ChunkFusion

A Learning-based RGB-D 3D Reconstruction Framework via Chunk-wise Integration

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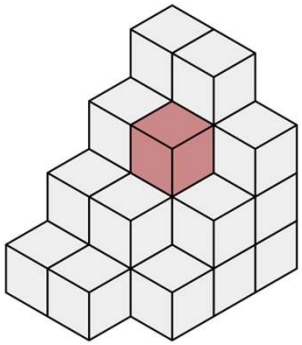
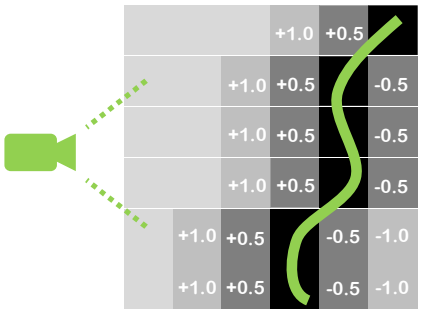
https://github.com/Goochaozheng/ChunkFusion

RGB-D Reconstruction Methods

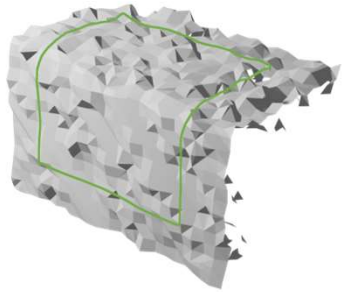
- Reconstruct mesh model from RGB-D scans.
- TSDF, Truncated Signed Distance Function.



Voxel Representation



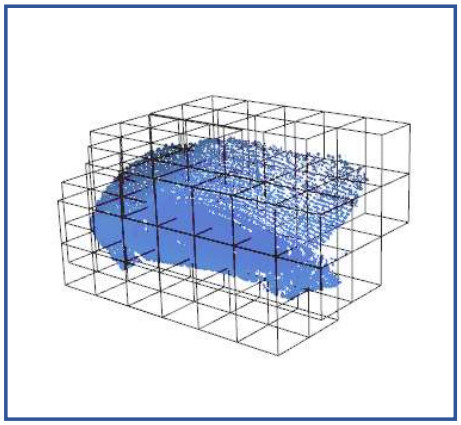
TSDF Integration



Sensitive to noise

Learning-based RGB-D Reconstruction

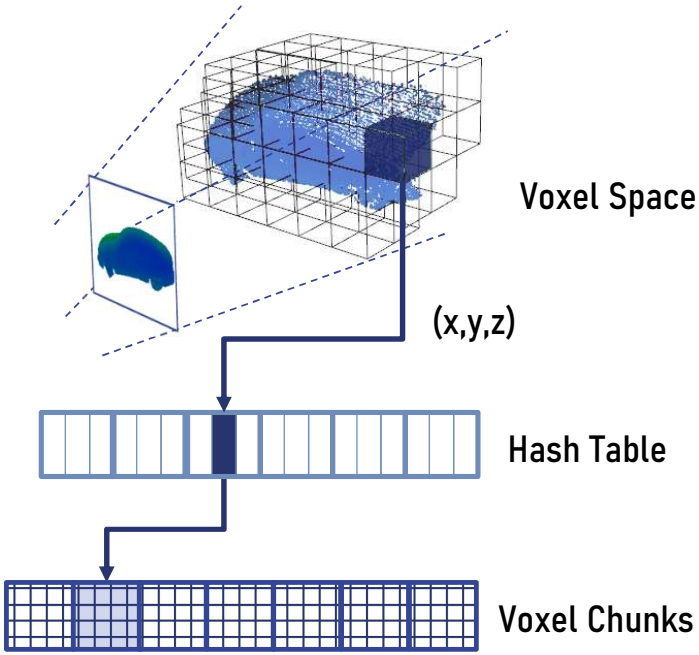
- Fuse the entire voxel volume for model refinement.
- Limited to a small input voxel volume with a fixed size.
- Not capable of online reconstruction.



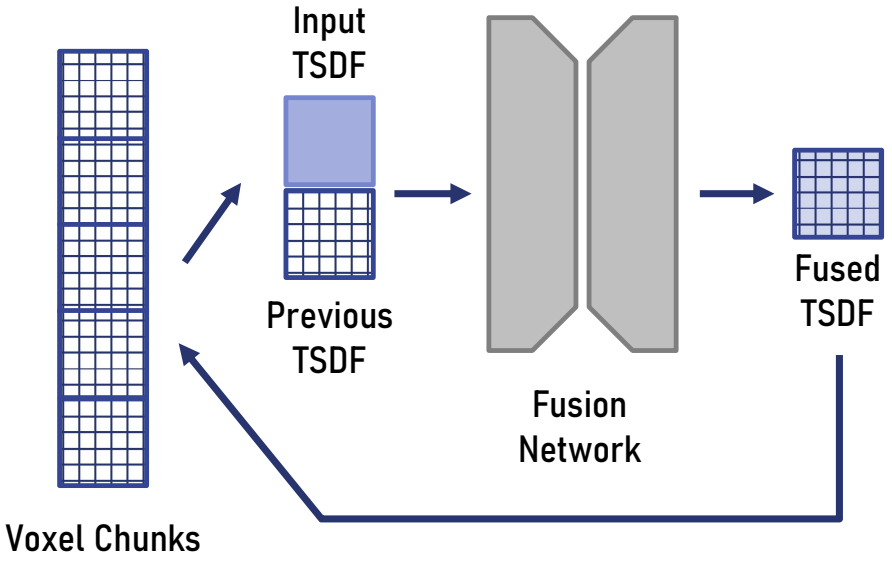
Voxel Volume

Fused Model

Chunk-wise Learning-based TSDF Integration

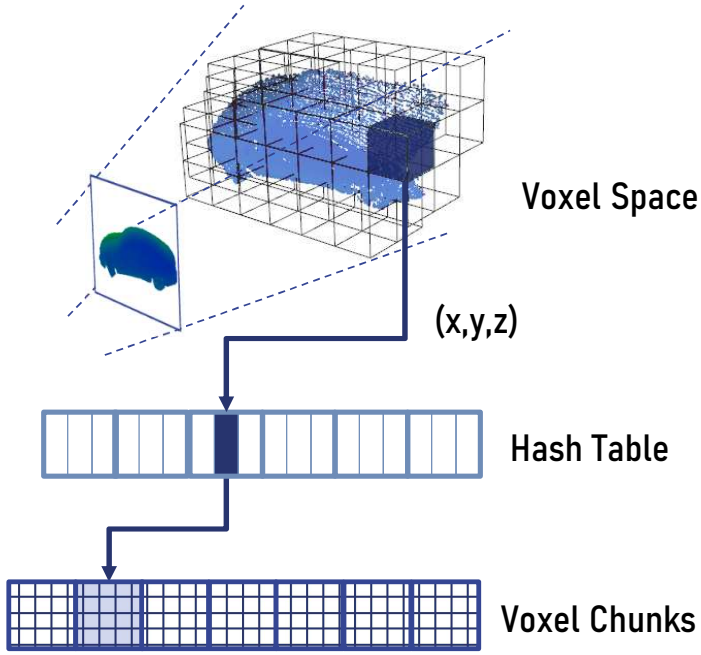


Voxel Chunk Hashing



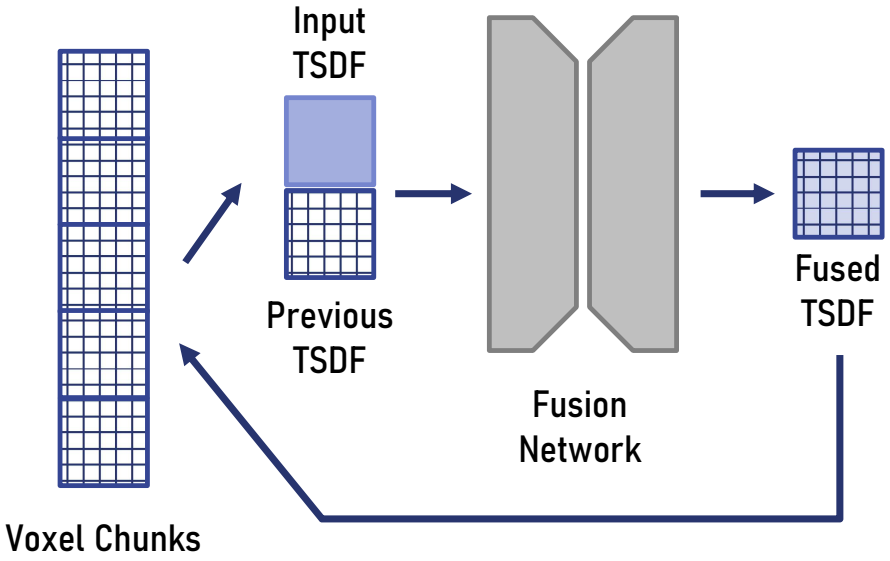
Learning-based TSDF Integration

Voxel Chunk Hashing



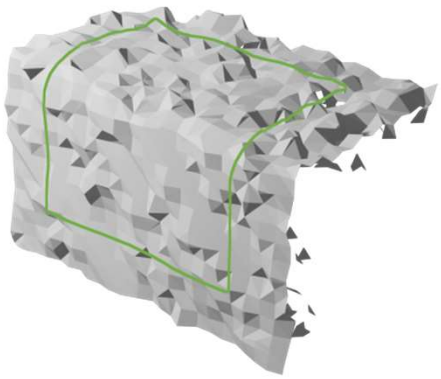
- Divide the voxel space evenly into chunks.
- Allocate chunks at occupied space.
- Manage allocated chunks with a hash map.

Learning-based Integration

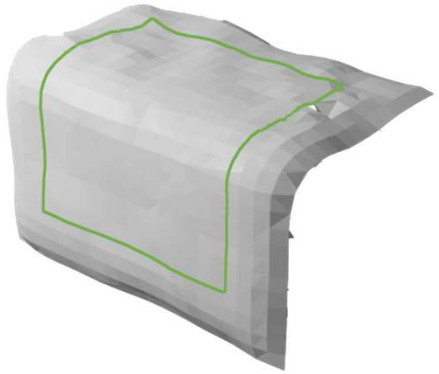


- TSDF of each chunk are updated with the fusion network.
- Fusion network learns to integrate partial surface regions.
- Similar partial regions ensure better generalization ability.

Learning-based Integration



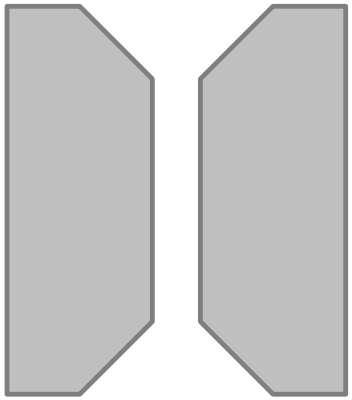
Noisy Chunk Input



Fused Chunk Surface

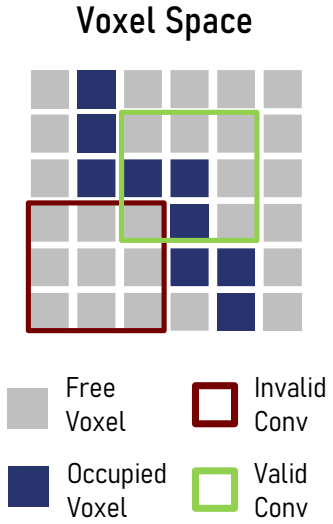
- TSDF of each chunk are updated with the fusion network.
- Fusion network learns to integrate partial surface regions.
- Similar partial regions ensure better generalization ability.

Fusion Network



Encoder Decoder

- 3D convolutional neural network.
- Two stage U-Net architecture.

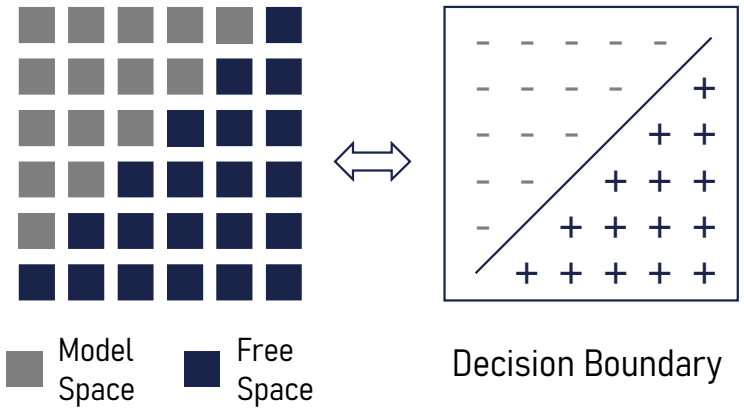


- Sparse convolution layer.
- Convolution is performed sparsely on occupied voxels solely.

Loss Function

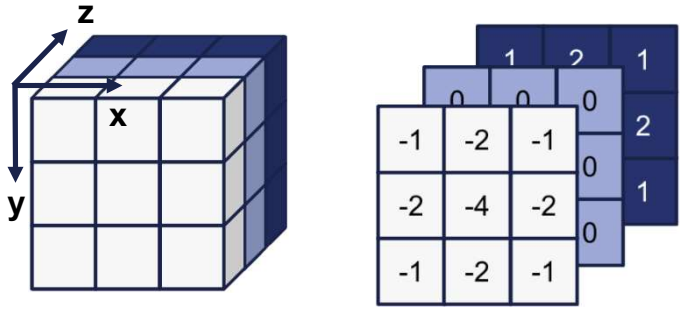
Sign Loss

$$\mathcal{L}_{sign} = BCE\left(sign\left(\mathcal{F}\left(\hat{\boldsymbol{v}}_i^{\boldsymbol{t}}, \boldsymbol{v}_i^{\boldsymbol{t-1}}\right)\right),\ sign(\boldsymbol{v}_i^{*}) \right)$$



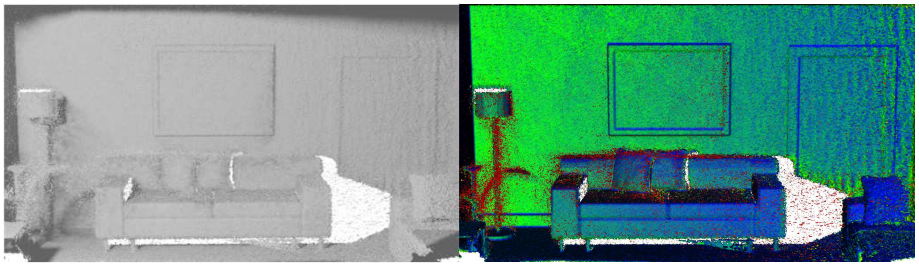
Gradient Loss

$$\mathcal{L}_{grad} = \sum_{j=x,y,z} \frac{1}{k^3} \left\| \nabla_j \left(\mathcal{F}\left(\hat{\boldsymbol{v}}_i^{\boldsymbol{t}}, \boldsymbol{v}_i^{\boldsymbol{t-1}}\right) \right) - \nabla_j(\boldsymbol{v}_i^{*}) \right\|_1$$

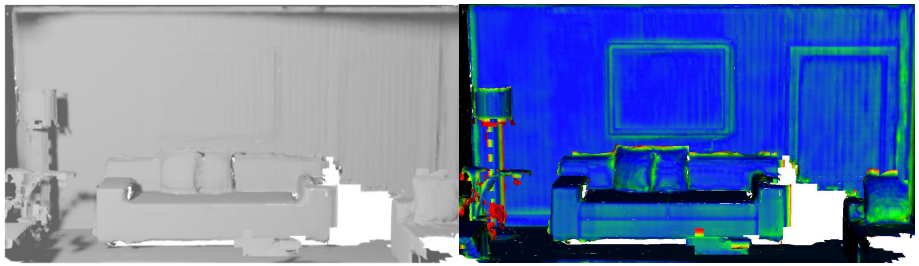


3D Sobel Gradient

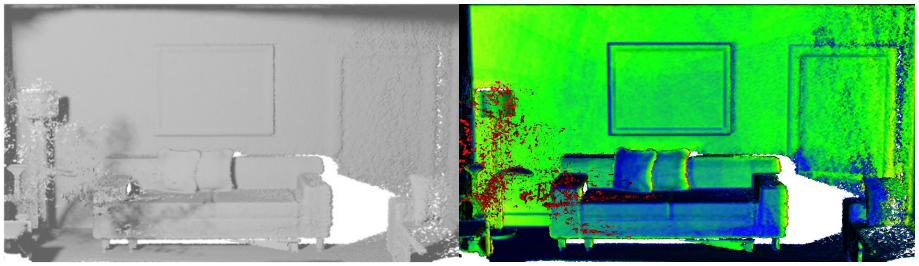
Surface Error



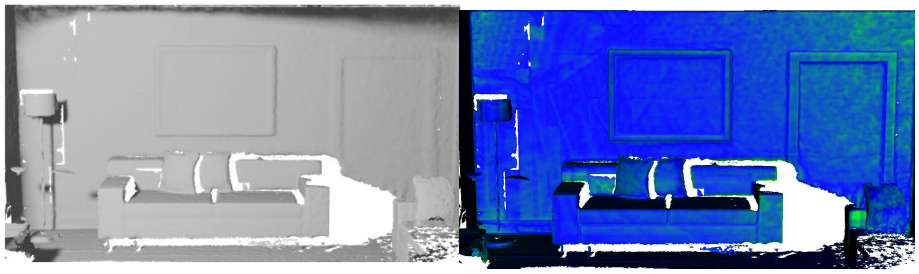
Standard TSDF – Average Error 0.0539



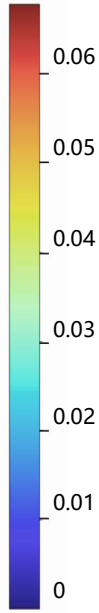
DI-Fusion – Average Error 0.0127



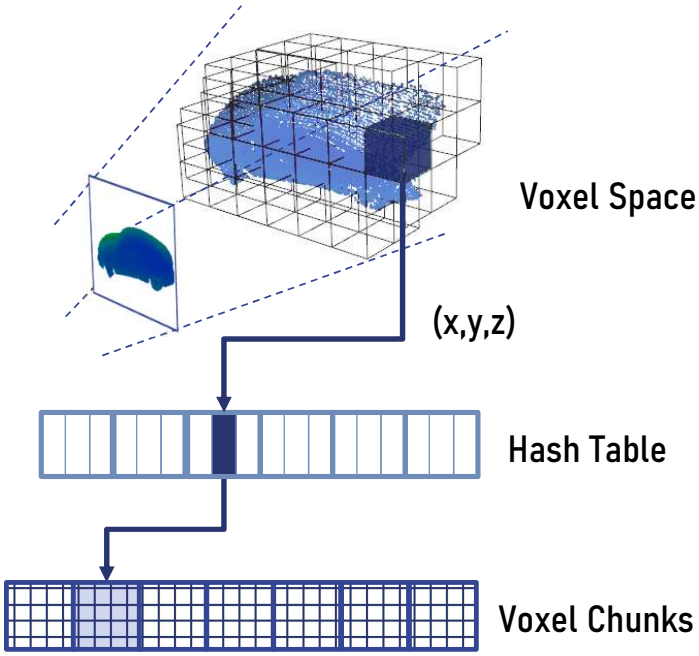
RoutedFusion – Average Error 0.0405



ChunkFusion – Average Error 0.0062



Conclusion



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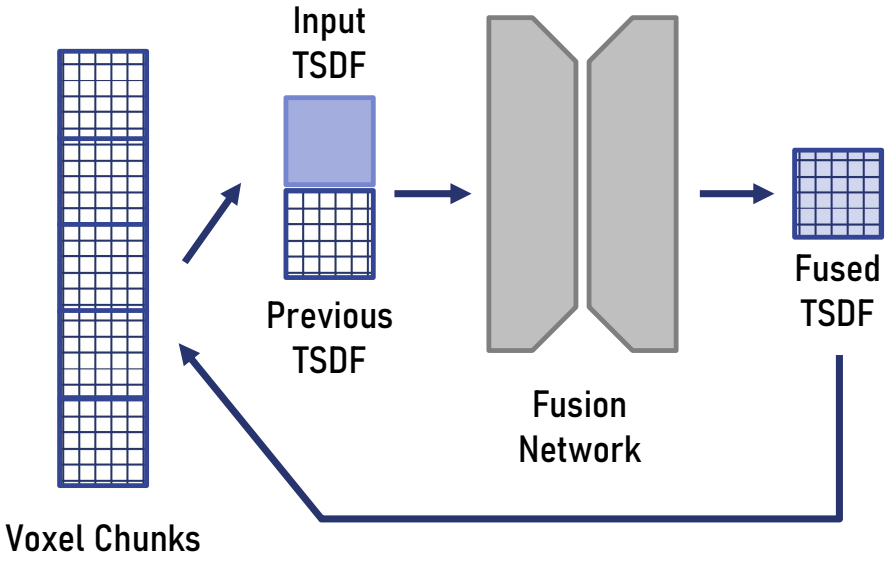

Learning-based TSDF Integration