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CCD Charge Shuffling Improvements for ICE

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Abstract. NOAO has been using IRAF at its telescopes since Unix workstations were first placed in the domes. At the Kitt Peak National Observatory, this has included data acquisition using the ICE (*IRAF Control Environment*) package that was developed in coordination with Skip Schaller at Steward Observatory. ICE continues to be used both inside KPNO and Steward and at other observatories.

Improvements to ICE are described that support a dual exposure mode implemented via charge shuffling techniques. Charge shuffling involves repeatedly shifting the charge back-and-forth from side-to-side of a CCD while nodding the telescope alternately from an object to a blank sky position. The CCD is optically masked such that the sky pixels are kept dark while the object pixels are exposed and vice versa. The nodding and shuffling and opening and closing of the camera shutter occurs on a short enough time scale that the sky brightness variations are frozen.

The output of this process is a dual exposure of contemporaneous object and sky spectra accumulated through the exact same optical path. This mode is beneficial, for instance, for multi-slitlet observations such that the width of each slitlet can be minimized to allow many more slits per exposure. New parameters added to ICE include the number of nods and the number of pixels to shift for each exposure. A variety of different nodding patterns are supported, such as a simple ABAB object/sky pattern and a bracketed pattern that begins and ends with a half-length sky subexposure. The on-object and on-sky exposure times may be specified separately.

1. Discussion

The nod-and-shuffle spectroscopic observing mode was first brought to the attention of NOAO personnel by Karl Glazebrook who helped implement this mode on the LDSS++ spectrograph at the Anglo Australian Observatory.

[1]Image Reduction and Analysis Facility, distributed by the National Optical Astronomy Observatories

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The acquisition of charge shuffled images requires the tight coupling of several software systems typically maintained by different personnel at a given observatory. The fundamental method relies on using familiar CCD charge shifting techniques in new ways. At the same time, the telescope is required to nod back-and-forth between object and sky guide stars with as little overhead as possible. The data acquisition package (ICE at KPNO) must synchronize and manage both of these systems.

The microcode for the standard KPNO CCD 2901 controllers has always supported the feature of being able to shift charge both toward and away from the readout amplifier. No changes were necessary to this software (maintained by the CCD laboratory).

The mountain programming group (MPG) was responsible for implementing the new telescope offsetting feature. Several possible designs were discussed between the MPG and IRAF programmers that positioned the functional divide either closer to or farther away from the telescope control or data acquisition sides of the equation. The final choice was to fully implement a high level TCS multi-target offset function.

The IRAF group was responsible for modifications to the ICE CCD data acquisition software. The nodding/charge shuffling exposure mode requires that only the middle third of the chip be unmasked. After each object or sky subexposure is taken, the shutter must be closed, the charge shifted to one side or the other and the telescope nodded to the other offset position. This is repeated through many exposures, back-and-forth.

Given the requirement to repeat this on time scales of a minute or quicker for an hour or more at a time for each exposure, any successful implementation of charge shuffling must parameterize the most useful exposure parameters while hiding the complexity of the multiple offset exposures from the observers and the telescope operator.

The familiar IRAF parameter mechanism has provided this service for several other unique observing modes in the past (e.g., the 4m scan table and the Fabry-Perot). New parameters added to ICE include the number of nods to include in each exposure and the number of pixels to shift for each exposure. It is possible to turn the mode on and off at will and to easily change the parameters with each new exposure.

In addition, since preferred NOAO observing recommendations for charge shuffling are still being evaluated, access was provided to a variety of different nodding patterns. These include a simple ABAB object/sky pattern versus a bracketed pattern that begins and ends with a half-length sky subexposure. The idea of this feature is to ensure that the mid-UT of the sky exposure coincides with the mid-UT of the object exposure. The trade-off is that the sky spans a slightly longer open shutter duration. A second evaluation feature allows the on-object and on-sky exposure times to differ. Whether these options are preserved as user parameters, or are rather implemented as hardwired defaults, will depend on the scientific evaluation of their utility.

The added complexity of the shuffling mode required revamping various abort procedures and other infrastructure and the addition of several new keywords to the image headers. We are still finalizing the additions to the keyword dictionary.

A fully supported implementation of charge shuffling as a KPNO facility class instrument will require further discussions and effort on both observing run preparation (to better generate slit masks, for instance) and on the data reduction facilities for these new image types.

2. Status

One full engineering run has been completed and another is in progress contemporaneously with the ADASS X conference. The current engineering run is also testing a new auto-guider and a new engineering grade CCD. Results are encouraging but several areas of instrument level concern have been identified:

1. During the first engineering run we found that the slit masks were likely to move around during these more demanding exposures.
2. The physical nodding of the telescope takes more time than desired.
3. The heuristics used by the active support system for the primary were never intended for such a purpose. This has the result of adjusting all the actuators with each separate offset.

The corresponding overhead of such effects was quite significant during the first engineering run, amounting to about 900 seconds for a typical one hour (grand total) exposure of 30 60-second on target plus 30 60-second off target exposures. (Or about 15 seconds per offset.) We are trying a variety of strategies to mitigate this overhead. For instance, it is possible to turn off the active support during the offsets while leaving the normal tracking updates functioning.

Of course, these difficulties can also be considered positive factors since the nodding mode will drive improvements for normal operations as well.

References

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