Deep Inverse Sensor Models as Priors for evidential Occupancy Mapping

Motivation

R_T

estimated occupancy state

reference occupancy state

Where can I drive?
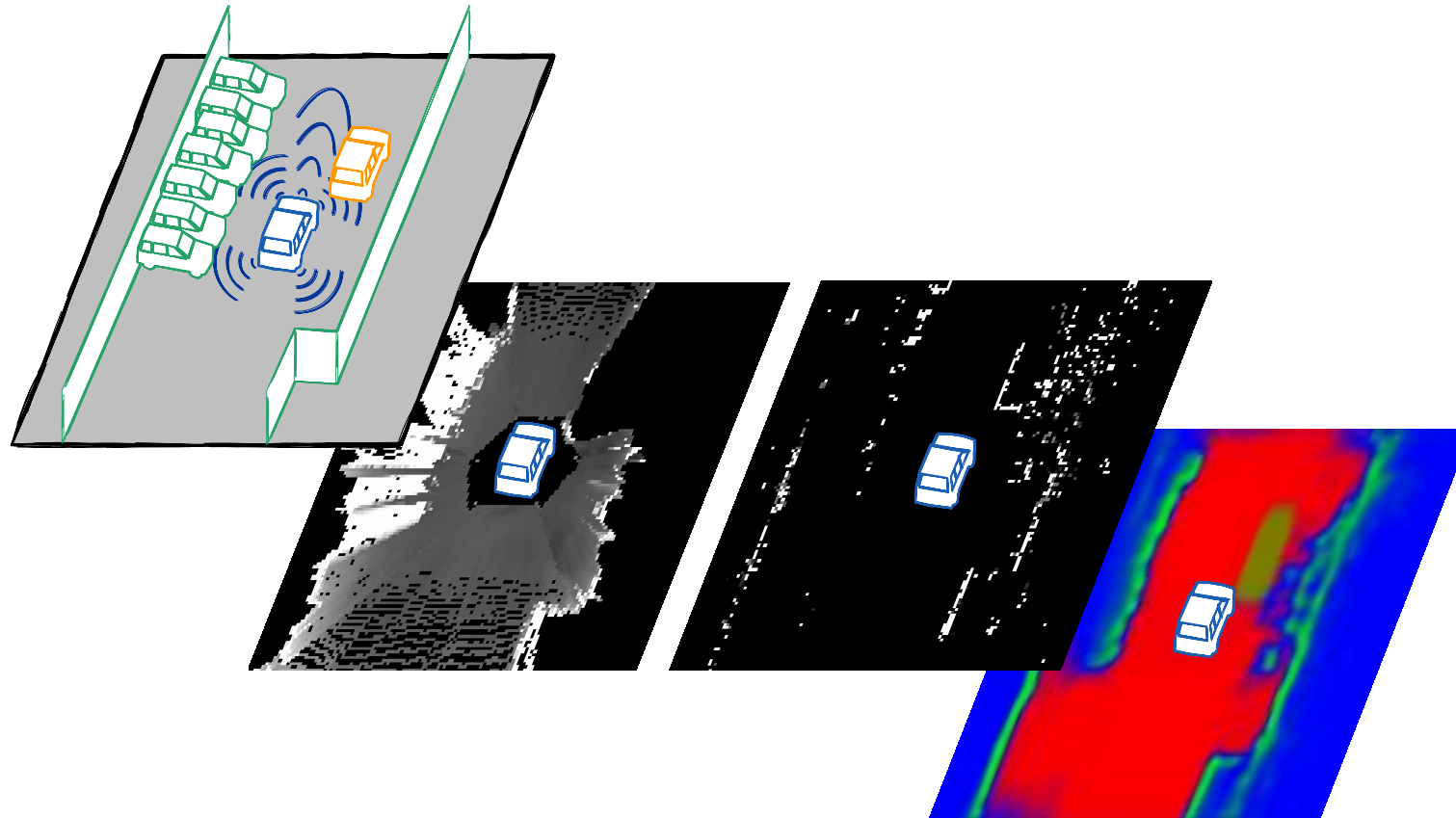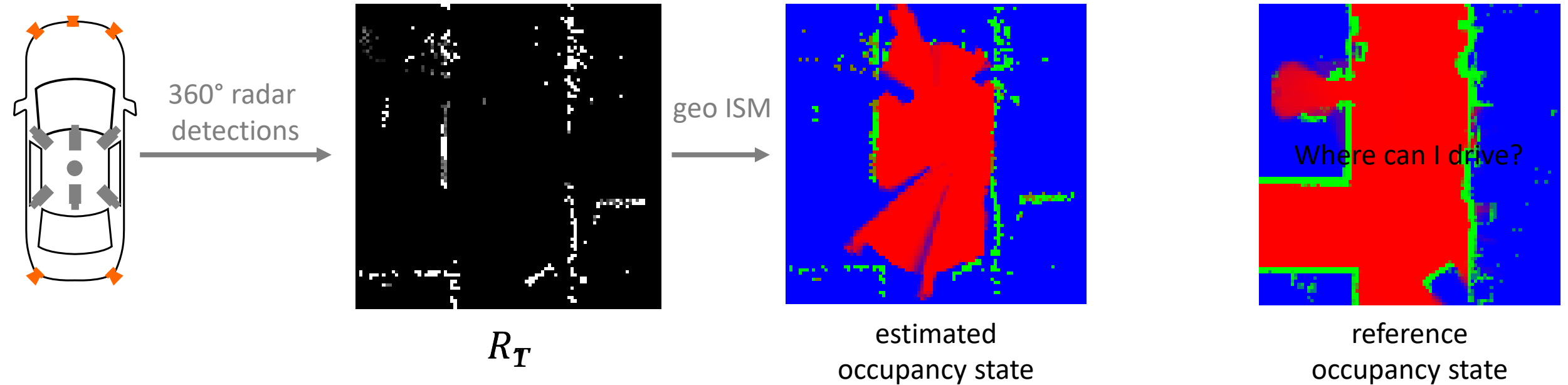
Problems with geo ISMs
- initial sparseness of predictions
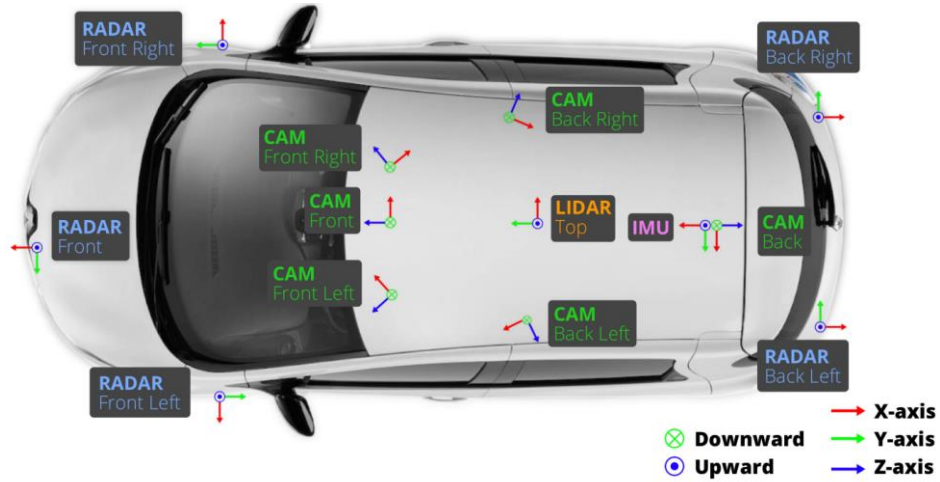- spatial coherence in the data not utilized
- dynamic objects not well captured

Problems of deep ISMs as Priors for OccMaps
- accumulation temporal redundancy
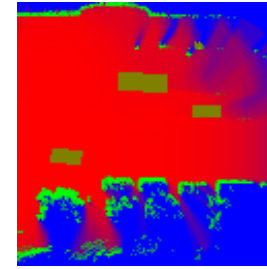- deep ISM should only be used for initialization

free | occupied | unknown

Structure

Dataset

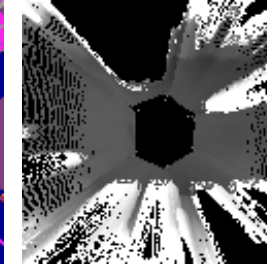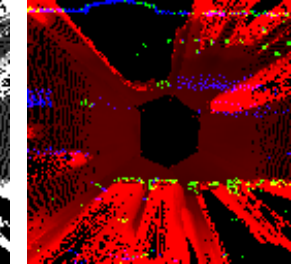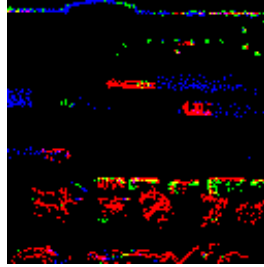L GT R_1 R_T $R_{T|1}$
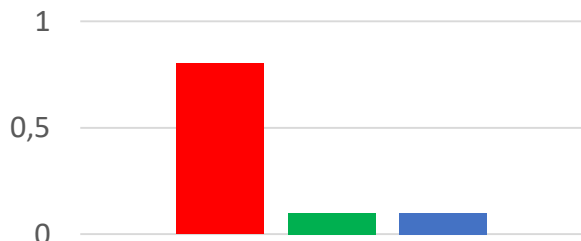
C_{RGB} C_S C_D $C_D\&R_T$ $L\&R_T$

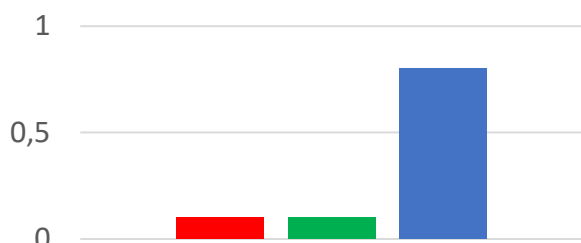| Sensor	Details
6x Camera	RGB, 12Hz capture frequency, 1/1.8" CMOS sensor, 1600×900 resolution, auto exposure, JPEG compressed
1x Lidar	Spinning, 32 beams, 20Hz capture frequency, $360°$ horizontal FOV, $-30°$ to $10°$ vertical FOV, $\leq 70m$ range, $\pm 2cm$ accuracy, up to $1.4M$ points per second.
5x Radar	$\leq 250m$ range, 77GHz, FMCW, 13Hz capture frequency, ± 0.1km/h vel. accuracy
GPS & IMU	GPS, IMU, AHRS. $0.2°$ heading, $0.1°$ roll/pitch, 20mm RTK positioning, 1000Hz update rate

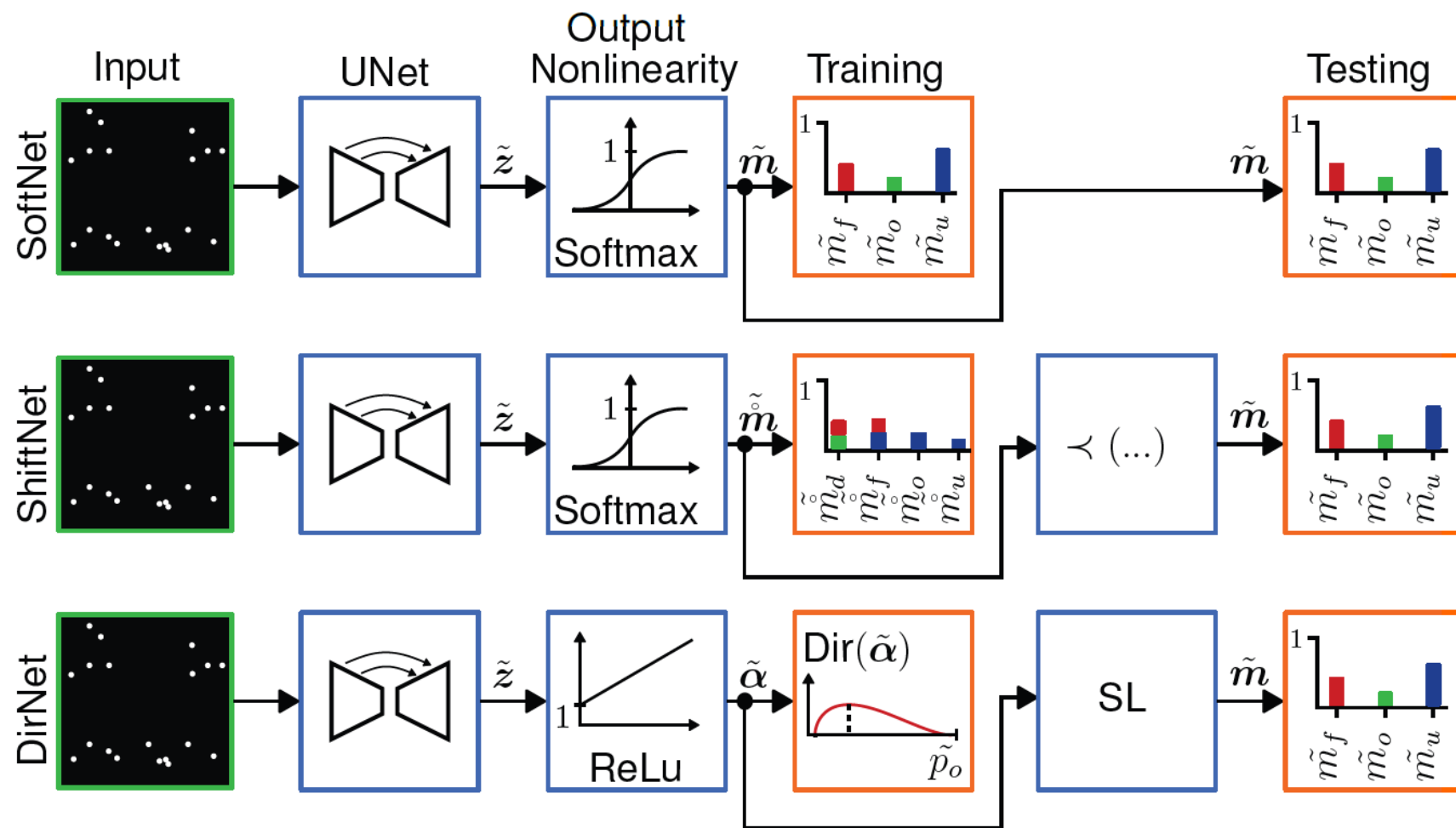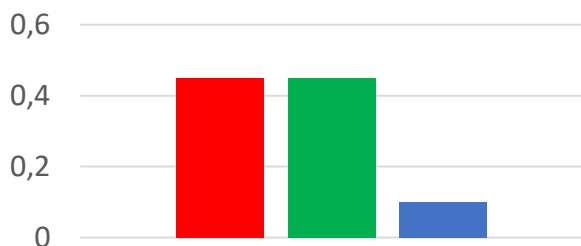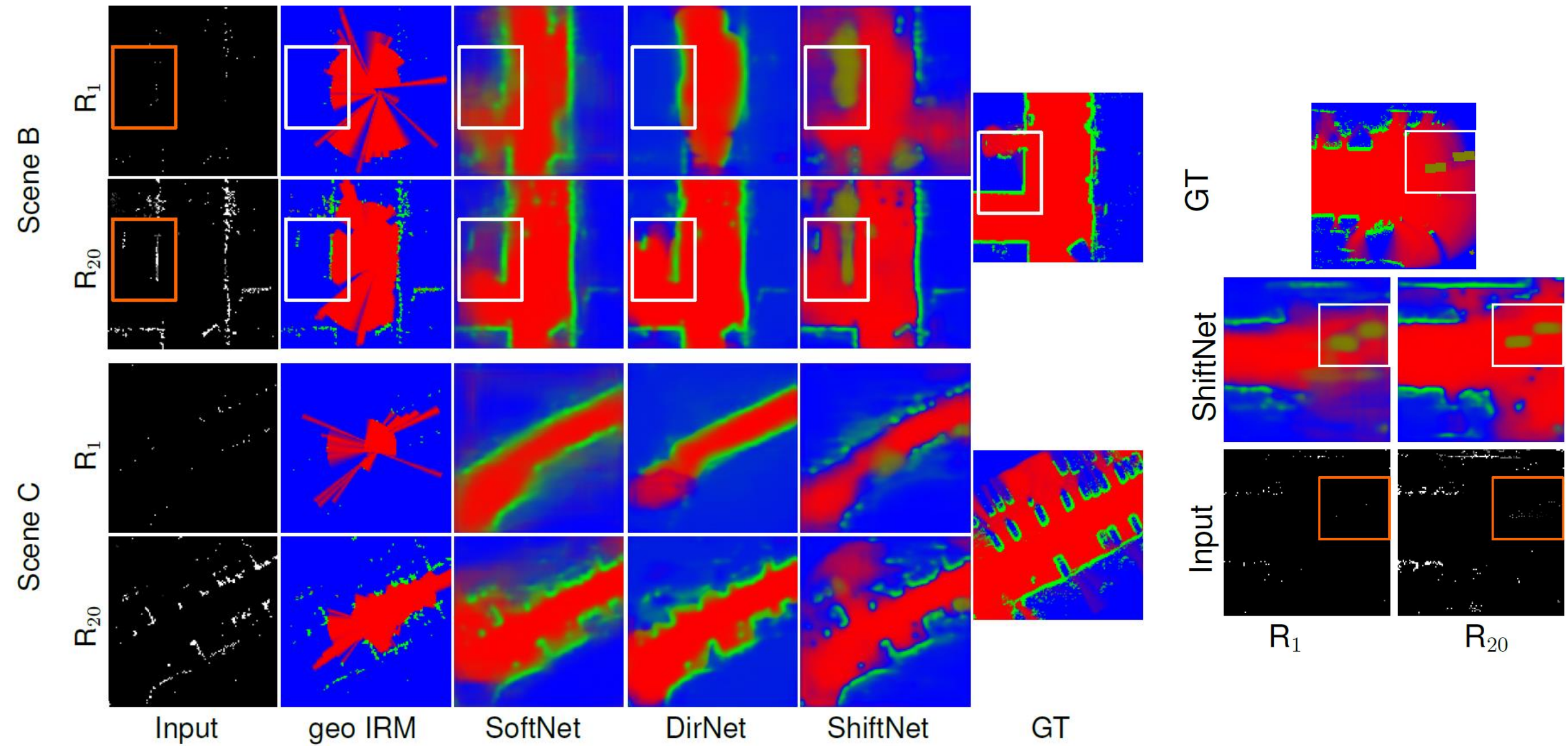Table 2. Sensor data in nuScenes.

Unknown vs. Dynamic

Input geo IRM SoftNet DirNet ShiftNet GT

Deep ISM Input Comparison

Camera

Input

Prediction

Input

Prediction

Scene B

Scene C

deep $IC_{RGB}M$ deep IC_SM deep IC_DM deep $IC_DR_{20}M$ deep $IR_{20}M$ GT

Lidar

Input

Prediction

Input

Prediction

Scene B

Scene C

geo ILM deep ILM deep $ILR_{20}M$ deep $IR_{20}M$ GT
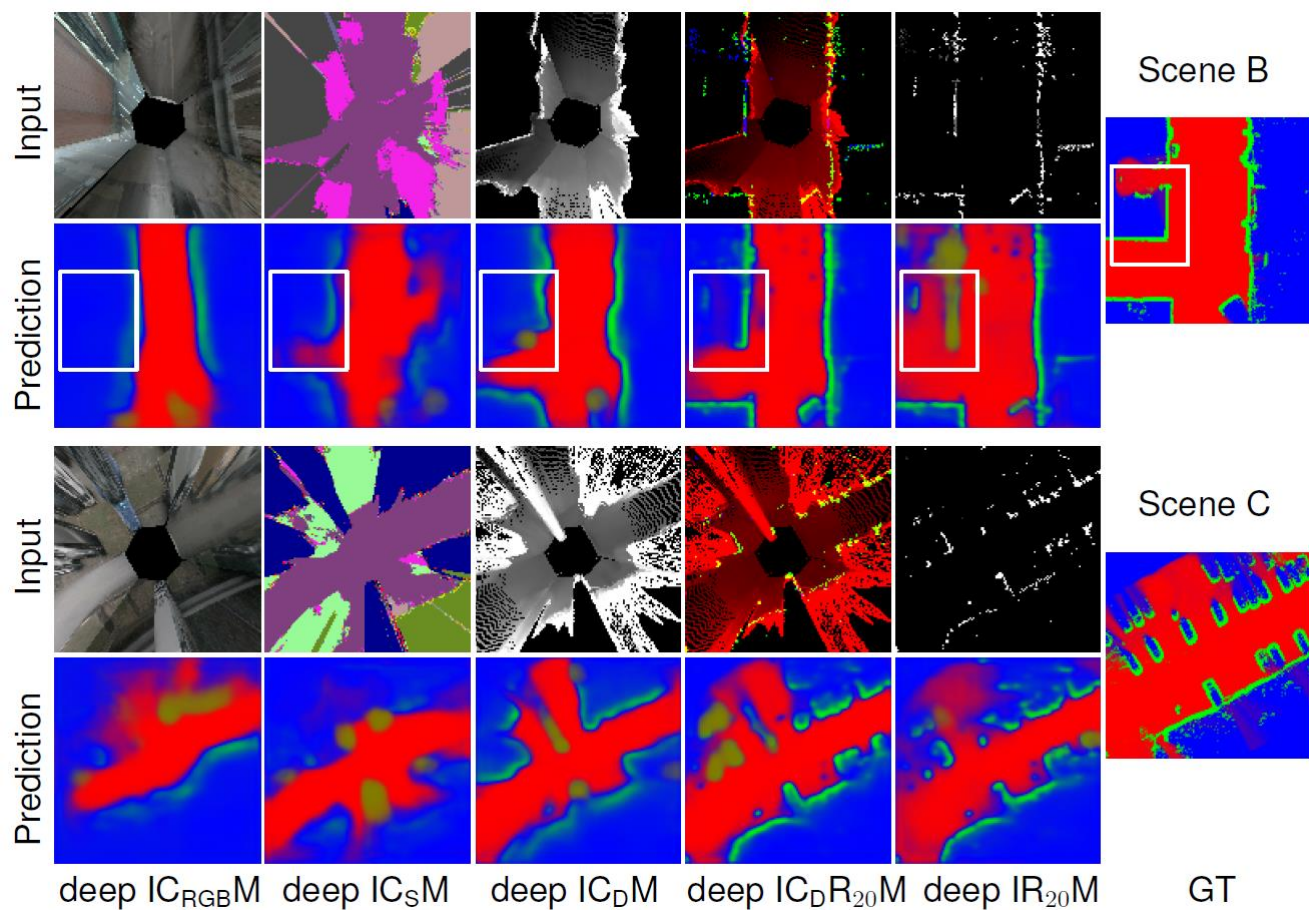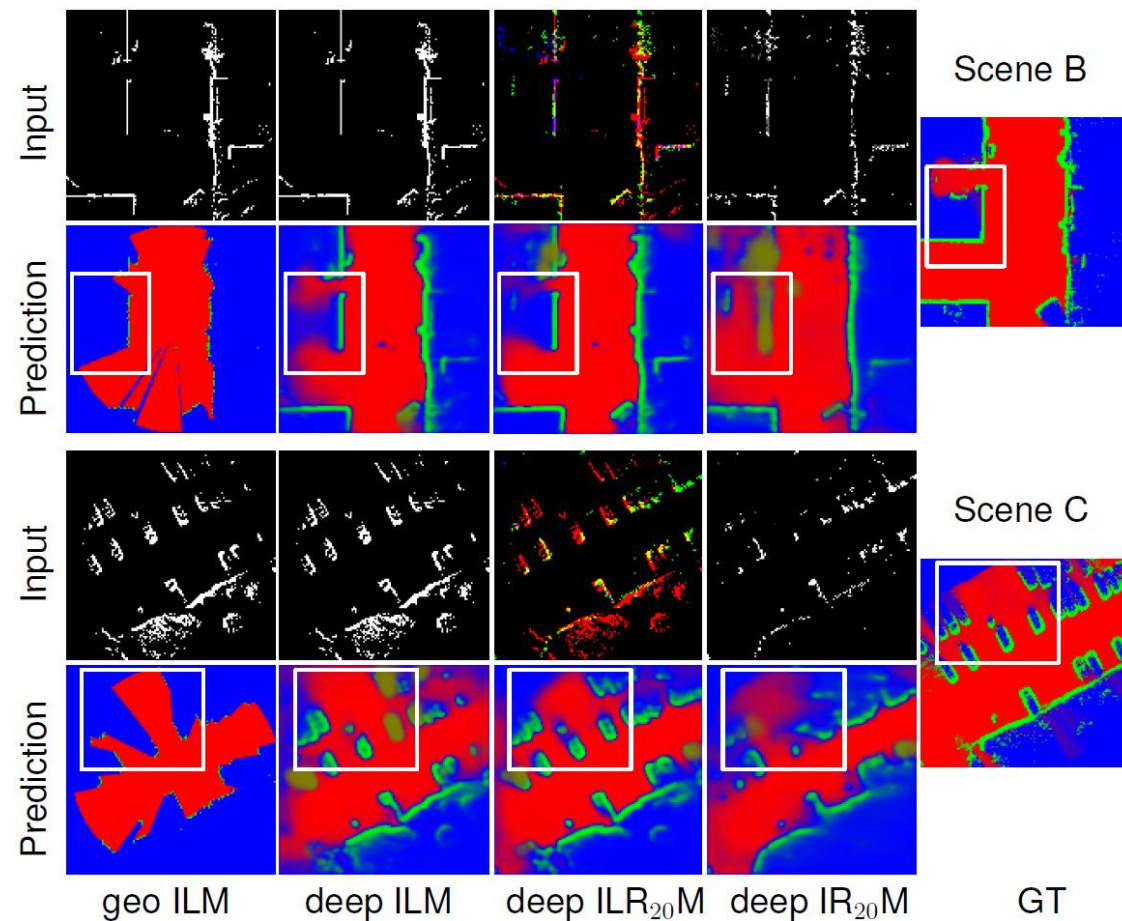
Structure

1. Motivation

2. Deep ISMs
   a. Uncertainties in deep ISMs
   b. Camera, Lidar and Fused Inputs for deep ISMs

3. Deep ISMs as Priors for OccMaps
   a. Temporal Redundancy Reduction
   b. Restriction to Initialization
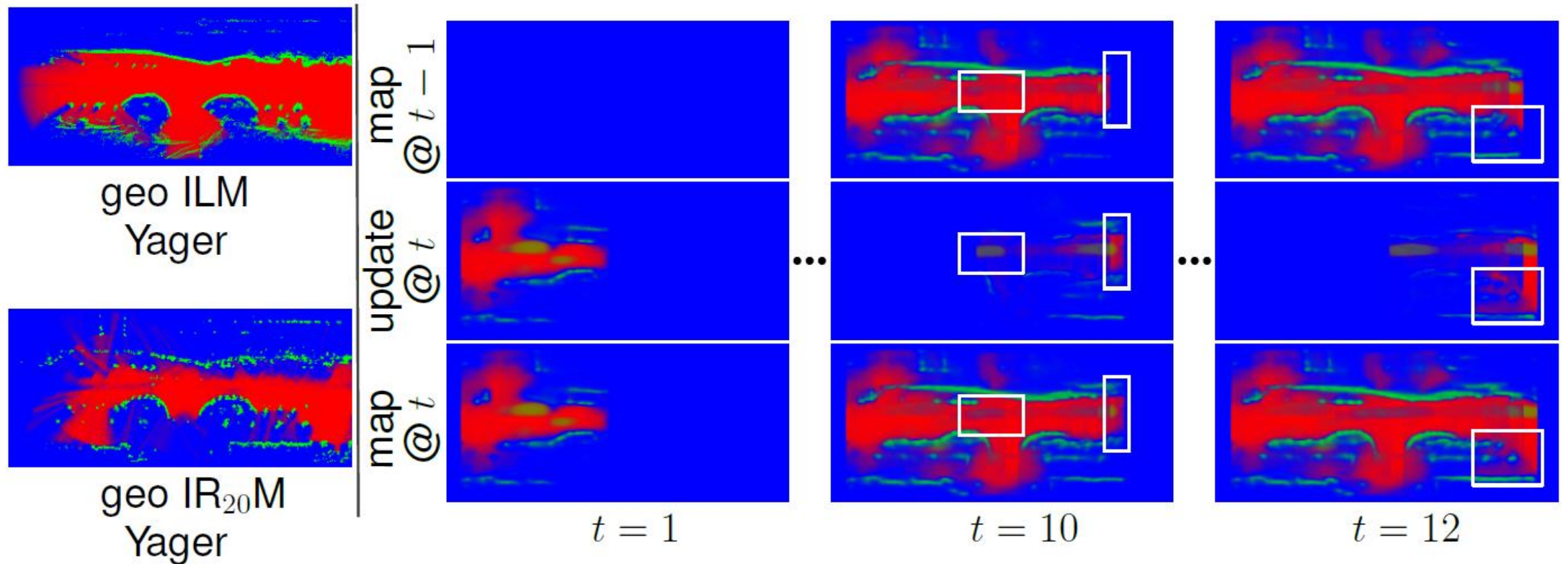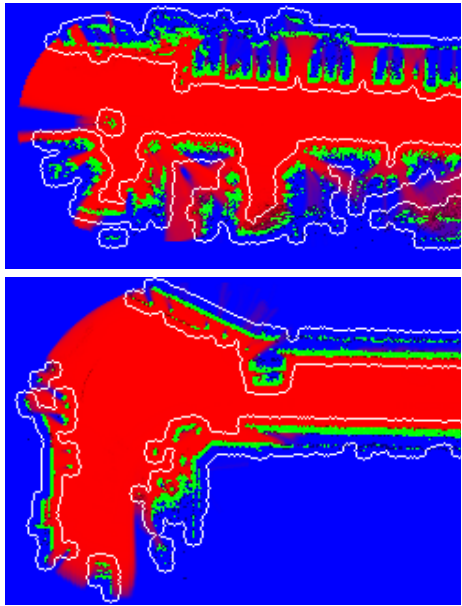
Redundancy reduced Update

discount operation

$$\gamma \otimes \boldsymbol{m} = \begin{bmatrix} \gamma m_f \\ \gamma m_o \\ 1 - \gamma + \gamma m_u \end{bmatrix}$$
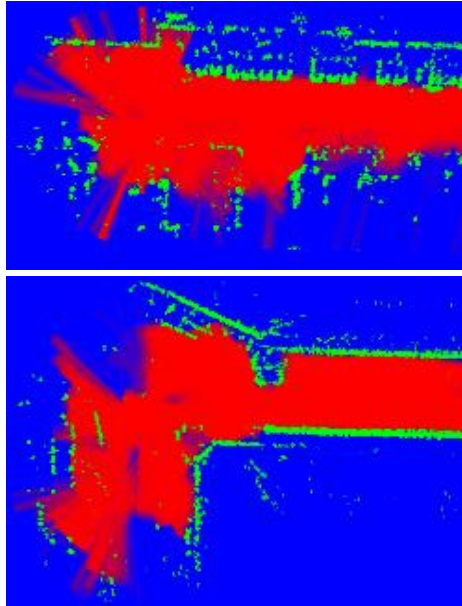
redundancy reduction factor

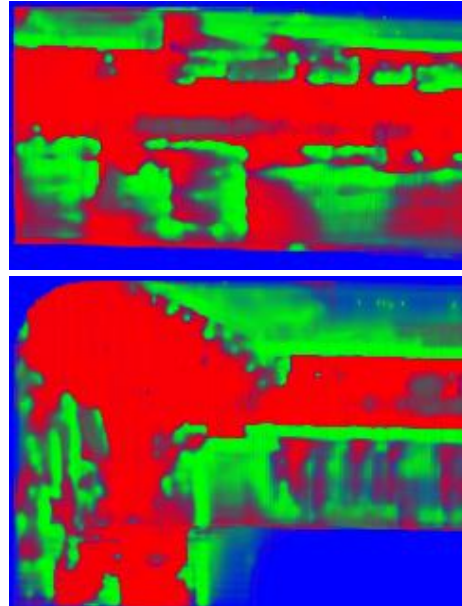$$\gamma = \text{ReLU}(\Delta m_u + K) \in [0,1]$$
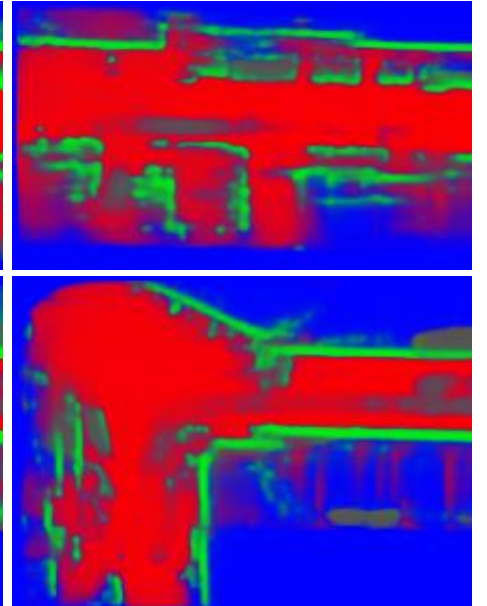
Temporal Redundancy

GT   geo IRM   deep IRM   geo & deep IRM   deep, red. IRM

OccMaps from Radar, Cam & Lidar

geo ILM Yager | geo $IR_{20}M$ Yager | deep, red. $IR_{20}M$ Yager | deep, red. IC_DM Yager | deep, red. $IC_DR_{20}M$ Yager | deep, red. ILM Yager | deep, red. $ILR_{20}M$ Yager
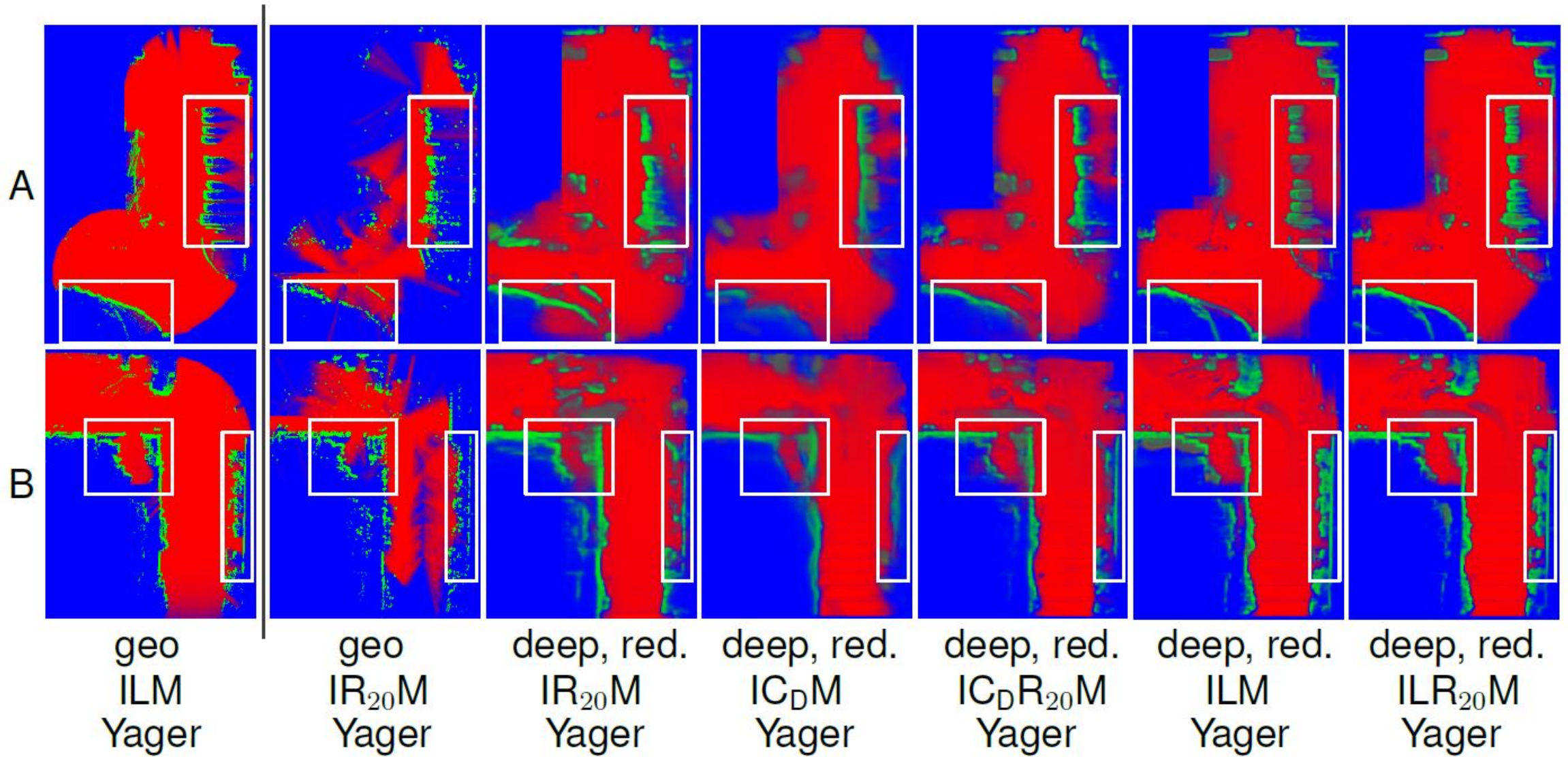
Deep IRMs as Priors

1. lower-bounded prediction $\quad\quad\quad\quad\quad\quad \underline{m} = (1 - \underline{m_u}) \otimes m$

2. redundancy reduction factor $\quad\quad\quad\quad\quad \gamma = \text{ReLU}(\Delta m_u + K) \in [0,1]$
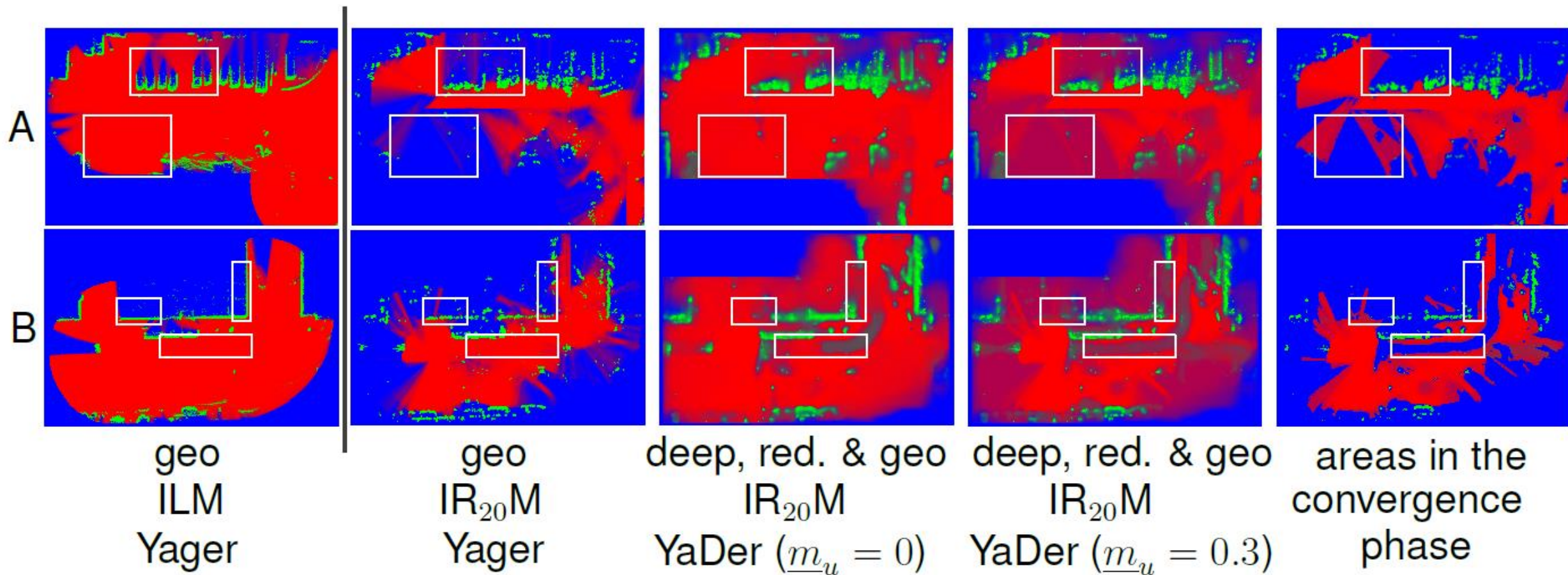
→ Ensure that deep ISM prediction never alters map cells with $m_u < \underline{m_u}$
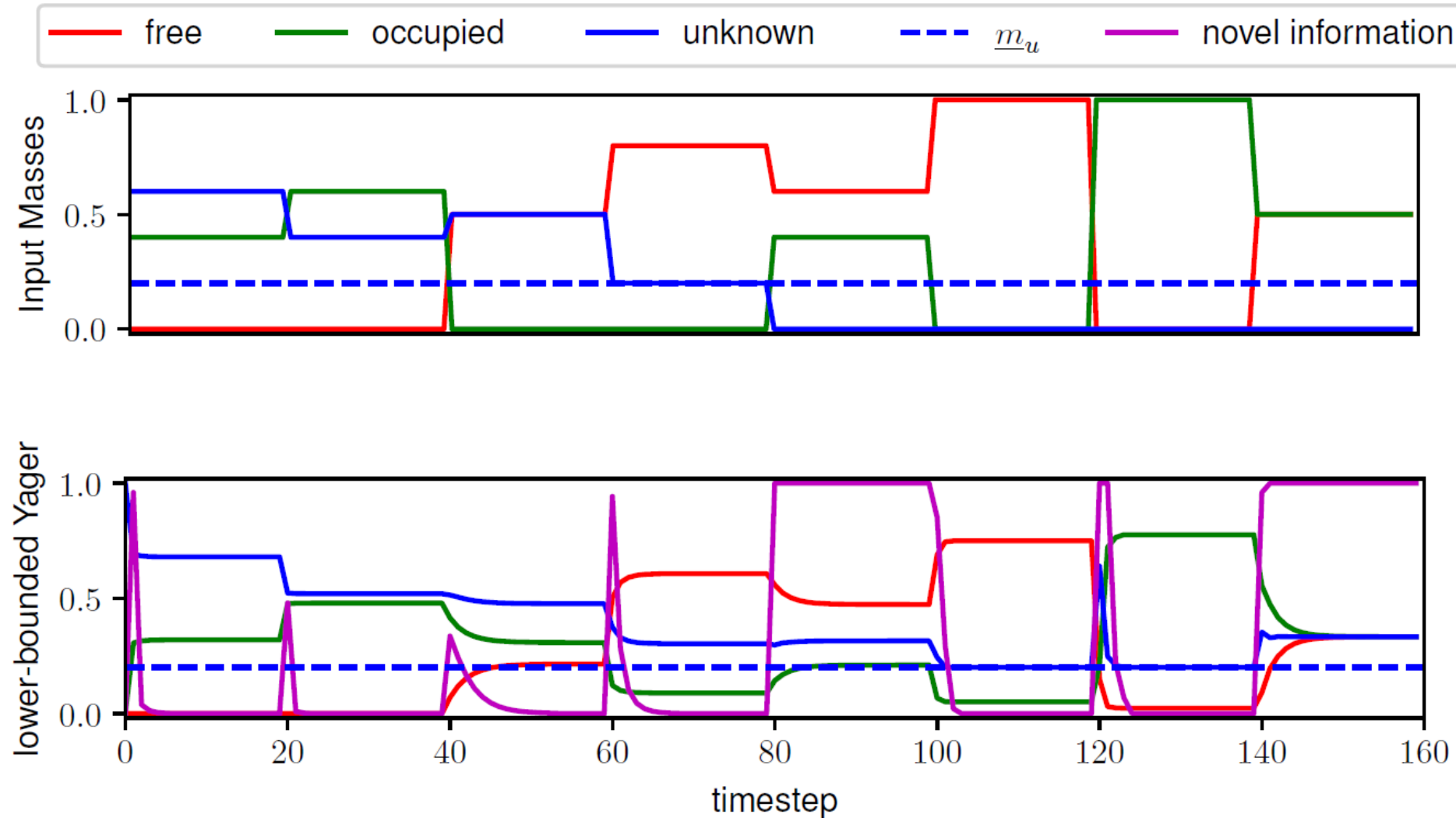
Deep IRMs as Priors

| | geo ILM Yager | geo $IR_{20}M$ Yager | deep, red. & geo $IR_{20}M$ YaDer ($\underline{m}_u = 0$) | deep, red. & geo $IR_{20}M$ YaDer ($\underline{m}_u = 0.3$) | areas in the convergence phase |
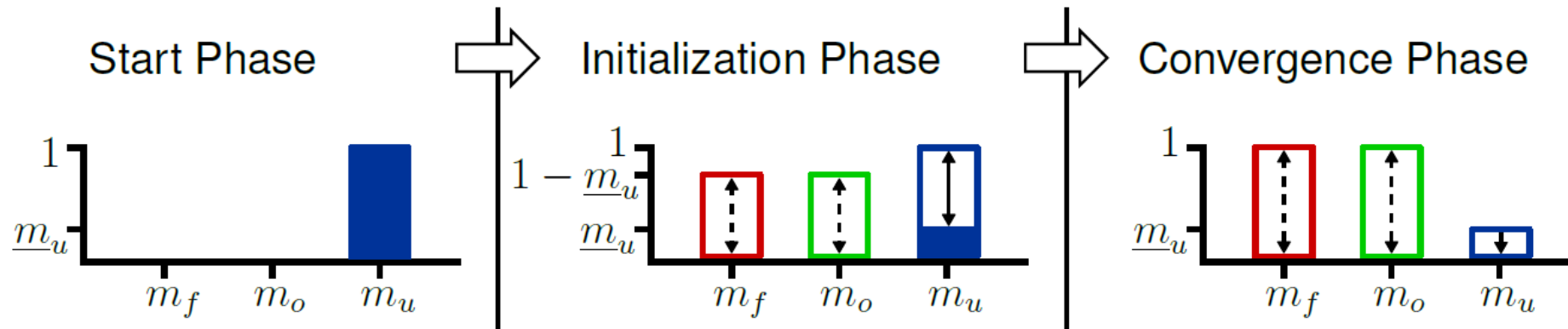
Redundancy reduced Update
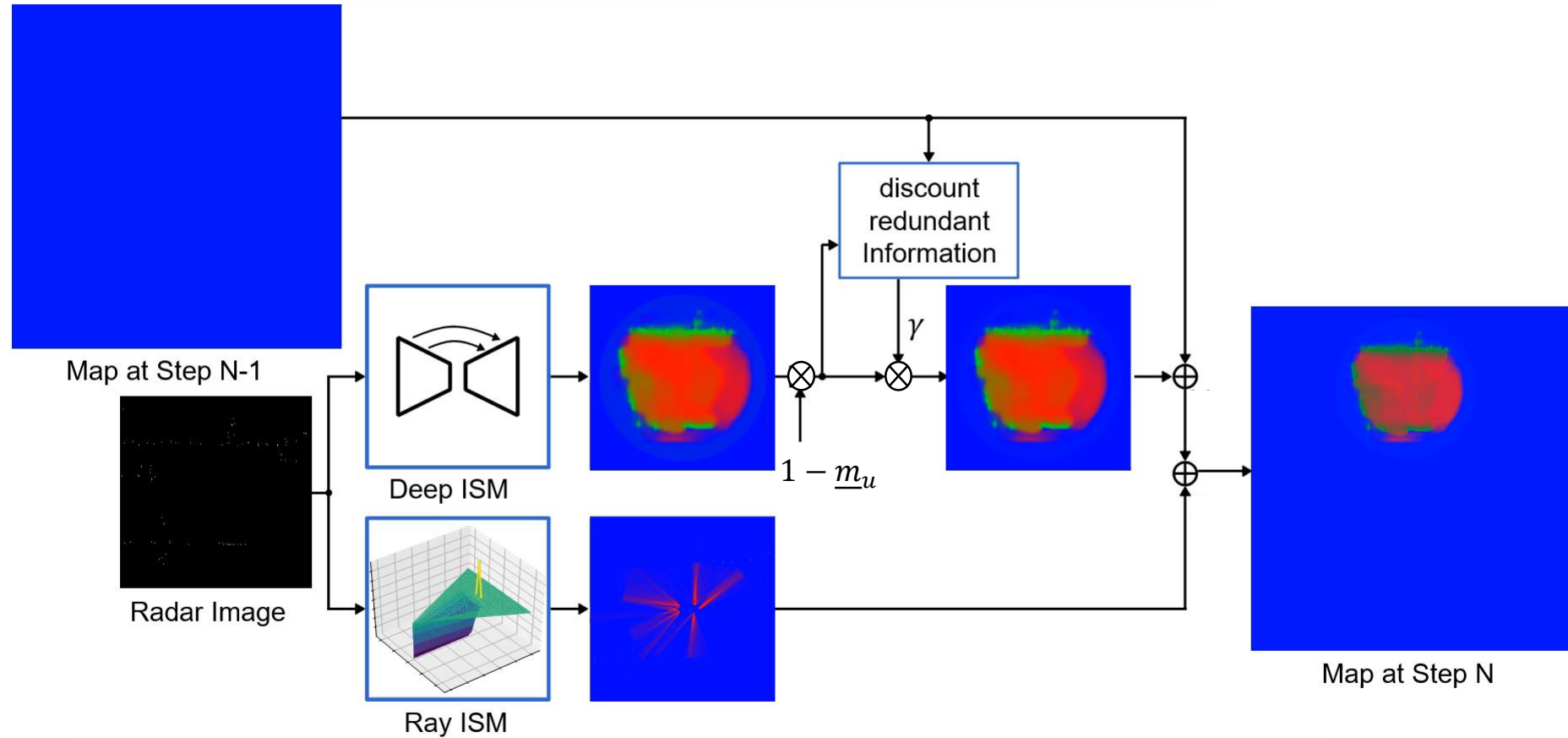
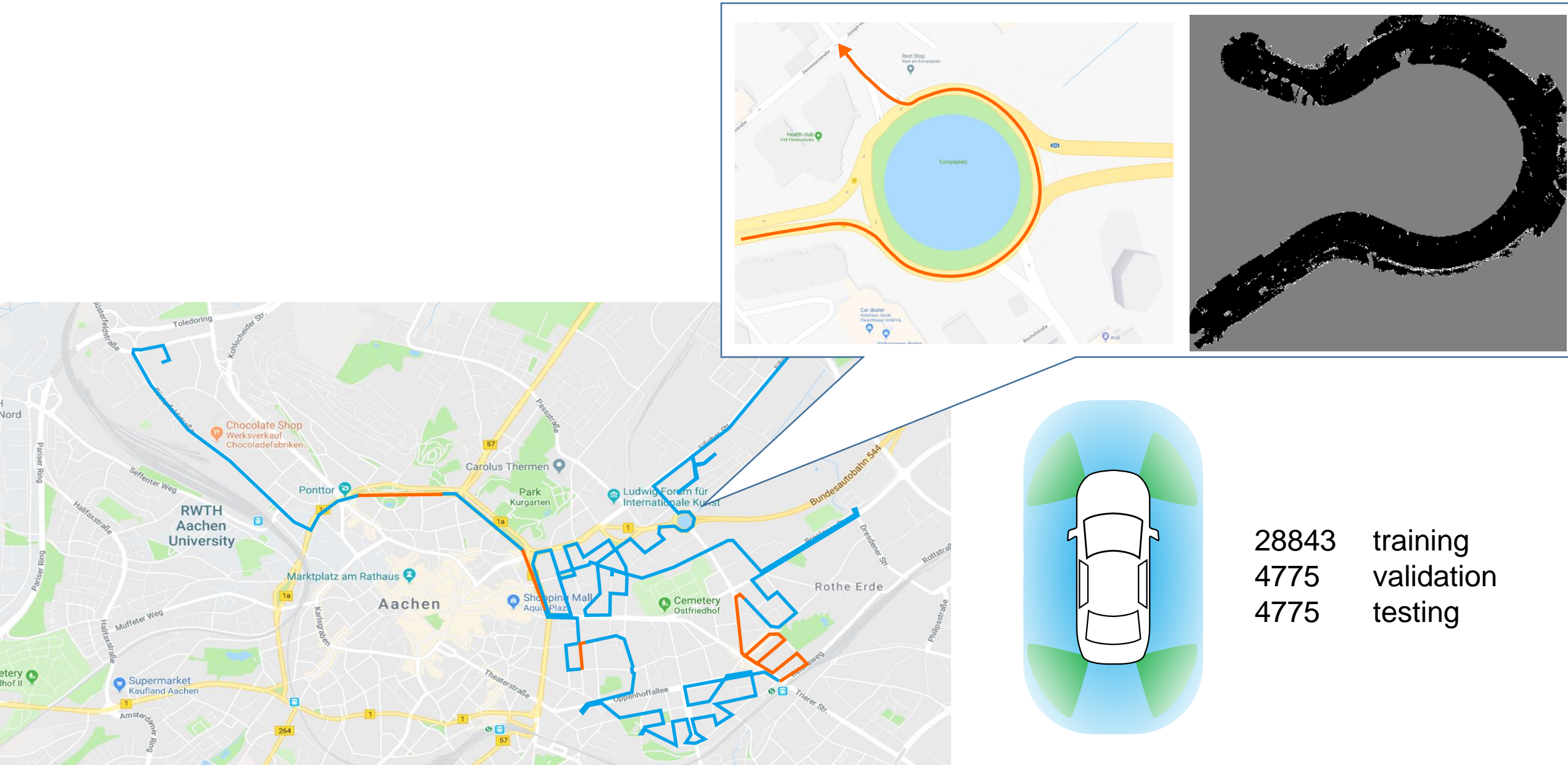# Appendix

Redundancy reduced Update

discount factor $\quad\gamma = \text{ReLU}(\Delta m_u + K)$

Custom Radar, Lidar & Odometry Dataset

28843   training
4775   validation
4775   testing

Motivation