Fusing Oblique Imagery with Augmented Aerial LiDAR

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Background

Aerial Light Detection and Ranging (LiDAR) is a time and cost efficient technique for digitizing large scale terrain and urban areas. In addition to geometric data collection, the use of imagery as textures in 3D landscape visualizations is an important methodology to improve appearance, 3D perception and interpretation by adding essential visual cues in color that are absent in the geometry.

Current approaches to fuse color with geometric data:
- Texture mapping of triangle meshes
- Color mapping of points

Figure 1: Rendering of a point cloud with (right) and without (left) colors.

Results

Color Mapping

Given an oblique image \( I_i \) with calibration matrix \( M_i \).

- **Rendering Pass**
  Points of visible subsets are projected onto \( I_j \) via \( M_j \) and rendered as splats using a modified visibility pass of GPU splatting:
    - The depth buffer is regular with no offset.
    - An additional off-screen rendering buffer \( B_{wi} \) is used to store weight and point-index per pixel.

The resulting buffer \( B_{wi} \) only stores information of visible points.

- **Accumulation Pass**
  Each pixel \((u, v)\) of the buffer \( B_{wi} \) is parsed. For a valid weight and point-index pair \((w, j)\), we locate the point in the file \( F \) on disk and accumulate the color and weight of image \( I_i \) as follows:

\[ F[j].rgb += I_i(u, v) \times w \]
\[ F[j].a += w \]

The weighting scheme effectively takes into account Image Resolution and Surface Orientation.

- **Color Normalization**
  After processing all images, the final color of point \( j \) is the normalization of the accumulated color: \( F[j].rgb /= F[j].a \)

Figure 3: Colored USC campus.

Our Approach

Fusing the color information from multiple pre-registered aerial oblique images with an aerial LiDAR point cloud.

- **Augmentation**
  To fill gaps on building walls and under tree canopies of aerial LiDAR point data.

- **Out-of-core Processing**
  To handle large scale image and point data sets.

- **GPU Splatting for Color Mapping**
  To determine the visibility of points with any spatial resolution to an image.

Figure 2: The color mapping framework.

Figure 4: Comparison of colored points (left) and textured polygonal models (right).

Figure 5: Comparison of colored points (left) and a full-size oblique image.

Contribution and Future Work

We believe this is the first algorithm for mapping multiple overlapping images into augmented aerial LiDAR points.

- We apply a modified visibility pass of GPU splatting to map colors for points while determining visibility in a single pass. The method works for point clouds with any spatial resolution.
- We present a complete color mapping system that is generic to any co-registered oblique imagery and aerial LiDAR point cloud, regardless of sources.

Results show that our system successfully produces textures on roads, vegetation, less salient structures, building roofs and walls that are comparable to the ground truth image.

Conclusion and Future Work

We presented a scalable out-of-core technique for mapping color information from aerial oblique imagery to large scale aerial LiDAR point cloud that are from the same or different sources. The presented system is simple to implement, effective to produce good results, scalable to arbitrarily large data and generic to be applied to data with any resolution. Experimental results show that color mapping of points can greatly improve the quality of LiDAR points visualization.

For future work, we will apply image processing techniques to handle occlusion and illumination variance in the oblique images. The current weighting scheme can be further improved by considering other heuristics like viewing distance, photometric estimators, etc.