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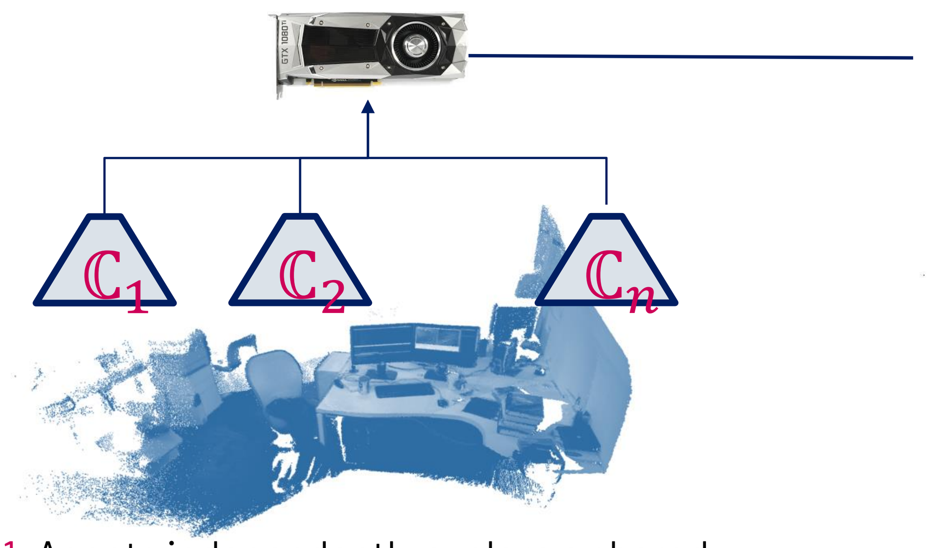
Spatial AI: Dense Visual Mapping

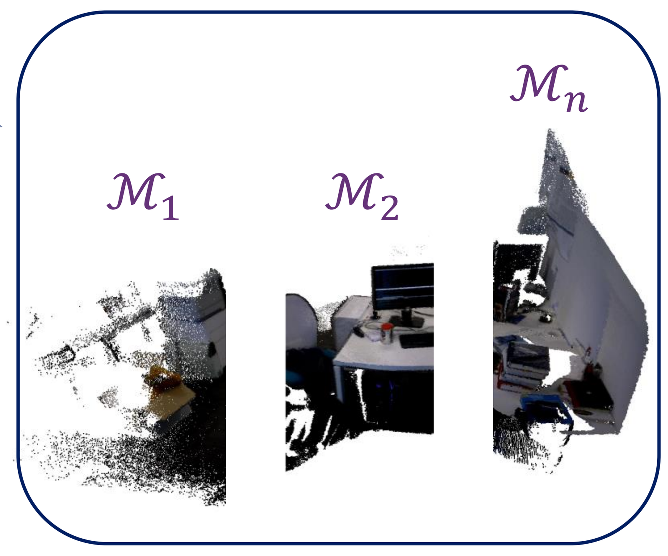
Valeo

Louis Gallagher, John McDonald

1 COLLABORATIVE DENSE VISUAL SLAM:

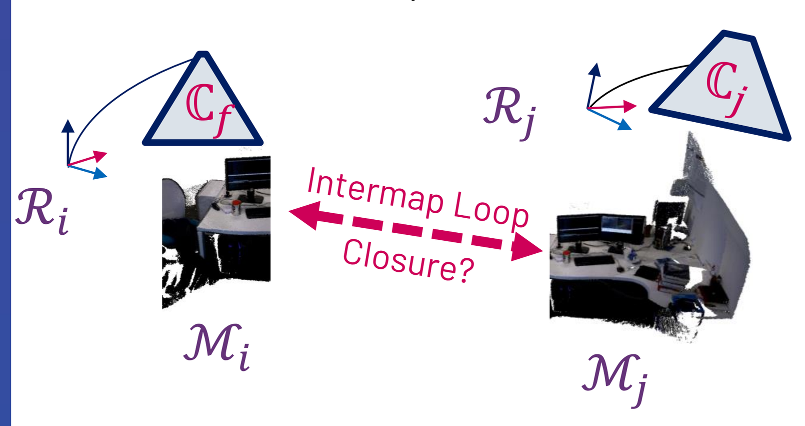
- Spatial understanding for multiple collaborating autonomous agents
- Agents work together to build and maintain a shared representation of their workspace



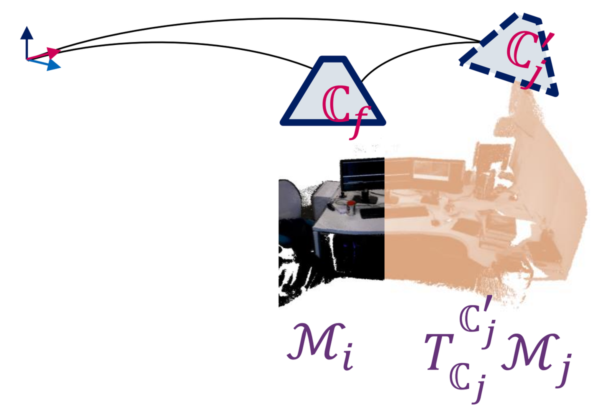


1. Agents independently explore a shared workspace

2. Initially, each agent builds a separate submap of the environment.



3. A centralised mapping node searches for inter-map loop closures, i.e., overlap between each agents submap



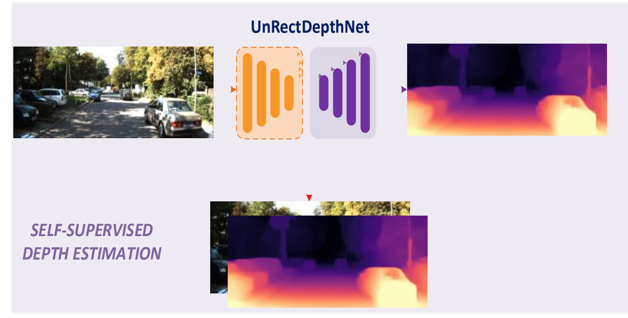
4. Overlapping submaps are brought into alignment and fused into a single global map of the environment, shared by all agents

L. Gallagher and J. McDonald. Collaborative Dense SLAM. In Proceedings of the 2018 IPRCS, Irish Machine Vision and Image Processing Conference, 2018, Best Paper Award.

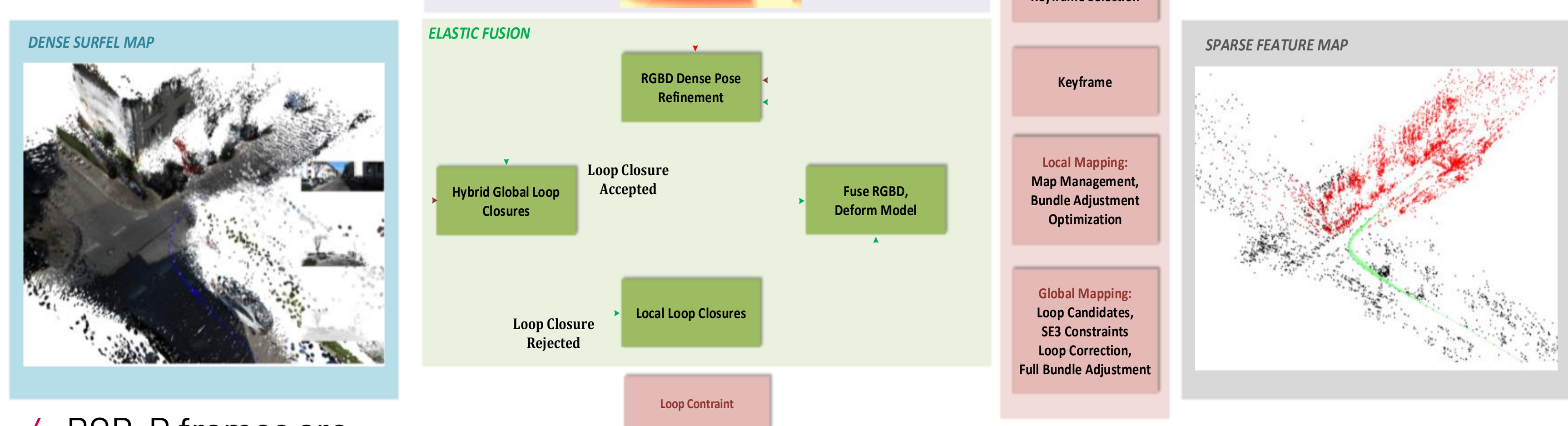
2 HYBRID SPARSE-DENSE MONOCULAR SLAM:

- Dense 3D visual mapping for automotive applications
- Combine sparse and dense SLAM approaches with CNN-based dense geometry prediction

1. UnRectDepthNet predicts 2.5D depth map for each colour frame

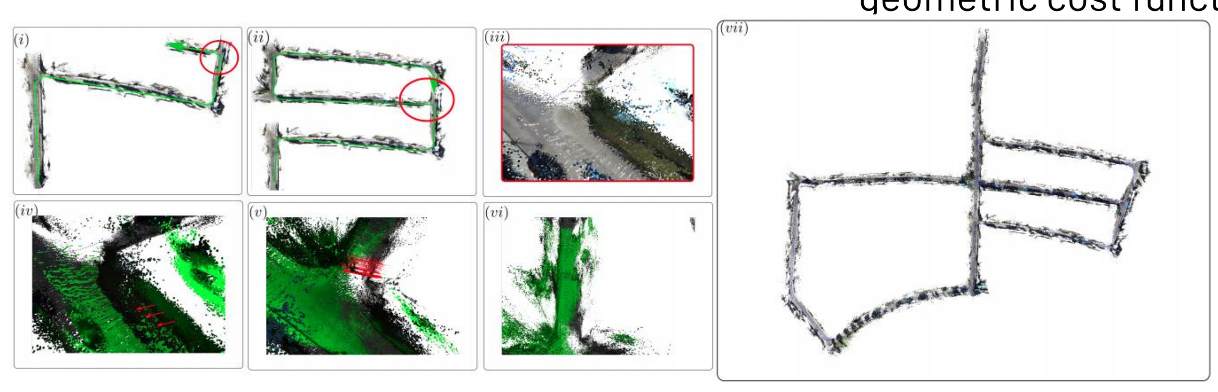


2. ORBSLAM-3 performs sparse, feature-based SLAM: suitable for fast, wide-baseline camera motion



4. RGB-D frames are fused into a dense surfel model

3. The sparse pose is brought into tight alignment with the dense model via a 6-DOF optimisation based on a joint photometric and 2.5D geometric cost function

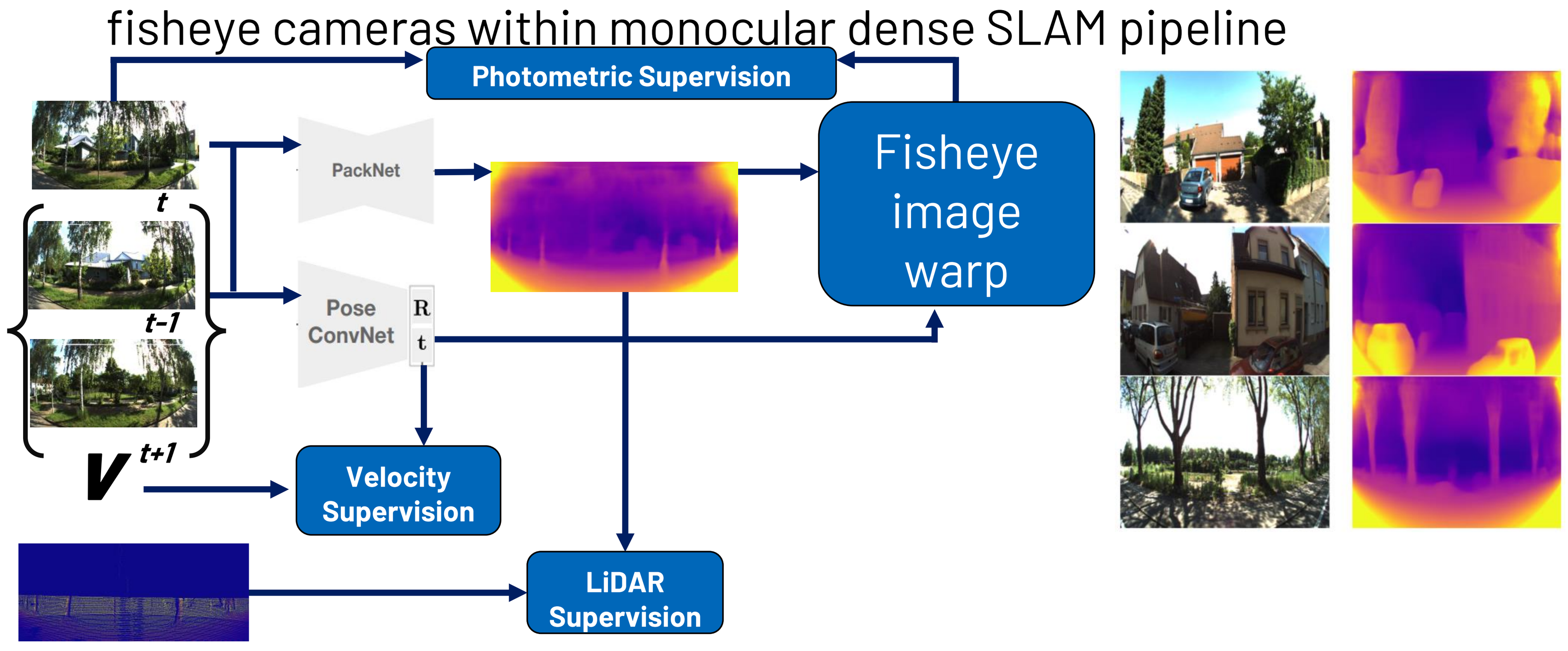


Loop closure constraints generated by ORBSLAM are reflected in the dense surfel map via a deformation graph of affine transforms

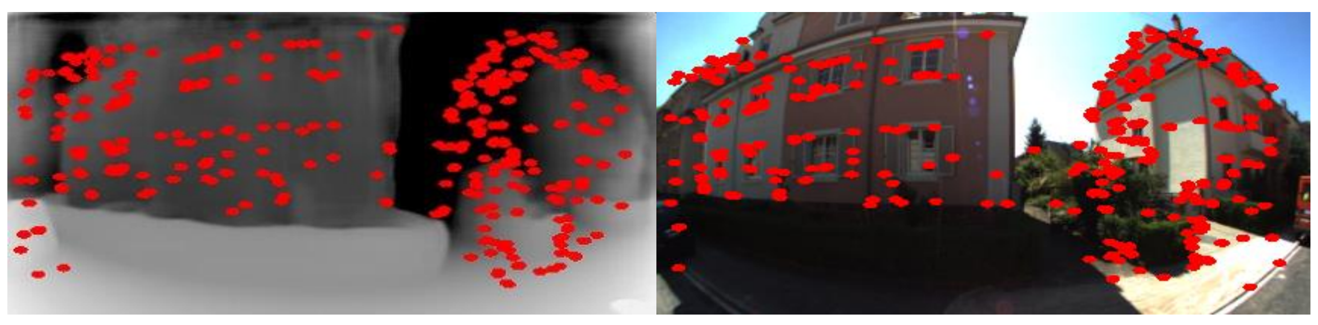
L. Gallagher, V. Kumar, S. Yogamani, and J. McDonald. A Hybrid Sparse-Dense Monocular SLAM System for Autonomous Driving. In 2021 European Conference on Mobile Robots(ECMR), pages 1–8, 2021

3 DENSE VISUAL SLAM FOR FISHEYE CAMERAS:

- Extend hybrid SLAM architecture (2, above) to support wide FOV fisheye cameras within monocular dense SLAM pipeline



1. Fisheye depth estimation CNN builds on PackNet to support Kannala-Brandt camera model without any rectification (Left). Example results on challenging inputs (Right).



Sparse point cloud overlaid on dense metric depth

Sparse map overlaid on color image for reference

Per-frame scale ratio $s_t = \frac{med(D_t)}{med(D_{orb})}$

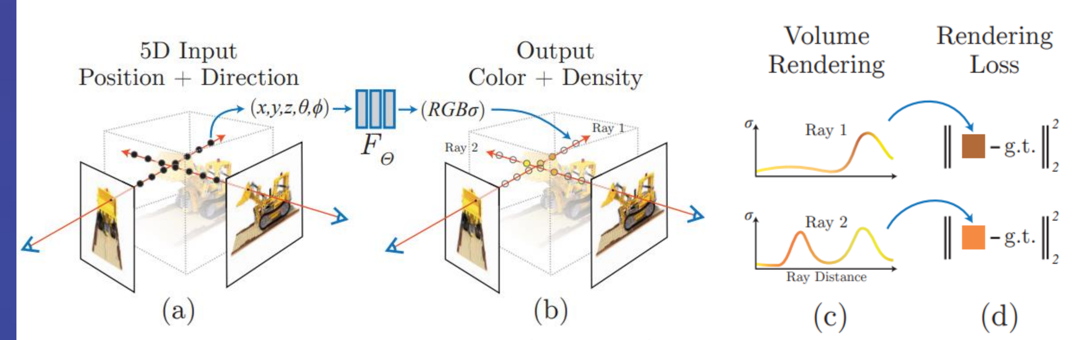
$\{s_i \in \mathbf{S} | s_i \in [\mu_S \pm 2\sigma_S]\}$ **Rolling buffer to remove noise**

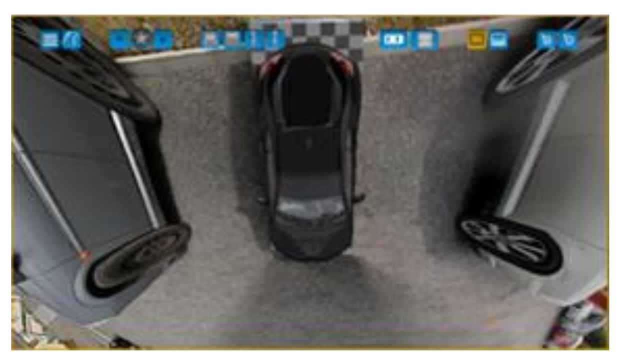
2. Scale ambiguous ORBSLAM map needs to be aligned to the metric-scale of the predicted depth maps. We do so by estimating the scale ratio between the predicted dense depth map and a sparse depth map rendered from ORBSLAM, averaged over a rolling buffer of frames to account for scale drift

L. Gallagher, G. Sistu, J. Horgan, and J. B. McDonald. A system for dense monocular mapping with a fisheye camera. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) Workshops, pages 6478–6486, June 2023

4 NERF-XR:

- Photorealistic novel view synthesis for near-field, surround-view visualisation in automotive applications

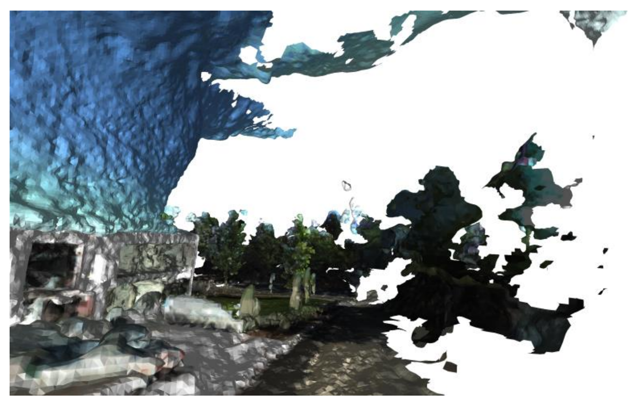




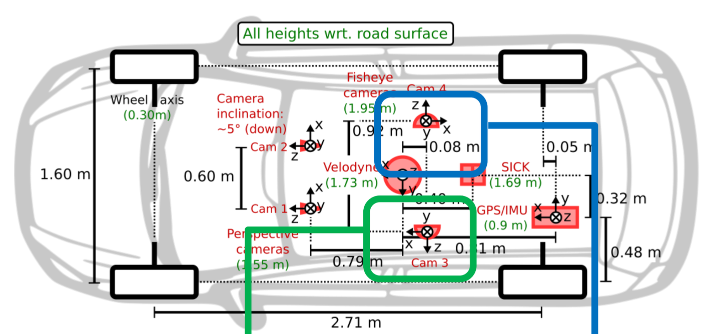
1. NeRFs represent the radiance field of a scene in the weights of an MLP. Weights are optimized via differentiable rendering

2. Can we use this representation to improve over existing surround-view visualization approach based on fixed bowl geometry which results in visualization artefacts?

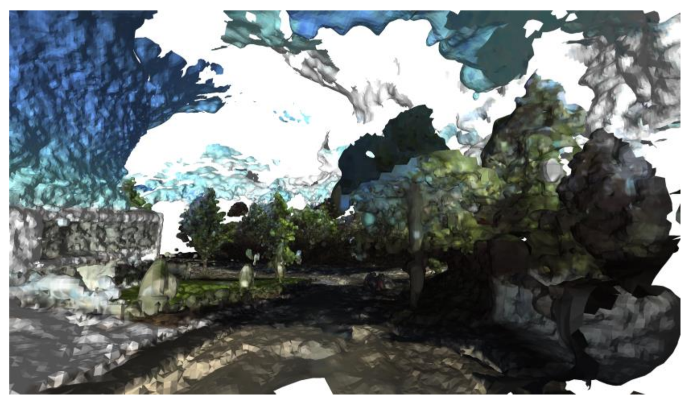
3. We use both KITTI-360 fisheye cameras to construct a surround view model in the periphery of the car



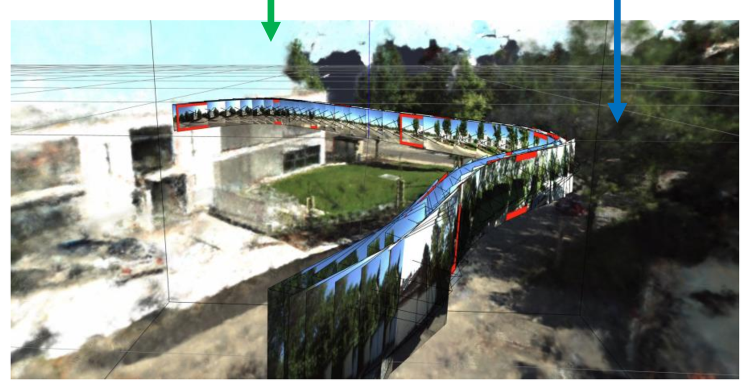
Reconstruction using one camera



KITTI-360 sensor set-up



Reconstruction using two cameras



Surround-view NeRFacto Training W/ KITTI-360

HOST INSTITUTION
University of Limerick — Ollscoil Luimnigh

PARTNER INSTITUTIONS
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