one of the Nasmyth foci), built under the direction of Steve Vogt of Lick Observatory, with Bob Kibrick assuming responsibility for the software, computer interfacing, and related matters. HIRES uses the same CCD and the same CCD electronics as does

LRIS. It was therefore deemed highly desirable to maintain common software and computer hardware, maintain identical user interfaces (in style, although not in the details of names of motor stages or optical components), and given the large amount of work to be done and very limited available funds, to share the software development between the two institutions.

3. The Two LRIS VME Crates

As standards for the first light Keck instruments, Unix was chosen as the operating system, and Sun machines were chosen as the hardware platform. Because of concern at the use of Unix as a real time system, time critical functions were divorced from the main Sun instrument computer. LRIS thus has two separate VME crates, the CCD detector crate and the LRIS motor control crate, each attached to the Sun workstation by a private ethernet. (The Sun workstation has two ethernet boards. One is used to talk to other workstations on the Keck network. The second is reserved for instrument/detector control.) The Sun 1E CPUs on the VME crates are running VxWorks, a real time operating system developed by Wind River Systems. In addition, the CCD crate contains a CCD controller (CCD computer interface card, designed by Fred Harris of Caltech and Terry Ricketts of UCSC), 32 Mbytes of Chrislin memory, and an Ikon 10089 DMA controller. The motor control crate contains a serial ports card as well.

The desire to have minimum cables going though the cable wrap to the Cassegrain focus, and to minimize heat input into the dome, meant that both of these crates are located in the Keck computer room, while the Sun workstation is located in the control room. There are 2 fiber optic cables which communicate between the CCD computer interface card and the CCD saddle bag electronics. That chassis contains cards designed by Bob Leach of San Diego State University, namely a timing board, a utility board, and an analog board for each amplifier in use. Some of these boards use a Motorola DSP 560001 chip. The fiber optic cable that transmits the data down to the VME crate is running at 40 Mbaud. The second fiber cable which receives instructions from the CCD crate runs at 4 Mbaud.

For the motor control VME crate, there are too many motors to assign each to its own serial cable running through the cable wrap. Instead the signals are multiplexed onto a single serial cable, demultiplexed at the instrument, and distributed to the various motors. Additionally the 22 motors are multiplexed to 4 motor controllers

The partition of work with Lick left Caltech with the responsibility for the code to read out the CCD into the workstation's memory, for the LRIS motor control software, for the responsibility of developing a fast X windows display server, and for the necessary astrometry codes specific to LRIS.

The CCD readout process, designed and coded by S. Southard, Jr., is rather complicated due to the two-stage transfer (CCD computer interface card to the VME crate via DMA, VME crate to the Sun workstation via Ethernet) required by the hardware design. Our analog to digital amplifiers can operate at 10 micro-sec/pixel, or 200 Kbytes/sec. We are actually running at 22 micro-sec/pixel, with 2 amplifiers interleaved, for a total data rate of 182 Kbytes/sec.

It is the number of working amplifiers on the CCD and the pixel transfer time which are limiting our readout rate. However, when the data transfer software was designed, the system design called for up to 16 interleaved amplifiers, for a maximum total data rate of 3.2 MBytes/sec, well exceeding the ethernet capacity. For this reason, the UDP protocol, which is faster but does not guarantee packet delivery, was chosen. Packets which are lost in ethernet transmission are re-sent at the end of the image.

Windowing and binning of CCD frames are also supported.

We are routinely reading out and storing to disk in the Sun instrument computer 2048 x 2048 16 bit deep (no sign bit, 16 bits of data) images with 2 amplifiers interleaved in under 90 seconds. We are routinely manipulating such images with our quick look software, as well as with standard large astronomical packages (IRAF and FIGARO).

4. LRIS Mechanisms

The LRIS motor control VME crate, whose software was designed and written by J.Cromer, runs the motorized mechanisms listed below (plus their associated brakes, absolute or incremental encoders, etc.). We are using API (American Precision Instruments) controllers, Compumotor AC stepping motors, Canon rotary incremental encoders, and Compumotor rotary absolute encoders.

Table 1. LRIS Mechanisms.

Mechanism	No. of motors	Type of Position Feedback
red filter juke	2	switch-encoder, limit switches
slitmask juke	2	switch-encoder, limit switches
red camera focus	1	absolute rotary encoder
offset guider	2	absolute rotary encoders
guider filter wheels	2	none
grating turret	1	switch-encoder
grating turret detent	1	limit switches
grating cells	10	incremental rotary encoders and limit switches
trapdoor	1	limit switches

Mechanisms were divided into groups depending on how many positions they had and how they were encoded. By identifying these common operating modes only 4 software functions were required to handle the moves of all stages.

5. User Interface

The user interface has two alternate modes. The first is a standard command line. The second brings up a number of Motif X window displays which offer buttons for choosing or changing selected actions. At the present time only the most frequently used keywords are implemented in the two LRIS X window displays, written by Al Conrad of the Keck Observatory staff based on an initial design by J. Cohen and J.B.Oke.

The current list of implemented keywords for the LRIS has about 55 items (nouns). The command line (and internal software) allows only simple manipulations of keywords, along the lines of "show redfilt" (this results in a status display for the red filter changer), "modify redfilt = visual" (changes the red filter changer so that the visual filter is in the optical path), and "configure slitmask 16hr_field = 1 Abell_104 = 2" (associates names with positions of the mechanism). The number of verbs ("show" etc.) supported is under 5, making the command line interface very easy to learn to use.

The system for internally processing these keywords, passing the appropriate messages around, etc., was written by the HIRES group based in part on a previously existing package in use at the time at Lick Observatory. They also wrote the software for passing messages to/from the telescope drive and control system.

S. Southard, Jr, wrote an X windows display server currently used by the PGPLOT and Figaro pacakges. The same software is used to provide real-time image display of the data being transferred from the CCD. This software's functionality is described in this year's software report for Figaro in the Bulletin of the AAS.

The astrometric software to assign objects to multi-slits was written by Caltech undergraduate student D. Clowe with help from J.Mould based on software written for the Norris spectrograph by J.Cromer. J.Cohen has modified large parts of this code and written the other necessary pieces. This pre-observing planning software is the only part of the code written in Fortran; all the CCD, instrument, and motor control software is in C.

6. Current Status

The current status is that the preliminary design review for this system was held (together with the identical HIRES review) on Jan. 29, 1990. The instrument is now complete. It was shipped to Hawaii in May 1993. There have been 3 instrument commissioning runs at the Keck telescope on Mauna Kea. The overall impression of the software (and not just by us) is that we have met our goals. It is robust, easy to use, and powerful enough to perform the necessary functions. We look forward to routine observing by people not associated with the LRIS project as the final test of our success. We expect routine observing to start early in 1994.

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