Dense 3D Reconstruction Using Semi-Global Matching and PatchMatch Stereo Matching

Mobile Robotics

Kunal Kamalkishor Bhosikar - 2022121005
Prakhar Jain - 2022121008

Problem Statement

- **Overview:**
  - Dense 3D reconstruction is essential for robotics and computer vision applications like autonomous navigation, object manipulation, and augmented reality.
- **Challenges:**
  - Disparity estimation in stereo images
  - Handling occlusions and texture-less regions
- **Goal:**
  - Use stereo images to compute disparity maps, convert them to depth maps, and reconstruct 3D scenes for practical applications in robotics.

What Was Accomplished

- Key Milestones:
    - Implementation of SGM and PatchMatch for Stereo Matching
    - Conversion of Disparity Maps to Depth Maps Using KITTI Calibration Data
    - Dense 3D Point Cloud Reconstruction and Visualization Using Open3D
    - Evaluation of Disparity Accuracy and Computational Efficiency

Related Work

- **Classical Methods:**
  - **SGM (Hirschmüller 2008):** Balances accuracy and efficiency.
  - **PatchMatch (Barnes 2009):** Fast iterative refinement of disparity maps.
- **Deep Learning Approaches:**
  - **GC-Net (Kendall 2017):** Uses 3D CNNs for cost volumes.
  - **PSMNet (Chang 2018):** Uses pyramid pooling for better context understanding.
- **Our Approach:** Revisits classical methods to balance accuracy and efficiency in real-time applications.

Dataset Preparation and Processing

- **KITTI Stereo Dataset:**
  - High-quality stereo images and calibration data.
- **Steps:**
  - **Download and Organization** of data.
  - **Rectification** using pre-rectified images to eliminate alignment errors.
  - **Calibration** using intrinsic and extrinsic parameters.
  - **Disparity Ground Truth** used for validation.

Approach and Method

- **Stereo Matching:**
  - **SGM:** Minimizes energy functions over pixel neighborhoods.
  - **PatchMatch:** Iterative optimization for fast disparity estimation.
- **Disparity to Depth Conversion:**
  - Depth calculated as:

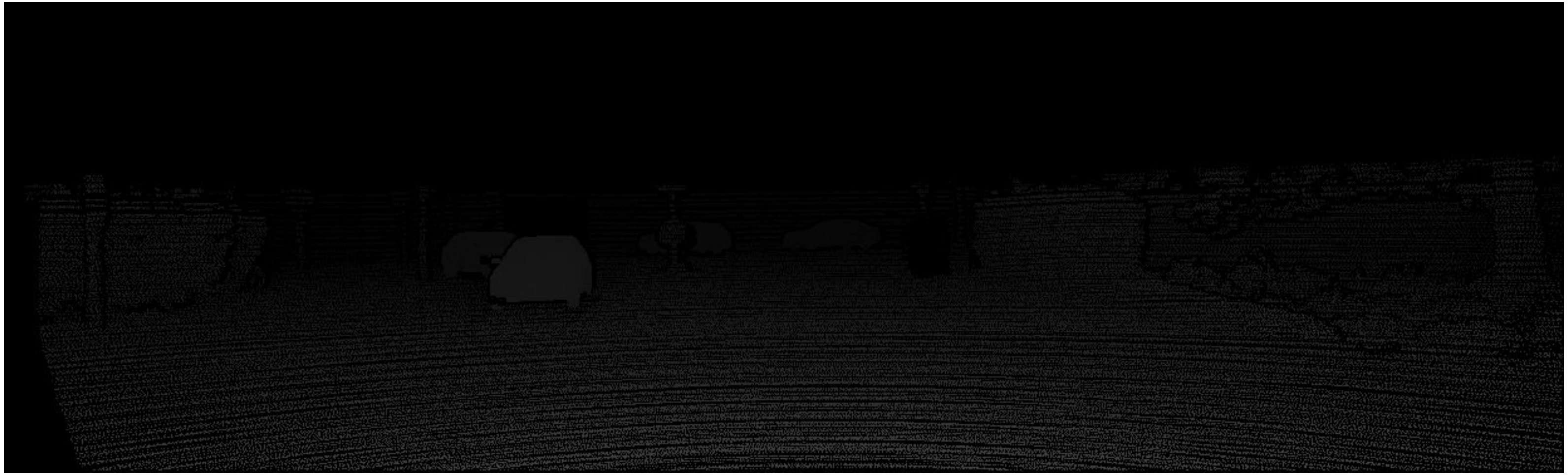
    Depth = (*f* . *B*) / Disparity
- **3D Point Cloud Generation:**
  - Unproject depth maps to 3D space and map color info from stereo images.

Results

- **Disparity Maps:** High-quality maps from SGM (Fig. 1) and from PatchMatch (Fig. 2).
- **3D Point Cloud:** SGM and PatchMatch visualized using Open3D (Fig. 3 and Fig. 4).
- **Quantitative Comparison:**
  - Average error with KITTI ground truth (SGM = 0.1282 pixels, PatchMatch = 11.7196 pixels).
- **Performance Evaluation:**
  - Comparison of accuracy vs. computational efficiency.

Results

- **Figure 1:** Example of Disparity Map from SGM



Results

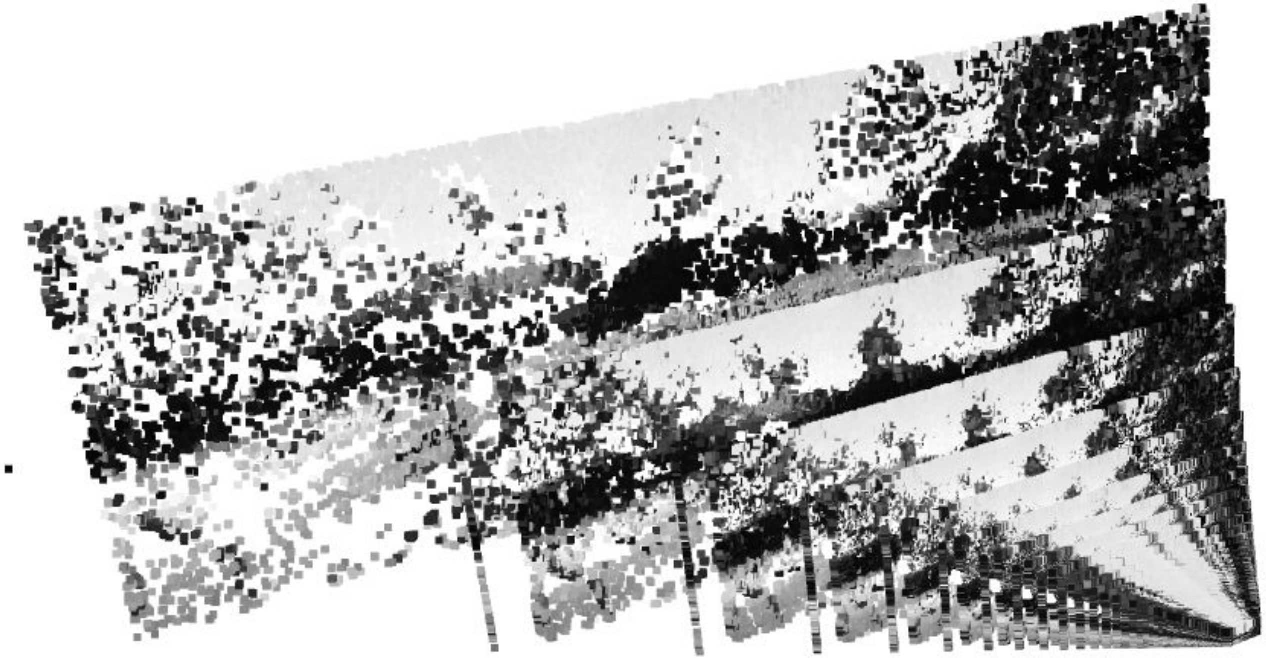
- **Figure 2:** Example of Disparity Map from PatchMatch

Results

- **Figure 3:** 3D Point Cloud from SGM

Results

- **Figure 4:** 3D Point Cloud from PatchMatch



Contribution of Team Members

- **Kunal Kamalkishor Bhosikar:**
    - Led the implementation of stereo matching algorithms (SGM and PatchMatch).
    - Conducted the dataset preparation and calibration.
    - Worked on 3D point cloud visualization and Open3D integration.
- **Prakhar Jain**
    - Helped with performance evaluation and testing.
    - Assisted with the dataset download and processing.

Conclusion

- **Summary:**
  - Successful implementation of classical stereo matching algorithms (SGM, PatchMatch) for dense 3D reconstruction.
  - Demonstrated the potential for real-time applications with efficient computational performance.
- **Future Work:**
  - Explore deep learning-based methods for higher accuracy.
  - Improve robustness in handling occlusions and texture-less regions.

Thank You