From Ideas to Innovation

— Selected Applications from the CRC Research Lab in Advanced Geomatics Image Processing

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Selected Research Applications

(1) **3D Building Mapping: Optical-Elevation Data Co-registration**
- Alaeldin Suliman (PhD Candidate), Dr. Yun Zhang

(2) **3D Building Mapping: Off-terrain Objects' Disparity Mapping**
- Alaeldin Suliman (PhD Candidate), Dr. Yun Zhang

(3) **Multi-Epipolar Images of VHR Satellite images with Elevation Proportional Disparities for Several Products**
- Alaeldin Suliman (PhD Candidate), Dr. Yun Zhang

(4) **Urban Change Detection using off Nadir Images**
- Dr. Shabnam Jabari (Post-Doctoral Fellow), Dr. Yun Zhang

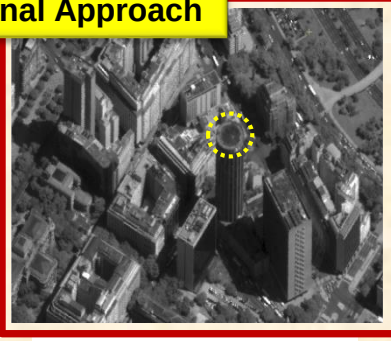
(5) **Target Detection Using High Resolution Panchromatic Images**
- Mohammed Rezaee (PhD Candidate), Dr. Yun Zhang

(1) Optical-Elevation Data Co-registration for Better 3D Representation and Building Mapping

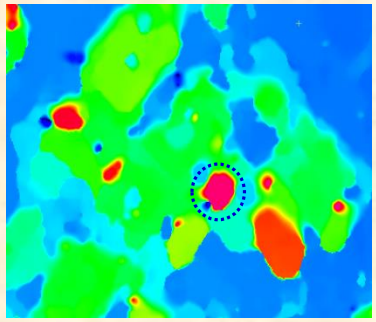
Optical Data	Elevation Data	Registration Result	3D Representation

Conventional Approach

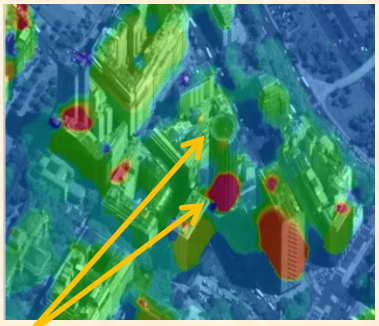
Registration Using *Conventional Ortho* DSM



Off-nadir VHR imagery



Conventional DSM



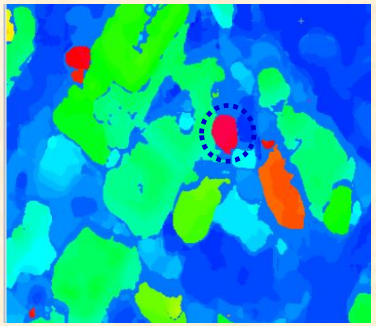
Misregistration

3D Representation of the integrated datasets

CRC-AGIP Approach

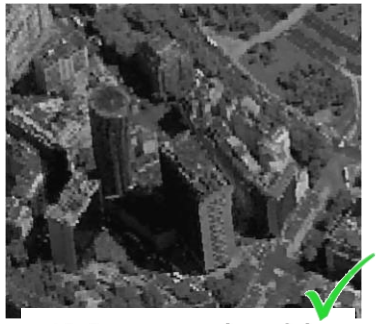
Registration Using *line-of-Sight* DSM

Off-nadir VHR imagery



line-of-Sight DSM

Accurate Registration



3D Representation of the integrated datasets

Description: The algorithm uses sensor information to adjust the orthographic DSM to have the perspective characteristics of any off-nadir and perspective imagery and also allows for sub-pixel level registration. The algorithm provides an improvement in rooftop building detection of almost 12% in comparing to conventional techniques (without incorporating sensor model info.). Improvement is due to the accurate registration achieved. This algorithm is robust and it is currently not available in any commercial software product.

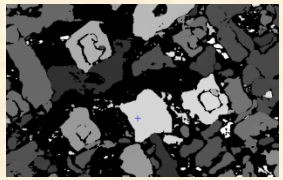
(2) Off-terrain Objects' Disparity Mapping for Better 3D Representation and Building Detection

Conventional Approach

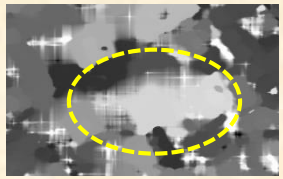
Stereo VHR images over dense urban area

CRC-AGIP Approach

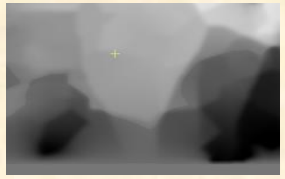
Matching-based **Stereo information**



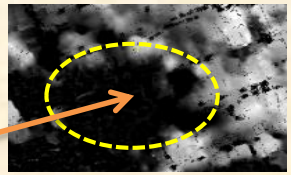
Filling occlusion gaps by **interpolation**



Extracted Terrain by conventional techniques



Missed off-terrain objects

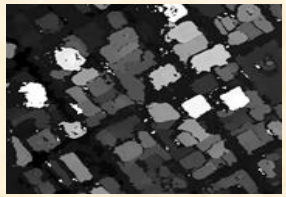


DSM

DTM

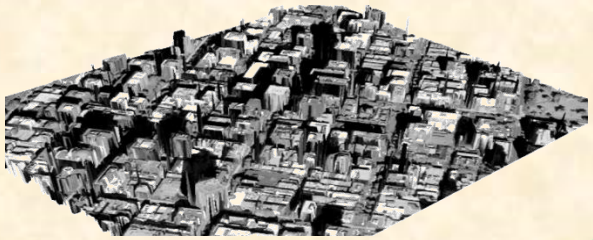
Normalized DSM

Epipolar rectified images followed by registration-based terrain subtraction to keep off-terrain objects



Off-terrain Disparity Map

Mapped Buildings



3D Disparity representation (flat terrain)

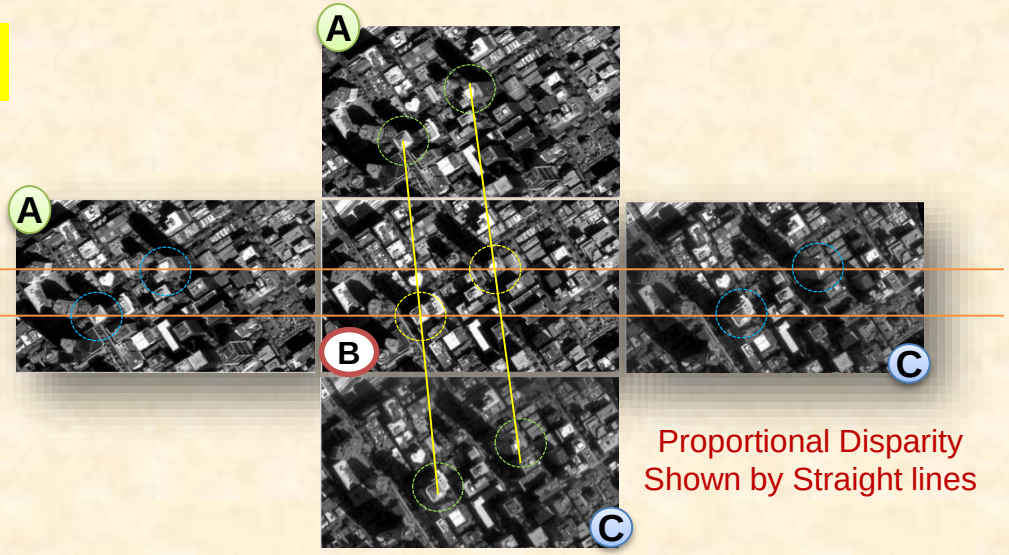
Description: The algorithm forces the matching techniques to map only the disparities of building rooftops by subtracting the terrain level features in the image space. It also takes the advantages of along-track stereo images of opposite directions to exclude building facades. The product of this algorithm is a disparity map that contains only the building rooftops. The algorithm is well suited for dense urban areas since the terrain variation is reasonable.

(3) Multi-Epipolar Images of VHR Satellite images with Elevation Proportional Disparities for Several Products

In Progress …

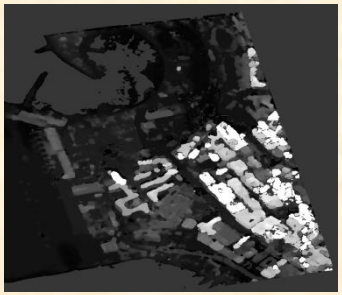
Epipolar images

Same pixels lie on the same row

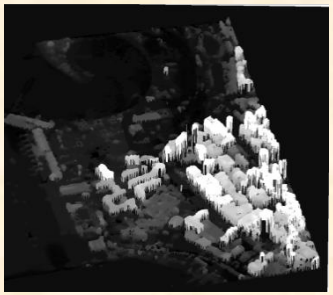


Proportional Disparity Shown by Straight lines

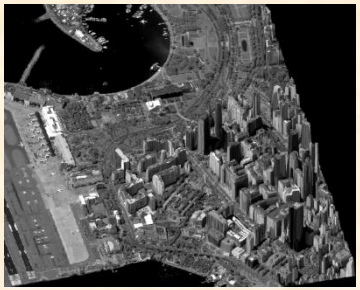
This property is useful for generating:



1. Dense disparity map

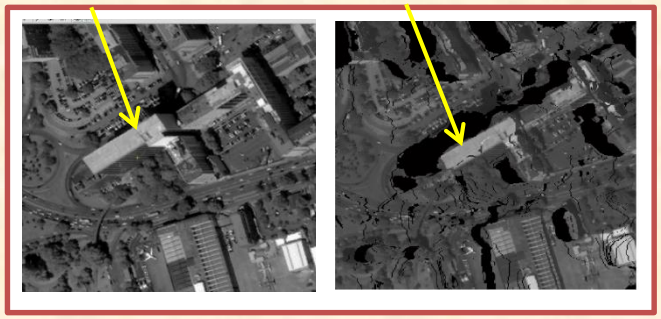


2. One-Step Dense DSM



3. 3-D Representation

Shifted rooftop in off-nadir imagery **Corrected rooftop location**



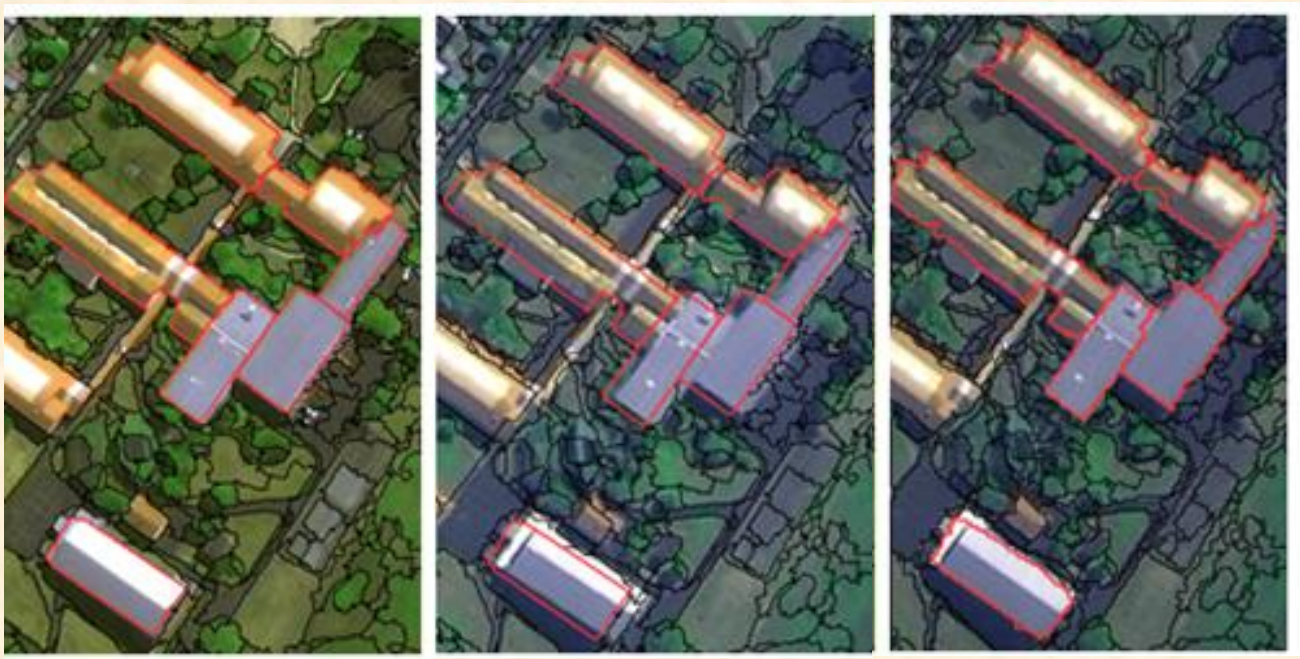
4. True-orthoimage via disparity info.

Description: The algorithm utilizes sensor information to construct epipolar images of multi along-track stereo images. The images are processed to develop disparity values proportional to each other as well as to the ground elevations. This robust algorithm tremendously facilitates the following: (1) Disparity values transferability from image domain to another one. (2) Occlusion gap-filling for and mismatches detection and correction. (3) Direct DSM generation without triangulation and bundle adjustment. (4) True Ortho-image generation by disparity data (without DSM).

(4) Urban Change Detection Using off Nadir Images –

Co-registration of off-Nadir Satellite and Airborne images using a Patch-Wise Co-Registration (PWCR) approach

Co-registration Problem For change detection:



Original Segmentation in **base** image

Segments transferred to the **target** image using conventional method (using the segments from the base image as thematic layer)

Segments transferred to the **target** image using our PWCR

Description: The main problem in urban change detection using off-nadir satellite or airborne imagery is to find similar objects in bi-temporal images (**base** image and **target** image) regardless of the attitudes and acquisition angles of the imagery. This task is challenging due to relief displacements of elevated objects towards different directions in different imagery. We proposed a Patch-Wise Co-Registration (PWCR) method to overcome this problem and to find the corresponding objects in bi/multi-temporal images.

We tested the PWCR method on IKONOS, QuickBird, GeoEye-1, WV-2, and Airborne imagery and the results are very consistent which shows the robustness of the work.

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(4) Urban Change Detection Using off Nadir Images, cont. –
Co-registration Results

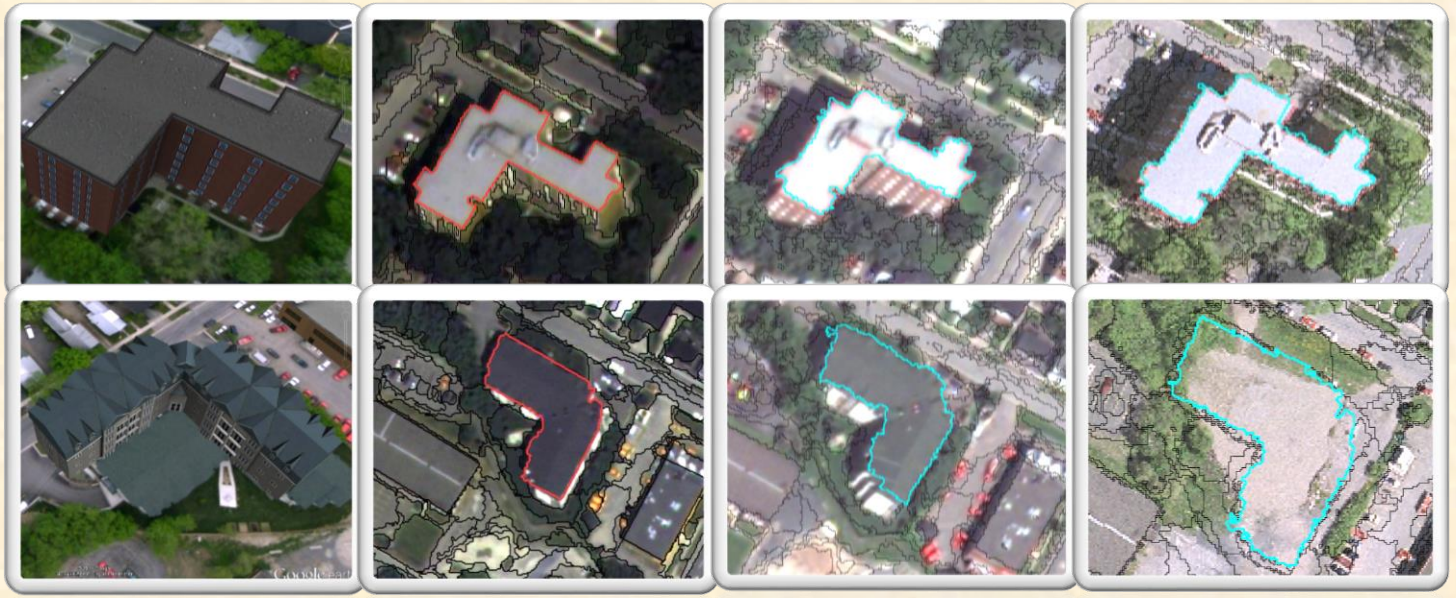


Image 1: Samples of urban buildings
Imagery Courtesy Google Earth

Image 2: WorldView2 image acquired in 2011
Off-Nadir Angle: 17 °

Image 3: WorldView2 image acquired in 2013
Off-Nadir Angle: 27 °

Image 4: Airborne image acquired in 2005

In the above images, Image 1 shows 3D representations of sample buildings in Google Earth imagery. Image 2 is the borders of the building roof generated manually in a WV-2 image. We used this image as a base image for change detection. Using PWCR, the building roof borders are transferred to a high off-nadir satellite image (Image 3) and an airborne image (Image 4). These latter images are target images so that the transferred borders fit the actual building borders closely. These Images highlight the ability of the PWCR method to find the exact position of the objects (in this case building roof) regardless of the attitude and geometry of the images. As can be seen, there is no change between Image 3 (target) and Image 2 (base images), but one of the buildings in image 4 is a new construction and the borders of the roof fall on the bare ground since the building was not built yet.

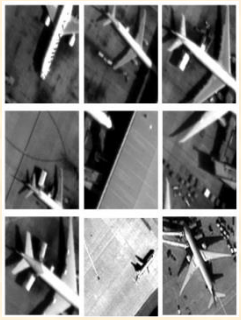
A comparison method such as correlation Analysis or MAD Transform can then be applied to these results to determine whether or not an object has changed.

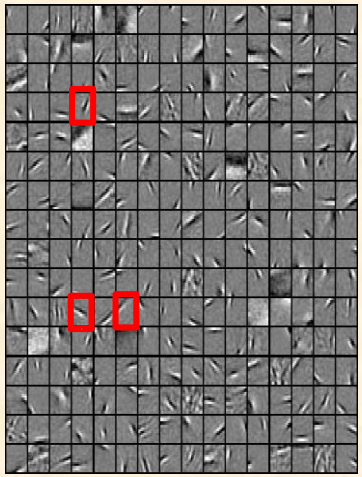
(5) Complex-shape Target Detection Using High Resolution Panchromatic Images

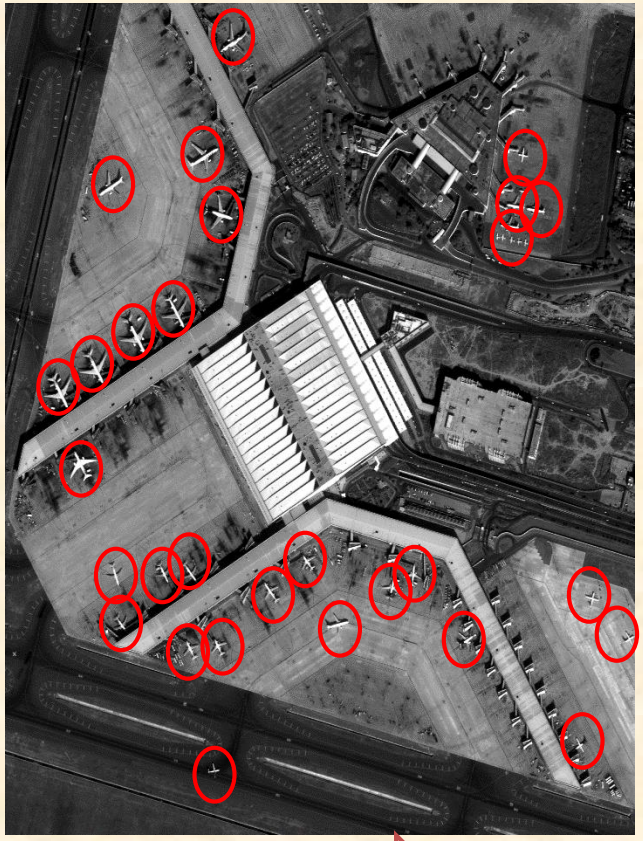
Start with a database that contains one or more images of the desired target (e.g. airplane)

Generate a dictionary for that target

Find the location of the target (e.g. airplanes) in different images – that is, search a collection of images for matches with the information contained in the dictionary







Database
Airplane & Background

Dictionary

Result

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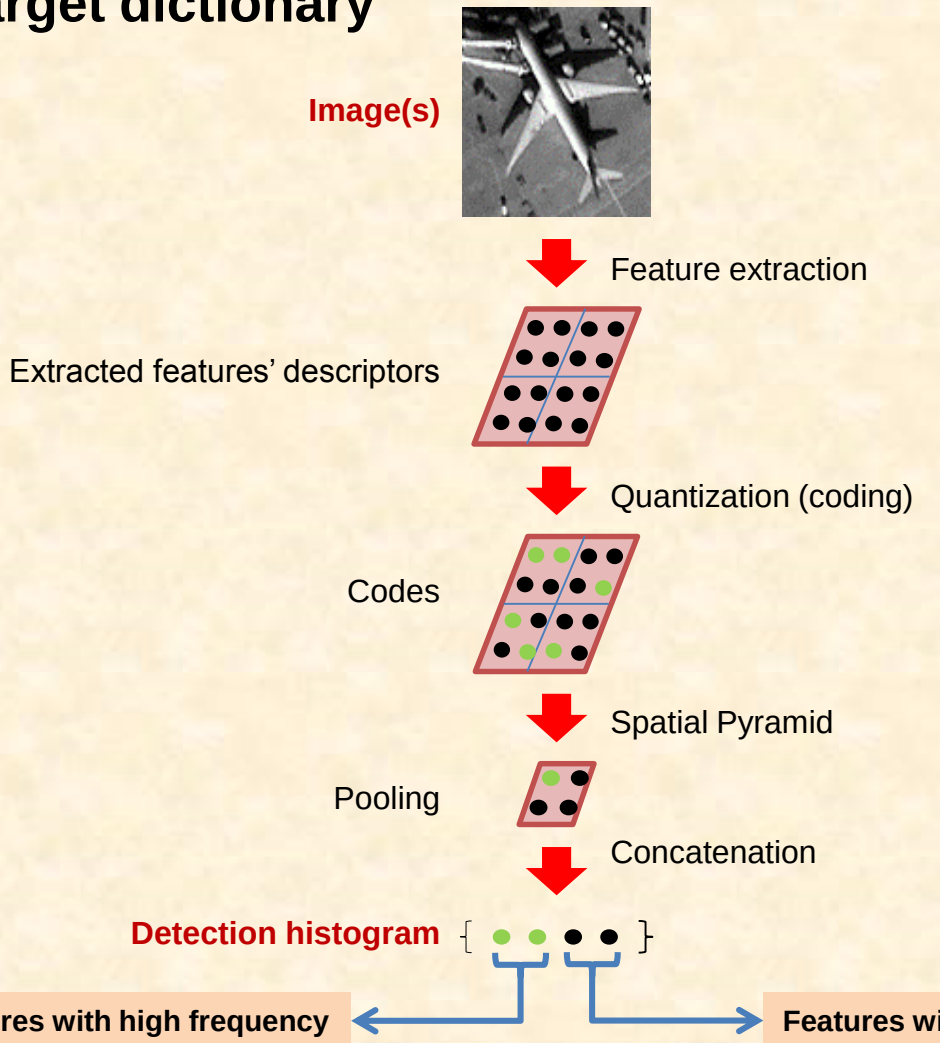
(5) Complex-shape Target Detection Using High Resolution Panchromatic Images, cont.

- **Methodology used to create target dictionary**



- **Advantages**
  - ✓ Invariant to rotation and scale
  - ✓ Dictionary is saveable for further use
  - ✓ Applicable to transportation (Ship, plane)
  - ✓ Resistant to occlusion