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INSPEX: Integrated portable multi-sensor obstacle detection device

Application to navigation for visually impaired people



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H2020 INSPEX project: Augmenting capabilities of the white cane

- Our motivation:

Help vision impaired persons on their daily commute.

According to the definition of visual impairment of the World Health Organisation:

- 1.6 million people suffer of blindness in EU, only 5% are fully autonomous in their daily mobility. [WHO12]
- 40% of the visually impaired suffer head level accidents at least once a month, and 30% suffer a fall accident at least once a month.[MK11]



- Existing Electronic Travel Aid (ETA):

- Some wearable solutions (sunglasses, gloves...) are sometimes considered as extra prosthesis, **cumbersome** and **stigmatizing**.
- Rely on a single sensor technology: ultrasound which is sensitive to multi-echo leading to **wrong detections**.
- Perception is limited to range sensing (of the nearest target). Current experiments on environmental perception require non autonomous and non embedded devices.



Sonar Glasses



OptekSystems

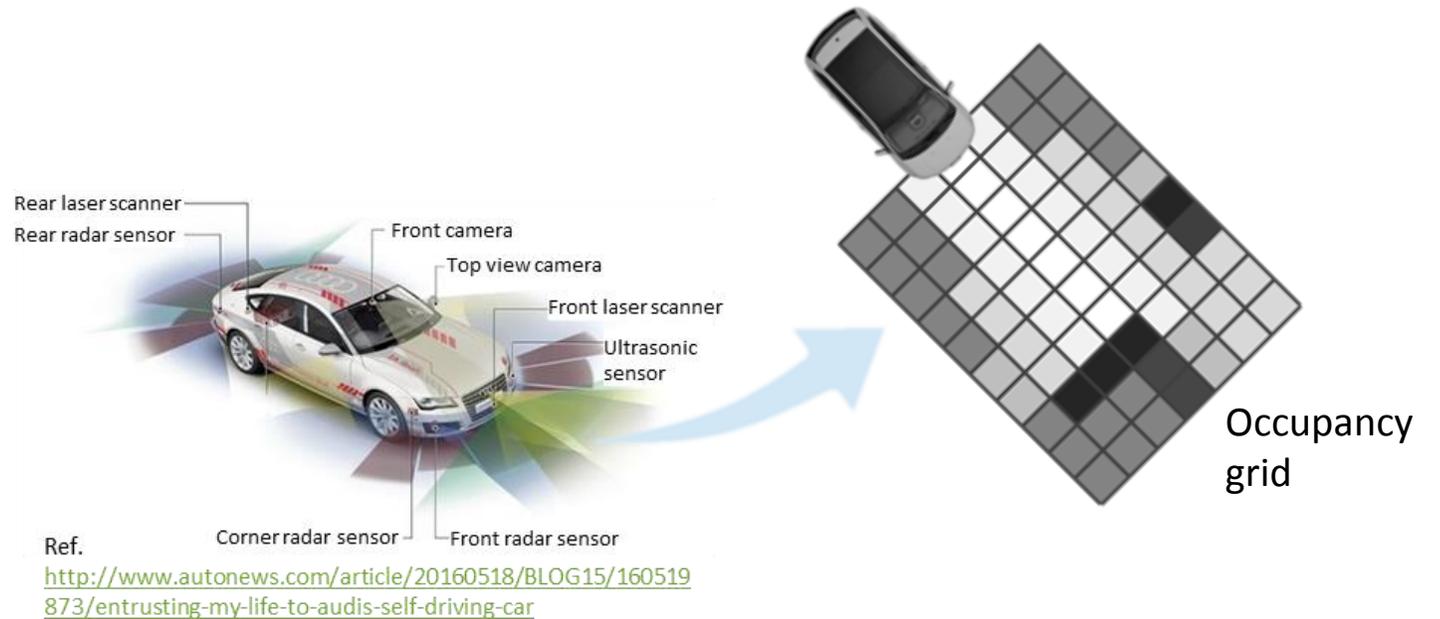


GoSense

Context and objectives

- **Context:**

- Obstacle detection available in high-end vehicles
- Multi-sensor (LiDAR, radar, ultrasonic, vision) solutions to compensate the drawbacks of each sensor technology
- Data Fusion highly demanding in terms of memory and computation to construct a representation of the vehicle surroundings

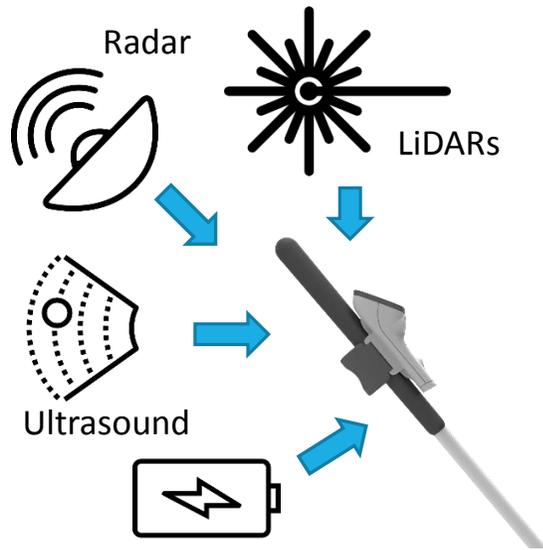


- **Objectives:** integrate obstacle detection capabilities in a portable device to offer a **virtual safety cocoon** to its “user”. This requires:
 - **Integration** of several sensor technologies to ensure detection of various obstacles (material, size, shape, colour) in 3D, at different heights and ranges, in various environment conditions
 - **Low-power light-weight small-size range sensors**
 - **Highly efficient fusion technique** to be embedded on a small computing platform (typ. μ Cont.)
 - **Modular** system to tackle different application domains that might benefit of such functionality to improve the “user” navigation experience and safety (e.g. drone)

A portable multi-sensor obstacle detection device

User
needs

User
req.

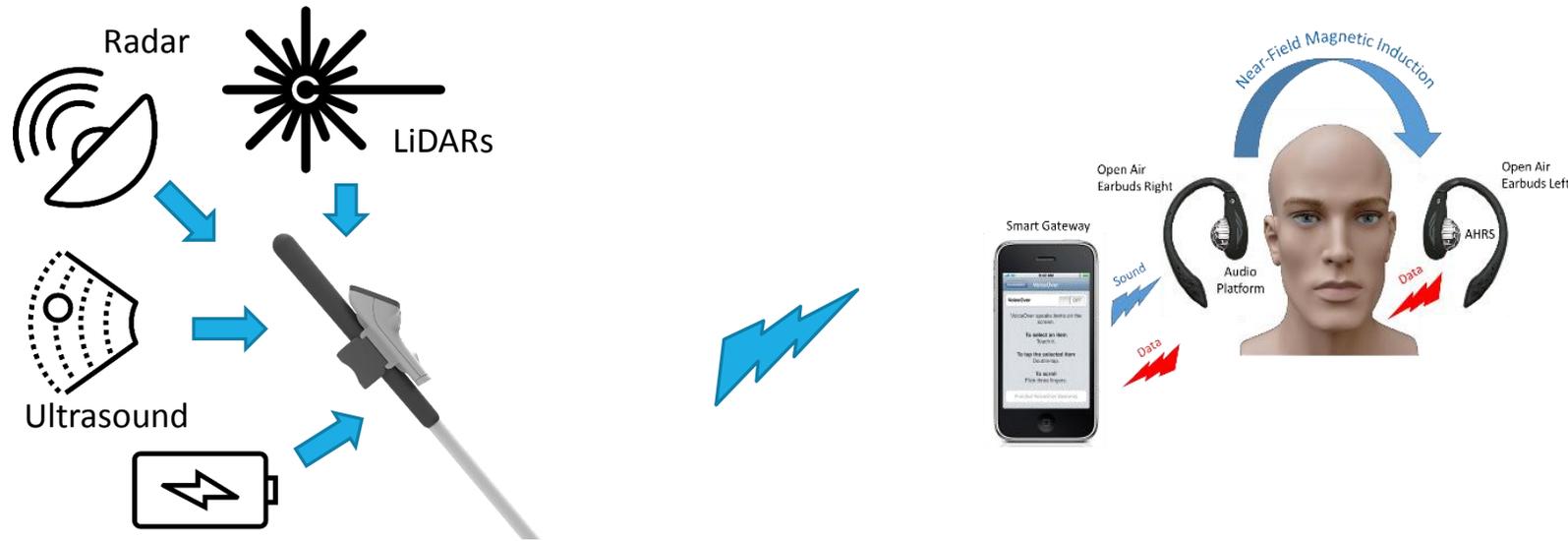


- Integration of a single portable device in charge of **environment perception**.
 - various weather conditions,
 - weight and size constraints,
 - connection to smart environment,
 - detection of obstacles at head and waist level
- Different range sensing technologies (**lidar, radar, ultrasound**) , each one compensating the drawbacks of another one.

A portable multi-sensor obstacle detection device

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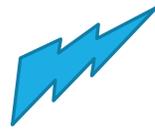
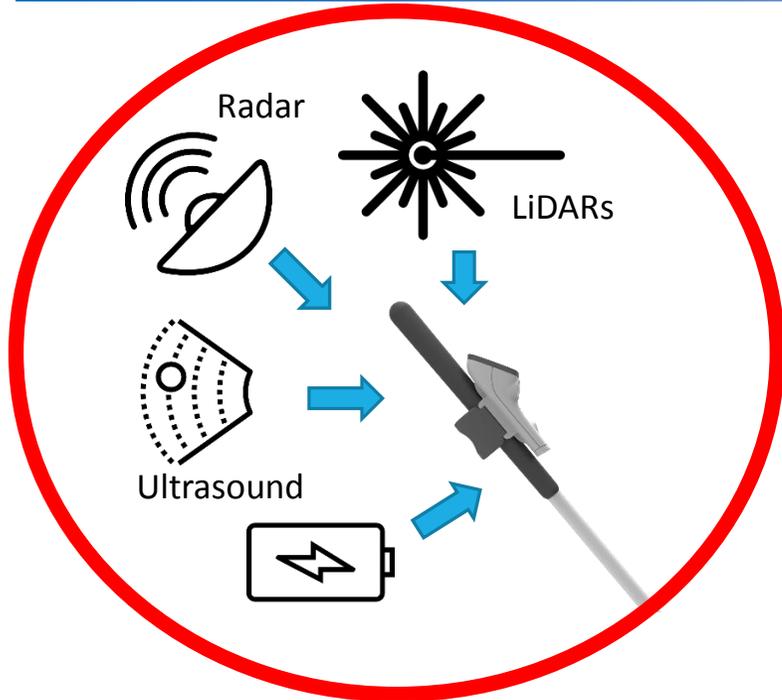


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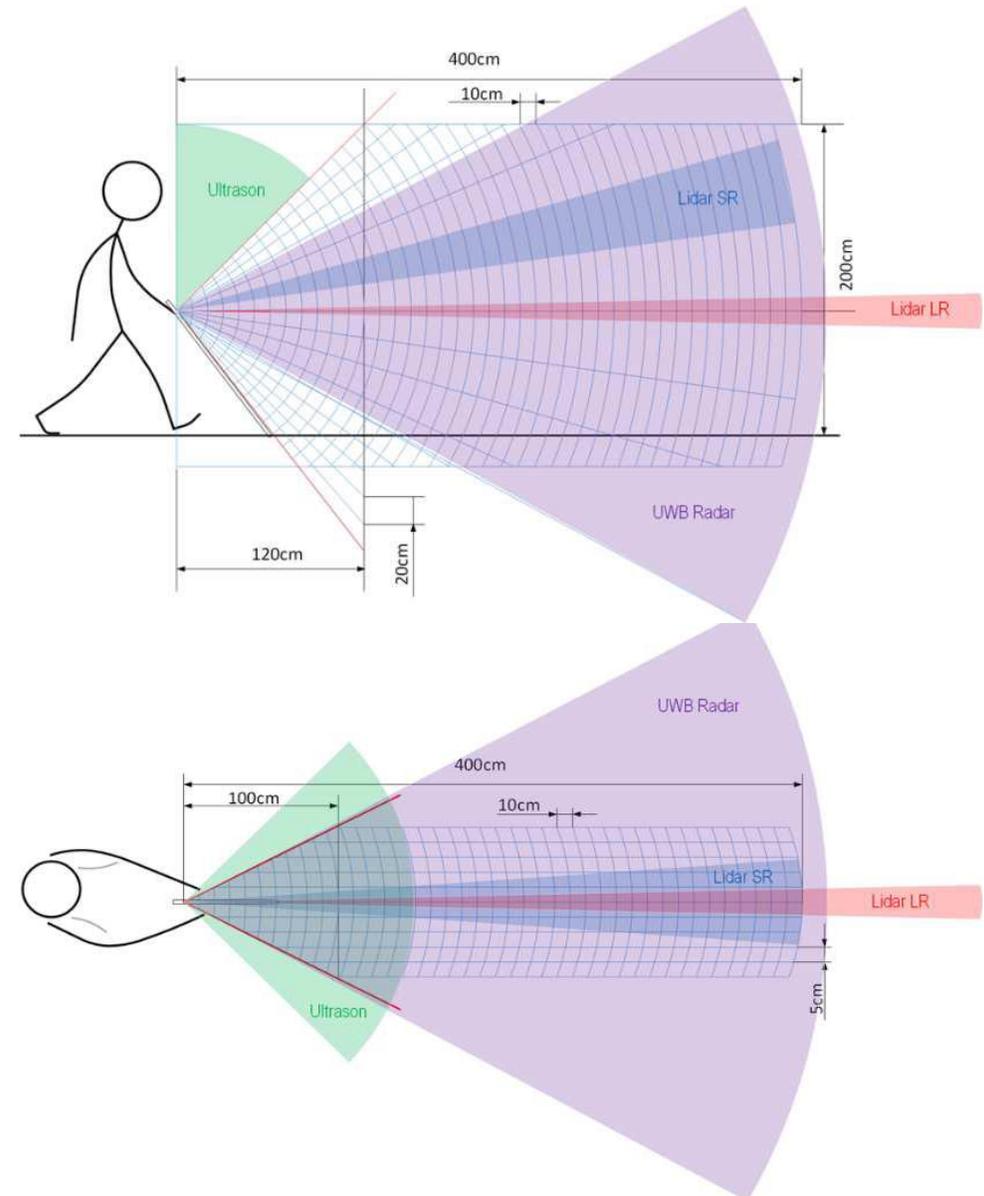
System requirements

User needs

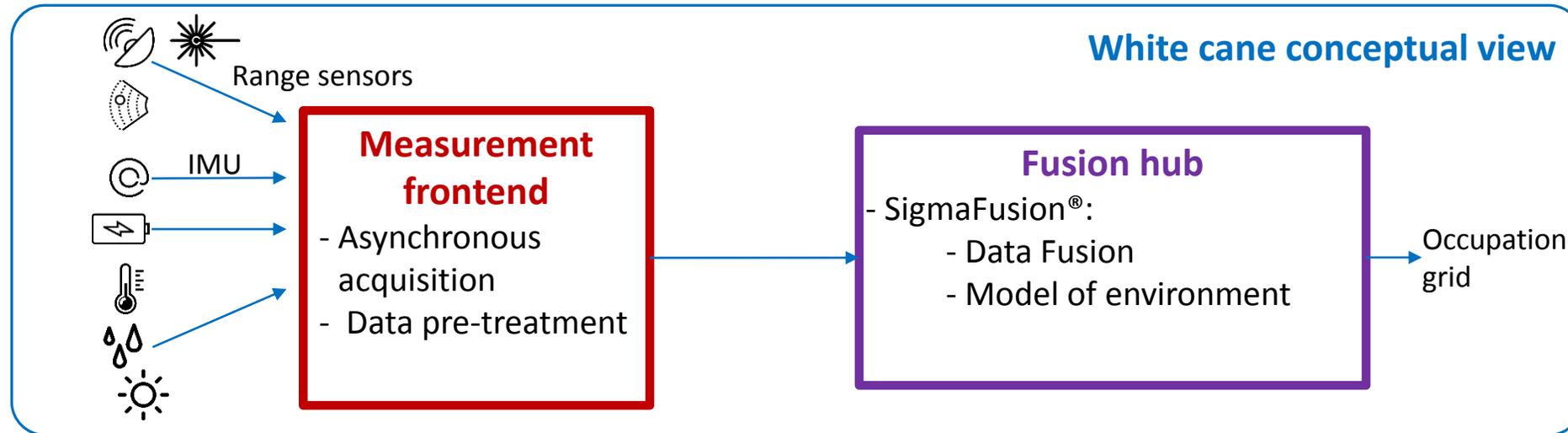
User req.

System req. & archi

- Portable device ($\approx 200\text{gr}$, 100cm^3 , 500mW)
- Environment sensors for Context awareness:
 - Ultrasound sensors (range 2m),
 - Radar (range 10m, FoV 60°),
 - short/long ranges LiDAR (3-5m/10m),
 - Inertial measurement unit
- Overlap of sensors Field-of-View
- Autonomous 10 hours lifetime
- Detect obstacles up to a distance of 4m, moving at a relative speed of $\sim 1.4\text{ m/s}$ worst case



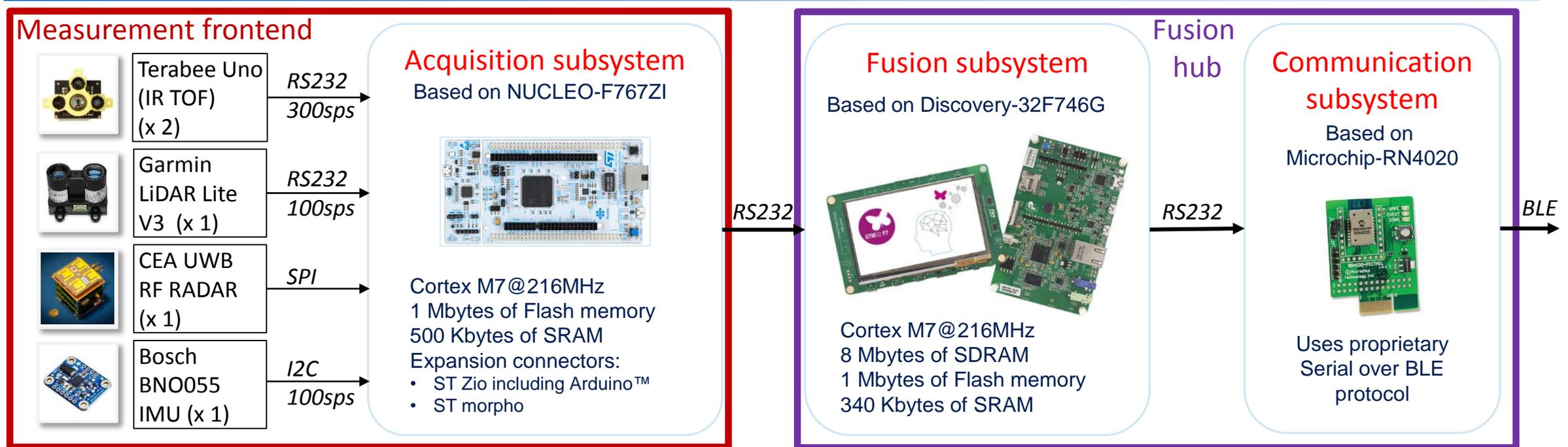
Conceptual architecture



- **Adapt or develop new sensing technologies :**
 - Development of *new sensors* (LR lidar, UWB radar, Ultrasound piezo)
 - ***Mechanical and electronical integration*** of existing sensors (SR lidars)
 - Develop ***innovative post-treatment*** for obstacle detection, sensor positioning

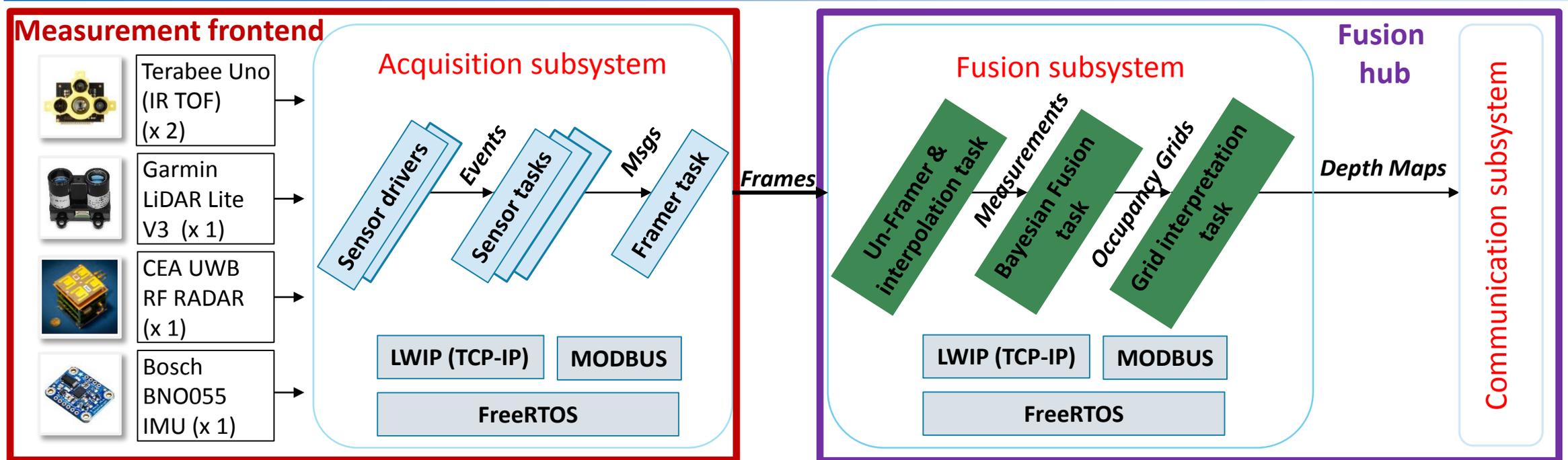
- **Transfer data fusion techniques from the automotive domain into the white cane:**
 - 3D data fusion based on 3D occupancy map of the device surrounding thanks to SigmaFusion® Algorithm (Bayesian fusion)

Detailed architecture of the proof-of-concept demonstrator (HW)



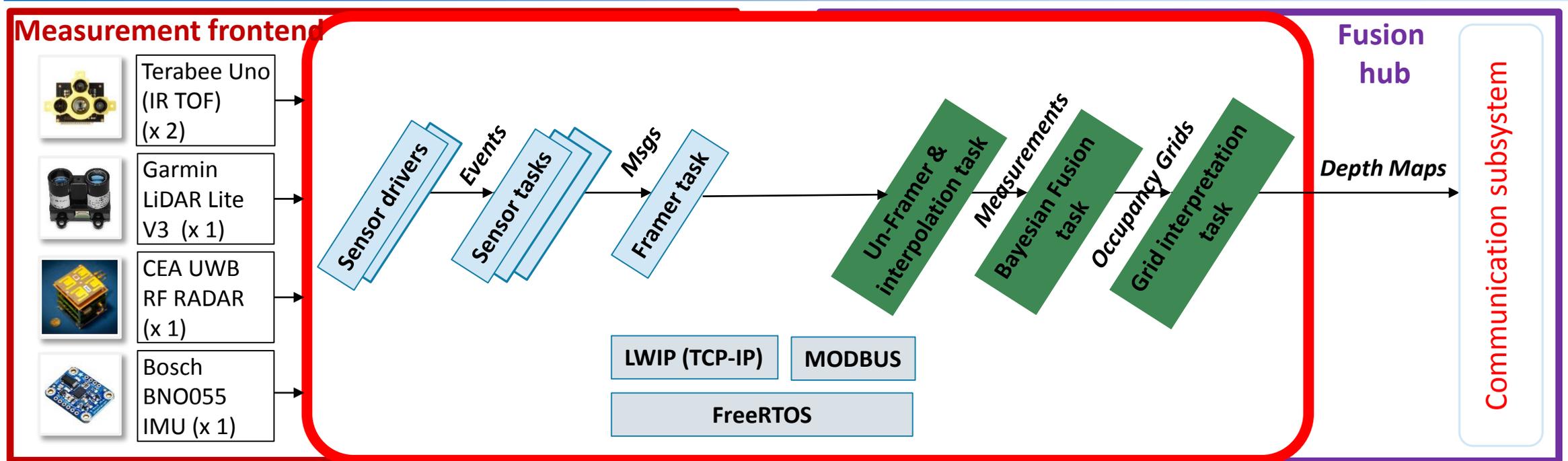
- A basic architecture with an **scalable ecosystem** based on **two high-end MCUs** (CORTEX M7)
- The split in two part is appropriate for **separation of concerns** (i.e. sensor providers do not interfere with the SigmaFusion algorithm/IP).

Detailed architecture of the proof-of-concept demonstrator (software)



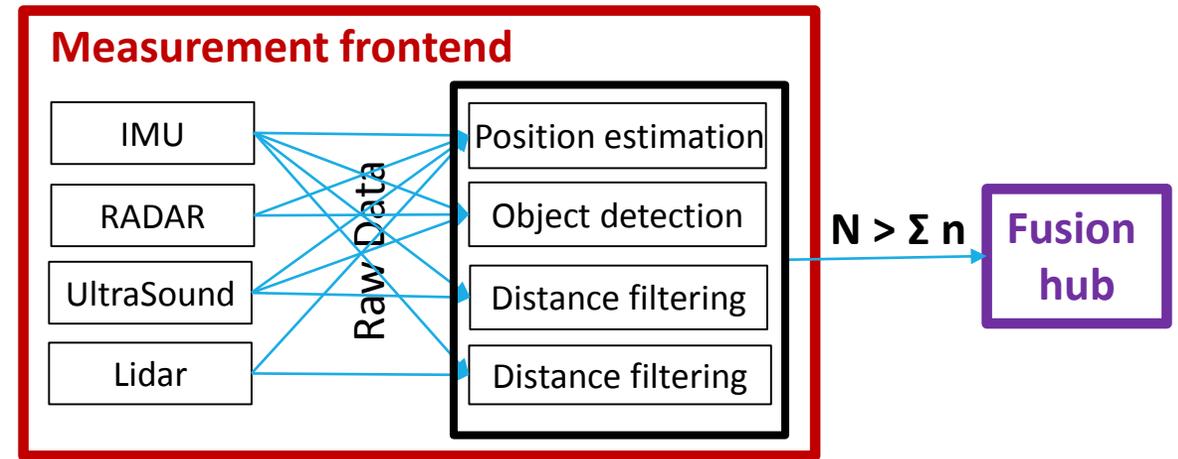
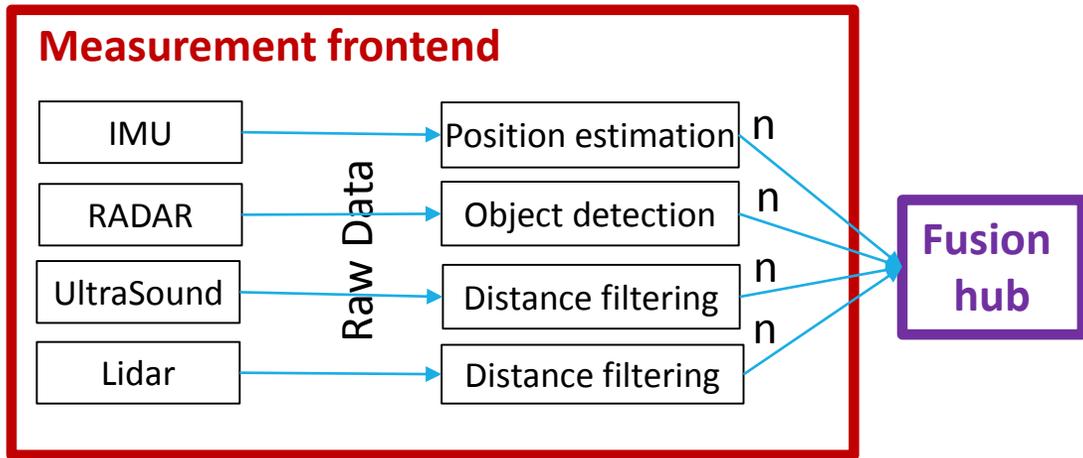
- The software architecture has been designed in compliance with the system requirements, i.e. ensuring **modularity, software reuse**.

Detailed architecture of the proof-of-concept demonstrator (software)

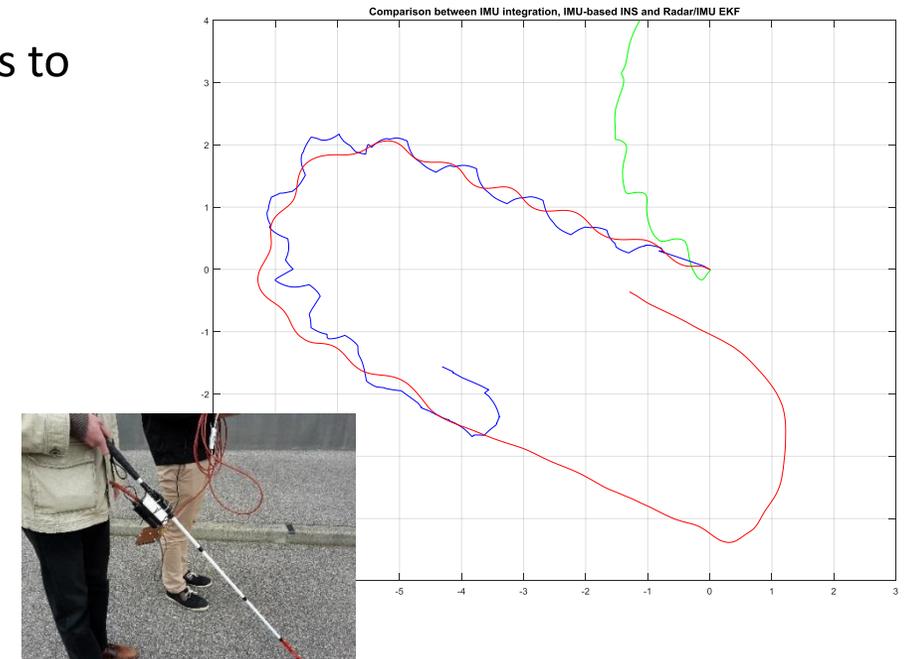


- The software architecture has been designed in compliance with the system requirements, i.e. ensuring **modularity, software reuse**.
- The same runtime is running on both subsystems in order to ease **future evolution** of the hardware platform with the integration of the whole software on a **unique computing platform** (provided it offers enough memory and computational capability).

Focus on the measurement front-end



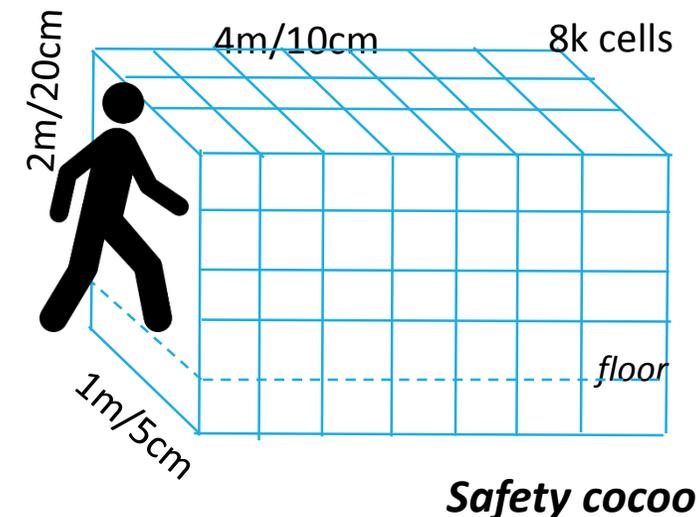
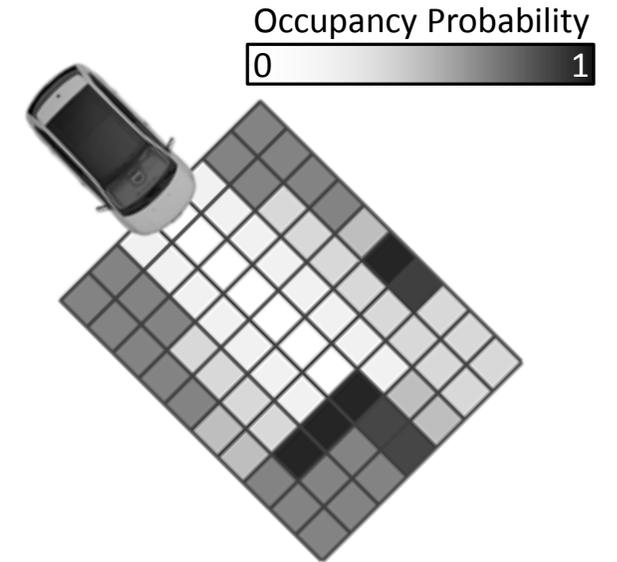
- Traditionally **sensors and post-treatment are paired**. There is no access to the raw data.
- In the white cane architecture, the post-treatment is done in the measurement front-end MCU:
 - It enables accesses to sensors raw data
 - **A post-treatment module can also consider information from other sensors**
- Enables development of more efficient algorithms based on the whole sensing ecosystem.



Focus on the fusion hub

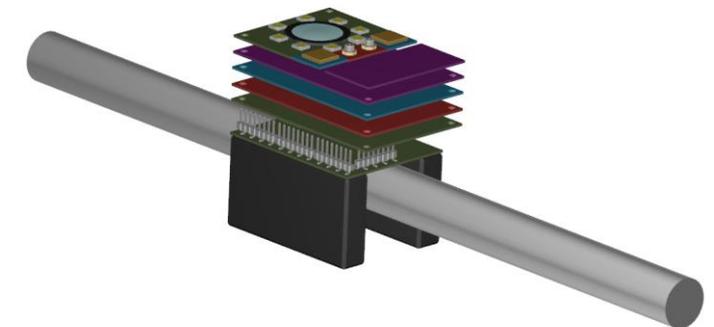
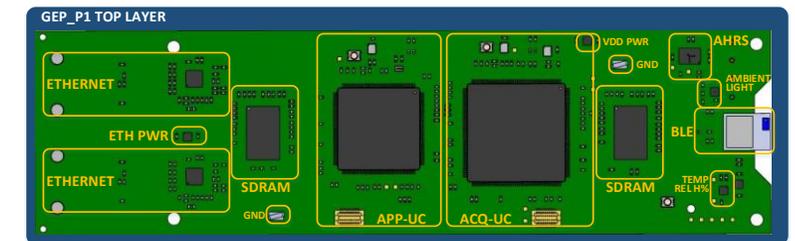
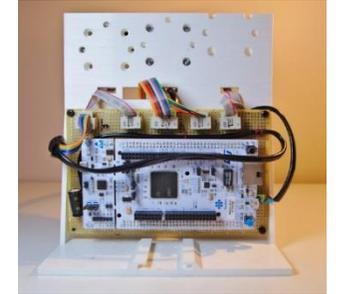
	BMW F. Homm [IV'10]	Mercedes D. Nuss [IV'15]	CEA (2016) [DAC'16]	CEA (2017) [ITS'17]
Performance	1	x0,39	x1	x1 (<50%CPU)
Power	204W	80W	0,5 W	1.5 W
HW	Nvidia GeForce 268GTX	Desktop	μC Cortex M7 @200 MHz	μC Aurix TriCore @300 MHz
ISO26262 ASIL-D	Non	Non	Non	Possible

- Model of environment is based on 3D occupancy grid.
- SigmaFusion™ is based on Bayesian sensor fusion.
 - SigmaFusion™ 2D has been extended to the 3D.
 - SigmaFusion™ has been extended to take into account odometry and filtering over time.
- A **safety cocoon** of 8000 cells is scanned at 20Hz. Information is compressed and sent to the user's smartphone for rendering.



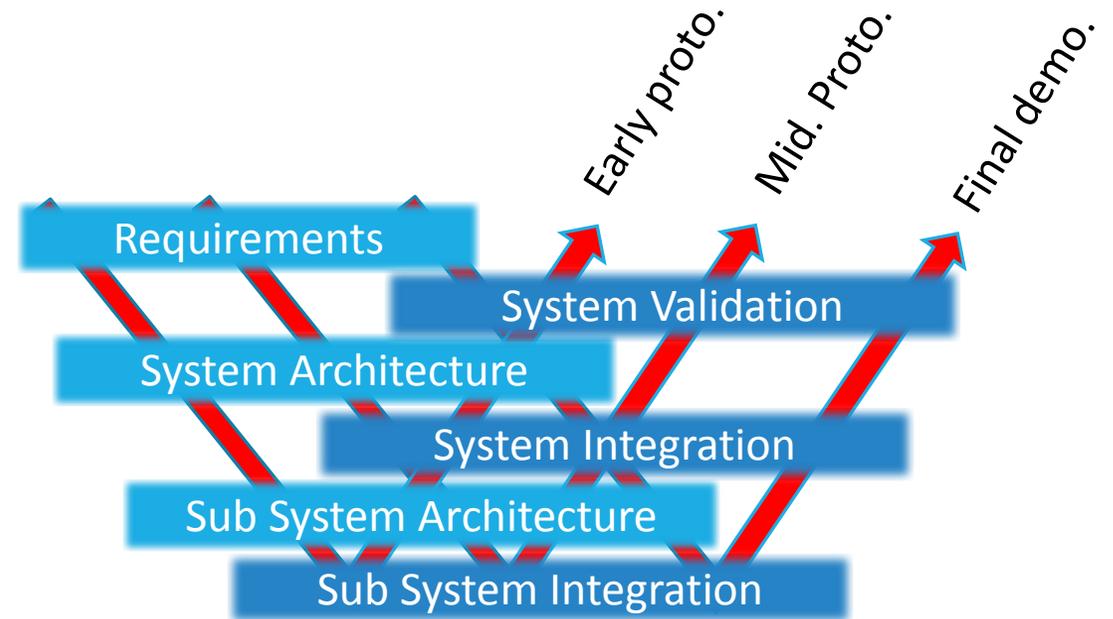
A incremental approach up to the final integration

- The **early prototype** is used in sensor experiments and **firmware development**. It is based on standard development kits and out of the shelf sensors. It has enabled embedded software development during the specification of the mechanical and electrical constraints.
- The **intermediate prototype allows connectivity** with the new sensors developed in the project. It embeds the two sub-systems but **one micro-controller can be bypassed** to try to go one step further in the software integration.
- The **final prototype** is a smart and **miniaturized device** issued from the user's needs. So the specification task started at the beginning of the project and preliminary investigations have been used as guidelines for the modules developments.



Conclusions

- The objective of Inspex project is to **transpose automotive technologies** for environment perception to portable devices.
- New system requirements imply development of innovative sensor technologies and algorithms while supporting the integration.
- A basic architecture based on two high-end MCUs allows **separation of concerns** and helps **mitigating the risks** all along the project.



- Integrating and sharing sensor post-treatment on the same CPU increases the entropy of data manipulated.
- 2D map fusion has been extended to 3D without additional computing resources.
- A **roadmap of demonstrators** allows confrontation of the results from the early prototype validation with the requirements of the final demo.

References

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- [MK11] Roberto Manduchi, Sri Kurniawan, *Mobility-Related Accidents Experienced by People with Visual Impairment*, Research and Practice in Visual Impairment and Blindness, 2011.
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