Remote Sensing of Roads and Highways in Colorado

Large-Area Road-Surface Quality and Land-Cover Classification Using Very-High Spatial Resolution Aerial and Satellite Data

Contract No. **RITARS-12-H-CUB**

Quarterly Progress Report #1

Quarter from 08/15/2012 to 12/31/2012

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GLOSSARY

CDOT	The Colorado Department of Transportation
CU	University of Colorado
DG	DigitalGlobe Inc.
DN	Digital Number
IRI	International Roughness Index
MPO	Municipal Planning Office
QB	QuickBird
WV2	WorldView-2

EXECUTIVE SUMMARY

This projects seeks to find ways to link high spatial resolution optical satellite imagery to road surface conditions in Colorado as a way of reducing the cost of collecting this information by the relevant Colorado transportation agencies. The project has been organized with an advisory committee made up of representatives of government agencies, university personnel, and participants from our satellite partner, DigitalGlobe Inc.

Initial efforts consisted of gathering both historical in-situ data, collected by the responsible government agencies, and acquiring the corresponding satellite data. A special set of in-situ and satellite data in a small area of Colorado Springs has been collected for this initial study. Preliminary analyses have suggested that a simple direct comparison between satellite radiances and in-situ measurements of road surface conditions does not yield useful information.

As a result, statistical methods must be employed to link satellite data to the in-situ measurements. In addition, other methods are being explored where the satellite data is first classified and then linked to the in-situ observations. Also, classification analyses of satellite data may first be required to bring out features of interest at road levels. A workflow approach has been developed to improve these statistical links.

I — TECHNICAL STATUS

We are at the initial stage of the research, satellite imagery and in-situ data of surface conditions have been obtained and the primary assessments have been performed. The project website has been created. Two meetings of the project advisory committee have been held at CU. Preliminary comparisons between satellite and in-situ data have revealed a large difference between the resolution of the satellite data and that of the in-situ data sets. Thus, we need to learn more about each individually in order to optimize our analysis of them together. This report will end by introducing the workflow method we have developed to address these issues.

Data Acquisition

In-situ data have been acquired from Municipal Planning Offices (MPO) partners for: Colorado Spring Survey (El Paso and Teller Counties) in 2007, Larimer County in 2011 and 2012, and CDOT from 2007 to 2012. While each MPO uses a different pavement management system, we have successfully extracted road surface information for the assessment from the provided data.

Corresponding to the in-situ data collection time, satellite imagery and aerial data were selected from the archives and purchased from DigitalGlobe Inc. (DG). The coverage of these imageries overlap the in-situ data survey area well, and only small numbers of cloudy pixels are included since they cannot be utilized in the investigation. The obtained products information summary is listed in the following.

Sensor: WV02
Area of Interest: Colorado Springs, CO
Acquisition Date: 11/24/2012
Catalog ID: 103001001D5A4900

Sensor: WV02
Area of Interest: Larimer County, CO
Acquisition Date: 08/29/2012
Catalog ID: 103001001B7CC500

Sensor: QB
Area of Interest: El Paso and Teller Counties, CO
Acquisition Date: 10/26/2007
Catalog ID: 10100100074D0500

Aerial Data
Area of Interest: Larimer County, CO
Acquisition Date: 04/22/2011
Catalog ID: 5060010081239001

Additionally, a special in-situ data collection over a small region of interest in Colorado Springs was scheduled for the week of November 26, 2012 and completed. This was prearranged as part of this project to yield the highest possible in-situ data set for comparison with coincident satellite measurements. Our partner, DG, collected a very clear WV2 image over the target area a few days before the ground survey. Both satellite imagery and in-situ data process are in progress and planned to be delivered to us in the next quarter.

This should be an ideal data set to test our methods. The area survey was collected as part of this project to test satellite assessment of road surface conditions, and we plan to use these results to evaluate road conditions in a nearby area from satellite data alone for subsequent comparison with a new data set of in-situ data collected by the Pikes Peak (Colorado Spring) Municipal Planning Organization (MPO, Craig Casper, Analyst).

Preliminary Assessment

To develop satellite quality metrics and correlate with in-situ measurements, a small portion of QB panchromatic image is extracted and analyzed. In this small domain, as shown in Figure 1, pixels along three roads are manually selected and the corresponding digital number (DN) and surface parameters are compared. DN is closely related to at-ground spectral radiance, representing ground surface condition.

Figure 1. QB Panchromatic Image for a small portion of Colorado Springs

Figure 2 shows that satellite DN and road surface parameters plotting along Carefree Circle West road, which is indicated with Magenta line on the satellite image. While DN variability is significant, only three changes appear in the in-situ data over the same domain. This means there is a large difference between the resolution of the satellite data and that of the in-situ data sets.

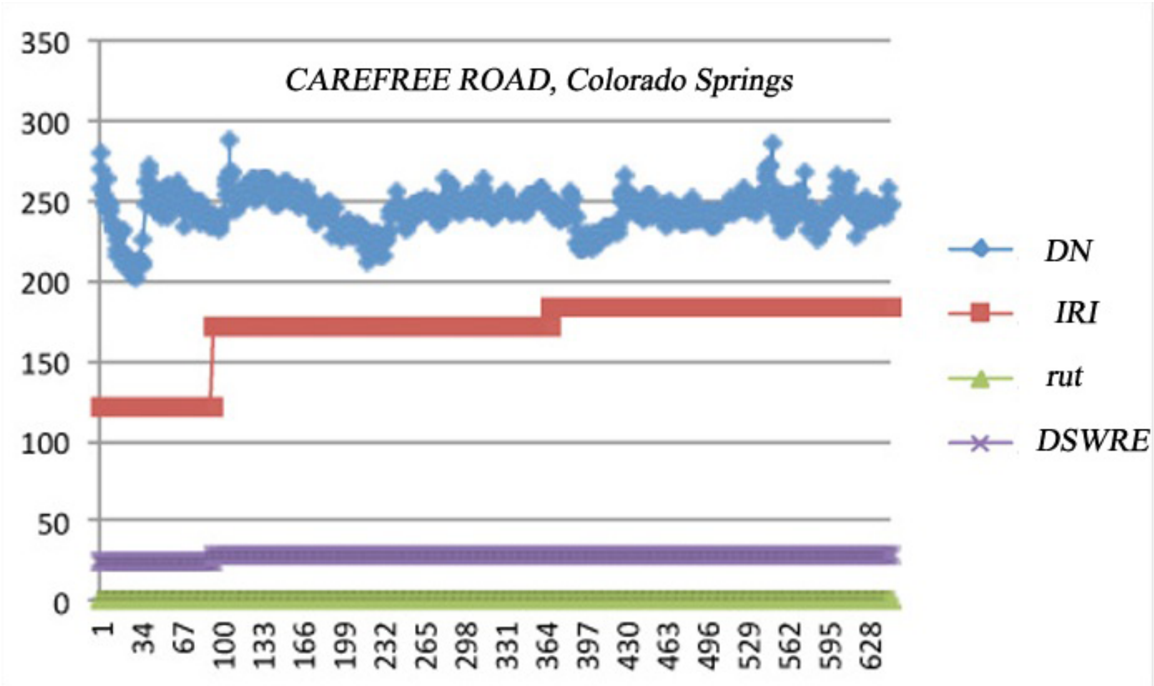


Figure 2. DN and road surface parameters

Therefore, it is necessary to aggregate the satellite pixels in order to match the in-situ data resolution to develop correlations. To accomplish this task, we need a better understanding about the nature of the variability of the spatial series. It is possible to quantify the spatial structure of the satellite data by using a wavenumber spectrum. Accordingly, wavenumber spectra of the roads are examined at the full QB spatial resolution. Figure 3 shows that DN variation along Rebecca Lane, which is indicated with red line on Figure 1. The corresponding wavenumber spectrum is shown in Figure 4 and the converted wavelength scale in meter is indicated at the top. This shows that the amplitude is significantly increased where the wavelength is shorter than approximately five meters. This tells us that there is a lot of variability in these DN that we can use for the analysis of road surface conditions. We hope that this type of analysis will point out the range of wavelengths characteristic in the satellite data that correspond to features that are seen in the in-situ data sets.

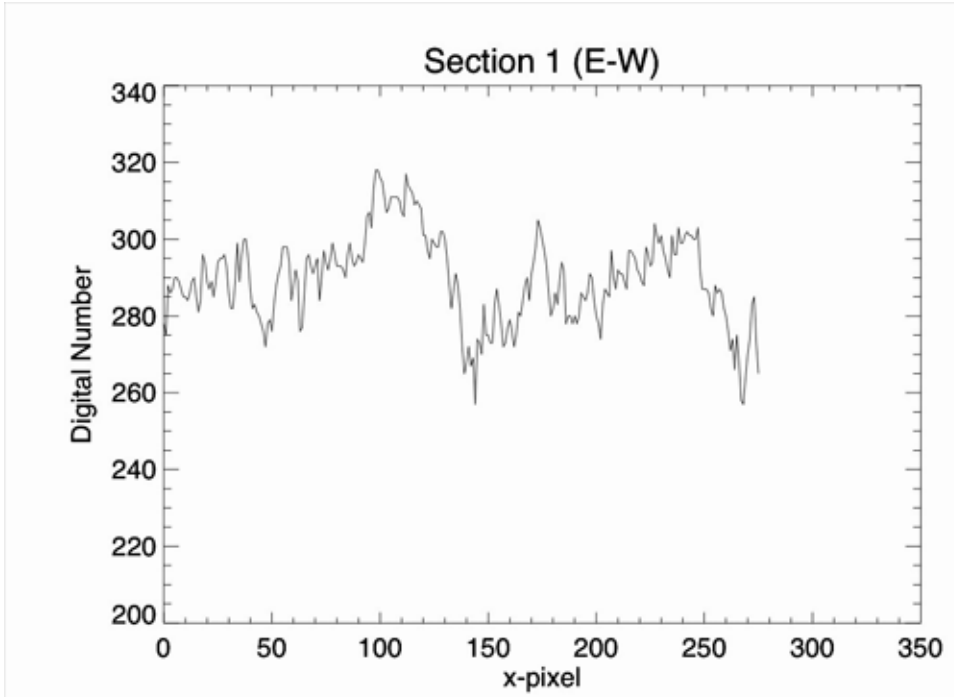


Figure 3. DN along Rebecca Lane in Colorado Springs

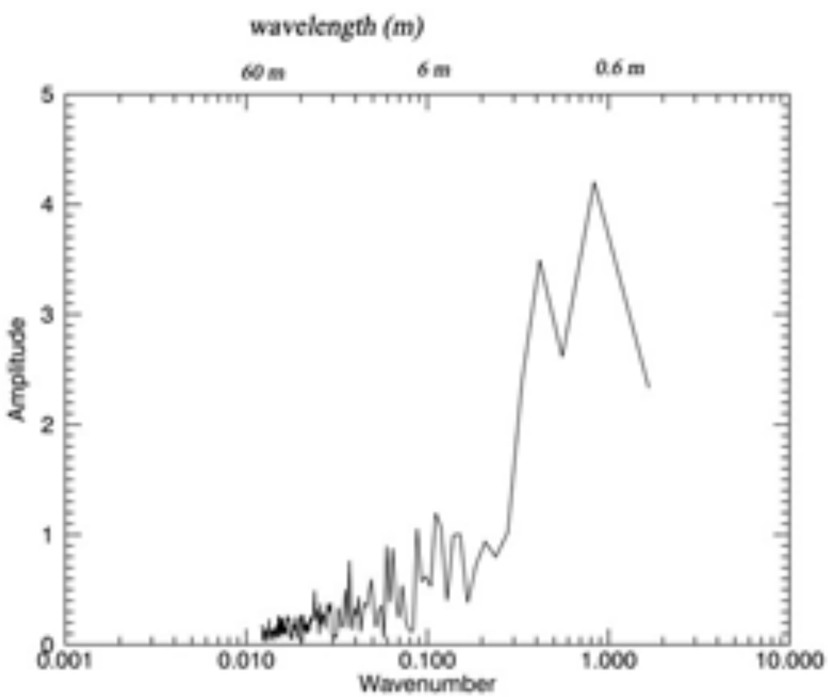


Figure 4. Wavenumber spectrum along Rebecca Lane in Colorado Springs

We also examined CDOT in-situ data between the years 2007 through 2012 to study highway degradation. Figure 5 shows IRI spatial variation along CDOT Highway Stretch #002A. It is noticeable that the lines are well correlated between all the years from beginning to end and some large and random spikes exist. This means that the IRI values suddenly increased in those ~0.1 mile segments. IRI is generally increased as time passed by, which implies that the pavement deterioration depends on time sequence.

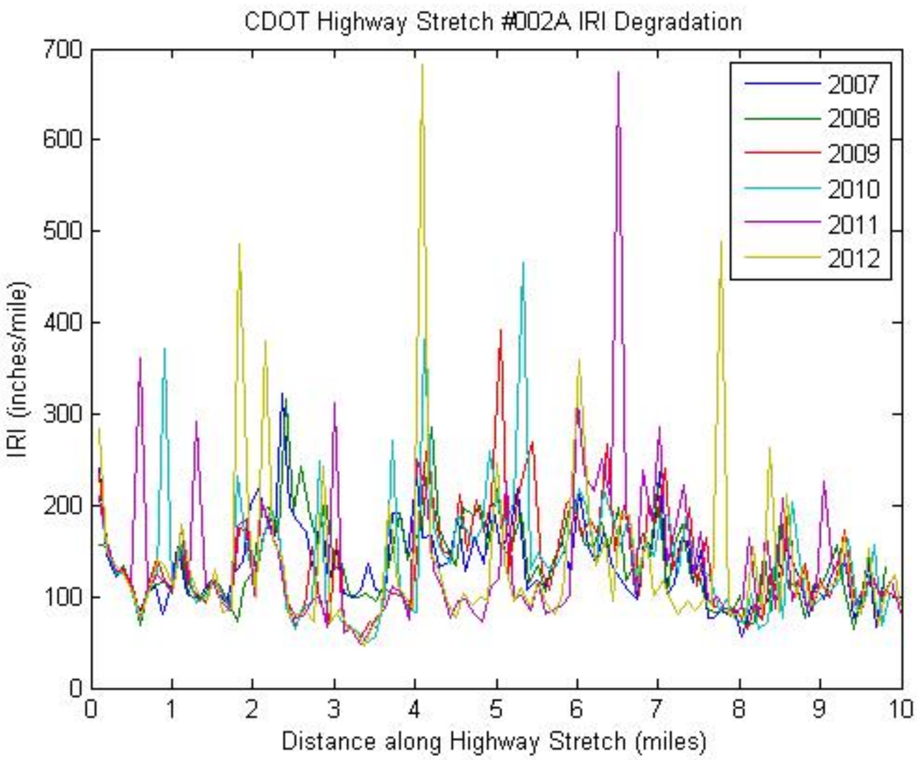


Figure 5. IRI spatial variation of CDOT Highway Stretch #002A

Figure 6 shows a rutting parameter histogram of CDOT Highway Stretch #002A. The higher and lower quality bins are located on the left and right in the plot, respectively. We can see normal distribution shifting towards the right from the left as the years go by. This trend also show the degradation is related to time sequence similar to the previous IRI analysis. These results imply that it is possible to find an accurate surface degradation rate by obtaining road-repaving information.

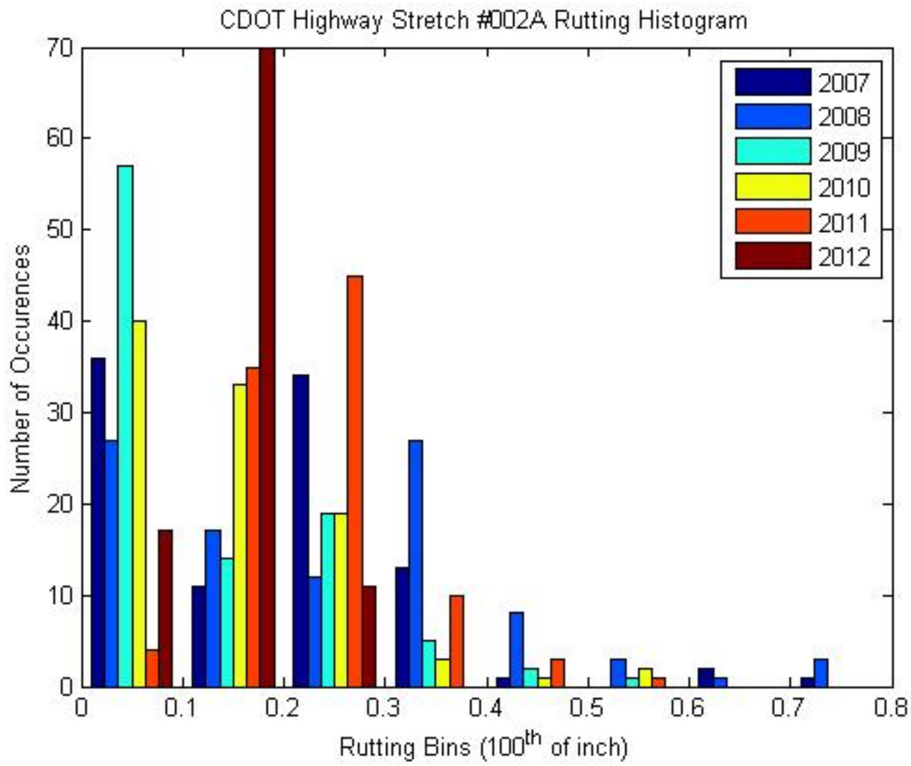


Figure 6. Rutting parameter histogram of CDOT Highway Stretch #002A

Project website

To communicate results to a wider audience of interested MPOs and related state and local government offices, the project website, Remote Sensing of Roads and Highways in Colorado, has been created. The URL is:

http://ccar.colorado.edu/dot/

The contents will be updated along with the research progress for the duration of the project.

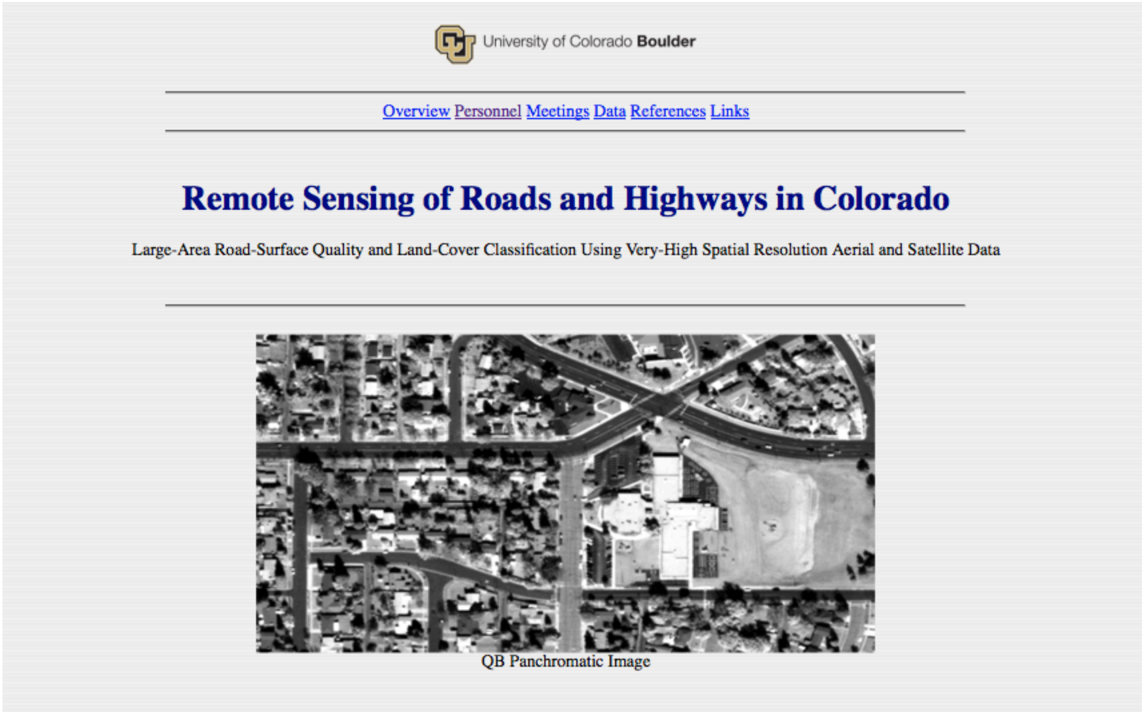


Figure 7. Top page of the project website

Future Plans

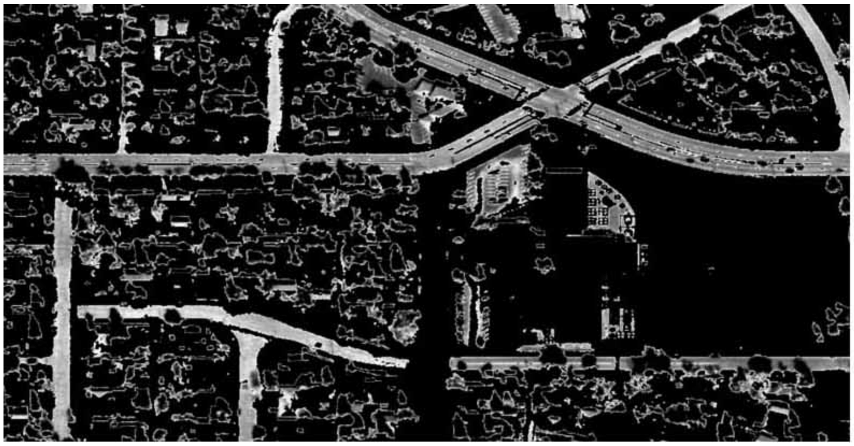
Our preliminary analysis shows that the direct comparison of collocated DN of satellite imagery and road surface parameters such as IRI is not a valid approach to develop a new algorithm. There is a distinct discrepancy of spatial resolution between satellite imagery and those parameters of in-situ data due to their definitions. For example, the IRI is calculated as a continuous property of a profile with units of slope (in/mi, m/km, etc.). On the other hand, satellite images are composed of pixels and the spatial resolution of QB and WV2 is approximately a half-meter. Since in-situ data is essential information for pavement planning and management, it is necessary to find valid processing techniques of satellite data and merge them to the in-situ measurements.

To establish a new algorithm, we also need to be aware of the undesirable information of satellite imagery. If a vehicle, white/yellow lines, shade, or any obstacles exists in a pixel, the corresponding pixel does not accurately represent the road surface condition. Thus, these contaminated pixels need to be eliminated for the comparison. The elimination will be manually performed at first, and some automated procedures will be implemented when the processing validity is confirmed.

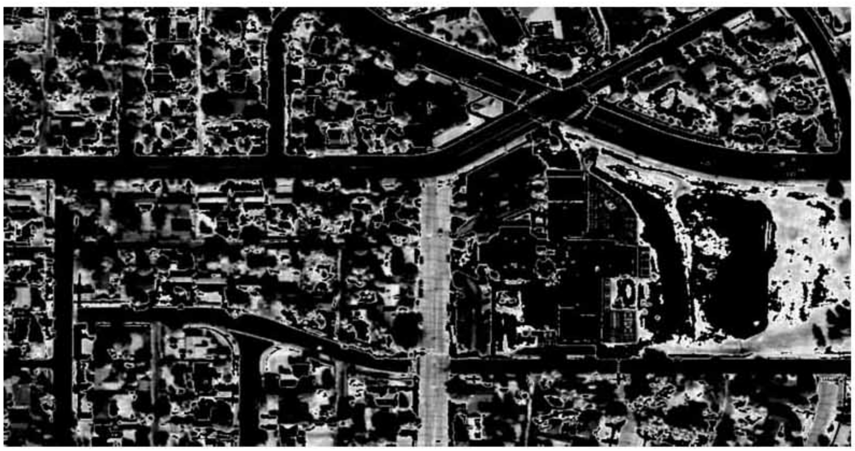
The series of images in Figure 8 demonstrates that there are indeed significant changes in surface roughness revealed by the satellite data itself. We need to develop methods to relate these changes to the in-situ data. The simple direct approach did not yield results due to the large difference in spatial resolutions. We need a new statistical approach that will capture the benefits of satellite data for analysis of the road surface information.

We also realize that there are other approaches that may prove better in linking satellite and in-situ data. For example, it may prove valuable to first spatially classify the road surface images before comparing them with the in-situ data sets. This would change the statistics dramatically from the 50 cm detail level to that of the analyzed satellite image.

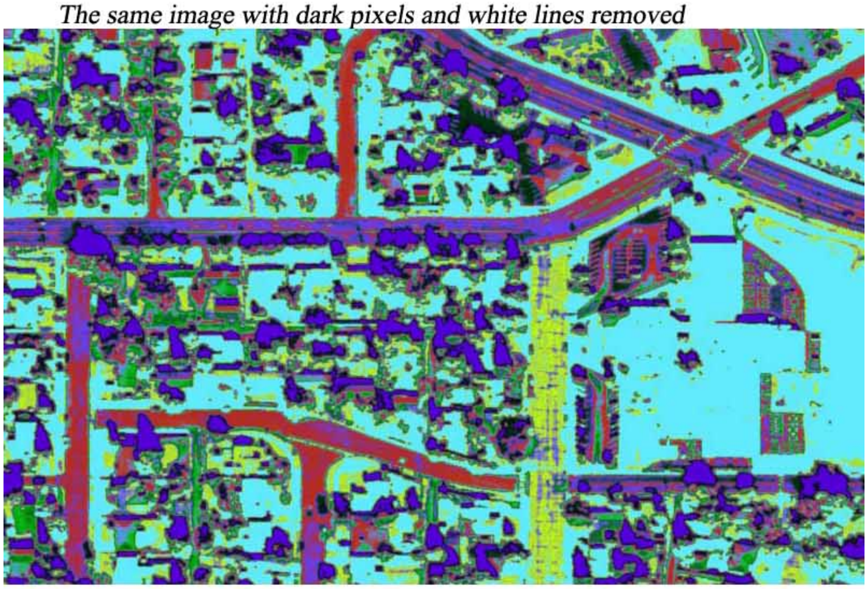
To merge satellite data and in-situ road surface data, we plan to explore larger road segments consisting of all the pavement conditions. Various statistical approaches will be applied and a machine learning technique will be utilized to establish empirical formulas. The whole process, which requires several software packages and individual procedures are shown in Figure 9 as a workflow diagram.



Original satellite image of roads in Colorado Springs



The same image with dark pixels and white lines removed



Color image showing changes in road surface conditions

Figure 8. QB images of the original DN and processed in different techniques over a small portion of Colorado Springs

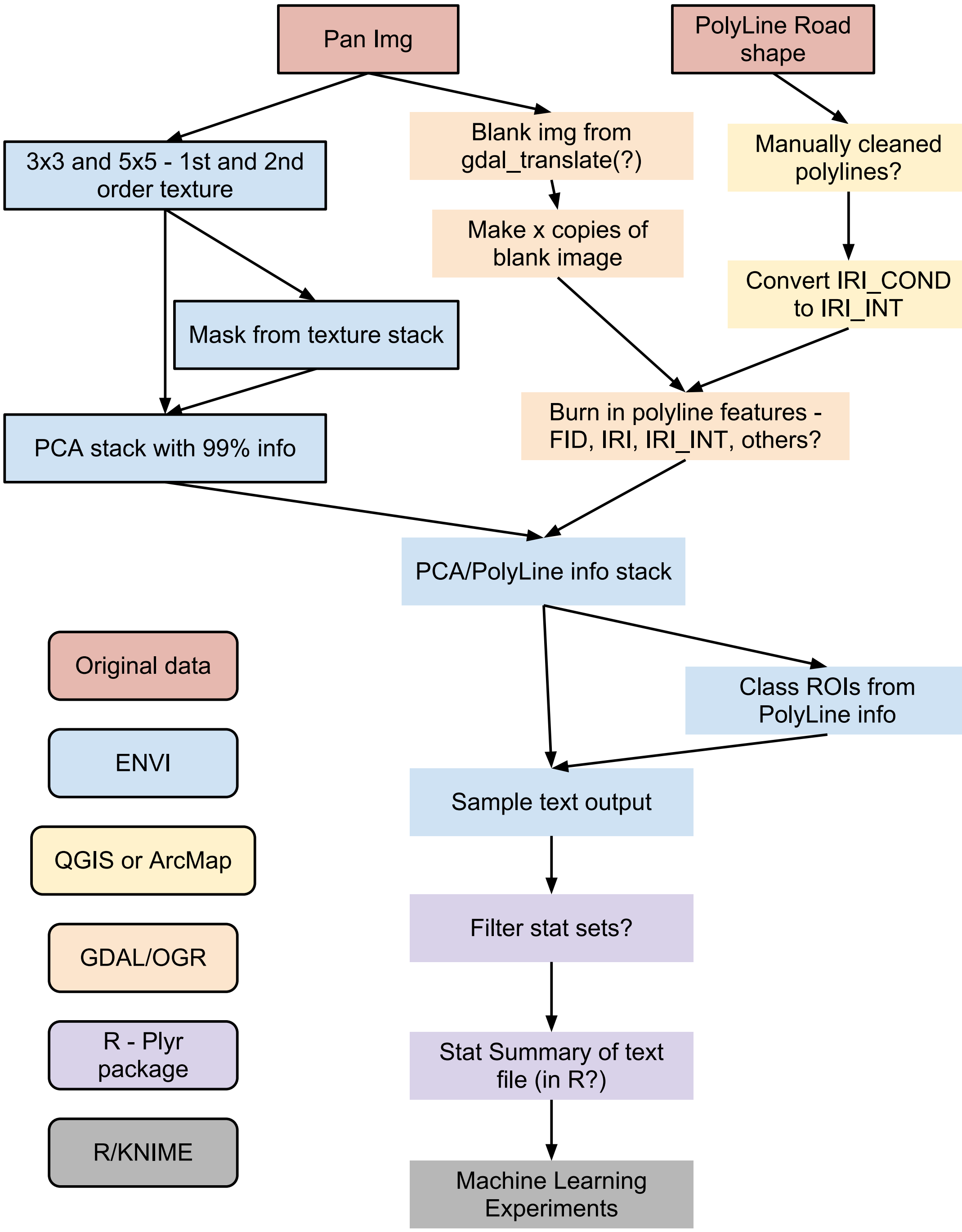


Figure 9. Statistical workflow diagram

II — BUSINESS STATUS

Please see Appendix.

ADVISORY COMMITTEE MEETINGS

The Technical Advisory Board has been established. Table 1 shows the committee members and other participants for the project. Two meetings have been held during this quarter at the Onizuka Conference Room of in the Engineering Center at CU-Boulder. Some participants attended remotely via phone and/or computer. The meeting dates were on August 20 and November 13 in 2012. The meeting materials are posted on the project website:

http://ccar.colorado.edu/dot/meetings.html

Name	Affiliate	Notes
Ted Borstad	Borstad Consulting Services LLC.	Technical Advisory Committee
Craig Casper	Pikes Peak Council of Governments	Technical Advisory Committee
Paul Chinowsky	Civil, Environmental, and Architectural Engineering Department, CU-Boulder	Technical Advisory Committee
John Daggett	Embrace Northern Colorado	Technical Advisory Committee
Cliff Davidson	North Front Range Metro Planning Organization	Technical Advisory Committee
William Emery	Aerospace Engineering Sciences Department, CU-Boulder	Principal Investigator, Lead Manager
Stephen Henry	Colorado Department of Transportation	Technical Advisory Committee
J. Pat Hill	City of Greeley Colorado	Technical Advisory Committee
Milan Karspeck	DigitalGlobe Inc.	Co-Principal Investigator
Tomoko Koyama	Atmospheric and Oceanic Sciences Department, CU-Boulder	Graduate Student
Nathan Longbotham	Aerospace Engineering Sciences Department, CU-Boulder	Technical Advisory Committee
Fabio Pacific	DigitalGlobe Inc.	Technical Advisory Committee
Amy Schweikert	Civil, Environmental, and Architectural Engineering Department, CU-Boulder	Graduate Student
Brett Thomassie	DigitalGlobe Inc.	Co-Principal Investigator
Ashwin Yerasi	Aerospace Engineering Sciences Department, CU-Boulder	Graduate Student

Table 1. Technical advisory committee members and research personnel

Appendix

FEDERAL FINANCIAL REPORT

(Follow form instructions)

1. Federal Agency and Organizational Element to Which Report is Submitted Department of Transportation	2. Federal Grant or Other Identifying Number Assigned by Federal Agency (To report multiple grants, use FFR Attachment) RITARS-12-H-CUB	Page 1 of 1 pages

3. Recipient Organization (Name and complete address including Zip code)

THE REGENTS OF THE UNIVERSITY OF COLORADO, 572 UCB,3100 MARINE ST, BOULDER CO 80309

4a. DUNS Number	4b. EIN	5. Recipient Account Number or Identifying Number (To report multiple grants, use FFR Attachment)	6. Report Type	7. Basis of Accounting
00-743-1515	1846000555A	1549569 & 1549570	☑ Quarterly ☐ Semi-Annual ☐ Annual ☐ Final	☑ Cash ☐ Accrual

8. Project/Grant Period From: (Month, Day, Year)	To: (Month, Day, Year)	9. Reporting Period End Date (Month, Day, Year)
08/15/2012	8/14/2014	12/31/2012

10. Transactions	Cumulative
(Use lines a-c for single or multiple grant reporting)	
Federal Cash (To report multiple grants, also use FFR Attachment):	
a. Cash Receipts	0.00
b. Cash Disbursements	59,918.05
c. Cash on Hand (line a minus b)	-59,918.05
(Use lines d-o for single grant reporting)	
Federal Expenditures and Unobligated Balance:	
d. Total Federal funds authorized	509,290.00
e. Federal share of expenditures	59,918.05
f. Federal share of unliquidated obligations	
g. Total Federal share (sum of lines e and f)	59,918.05
h. Unobligated balance of Federal funds (line d minus g)	449,371.95
Recipient Share:	
i. Total recipient share required	509,290.00
j. Recipient share of expenditures	25,847.91
k. Remaining recipient share to be provided (line i minus j)	483,442.09
Program Income:	
l. Total Federal program income earned	0.00
m. Program income expended in accordance with the deduction alternative	0.00
n. Program income expended in accordance with the addition alternative	0.00
o. Unexpended program income (line l minus line m or line n)	0.00

11. Indirect Expense	a. Type	b. Rate	c. Period From	Period To	d. Base	e. Amount Charged	f. Federal Share
	Predetermin	52.50%	8/15/12	12/31/12	39290.52	20627.53	20627.53
		0.00%					
				g. Totals:	39,290.52	20,627.53	20,627.53

12. *Remarks: Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation:*

13. Certification: By signing this report, I certify that it is true, complete, and accurate to the best of my knowledge. I am aware that any false, fictitious, or fraudulent information may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 18, Section 1001)

a. Typed or Printed Name and Title of Authorized Certifying Official Andy Wang, Grant Accountant 1/10/2013	c. Telephone (Area code, number and extension) 303-492-8925 d. Email address xingji.a.wang@colorado.edu
b. Signature of Authorized Certifying Official Andy Wang Digitally signed by Andy Wang DN: cn=Andy Wang, o=Sponsored Project Accounting, ou=The University of Colorado at Boulder, email=xingji.a.wang@colorado.edu, c=US Date: 2012.05.24 19:08:37 -06'00'	e. Date Report Submitted (Month, Day, Year) 01/10/2013
	14. Agency use only:

Standard Form 425
OMB Approval Number: 0348-0061
Expiration Date: 10/31/2011