Non-parametric Models for Large Scale Aerial Image Registration

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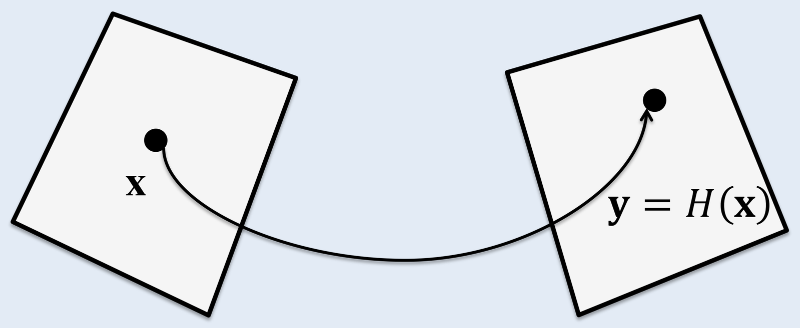
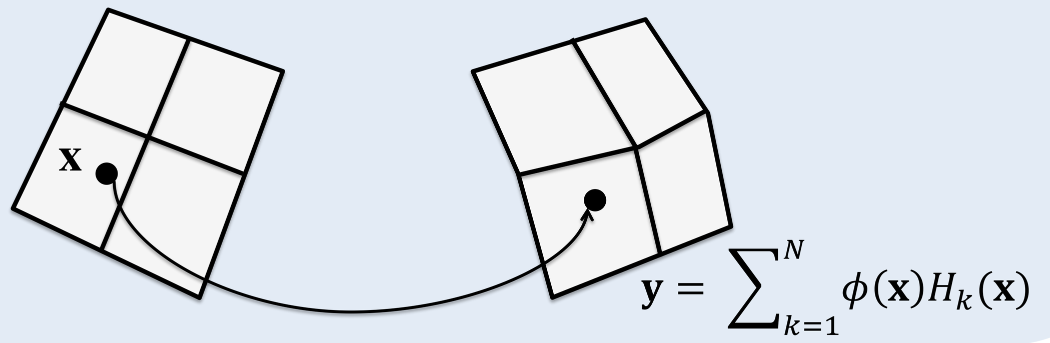
We present a method for registration and 3D reconstruction of large scale aerial imagery using non-parametric models. Unlike parametric models, which fit a fixed number of parameters to camera models and the geometric relationships between images, our model adapts the parameters to the image size and nature of the image and does not rely on a particular model.
This methodology is carried out from early registration of aerial imagery to 3D reconstruction via motion factorization and fusion of multi-modality images.

Registration via non-parametric ground plane estimation

In a typical scenario, registration can be obtained by finding camera poses, typically defined in terms of camera center, rotations, focal length and radial distortion parameters.

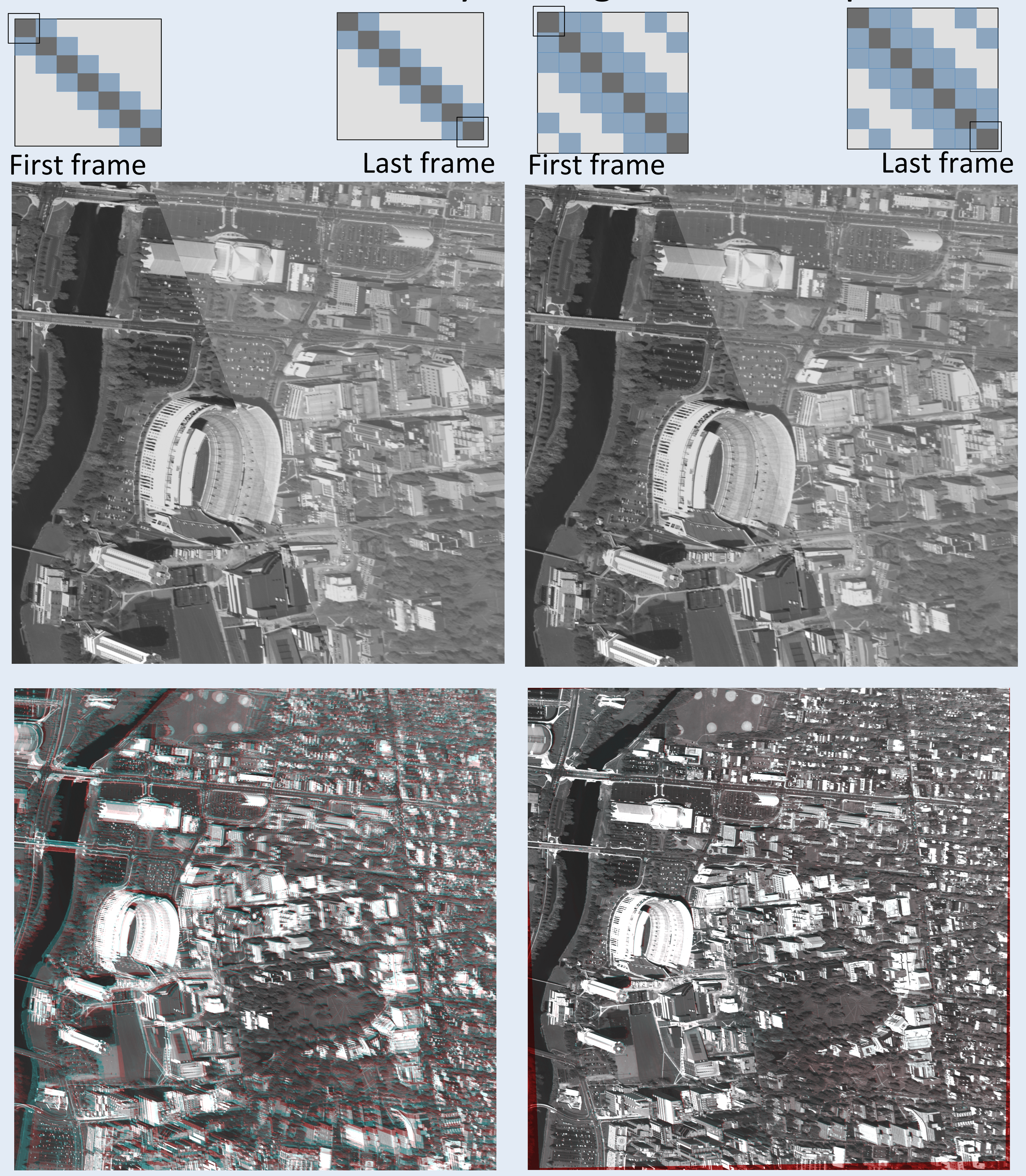


In a non-parametric model, the global "camera" is a collection of regions, each mapped to a different "virtual camera" using a homography transformation. The final projection of a point is a weighted sum of these transformations.



Drift-free registration of orbital imagery

Instead of relying on bundle adjustment - which requires a parametric form, we adapted Schroeder et al.'s method to account for weighted homographies. The "optimal" transformation is found by solving a block SVD problem.

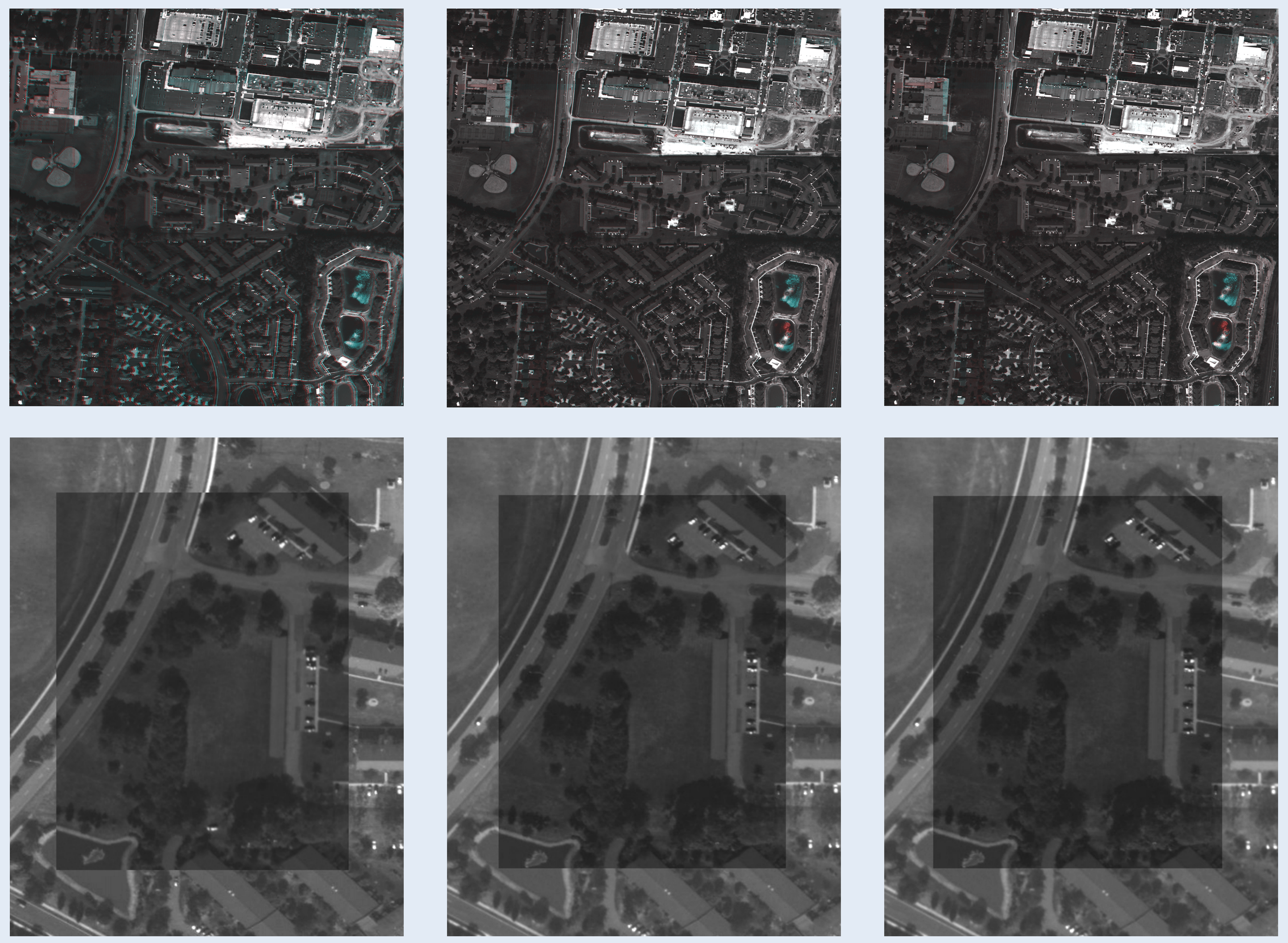


Without global optimization

With global optimization

Registration of non-pinhole cameras

Some sensors and imaging systems produce images that need to be stitched or come from a push-broom camera, which results in non-pinhole images. Non-parametric models can be used to register these images.



Inter-frame homographies (Suffers from drift)

Globally-aligned Homographies
Single ground plane
(Registration problems Since the camera is no longer a pinhole camera)

Non parametric ground plane surface using block displacements

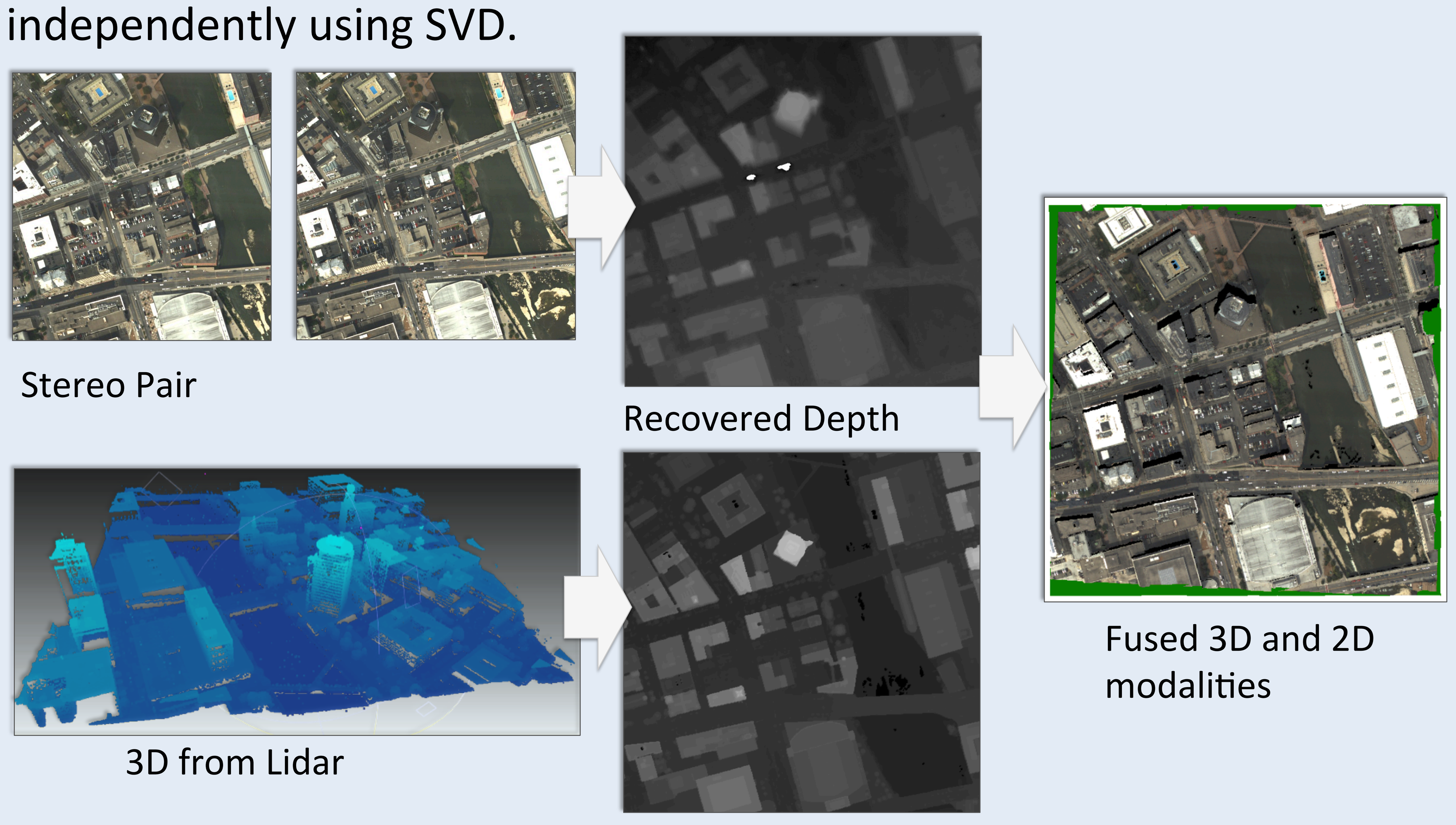
Fusion of multiple modalities

We perform fusion of 3D Lidar and imagery using 2.5D images resulting from factorizing motion from stereo disparities. Similar to registration, we can define depth from motion in a non-parametric form and solve independently using SVD.

$$x_{ip} = x_p + \sum_{k=1}^{N} \phi_k(p) c_i^{(k)} w_p^{(k)}$$

$$\begin{bmatrix} \delta x_{11} & \dots & \delta x_{1n} \\ \delta x_{21} & \dots & \delta x_{2n} \\ \vdots & & \vdots \\ \delta x_{m1} & \dots & \delta x_{mn} \end{bmatrix}^{(k)} = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_m \end{bmatrix}^{(k)} \begin{bmatrix} w'_1 & w'_2 & \dots & w'_n \end{bmatrix}^{(k)}$$

$$w'_n = \sum_{k=1}^{N} \phi(p_n) w_n$$



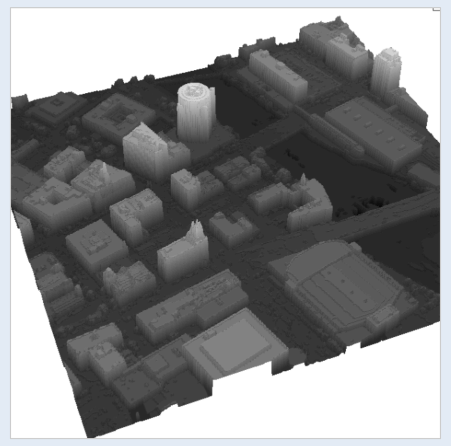
Stereo Pair

Recovered Depth

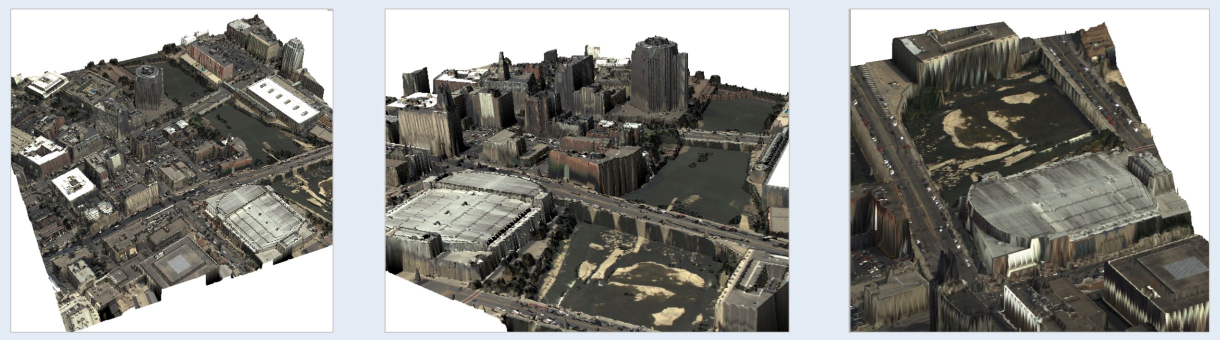
3D from Lidar

Depth from Lidar

Fused 3D and 2D modalities



Untextured Lidar



Textured Lidar from aerial imagery

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