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GIS SOFTWARE DEVELOPMENT: SUMMER INTERNSHIP WITH CLARK LABS

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GIS SOFTWARE DEVELOPMENT: SUMMER INTERNSHIP WITH CLARK LABS

ZIKANG ZHOU

MAY 2015

A MASTER'S PROJECT

Submitted to the faculty of Clark University, Worcester,
Massachusetts, in partial fulfillment of the requirements for
the degree of Master of Science in the department of International Development,
Community, and Environment

And accepted on the recommendation of

Yelena Ogneva-Himmelberger, Chief Instructor

ABSTRACT

GIS SOFTWARE DEVELOPMENT: SUMMER INTERNSHIP WITH CLARK LABS

ZIKANG ZHOU

This paper describes my personal internship experience during the summer of 2014. I worked as a part-time student research assistant at Clark Labs and focused on the development of new modules for IDRISI GIS software. I created the new LANDSAT module for importing and preprocessing Landsat Archive imagery. I also created an option in the TassCap module for performing Landsat 8 Tasseled Cap transformation.

Through collaboration with GIS and remote sensing professionals at Clark Labs, I successfully applied my geospatial knowledge to real-world software development works.

This experience also sharpened the skills I learned at Clark University and was directly related to my career goals. I highly recommend this internship to future GISDE students who wish to apply their knowledge to programming GIS software that facilitates geographers' understanding of the world.

Yelena Ogneva-Himmelberger, Ph.D.

Chief Instructor

ACADEMIC HISTORY

Name: Zikang Zhou

Date: May 2015

Baccalaureate Degree: Bachelor of Engineering, Remote Sensing Science and Technology

Source: Wuhan University, Wuhan, Hubei, China

Date: June 2013

DEDICATION

This paper is dedicated to Clark Labs fellows for the fabulous summer.

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I would like to thank Professor J. Ronald Eastman for providing me this internship opportunity and for his support of my work. I would also like to thank Professor Yelena Ogneva-Himmelberger for guiding me throughout this internship paper. Moreover, I would like to thank Molly Cox, Holly Zanoni, and Shu Zhang for the valuable suggestions on editing this paper. At last, I would like to thank our GISDE crew for the wonderful studying and working experience I have never had before.

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CHAPTER 1: INTRODUCTION

The Geographic Information Science for Development and Environment (GISDE) program is a joint master's program of the International Development, Community, and Environment (IDCE) department and the Graduate School of Geography at Clark University. As partial fulfilment of the requirements for this graduate program, I completed a GIS software development internship at Clark Labs in the summer of 2014. Clark Labs is best known for the IDRISI GIS and Image Processing software. Upon the release of the newest version, I was mainly responsible for two modules during the three-month internship. I created a new LANDSAT module for importing and preprocessing Landsat Archive imagery automatically. I also updated the TassCap module for supplementing an option to process multispectral image bands acquired by Operational Land Imager (OLI) sensor onboard the Landsat 8 satellite.

This internship was not only a perfect match for my research interests combining geography and computer programming, it also guided my ongoing GIS career towards a more explicit goal. In addition to what I have contributed to IDRISI, I have also harvested a significant amount of knowledge and experience in GIS software development through this valuable internship opportunity which will benefit me in the second year's course study and throughout my job hunting in the future.

This paper is an official report of my personal internship experience with the programming team of Clark Labs. It is organized into five separate chapters to provide the introduction and background information of this internship (Chapter 1), the history,

missions and team structures of Clark Labs (Chapter 2), my intellectual contribution to Clark Labs during the summer (Chapter 3), the overall self-assessment of my responsibilities (Chapter 4), and the conclusion and recommendation for other GISDE students who would be interested in working at Clark Labs (Chapter 5).

CHAPTER 2: DESCRIPTION OF ORGANIZATION

Graduate School of Geography at Clark University

Established in 1921, the Graduate School of Geography at Clark University is the oldest Geography graduate program in the United States that remains in existence.

Through almost 100 years of dedication in the development of geographical topical fields and technologies, Clark Geography has witnessed how traditional geography interacts with other disciplines and evolves over time.

Geographic Information Science (GIS) is rapidly growing information technology. The Graduate School of Geography at Clark University serves as the solid background of Clark Labs and provides innumerable technical, monetary, and educational supports to help Clark Labs on the development of an epicly distributed geographic information system – the IDRISI GIS and Image Processing System. From an administrative level, Clark Labs is a research laboratory of the Graduate School of Geography. From this perspective, the Graduate School of Geography at Clark University is one of the only degree-granting programs to have its own commercial GIS software (Clark University 2014).

History and missions of Clark Labs

Professor J. Ronald Eastman, who is the prime developer and chief architect of software product, founded Clark Labs in the mid-1980. Clark Labs has been dedicated to conducting scientific research and applying geospatial technologies to a wide range of

programs including: the IDRISI GIS and Image Processing software system, the CARTALINX Spatial Database Builder software system, technology transfer for international development, GIS Training, and educational materials development.

Clark Labs focuses on providing GIS tools for the manipulation and analysis of geospatial data in recent decades. Its well-known flagship product, the IDRISI software system, was first released in 1987. IDRISI offers a complete set of toolkits to conduct remotely sensed image processing tasks. In addition to the basic GIS and image processing and analysis tools, IDRISI also provides unique modelers to help guide responsible environmental decisions. These modelers include Land Change Modeler (LCM) for land use management, Earth Trends Modeler (ETM) for time series data analysis, and Ecosystem Service Modeler (ESM) for sustainable ecosystem management.

Over nearly 30 years of development, Clark Labs has gained over 100,000 registered users within more than 180 countries worldwide. Its partner organizations include the Gordon and Betty Moore Foundation, Environmental Systems Research Institute (ESRI), Google.org, USDA, the United Nations, and Conservation International. “Clark Labs leverages its academic base to develop innovative and customized research tools, to provide software solutions to organizations in need, and to apply geospatial expertise to a range of real-world problems.” (Clark Labs 2014) Until today, IDRISI has accumulated nearly 300 professional modules to support geospatial solutions.

Organization structure of Clark Labs

Clark Labs, as an environmental consulting service provider and a geospatial software development organization, has three collaborative teams working together to serve its clients and provide software solutions. The three teams are programming team, testing team, and researching team.

Supervised by the Director Professor J. Ronald Eastman and Executive Director Dr. James Toledano, these three teams are effectively working together to “provide quality products for researchers, scientists, organizations, and companies engaged in analyzing earth system dynamics for effective and responsible decision making for environmental management, sustainable resource development and equitable resource allocation” (Wikipedia 2014).

The main duty of the programming team is to develop new modules and fix bugs within existing modules of IDRISI. This team also provides software solutions and creates compatible software extensions or online geospatial services to clients.

The main duty of the testing team is to locate potential logic and appearance bugs of newly developed modules as well as providing technical support to IDRISI users worldwide.

The main duty of the research team is to conduct research and offer geospatial solutions on environment, sustainability, and conservation projects.

CHAPTER 3: INTERNSHIP RESPONSIBILITIES

Software development at Clark Labs

My internship at Clark Labs lasted from June 1 to August 31 in 2014. Supervised by Professor J. Ronald Eastman, I worked as a part-time research assistant focusing on developing IDRISI software.

Software development work at Clark Labs follows very strict regulations in downloading and uploading codes through a version control software. This strategy ensures automatic codes archiving, convenient codes sharing, and flexible software version controlling. In case of extreme situations, Clark Labs also keeps another copy of entire codes in a remote server located at Information Technology Services (ITS) office of Clark University.

Programmers at Clark Labs are required to comply with a Non-Disclosure Agreement (NDA) and thus are prohibited to reproduce, represent, or share any of their outcomes from Clark Labs without being approved. This agreement ensures the ingenuity of geospatial software solutions offered by Clark Labs, and creates an unmatched position for Clark Labs in today's terrestrial modeling software market.

I spent the first few weeks of my internship getting familiar with the general procedures of software development at Clark Labs. I learned the fundamental structures of IDRISI and how it evolved with computer information technologies. To get a better understanding of IDRISI software development, I was trained in creating basic overlaying

functionalities with Delphi, which is the major programming language for IDRISI development.

Then, I successively took the responsibility for two tasks. The first one was to update the Tasseled Cap transformation (TassCap) module to make it compatible with Operational Land Imager (OLI) imagery from Landsat 8. The second one was to redesign the Landsat module to assist the data format conversion and atmospheric correction work.

Tasseled Cap transformation (TassCap) module

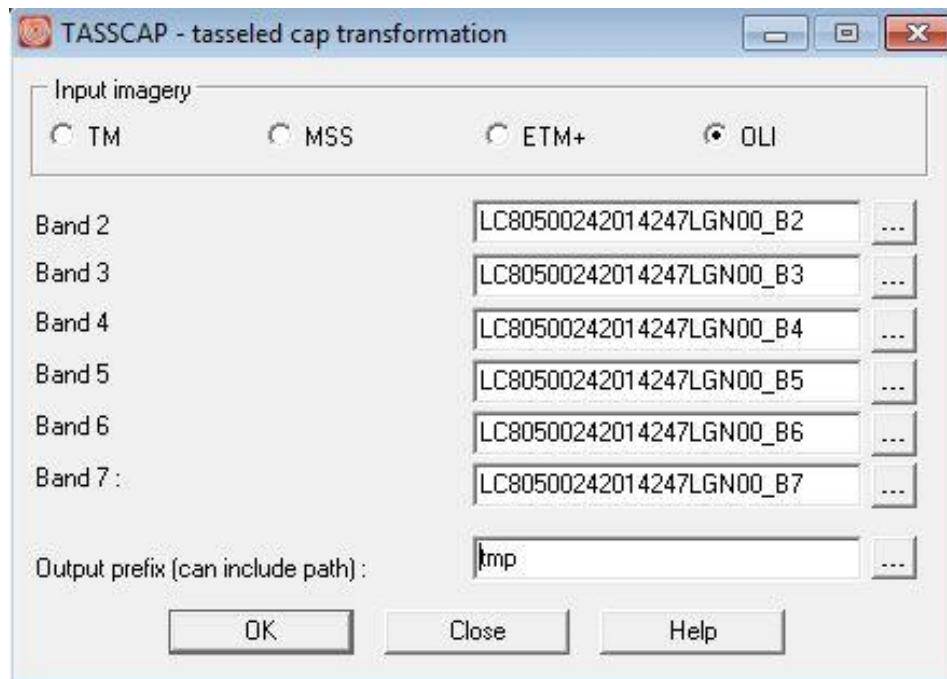


Figure 1. Graphic User Interface of TassCap module

New research outcomes of Tasseled Cap transformation based on Landsat 8 at-satellite reflectance (Muhammad Hasan Ali Baig et al. 2014) were applied for the new input option (OLI).

Tasseled Cap transformation is a conversion from original multispectral bands to a new set of bands with predefined interpretations that are useful for vegetation mapping. Essentially, it is a linear combination of the original multispectral bands. However, the coefficients used to create the tasseled-cap bands are derived statistically from images and empirical observations. Thus, different research groups provide different coefficients for Tasseled Cap transformation based on various sensors and experiment environment.

IDRISI TassCap undertakes a “Kauth and Thomas” Tasseled Cap 4-dimensional transformation on 4 bands of Landsat Multispectral Scanner (MSS) or 6 bands of Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and OLI to extract three or four new index images. If TM/ETM+ imagery is used, the bands produced are Brightness, Greenness, and Moistness. If MSS imagery is used, the bands produced are Greenness, Yellowness, Brightness, and No-such. If OLI imagery is used, the bands produced are Brightness, Greenness, and Wetness. The Brightness image of TM/ETM+/OLI refers to soil brightness, while that of MSS refers to soil brightness and moisture. The Greenness image, sometimes referred to as Green Vegetation Index (GVI), highlights green vegetation cover or biomass above ground. The Moistness/Wetness image refers to soil moisture or ground wetness. The Yellowness, or Yellow Vegetation Index (YVI) of MSS contains information on vegetation that is decaying or drying out. The No-such image is associated with atmospheric noise.

As noted above, Muhammad Hasan Ali Baig et al. (2014) has derived a new set of the Tasseled Cap transformation coefficients for Landsat 8. These coefficients should be used cooperatively with the at-satellite reflectance products of original OLI bands. To get

those coefficients, Muhammad Hasan Ali Baig et al. (2014) adopted a newly developed standardized mechanism to transform the principal component analysis (PCA)-based rotated axes through Procrustes rotation (PR) conformation according to the TM-based Tasseled Cap space.

Firstly, OLI data were transformed into TM Tasseled Cap transformation space directly and considered as a dummy target. Then, PCA was applied on the original bands. Finally, PR was applied to get the transformation results in the best conformation to the dummy target image. Results showed that the coefficients for Landsat 8 OLI sensor derived by Muhammad Hasan Ali Baig et al. (2014) were in consistent with its predecessors.

I applied the following equations to calculate the Brightness, Greenness, and Wetness images from at-satellite reflectance image products according to the coefficients for Landsat 8 OLI sensor:

$$OLI\ Brightness = (OLI_2 \times 0.3029) + (OLI_3 \times 0.2786) + (OLI_4 \times 0.4733) + (OLI_5 \times 0.5599) + (OLI_6 \times 0.5080) + (OLI_7 \times 0.1872)$$

$$OLI\ Greenness = (OLI_2 \times (-0.2941)) + (OLI_3 \times (-0.2430)) + (OLI_4 \times (-0.5424)) + (OLI_5 \times 0.7276) + (OLI_6 \times 0.0713) + (OLI_7 \times (-0.1608))$$

$$OLI\ Wetness = (OLI_2 \times 0.1511) + (OLI_3 \times 0.1973) + (OLI_4 \times 0.3283) + (OLI_5 \times 0.3407) + (OLI_6 \times (-0.7117)) + (OLI_7 \times (-0.4559))$$

The Brightness, Greenness, and Wetness images in figure 2 are the sample Tasseled Cap transformation images produced by IDRISI TassCap. The original imagery is a single Landsat 8 scene from U.S. Geological Survey (USGS).

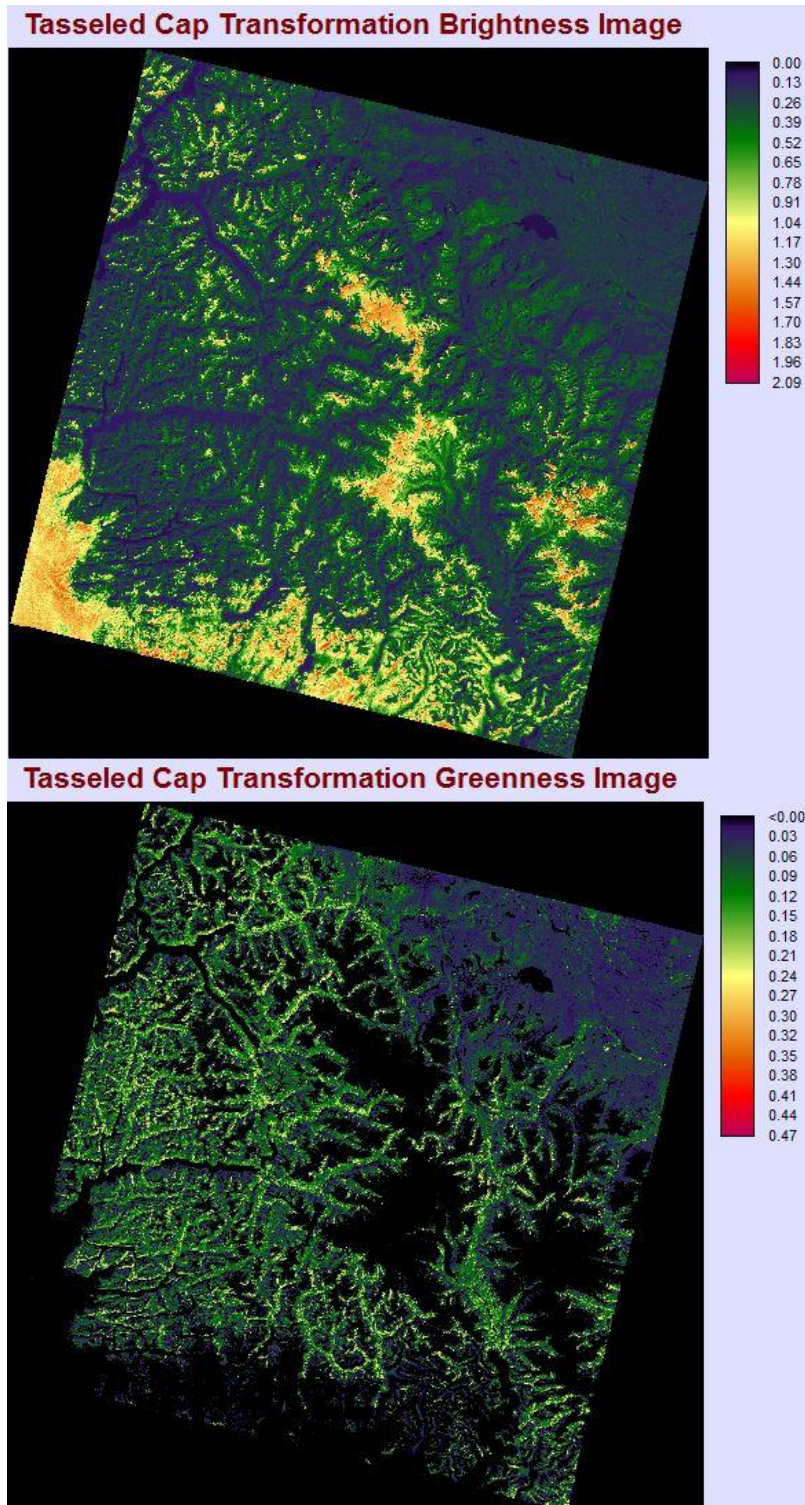


Figure 2. Tasseled Cap transformation images from Landsat 8 product

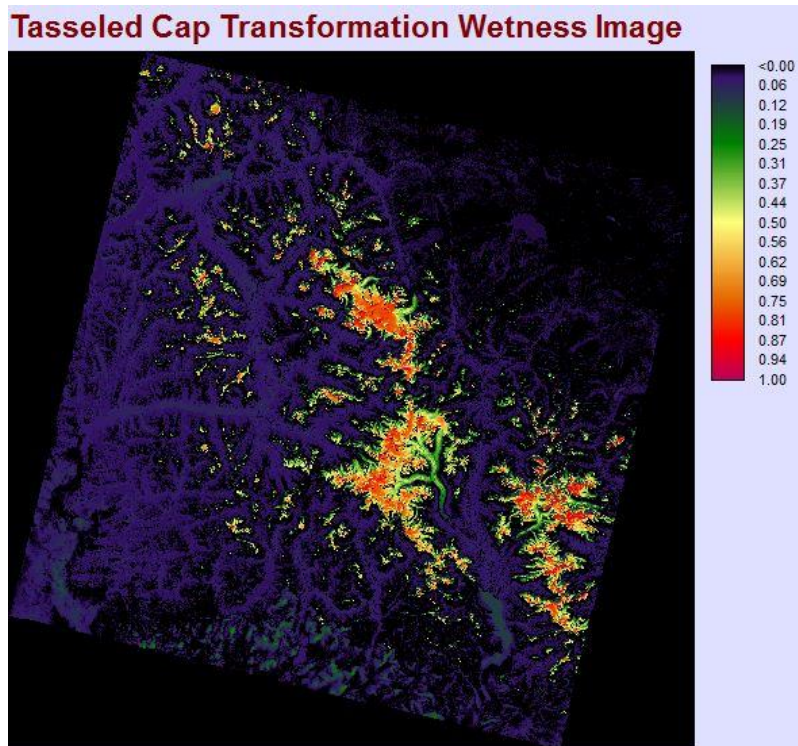


Figure 2 (continue). Tasseled Cap transformation images from Landsat 8 product

Landsat archive import (LANDSAT) module

I created the new IDRISI LANDSAT module to import archived Landsat data in GeoTIFF format to IDRISI RST format. This module uses metadata information from the MTL text file accompanying each Landsat scene. It provides functionalities including import of Landsat multispectral bands to IDRISI RST format as raw digital number (DN), top-of-atmosphere radiance, or reflectance with multiple correction method. It also offers the options to import Landsat thermal bands to IDRISI RST format as raw DN, top-of-atmosphere radiance, or at-satellite brightness temperature.

This module is intelligent enough to recognize metadata information about the Landsat scene that will be imported and processed. In addition, it will also disable invalid

options based on the bands that will be included. If one or more bands are not in current IDRISI working or resource folders, this module will report the missing information as well.

Compared with this module in the former version – IDRISI Selva, it is more powerful, convenient, and intelligent. It has fully considered all the possible Landsat missions and possible bands that the user may need, including Landsat 7 Gap Masks and Landsat 8 Quality Assessment Band.

See figure 3 for the Graphic User Interface (GUI) of the most powerful Landsat import and preprocessing tool in IDRISI.

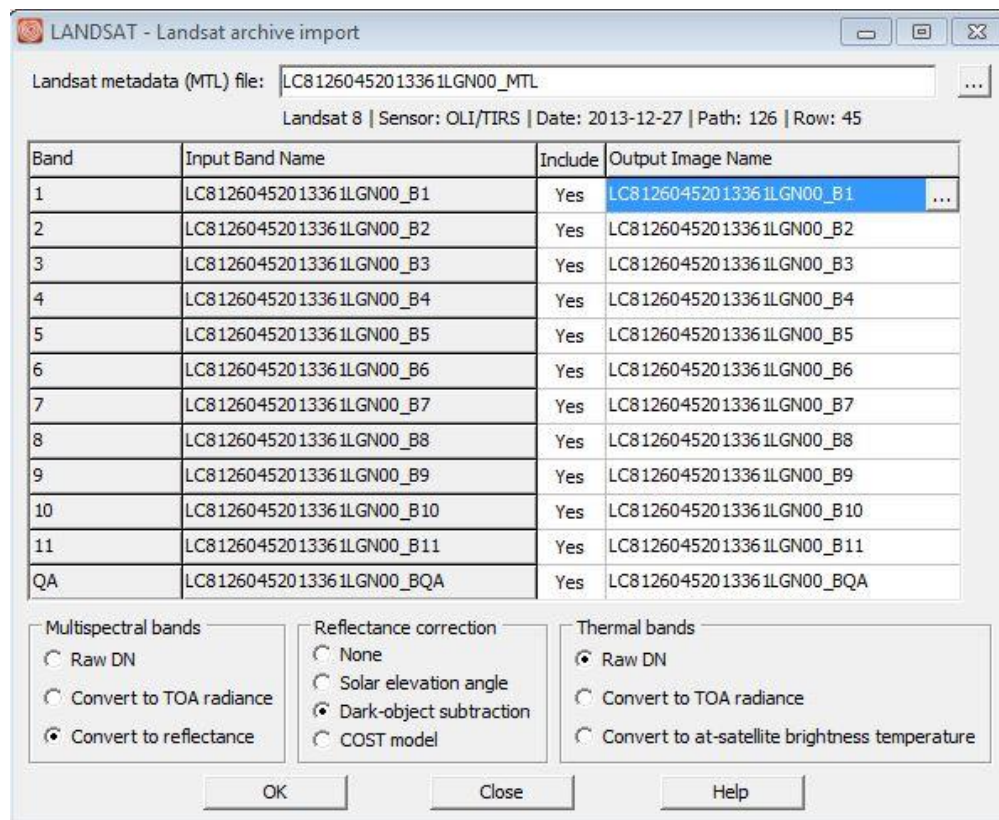


Figure 3. Graphic User Interface of LANDSAT module

The reason we made such big changes for this module lie in a recent act of USGS, the data producer and provider of Landsat imagery to standardize the image format (GeoTIFF) of all Landsat missions and distribute through the Landsat Satellite Archives in their Long Term Archive website (<https://lta.cr.usgs.gov/>). USGS also standardized the naming formats of images and metadata files of all Landsat missions as well as the contents of metadata files associated with Landsat Level 1 Products which are published for free. This act dramatically increased the efficiency of systematic searching and archiving practices of data (USGS 2014).

According to the relevant information provided in the Landsat metadata file of each scene, Landsat mission number, sensor name, acquisition date, and Worldwide Reference System (WRS) path and row will be extracted and displayed on the GUI interactively. Further, this module will search and identify the corresponding names among GeoTIFF files in the current working and resource folders. If any of the bands related to the metadata file provided cannot be found, warning information will be displayed in the corresponding grid. Otherwise, output image names will be generated automatically in the grids. Users can also switch the “include” option for each of the valid bands. This will be an important clue for the data preprocessing types of both multispectral and thermal bands.

The “Raw DN” option for both multispectral and thermal bands is the fundamental function. It only performs data format conversion from GeoTIFF to RST. This is also the default choice for the Landsat 8 Quality Assessment Band and Landsat 7 Gap Mask Bands.

For multispectral and thermal bands, more options are offered by new IDRISI LANDSAT. With the band-specific multiplicative and additive rescaling factors from the metadata file, raw DN can be converted to top-of-atmosphere radiance by this module:

$$L_{\lambda} = M_L Q_{cat} + A_L$$

L_{λ} : top-of-atmosphere spectral radiance (Watts / (m² * srad * μm)); M_L : Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number); A_L : Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number); Q_{cat} : Quantized and calibrated standard product pixel values.

For thermal bands, at-satellite brightness temperature can be derived from spectral radiance along with the thermal constants provided in either the metadata file (Landsat 8) or other research papers (Landsat 4, 5, 7) (Irish 2000, Chander et al. 2003):

$$T = \frac{K_2}{\ln\left(\frac{K_1}{L_{\lambda}} + 1\right)}$$

T : At-satellite brightness temperature (K); L_{λ} : TOA spectral radiance (Watts / (m² * srad * μm)); K_1 : Band-specific thermal conversion constant 1; K_2 : Band-specific thermal conversion constant 2.

For multispectral bands, top-of-atmosphere reflectance images can be derived from band-specific multiplicative and additive rescaling coefficients provided in the product metadata file:

$$\rho_{\lambda}' = M_{\rho} Q_{cat} + A_{\rho}$$

$\rho\lambda'$: TOA planetary reflectance, without correction for solar angle; M_ρ : Band-specific multiplicative rescaling factor from the metadata (*REFLECTANCE_MULT_BAND_x*, where x is the band number); A_ρ : Band-specific additive rescaling factor from the metadata (*REFLECTANCE_ADD_BAND_x*, where x is the band number); Q_{cal} : Quantized and calibrated standard product pixel values.

Once the top-of-atmosphere reflectance images are calculated, various reflectance correction options can be specified: “Solar elevation angle” option applies the solar elevation angle, “Dark-object subtraction” option applies an automatic haze removal algorithm to eliminate dark-object effect, and “COST model” option adopted dark-object subtraction plus a procedure for estimating the effects of absorption by atmospheric gases and Rayleigh scattering (Chavez 1996).

This module involves most Landsat data import and preprocessing needs for IDRISI users. This powerful, convenient, and intelligent module will absolutely increase the efficiency of working with Landsat data.

CHAPTER 4: INTERNSHIP ASSESSMENT

My internship at Clark Labs during the past summer was very productive regarding what I have learned and what I have contributed. It would be an excellent opportunity for any GISDE student to intern at Clark Labs as a GIS software developer in my perspective. Studying in this rapidly growing geographic technology, GIS students should take the responsibilities to develop geographic analytical methods and tools. This is fundamental to embrace people's growing needs in hi-tech geographic information products as well as to facilitate the development of traditional human and natural geographic studies.

My supervisor Professor Eastman is the instructor of *Advanced Raster GIS*, which is a required course of GISDE students, and the knowledge from *Introduction to Remote Sensing* taught by Dr. Alex Gardner also played an important role when I worked on my modules (TassCap and LANDSAT). The input data sources for these two modules are well-known remotely sensed imagery and products in raster formats. The processing methods applied on these modules are also well published and widely accepted in remote sensing and image processing fields. In terms of connection with my overall career goals, this internship at Clark Labs provided an excellent opportunity for me to develop GIS and image processing software. This is crucial for Clark Geography students who wish to take a GIS programming career path.

This internship offered me a valuable opportunity to work in a strong academic environment within the geography department. Through extensive interaction with people at Clark Labs, I have gained significant hands-on experience in GIS. I also learned a lot in

regards to the object programming skills and other essential computer skills in software development that I have never worked with before. Overall, I believe this internship gives me huge advantage in the GIS-related programming job market.

CHAPTER 5: CONCLUSION

Having the opportunity to work at Clark Labs is the most important reason why I chose the GISDE program at Clark University for my graduate studies. I was honored to be a student research assistant during last summer with the programming team within Clark Labs. This 3-month internship experience has successfully proved my choice to be one of the best decisions that I have ever made.

At Clark Labs, I was intensively trained to use IDRISI Application Programming Interface (API) for programming in Embarcadero RAD Studio XE4 environment. I learned Delphi programming language basics through getting familiar with IDRISI sample modules. For me, this was a crucial supplement to my GIS programming skills which I learned from *Computer Programming for GIS* course at Clark University. From this perspective, I recommend that GISDE students who wish to pursue a GIS programming career should add Clark Labs to their list. Guided by my supervisor at Clark Labs, I smoothly completed my tasks in time and obtained another offer to work at Clark Labs during the Fall 2014 Semester. My modules have been strictly tested by the testing team of Clark Labs and they will be published along with the latest IDRISI version.

In all, Clark Labs is an excellent academic research center focused on GIS software development. The GIS professionals at Clark Labs are all very friendly and ready to help which made my summer internship meaningful and fruitful.

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