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 #3

Quarter from 04/01/2013 to 06/30/2013

Principal Investigator
William Emery
Professor
Aerospace Engineering Science Department,
University of Colorado at Boulder

Program Manager
Mr. Caesar Singh
Research Innovative Technology Administration,
U.S. Department of Transportation

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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
PPACG	Pikes Peak Area Council of Government
QB	QuickBird
WV-2	WorldView-2

EXECUTIVE SUMMARY

One of the most notable successes of the previous quarter was the discovery that visual signatures of highway fatiguing could be observed in aerial photographs. In this quarter, we investigated this observation further. We resampled the aerial images to create synthetic satellite images. The purpose of this resampling was to determine whether the fatigue signatures were still present in low-resolution images. Although the fatiguing was not as clear, it could still be discerned. We performed some statistical analysis on the resampled images to find out if the fatiguing could be quantified. The statistical metrics that show the greatest promise for fatigue quantification are digital number, second correlation, and first skewness. Future investigation shall look more in depth into the road distress measuring potential of these metrics.

In addition, we have finally acquired the set of satellite images of Colorado Springs that coincides with the PPACG road survey that took place in December of last year. The familiar signs of fatigue were not quite evident in the satellite photographs. However, when the satellite images were swapped with Google Maps images, which have higher resolution and are colored, the fatiguing becomes clearer. We shall make greater use of the Google Maps images as we try to determine how road damage can be remotely sensed.

I — TECHNICAL STATUS

Resampling Study

The aerial images of Larimer County have shown signs of promise regarding the feasibility of using remote sensing techniques to study road surface quality. These images, which were taken on 4/22/2011, contain parts of CDOT Highway Stretch #34A. According to CDOT's survey of #34A, which took place on 2/18/2011, the highway stretch contains net fatigue values of 171 ft^2 between milestones 114.6 and 114.7 and 6567 ft^2 between milestones 114.8 and 114.9. Likewise, the fatigue indices are 97.3 in the former road piece and 0 in the latter. Aerial photographs of these road pieces are shown in Figures 1 and 2 below. The red dots indicate the milestones.

Figure 1: CDOT Highway Stretch #34A (Mile 114.6-114.7)

Figure 2: CDOT Highway Stretch #34A (Mile 114.8-114.9)

In these photographs, there are visual signatures that might indicate road quality. The low fatigue road piece in Figure 1 is noticeably darker and smoother. By contrast, the high fatigue road piece in Figure 2 is lighter and cracking is evident.

Although aerial photographs have the advantage of higher spatial resolution, they are more expensive and logistically difficult to procure than satellite images. Therefore, it beneficial to test whether or not these visual signatures are also visible in satellite imagery. Unfortunately, our satellite imagery of Larimer County, which was captured by DigitalGlobe's WorldView-2 spacecraft, did not contain the aforementioned road pieces. To make up for this, we synthetically reproduced analogous satellite photographs by converting the RGB values of the aerial photographs into panchromatic values and reducing the spatial resolution. Figures 3-8 show the panchromatic aerial image chips and the synthetic analogous WorldView-2 and QuickBird images.

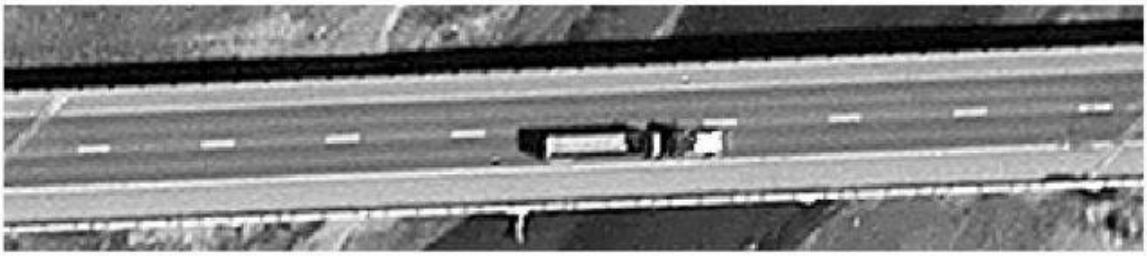

Figure 3: Panchromatic Aerial Image (Low Fatigue)

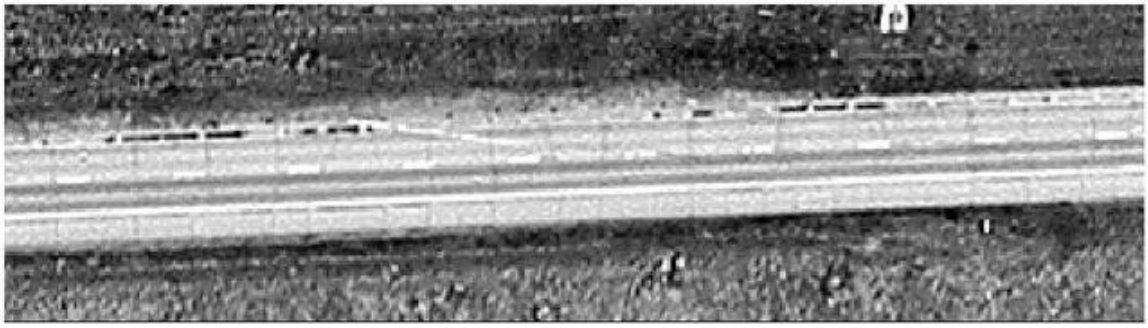

Figure 4: Panchromatic Aerial Image (High Fatigue)

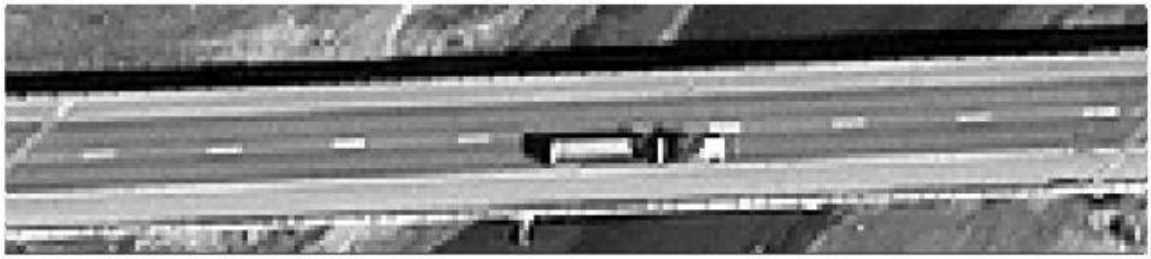

Figure 5: Synthetic WorldView-2 Image (Low Fatigue)

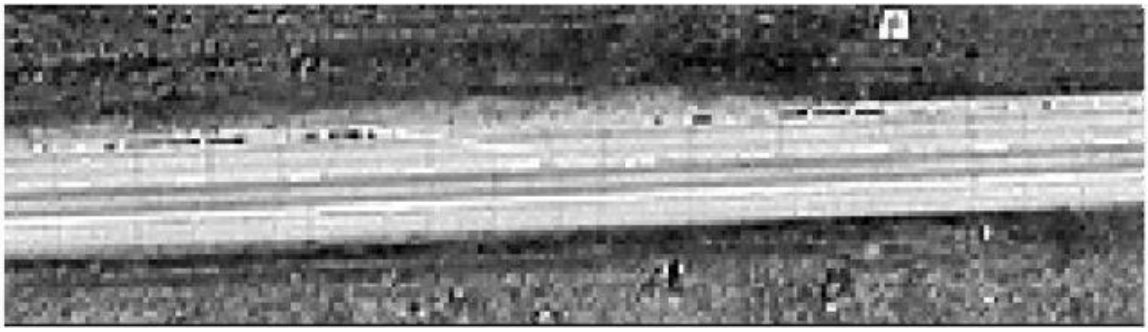

Figure 6: Synthetic WorldView-2 Image (High Fatigue)

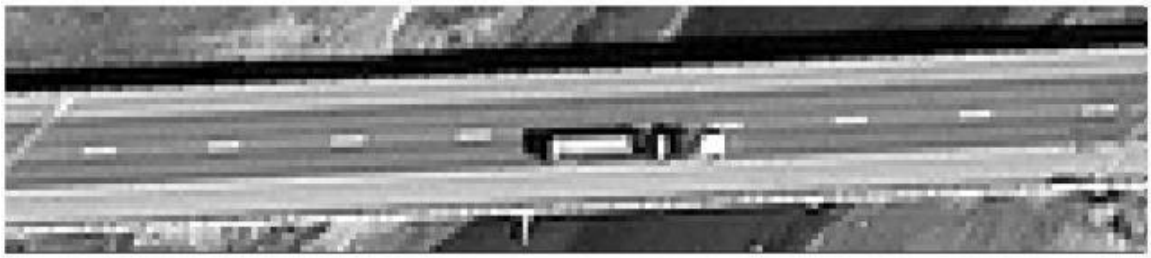

Figure 7: Synthetic QuickBird Image (Low Fatigue)

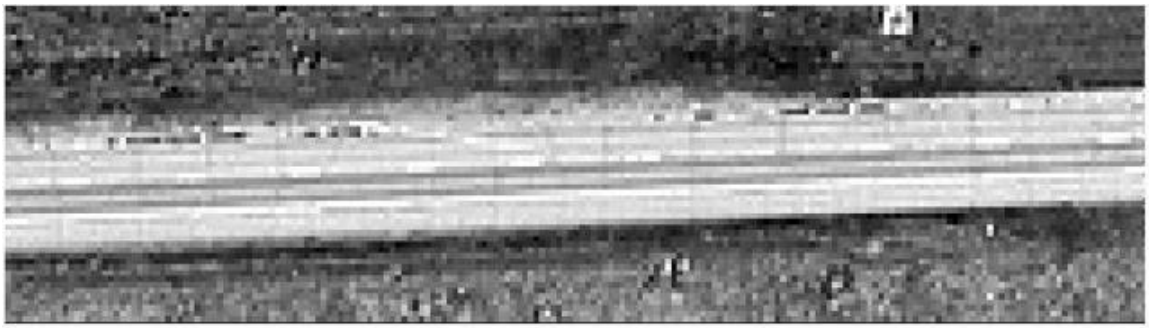

Figure 8: Synthetic QuickBird Image (High Fatigue)

Although the quality of the images decreases with lower spatial resolution, the visual signatures of road fatigue are still discernible. Some preliminary analysis was performed to assess whether fatigue could be determined from the optical information within the photographs. Using the ENVI software, a variety of statistical analysis procedures were applied to the images, which resulted in new images corresponding to these procedures. The first order metrics were data range, mean, variance, entropy, and skewness with a 3x3 pixel window. The second order metrics were mean, variance, homogeneity, contrast, dissimilarity, entropy, 2nd moment, and correlation with a 3x3 pixel window and 1x1 pixel offset. Finally, image entropy metrics were calculated with 3x3, 5x5, and 7x7 pixel windows. A geographic transect was drawn over these new sets of images (both the low fatigue set and the high fatigue set) and the values representing the pixels underneath them were extracted and plotted against normalized distance. The plots that show the most notable features are presented in Figures 9-11.

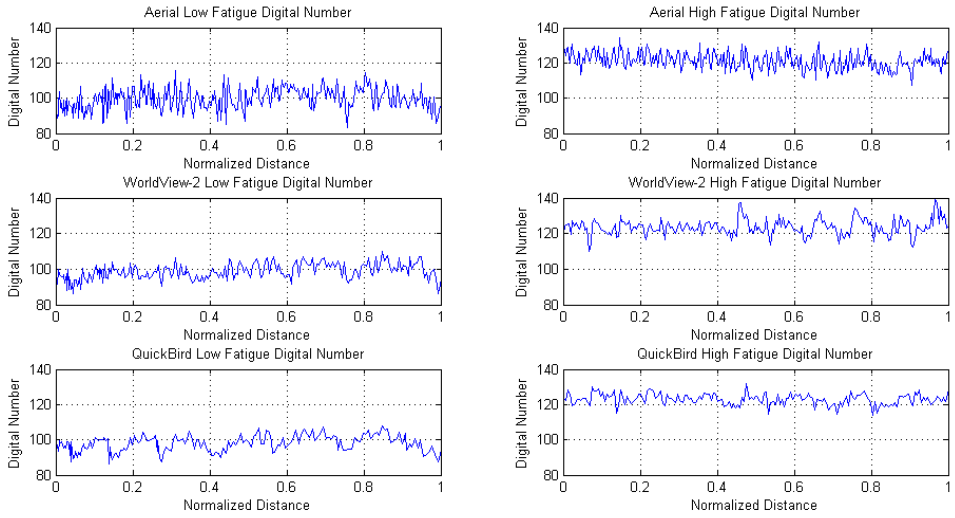

Figure 9: Digital Number Comparison

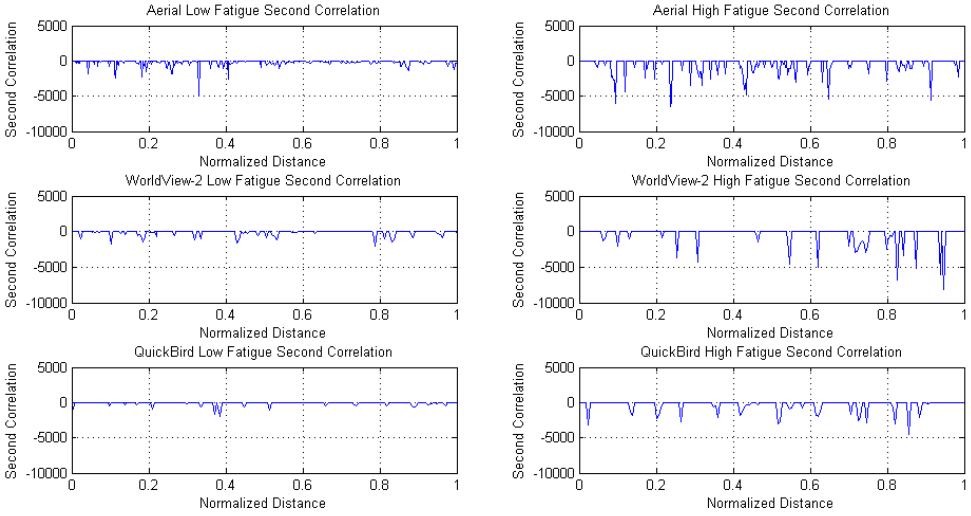

Figure 10: Second Correlation Comparison

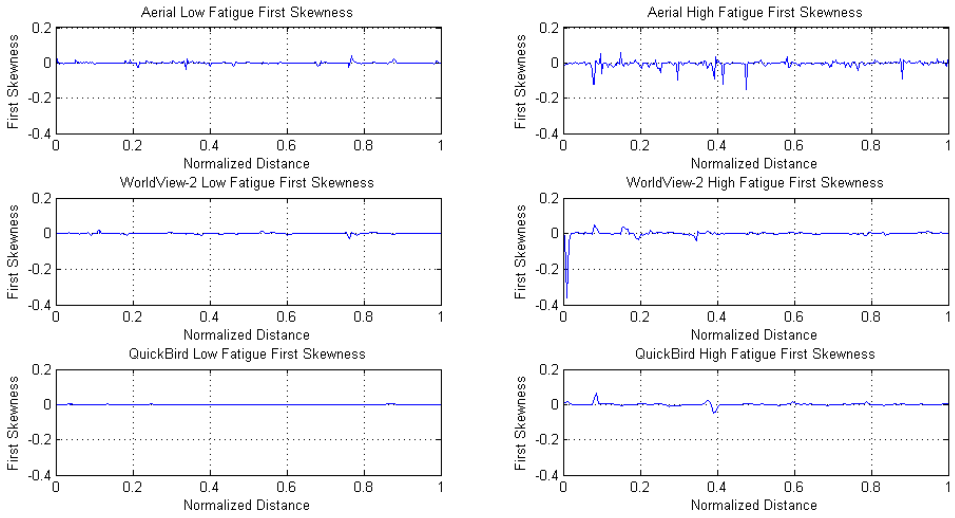

Figure 11: First Skewness Comparison

There is an obvious difference in the 8-bit digital number values between the low fatigue and high fatigue road pieces. The former is lower (~100) whereas the latter is higher (~120). This is consistent with visual observations of the photographs, since the low fatigue road piece is darker and the high fatigue one is brighter. The second correlation and first skewness metrics may also suggest road fatiguing. In both Figures 10 and 11, the high fatigue plots contain more variation than the low fatigue ones, which are comparatively flatter. Because this is only a two-case study, there is not enough evidence to conclude whether these metrics are true indicators of road fatigue. Perhaps a multiple-case study combined with spectral analysis will determine the full extent of these metrics' potential.

Colorado Springs Coincident Data Collection

In early December of 2012, the PPACG conducted a road quality survey over a small region within Colorado Springs. This road data was packaged in the form of a GIS shapefile. On 11/24/2012 the WorldView-2 spacecraft captured imagery of that same region. The intent of this coincident data collection procedure was to determine how road damage could be observed in satellite imagery. Using the QGIS software, the road data was placed over the WV-2 image. Figures 12 and 13 show a part of this region with and without the road damage information. The names of the visible streets are Teardrop Circle and Escapardo Way.

Figure 12: WorldView-2 Panchromatic Image with Road Damage Information

Figure 13: WorldView-2 Panchromatic Image without Road Damage Information

In Figure 12, the red shapes and lines represent severe road distress and the orange ones represent moderate distress. The allegedly severe damage is not obvious from eyeball inspection when the road damage information is removed. Perhaps they could be revealed when the statistical analysis described in the two-case study is implemented.

It was discovered that QGIS features a plug-in which allows Google Maps satellite and aerial imagery to be displayed as a GIS layer. The road damage shapefiles were placed over the Google Maps imagery so that appropriate comparisons can be made. Figures 14 and 15 show such images with and without the road damage information.

Figure 14: Google Maps Aerial Image with Road Damage Information

Figure 15: Google Maps Aerial Image without Road Damage Information

These particular photographs were collected on 10/22/2011, approximately a year before the PPACG road survey. It is assumed that the road quality has not changed considerably in the time lag. With the higher resolution and color, the visible signs of fatigue, which include greyness and cracking, are more apparent. Although the Google Maps images are not the purest form of scientific remote sensing data, they do provide a qualitative indication of road surface conditions.

Also, they are readily available at no cost, at least for single time periods. They will be a useful resource in this investigation.

Future Plans

We plan to make further use of the Google Maps imagery to study the visual signatures of road fatiguing. We have a document provided by CDOT which contains the years when highway repavement took place. We shall inspect Google Maps images of Colorado highways that were taken during, right before, and right after repavement. By doing so, we can create a more robust list of road fatigue signs that may influence CDOT's decision to perform repavement.

Regarding the WorldView-2 images in our inventory, we have been mostly studying the panchromatic data. However, we believe that there might be some useful information within the multispectral data. Although the spatial resolution of the multispectral images is lower than that of the panchromatic images, they might contain some useful information regarding the properties of the road asphalt. As roads age, their chemical composition changes. We believe that these changes might be detectable if one were to observe the spectra of the roads. The WorldView-2 spacecraft is equipped with eight sensors that can detect shortwave radiation. We shall take a closer look at the multispectral data to see if there are any major differences between fresh and damaged roads.

II — BUSINESS STATUS

Please see Appendix.

FEDERAL FINANCIAL REPORT

(Follow form instructions)

1. Federal Agency and Organizational Element to Which Report is Submitted	2. Federal Grant or Other Identifying Number Assigned by Federal Agency (To report multiple grants, use FFR Attachment)	Page	of
Department of Transportation	RITARS-12-H-CUB	1	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	08/14/2014	06/30/2013

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	88,631.02
b. Cash Disbursements	170,824.40
c. Cash on Hand (line a minus b)	-82,193.38
(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	170,824.40
f. Federal share of unliquidated obligations	3,870.00
g. Total Federal share (sum of lines e and f)	174,694.40
h. Unobligated balance of Federal funds (line d minus g)	334,595.60
Recipient Share:	
i. Total recipient share required	509,290.00
j. Recipient share of expenditures	154,307.13
k. Remaining recipient share to be provided (line i minus j)	354,982.87
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	6/30/13	103162.22	54160.18	54160.18
		0.00%					
				g. Totals:	103,162.22	54,160.18	54,160.18

12. *Remarks: Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation:*
Tuition charges of $17,263.00 is exempt from F & A base. Only first $25K on sub-contract is charged with F&A.

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	c. Telephone (Area code, number and extension)
Andy Wang, Grant Accountant	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): 07/29/2013
	14. Agency use only:

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

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