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Co-Design of Automotive Boardnet Topology and Architecture

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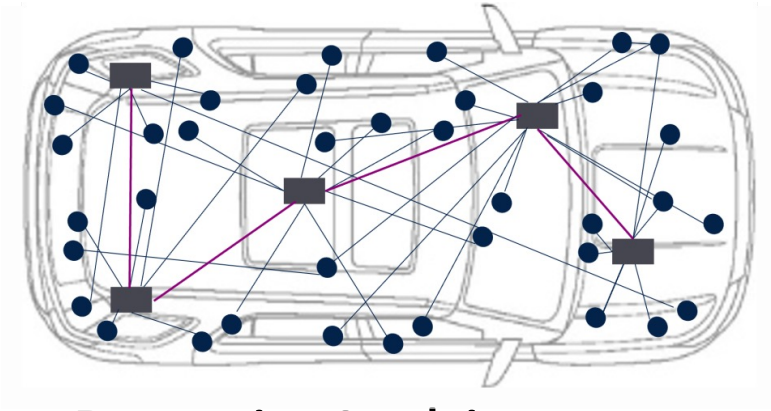
accellera SYSTEMS INITIATIVE

Introduction

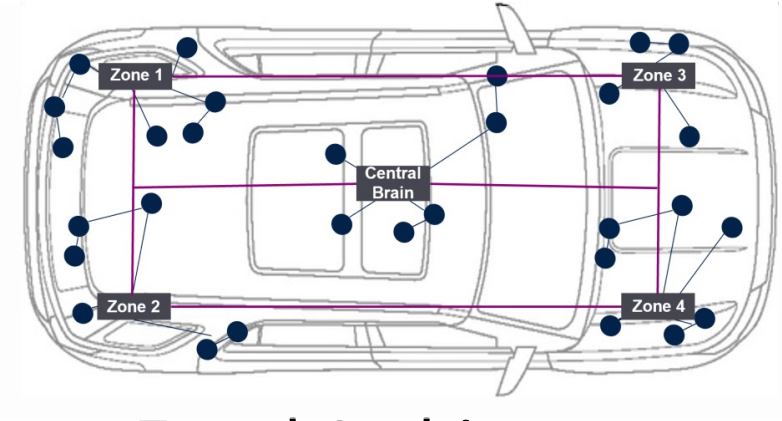
- High and growing number of software and AI functions in modern cars

  ➔ connection via boardnet needed



Domain Architecture

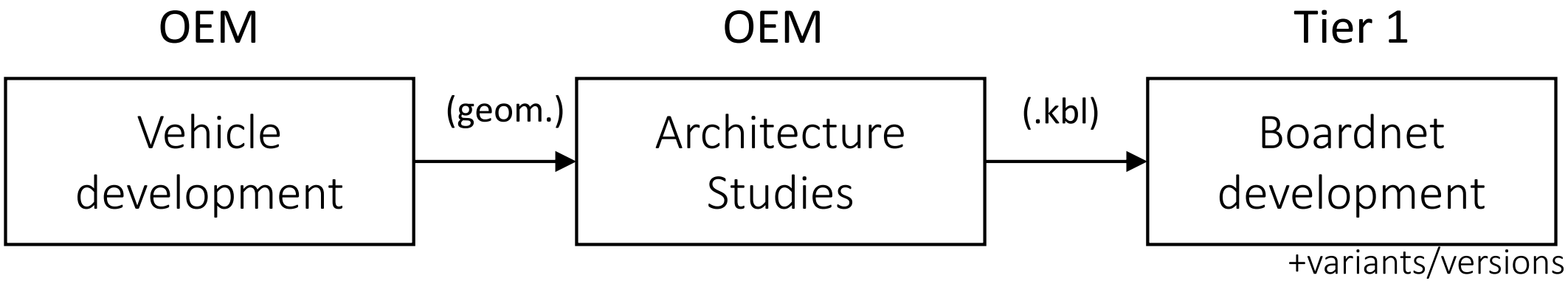
transforms to



Zonal Architecture

- Alternatives: centralized architecture and a mixture of different type

Introduction



- Problems
  - Variations and branches of vehicles not considered efficiently
  - No Specific solutions for different variants

State of the Art and Related Work

- Analyze and/ or optimize given boardnet architecture [1]
- Focusing on improving collaboration in the value chain [2]
- Do so with standardization or tool interoperability like AutoSAR [3]
- SysML v2 standard with standardized REST API for change management
  - No usage for this purpose known

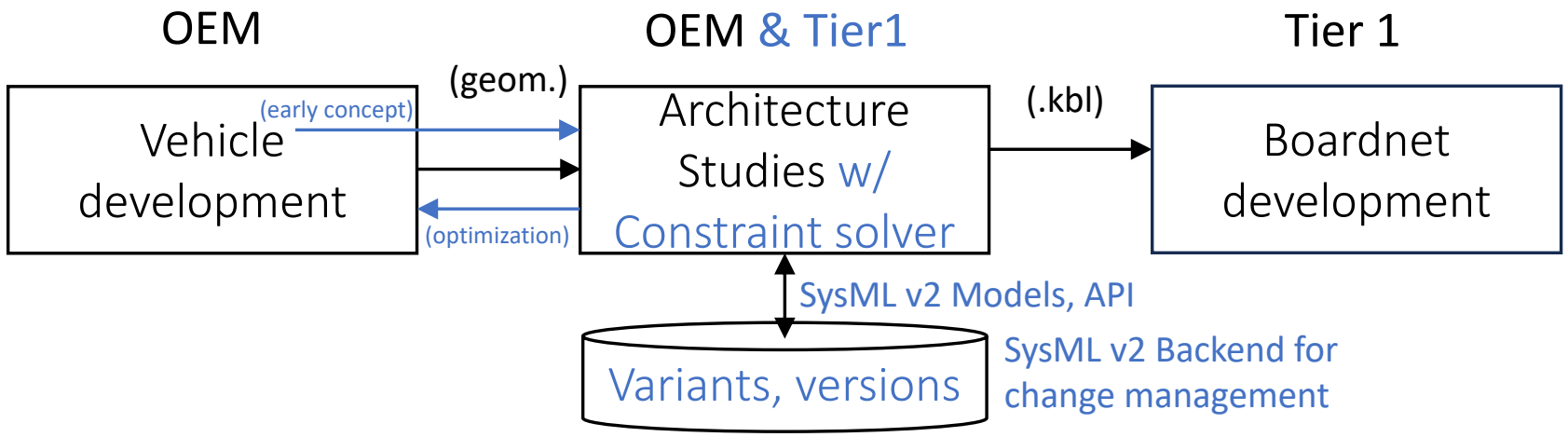
[1] Bowen Zheng, Hengyi Liang, Qi Zhu, Huafeng Yu, and Chung-Wei Lin. Next generation automotive architecture modeling and exploration for autonomous driving. In 2016 IEEE Computer Society Annual Symposium on VLSI (ISVLSI), pages 53–58, 2016.

[2] Pelliccione, Knauss, Heldal. Auto- motive architecture framework: The experience of volvo cars. *Journal of Systems Architecture*, 77:83–100, 2017.

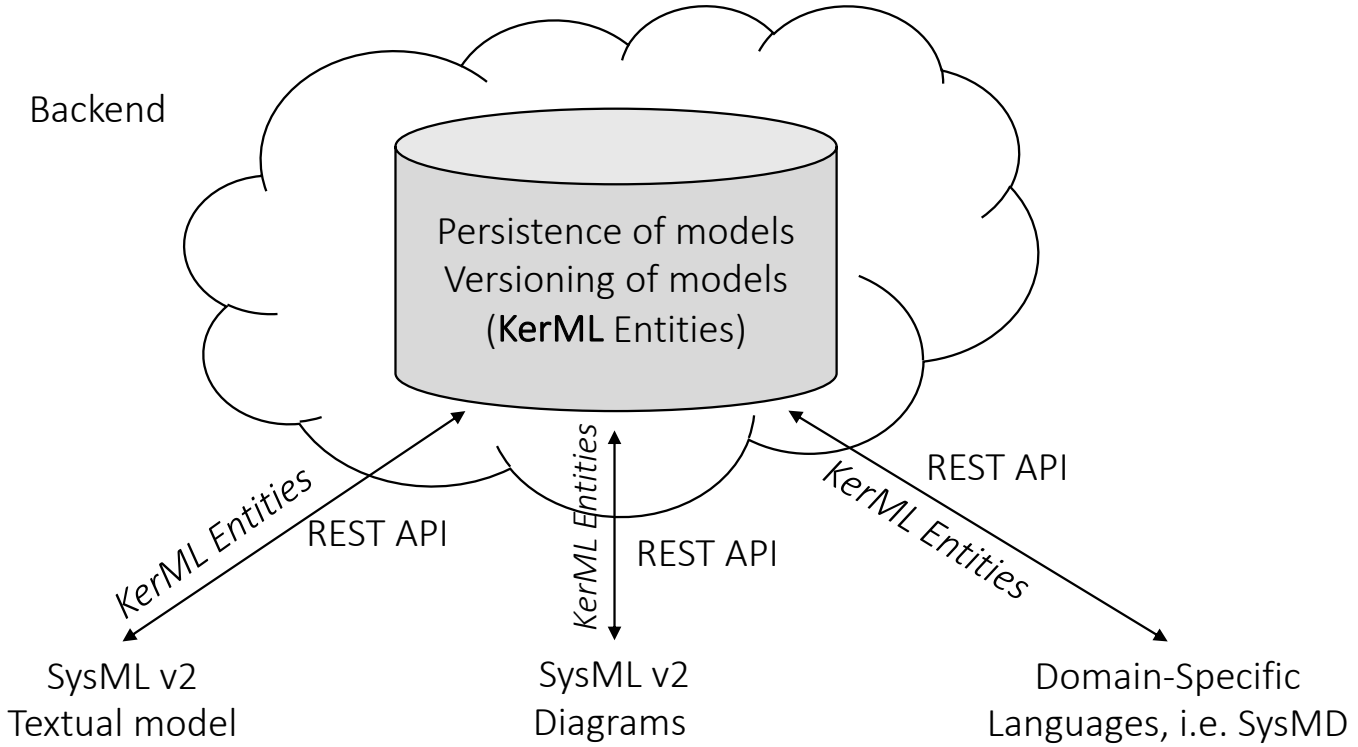
[3] Mozhan Soltani and Eric Knauss. Challenges of requirements engineering in autosar ecosystems. In 2015 IEEE 23rd International Requirements Engineering Conference (RE), pages 294–295, 2015.

Processes

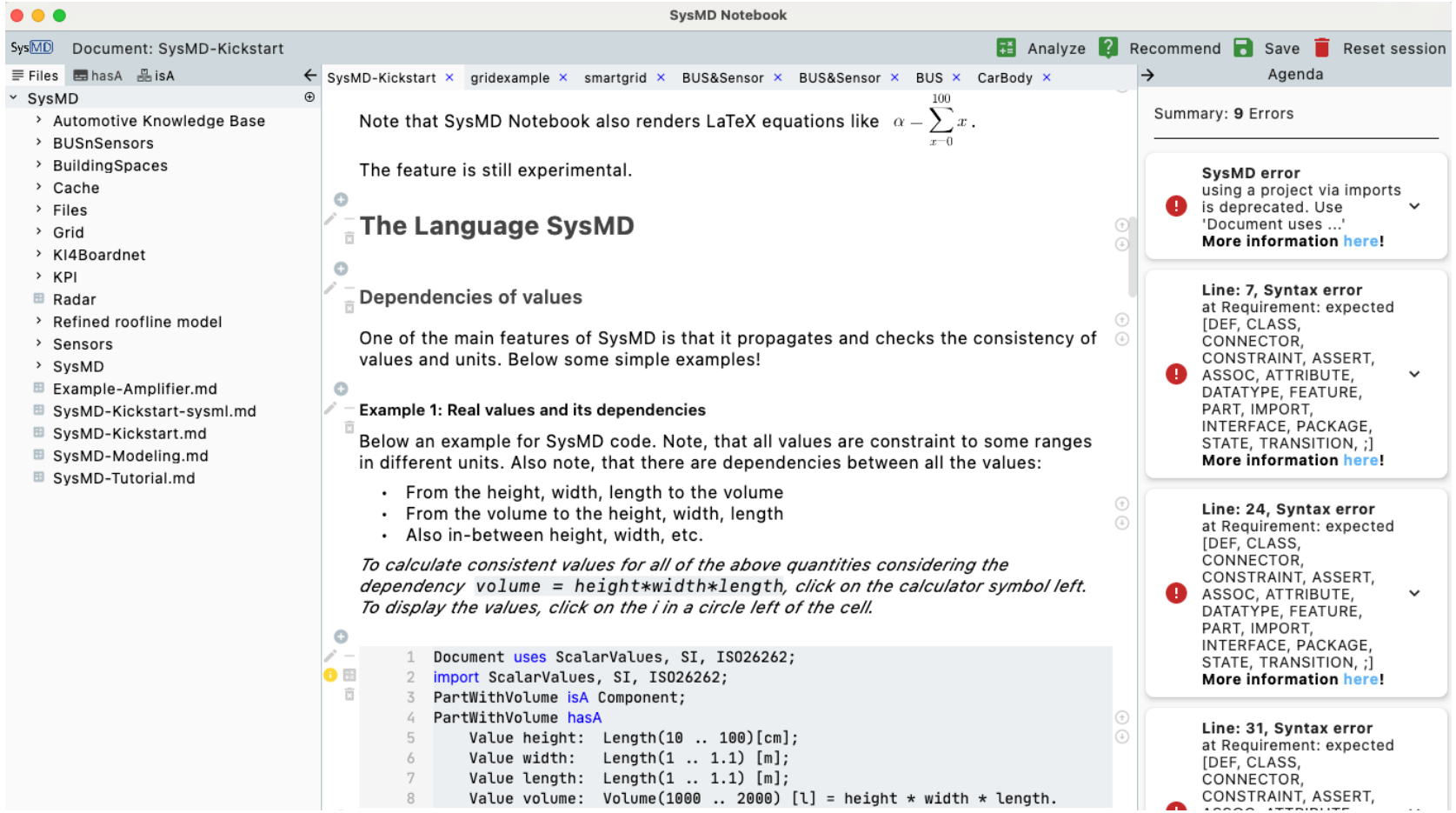
- Target: Cooptimize of vehicle body and boardnet (building spaces, bending radii, …)



Tool Ecosystem



SysMD Notebook



SysMD

- Based on SysML v2 with some extensions and constraint propagation

Language: SysMD Package:

```
1  Package CarParts.
2  CarParts defines
3      Body isA Part;
4      Engine isA Part;
5      Wheel isA Part.
6
7  CarParts::Engine hasA Value mass: Real(200.0) [kg].
8  CarParts::Wheel  hasA Value mass: Real(50.0) [kg].
9  CarParts::Body   hasA Value mass: Real(100.0) [kg].
10
11 Vehicles::Car hasA
12     Part body:   CarParts::Body;
13     Part wheels: [4 .. 4] CarParts::Wheel;
14     Part engine: [1 .. 2] CarParts::Engine;
15     Value mass: SI::Mass (100 .. 2000) [kg] = sumOverParts(mass).
```

Constraint Propagation

- Implemented constraint propagation to all dependent values and expressions
- Supports intervals and units for reals and intervals for integers

```
AreaCalculation isA Component;
AreaCalculation hasA
   Value width:   Length(1 .. 10) [m];
   Value length:  Length(200 .. 200) [cm];
   Value area:  Area(6 .. 8) [m^2] =  width * length.
```

➔ Result: width = 2..3 m

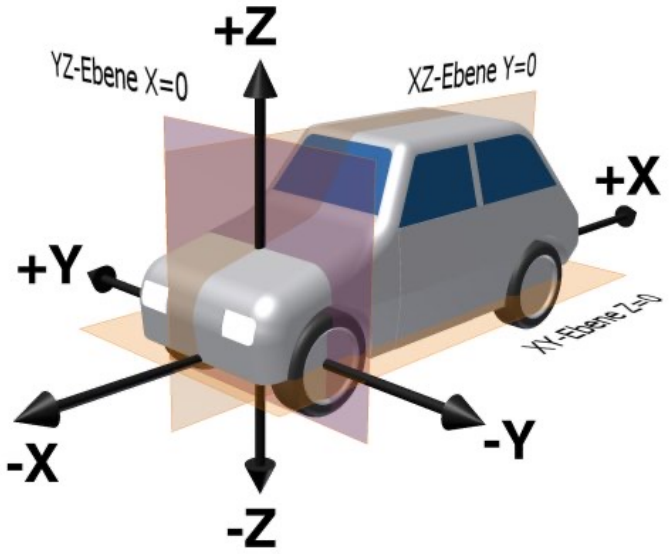
```
Package HybridExample.
HybridExample hasA
            Value a: Real(1.0 .. 2.0);
            Value b: Real(1.1 .. 2.1) = a + 0.1;
            Value c: Boolean(true) = a > b.
```

➔ Result: not satisfiable

SysMD package for analysis of boardnets

- Analysis of wires with the following aspects:
  - wire length
  - wire costs
  - the data rate of the wire
  - the type of the wire, which influences the latency
- Geometric model of the car:
    - Positions stored as Vectors

      e.g. (3.0,- 0.5, 2.0) m



Libraries

```
SysMD    Package: Car::CarComponents
CarComponent hasA
    Value position: Length(-1.5..6, -1.25..1.25,-0.5..4.0) [m],
    Value plugCosts: Currency(1..2) [€].

Gateway hasA
    Value position: Length(0..6, -0.5..0.5,-0.5..2.0) [m],
    Value plugCosts: Currency(1..2) [€] = 1.0 [€].

CentralController hasA
    Value position: Length(0..6, -0.5..0.5,-0.5..2.0) [m],
    Value plugCosts: Currency(1..2) [€] = 1.0 [€].
```

CarComponents Library

```
SysMD    Package: Car::WireTypes
Wiretype hasA
    Value specificWeight: Quantity(1..100) [g/m],
    Value CostsPerMeter: Quantity(0.0..1.0) [€/m],
    Value DataRate: Quantity(0.001 .. 1000.0) [MB/s],
    Value DataSizePerPackage: Quantity(0..10000) [B],
    Value OverheadPerPackage: Quantity(0..1000) [B].

Ethernet hasA
    Value specificWeight: Quantity(15..25) [g/m],
    Value CostsPerMeter: Quantity [€/m] = 0.8 [€/m],
    Value DataRate: Quantity [MB/s] = 10.0 [MB/s],
    Value DataSizePerPackage: Quantity(42..1500) [B],
    Value OverheadPerPackage: Quantity(26..30) [B].
```

WireTypes Library
including Protocols for wires

Estimation of performances

- Estimation of wire length:

$$wireLength = CityBlockDistance(start.position, end.position) * factor$$

- Estimation of the latency of a wire:

$$latency = \frac{dataPerFrame + overheadPerFrame}{dataRate}$$

- Total Length of all wires

$$totalLength = \sum_{i=1}^{N} i.wireLength$$

Estimation of performances

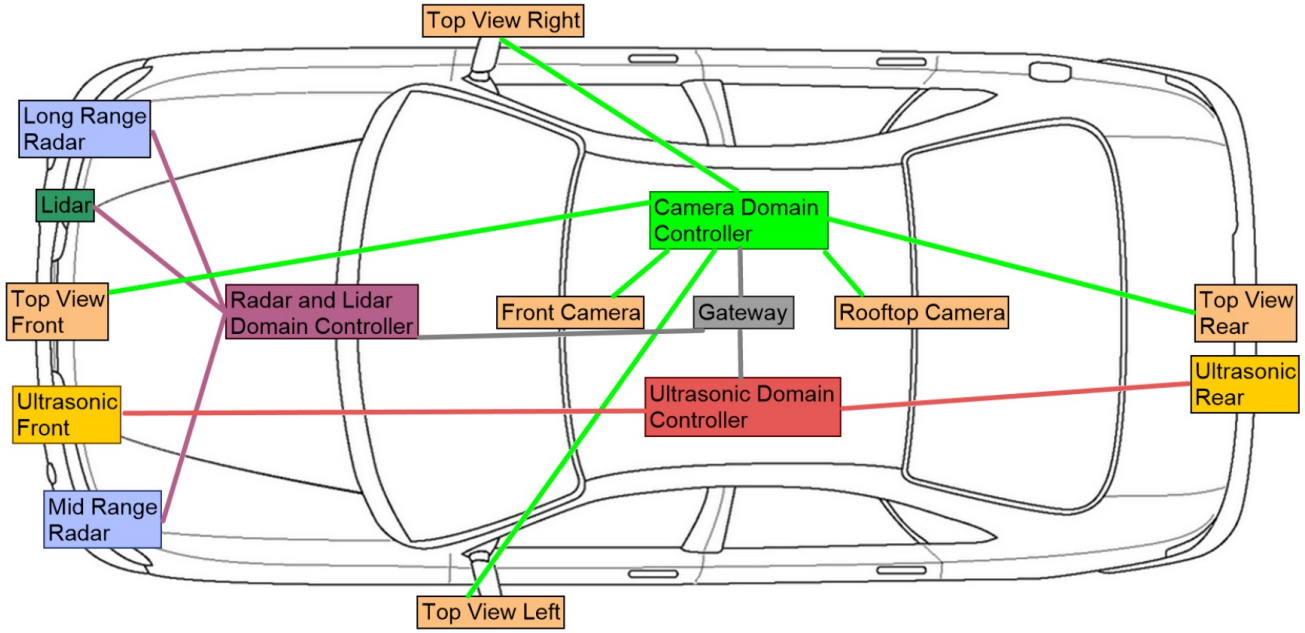
- total weight of all wires:

$$totalWeigth = \sum_{i=1}^{N} i.WireType.specificWeigth * i.wireLength$$

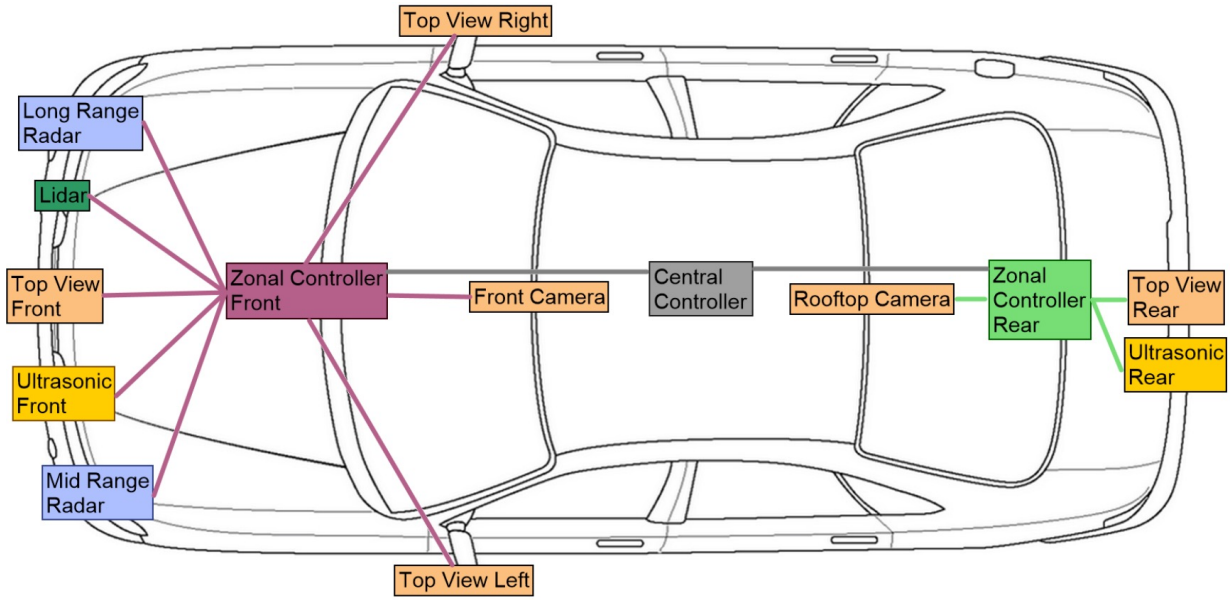
- Estimation of the total Cots of a wire:

$$totalCosts = \sum_{i=1}^{N} (i.WireType.costsPerMeter * i.wireLength + i.Start.plugCosts + i.End.plugCosts)$$

Case Study: Analysis of Boardnet Architectures



Domain Architecture



Zonal Architecture

Case Study: Definition of the Architecture

- Define cables as connections between two **CarComponents** with a **WireType**
- Define zonal and domain Architecture with all the cables
- Apply the calculations for the estimations of performances
  - For the sum, the *sumOverParts* function of SysMD is used
- Define the Architecture as a summary of all architectures
  - To summarize all values, the SysMD *bySubclasses* function can be used

Case Study: Modelling of variants

Language: SysMD Package: Car

```
1  DomainArchitecture hasA
2      Value TotalLength: Length [m] = sumOverParts(wireLength),
3      Value TotalWeight: Mass [kg] = sumOverParts(Wiretyp::specificWeight * wireLength),
4      Value TotalCosts: Currency [€] = sumOverParts(Wiretyp::CostsPerMeter * wireLength)
5                                     + sumOverParts(Start::plugCosts + End::plugCosts),
6      Part wireCameraControllerGateway: WireCameraControllerGateway,
7      Part wireUltrasonicControllerGateway: WireUltrasonicControllerGateway,
8      Part wireRadarAndLidarControllerGateway: WireRadarAndLidarControllerGateway,
9      Part wireMidRangeRadarRadarAndLidarController: [0..1] WireMidRangeRadarRadarAndLidarController,
```

- Use [0..1] as the multiplicity of optional components

Conclusion and Outlook

- Advantages of our approach:
  - Uncertain values by using ranges
  - Modeling variants
  - Missing values or open design decisions are possible
  - Analyzing complex architectures
  - Get results in a sufficient time (1 sec for our model)
  - Share results with others across the value chain
- Look at other aspects like safety and reliability
- Support of SysML v2 textual with SysMD extension

Questions