# LOW COST IMAGE PROCESSING ON PERSONAL COMPUTERS: THE MACINTOSH-II BASED DIRIGO SYSTEM

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## ABSTRACT

Interactive image processing systems for the analysis of remotely sensed data are readily available for IBM compatible PCs and various mini- and micro-computers. Image processing software to be used on Macintosh PCs, however, has usually been associated with desktop publishing or medical/biological applications. With the advent of standard color displays for the Macintosh II series, image processing systems could be expanded to include remote sensing applications. Combining the user-friendly Macintosh interface with the capability of displaying multispectral remote sensing image data offers the unique possibility of a 4th generation image processing system design.

During a one-semester course in image processing, students of the Department of Surveying Engineering at the University of Maine designed and implemented the Dirigo software package for the analysis of remotely sensed data on an off-the-shelf Macintosh II. The students were assigned to teams, each tackling a specific component of the system. Coordination was maintained through status reports and intensive discussions and resulted in the integration of all application software components in <u>one</u> common user interface.

Concentrating on the components necessary for remote sensing applications, Dirigo contains menus for (a) point operations; (b) spatial filtering; (c) geometric corrections and georeferencing; (d) multispectral classifications; and (e) general utilities (e.g. pan and zoom). The software was written from scratch using exclusively Macintosh intuitive tools for the interface design. This allows inexperienced users and computer novices to get familiar with the system quickly and avoids unnecessary overhead in the learning curve.

This paper describes specifications and performance of the Dirigo system, compares it with existing software packages and outlines future developments.

## INTRODUCTION

The past decade has witnessed rapid technological development in computing hardware producing continual reductions in the cost of systems. High level microprocessors in personal computers vastly outperform their forerunners of only a few years ago and challenge minicomputers in performance. Two manufacturers of high performance chips for the use in super microcomputers have established themselves as marketleaders, Intel and Motorola (Ferns and Press, 1988). The Intel 80xxx series and the Motorola 68xxx family are the most widely used and may be associated with the 'IBM world'

(IBM PCs and compatibles) and the 'Macintosh world', respectively. The shift from mainframes and minicomputers to inexpensive PCs for image processing in remote sensing was a natural consequence of the users' desire to have a dedicated system for personal use.

Image processing in remote sensing, however, is constrained by a number of processing requirements, including: (1) image sizes are much larger than standard CCD images used in robot vision and automated manufacturing applications and can exceed hundreds of megabytes for satellite data; (2) images are usually multispectral and/or have to be registered with other images; and (3) remote sensing images are inherently 'fuzzy' and image interpretation based on a priori information such as solid geometric models often used in computer vision is of limited value (Muller, 1988; Sanz, 1988). Consequently, image processing systems for remote sensing have to be capable of large data file handling, must make use of color display techniques, and have to enable easy and efficient user interaction.

Full functional image processing systems for PCs usually require the acquisition of an additional high resolution graphics board and display (e.g., 1024 x 1024 pixels x 32 bits) (Sabins, 1986; Richards, 1986). However, progresses in standard color display PC technology starting with the introduction of the enhanced graphic adapter (EGA) in the early 1980s has made digital image processing of remotely sensed data possible with off-the-shelf products (Myers and Bernstein, 1985; Welch, 1989). It must be noted that more or less all of these developments were based on IBM compatible computers since the Macintosh series of PCs until recently abstained from color. Consequently, image processing software for Macintosh PCs could mainly be associated with desktop publishing or medical/biological application. With the introduction of the 8-bit graphics option for the Macintosh-II, however, the monochrome impediment was removed facilitating for the first time *multispectral* image processing on the MAC-II (Ehlers, 1990).

## BACKGROUND

The Department of Surveying Engineering operates successfully a number of Macintoshes in its curriculum. Students seem to get easily familiar with the Macintosh interface and menu structure and are immediately fascinated by the *'What you see is what you get'* display philosophy. It were actually the students that suggested the use of Macintoshes for a graduate level course in 'Image Processing in Remote Sensing' to be taught in Spring 1989.

At the start of the course, no commercial image processing system for the analysis of remotely sensed data was available for the Macintosh. If we were to use the Macintosh computers for programming assignments, we had to design and develop our own image processing software. Instead of using existing software or adding specific modules to commercial packages, we decided to gain experiences in image processing by designing a prototype system on the MAC-II. These practical assignments would accompany the lectures and allow a first hand experience in putting into reality classroom concepts and theories (Ehlers, 1990).

## THE DIRIGO SYSTEM

Dirigo Design

The first assignment for the students was to decide on the essential components of an image processing system. Based on their remote sensing experience, they were to describe the software components for a digital image processing system designed to process remotely sensed data. These components should be structured into (a) absolutely essential; (b) necessary; (c) useful; and (d) "nice to have". The answers were discussed in class and modified based on these discussions (Table 1).

Table 1: Components of an Image Processing System in Remote Sensing

| | |
|---|---|
| Absolutely Essential | I/O<br>Display (CRT)<br>Image File Management<br>Interface |
| Necessary | Geometric Correction<br>* Registration<br>* Rectification<br>* Resampling<br>Enhancement<br>* Point Operations (LUT)<br>* Filtering (Spatial)<br>Classification<br>* Density Slicing<br>* Supervised<br>* Unsupervised |
| Useful | Transforms<br>* Fast Fourier Transform<br>* Principle Component Transform<br>* Intensity-Hue-Saturation Transform<br>Algebra<br>* Linear Combination<br>* Band Ratio |
| "Nice To Have" | All The Rest |

Teams were assigned to work on the components that were rated as essential and necessary (Figure 1). One of the most important design considerations was that all application software was to be accessible through a common user interface that should strictly adhere to Apple's Macintosh interface guideline. The interface should provide state-of-the-art interaction based on pull-down menus and use of the mouse wherever possible.

User Interface

Complaints about user interfaces for image processing software packages have ranged from needlessly cumbersome to non-intuitive to downright cryptic. In the early stage of image processing, it was assumed that only the experienced user was able to work with image processing software, especially with packages originating from the academic environment. In some instances, the user was required to learn a new operating system and manuals with thousand and more pages had to be used frequently to gain some understanding in the structure of the software. Today, however, users want to be quickly familiar with the system, especially when they are used to work with Macintoshes or operating windows. The Dirigo user interface adheres strictly to the Macintosh interface guidelines and all but limits typing to only a few occasions (e.g., class names or coordinates). The Dirigo interface makes use of pull-down menus and dialog boxes (Figure 2).

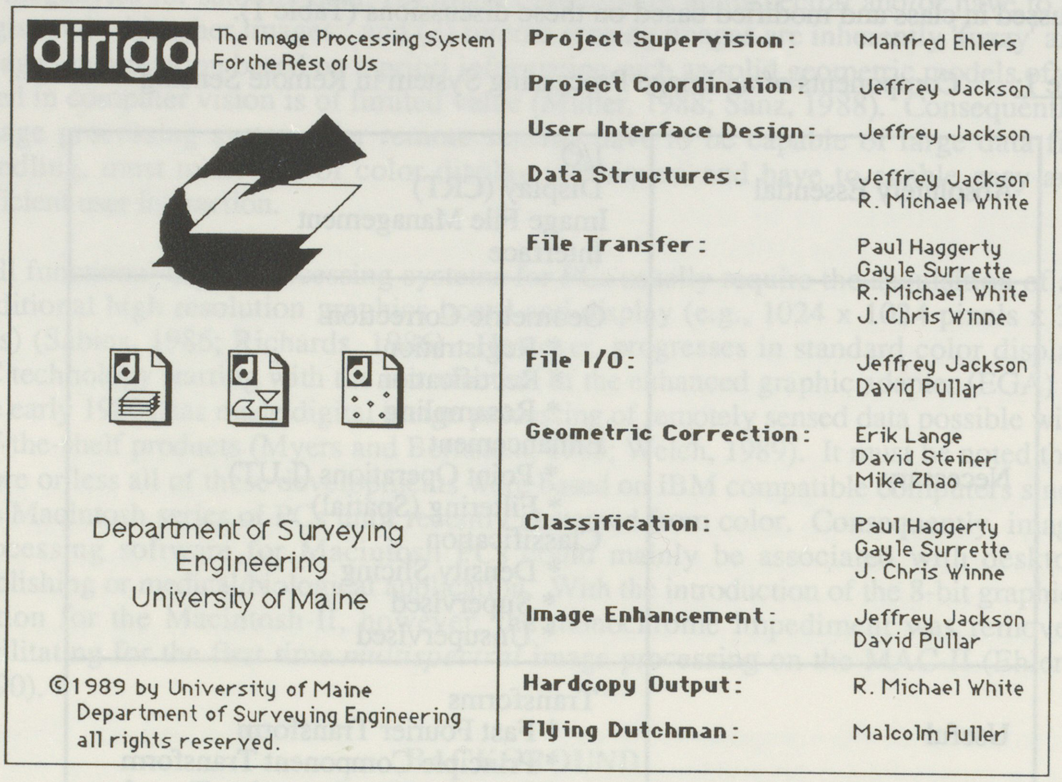


Figure 1: Dirigo components and design teams

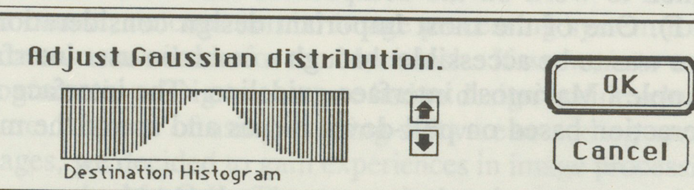


Figure 2: The Dirigo menu for Gaussian histogram fitting

Image histograms and index can be displayed simultaneously with the image and a tool box provides real-time pan and zoom as well as control point and training area selection (Figure 3).

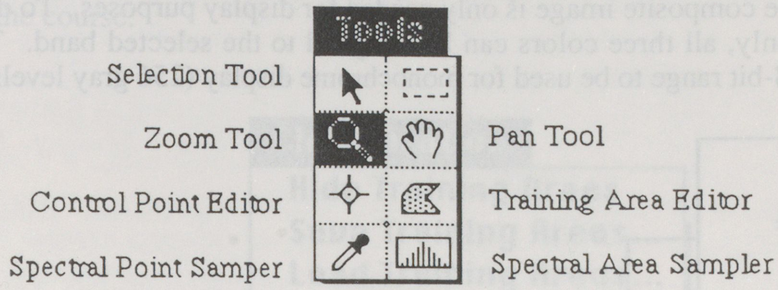


Figure 3: Dirigo tool box.

Image Data Management
Based on our experiences in remote sensing and the display size of the Macintosh-II, we designed the image management system to handle files of 512 x 512 pixels. The number of bands is limited only by disk space. However, the user can only select three bands for display and interactive manipulation (Figure 4). Band description (e.g., spectral information) can be stored in the header and is provided to the user when an image file is opened. The Dirigo system supports four different file formats: (1) image data; (2) ASCII text files (control point coordinates or training area statistics); (3) classified images; and (4) training areas for classification. Intelligent interface design ensures that only files with the appropriate format can be opened for the selected application tasks.

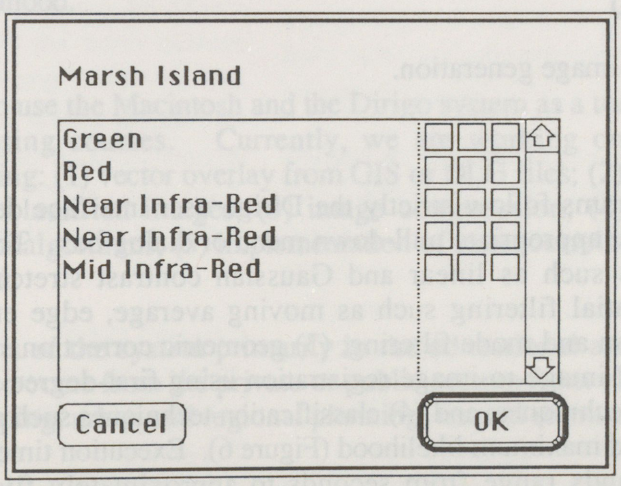


Figure 4: After opening an image file (here Marsh Island), the header information is made available to the user. The user can then select three bands for display.

Image Display
Dirigo provides color display for up to three eight-bit input channel. The user can select three spectral bands from an input image by assigning red, green and blue color squares

to the input channels. The selected bands are then loaded into memory. For display, the three input bands with a total of 24 bits are compressed into one 8-bit composite image. Both, the original image with three bands and the composite image are stored in memory (Figure 5). This ensures that image processing can be performed on the *original* image data whereas the composite image is only needed for display purposes. To display one spectral band only, all three colors can be assigned to the selected band. This mode allows the full 8-bit range to be used for monochrome display (256 gray levels).

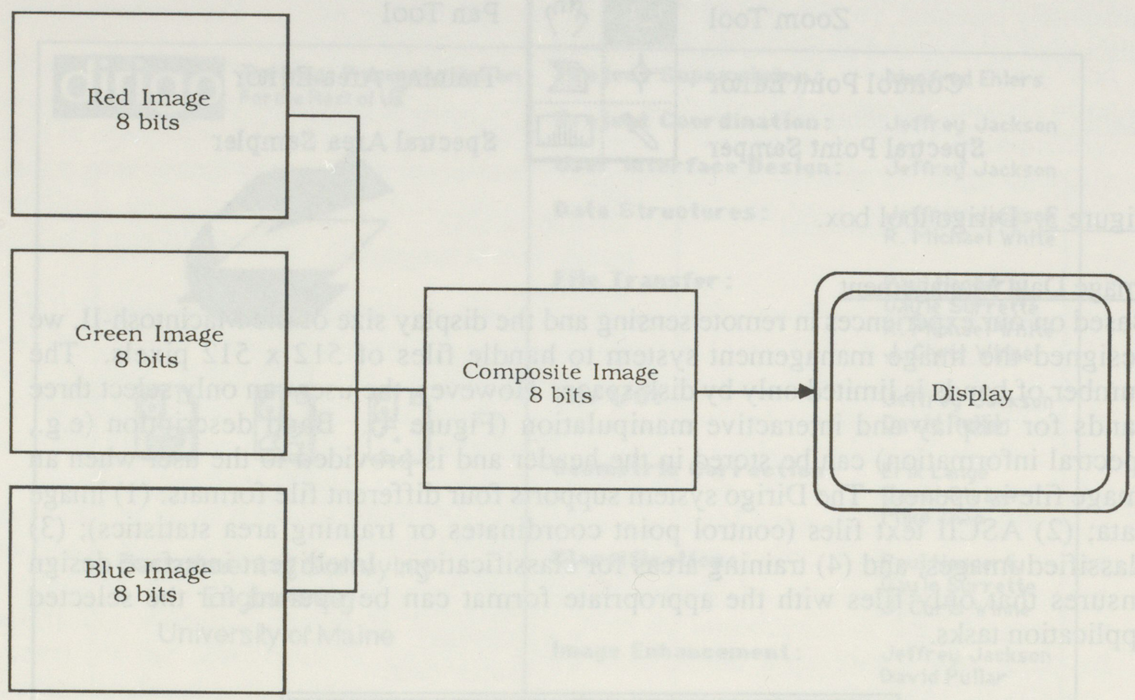


Figure 5: Composite image generation.

Application Programs
All application programs follow strictly the Dirigo user interface design and can be executed by using the appropriate pull-down menu or dialog box. The menus include (1) point operations such as linear and Gaussian contrast stretch and histogram equalization; (2) spatial filtering such as moving average, edge enhancement and extraction, and median and mode filtering; (3) geometric correction such as image-to-map rectification and image-to-image registration using first-degree polynomials and standard resampling techniques; and (4) classification techniques such as parallelepiped, minimum distance and maximum likelihood (Figure 6). Execution times for a 512 x 512 image with three bands range from seconds to approximately five minutes for a maximum likelihood classification with six classes. In all instances, a color bar provides feedback to the user about the progress of the selected application program.

## CONCLUSION

The course on digital image processing in remote sensing with the design of an interactive image processing system on the Macintosh-II turned out to be more successful than anybody involved in the course had hoped for. The students were excited and worked extremely hard as they recognized that the 'by-product' of the class turned out to be a prototype for a 4th generation image processing system combining state-of-the-art interface design with powerful image processing techniques. All feedback from the students indicate that they not only 'learned a lot but also had a lot of fun' during the course.

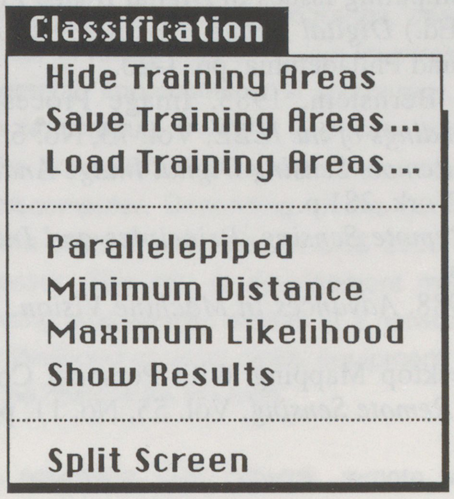


Figure 6: The Dirigo classification menu allows for saving and loading of training areas and provides three classification algorithms: parallelepiped, minimum distance, and maximum likelihood.

We will continue to use the Macintosh and the Dirigo system as a tool in remote sensing and image processing courses. Currently, we are working on additional Dirigo components including: (1) vector overlay from GIS or DLG files; (2) automated creation of polygons from classified images; (3) image compression; (4) unsupervised and hybrid classification algorithms; (5) implementation of stereocorrelation techniques; and (6) hardcopy output.

We see applications of the system primarily in the educational area. Potential users, however, might also come from the private or public sectors from various fields such as surveying and mapping, urban and regional planning, natural resource management, and growth monitoring.

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