CISC 322 A3 Presentation

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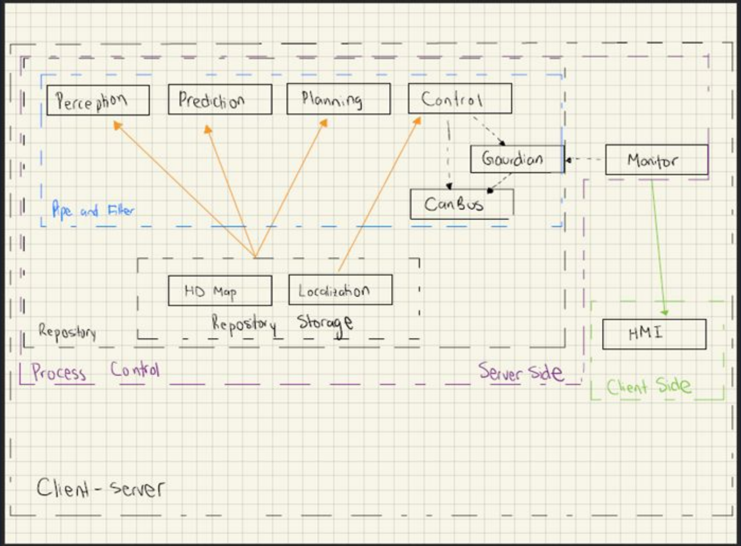
Enhancement Feature

- We have decided to implement the “Enhanced Pedestrian Protection System” to improve the functionality and effectiveness of Apollo’s self-driving system
- The feature adds full support for thermal cameras to the software, as well as the necessary hardware
- Currently, Apollo relies on visible-light cameras, RADAR and LiDAR which limits Apollo to driving in good weather conditions, since neither of these technologies can perceive accurate data in bad weather conditions like rain, snow and fog
- Adding thermal camera support to the software will bring the system much closer to full autonomy, allowing the driver to safely give up control in a wider range of situations like driving during bad weather or in rural areas

Recap of Conceptual Architecture

- We based our conceptual architecture on our initial A1 report on Apollo's architecture as well as the same report from Group 6: Dash
- Our final conceptual architecture combined elements from the pipe-filter, repository, process control, and client-server architectures to represent the Apollo system



Non-Functional Requirements

- Any unnecessary latency between detection and reaction could have catastrophic consequences, especially because the situations in which thermal scanning would be most useful are in reduced-visibility situations, where driver vision is limited
- The thermal camera enhances the safety of autonomous driving, so it should be ensured that the thermal camera is working without errors since that could potentially lead to an accident if the camera data is inaccurate
- The thermal camera is not only needed for autonomous driving, but also in extreme weather situations
- The thermal camera would be a key safety feature in those scenarios and as a result, it should be available at all times during vehicle operation

Implementation - 1

- The first approach for implementing our new feature is by adding submodules to existing architecture, taking advantage of the modular and extensible design of Apollo and its components
- The most important addition would be a “Thermal Camera Manager” submodule in the perception module
- The processed data from the submodule can then be combined with other perception data and used by modules which receive output from the Perception module
- A new submodule can be added to the Monitor module which is responsible for monitoring the sensors and software systems needed for the enhancement, and ensuring everything is running smoothly
- Finally, we would add an additional component to the HMI module, so that users can get visual information from the thermal cameras
- The thermal camera video feed can allow passengers to see what the car is seeing in low visibility conditions.

Implementation - 2

- Another approach to the implementation of the Thermal Cameras to the existing architecture of Apollo would be to include it as a separate module
- This would decrease the number of dependencies of each of the existing sub-systems in the architecture, thus building a more robust architecture
- This new module would take data from the Localization, Perception and HMI modules and output to the Prediction, Planning and Control modules
- In order to optimize its performance, it can also take in useful data from RADAR and LiDAR when it is appropriate to do so, thus improving its accuracy in terms of general obstacle detection
- Additionally, we can also add a sub-module in the Control module that assesses the visibility conditions outside the car so that the system can automatically switch to the Thermal Camera when visibility is poor

SAAM Analysis #1

- The surroundings are quite foggy, so the system changes the primary source of external stimuli data to the Thermal Camera rather than the RADAR and LiDAR
- A visibility test will be conducted by the Control module, which facilitates the change of the primary source of information to Thermal Camera from RADAR and LiDAR
- Next, the outputs of the Localization module would get redirected to the Thermal Camera module in order to produce more accurate images for the Perception and Planning modules

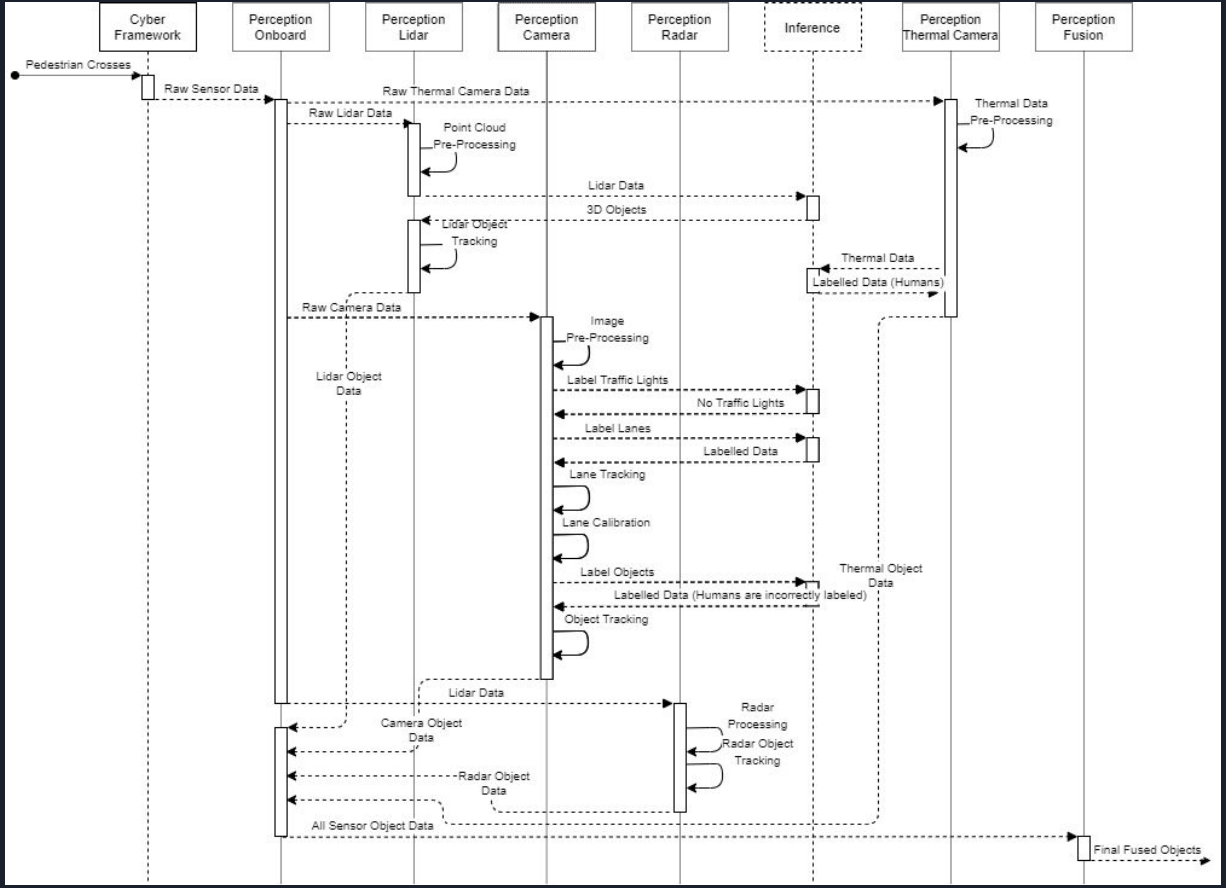
SAAM Analysis #2

- There is a deer fast approaching the highway, where the car is being driven
- With the Thermal Camera module in use, the presence of an animal will be sensed and this data will be sent to the Perception and Planning modules, which will test the animal's trajectory and speed to calculate whether or not the vehicle will be close to the animal
- If these trajectories meet, then the planning module will take this into consideration and hence, reduce the speed so that the animal can cross safely

Impacted Subsystems

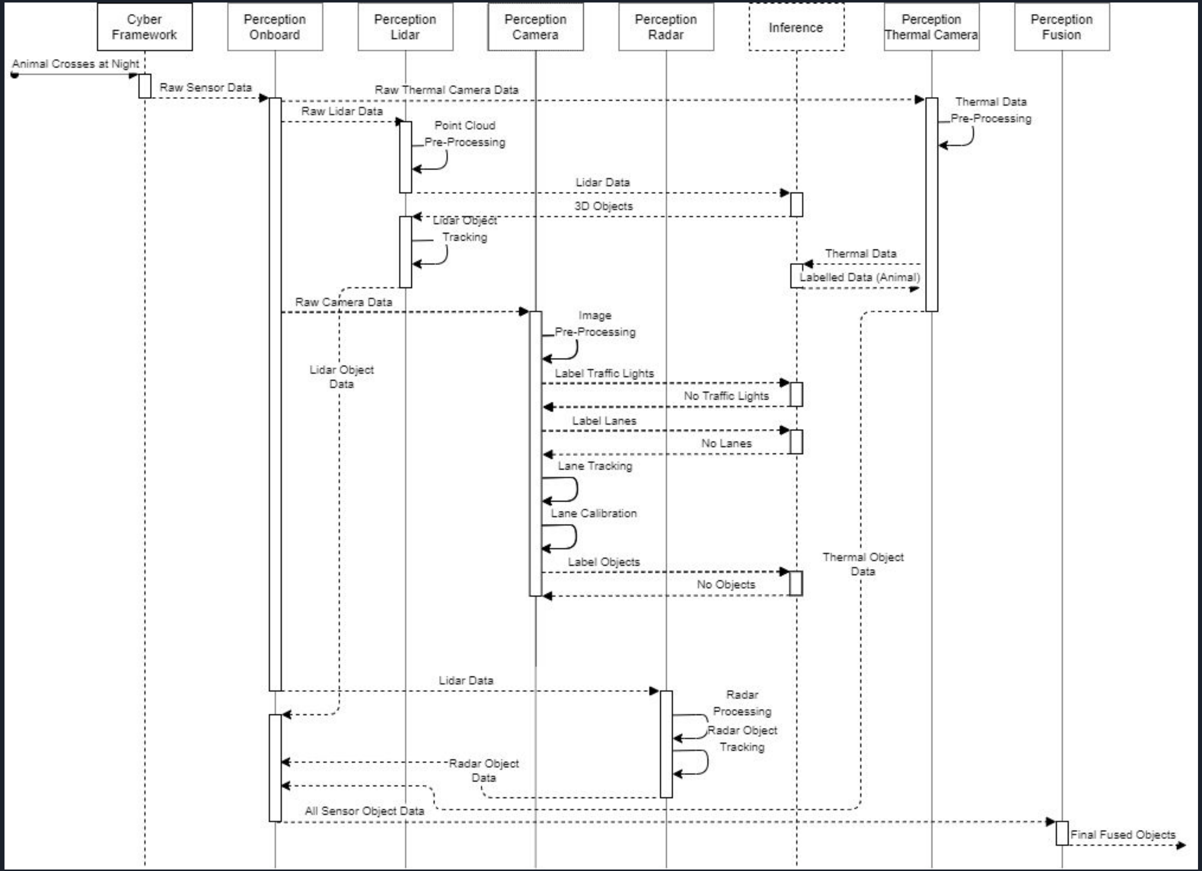
- The most heavily impacted subsystem would be the Perception module, and modules which receive data from it
- The thermal camera data would need to be combined with the existing perception data in a way that does not impact the normal functioning of the system, but serves as a secondary check for hazards which are more difficult for other sensors to detect
- The Monitor and Guardian modules would need modification to work with the new hardware and software related to the thermal camera components, and the HMI module would need modification in order to receive thermal camera output, as well as processed thermal imaging showing detected obstacles
- Depending on implementation, the Prediction, Planning, and Control modules may also be modified to use the thermal data as a secondary check to ensure the planned route is free of obstacles detected by the thermal camera

Use Case #1



Cyber Framework
Perception Onboard
Perception Lidar
Perception Camera
Perception Radar
Inference
Perception Thermal Camera
Perception Fusion
Pedestrian Crosses
Raw Sensor Data
Raw Thermal Camera Data
Thermal Data Pre-Processing
Raw Lidar Data
Point Cloud Pre-Processing
Lidar Data
3D Objects
Lidar Object Tracking
Thermal Data
Labelled Data (Humans)
Raw Camera Data
Image Pre-Processing
Lidar Object Data
Label Traffic Lights
No Traffic Lights
Label Lanes
Labelled Data
Lane Tracking
Lane Calibration
Label Objects
Thermal Object Data
Labelled Data (Humans are incorrectly labeled)
Object Tracking
Lidar Data
Radar Processing
Camera Object Data
Radar Object Tracking
Radar Object Data
All Sensor Object Data
Final Fused Objects

Use Case #2


Cyber Framework
Perception Onboard
Perception Lidar
Perception Camera
Perception Radar
Inference
Perception Thermal Camera
Perception Fusion
Animal Crosses at Night
Raw Sensor Data
Raw Thermal Camera Data
Raw Lidar Data
Point Cloud Pre-Processing
Thermal Data Pre-Processing
Lidar Data
3D Objects
Lidar Object Tracking
Thermal Data
Labelled Data (Animal)
Raw Camera Data
Image Pre-Processing
Lidar Object Data
Label Traffic Lights
No Traffic Lights
Label Lanes
No Lanes
Lane Tracking
Lane Calibration
Label Objects
Thermal Object Data
No Objects
Lidar Data
Radar Processing
Radar Object Tracking
Radar Object Data
All Sensor Object Data
Final Fused Objects

Testing Plans - 1

- The purpose of developing new verification techniques is to mitigate or decrease superfluous testing, as well as to create tests that ensure that the presumed failure will not occur in practice
- Product development efficiency must continue to improve in today's world. The demand for innovative sensors and functionality is critical, particularly in the automobile sector

Testing Plans - 2

- The first stage is to define the robustness requirements for the product, i.e., the conditions that the product must be able to bear while keeping full operation
- The development time is critical in the product development process, and achieving an acceptable degree of robustness in the lowest possible period is vital
- This strategy allows you to concentrate on the most important robustness goals and assist you in achieving either the targeted robust product or a proven risk-based compromise

Risks and Limitations - 1

- The temperature sensor is turned on by default for safety-related equipment, and the uncalibrated threshold may fall inside the working temperature range, thus not allowing the chip to boot and execute the program
- When the calibration data changes, the temperature sensor is activated, hence, the status cannot be assured at that point
- In the event that the temperature sensor stops working fully (false indication or no indication), the situation can potentially be deadly since the chip may be turned off entirely or continue to operate in an unreliable state

Risks and Limitations - 2

- The materials used to make thermocouple wires are not inert, and the thermoelectric voltage created throughout the length of the wire can be affected by corrosion and other factors
- In a certain temperature range, thermo-sensors are not as precise as RTDs and are prone to drifting over time
- Non-linearity, low stability, low sensitivity, and low voltage are issues which can easily occur if precautions are not put in place

Conclusion

- Thermal imaging, like all other automobile sensory systems, has a straightforward goal: to provide drivers with data about their environment and to assist them in reacting quickly—and sometimes automatically—to possible threats
- It joins other advanced systems, such as medium and long radar, in providing a comprehensive set of safety measures
- In our implementation, the thermal imaging feature will only be enabled in certain situations when surrounding conditions are unfavorable
- The current architecture limits Apollo only to fair driving conditions, and is thus not suited to real-world conditions.
- Thermal imaging will play a critical role in getting self-driving cars on the road as soon as feasible

THANK YOU!