Scientific Perspectives on Gemini Data Reduction

Phil Puxley
24 March 1996
v1.0

Introduction

Conclusions drawn from data handling system (DHS) SDR documentation, personal information from reviewers and others, and from the review committee comments are that some concepts of the data handling system (particularly the "quick look display", "on-line reduction" and "synchronous reduction") are ambiguous, occasionally misnamed and therefore misleading. Furthermore the functions of these sub-systems are not clearly defined from the scientific perspective.

To clarify the scientific requirements, and avoid the aforementioned perjorative terms, the various functions of the DHS are herein separated into four "tool boxes". [It is part of the task of the DHS team and IGPO to identify to what extent these functions fall within the remit of the DHS workpackage and can be accommodated within one or more existing software packages e.g. PVwave/IDL, IRAF, Figaro, skycat]. The four tool boxes are briefly defined thus:

1) **Data display tool** - provides general data display in a variety of formats.
2) **Movie tool** - provides manipulation of data for crude and quick verification of correct data acquisition (may well be a subset of tools in item (3)).
3) **Data reduction tool** - provides manual and recipe reduction to permit quantitative scientific assessment of data.
4) **Observing assistance tool** - provides miscellaneous tools for observing preparation e.g. guide star selection, GMOS mask definition.

The specific functions of these tools and their scientific requirements are outlined below.

Data Display Tool

The data display tool provides generic display of data. Note that the source of the data is not specified, nor is the displayed information necessarily the pixel values themselves - it could be the data error or quality, for example.

This tool displays data generated by the movie tool and by the data reduction tool, at least, and ideally by the observing assistance tool as well.

Optional forms of data display required are:

1. 2D image
1.1. Pixel colours defined by colour table that can be easily manipulated. Special colours reserved for specific circumstances e.g. black for bad pixels, flashing for saturated pixels (pixel values greater than some instrument-specific threshold).
1.2. Overlay of image with polarisation vectors; length proportional to polarisation and showing field parallel or perpendicular angle.

1.3. Display in pixel or world co-ordinates.
1.4. Pan and zoom of the image (e.g. SAO image).
1.5. Overlay of contour map on image plane (not necessarily contours of same data as in image).

2. 1D spectrum
2.1. Spectrum optionally shown with error bars derived from data variance (if present). Data points not plotted if data bad. Display spectrum in choice of colours.
2.2. Overlay of two spectra.

3. Contour map
3.1. Bad data ignored when contouring. Choice of line colour, scaling (linear, logarithmic) and contour intervals. Optional of quick auto-contour with reasonable defaults.

4. Histogram of frequency vs. value (pixel or data error).
4.1. Choice or number of histogram bins.

5. Rumpled 3D grid.
5.1. Choice or arbitrary viewing angle (rotation and tilt).

There are a number of general requirements on the data display tool:

6. Data displayed can be arbitrary rectangular subset of the full data frame e.g. a subset of the image, or a section of the spectrum.
7. Maximum pixel value, minimum, σ and median to be reported for displayed data (bad data ignored).
8. Data display should optionally autoscale between min-max, zero-max, $\pm n\sigma$ or a selectable range.
9. Colour table should not wrap outside of the selected display range.
10. Selection of object in image and communication of location of selected data to other sub-systems (e.g. for spectrograph target acquisition). Option of "snap-to-centroid"; useful for selection of GMOS targets etc.
11. Overlay of catalogued objects (world coordinates) e.g. for guide star selection (cf "skycat").
12. Output of any display in standard formats e.g. postscript file (option to auto-submit to print queue), gif, jpeg.
13. Data display configuration saveable/recoverable from named configuration file (e.g. CGS4).
14. Multiple display access to data possible (not restricted to one physical display screen).

Movie Tool

The pupose of the movie tool is to provide crude manipulation of data so as to verify correct operation e.g. Has the science array lost a quadrant ? Has the source moved out of the slit ? Has cloud obscured the source?

It is anticipated that the simple data manipulation functions of the movie tool will be a subset of those provided by the full data reduction tool.

The requirements of the movie tool manipulation of data are :

1. Display of raw data. Optional application of bad pixel mask.

2. Display of data array with second array subtracted. Examples are subtraction of a bias frame, a dark frame, a previously stored data frame or subtraction of the last "sky" from an "object" frame.

3. The speed requirement is that the display be updated at a rate of at least 1Hz (or the data rate if slower). [Check A& G camera speed requirement - may be 10Hz]

Data Reduction Tool

The data reduction tool provides the procedures for producing data suitable for assessment of the scientific quality e.g. for termination of a queue-scheduled observation ahead of time due to better than expected observing conditions. This quantitative assessment of the data implies that the following general concepts must be supported:

1. Automated reduction according to definable recipes built from simple tools. The reduction queue must be capable of manipulation (re-reduction, clearing etc.) e.g. CGS4. The reduction of a group of frames might be 'triggered' by e.g. accumulation of an object-sky-sky-object quad or completion of each cycle around a mosaic.
2. Read noise and dark current estimater. This requires knowledge of the e-/DN gain conversion as well as the composition of the data (e.g. how many individual frames in the image). Useful for daytime assessment of correct instrument function.
3. Flux and/or magnitude estimater. This requires application of instrumental zero points and/or defintion of flux calibration (e.g. for assessment of the limiting magnitude in an image).
4. Wavelength calibration of spectra, either from supplied instrument parameters or from a nominated (pre-reduced) calibration frame. Note that the wavelength scale may be non-linear.
5. Mosaicing capability, using telescope offsets and/or astronomical sources in the field.
6. Crude astrometry. Centroiding of objects in the frame and differential positions in pixel or world coordinates.
7. Saving and recovering of data reduction configuration from named configuration files.

Reduction of the raw data should include (but is not limited to !) the following procedures loosely grouped according to function:

(a) basic tools
a1. bias subtraction
a2. dark subtraction
a3. flat-fielding (generation of flat-field and division by it)
a4. median filtering
a5. subsetting and supersetting of data
a6. object-sky subtraction (including appropriate treatment of chopped data which may have sky already subtracted)
a7. time series plots of source brightness (e.g. constructed as 'spectrum' from sequence of frames)
a8. and 2D FFT
a9. simple mathematical operations (including +, −, /, *, log, 10^x) e.g. using a calculator-style tool (cf IRTF tool)
a10. basic boolean operations for manipulating bad pixel masks (including or, and, not)

(b) image reduction tools
b1. spatial profile cuts through images at arbitrary angle
b2. simple photometry (circular or square apertures, sky data from annulus or separate position)
b3. calculation of the 2D PSF and Strehl ratio (cf "IQE")

(c) spectral reduction tools
c1. extraction of spectra from S-distorted frames, or IFU or selected multislit data
c2. division of spectra
c3. joining of spectra (e.g. x-dispersed data)
c4. averaging of spectra from several (nodded) positions along slit
c5. construction of 3D data cube from IFU or slit-scanning observations
c6. manipulation of 3D cubes (including slicing and binning)
c7. movie display through 3D cube
c8. black-body spectrum generator (for removing standard star spectral shape)

c9. spectral line (and continuum) fitting with standard profiles (Gaussian, Lorentzian, triangle)

The time requirement for update of the data display including basic reduction according to the instrument-specific recipe is within 20s.

Observing Assistance Tool

This is a miscellaneous group of functions which will be required for preparation and execution of observations. This list includes :

1. Selection of guide stars. Display of field with potential guide stars indicated and ranked according to magnitude (e.g. size of marker). Automatic suggestion of best guide stars (on basis of position and brightness) e.g. different colour marker. Selection of guide stars to be communicated to relevant Gemini systems.

2. Target selection for spectrometers. Selection of object in image (e.g. mouse click, optional centroiding) to select location of spectrometer slit. Optional selection of two objects to define position angle.

3. New guide star colours. Automatic reduction and photometry of multi-filter data to measure colour for star of unkown spectral type (required for accurate dispersion correction).

Questions still to be addressed :

How to reduce data from a focus run ? (What does this data look like ?!)
How to extract data from an IFU frame ?
What data reduction is required for “new guide star” colour measurements ? What colour accuracy is required ? How to enter this info into the catalogue for future use ?
What will be the basic instrument checks other than read noise and dark current ? Throughput ? Focus ? (Ensure that reduction of these can be ‘automated’ to provide idiot-proof health check).