FIES Reduction Software
Specification of Requirements

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April 27, 2004

1 Introduction

FIES (FIber-fed Echelle Spectrograph) is to be commissioned at the NOT at the end of 2004. As part of this commissioning an online data reduction system will be developed. Because FIES observations are performed in a more or less stable configuration, the implementation of such an online data reduction system is feasible. The overall goal of this system is to perform high-quality automatic processing of observed spectra in such a way that an observer will be able to use these spectra for scientific analysis. Similar automated data reduction systems (often called 'pipelines') are in use at, for example, ESO (VLT, 2.2m) and STScI (HST).

At the moment the instrument design is not yet completely finalized. This means that it is not yet possible to set detailed specifications on the spectral resolution and wavelength stability of the reduced spectra.

2 Goals

The main purpose of the reduction software is to automatically process data obtained with FIES, and provide spectra that can be used for immediate scientific analysis. In order to do this, the software will be controlled through the following interfaces :

1. **Quick-look reduction interface**

   At the end of every exposure the software will provide the user with extracted spectra that can be used to do a preliminary assessment of the obtained data. These spectra are not intended for scientific analysis.

2. **A science-grade reduction interface**

   The science-grade reduction interface can in turn be divided into two modes of operation.

   - In *pipeline mode* the software will process a set of data (typically one night) with fixed parameters, providing reduced spectra that can be used for scientific analysis.
   - In *user mode*, the user will download a stand-alone version of the reduction package, so that it can be used at the home institute for processing of earlier obtained data with parameters that can be defined/refined by the user.

3 Requirements

3.1 General

- The package will be accompanied by documentation for the user, as well as procedures for NOT staff (software operations and software maintenance).
- Basic documentation will be integrated in the interfaces (on-line help).
- The package will be accompanied by reference (example) frames, that can be used to test and setup the reduction software.
- Normal operation of the software will be performed through a Graphical User Interface (GUI).
- The input data to the package will be frames obtained with the default configuration(s) of the FIES spectrograph at the NOT.
- Unusable input data (low S/R-ratio, incompatible order layout) will produce warnings to the user, but not interrupt the reduction process.
- Extracted spectra should be compatible with IRAF, one of the most popular data reduction packages.

3.2 Quick-look reduction

- Quick-look reduction will not require any initial configuration, and can be started at any moment by the user.
- Reduction will start automatically when a new frame has been obtained with FIES. The reduction of a single frame should take on the order of 10 seconds or less.
- The software will make use of a pre-determined master bias, master flat field, solution of the order locations and wavelength solution. Depending on the stability of the instrument, these frames will be taken from a database, or be determined just before the night of observations.
- The quick-look reduction will perform bias subtraction, fringe correction and order extraction.
- Normalization (blaze-shape correction) of extracted spectral orders will be optional.
- If the data is binned (1x2, 2x1, 2x2) or windowed, the package will perform at least order extraction.
- The reduction package will display the extracted spectral orders on screen and save them to disk.

3.3 Science-grade reduction - pipeline mode

- Pipeline data reduction of a set of observed frames will be initiated by the observer at the end of each night.
- For a proper reduction of science frames, an appropriate set of calibration data needs to be obtained before/during the night. These data may consist of :
  - A set of flat fields (number to be determined later)
  - A set of bias frames (number to be determined later)
  - An order definition frame, with a S/N-ratio per pixel of at least 10 in the orders that are to be extracted
  - Wavelength calibration frames
- A suggestion for the initial setup of the pipeline (selection of bias frames, flat-field frames, order definition frame and wavelength calibration frame) based on the contents of FITS headers will be provided.[1]
- After selecting the input calibration files for the pipeline through interaction with the user, the package will perform averaging of bias frames, summation and 2D normalisation of flat field frames, modelling of scattered light, tracing of order locations, determination of wavelength solution (from separate calibration lamp spectra or from simultaneous interlaced calibration lamp spectra). The interaction with the user should be simple and limited as much as possible. These calibration steps are not time-critical.
- Without further interaction, the pipeline will perform batch processing of object frames (bias subtraction, pixel-to-pixel correction, fringe correction, scattered light subtraction, order extraction, blaze-shape correction, wavelength calibration and order merging).
- Bias subtraction, blaze-shape correction, cosmic ray removal and merging of spectral orders will be optional.
- It will not be possible to perform optional steps on a subset of frames, only on the entire set.
- Batch processing of 30 full-sized object frames should not take more than 6 hours.
- The reduction package will save to disk the extracted spectra, as well as the master bias frame, the 2D-normalized master flat field and intermediate results of the reduction process.
- The wavelength solution, from associated calibration frames, should have an RMS deviation of better than 60 m/sec between calculated and observed wavelengths[2] (unwindowed frames only).

3.4 Science-grade reduction - user mode

- In user mode, the software will offer a reduction identical to the one described for pipeline mode
- In addition, the user will be able to modify the settings that control the behaviour of the individual reduction steps.

[1] Currently not possible due to lack of adequate headers.

[2] This requirement is to be reconfirmed after the spectrograph has been reassembled and moved to its new location.

4 Implementation

4.1 Software

- The different interfaces to the reduction package will use routines that are more or less identical.
- The data reduction routines will, at least in the first development stage, be based on existing IRAF routines.
- The interaction between IRAF, the GUI and other routines will be coordinated by the high-level scripting language Python.
- The implemented software shall consist of modules (see below), allowing for stepwise future improvements of reduction routines.
- The reduction package will consist of a fixed set of algorithms that are optimized for FIES data. NOT staff will be able to perform the evaluation and calibration of the parameters of these algorithms.

Distinct modules to be developed are :

- Averaging of bias frames in order to construct a master bias frame.
- Finding and tracing of order locations by fitting a polynominal to the position of the orders across the CCD.
- Summation and 2D normalisation of flat field frames in order to construct a master flat field frame and determine the blaze shape in each order.
- Modelling of scattered light from the inter-order regions.
- Determination of wavelength solution by fitting a polynominal to the position of arc lines, either from seperate calibration lamp spectra or from simultaneous interlaced calibration lamp spectra.
- Pre-processing of science frames (bias subtraction, division by the normalized flat field, scattered light subtraction).
- Extraction of observed spectral orders. The used method will depend on the available computing time in each mode of data processing (quick-look or science-grade).
- Normalisation of extracted spectral orders though division by the blaze shape of each order.
- Merging of spectral orders.

Within the time limits imposed on the different modes of data processing, the implemented data reduction methods should provide the highest feasible S/N-ratio in the extracted spectra.

5 Documentation

Documentation will consist of :

- A user manual, containing a description of the reduction package, and instructions on how to use it.
- An installation manual, containing instructions on how to setup and configure the different interfaces of the reduction package.
- A maintenance manual, describing the internal layout of the reduction package and its software, and how the package can be developed further.
- On-line help functions.
- Commented source code.