Advancing Seafloor Mapping with Machine Learning: A Point Convolution Approach for Filling the Gaps in Multibeam Echo Sounder Data

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Abstract:

Modern ocean mapping relies on Multibeam Echo Sounder (MBES) systems to collect high-resolution bathymetric data. However, environmental constraints, vessel motion, and sonar geometry can lead to gaps in seafloor coverage. These missing regions pose significant challenges for analysis and visualization, especially when they occur in areas of complex morphology. To address this, we propose the use of deep learning models designed for point cloud completion, specifically the LAKe-Net architecture, to reconstruct plausible seafloor surfaces from incomplete sonar point clouds.

Point cloud completion has been actively researched in the computer vision community, primarily focusing on synthetic datasets such as ShapeNet. Early approaches such as Point Completion Network (PCN) reconstruct object shapes from partial views using encoder-decoder structures (Yuan et al., 2018). More recently, topology-aware models such as LAKe-Net have introduced a Keypoint-Skeleton-Shape representation, using learned multi-scale keypoints and surface skeletons to guide the completion process (Tang et al., 2023). While these models have shown promise on clean, synthetic data, their adaptation to noisy, real-world geospatial data like MBES remains underexplored. Our work bridges this gap by applying and evaluating LAKe-Net on real bathymetric sonar datasets.

Our pipeline adapts LAKe-Net's three-stage structure to sonar data:

- **Stage 1 – UMKD (Unsupervised Multi-scale Keypoint Detector)**: We train the UMKD module on full MBES tiles to detect aligned keypoints across scales (64, 128, 256). These keypoints are designed to represent topologically meaningful areas of the seafloor.
- **Stage 2 – Surface Skeleton Decoder**: Using the keypoints as input, this decoder generates a dense point cloud representing a completed seafloor patch.
- **Stage 3 – Refinement (optional)**: A final refinement MLP further improves point continuity and removes minor artifacts.

Training data is derived from survey test sites in the region of the Gulf Islands, British Columbia where full point clouds are uniformly partitioned. Partial inputs are simulated by randomly subsampling 50% of the points in each tile. Ground truth completion targets use the original full-resolution mosaics.

This work presents an adaptation of LAKe-Net, a topology-aware point cloud completion model, to the domain of multibeam sonar mapping. By training on mosaicked MBES data and simulating realistic gaps, we want to reconstruct missing regions of the seafloor using neural networks instead of interpolation techniques.

References

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