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A NEW PARADIGM IMAGE ANALYSIS TOOL

Steven G. Hoffert*, Alfred M. Powell, Jr., Philip Anderson,
Phillip A. Zuzolo, Geoffrey Greene, Michael Conte,
Patti Fetz and Daniel Blyth

Boeing Autometric, a wholly owned subsidiary of The Boeing Company
Springfield, VA 22153

1. INTRODUCTION

Through its products, Boeing Autometric encourages the use of remotely sensed data for a variety of applications. Image analysts traditionally rely on functions built into the tools designed to provide analysis assistance. However, the functions are not easily or generally modifiable to suit individual user needs. To support users more directly, a new paradigm image analysis tool was investigated with the goal to derive a more flexible approach to algorithm development. In this approach, the user controls the equations and other analytical functions, such as image colorization and classification techniques, to produce a final analysis without having to directly implement any specific coding or scripting languages to accomplish their goal. In addition, users are allowed to save the algorithms and exchange them with contemporaries. This new paradigm analysis tool provides greater flexibility and faster review or experimental algorithms through the save and exchange process, and thereby improves the efficiency with which new analysis techniques can be created, shared and used across the community. The approach is extremely valuable for training new analysts to compare algorithm results and determine how changes to an existing algorithm may impact its performance. Through initial connectivity to NOAA data formats and the SeaSpace commercial TeraScan format, as well as export capabilities to standard formats such as JPEG and TIFF, the tool can be used to help support the analysis, generation and distribution of remotely sensed products from operational data. A brief discussion of capabilities is provided.

2. MAIN FEATURES

The image analysis tool (IAT) was designed to provide features that allow analysts to implement their own algorithms to produce the desired results. Today, the vast majority of image analysis tools limit analysts to a finite set of algorithms and function implementations built directly into the tools. This can significantly limit an analyst's ability to take full advantage of their own knowledge in image analysis and can be a big constraint when trying to investigate new problems. In addition, data types that fall outside the realm the remotely sensed bands or channels of data should also be made available to assist analysts in accurately classifying objects within the area of interest. Traditional image analysis products often prevent analysts from implementing algorithms that use non-image (ancillary) data, and force the analyst to program their algorithms outside the tool, thereby effectively reducing the intrinsic value of the tool itself. With this new paradigm image analysis tool, the inherent problems associated with fixed functions and the inability to use ancillary data is significantly reduced.

3. IMAGE ANALYSIS CAPABILITIES

The image analysis tool (IAT) proposes to solve the key issues mentioned above by providing greater flexibility and efficiency to the image analysis process. To accomplish these goals, several analysis capabilities have been developed and are summarized. These include the fusion of disparate data and image types, alternative colorization techniques, and the ability to implement plugin algorithms and statistically verify those algorithms.

3.1 *Data Fusion*

In IAT, each data type is handled independently as a 'layer' of data. The imagery is processed in a projected mode that allows multiple types of data to be subsequently layered together. Three different 'layers' of data were initially brought together to demonstrate the proof-of-concept behind this technique. These include visible imagery from the Geostationary Operational Environmental Satellite (GOES), microwave imagery from the Defense Meteorological Satellite Program (DMSP) and ESRI Shapefile data to depict geographical boundaries. These three data sources each have differing data resolutions, coverages, and formats. Combining them together into a single analysis was key to

***Corresponding author address**: *Steven G. Hoffert, Boeing Autometric, 7700 Boston Blvd., Springfield, VA 22153, 703-923-4052; e-mail: shoffert@autometric.com*

demonstrating the critical capability of fusing different image types with ancillary data. To accomplish the data fusion, each data set was converted to a common reference frame. An example of the combined data layering capability is shown in Figure 1. Other examples of ancillary data that may be used are cloud masks, land-sea masks, land classification categories or digital terrain elevation data. Some of these ancillary data sets could be produced in the tool or obtained from other sources.

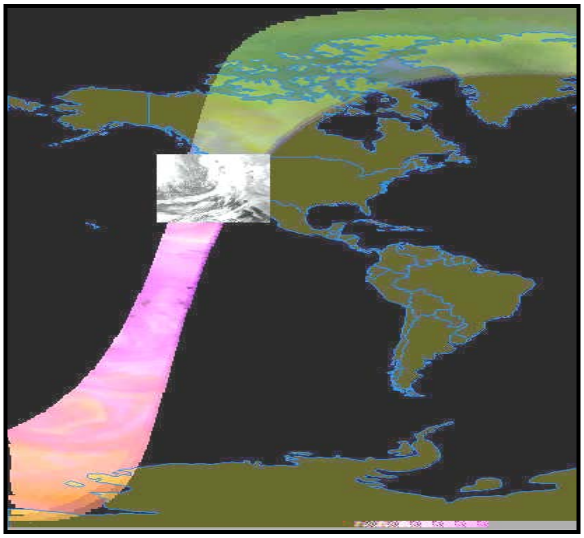
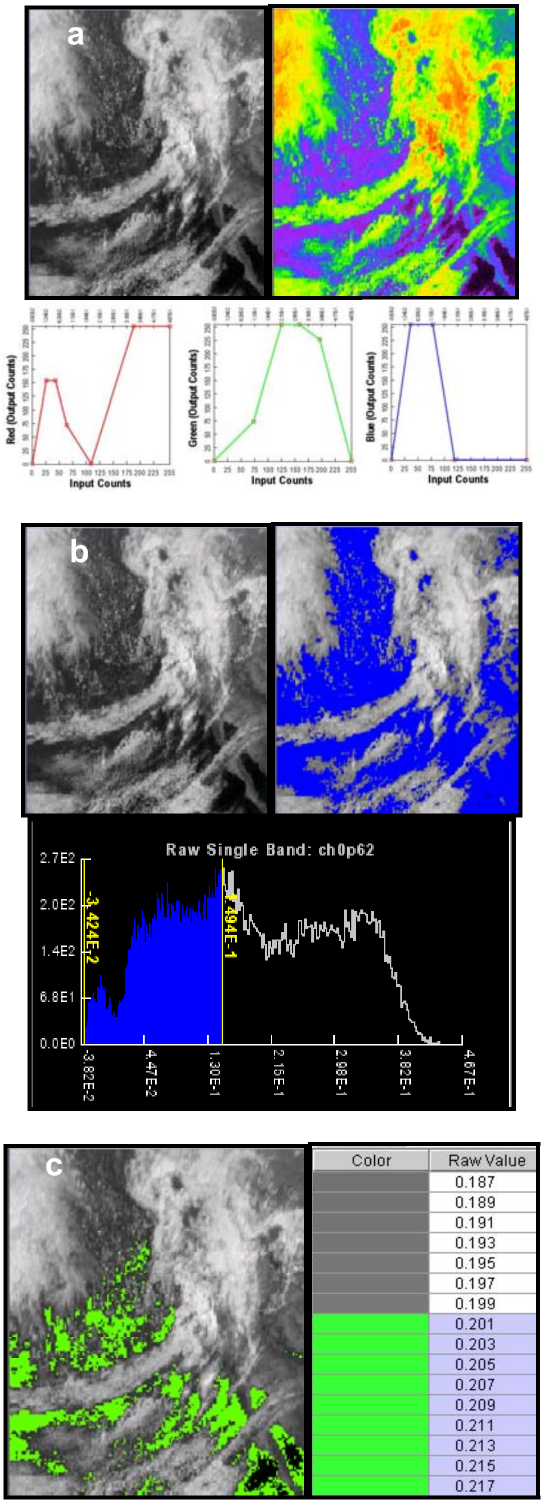


Figure 1. Layer Composite Capability. Shows the composite of three different layers of data: a GOES image subset (greyscale), microwave imagery (colored orbit swath), and a color-filled global Shapefile for country outlines.

3.2 *Colorization Techniques*

One of the key features developed allowed users to create single-band or multiple-band (composite) images and to manipulate the colorization of the image through several easy-to-use ‘point-and-click’ graphical techniques. Figure 2a depicts a single GOES visible channel (left) and the resulting colorized image (right) using user-defined RGB color enhancement curves based on raw data input counts vs. color output counts (bottom). Figure 2b depicts a second technique using the same GOES visible channel (left) with a resulting colorization of certain pixels (right) based on a user-specified range of raw data values, albedo in this instance, from within a frequency distribution of all possible raw data values in the image (bottom). Figure 2c depicts a third technique using the GOES visible image, this time with certain pixels colored (left) based on the user specifying different colors for specific raw data values, or ranges of raw data values (right).



Color	Raw Value
▨	0.187
▨	0.189
▨	0.191
▨	0.193
▨	0.195
▨	0.197
▨	0.199
🟩	0.201
🟩	0.203
🟩	0.205
🟩	0.207
🟩	0.209
🟩	0.211
🟩	0.213
🟩	0.215
🟩	0.217

Figure 2. Colorization Capability. Image colorization of a GOES visible channel using (a) RGB color enhancement curves, (b) raw data value frequency distribution color bins, (c) raw data value color editing.

3.3 *Plugin Algorithms*

The most powerful analysis feature developed in IAT allows users to develop and ‘plug in’ their own sets of equations (i.e. algorithmic analyses) into the tool. To accomplish this, a graphical user interface was invented to allow the analysts to build equations, or a sequence of equations, via a straightforward ‘point and click’ paradigm. Once loaded into the tool, the analyst may designate individual image bands and supporting data layers as variables when entering the equations making up the algorithm. The analyst may save the equation or sequence of equations just entered, and name/comment them appropriately for sharing with others. In fact, it is important to note that the saved algorithms are 1) language independent and 2) may be re-used by contemporaries with the same tool, either on the same or different data sets. To demonstrate this capability, three algorithms were identified via an Internet search and entered in sequence and processed as a single image. The results are shown in Figure 3.

The three algorithms were:

(1) A cloud identification algorithm from the University of Wisconsin web site that uses the difference between the 10.68 and 11.28 micrometer bands to establish a cloud mask. This algorithm was developed for MODIS. (http://cimss.ssec.wisc.edu/modis/cldmsk/newmask.html)

(2) A sea surface temperature determination algorithm from the University of Miami web site. This algorithm was also developed for MODIS. (http://www.rsmas.miami.edu/modis/ir_atbd_05_99.pdf)

(3) A land surface temperature determination algorithm from Raytheon Corporation and the University of Colorado land surface temperature ATBD document for NPOESS (the National Polar-orbiting Operational Environmental Satellite System). This algorithm was developed for the new VIIRS sensor, the next-generation to MODIS. (http://npoesslib.ipo.noaa.gov/atbd/viirs/Y2399-LandTemp-ATBD-v5.doc)

The three algorithms were entered into the IAT equation editor, with undefined constants entered as representative values for the proof-of-concept demonstration, and implemented in sequence for a test MODIS image. First, however, a land-sea mask was derived from the image using a ratio technique of channels 1 and 2 of the MODIS image and used subsequently as outside ‘ancillary data’ for the exercise. The first algorithm generated a cloud mask and thus filtered out pixels in the image for which neither land nor sea surface temperatures could be calculated. From the remaining pixels, the land-sea mask was then used to determine the pixels where the second and third algorithms could be applied, respectively, to calculate the sea surface temperatures and land surface temperatures. The sea surface temperatures reached a maximum of 284.15 degrees Kelvin. The land surface temperatures ranged from 258 to 340 degrees Kelvin. The MODIS image was taken sometime in late February and reasonable values were approximated for the constants and coefficients. As a result, any inaccuracies were solely due to the selection of parameters and coefficients and do not necessarily reflect upon the algorithms themselves or the investigators. The primary goal was to simply demonstrate that multiple algorithms could be culled from a variety of different sources and plugged into the tool and executed in a fast and robust manner. Each algorithm used different image bands from the raw MODIS image and, collectively applied, IAT was able to successfully analyze multiple characteristics (clouds, sea surface temperatures, and land surface temperatures) using a single process that ensured the application of the algorithms to the correct pixels using the appropriate masking information. Figure 3a depicts the cloud-masked pixels. Figures 3b and 3c depict the colorized sea surface temperatures and land surface temperatures for those pixels defined by the land-sea mask, respectively. Figure 3d depicts the combined scene based on all of the masks and related algorithms.

This proof-of-concept demonstration using the IAT tool was successful. It clearly shows that analysts can enter their own language independent algorithms, define and set relevant thresholds, update constants as needed, and select different image bands for analysis by simply editing the last saved version of the algorithm. Moreover, a full set of intrinsic mathematical functions are available in IAT from which the analyst can construct the equations required by the algorithm. Adding new mathematical functions to IAT is easy.

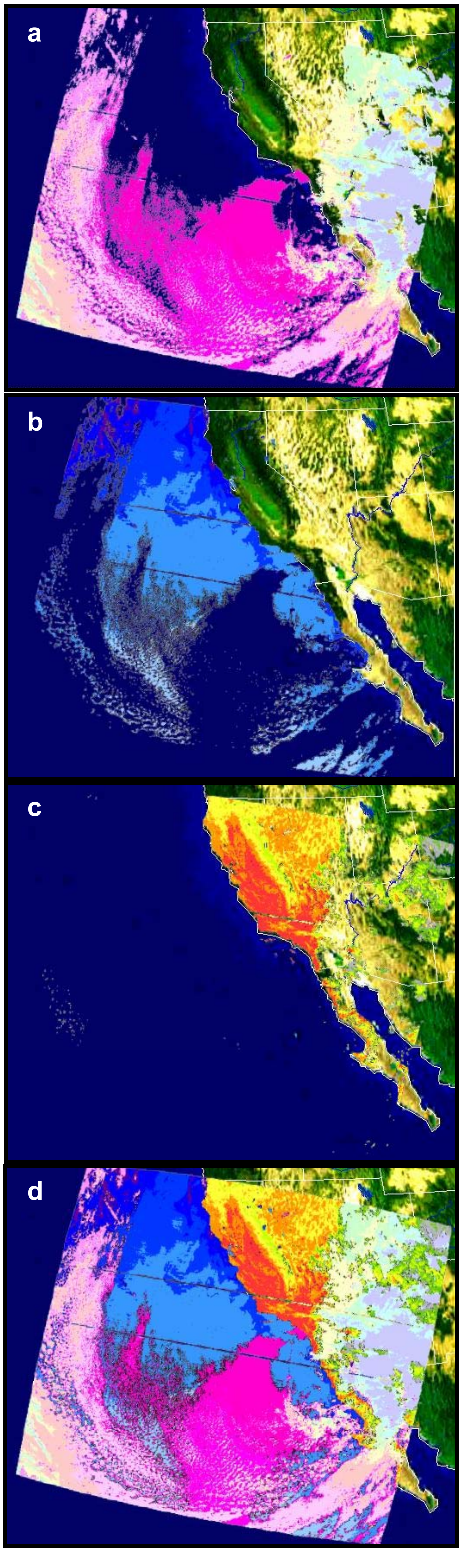
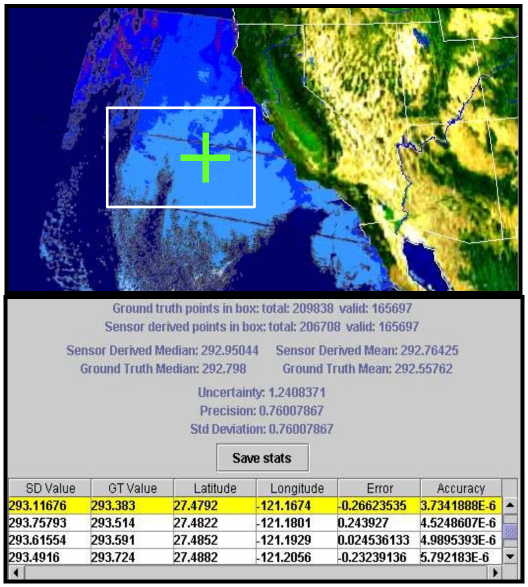


Figure 3. Algorithm Capability. (a) Cloud mask only shown as white to pink, (b) Sea surface temperatures only shown as shades of blue, (c) Land surface temperatures only shown as red, yellow, orange, and green, (d) Complete analysis. All analyses are shown against a background LANDSAT image of the Earth.

3.4 *Statistical Analysis*

An additional feature developed in IAT is the ability to bring in supporting gridded data types, such as forecast model output and ground truth data sets, that allow the analyst to statistically validate the performance of their sensor-derived algorithms. Figure 4 depicts the same MODIS-derived sea surface temperatures and user-defined area of interest (top), together with a table of correlation statistics (bottom), computed pixel by pixel, between the “sensor-derived” SST values and “ground truth” SST values imported as an ancillary gridded dataset. For each pixel in the box, a table lists the sensor-derived value (“SD Value”), the ground-truth value (“GT Value”), and several statistical parameters including error and accuracy. Similar statistics can be generated for 3-D datasets, such as an array of wind, temperature, or relative humidity vertical profiles derived from sounder data, versus a corresponding observational-based 3-D data cube. By being able to 1) directly compare a sensor- or algorithm-derived dataset with an ancillary ground-truth dataset and 2) quickly modify the algorithm using the equation editor, the analyst is able to effectively measure the performance of and, resultantly, minimize the error of the algorithm iteratively. This capability can significantly speed up the overall scientific development and analysis process.



Ground truth points in box: total: 209838 valid: 165697
Sensor derived points in box: total: 206708 valid: 165697

Sensor Derived Median: 292.95044 Sensor Derived Mean: 292.76425
Ground Truth Median: 292.798 Ground Truth Mean: 292.55762

Uncertainty: 1.2408371
Precision: 0.76007867
Std Deviation: 0.76007867

SD Value	GT Value	Latitude	Longitude	Error	Accuracy
293.11676	293.383	27.4792	-121.1674	-0.26623535	3.7341888E-6
293.75793	293.514	27.4822	-121.1801	0.243927	4.5248607E-6
293.61554	293.591	27.4852	-121.1929	0.024536133	4.9895393E-6
293.4916	293.724	27.4882	-121.2056	-0.23239136	5.792183E-6

Figure 4. Statistical Analysis Capability. Statistical comparison of sensor-derived SST values (SD Value) vs. an observational ground truth SST dataset (GT Value), computed for all pixels inside the box. The row highlighted in yellow shows the comparison for the user-defined pixel at the green plus sign.

4. CONCLUSION

Boeing Autometric continues to research and develop integrated tools for supporting the use of disparate data sets in a variety of environmental applications. The overarching goal of the image analysis tool (IAT) just described is to provide a more flexible approach to the image analysis process whereby analysts can enter their own algorithms and use non-traditional data sets in ways not previously available. The proof-of-concept demonstration of this capability was very successful in that regard.

The Operational Significant Event Imagery (OSEI) group within the National Oceanic and Atmospheric Administration's (NOAA) Satellite Analysis Branch is currently testing the utility of IAT for supporting their operational data analysis and product generation. Moreover, additional data interfaces are also being developed to support the analysis of commercially available data, such as the TeraScan format from SeaSpace Corporation, a key commercial provider of atmospheric, land, and oceanic-based remotely sensed data.

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