MULTI-SENSOR DATA FUSION IMPROVING TRAFFIC SIGNS RECOGNITION

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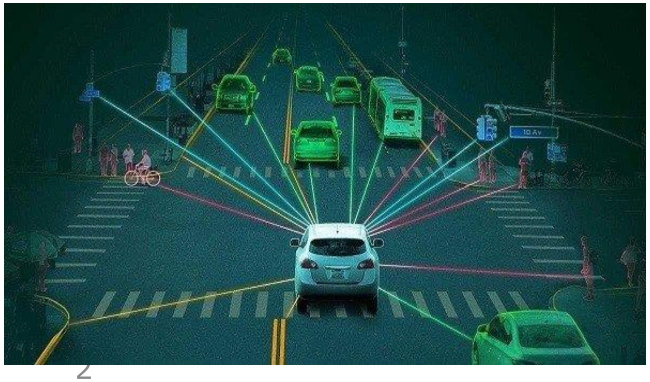
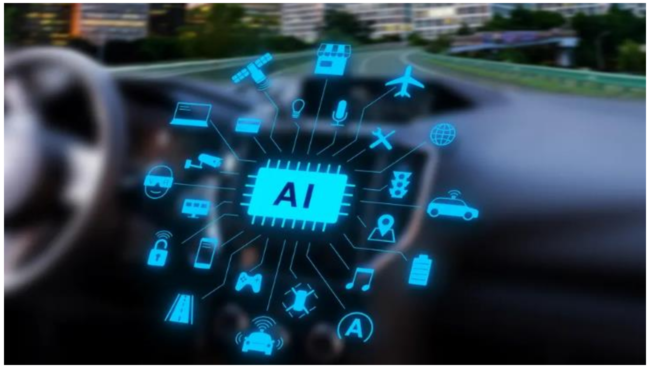
Context : Autonomous Driving

- The fast development of autonomous driving
- The autonomous driving system includes three main functional modules: perception, cognition, and execution
- The perception module of the system mainly consists of sensors such as LiDAR, RADAR, camera, IMU, GNSS, etc.
- Traffic signs recognition is an essential part of the perception system





Context : Traffic signs recognition issues

- Vision-based traffic signs recognition has always been a technical challenge : at night, with extreme weather conditions, intersections, multiple traffic signs, and other complex road conditions, etc.

➡ Improved vision-based traffic signs recognition system for autonomous driving, integrating **Deep Learning** and **Multi-sensor Data Fusion** : RTK BDS/GPS, IMU, Camera, LiDAR

Context : Why multimodal fusion?

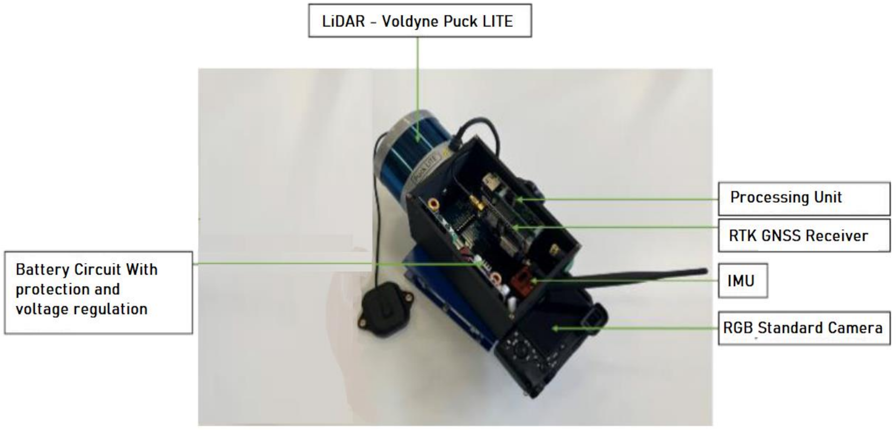
- The difference in measurement principle determines the good complementarity between multimodal sensing data.

- Multimodal data fusion is an effective method to improve the performance of the perception module.

Multi-sensors Data

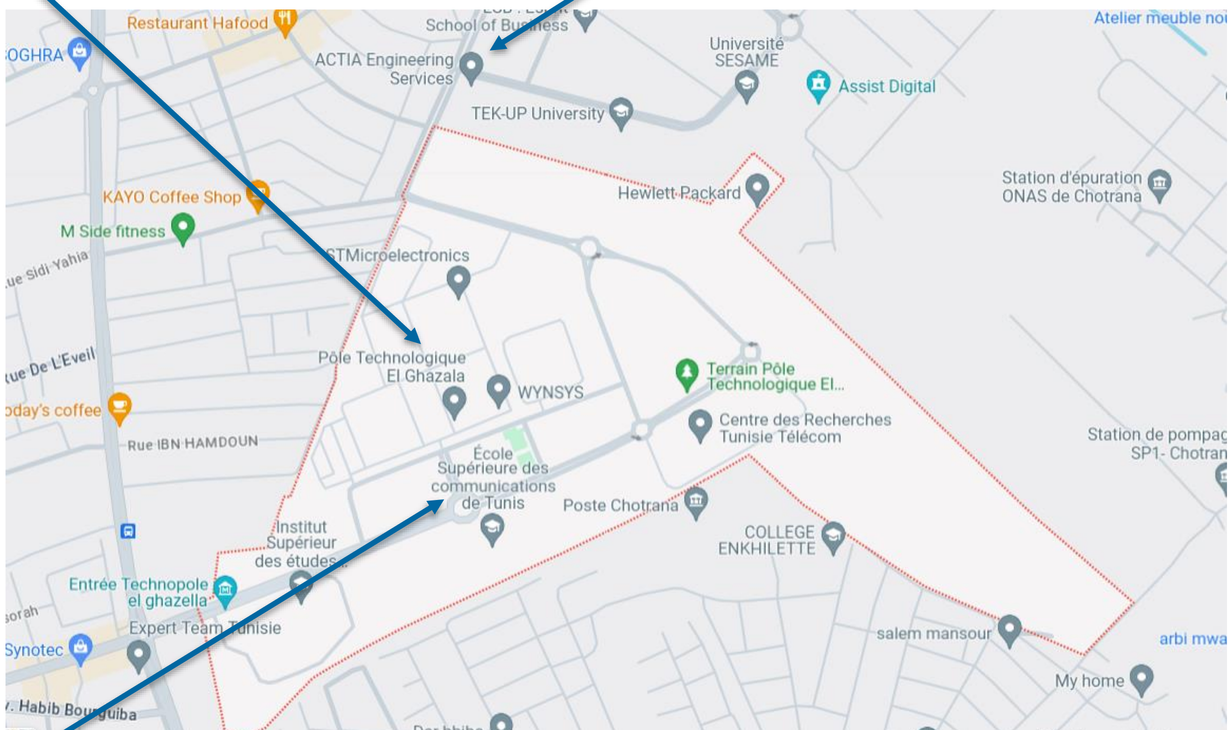
RTK BDS/GPS, IMU,

Camera, LiDAR



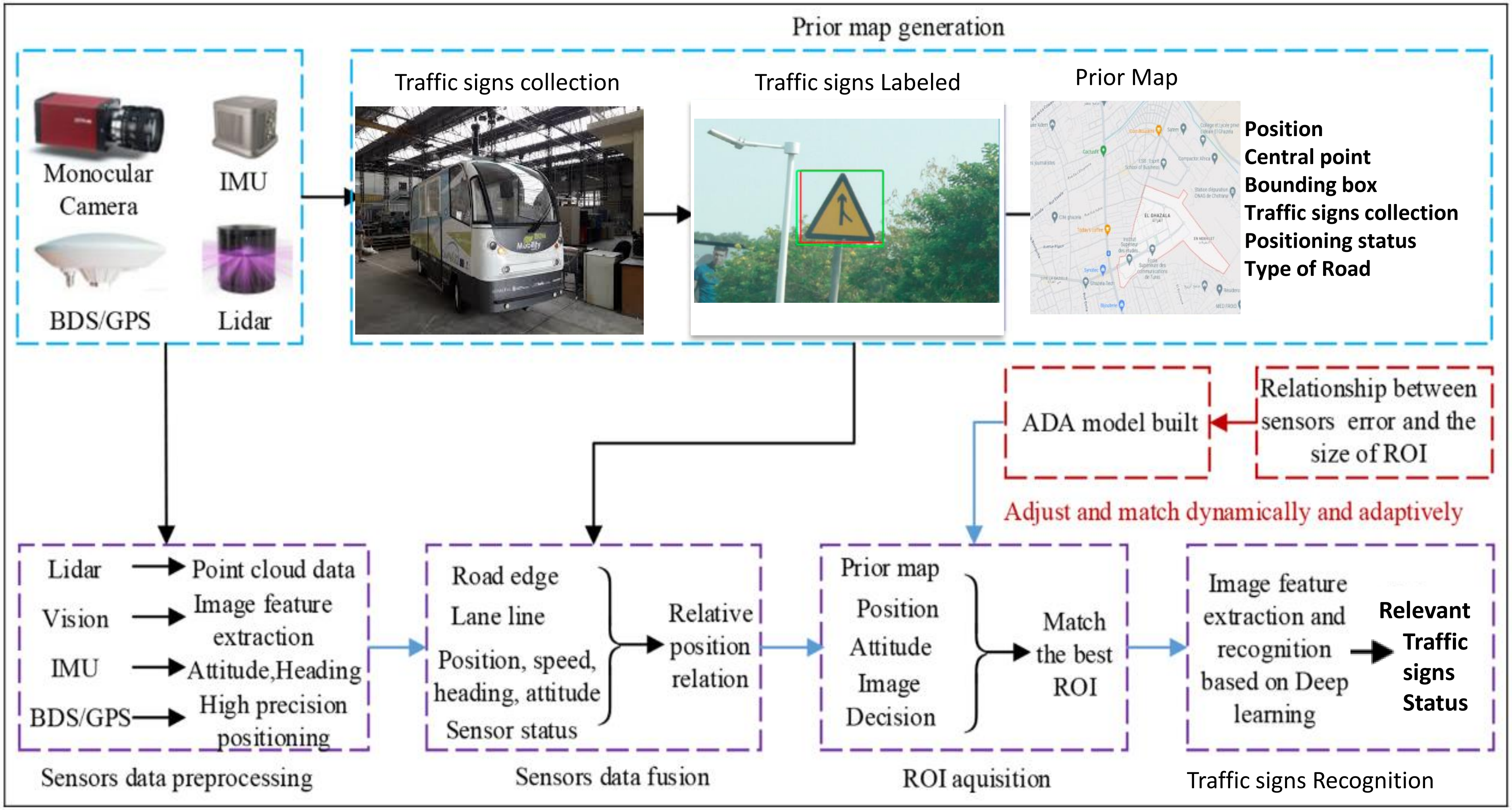
Perception module

Context: Project partners



Three partners located in Technoparc Elghazala

Proposed Solution



Outline

- Sensors' complementarities
- Data types
- Sensors' joint calibration
- Prior Map Generation
- ADA Model
- Feature Extraction and Recognition
- Conclusion

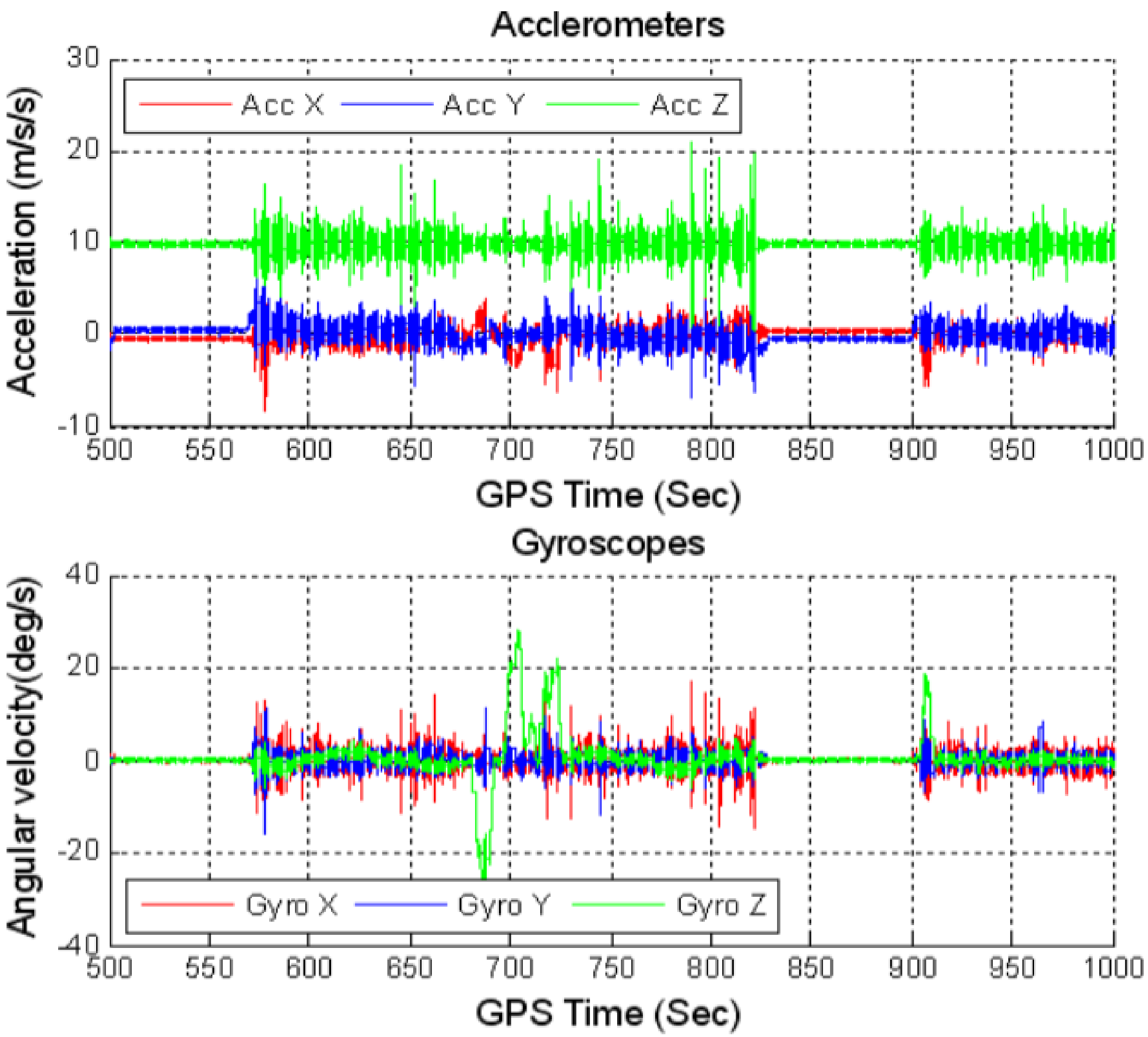
Sensors' complementarities

RTK BDS/GPS	IMU	Monocular Camera	LiDAR
- High precision global positioning all time and all weather	- No interferences by the external environment	- Achieve object detection	- Point clouds giving scene object details - Not sensitive to weather conditions
- Degradation/non positioning (occlusion and interferences)	- Accumulation of errors	- Not accurate positioning - Sensitive to weather conditions and nighttime	- Relative positioning

- The sensors are highly complementary
- Through multi-sensor fusion, we can achieve accurate and reliable perception for autonomous vehicles in complex scenarios.

Data types

- **IMU Data**



Data types

- **RTK BDS/GPS data**

- RTK Kit for
(1)Robotic Machine Precision Guidance,
(2)Structure Monitoring,
(3)RTK Survey.

- Receiver based L1/L2/E5b GPS / GLONASS / Galileo / Beidou / QZSS RTK receiver that provides centimeter-level accuracy RTK positioning.

- We apply fusion of GPS and BDS signals which improve the accuracy of the results

- Data : Resulted position coordinates

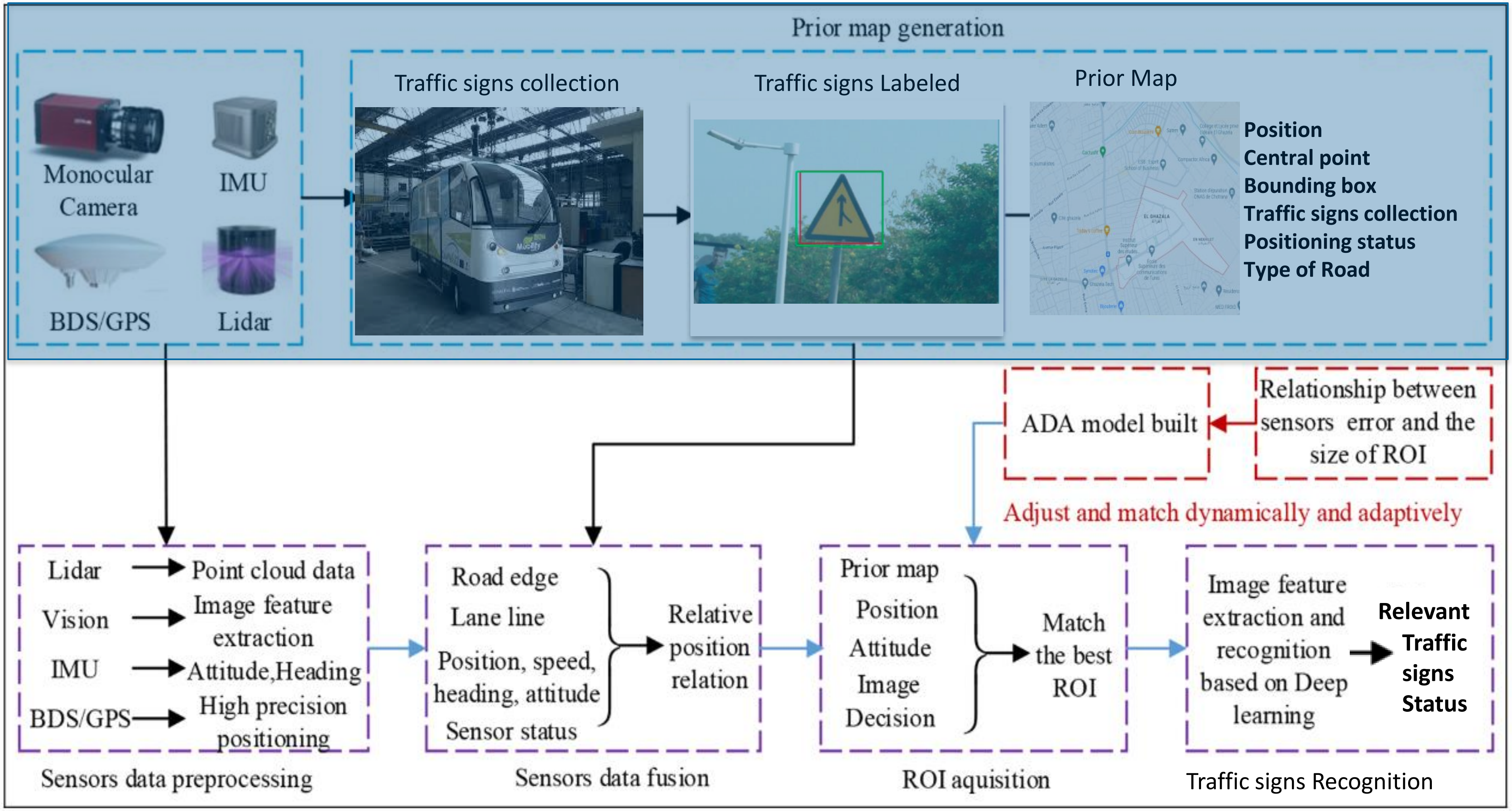
Data types

- **Monocular Camera data / LiDAR data**

Sensors' joint calibration

- The joint calibration of the sensors => an important step, which determines the accuracy of the results
- Temporal and spatial (rotation and translation) synchronization of data from different sensors through the conversion of the coordinate system of IMU, camera, BDS/GPS, and LiDAR
- The IMU, camera, and LiDAR were all rigidly connected to the vehicle body, and the relative position and attitude relationship were approximately unchanged
  - 1/ calibrate the transition matrix between the IMU and the camera : C_{IMU}^{C}
  - 2/ use C_{IMU}^{C} to obtain C_{IMU}^{LIDAR} (for LiDAR) and C_{IMU}^{Ant} (for BDS/GPS Antenna)
  - 3/ calibrate the position of BDS/GPS antenna (geographic coordinate system) with camera, LiDAR and IMU

Proposed Solution



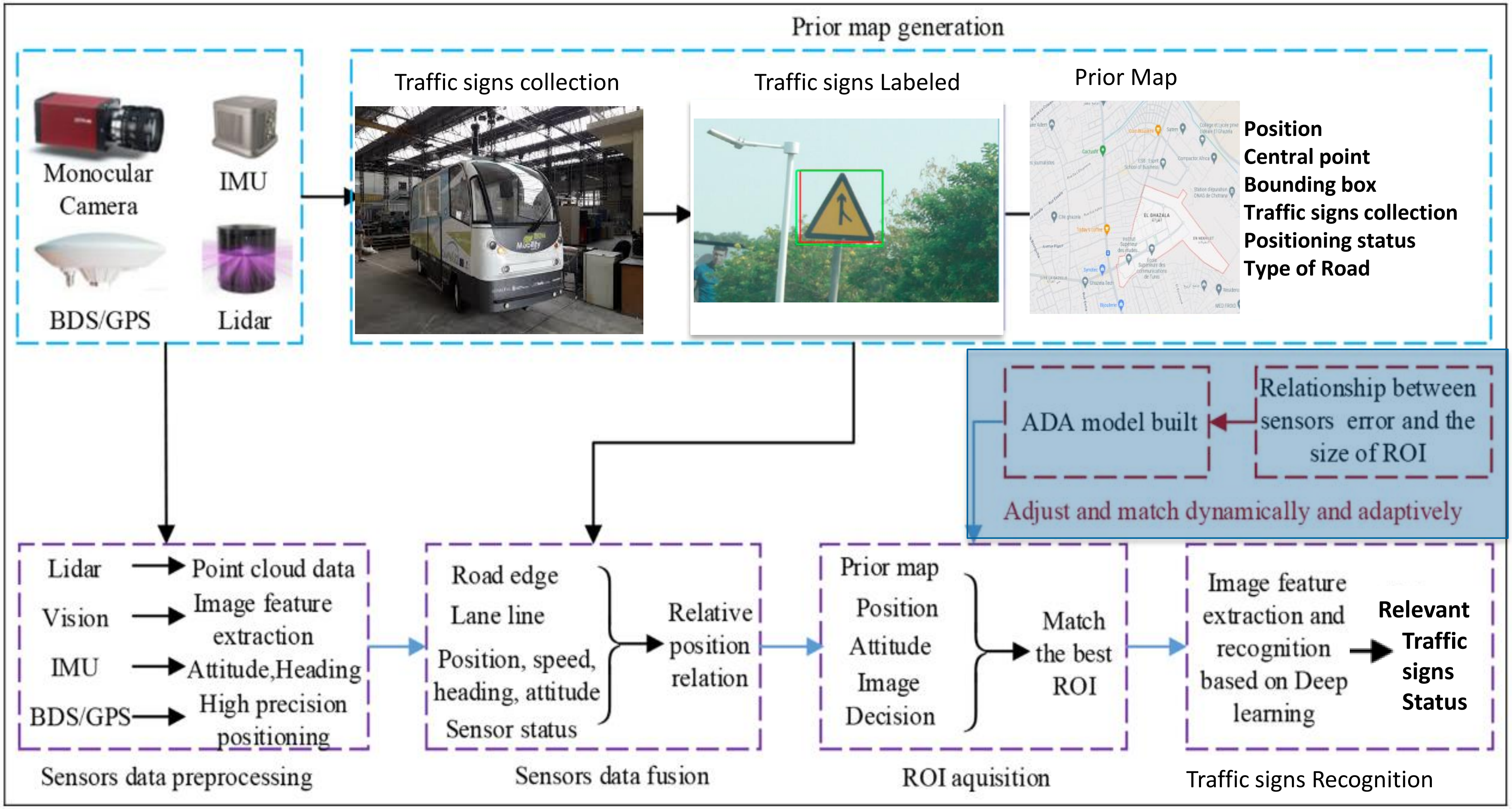
Prior Map Generation (1/2)

- Prior map : prior knowledge of traffic signs position and information
- Prior map generation main steps :
  - Use multi-sensors to collect urban road images, LIDAR point clouds, position, traffic signs in various illumination and weather conditions
  - Cluster the LiDAR point clouds and manually label the rectangular bounding box and calculate the coordinate of the center point and the size
  - Label the BDS/GPS receiver (RTK, degraded, outages) due to the occlusion of trees, tall buildings, bridges
  - Align, clean and structure the packaging of multi-sensor fusion data
- The prior map : the traffic signs center points, bounding box, traffic signs semantics, positioning status of the BDS/GPS receiver (RTK, degraded or outages), road type (straight, crossroad, roundabout, etc.)

Prior Map Generation (2/2)

- The center point and the bunding box of the traffic signs are represented with longitude latitude and altitude => need to calculate the coordinate parameters in the camera pixel coordinate system
- Using external calibration parameters, calculate its coordinates in the camera system
- Using intrinsic camera parameter, calculate its coordinates in the pixel coordinate system

Proposed Solution



Model build : ADA (1/4)

- An Adaptive Dynamic Adjustment (ADA) mechanism is applied to stabilize multidimensional dynamical systems
- Use ADA method to optimize the size of the ROI considering computational efficiency and precision
- The errors sources of the ROI : data labelling errors (joint calibration, positioning, point cloud clustering, the synchronization of the sensors) and the measuring errors of the sensors real-time.
- The ADA of the ROI size is mainly related to the error BDS/GPS receiver and IMU (real time positioning).
- The relationship between the working status of sensors and the ROI size is analyzed in two conditions : RTK BDS/GPS, RTK degraded

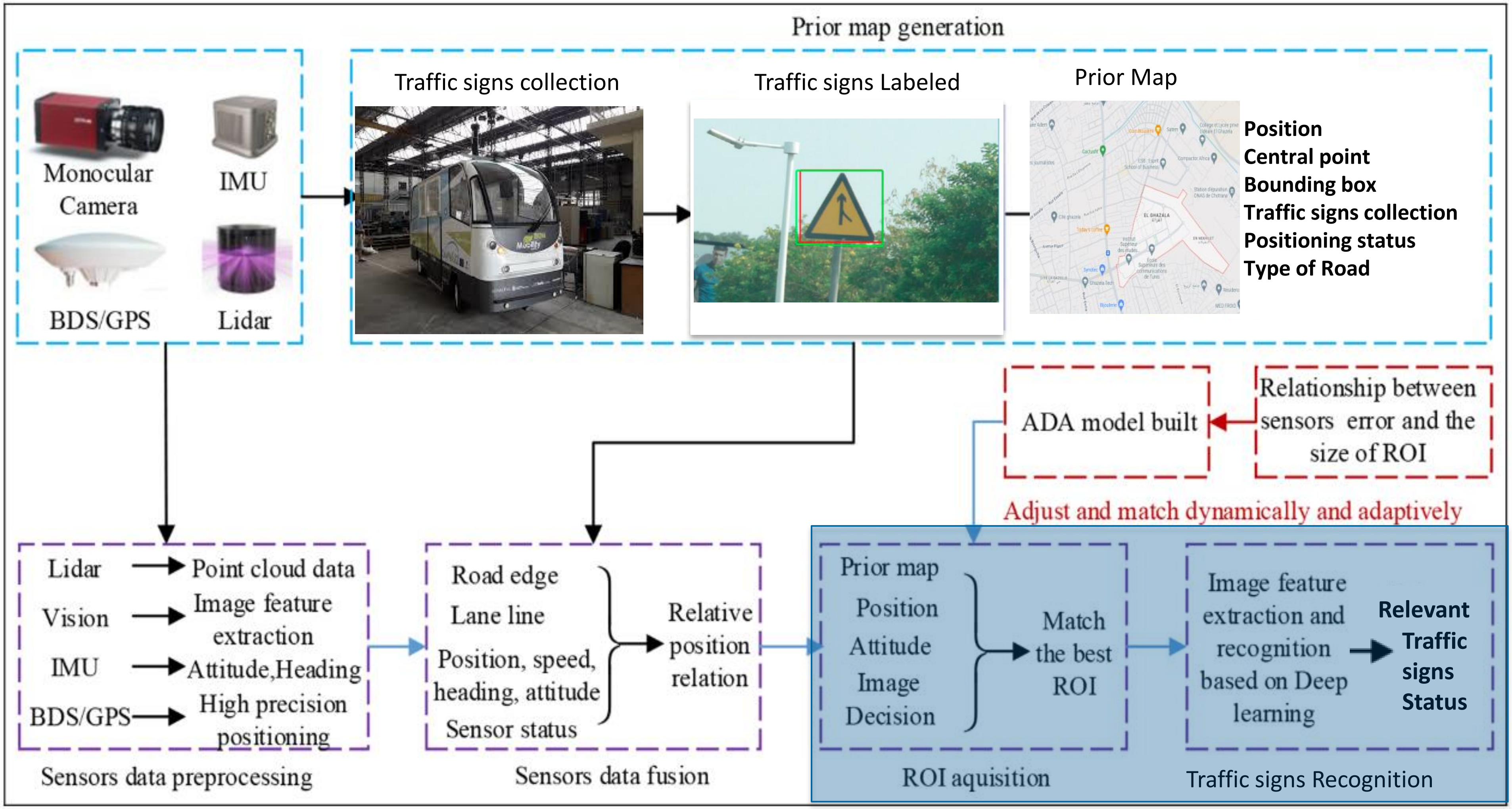
Model build : ADA (2/4)

- RTK BDS/GPS
  - Real time dynamic (RTK) differential and the positioning precision is 3cm (normal conditions)
  - Important synchronization errors BDS/GPS/IMU integrated navigation system/camera/LiDAR : fps=25 => 40ms => distance 0,7m (60km/h)
  - Error from the IMU angle of 0,5° results in an error of nearly 1 meter on the center point of the traffic sign image
  - The errors are expressed in both geographic coordinates and camera systems

Model build : ADA (3/4)

- BDS/GPS degraded
  - BDS/GPS receiver RTK differential working mode fails due to obstruction, interference, communication failure, etc.
  - The positioning errors can reach 10m
  - Obtain the ROI through the fusion data of the sensors IMU (heading and attitude), LiDAR (road boundaries and separation zone detection) and the camera (lane line detection).

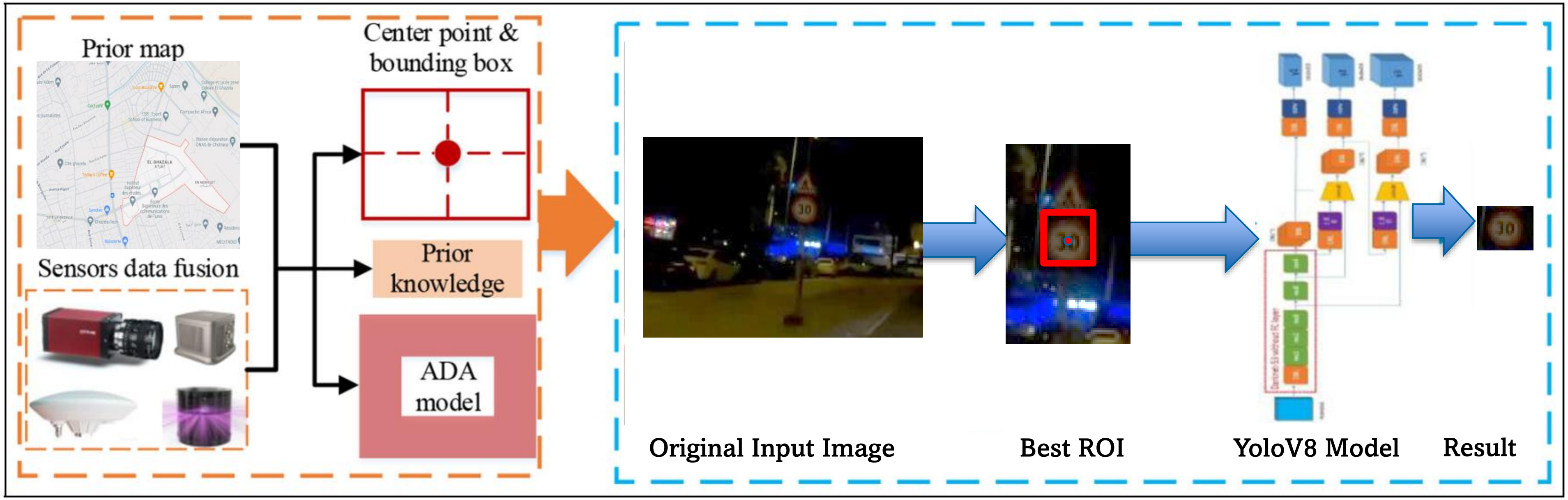
Proposed Solution



DL based Features extraction and recognition

- DL based techniques have higher accuracy in complex and open scenarios
- Yolo (image processing) has advantages in computing efficiency (real time performance)
- Selection of Yolo V8 higher accuracy and FPS = 45
- Multi-sensors fusion and prior map assistance significantly improve image quality
- The prior knowledge (ROI optimization with ADA) facilitate Yolo V8 traffic signs recognition

Traffic signs recognition



Experimental results

- LISA Traffic Sign Dataset (LISATSD) + GAN generation of night/rain/snow effects => Augmented LISATSD
- LISATSD : 7855 annotations on 6610 frames
- Augmented LISATSD : 1256 annotated frames



- Yolo V8 transfer learning on Augmented LISATSD
- NVIDIA Jetson TX2 platform

Experimental results

Approach	FPS on NVIDEA Jetson TX2	Accuracy
Proposed Method	36	83,7%
Yolo V8	15	78,7%

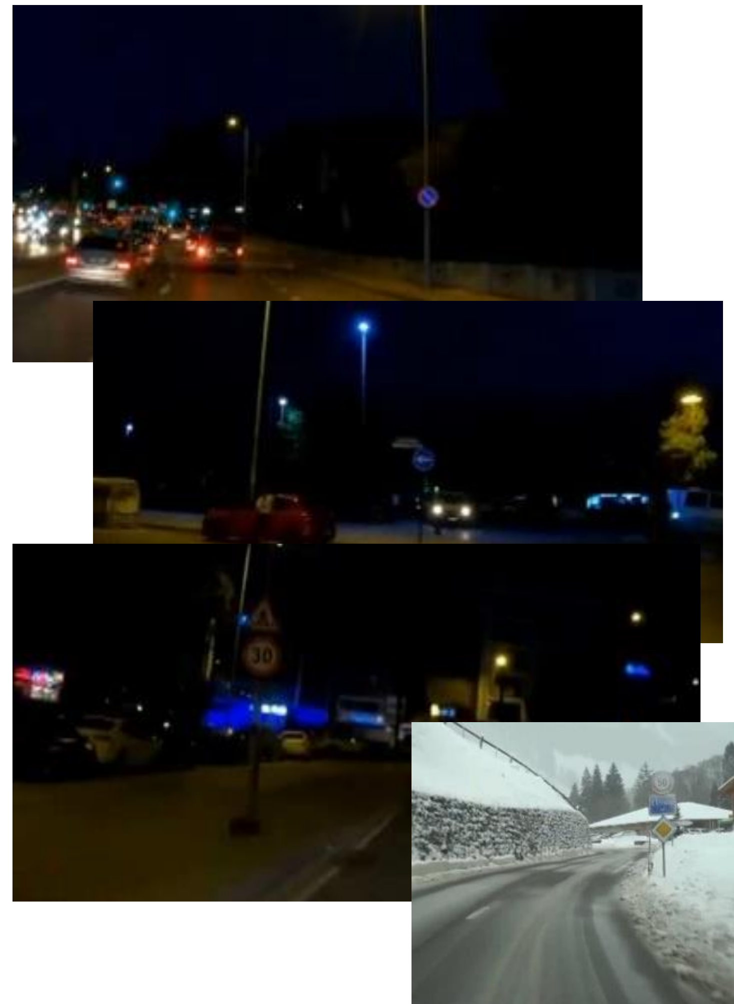
- Manually segment images for obtaining ROI of 64x64/128x128/192x192 to simulate the auxiliary effects of RTK BDS/GPS, RTK degraded

Test dataset	Accuracy before segmentation	ROI Segmentation	Accuracy after segmentation
RTK		64x64	87,6%
RTK Degraded	78,7%	128x128	84,2%
RTK Degraded		192x192	83.8%

Experimental results

Proposed method

Yolo V8



Conclusion

- It is challenging to recognize the traffic signs in harsh environments ; only camera don’t satisfy actual applications of autonomous driving
- Multi-sensors data fusion such as LiDAR, Camera, IMU, BDS/GPS and prior map to obtain the ROI is an effective method to improve the accuracy of Traffic signs recognition
- Analyzing the relationship between the error of the sensors and the size of the ROI, the ADA model improved the accuracy of the deep learning-based traffic signs recognition algorithm

=> Improve the security of autonomous vehicles in severe environments

Thank you for your attention