Vehicle Automation

Flanders MAKE

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Assessment: Vehicle automation

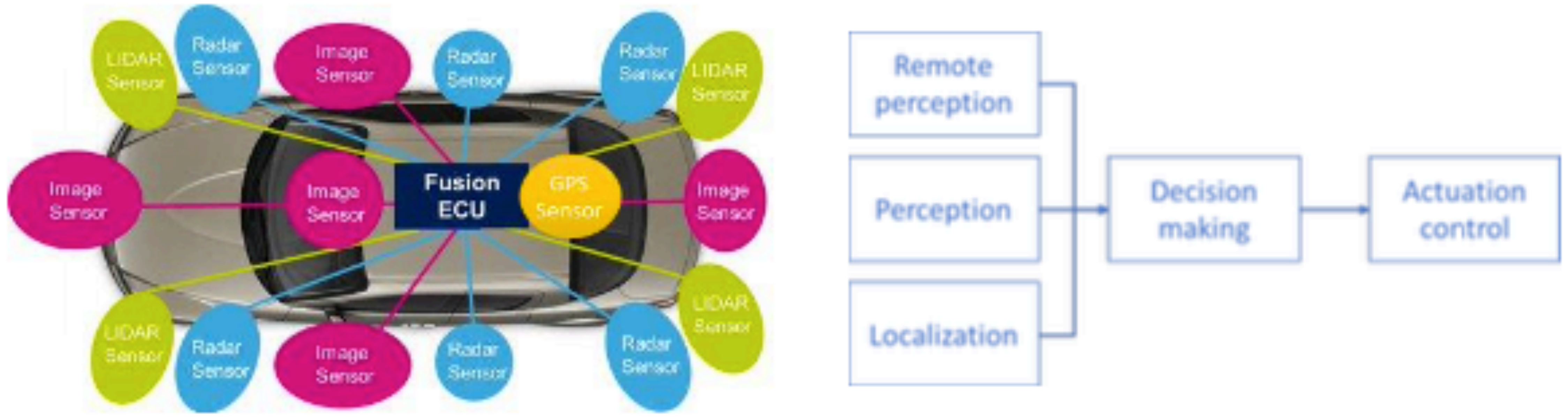
An startup in vehicle development requested to provide an autonomous driving solution. The purpose is to show a proof of concept for automation of the startup's vehicle. The provided solution should consist of perception and localization all the way to low level control, however excludes actuation.

The following requirements were derived by the system architect:

- To operate in urban environments.
- Ensure safety under all conditions.
- Maximum driving speed of 50kph.
- Interact with infrastructure, when existing, for better decision making.
- Infrastructure data sharing based on ITS-G5, using an ITS protocol stacks.
- Available sensors:

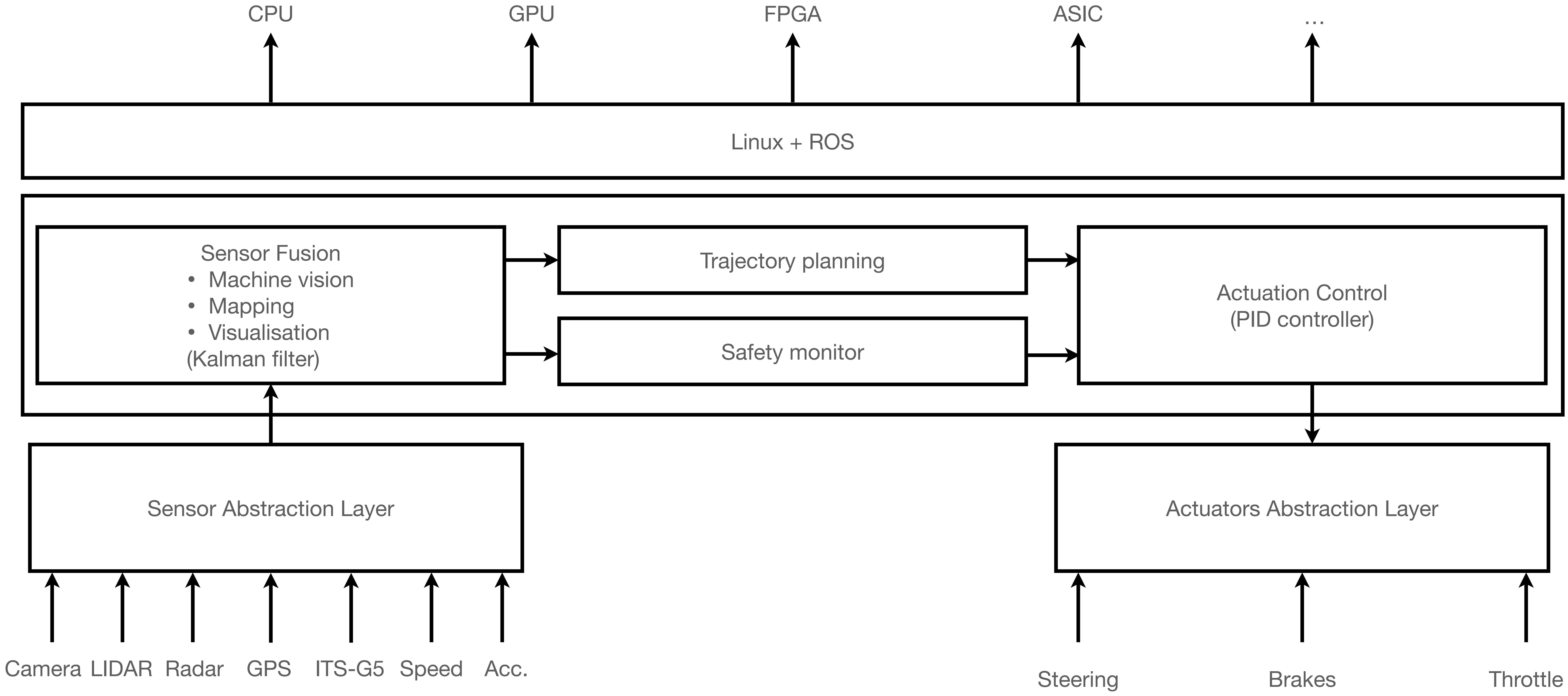
Sensor Type	Brand	Interface	Update rate	Data rate
Image	Leopard ar0231	GMSL	30 fps	800 Mbit/s
LIDAR	Velodyne VLP16	Ethernet 10/100	5-20 Hz	16 Mbit/s (in dual mode)
Radar	Continental ARS441	CAN	15 Hz	25 Kbit/s
GPS	Septentrio	USB	100 Hz	-

Based on the requirements, the system architect defined the following sensor distribution and high level system partitioning:

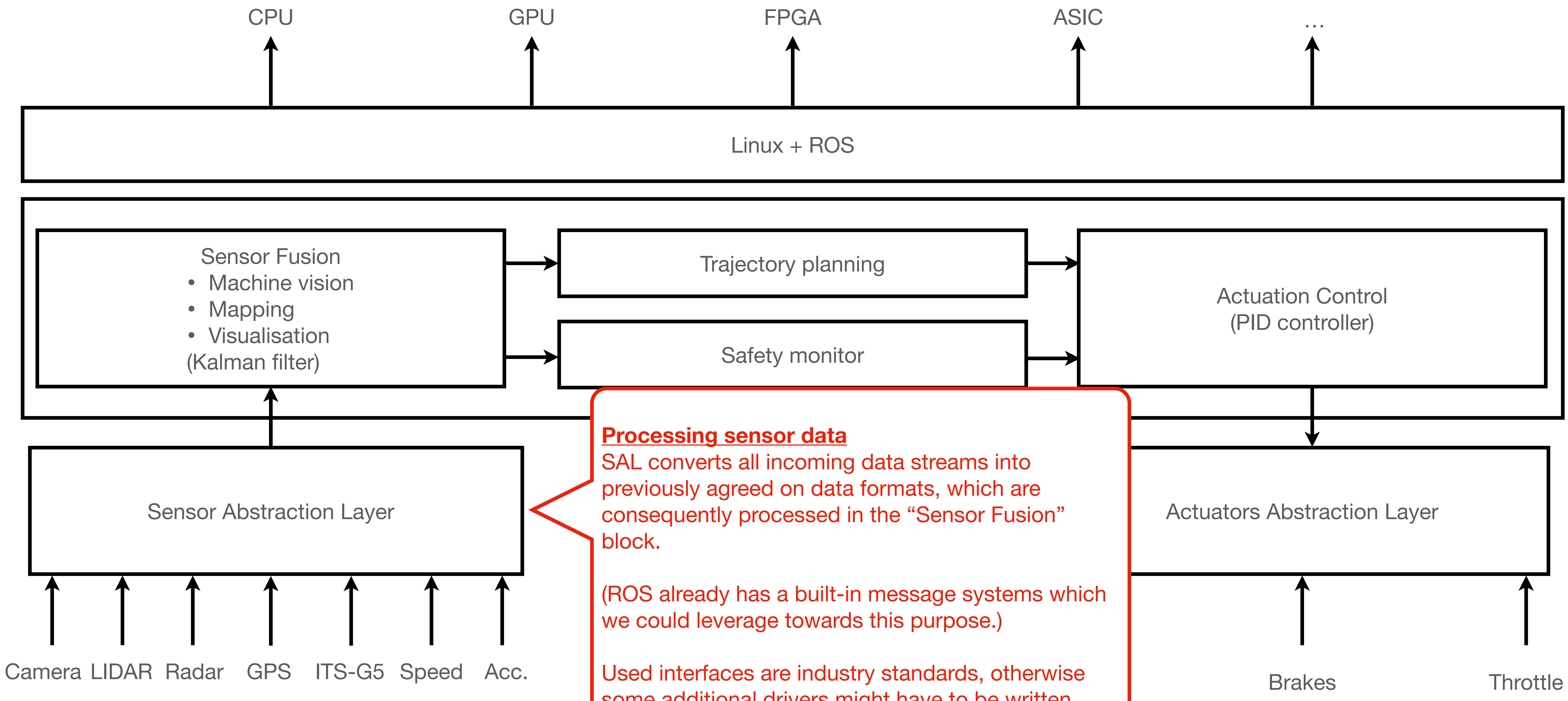


1. What software architecture would you propose
    a. in order to process all sensor data,
    b. with the need for sensor fusion to increase probability detection and
    c. to support modularity and scalability e.g. for future enhancements and use within multiple projects?

Software Architecture



Software Architecture

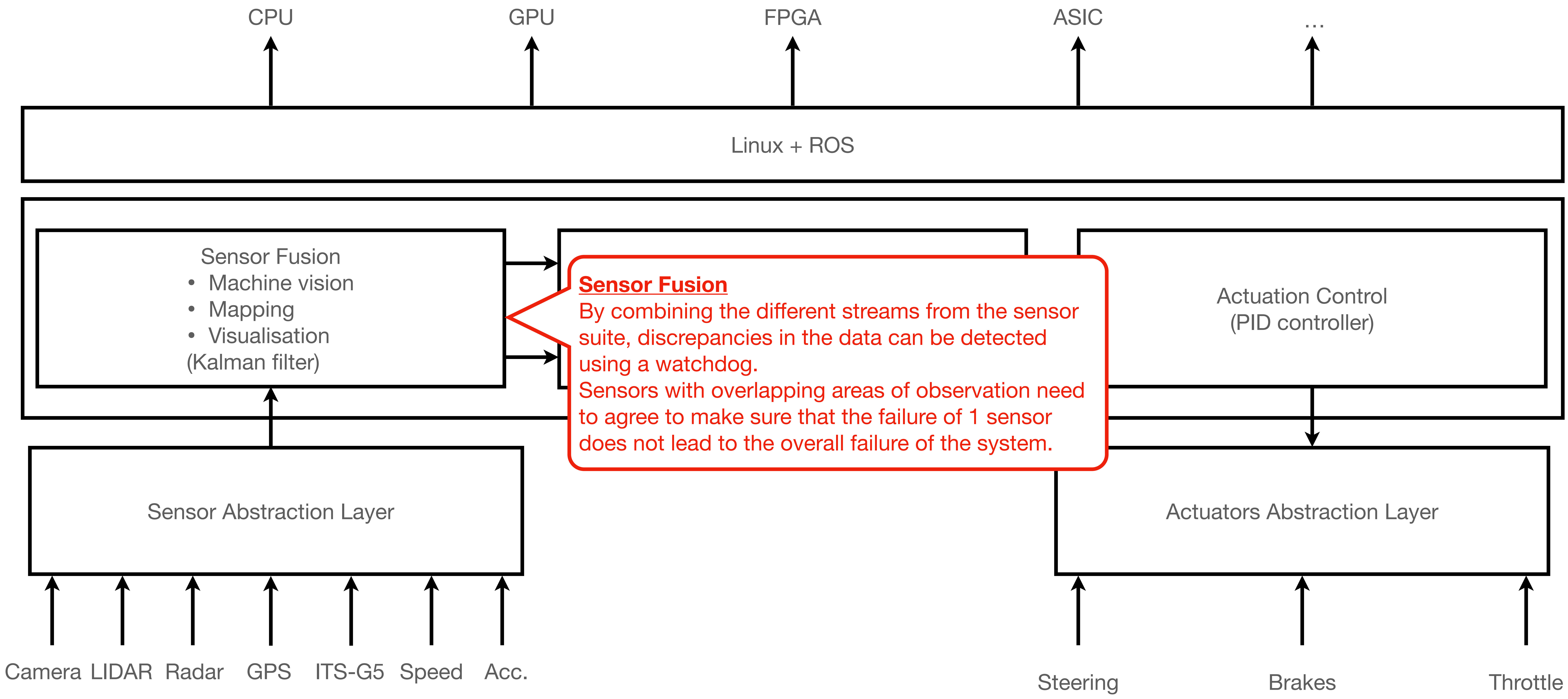


<u>Processing sensor data</u>
SAL converts all incoming data streams into previously agreed on data formats, which are consequently processed in the "Sensor Fusion" block.

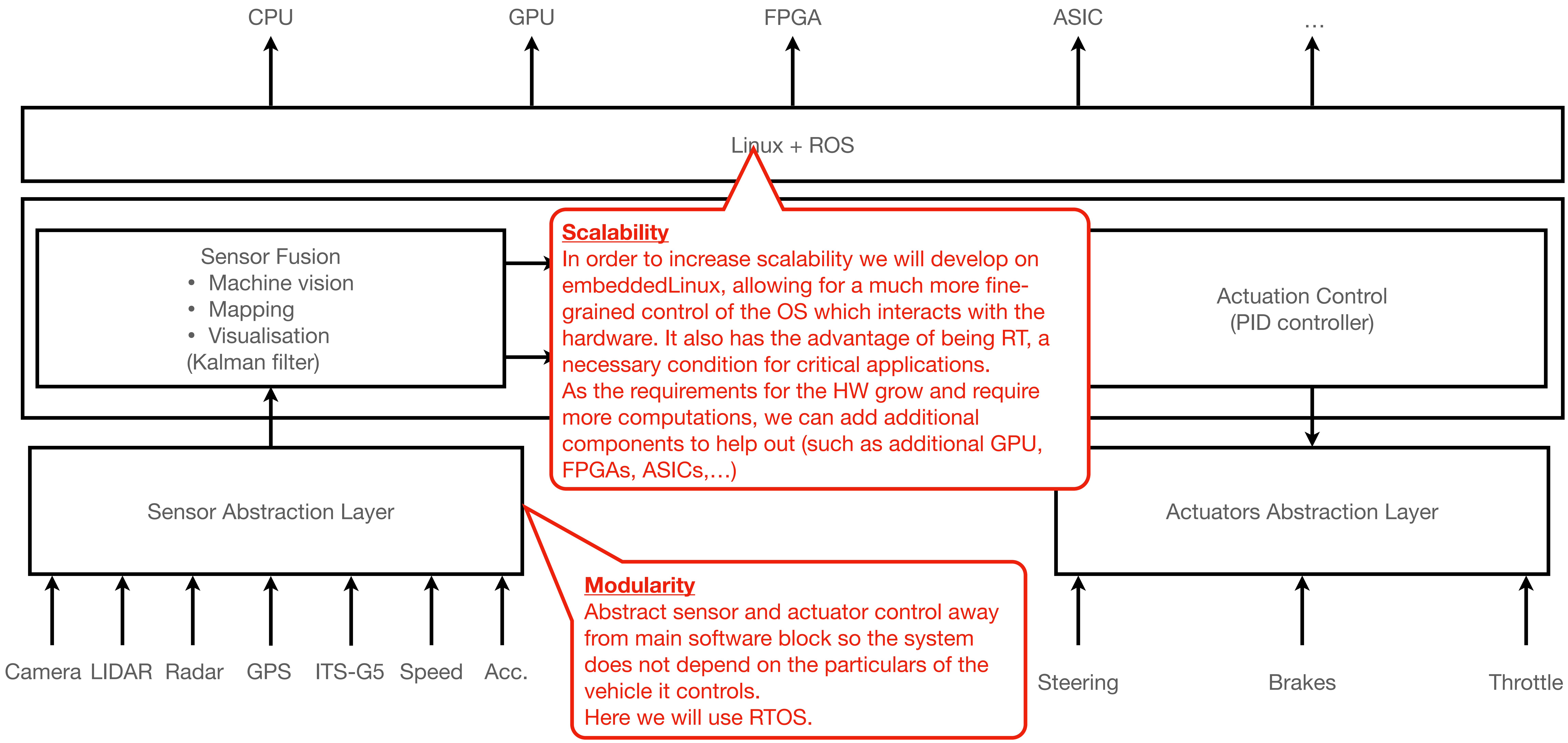
(ROS already has a built-in message systems which we could leverage towards this purpose.)

Used interfaces are industry standards, otherwise some additional drivers might have to be written.

Software Architecture



Software Architecture

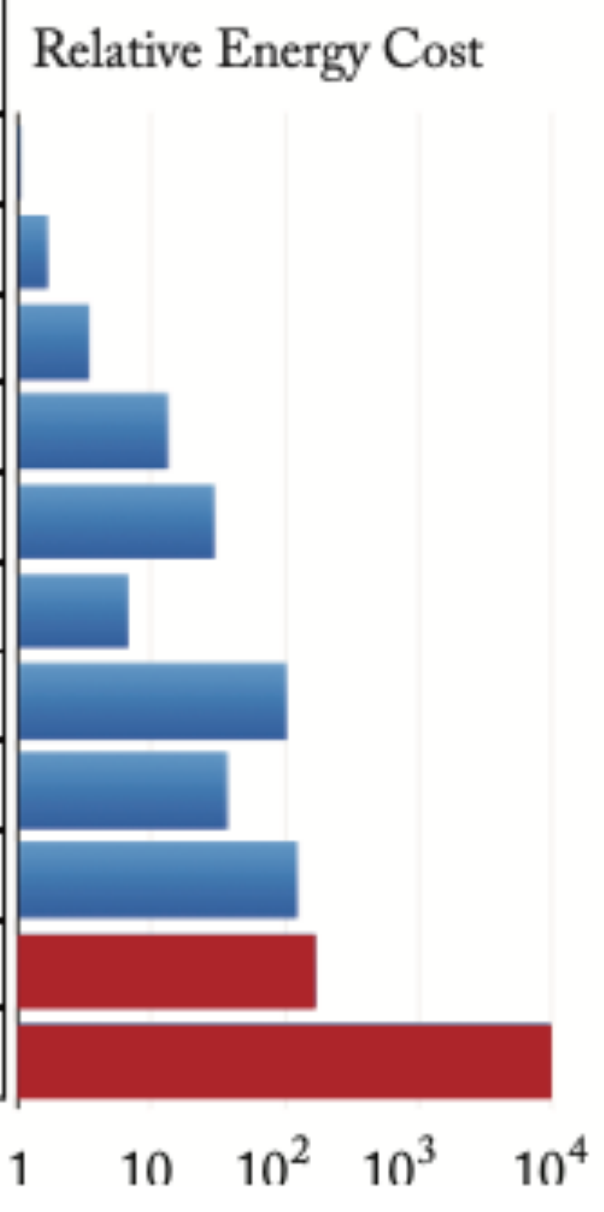


2. Where are the attention points/bottlenecks within the proposed architecture?

Attention points/bottlenecks

- Safety
  - SW
    - Failure to detect object (correctly), faulty planning drive
    - Resistance to outside interference (hack)
    - Safe stop
    - Condition: HW is operating correctly
  - HW
    - Failure of sensor, computing unit, power,…
    - Redundancy: Overlapping sensor, multiple cores, power supply,…
- Throughput/Latency
  - Optimise software for minimal latency (NN!)
  - Parallelism?
    - Which tasks can take place simultaneously?
    - Dependencies?
  - Batching (increases latency)
  - Task precedence
  - Impact of environment?
    - City environment: lots of variables (pedestrians, road signs,…)
- Testing
  - Determine testing strategy for each unit
  - Usage of feedback loops?
- ROS
  - Mainly meant for r&d
  - “Security and scalability are not main concerns”

Operation:	Energy (pJ)
8b Add	0.03
16b Add	0.05
32b Add	0.1
16b FP Add	0.4
32b FP Add	0.9
8b Mult	0.2
32b Mult	3.1
16b FP Mult	1.1
32b FP Mult	3.7
32b SRAM Read (8KB)	5
32b DRAM Read	640



Source

3. Propose derive hardware requirements, both performance as interface related, for the main blocks of perception, localization, decision making and actuation control?

Hardware requirements

- Power & Energy (<xW)
  - DNN (perception)
    - # of NN layers
    - Bit precision
    - # of off-chip accesses (SRAM <-> DRAM accesses)
  - Cooling
- Latency & Throughput
  - 30 fps -> $Latency_{max} < 33ms$
  - Min BUS speed:
    - 800 + 16 ~= 1 Gbit/s
  - Optimize for:
    - Object Detection (YOLO, DNN-based)
    - Object Tracking (GOTURN, DNN-based)
    - Localization (ORB-SLAM, FE)
  - Frame rate: 100Hz
- Cost < x€
  - Development cost
    - Off-the-shelf hw (GPU) <-> custom (ASIC/FPGA)
  - Unit cost
    - Computing unit
    - Cooling
    - Redundancy
  - Production cost
- Flexibility
- Impulse/vibration resistance
- Thermal constraints

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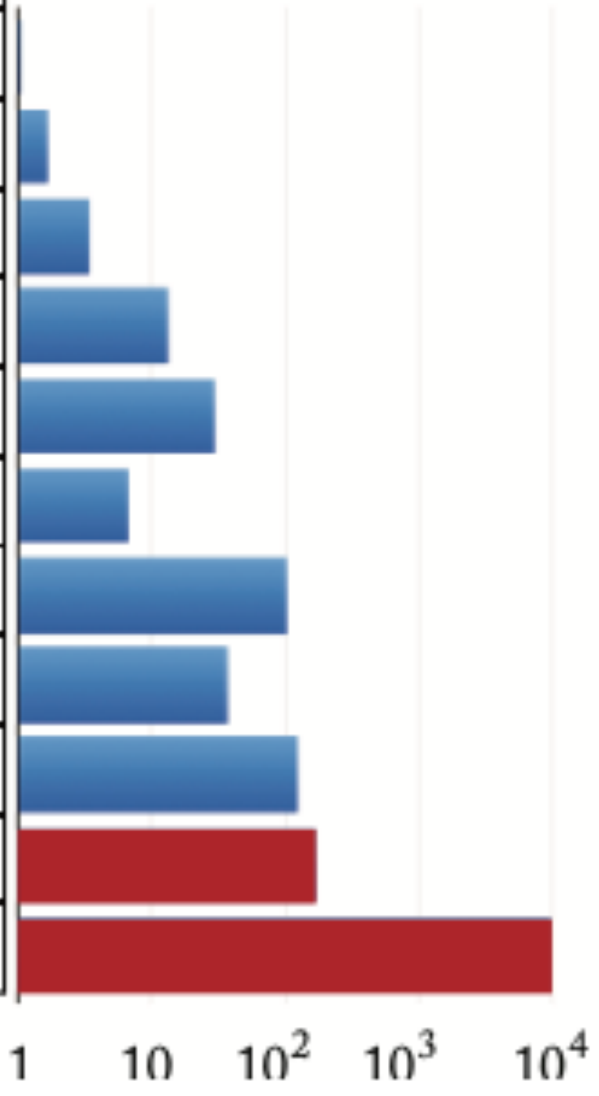
Relative Energy Cost



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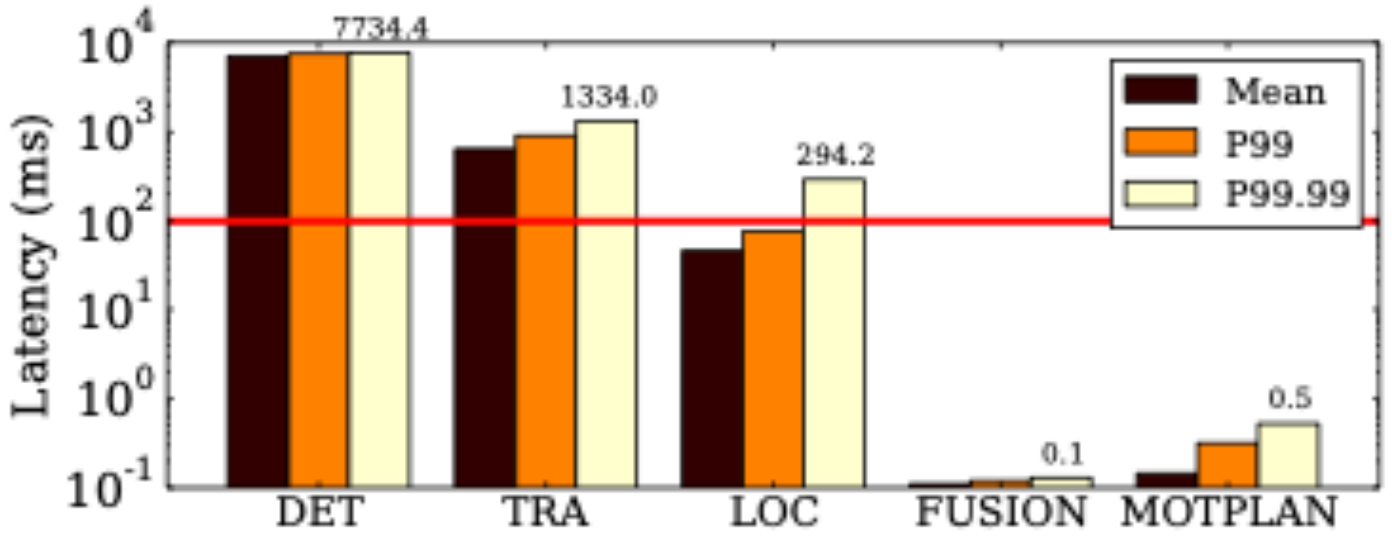


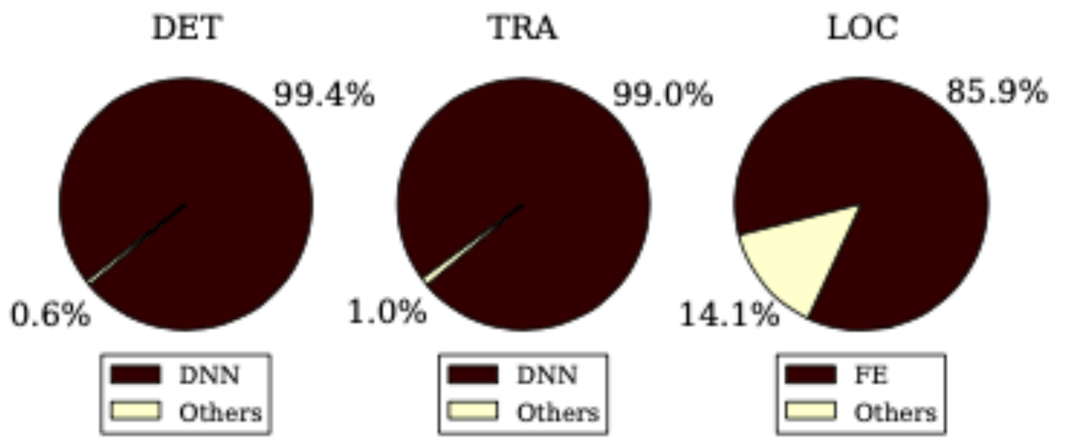


Figure 7. Cycle breakdown of the object detection (DET), object tracking (TRA) and localization (LOC) engines. The Deep Neural Networks (DNNs) portion in DET and TRA, and the Feature Extraction (FE) portion in LOC account for more than 94% of the execution in aggregation, which makes them ideal candidates for acceleration.

Source

Hardware requirement

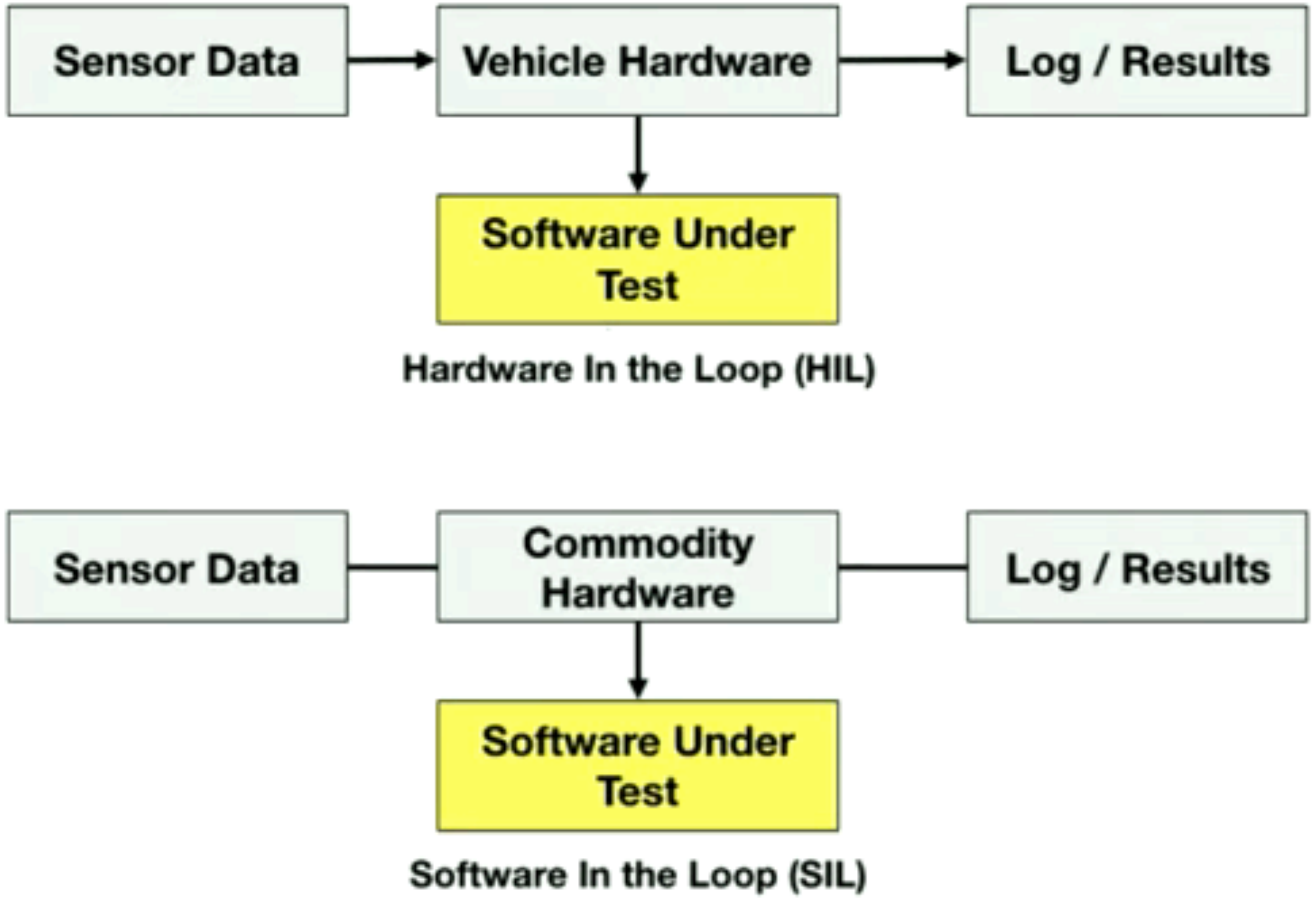
- Interface
    - GMSL (image sensor)
    - Ethernet 10/100
    - CAN
    - USB
    - 5G
    - HDMI

    - I2C/SPI
    - LEDs
    - Buttons/Switches
    - PCIe

4. How can the proposed architecture be validated?

Validation

- Simulation (SW)
  - Unit test for all sensors/actuators
  - Unit test for each software block of self-driving
  - Interface testing
  - Full testing of self-driving in simulation
    - Allows for intricate test adjustments
    - Account for difference real/simulated data
  - Testing using pre-recorded data (in simulation)
  - Simulation of city environment?
- Run H-I-L to verify hardware requirements
- Real Life Validation
  - Test track: port of Antwerp?
  - City environment



Source

Sources

- Autonomous driving systems hardware and software architecture exploration: optimising latency and cost under safety constraints
- A Standard Driven Software Architecture for Fully Autonomous Vehicles
- Efficient Processing of Deep Neural Networks: A Tutorial and Survey
- The Architectural Implications of Autonomous Driving: Constraints and Acceleration
- Efficient Processing of DNN
- Self-Driving Cars as Edge Computing Devices