MAJOR FEATURES OF THE CCD PHOTOMETRY SOFTWARE DATA ACQUISITION AND REDUCTION PACKAGE DISTRIBUTED BY OPTEC, INC.

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Abstract

The CCD Photometry Software Data Acquisition and Reduction Package, by Optec Inc., is a three-program software package designed for collecting and analyzing images made by most commercially available CCD cameras. The software runs on any IBM AT-class computer with EGA or better graphics and a hard drive. Some of the important features of the programs are discussed.

1. Introduction

The CCD Photometry Software Data Acquisition and Reduction Package sold by Optec Inc., is a software package for collecting and analyzing images made using CCD cameras. Originally, the software was designed to be used only with the SpectraSource Lynxx CCD camera. Now, it can reduce and perform photometric analysis on images produced from other commercially available cameras (e.g., SBIG ST-4 and ST-6, Photometrics Star-1 and Series 200). Anyone interested in using a CCD for image collection and photometric reduction should be very interested in this integrated software package that will run on any IBM AT-class computer (286 or higher) with EGA or better graphics and a hard drive. A math co-processor is highly recommended, but not required.

The software package is divided into three sequentially used programs. The programs are: 1) CCDRT (version 1.5), used to control a SpectraSource Lynxx CCD for image acquisition; 2) CCDRED, used to adjust the images so that photometry can then be performed; and 3) CCDPHOT, used to perform the actual photometry. These programs are highly integrated with each other. For example, images collected and saved with the CCDRT program contain a header that comprises additional information required by the CCDRED program. ASCII-format files saved by the CCDRED program are structured for input into the CCDPHOT program. In this way, much of the information required for data reduction is passed on from one program to the next without retyping it. Each program comes with a manual that covers the program's features, commands, and operation. I will discuss some of the more important aspects of each of the main programs below.

2. CCDRT: Real-Time Data Acquisition Program, Release 1.5

CCDRT (RT for Real Time) is designed to operate (only) the SpectraSource Lynxx CCD by controlling the interface card supplied with the CCD. All CCD settings and data collection procedures are performed with CCDRT. The program is predominately menu-driven and a mouse is mostly used for program operation. This makes it easy to operate in the cold with gloved hands! Occasionally, the user needs to enter numbers or text using the keyboard.

The red-text screen display is divided into three sections: a (main) menu for accessing the program functions (along the top), the CCD image display (on the left two-thirds of the screen), and the status of important data collection parameters (on the right

side). When a main menu topic is selected, the submenu of function-specific commands appears below the main menu. Some of the available commands are listed in Table 1. The functions seem to be thoughtfully grouped within each main menu topic. For example, all the commands needed to perform normal image acquisition and storage are located under the EXPOSE menu.

TABLE 1. Some selected commands accessible through the CCDRT pull-down menu.

MAIN MENU	SUBMENU	DESCRIPTION
EXPOSE	FILTER	Used to select which filter is being used.
	IMTYPE	Select the type of image to make (OBJECT, BIAS, FLAT, DARK). Selecting BIAS will automatically set exposure to zero seconds. Selecting DARK will automatically keep the shutter closed.
	OBJID	Enter up to 64 characters of text to describe the image.
	SPECIAL	Contains: COADD to automatically take and average a select number of images; MULTI to automatically take a select number of images, each of which are automatically stored to disk; and FOCUS that allows to CCD to take continuous exposures to help focus the CCD.
DISPLAY	GRAY	Selected to have pixel values represented on a gray scale.
	COLOR	Selected to have pixel values represented on a rainbow color scale.
	FULLSCALE	Sets the dynamic range of the display to fit the range of the image.
	YOURSCALE	Used to manually set the dynamic range of the display.
PLOTS	ROWS	Produces a plot of the pixel value-vs-position for a single row selected using the mouse.
	COLUMNS	Produces a plot of the pixel value-vs-position for a single column selected using the mouse.
	RADIUS	Produces a stellar profile plot. (See text for comments).
FILES	BASE	The main part (up to 8 characters) of the file name, prior to any extension. Usually expressed as the current date. For example, 941214 for December 14, 1994.
	EXT	Specifies the file extension (up to 3 characters). Usually expressed as the image number in the current imaging sequence.
	METHOD	User specifies the file naming method (see text). Choices are BY NAME or BY NUMBER.
	FORMAT	Saves images in either CCDRT's file structure called INTERNAL or in the FITS format.
MISCEL	COOLER ON	Turns the CCD's thermal electric cooler (TEC) on (default).
	COOLER OFF	Turns the CCD's thermal electric cooler (TEC) off.
	SPAWN	Shells to DOS, keeping the entire CCDRT program still in memory. This leaves more-or-less 100 K of free RAM to work with. While not much, it is enough to make directories, see what files are on a certain directory, etc.

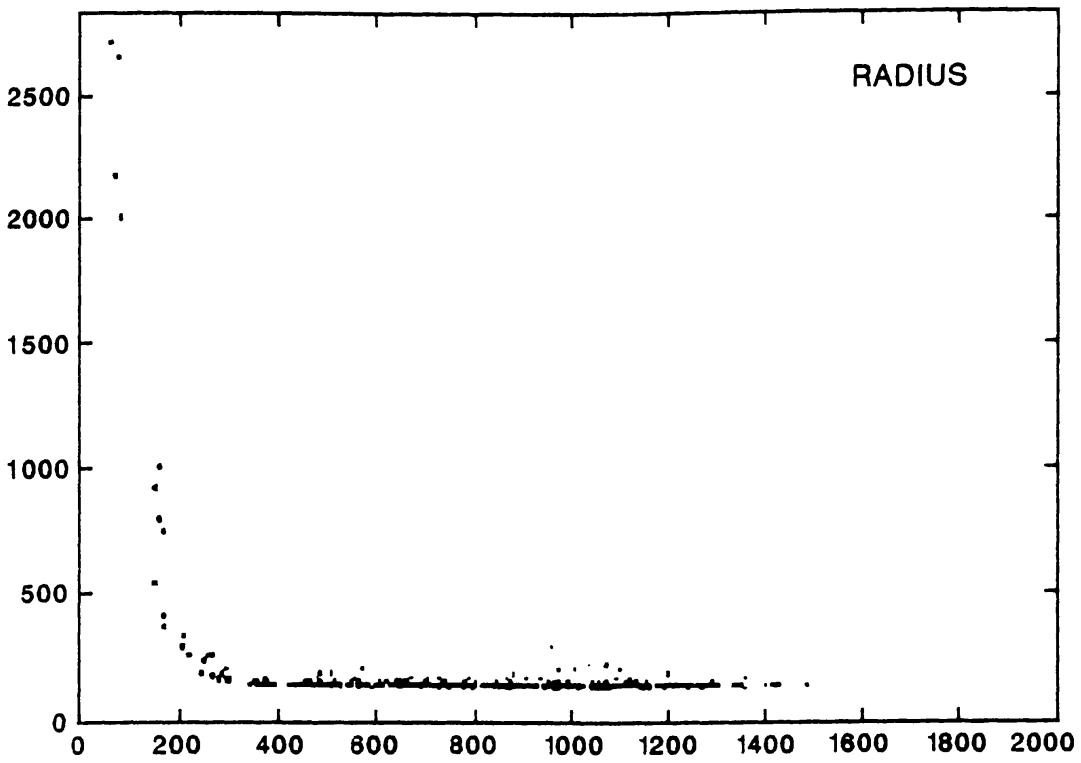

Figure 1. CCDRT screen (capture) of a stellar profile using the RADIUS command.

A convenient feature of the program is the way CCDRT names the images stored to disk. The BY NUMBER method allows the program to automatically store each image file using the current date (according to Universal Time) and a numbered file extension. The extension number is incremented each time an image is stored. For example, the first image stored on the December 14, 1994, observing run will be named 941214.001, the second image stored will be 941214.002, and so on. This file-naming method removes the need to type in the full name each time the user wishes to store an image file. This feature also has the important "date of imaging" built in.

Another important feature of the CCDRT program is the INTERNAL default image format. The saved images have a special header appended to the image data that includes: observatory latitude and longitude, frame type (e.g., Object, Bias, Dark, Flat), object name, photometric filter used, exposure length, and the UT time the exposure was taken. This information, as mentioned before, will be automatically passed on to CCDRED and CCDPHOT. Images can, however, be stored in the FITS format (an astronomical file standard) to be used by image processing programs like IRAF.

The program includes useful screen-plotting functions. Two are COLUMNS and ROWS that plots profiles of pixel value versus pixel number at the specified column or row. Another is RADIUS, where you select an object (like a star) on the image and the program finds the greatest pixel value within some radius of the mouse cursor and then plots the pixel intensity of the stellar profile (starting at the center of the star). This helps the user to judge the image intensity, quality, and seeing conditions. Figure 1 above shows a screen capture of a RADIUS plot of a star.

Along with the (Lynxx) CCD camera, you also need some means of inserting photometric color filters in front of the CCD in the light path. Optec Inc. also sells a device (the PFE-1, the Photometric Front End) that fits between the CCD and telescope focuser. The PFE-1 has a slot that accommodates filters (also sold by Optec Inc.) which are mounted on a 2-position (consisting of 2 filters, per) slide. The PFE-1 also comes

in a (higher priced) version (PFE-1A) that includes a stepper motor that can allow the CCDRT program to computer control a 6- or 10-position (but not the 2-position) slide. This option, however, requires either the additional purchase (from Optec Inc.) or construction of a controller card to operate the stepper motor. Although the Photometric Front End is not being reviewed here, its capability to have the filters automatically computer positioned, via CCDRT, is a desirable option.

3. CCDRED: Image Reduction Program, Release 1.8

This portion of the software package allows you to perform a wide variety of operations on the images you recorded and stored using CCDRT, including: 1) standard (data) frame reduction steps such as bias and dark frame subtractions, and flat field divisions; 2) general math, such as averaging and division, on image files; 3) view whole images, portions of the image, or graphs of pixel values for a particular row or column; and 4) select the stars and extracting photometric data for the CCDPHOT program.

The display consists of three sections: an image-displaying window (on the left); a slightly smaller window on the right for displaying a variety of user-specified information such as file header contents, row or column pixel values, or the image's screen scaling values; and across the bottom of the screen, a scrolling multi-line text region where you type the command (and associated "switches") you wish to have performed. The current version of CCDRED is not menu-driven.

All the object images collected for photometric work must be corrected for the bias (offset) in the chip's pixel voltages, for thermal or dark noise, and the different sensitivity of individual pixels. Therefore, bias, dark, and flat support frames (stored as files) taken by CCDRT are manipulated in CCDRED. There are a number of references

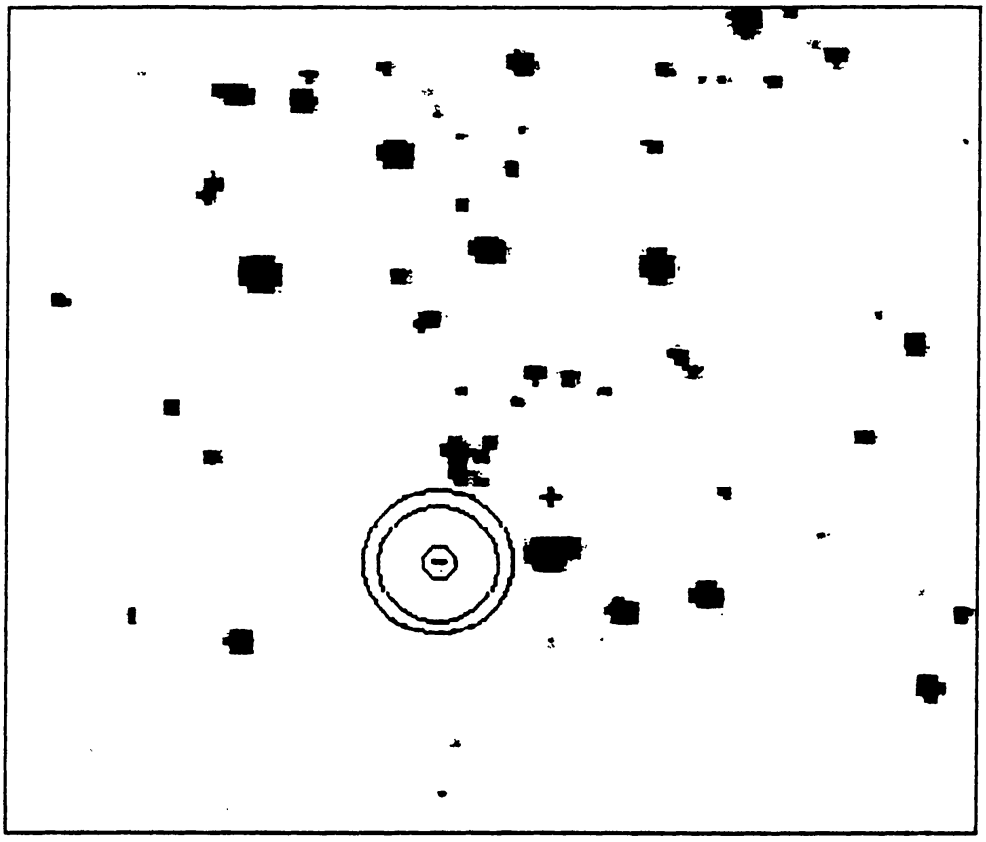

Figure 2. Annulus centered on a star during the EXTRACT command in CCDRED.

available that go into detail the various necessary CCD image reduction steps (Henden and Kaitchuck 1990; Howell 1992) and no more will be said about it here. Also, the CCDRED manual contains a very useful step-by-step discussion on image reduction using the supplied example image files.

Besides the usual (but very important) bias, dark, and flat field calibration, the CCDRED program lets you extract sky-background-subtracted instrument magnitudes of objects that were imaged through photometric filters. This step is accomplished by the SETAPT, SHOAPT and EXTRACT commands. You can select the size of the inner (star or photometric) aperture and the outer aperture (the annulus) that will be used in the sky-subtraction with the SETAPT command (Figure 2). The EXTRACT command is then invoked to use to extract the instrument magnitude of each object (e.g., star) in each filter image. This command can either use the outer annulus to determine the sky (instrument) brightness, or ask you to click another part of the image and the command will use the (inner) aperture (only) to determine the sky brightness. This is very useful if your object (star) is in a crowded portion in the image (e.g., within a cluster). To select an object, you simply place the mouse cursor near the center of the object and click. The program then finds the brightest pixel within the radius size selected for the star aperture and then calculates the centroid of the light distribution about that bright pixel. This method does not depend (to a large degree) on the initial placement of the cursor on the selected (stellar) object. As long as you place the cursor within the brightest portion (not pixel) of the (stellar) object, you will get reproducible brightness values. The extraction process stores the extracted sky background subtracted (ESBS) instrument magnitudes to an ASCII data file. You can create as many different files as your photometric program demands or append to a single file the extracted values from many (related) images.

One other note about CCDRED is that the program can be run using user-designed text files called scripts. These "batch files" contain CCDRED commands that run just as you would have typed the commands in normally. As the documentation suggests, scripts can be a powerful tool in performing repetitive tasks using as little keyboard entry as possible. There is an introduction to composing scripts in the documentation. At first, I found it difficult and initially time-consuming to write these scripts. After a few hours of creating, debugging, and using a script, however, I realized the time-saving benefits scripts can truly offer. New users may wish to bypass this feature until they are comfortable with the way CCDRED works (with the data).

4. CCDPHOT: Photometry Program, Release 1.2

This is program in which the final photometric procedures are carried out. The screen display consists of a list of commands to perform either differential or all-sky photometry. At the bottom is a command line similar to CCDRED.

Input files for CCDPHOT consist of the ESBS files created by CCDRED and user-designed photometric catalogue (CAT) files. Some of the more common standard photometric catalogues are provided. Output files consist of (the previously mentioned catalogue files,) instrument files (discussed below), extinction and transformation coefficient files, and files that contain color differential or standardized magnitudes and colors. All files are in ASCII format.

Nearly all of the photometric-related CCDPHOT commands use instrument (INS) files created in CCDPHOT by the INST command. INST takes the ESBS files and associated CAT files and produces an INS file that contains: 1) sorted instrumental magnitudes for each filter used, 2) calculated air mass values, and 3) heliocentric Julian dates and UT for each extracted observation. Information needed to perform these calculations was already stored in the object (image) files and the CAT files. As can be seen, this single command performs a great deal of "calculating" at once!

Another nice feature of CCDPHOT is the way information is presented during the

data reduction process. Many photometric parameters are often derived through graphical analysis. The program displays graphical plots each time such calculations are carried out. Additionally, calculated intermediate and final values with their error for air mass, extinction, color differences, etc. are displayed on screen. In this way, you can see if anything does not look right during data reduction and, if so, do something about it before you (or someone else) uses "bad" numbers.

There isn't enough room here to discuss all the ways you can reduce your data using this program. The (CCDPHOT) documentation contains a very helpful tutorial on the many ways to reduce photometric data. The tutorial includes: performing simple differential photometry, with or without extinction corrections; determining first- and second-order extinction coefficients (a few different ways); determining transformation coefficients (a few different ways); determining zero points, and differential and all-sky photometry on some standard system.

5. Conclusions

There are many reasons that this software package should be attractive to users of the CCD cameras. They include the following:

1. The package can reduce image files created from a number of commercially available CCD cameras. The CCDRT component (currently version 1.5) will only operate the SpectraSource Lynxx PC and its controller card. The CCDRED and CCDPHOT can use any of the previously mentioned image (formats).

2. The program runs on any widely available and relatively low cost IBM-compatible machine with EGA or better graphics. Since many of the available CCD cameras (like the Lynxx PC) requires such a machine anyway, the user doesn't need access to another (perhaps more powerful 386 or better) computer just to perform the necessary image reductions and photometric analysis. I run the software on an IBM-compatible computer using an (used and inexpensive) Intel 80286 with a 80287 math co-processor and am quite happy about the performance. I can even run the (CCDRED and CCDPHOT) programs in a DOS window in Microsoft Windows 3.1 on my 286 computer! True, it is not (yet) a Windows-format program like some other CCD image-reduction programs available, but neither does it require the computer "horsepower" that these other programs need.

3. The program package seems to have (nearly) all the features needed to do most any photometric data reduction job and do so correctly. I'm not surprised, since the creators of the software wrote one of "the" books on photometry (Henden and Kaitchuck 1990).

4. This reasonably-priced program (approximately $400) easily has enough features to reduce data for the AAVSO and its CCD variable-star program. It is available through Optec Inc., 199 Smith Street, Lowell, MI 49331.

6. Acknowledgments

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References

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Unified Software Systems, CCDPHOT, CCDRED and CCDRT (manuals), P.O. Box 21294, Columbus, OH 43221