Road Network Information Derived from High Resolution Satellite Platforms

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Purpose

Present image analysis methods that leverage unique aspects of DigitalGlobe satellite data to assess surface conditions of roadways.





CU/DG Collaboration – Previous Projects

- Change detection
- Texture classification
- Multi-angle classification
- Oil detection













DigitalGlobe's Satellite Constellation



QuickBird (2001) Pan + 4 MS

0.61m nadir GSD (0.67m) 496 km altitude Reaction wheels

WorldView-1 (2007) Pan only 0.5m nadir GSD 496 km altitude Control Moment Gyros



WorldView-2 (2009) Pan + 8 MS 0.46m nadir GSD 770 km altitude Control Moment Gyros

24 hour global coverage; imagery available from minutes to a few hours after collection

WorldView-3 (2014) Pan + 8 MS 35cm (TBD) Control Moment Gyros

30 Days of Collection



Excellent coverage providing timely updates for change detection or temporal based processes.

DigitalGlobe Value

- Constellation revisit rate
 - Capability to revisit all urban areas and lines of communication (e.g., roads, rails) on a weekly basis in the USA while performing global mission
- Time from collection to imagery product
 - Digitalglobe: tens of minutes to several hours
 - Aerial: days to months
- Applied R&D
 - Mapping products will directly integrate into near real-time operational systems and COTS software currently in use
 - R&D efforts from this collaboration will be directly applicable to DigitalGlobe imagery available from the DG library or through US government programs

















Improved Classification Accuracies



Multi-Pass Nadir Multi-Angle













Satellite Agility

• WorldView-1 and WorldView-2's Control Moment Gyros (CMGs) are state of the art and provide an acceleration >10x better than reaction wheel vehicles



In-track Multi-Angle







Unique Capabilities of WorldView-2

- Eight spectral bands @ 2 m spatial resolution
- Optical panchromatic band @ 50 cm spatial resolution
- Rapid retargeting (2x faster than similar spacecraft)

There are three aspects of WorldView-2 of interest to transportation system monitoring, of these, two are unique to the WorldView-2 platform









Benefits of Multi-Angle Information

- Differentiates materials with similar surface reflectance through spectral signatures
- Observes the shadowing of vertical objects
- Tracks the temporal surface changes
- Sun glint minimization
- Structure extraction

Multi-angle allows us to extract information otherwise not available in a single image









3D Views of Atlanta

Temporal Variation

- Differentiates land-use of similar spectral signature

 Highways vs. residential roads
- Encapsulates multi-angle spectral variability
 - Stationary vehicles

Spectral variability provides information that allows the differentiation of land-use classes that have similar spectral signature but have different temporal properties.







Roadways – Surface Condition

- Texture based roadway surface differentiation
- Eight-band spectral signatures provide additional differentiation power



Texture and spectral signatures can differentiate small changes in paved surfaces – this may be extended to include monitoring over time to detect surface degradation





Roadways – Unpaved Surfaces

 Similar texture based analysis can be used to track changes in unpaved surfaces







Planning - Derived Network Components









Planning - Vehicle Vector Extraction







Task 1. Create the Advisory Board (AB) and conduct Kick-off team meeting and other subsequent meetings with advisory board.

The AB will consist of government, industry and academic experts who will provide guidance and direction to the overall project as well as specific input for detailed aspects of the project. The AB will meet regularly during the execution of this project. The project manager will be consulted before finalizing the membership of this board.





The AB will be composed of 3 members from Municipal Planning Offices (MPOs, 1 Colorado Springs, 1 Fort Collins and 1 Denver) and 4 members from the project team (2 from University of Colorado (CU) and 2 from DigitalGlobe (DG)). This group will have regular face-toface (including video conf) meetings in alternating locations to review progress to date and provide guidance for the subsequent steps in the project. They will also conduct teleconferences as needed to direct the project. The responsibility for the organization of all meetings and telecons rests with the PI and his staff at CU. The first meeting will create a project plan which will be updated at each subsequent meeting.





Task 2. Develop satellite/aerial surface quality metrics and correlate with in-situ measurements

This task involves the analysis of satellite-aerial and in-situ data-bases held by our MPO partners to create aerial and in-situ surface quality maps for their areas of responsibility. These data need to be acquired and translated into a format that can be easily analyzed for this project.





Output/Deliverables

The primary output of this effort will be maps of surface quality based on the MPO data to use in the correlation analyses with the new DG satellite data. There will be a set of maps each based on a slightly different combination of aerial or in-situ data. We will combine all of the available (satellite-aerial and in situ) historical data for an overall surface quality (in terms of the International Roughness Index (IRI)). Others may be restricted to an IRI map using only in situ data or only aerial data. These will be used to explore the impacts of different sampling types on the final IRI mapping.





Task 3. Carry out satellite image model portability development

This task focuses on the need to apply an image classification model based on a single image to other images not independently classified. This is one core element of this project and different efforts are expected to yield varying degrees of success. Present studies suggest a variety of approaches to be tested out including the use of multi-angle satellite image sensing.





Output/Deliverables

The primary output of this effort is the estimation of the ability of various six-class image classification models over different regions using literature-based data space normalization methods. A written report on this task will be delivered to DOT within 12 months of the start of this agreement. A research paper on classification model portability will also be submitted at the end of the first year of the project.





Task 4. Creation and maintenance of a project web site for the duration of the project

This site will be used to communicate results to a wider audience of interested Municipal Planning Offices (MPOs) and related state and local government offices.





Output/Deliverables

This task is itself a deliverable as the web page can then be viewed by DOT and all other interested parties. We propose to have this site up and operating within the first 3 months of the project. It will grow with the project and results will be regularly posted to this site.





Task 5. Quarterly reports to DOT and local MPO's

Each quarter a project report will be generated to inform the various government partners (including the US DOT) as to the status of the project and plans for the immediate future. The report will be submitted electronically to the DOT and the participant MPO's.





Output/Deliverables

This effort will generate a quarterly report, which is itself a deliverable to the DOT. When appropriate reports may be extended and submitted as a research paper.





Task 6. Develop foundation land-cover classification

In this task a strategy will be developed to automate the image classification based on the model portability study in task 3. Specific procedures will be determined what procedures that will be used to apply the model developed in task 3 to larger data sets. This will facilitate the large-area deployment of a land-cover image classification analysis as applied to the DG satellite images.





Output/Deliverables

Analysis of the correlation between satellite image classes and the in situ estimates of surface condition. This analysis will involve truckmounted radar roughness measurements as well as satellite and aerial images of target surfaces. Results of this analysis will be summarized in report to the DOT within eighteen months of the start of the project. A research paper will also be submitted at the same time.





Task 7. Semi-annual collaboration meetings

While reports will be written and distributed each quarter we will only plan to have 2 face-to-face meetings of the MPO's and project technical staff to iron out any problems that have arisen and to go over plans for the next phase of the project





Output/deliverables

The report of each meeting will coincide with one of the quarterly reports in Task 5 above. A portion of this report will be devoted to a discussion of this meeting and this will constitute the output of this meeting.





Task 8. Assess the ability of the classification scheme to identify and locate roads

Development of roughment classification methodologies and algorithms from existing data-base sources from MPOs. Development of correlation algorithms between satellite imageries and in-situ data of surface conditions collected by the MPO partners both historically and during the project. The focus of this task will initially be targeted on paved surfaces taking advantage of the data bases and new collections of the various partner MPOs.





Newly collected in-situ road surface roughness data from the MPOs will be used to first classify the roughness estimates from the satellite imagery. These will be carried out in limited areas while the satellite data will be used to compute the same roughness for the entire MPO region of responsibility. A subsequent MPO sponsored in situ data collection will then be used to validate the accuracy of the satellite data roughness index. We will also explore extending this study to unpaved surfaces realizing that the in situ information is lacking for this type of roads. Still we believe that the basic concepts developed for the paved surfaces will apply to the unpaved roads.





Output/Deliverables

The result of this part of the study will be surface roughness classification maps based on the DG satellite imagery and the validation of portions of these maps by the MPO in situ measurements. A research paper will be written and submitted both for publication and as a report to all of the DOTs for this project.





Task 9. Optimization of the classification scheme for high-performance computing

To accelerate the classification processing the classification code will be optimized to run in the high-performance computing (HPC) environment available at DG which consists of a cluster of computer in a parallel processing configuration.





Output/Deliverables

A set of procedural codes capable of running on the DG HPC system, which includes a "scoringcode" to use models in the HPC environment for this analysis. A report on this task will be delivered to DOT within 24 months of the start of the project.





Task 10. Perform the paved/unpaved surface condition assessments

This is the critical task in this projects and it breaks into the following subtasks:

a. Develop surface feature set oriented to road travel vector. This amounts to quantifying the in situ measurements to the IRI standard.

b. Create IRI model from ground survey using aerial and satellite data. This critical step links the classified satellite and aerial data to the in situ measured IRI.





c. Validate image model from blind in-situ IRI data and measure accuracy. This independent step has the MPOs measuring a different area than that used for training to test the satellite image estimate of the IRI. This is a validation exercise and will allow us to quantify the error associated with a satellite estimate of the IRI.

d. Create IRI model from ground survey using WorldView-2 data. This is a satellite only estimate of the IRI for a large area.





e. Validate satellite model from blind in-situ IRI data and measure accuracy. This repeats the validation measurement of c above but for a different area.

f. Explore locating and sensing surface conditions of unpaved roads. If successful suggest an expanded new project to map and evaluate these types of surfaces necessary to accommodate advisory committee input.





Output/Deliverables

This last task is a review of many steps in the project:

a. A data sets of the historical in situ, satellite-aerial data for each MPO will be organized along with the matching IRI derived surface conditions as described in Task 2 above.

b. The results of Task 2 will be used to provide overall IRI maps for each primary area of interest to the various MPOs. A report on subtasks a and b will be delivered to DOT within the first year of this project.





c. The validation of the model fits described in subtasks a and b will yield a quantification of the errors associated with this process and errors maps for each MPO region will be generated. Reports will be submitted both to the US DOT and each of the MPOs.

d. The IRI maps derived from the DG satellite data will be generated for each of the MPOs and provided to them.





e. The DG satellite data derived IRI maps will be validated using a withheld independent data set for each of the MPO regions. A report on subtasks d and e will be submitted to the US DOT and to each of the MPOs.

f. Our exploratory study of unpaved surfaces will yield areas of future study and define a follow-on project focusing on unpaved roads. These results will be part of the report mentioned in subtask e. These results will be shared with our advisory committee and with the US DOT.





a and b will be carried out in the first year of the project and a report will be delivered to DOT within this first year. This report will include the mapping of historical in situ measurements in terms of the IRI. In addition a historical IRI based on all historical data will be created. The results will also be part of a research paper, which will include the results of the validation exercise in subtask c. Subtask c will use an independent smaller set of historical data not included in a and b to validate the mapping algorithm developed in a and b above.





Subtasks d-f will be carried out in year two of the project. Subtask d is at the core of the project and will produce the IRI model based on a mapping between the DG satellite data and the historical IRI based on past in situ and aerial/ satellite data. Task e is part of this process in that it will use a "limited" set of data withheld from the earlier analysis to validate the model developed in subtask d. A report on subtasks d and e will be delivered to DOT in the first 24 months of the project. At the same time the results of any exploratory studies of unpaved surfaces will be communicated to DOT. A follow on proposal to further study unpaved surfaces will be considered if the results are positive.



