Carnegie Mellon University

Introduction to Software Architecture

17-313 Fall 2022

S3D
Software and Societal Systems Department

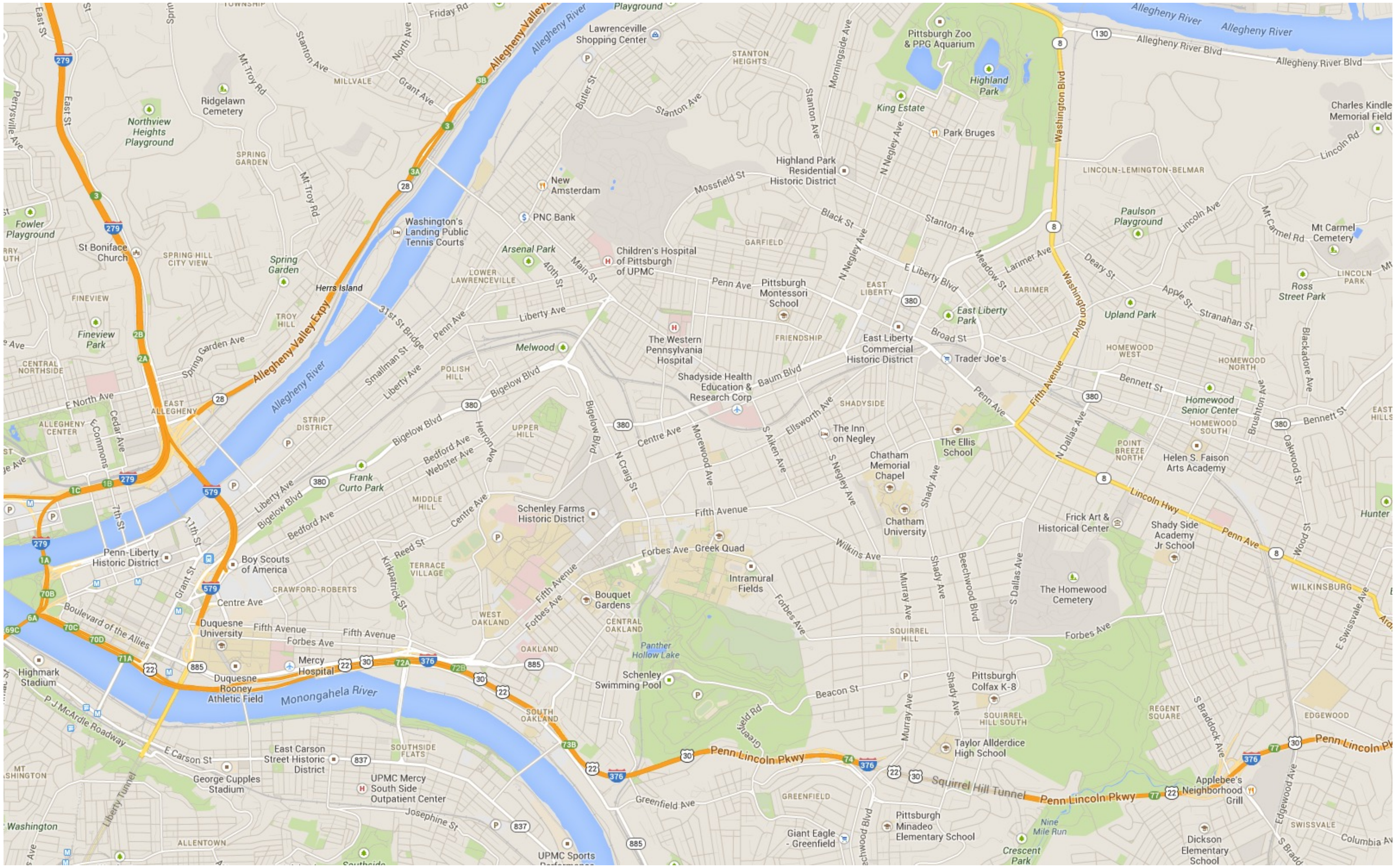
Administrivia

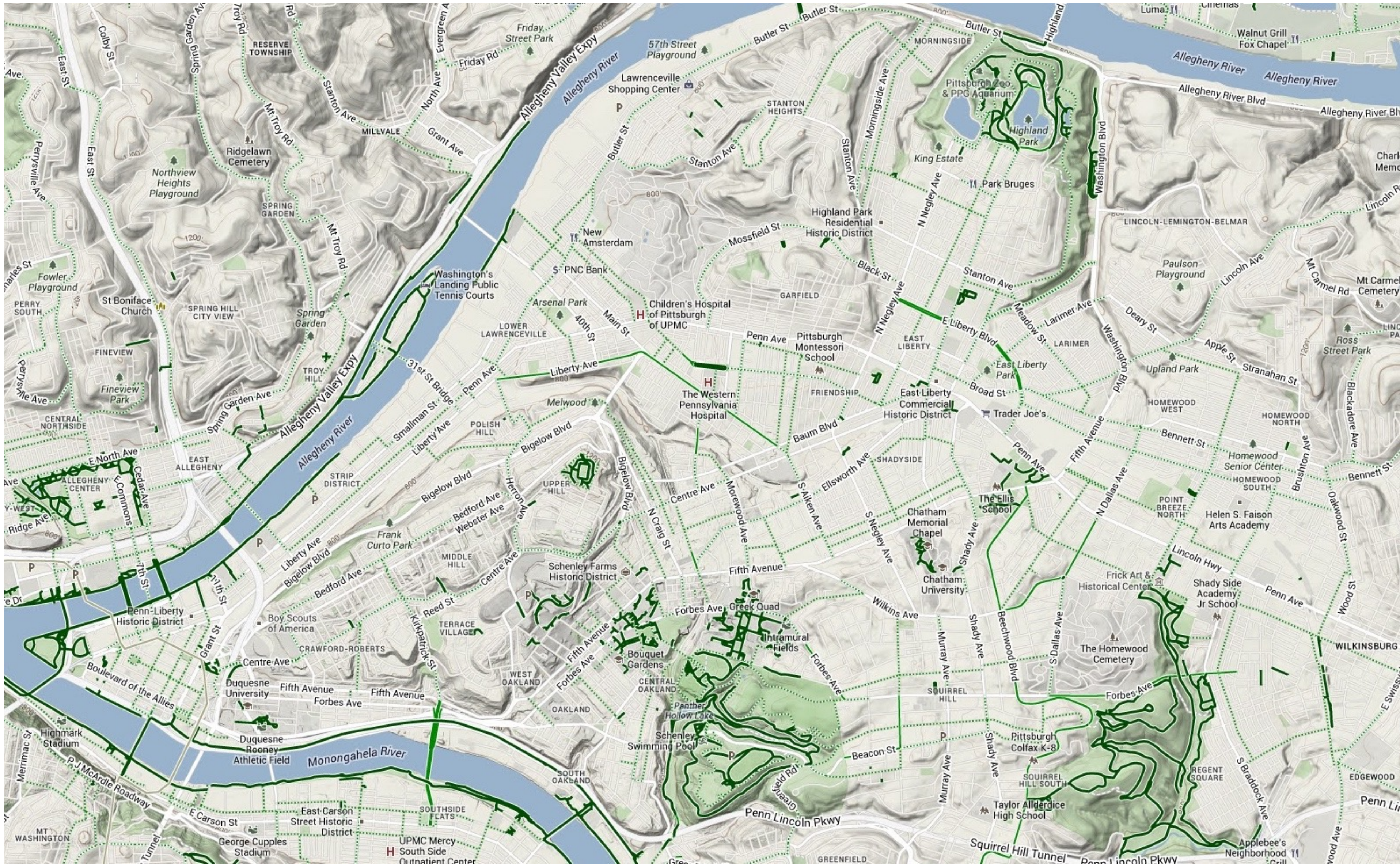
- Project 2B due Tonight @11:59pm
- Midterm Tue Feb 28
    - We will release practice midterms, and have a recitation for midterm prep

Learning Goals

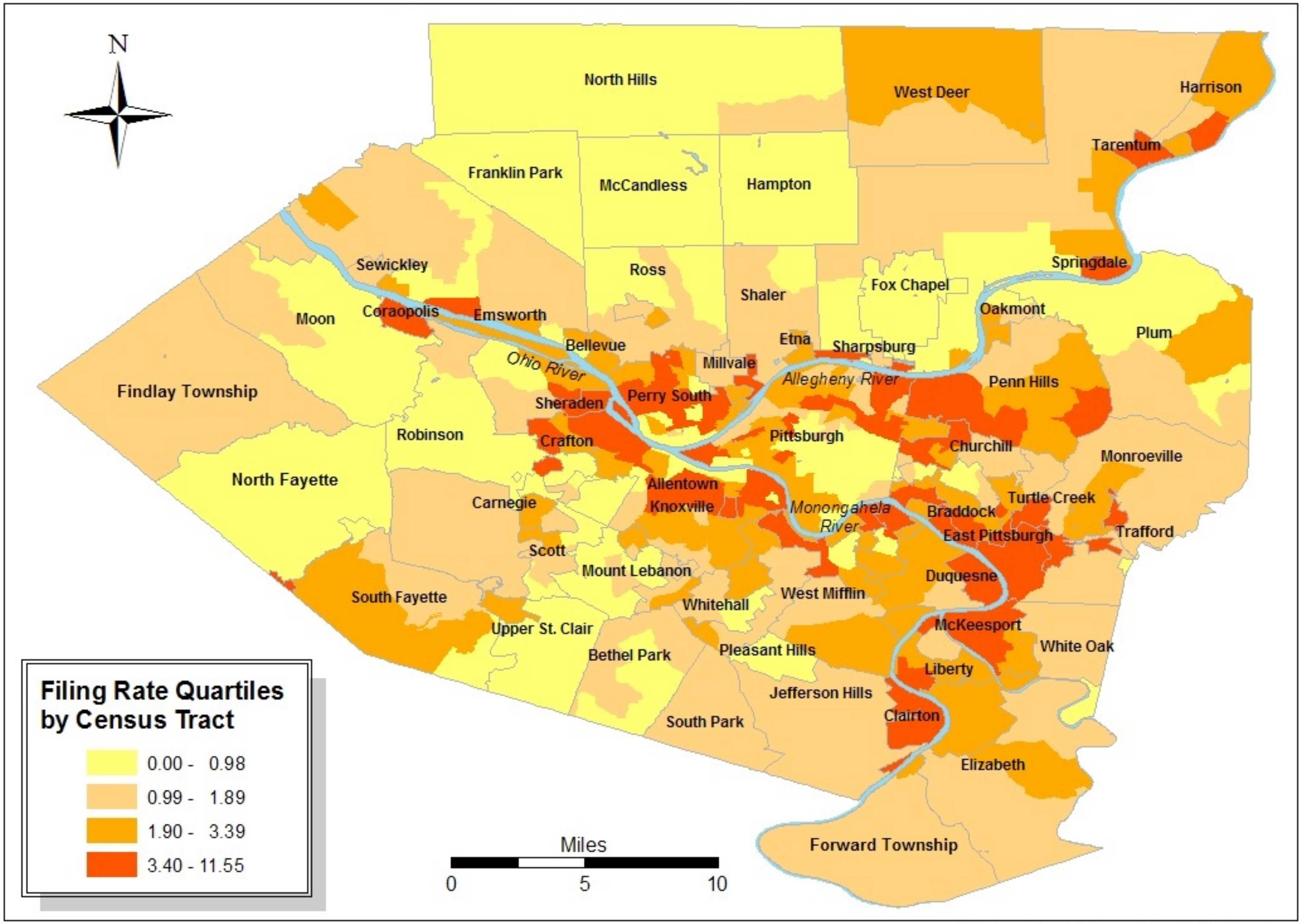
- Understand the abstraction level of architectural reasoning
- Appreciate how software systems can be viewed at different abstraction levels
- Distinguish software architecture from (object-oriented) software design
- Use notation and views to describe the architecture suitable to the purpose
- Document architectures clearly, without ambiguity

Views and Abstraction



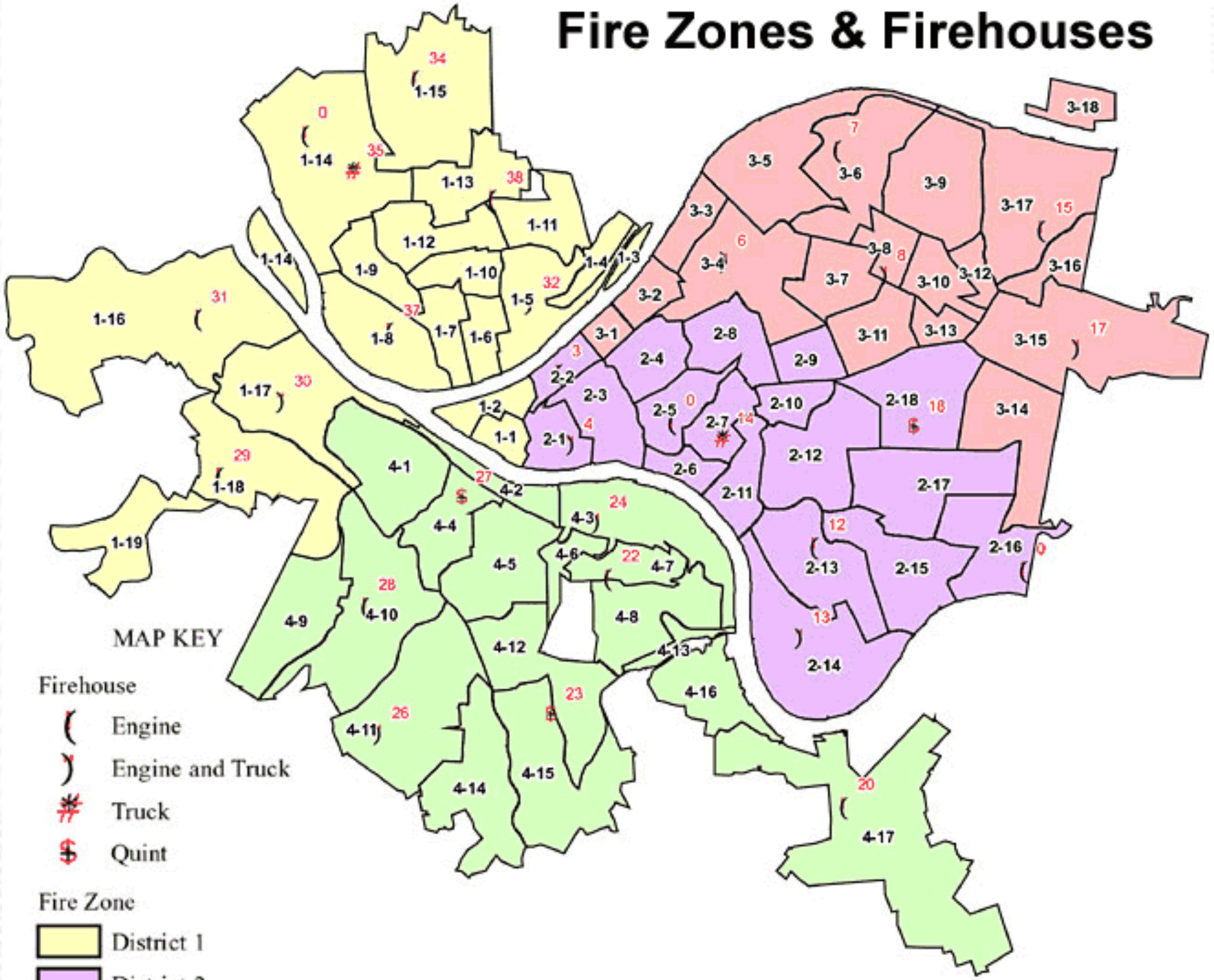


2007 Foreclosure Filing Rate per 100 Mortgaged Units in Allegheny County, PA



Data from the Allegheny County Prothonotary

Fire Zones & Firehouses



MAP KEY

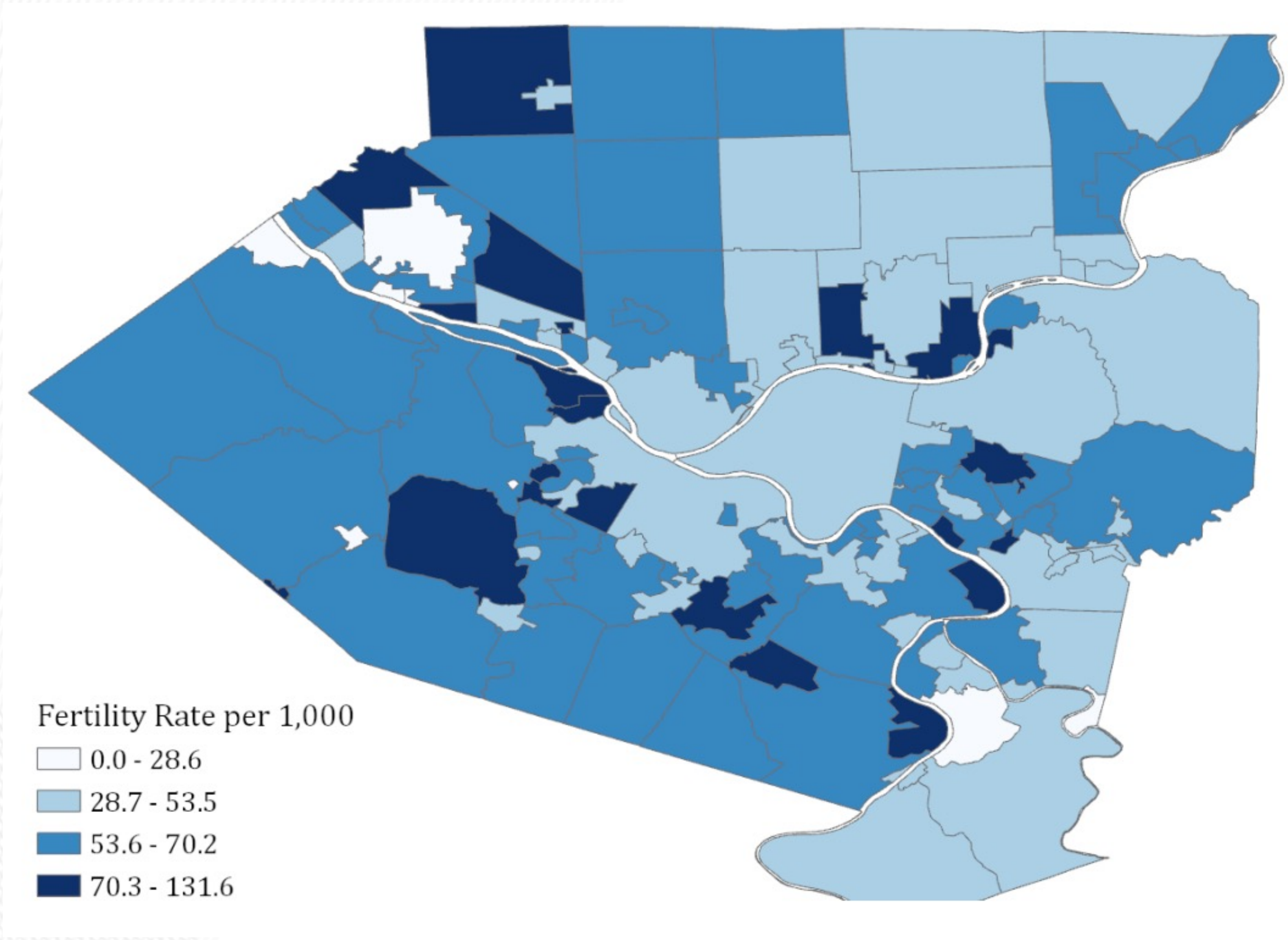
Firehouse

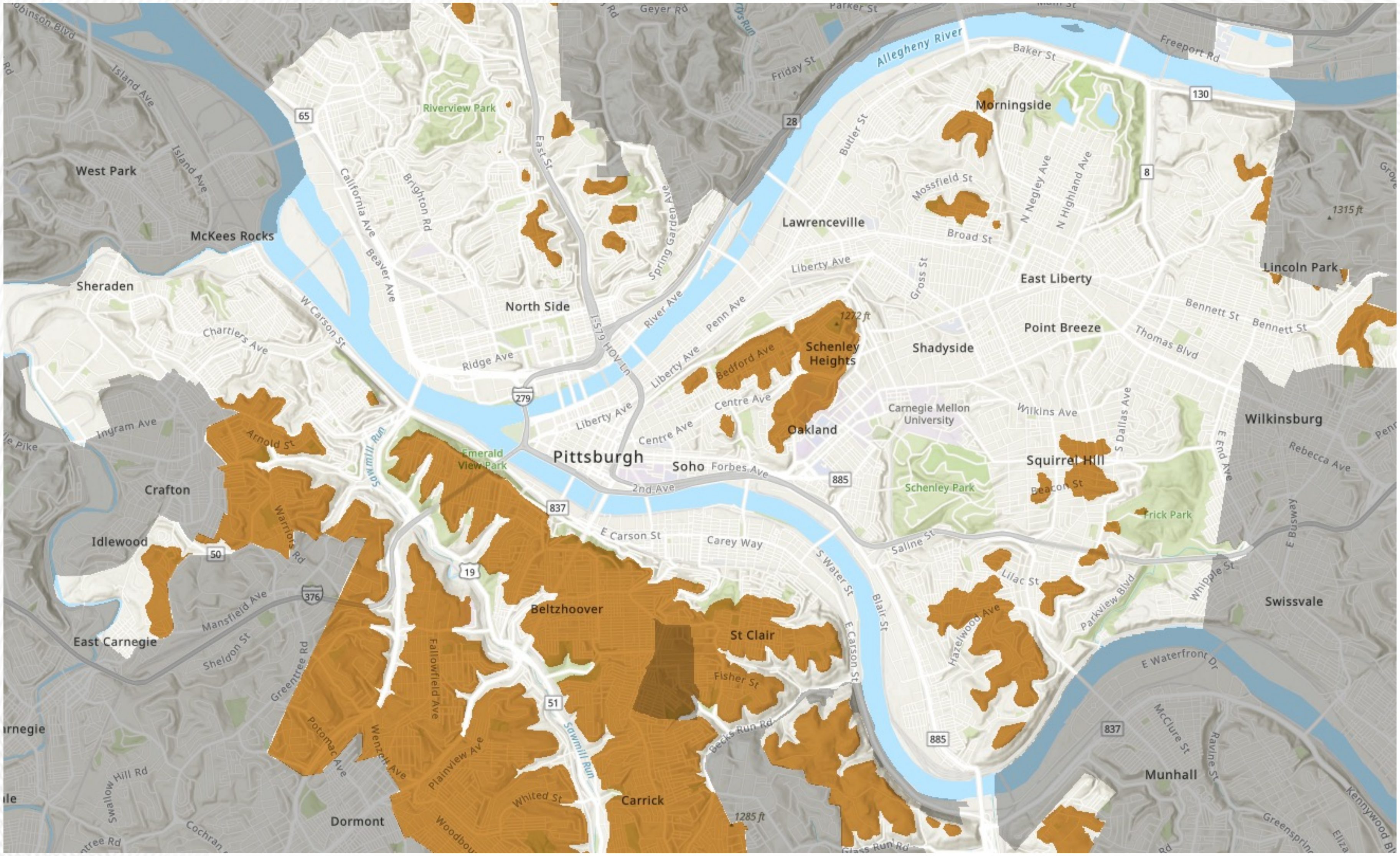
(	Engine
)	Engine and Truck
#	Truck
$	Quint

Fire Zone

🟨	District 1
🟪	District 2
🟥	District 3
🟩	District 4

General fertility rate per 1,000 population by Allegheny County municipality, 2017
Source: https://www.alleghenycounty.us/





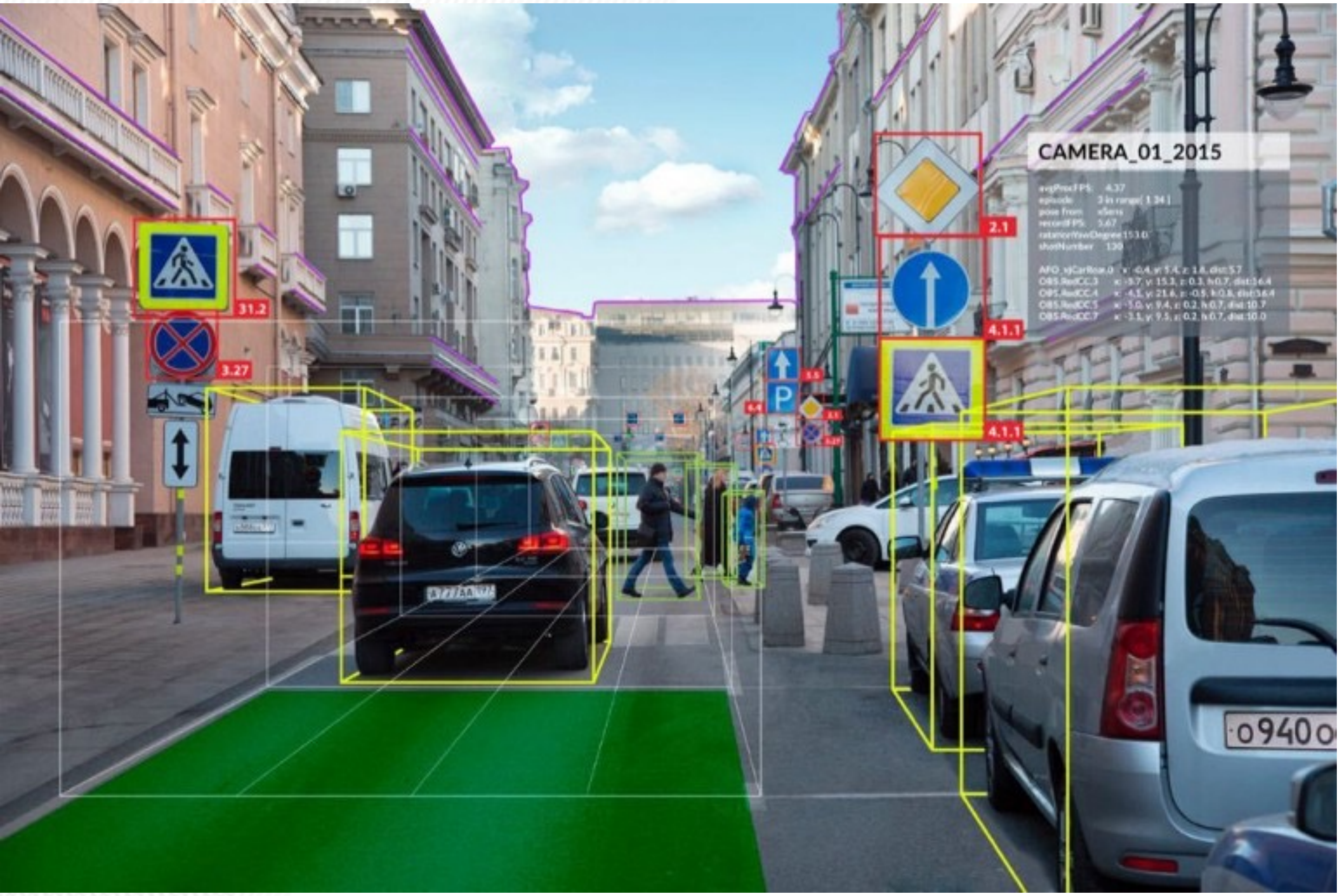
Source: Pittsburgh Zoning Map (https://gis.pittsburghpa.gov/pghzoning/)

Abstracted views focus on conveying specific information

- They have a well-defined purpose
- Show only necessary information
- Abstract away unnecessary details
- Use legends/annotations to remove ambiguity
- Multiple views of the same object tell a larger story

Software Architecture

Case Study: Autonomous Vehicle Software



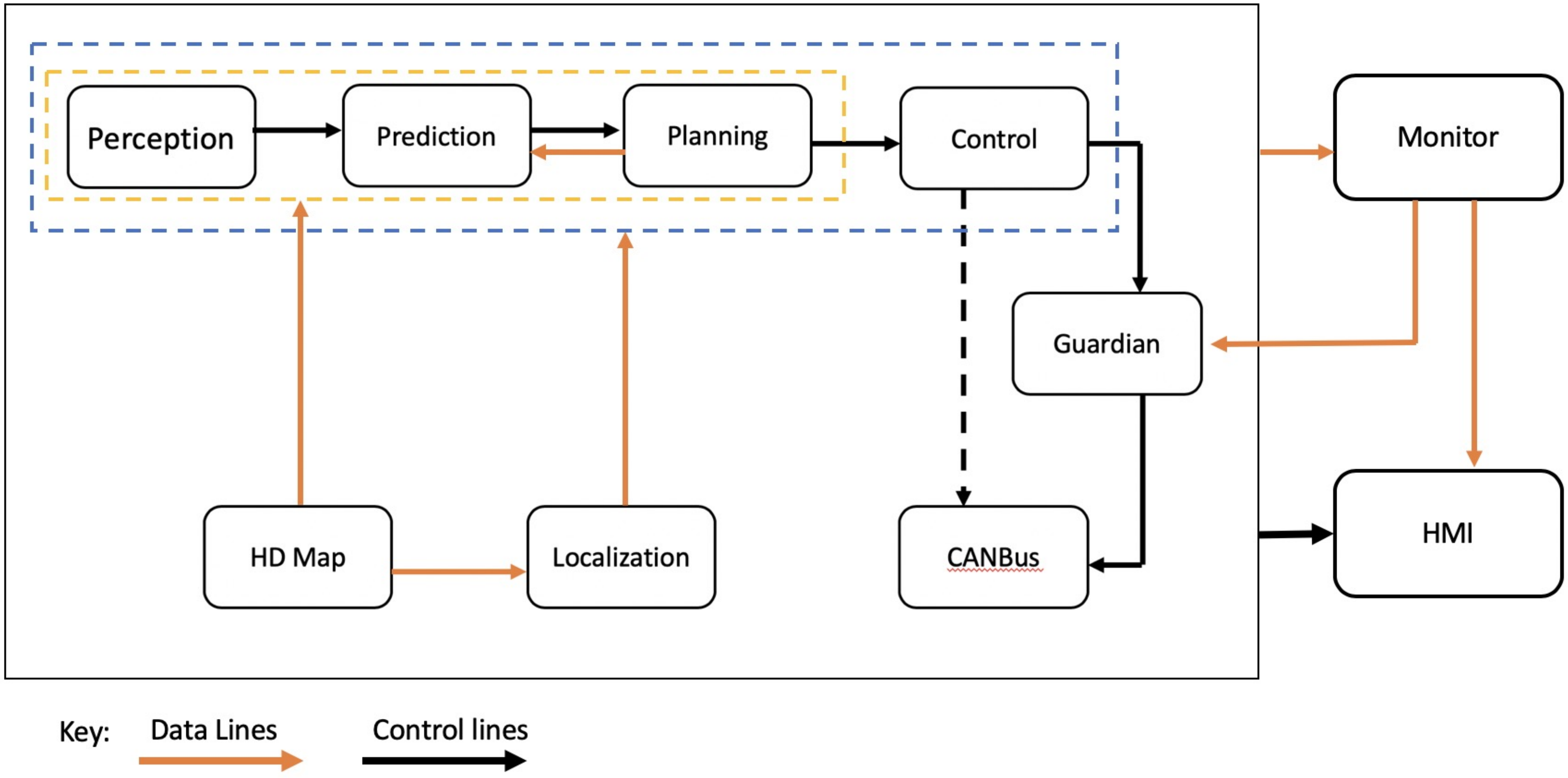
Case Study: Apollo

Check out the “side pass” feature from the video: https://www.youtube.com/watch?v=BXNDUtNZdM4

Source: https://github.com/ApolloAuto/apollo

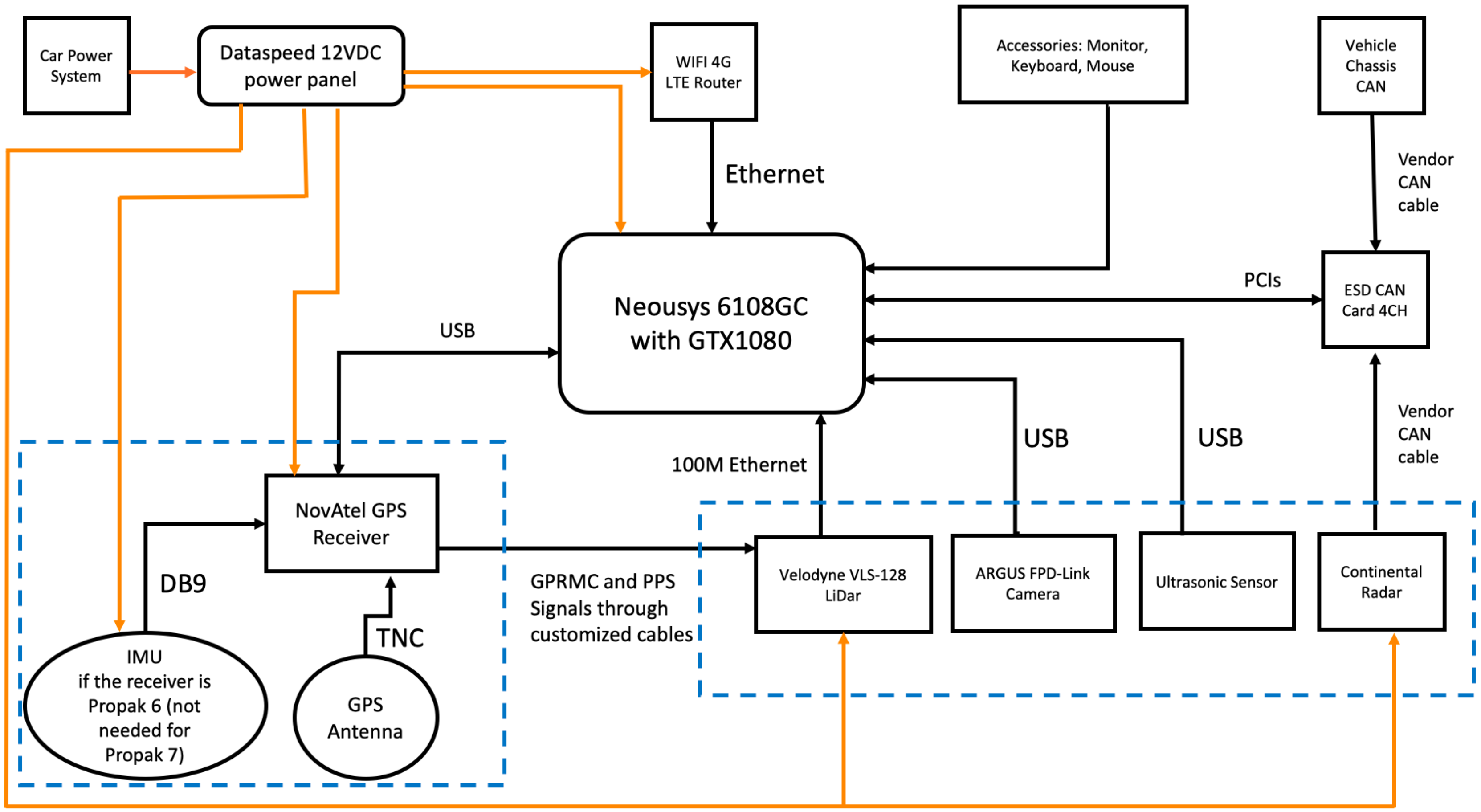
Doxygen: https://hidetoshi-furukawa.github.io/apollo-doxygen/index.html

Apollo Software Architecture



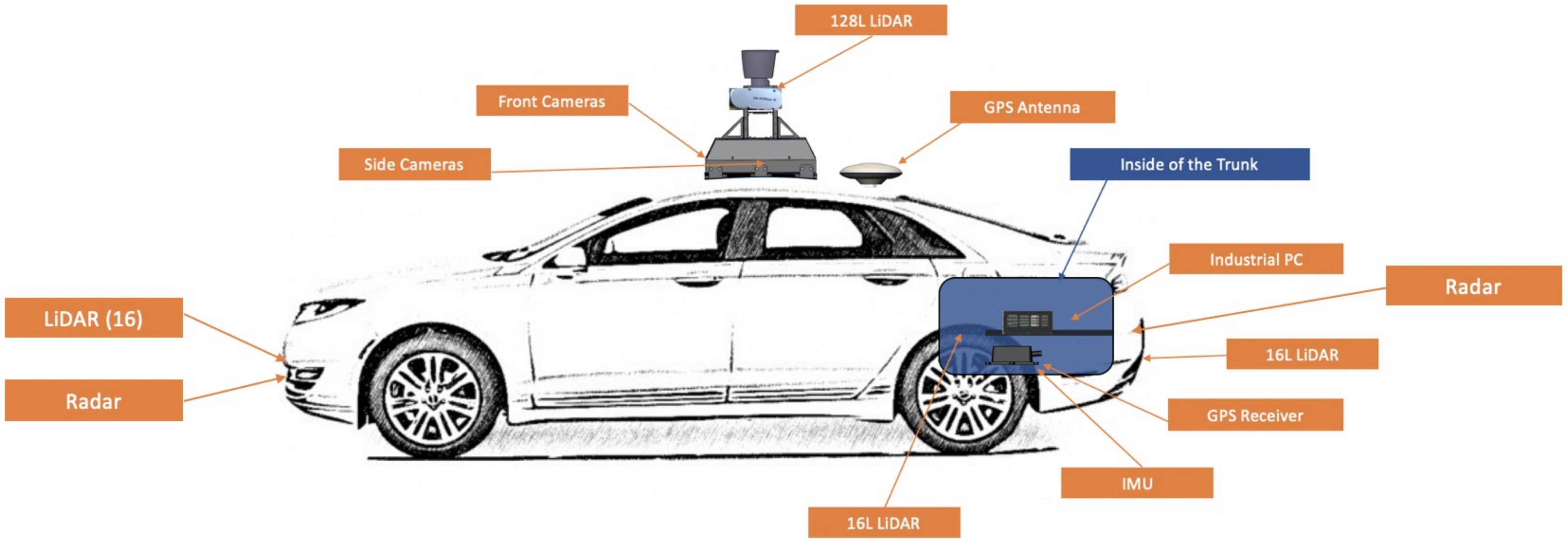
Source: https://github.com/ApolloAuto/apollo/blob/v6.0.0/docs/specs/Apollo_5.5_Software_Architecture.md

Apollo Hardware Architecture



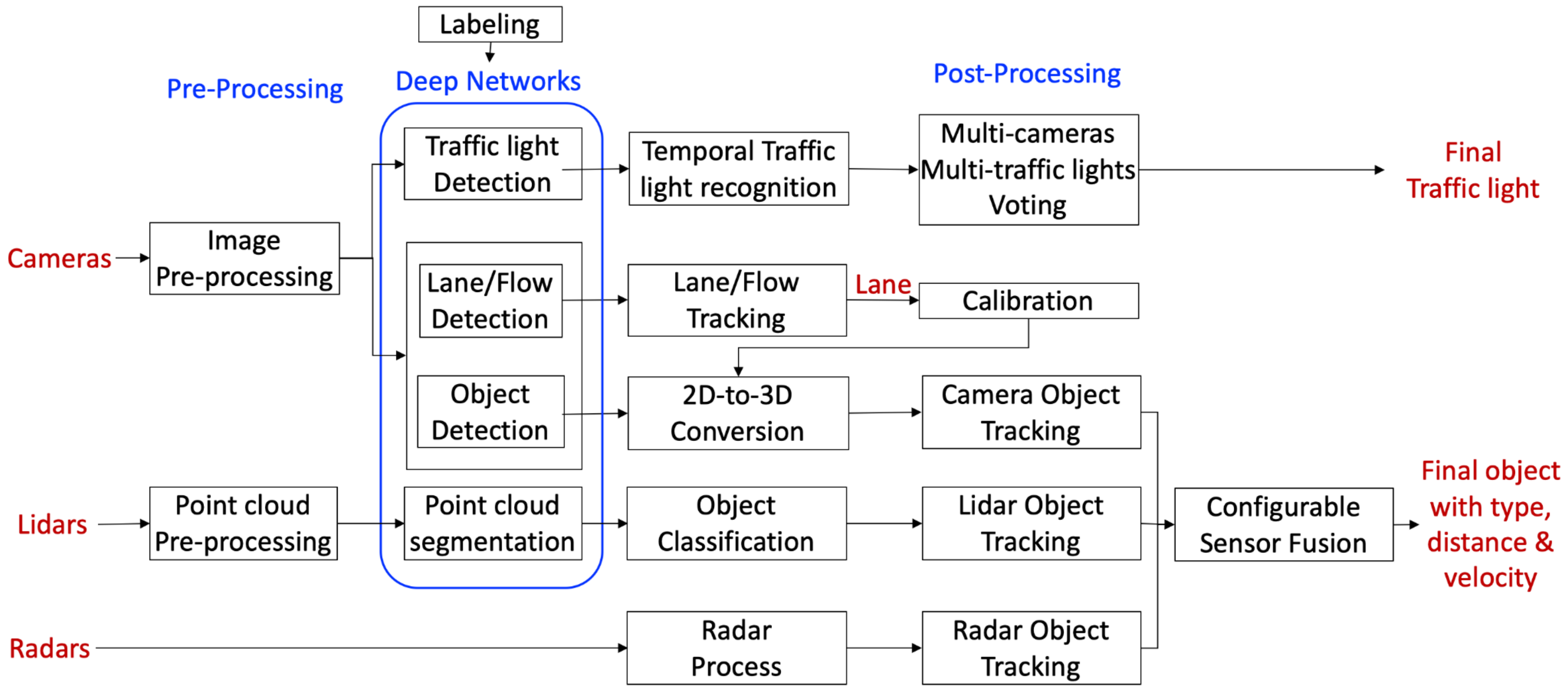
Source: https://github.com/ApolloAuto/apollo/blob/v6.0.0/README.md

Apollo Hardware/Vehicle Overview

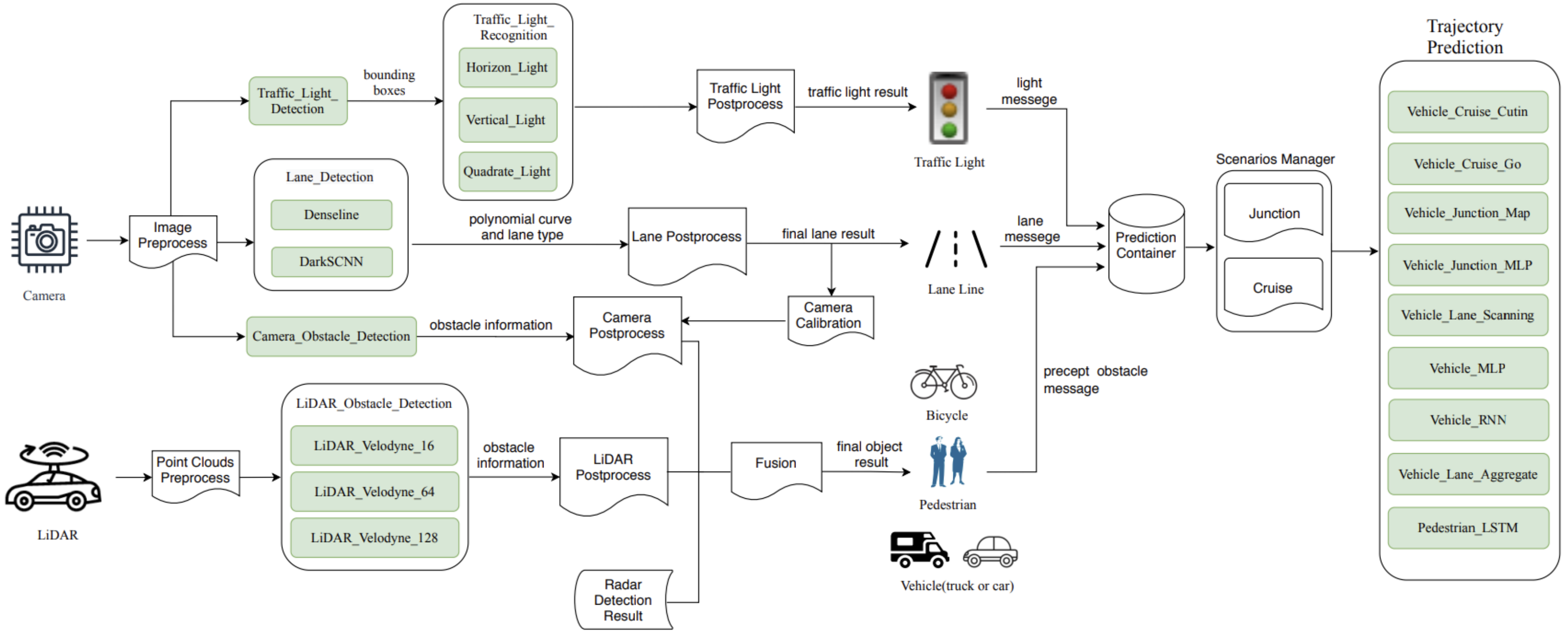


Source: https://github.com/ApolloAuto/apollo/blob/v6.0.0/README.md

Apollo Perception Module

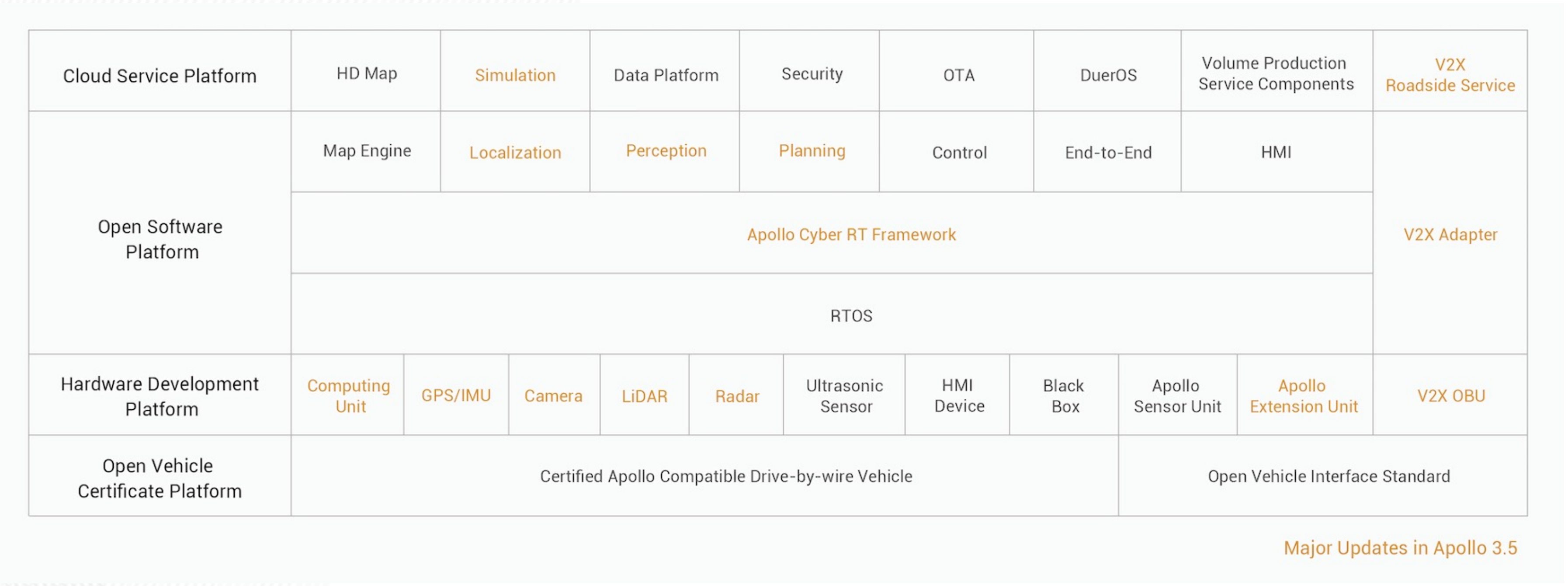


Apollo ML Models



Source: Zi Peng, Jinqiu Yang, Tse-Hsun (Peter) Chen, and Lei Ma. 2020. A First Look at the Integration of Machine Learning Models in Complex Autonomous Driving Systems: A Case Study on Apollo. In Proceedings of the 28th ACM Joint European Software Engineering Conference and Symposium on the Foundations of Software Engineering (ESEC/FSE '20), https://doi.org/10.1145/ 3368089.3417063

Apollo Software Stack

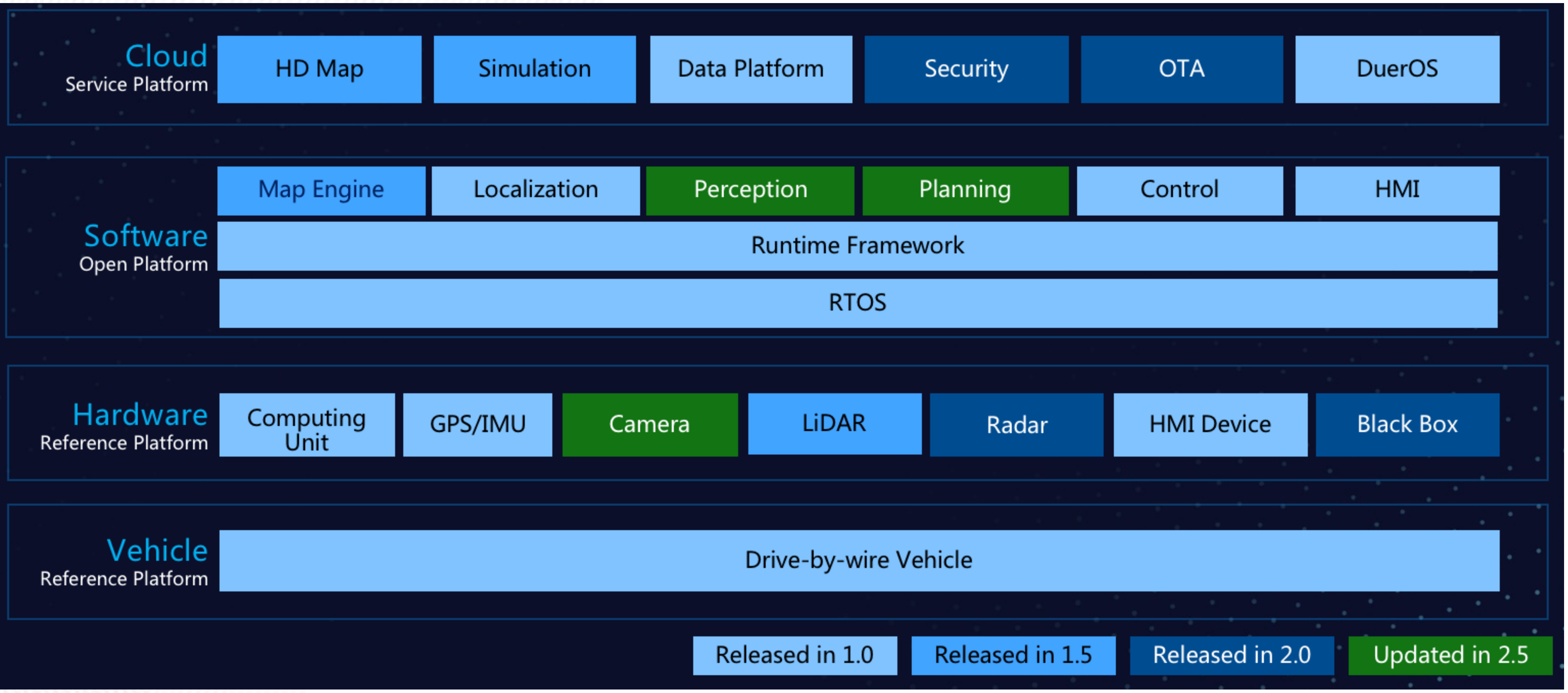


Cloud Service Platform	HD Map	Simulation	Data Platform	Security	OTA	DuerOS	Volume Production Service Components	V2X Roadside Service			
Open Software Platform	Map Engine	Localization	Perception	Planning	Control	End-to-End	HMI	V2X Adapter			
	Apollo Cyber RT Framework										
	RTOS										
Hardware Development Platform	Computing Unit	GPS/IMU	Camera	LiDAR	Radar	Ultrasonic Sensor	HMI Device	Black Box	Apollo Sensor Unit	Apollo Extension Unit	V2X OBU
Open Vehicle Certificate Platform	Certified Apollo Compatible Drive-by-wire Vehicle								Open Vehicle Interface Standard		

Major Updates in Apollo 3.5

Source: https://github.com/ApolloAuto/

Feature Evolution (Software Stack View)



Source: https://github.com/ApolloAuto/apollo

Software Architecture

The software architecture of a program or computing system is the structure or structures of the system, which comprise software elements, the externally visible properties of those elements and the relationships among them.

[Bass et al. 2003]

Note: this definition is ambivalent to whether the architecture is known, or whether it's any good!

Software Design vs. Architecture

Levels of Abstraction

- Requirements
  - high-level “what” needs to be done
- Architecture (High-level design)
  - high-level “how”, mid-level “what”
- OO-Design (Low-level design, e.g. design patterns)
  - mid-level “how”, low-level “what”
- Code
  - low-level “how”

Design vs. Architecture

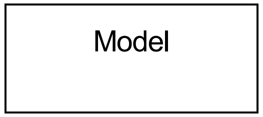
Design Questions

- How do I add a menu item in Eclipse?
- How can I make it easy to add menu items in Eclipse?
- What lock protects this data?
- How does Google rank pages?
- What encoder should I use for secure communication?
- What is the interface between objects?

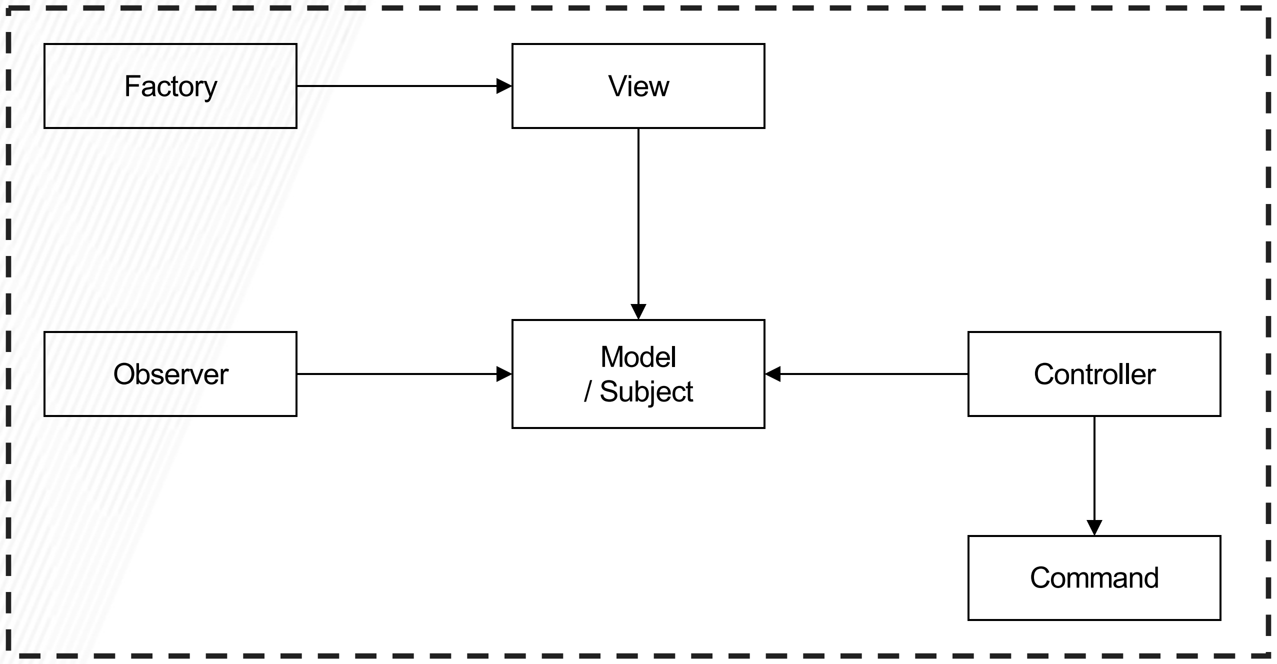
Architectural Questions

- How do I extend Eclipse with a plugin?
- What threads exist and how do they coordinate?
- How does Google scale to billions of hits per day?
- Where should I put my firewalls?
- What is the interface between subsystems?

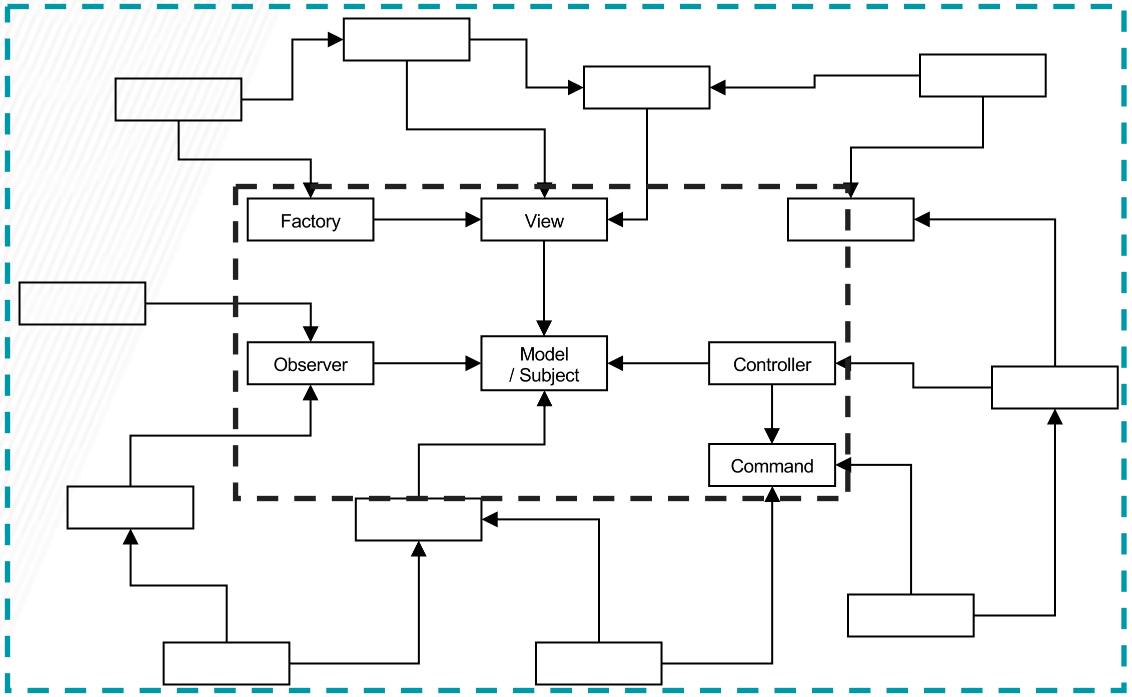
Objects



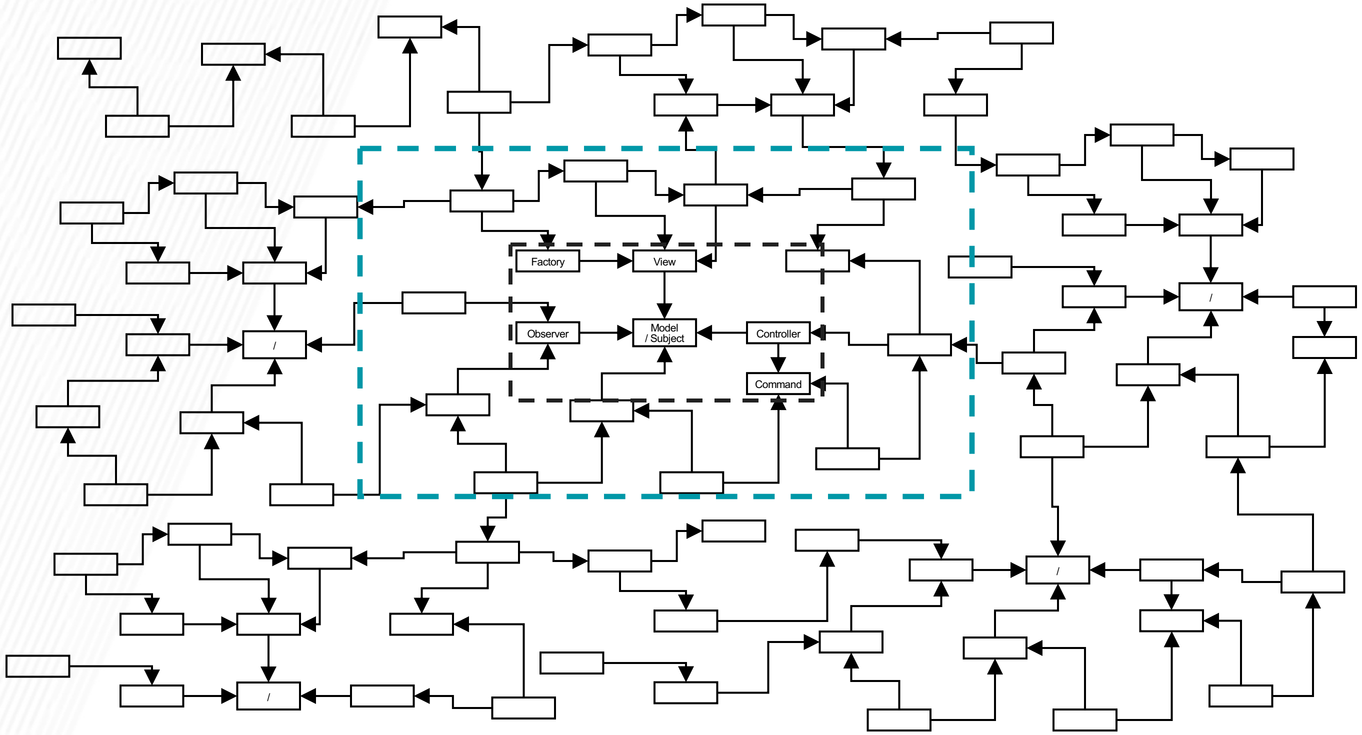
Design Patterns



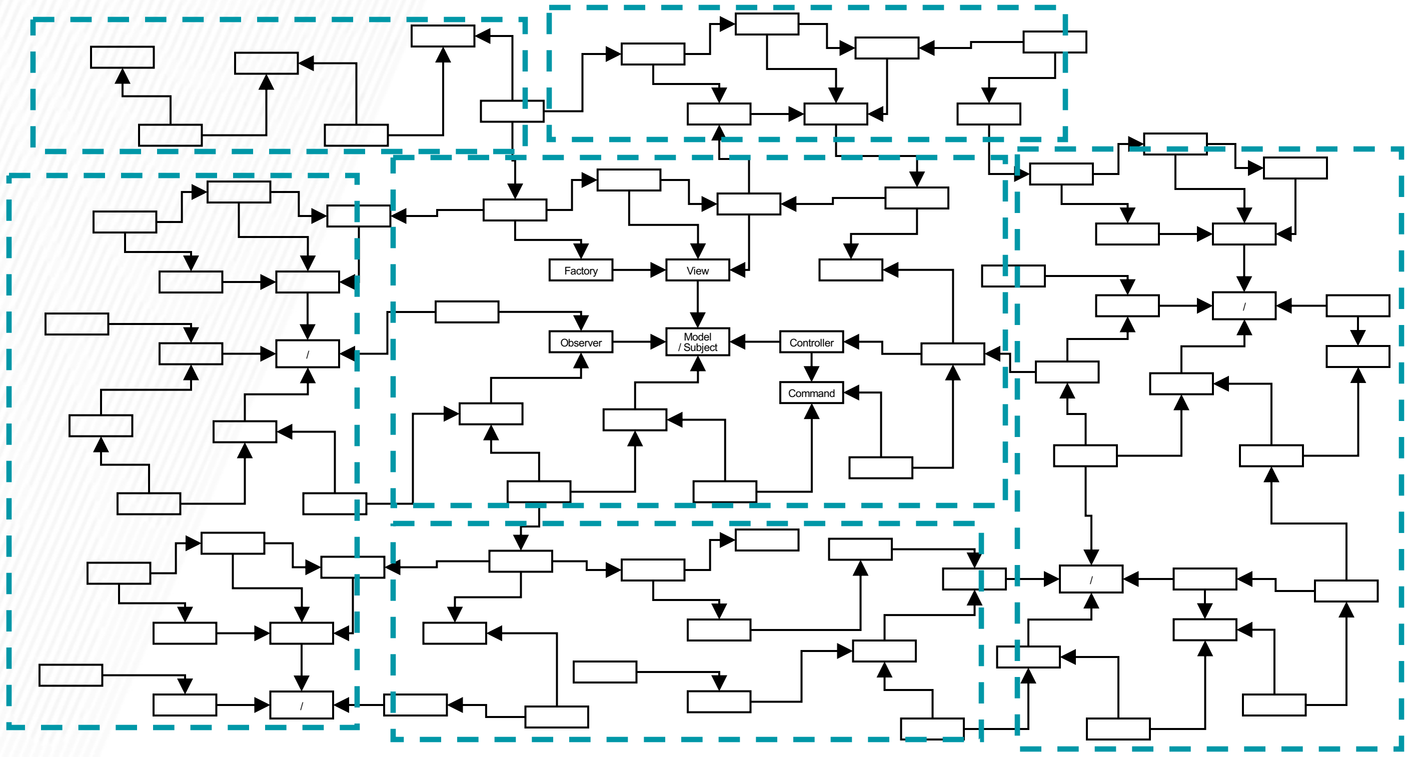
Design Patterns



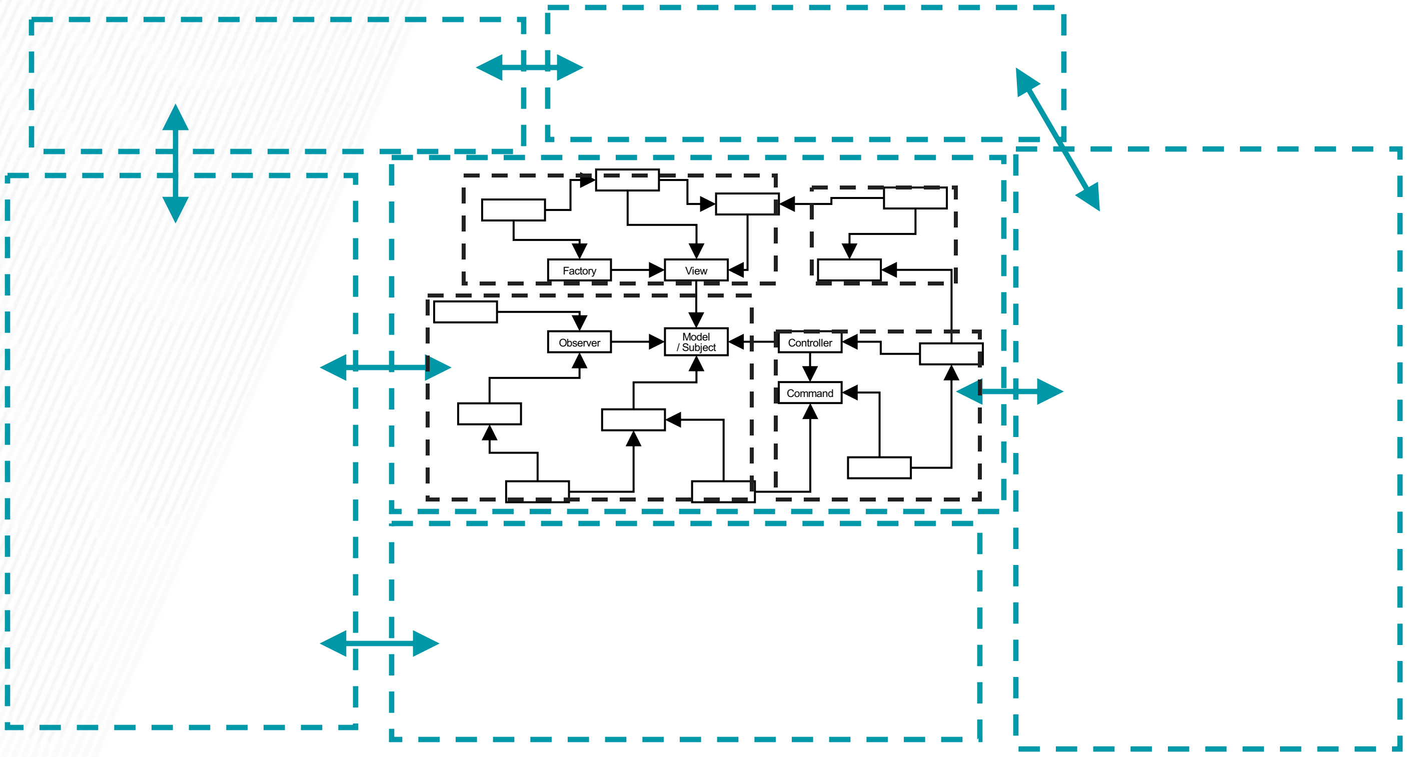
Design Patterns



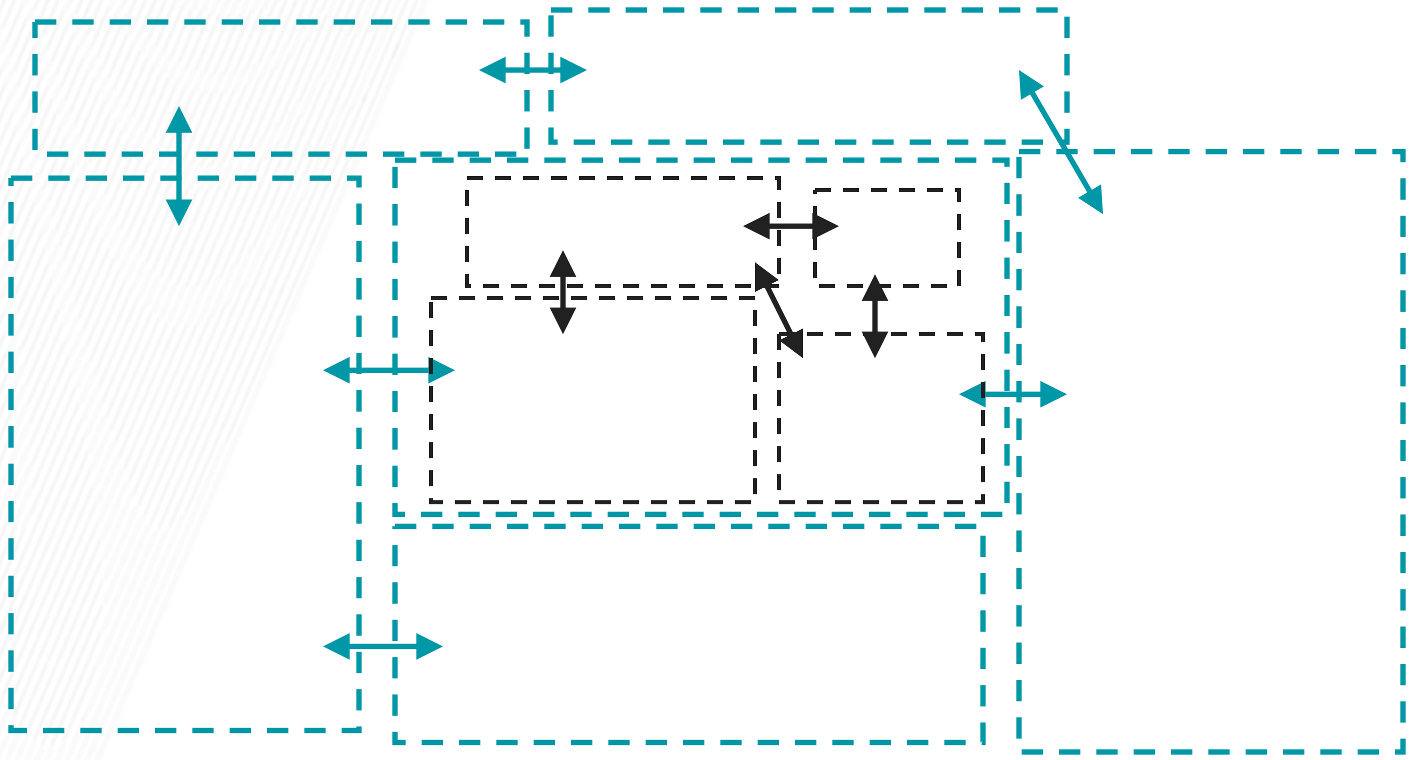
Architecture



Architecture



Architecture



Why Document Architecture?

- Blueprint for the system
  - Artifact for early analysis
  - Primary carrier of quality attributes
  - Key to post-deployment maintenance and enhancement
- Documentation speaks for the architect, today and 20 years from today
  - As long as the system is built, maintained, and evolved according to its documented architecture
- Support traceability.

Views and Purposes

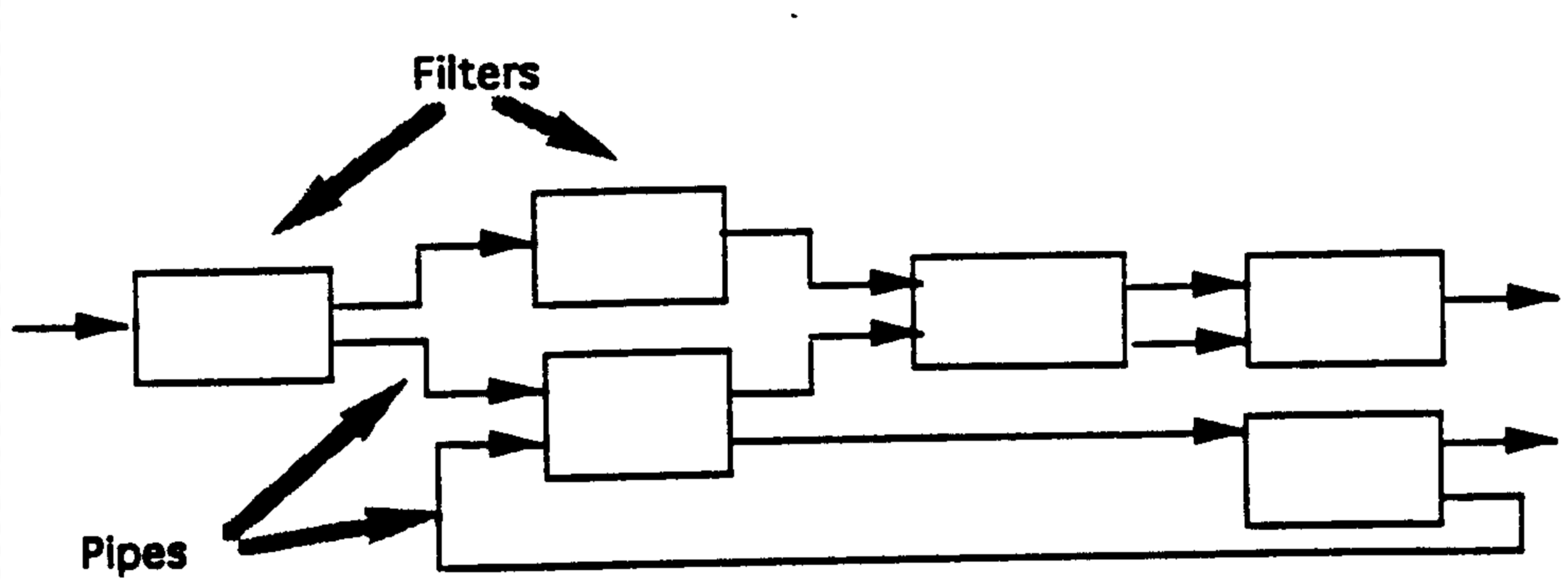
- Every view should align with a purpose
- Views should only represent information relevant to that purpose
  - Abstract away other details
  - Annotate view to guide understanding where needed
- Different views are suitable for different reasoning aspects (different quality goals), e.g.,
  - Performance
  - Extensibility
  - Security
  - Scalability
  - ...

Common Views in Documenting Software Architecture

- Static View
  - Modules (subsystems, structures)
    and their relations (dependencies, ...)
- Dynamic View
  - Components (processes, runnable entities) and connectors (messages, data flow, ...)
- Physical View (Deployment)
  - Hardware structures and their connections

Common Software Architectures

1. Pipes and Filters



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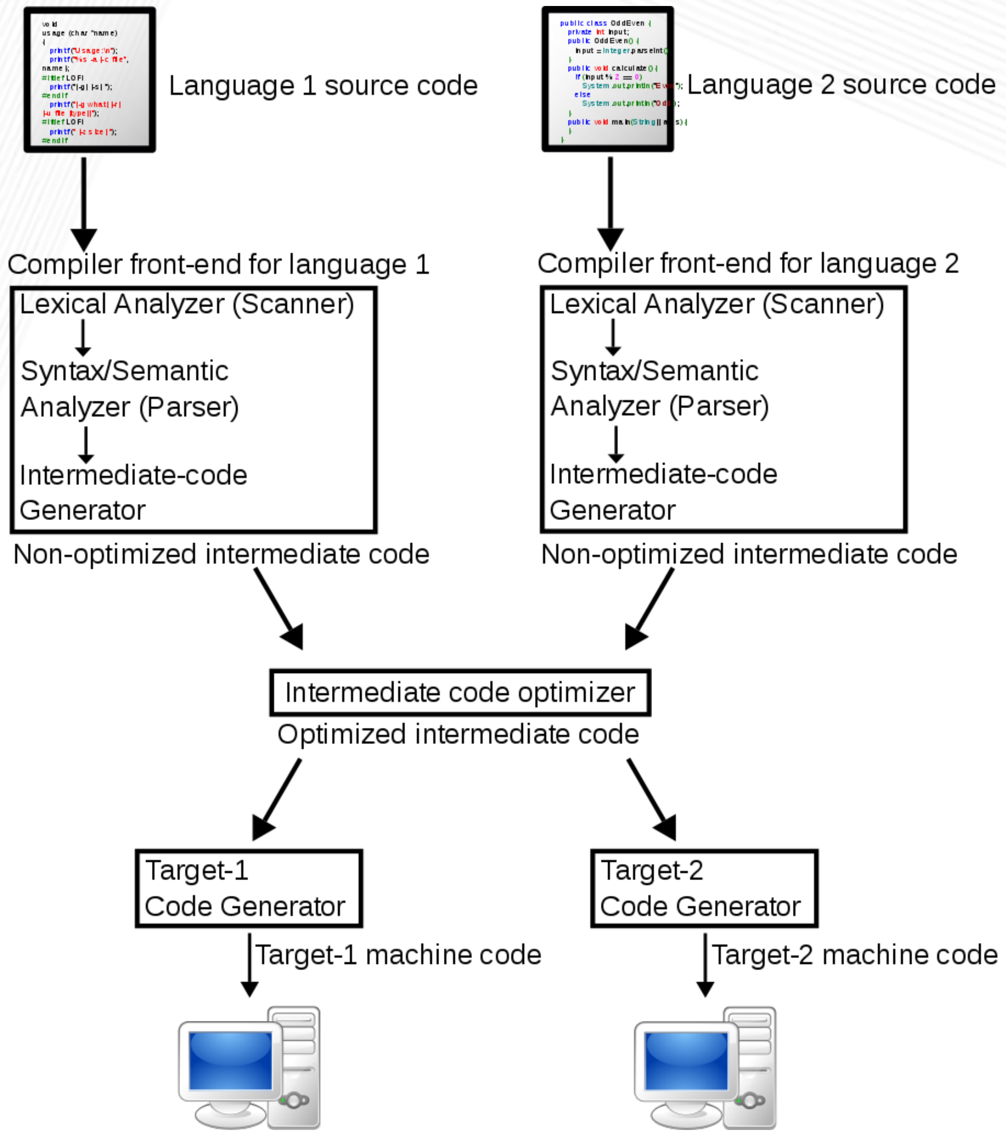
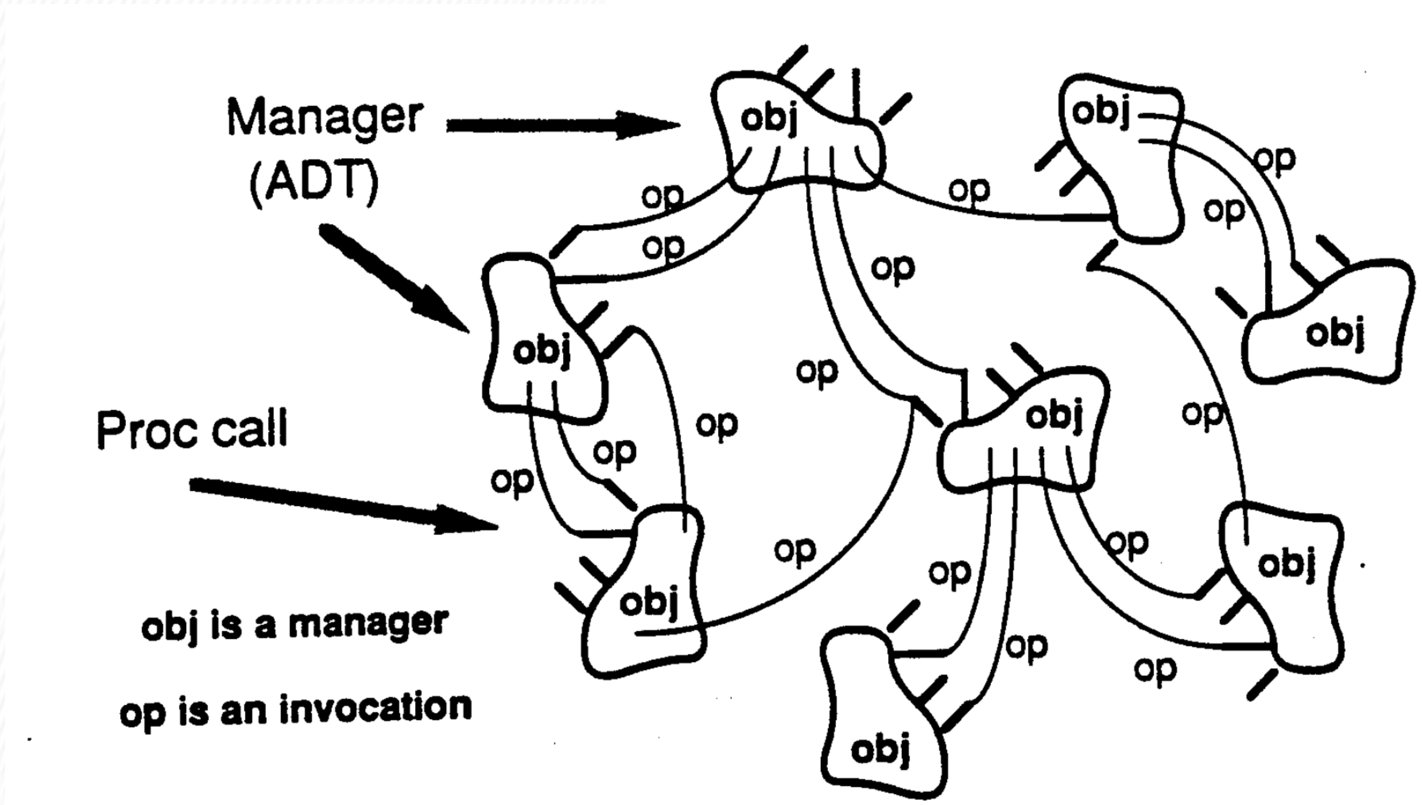
Example: Compilers



Language 1 source code
Language 2 source code
Compiler front-end for language 1
Lexical Analyzer (Scanner)
Syntax/Semantic Analyzer (Parser)
Intermediate-code Generator
Non-optimized intermediate code
Compiler front-end for language 2
Lexical Analyzer (Scanner)
Syntax/Semantic Analyzer (Parser)
Intermediate-code Generator
Non-optimized intermediate code
Intermediate code optimizer
Optimized intermediate code
Target-1 Code Generator
Target-1 machine code
Target-2 Code Generator
Target-2 machine code

2. Object-Oriented Organization



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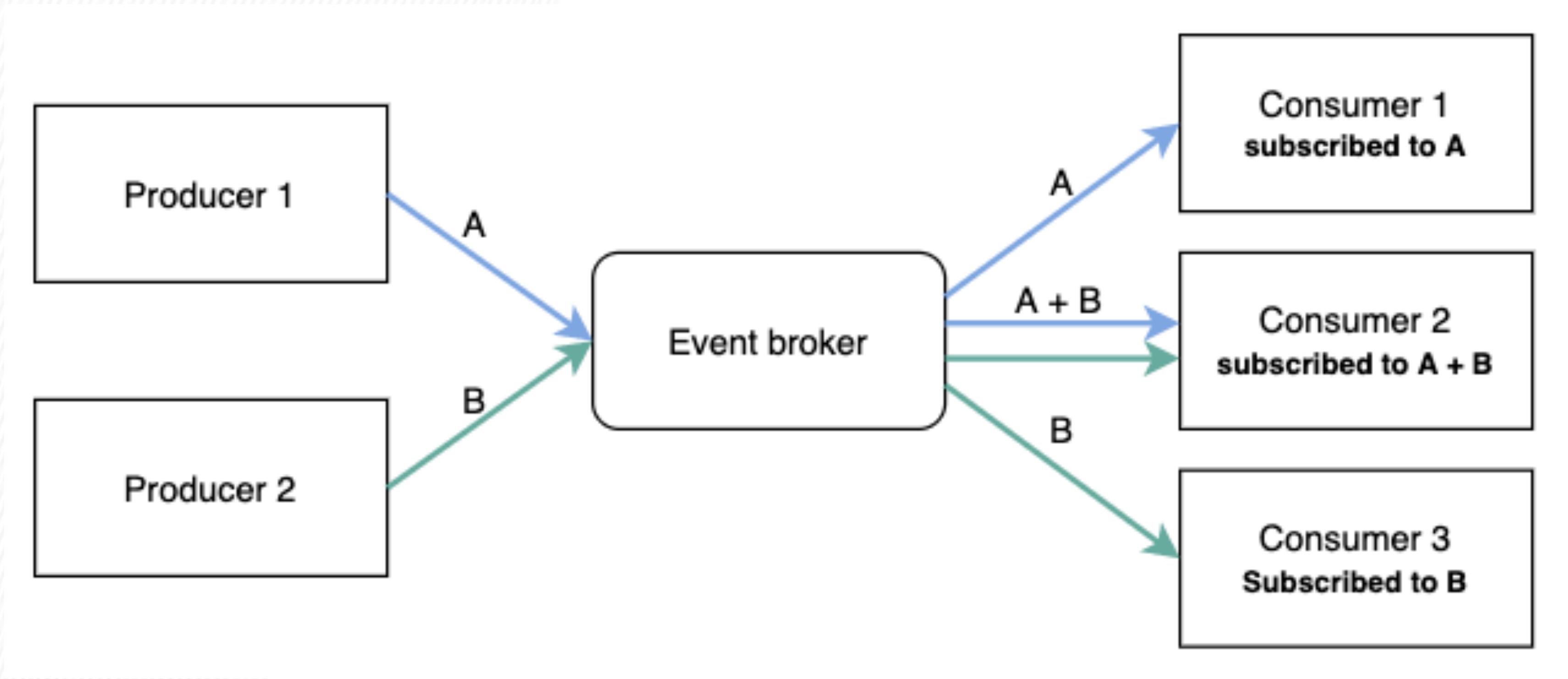
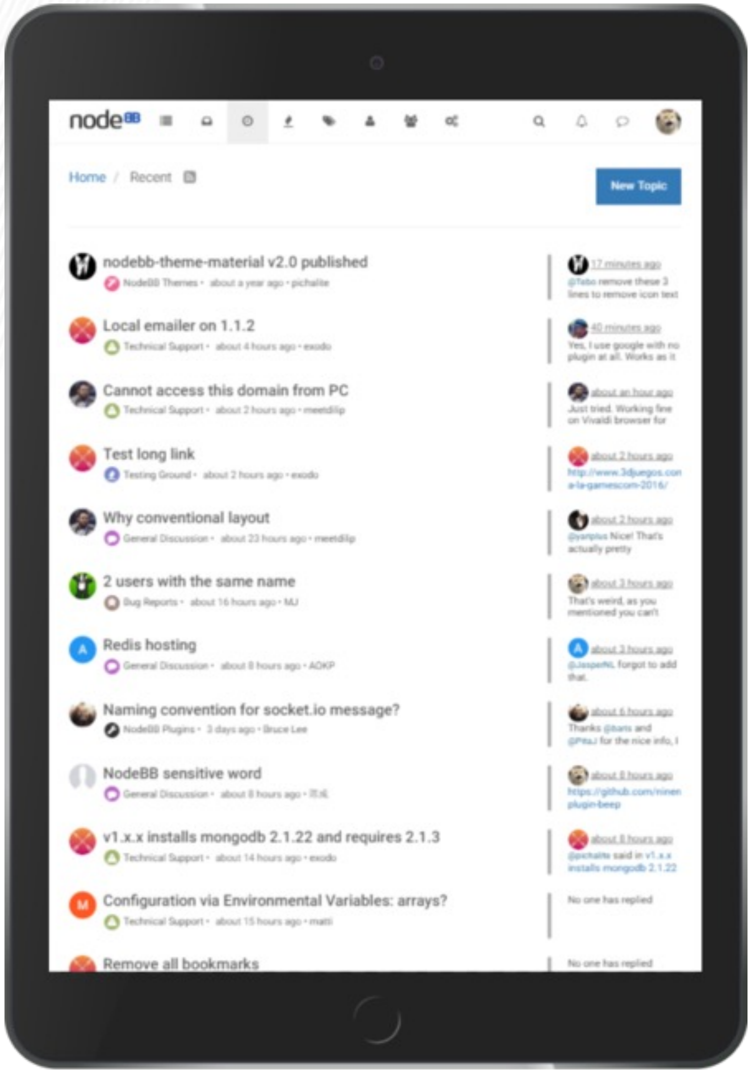
3. Event-Driven Architecture



Example: HTML DOM + JavaScript



nodebb-theme-material v2.0 published
NodeBB Themes • about a year ago • pichalite
17 minutes ago
@Tabo remove these 3 lines to remove icon text

Local emailer on 1.1.2
Technical Support • about 4 hours ago • exodo
40 minutes ago
Yes, I use google with no plugin at all. Works as it

Cannot access this domain from PC
Technical Support • about 2 hours ago • meetdilip
about an hour ago
Just tried. Working fine on Vivaldi browser for

Test long link
Testing Ground • about 2 hours ago • exodo
about 2 hours ago
http://www.3djuegos.con a-la-gamescom-2016/

Why conventional layout
General Discussion • about 23 hours ago • meetdilip
about 2 hours ago
@yariplus Nice! That's actually pretty

2 users with the same name
Bug Reports • about 16 hours ago • MJ
about 3 hours ago
That's weird, as you mentioned you can't

Redis hosting
General Discussion • about 8 hours ago • AOKP
about 3 hours ago
@JasperNL forgot to add that.

Naming convention for socket.io message?
NodeBB Plugins • 3 days ago • Bruce Lee
about 6 hours ago
Thanks @baris and @PitaJ for the nice info, I

NodeBB sensitive word
General Discussion • about 8 hours ago • [illegible]
about 8 hours ago
https://github.com/ninen plugin-beep

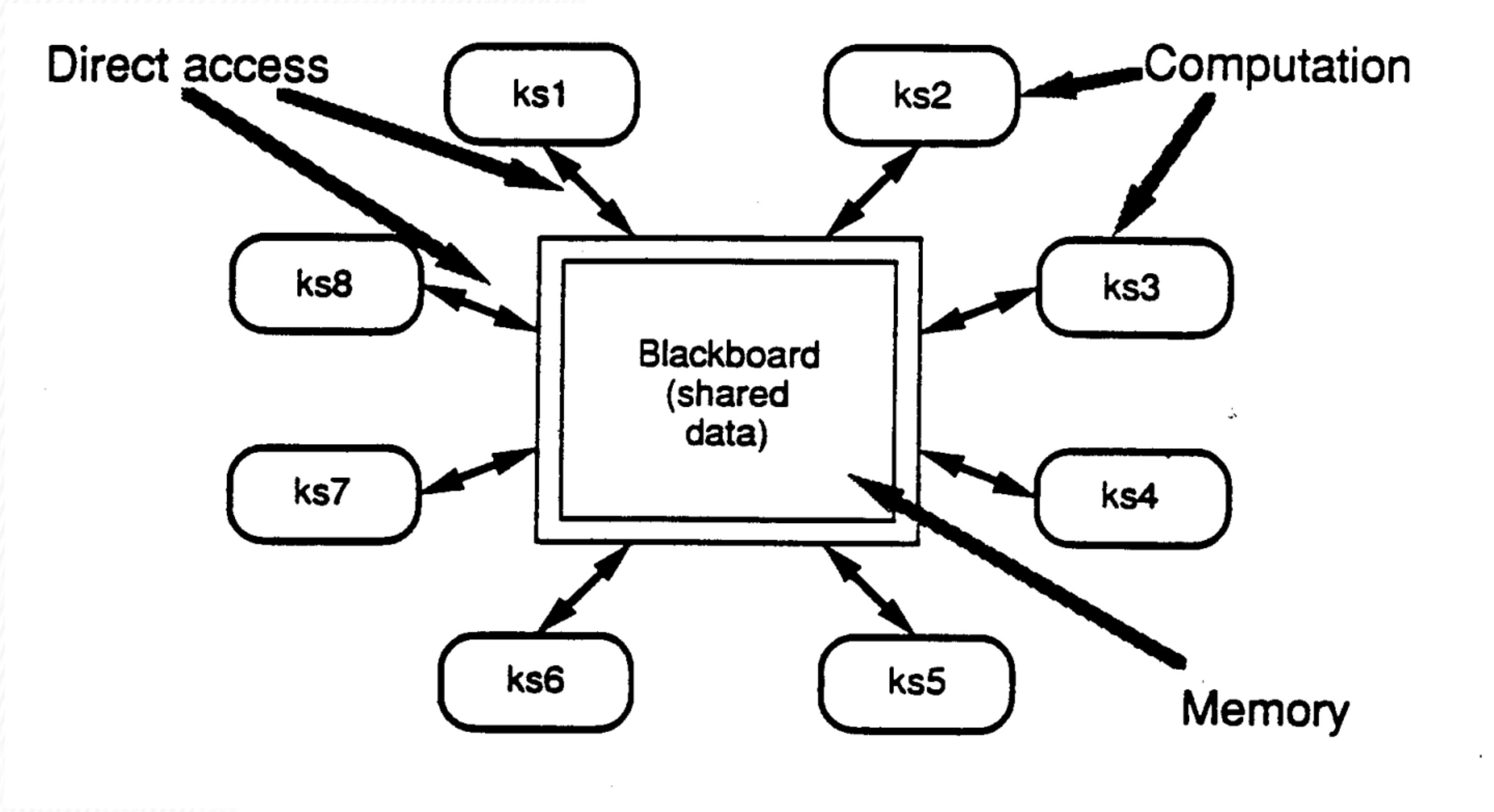
v1.x.x installs mongodb 2.1.22 and requires 2.1.3
Technical Support • about 14 hours ago • exodo
about 8 hours ago
@pichalite said in v1.x.x installs mongodb 2.1.22

Configuration via Environmental Variables: arrays?
Technical Support • about 15 hours ago • matti
No one has replied

Remove all bookmarks
No one has replied

S3D

4. Blackboard Architecture



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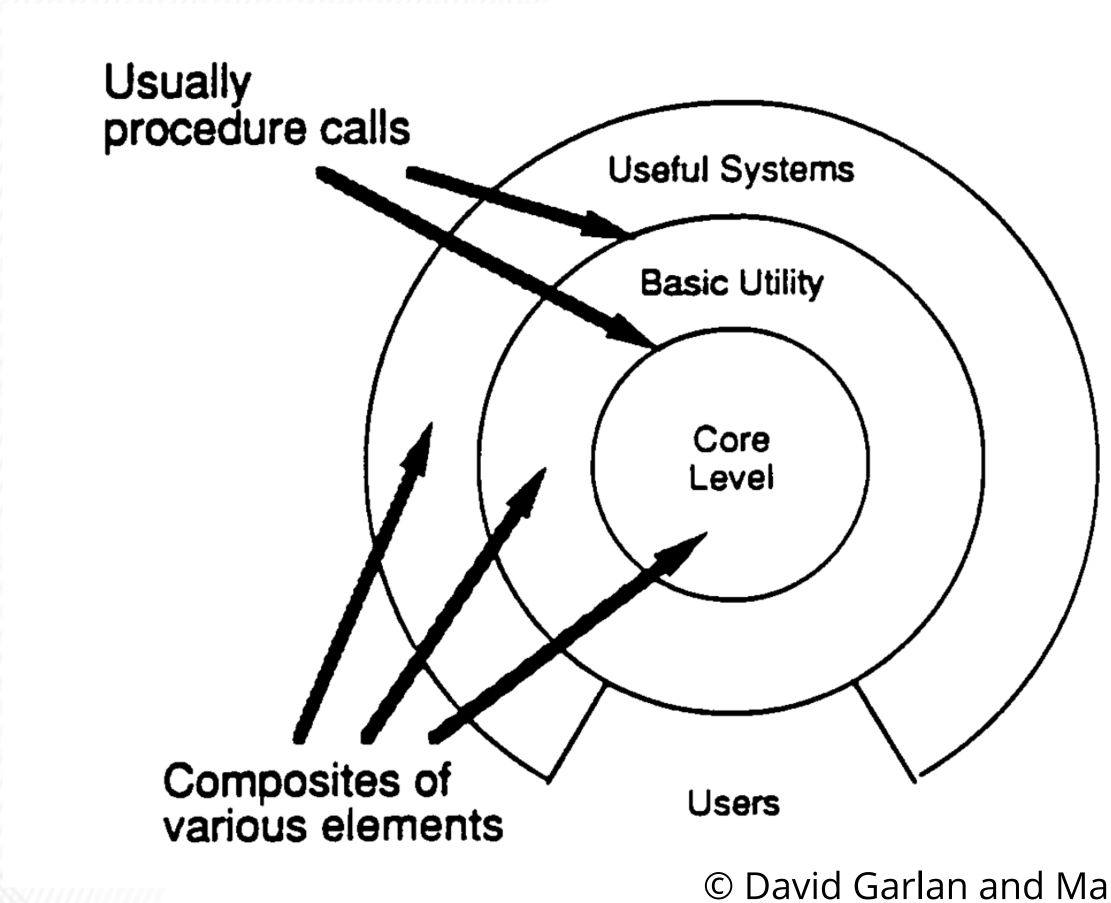
5. Layered Systems



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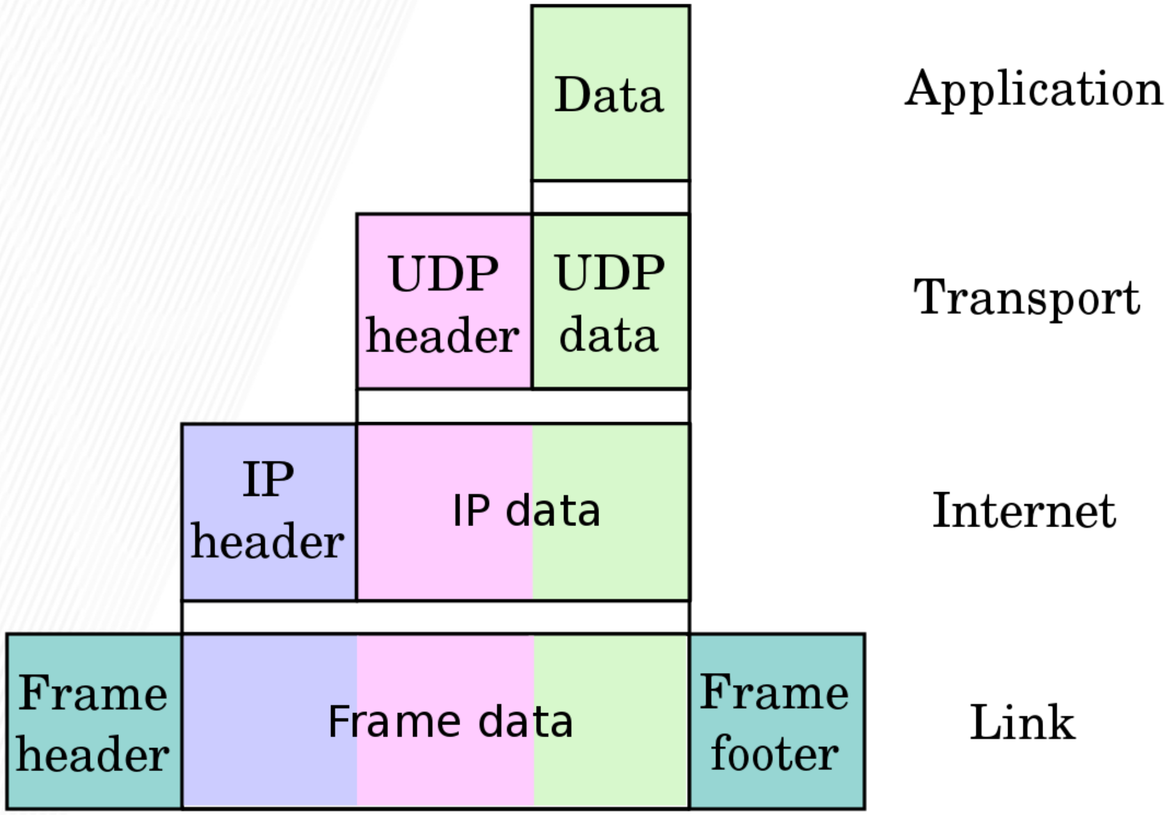
Example: Internet Protocol Suite



Guidelines for selecting a notation

- Suitable for purpose
- Often visual for compact representation
- Usually boxes and arrows
- UML possible (semi-formal), but possibly constraining
    - Note the different abstraction level – Subsystems or processes, not classes or objects
- Formal notations available
- Decompose diagrams hierarchically and in views
- Always include a legend
- Define precisely what the boxes mean
- Define precisely what the lines mean
- Do not try to do too much in one diagram
    - Each view of architecture should fit on a page
    - Use hierarchy

Next Up

- Microservices