



# Embedded Bayesian Perception by Dynamic Occupancy Grid Filtering

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# Embedded Bayesian Perception by Dynamic Occupancy Grid Filtering

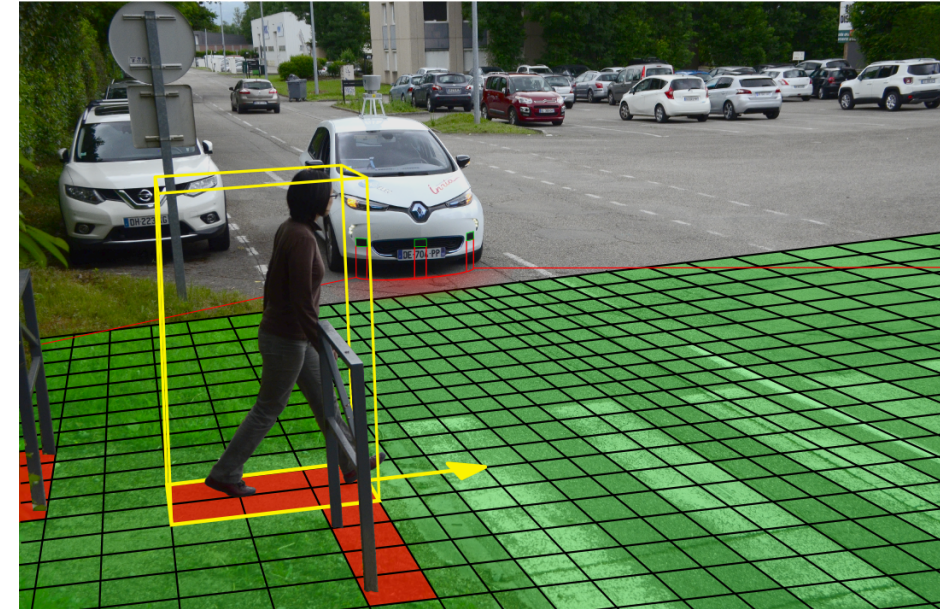
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## Abstract

A generic Bayesian perception framework, designed to estimate a dense representation of dynamic environments, by fusing and filtering multi-sensor data, has been developed, implemented and tested on embedded devices.

- Data from multiple sensors are properly fused in probabilistic occupancy grids
- Motion and robust occupancy are estimated by a specific Bayesian filter.
- Short-term collision risks and object parameters are assessed
- The whole system has been implemented and tested on Nvidia embedded devices, and produces real-time results

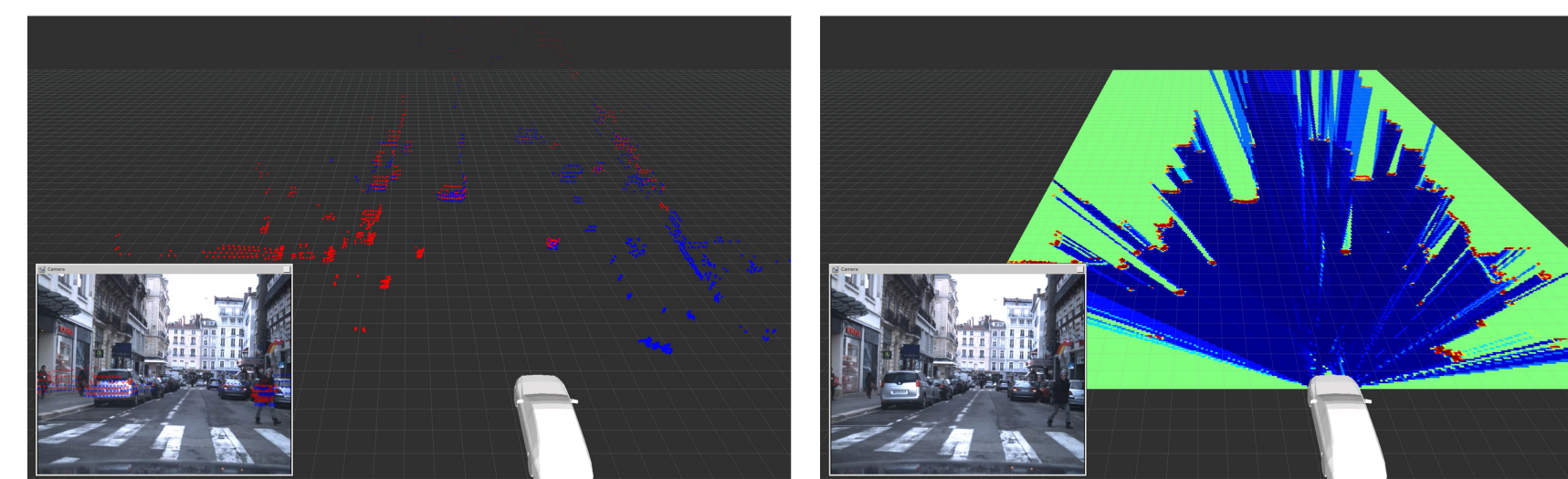


## Context and Objective

- Development of low cost sensors and miniaturized computing units enables advanced perception technologies to be embedded on realistic products.
- Most solutions based on a single-sensor approach are limited by its specific constraints, while multi-sensor fusion remains complicated.
- Object-based methods restrict the surrounding representation, and have difficulty in managing highly dynamic environments.
- Objective : propose a generic perception framework, especially suited to sensor data fusion and filtering at a sub-object level, offering performances adapted to the constraints of embedded systems.

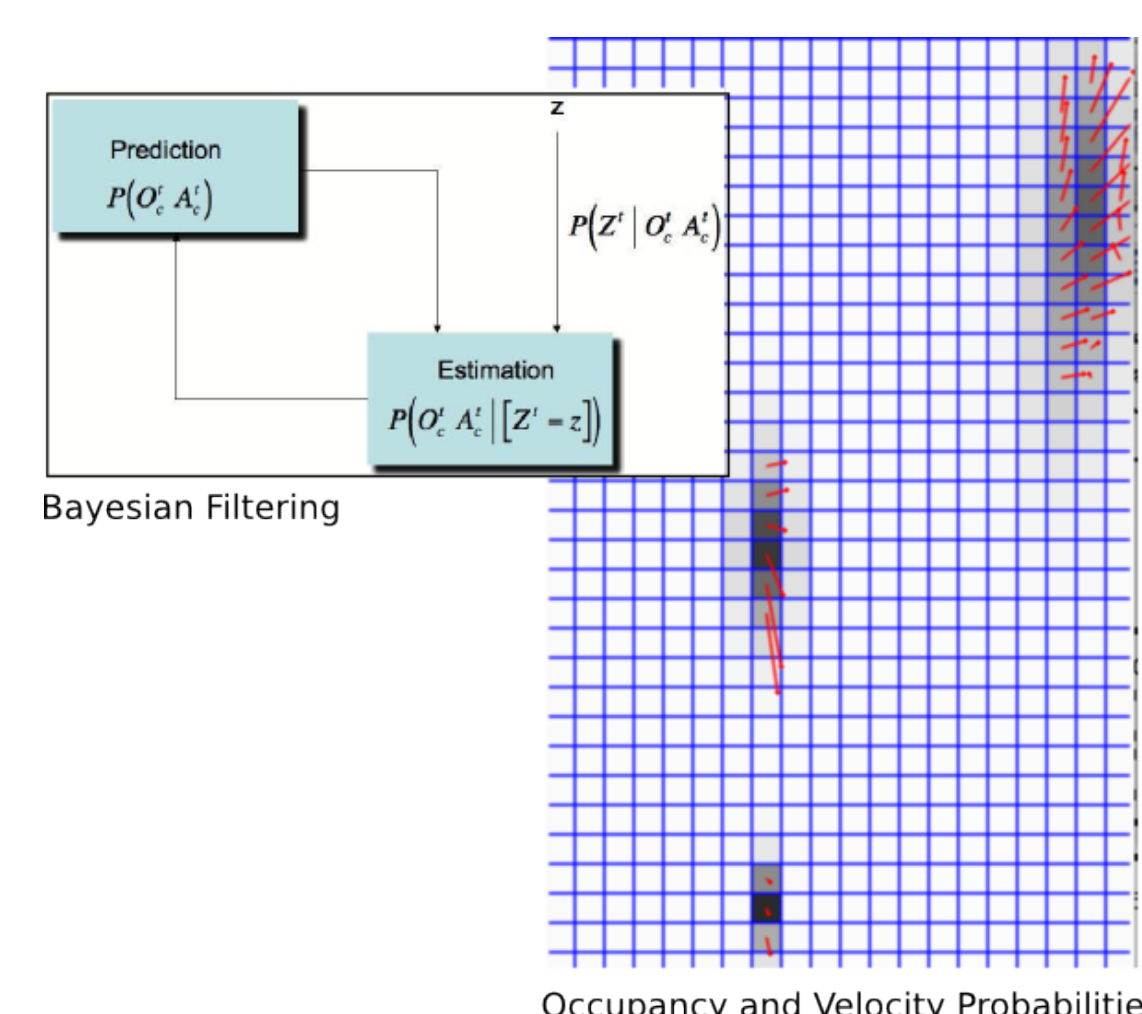
## Multi-Sensor Fusion in Occupancy Grids

- The environment is represented through probabilistic occupancy grids, a dense and generic representation especially adapted to parallel computing and clear management of uncertainty
- Each sensor data is converted to occupancy estimation using specific sensor model
- Sensor occupancy estimates are combined by Bayesian fusion in every cell.



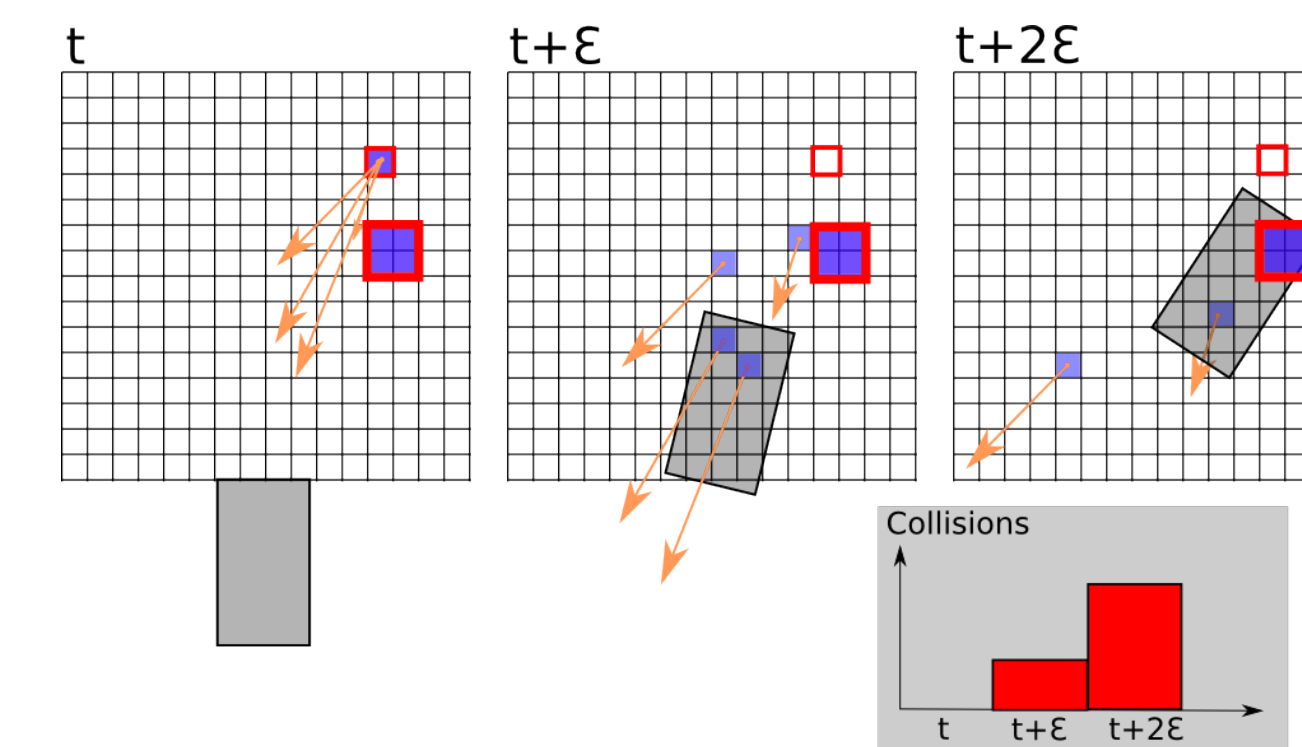
## Temporal Filtering and Velocity Estimation

- Spatial occupancy is filtered and motion field inferred by a Bayesian filtering at the cell level (CMCDOT)
- The method combines different forms of models to optimize computations (occupancy grids for static components, particles for dynamic parts)
- Areas with contradictory data and without data are processed differently, improving both estimation precision and computation efficiency

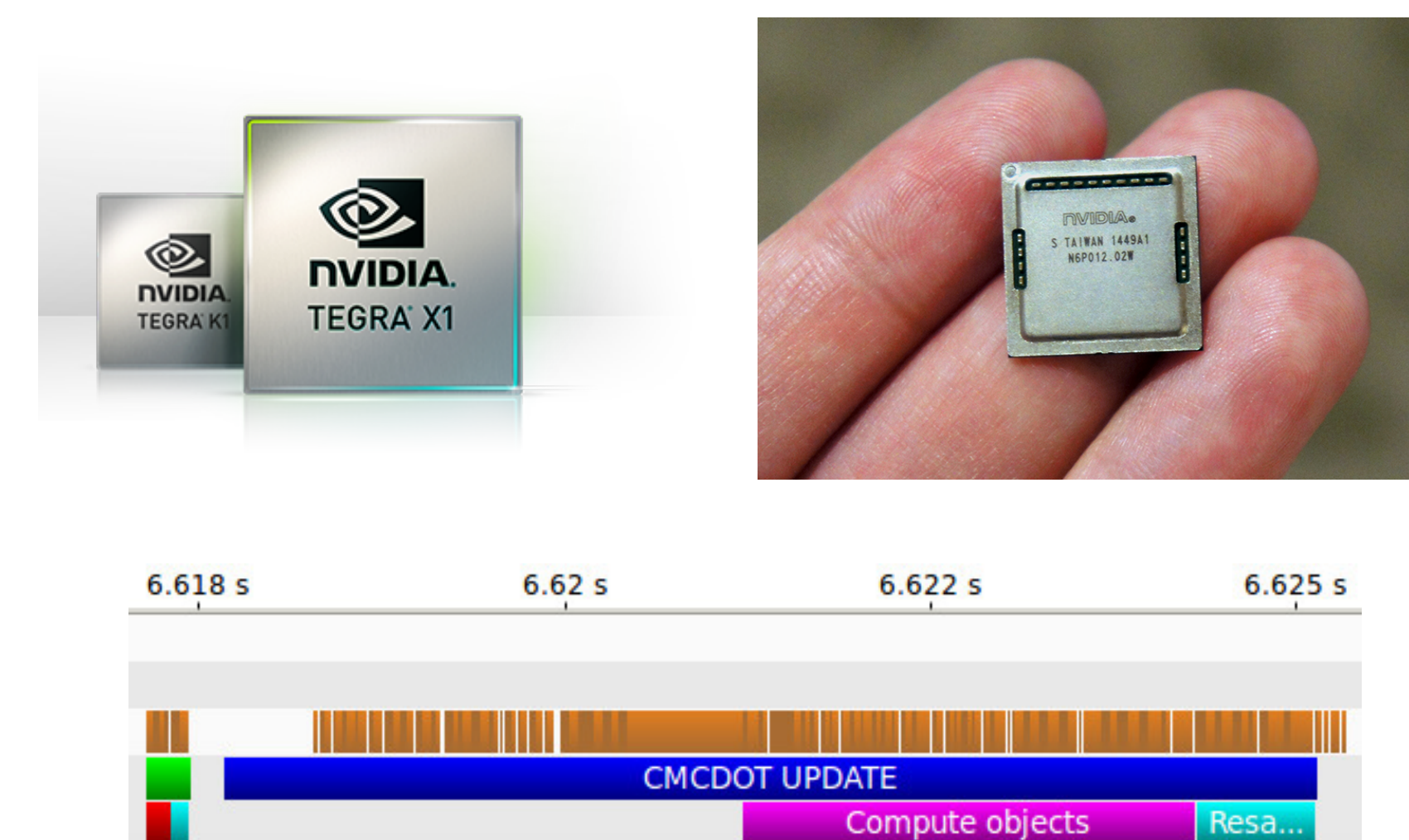


## Risk Estimation and Object Detection

- The occupancy and the vehicle are projected over time using the estimated dynamics, potential collisions are referenced and accumulated.
- Risk grids are thus generated, where collision risks are localized in space and time
- Dynamic parts of the scene are segmented into objects using particle propagation markers.



## Cuda Implementation

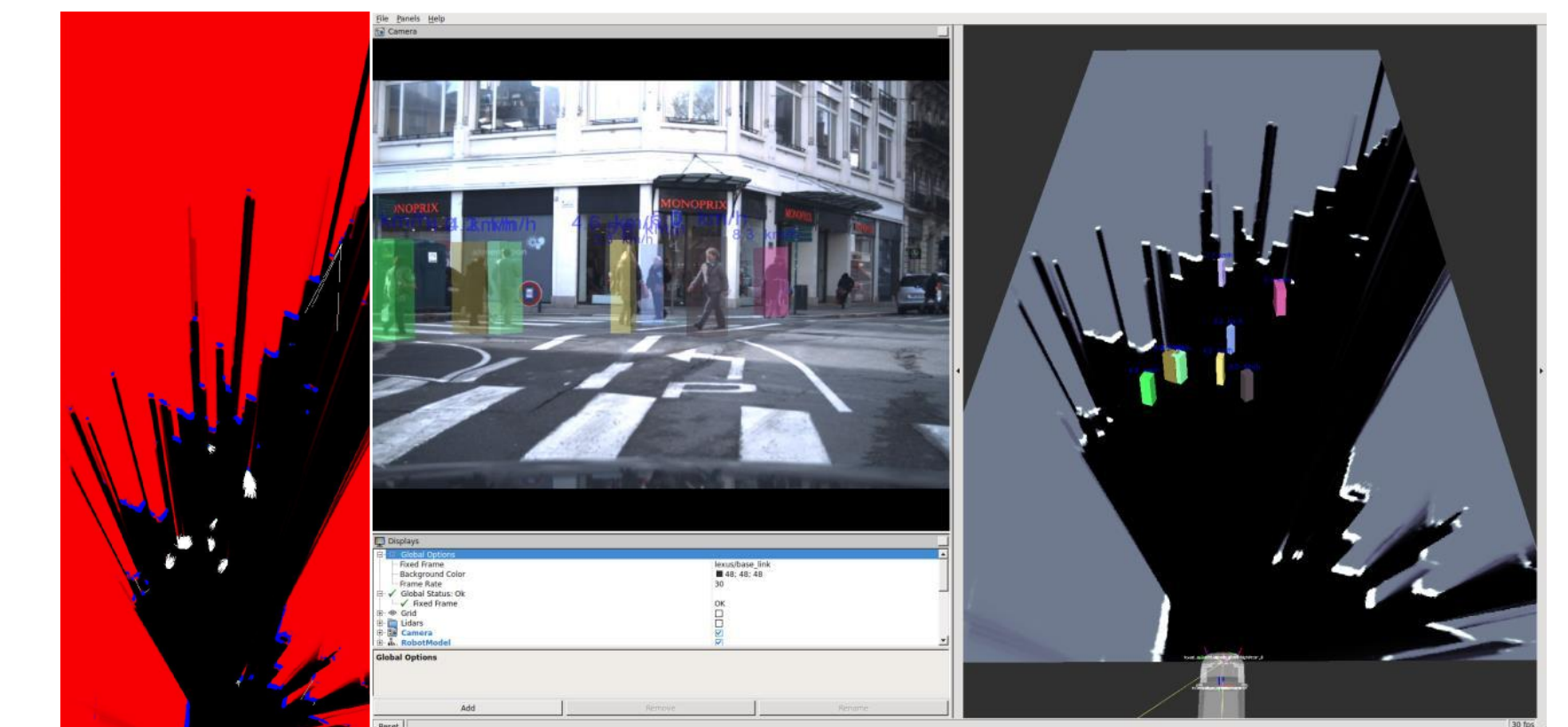


- Highly parallelizable framework, over cells and particles.
- Real-time implementation, optimized using Nvidia profiling utils
- Configuration with 8 Lidar layers (2x4), 1400x600 grids and 65536 velocity samples
- Jetson K1: Grid Fusion 17ms, CMCDOT 70ms
- Jetson X1: Grid Fusion 0.7ms, CMCDOT 17ms



## Experimentations and Results

- Tests are conducted on real-time embedded perception systems, integrated on vehicles or dedicated perception units.



## References

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- [www.youtube.com/watch?v=uwIrk1TLFiM](http://www.youtube.com/watch?v=uwIrk1TLFiM)



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