

Introduction to Software Architecture

17-313 Fall 2023

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

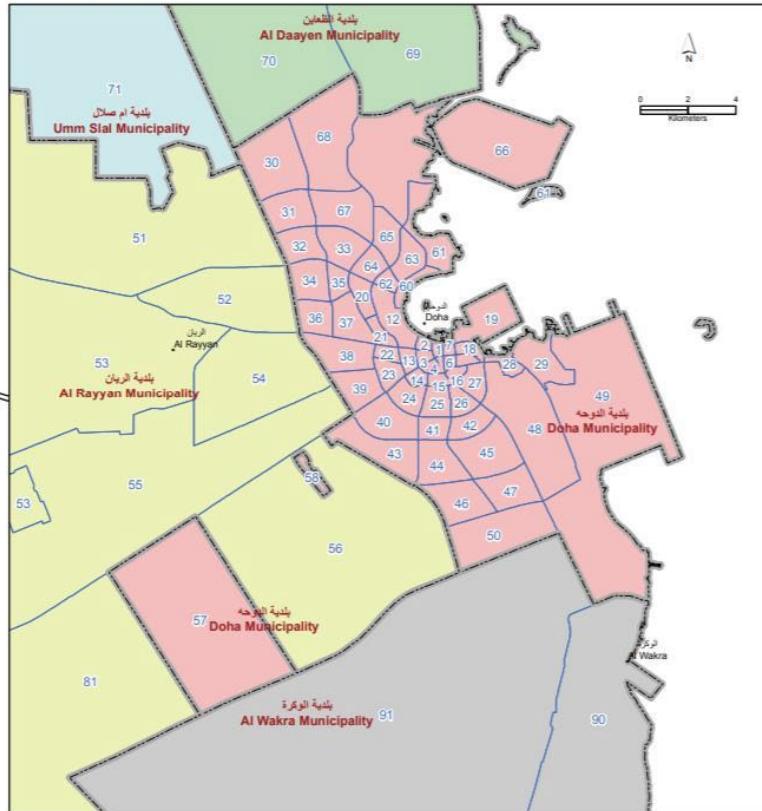
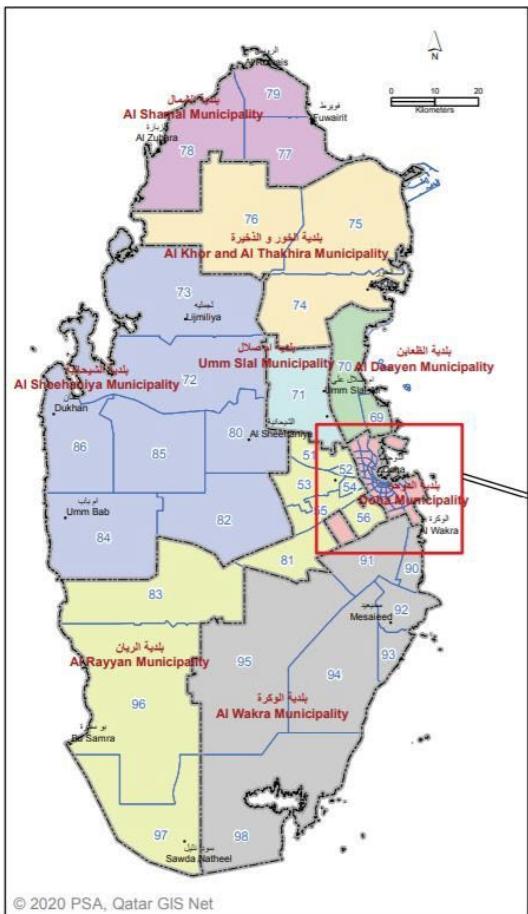


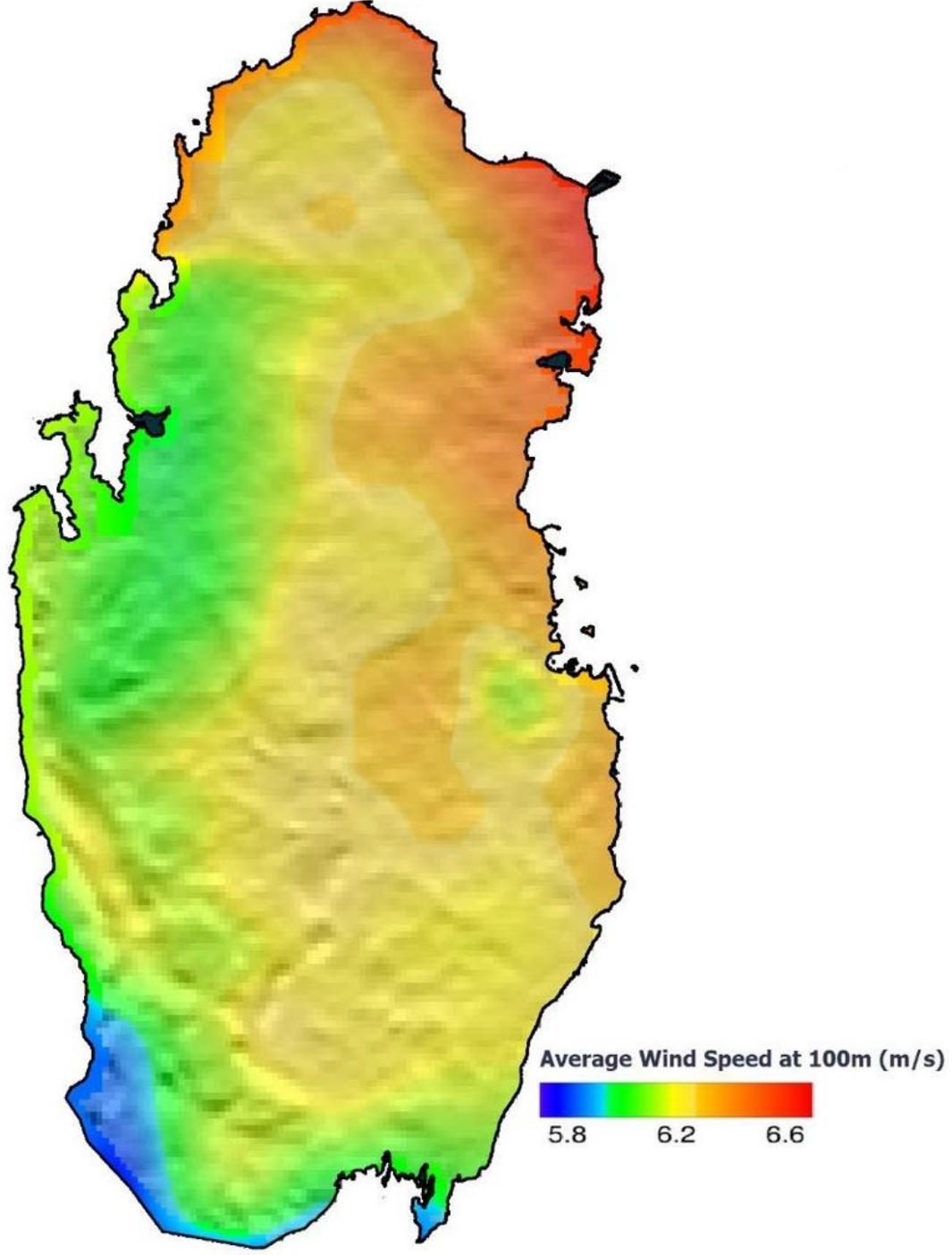


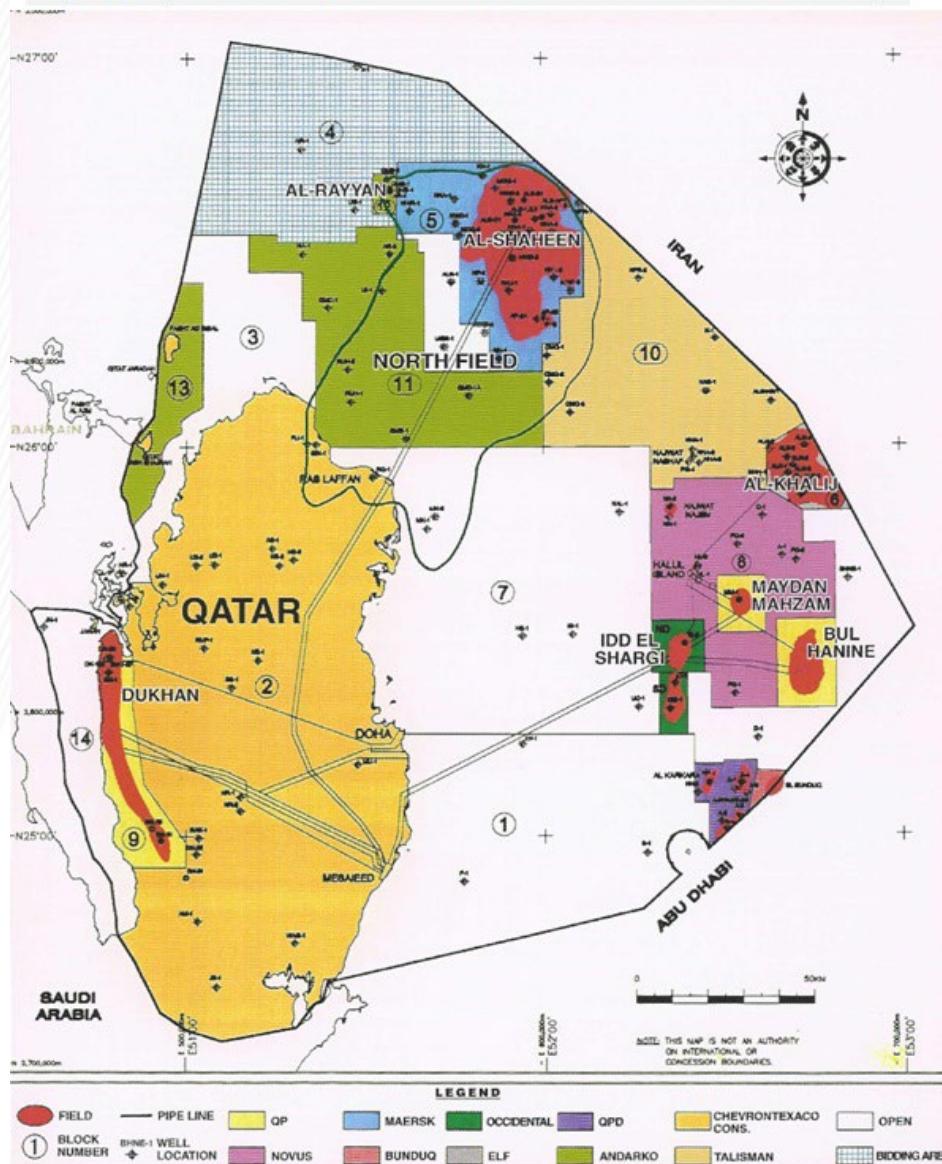
دولة قطر
State of Qatar

مفتاح الخريطة

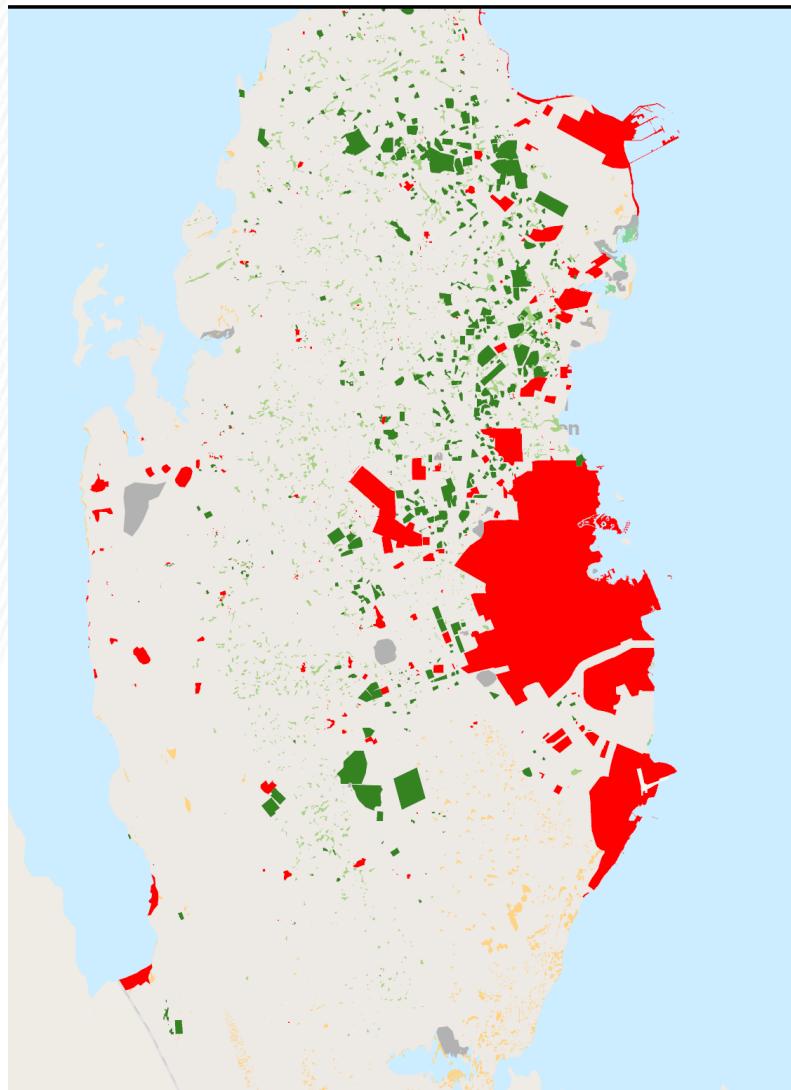
Zone Boundary 2020
حدود المنطقة 2020
Zone Number 2020
رقم المنطقة 2020







LandCover 2020



LandCover 2020

Settlements/Built-up

Farms/Agriculture

Shrubs/Rawada

Mangroves/ Forests

Sand/Sand Dunes

Barren Land

Others

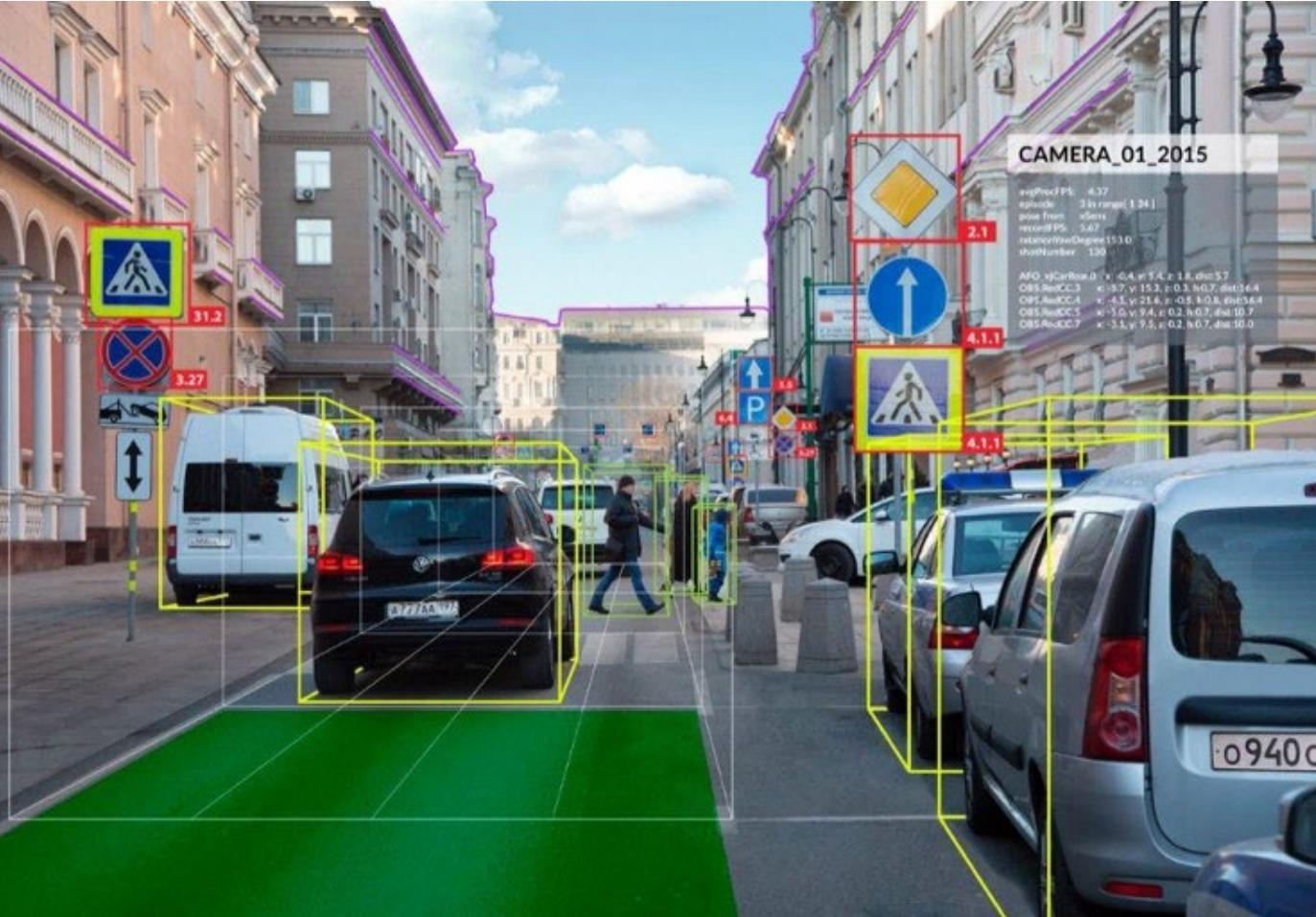


Abstracted views focus on conveying specific information

- 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:

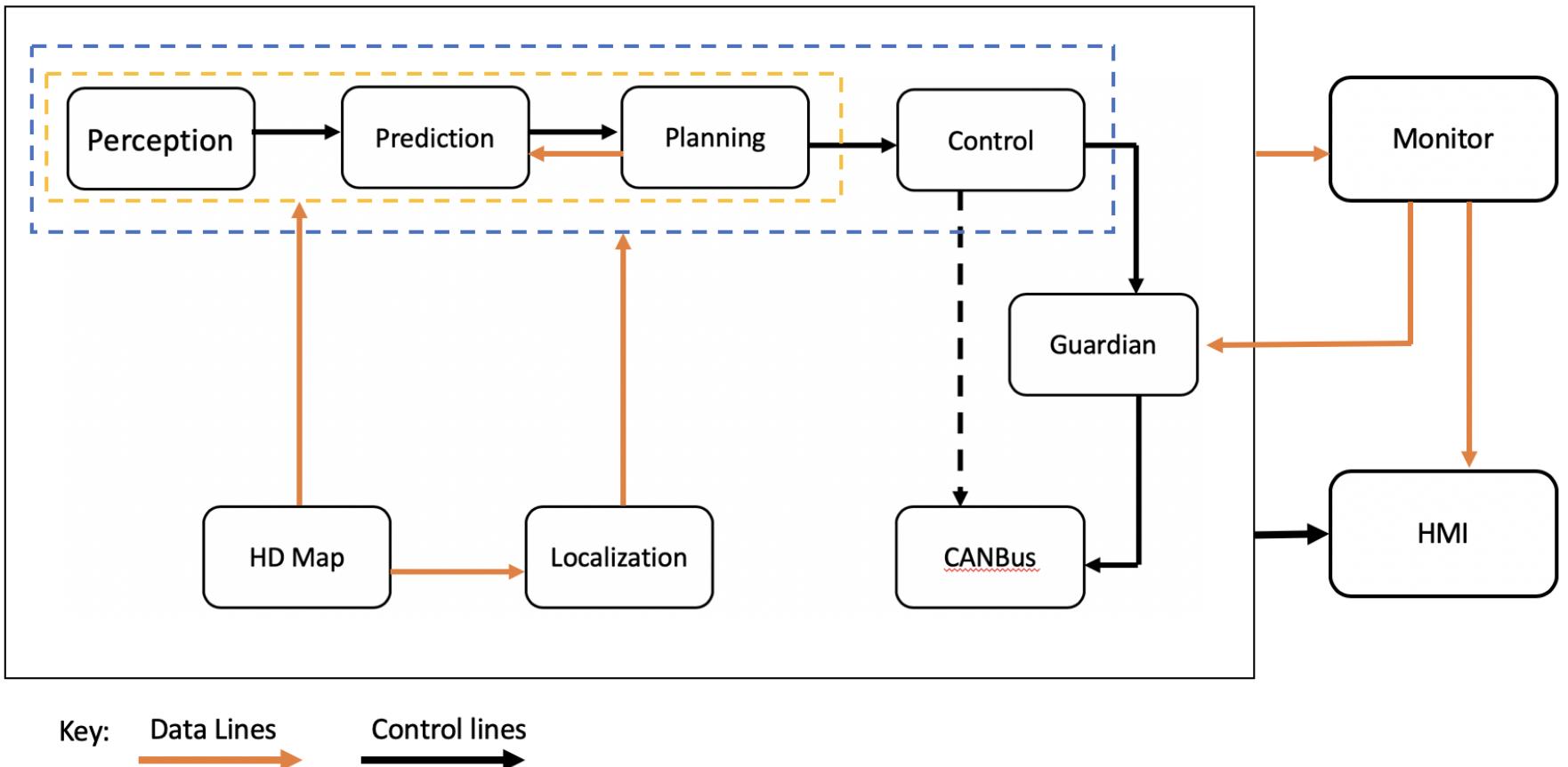
<https://www.youtube.com/watch?v=BXNDUtNZdM4>

- Discuss in teams of 4 **how** you would implement the side pass feature

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

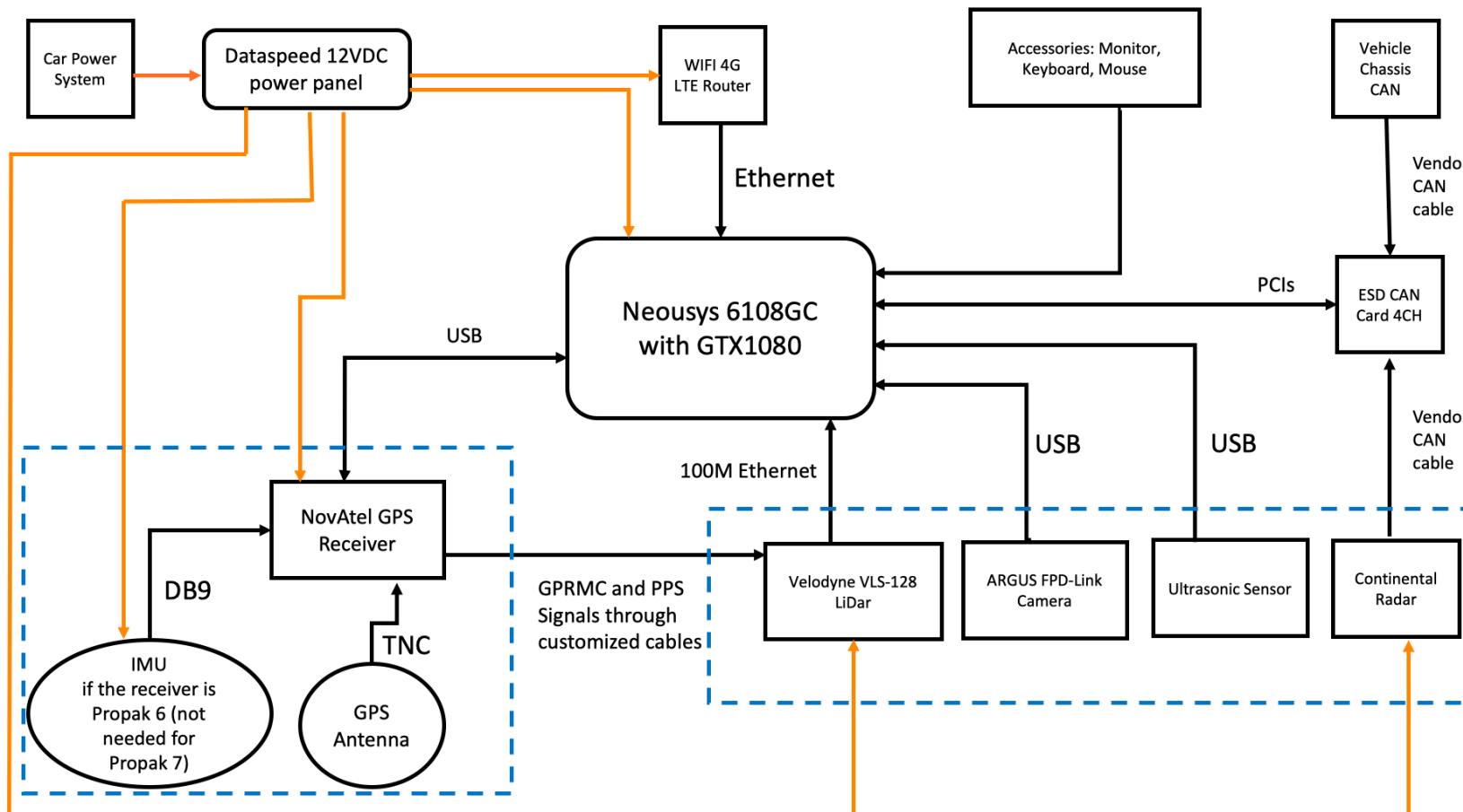
Doxxygen: <https://hidetoshi-furukawa.github.io/apollo-doxxygen/index.html>

Apollo Software Architecture



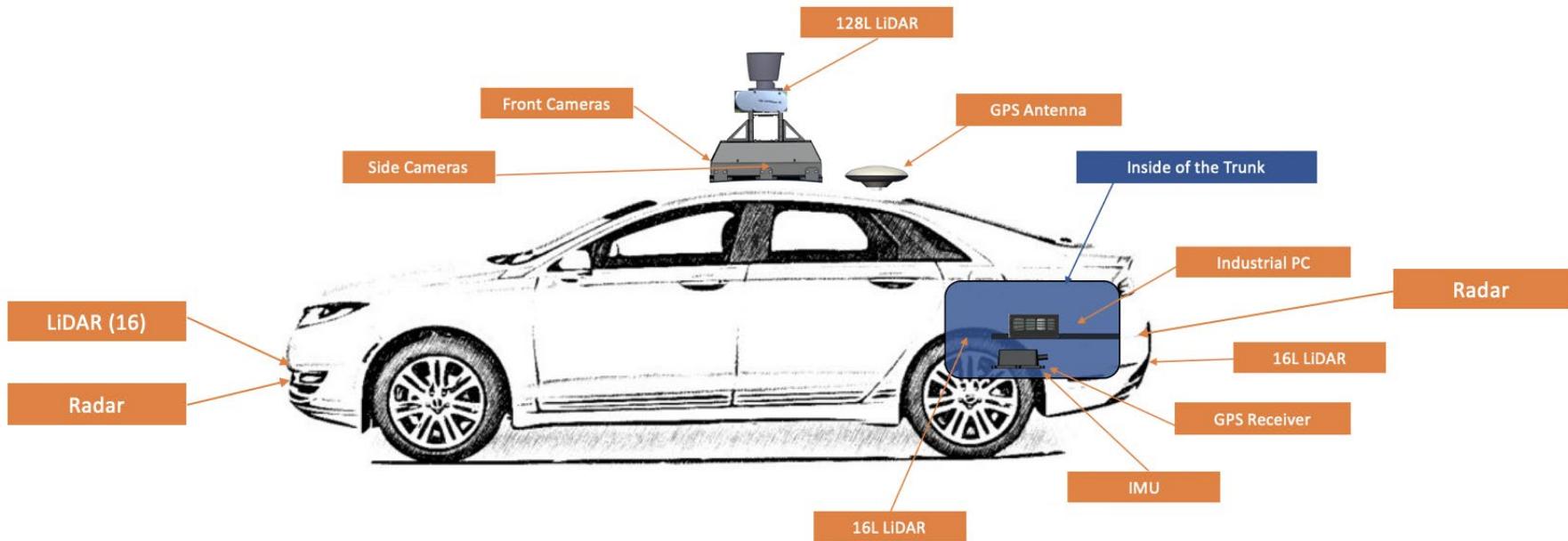
Source: https://github.com/ApolloAuto/apollo/blob/v6.0.0/docs/specs/Apollo_5.5_Software_Architecture.md

Apollo Hardware Architecture



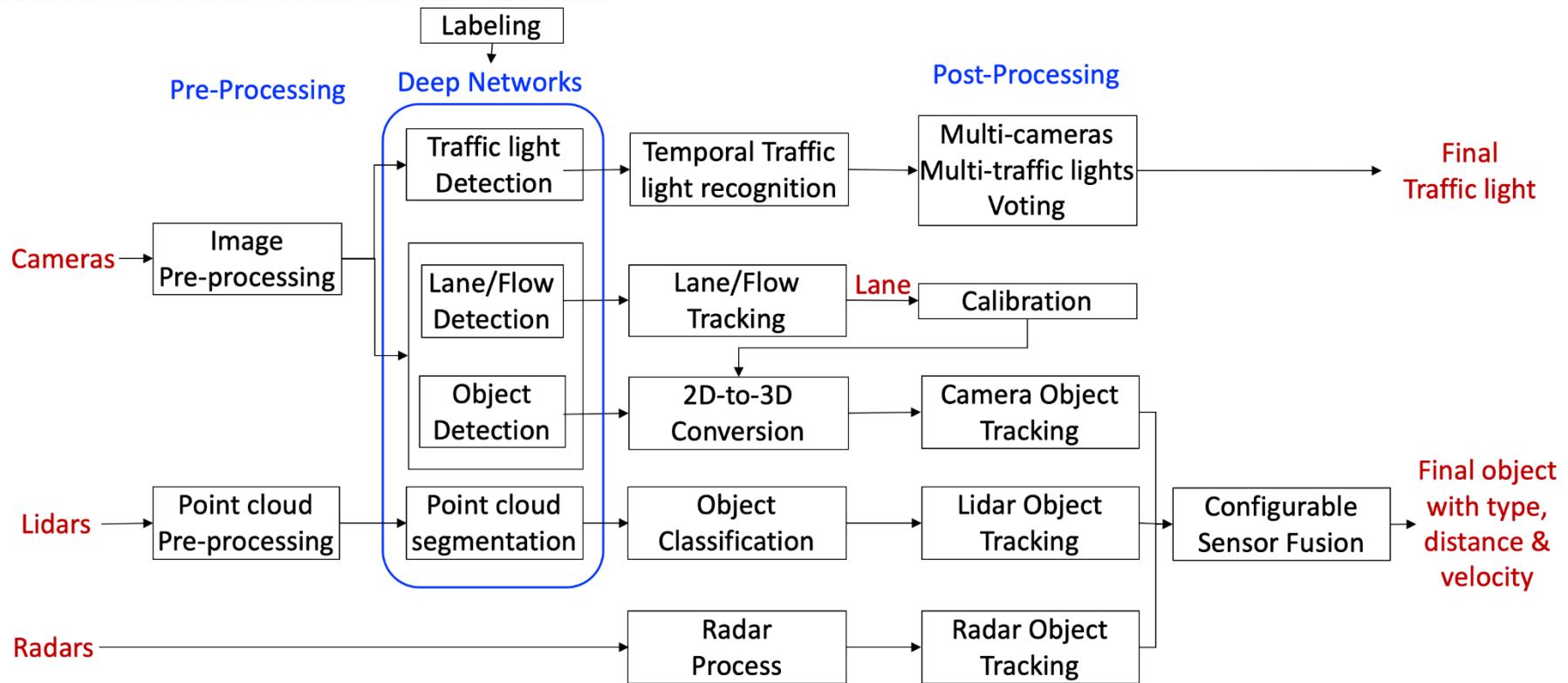
Source: <https://github.com/ApolloAuto/apollo/blob/v6.0.0/README.md>

Apollo Hardware/Vehicle Overview

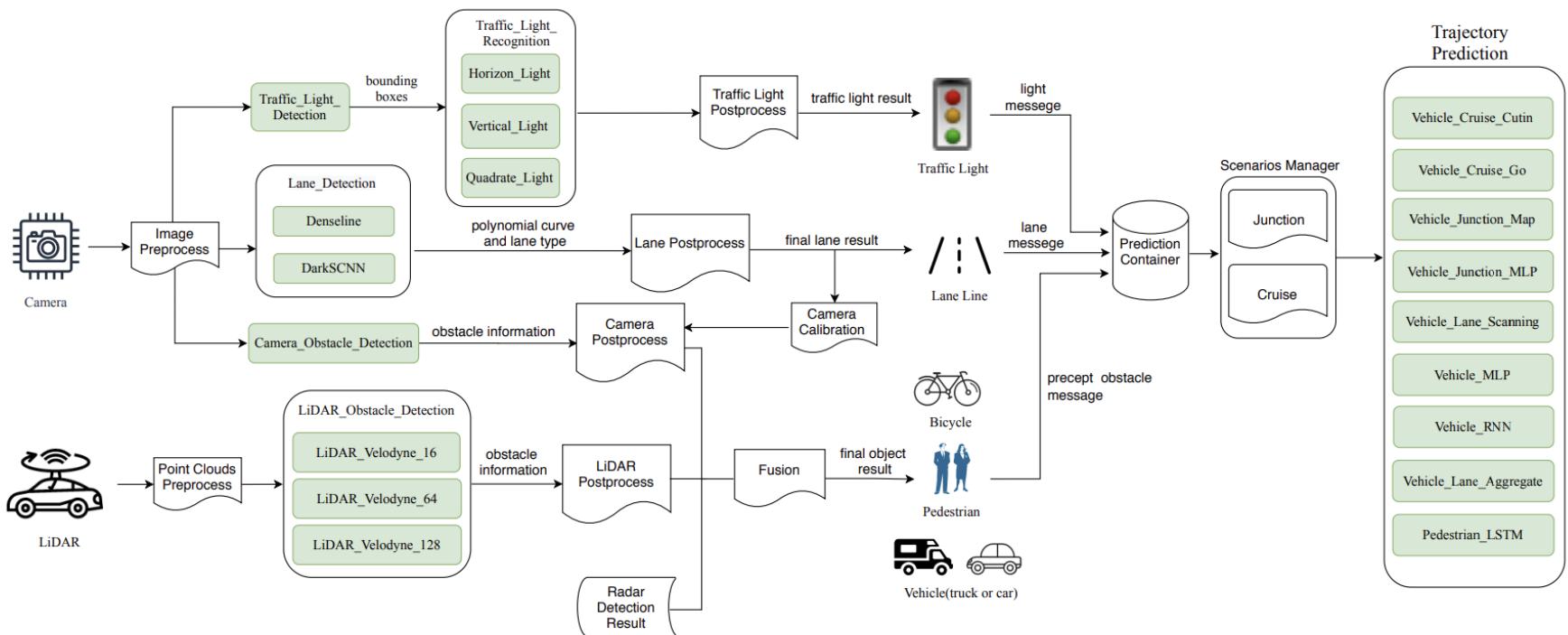


Source: <https://github.com/ApolloAuto/apollo/blob/v6.0.0/README.md>

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

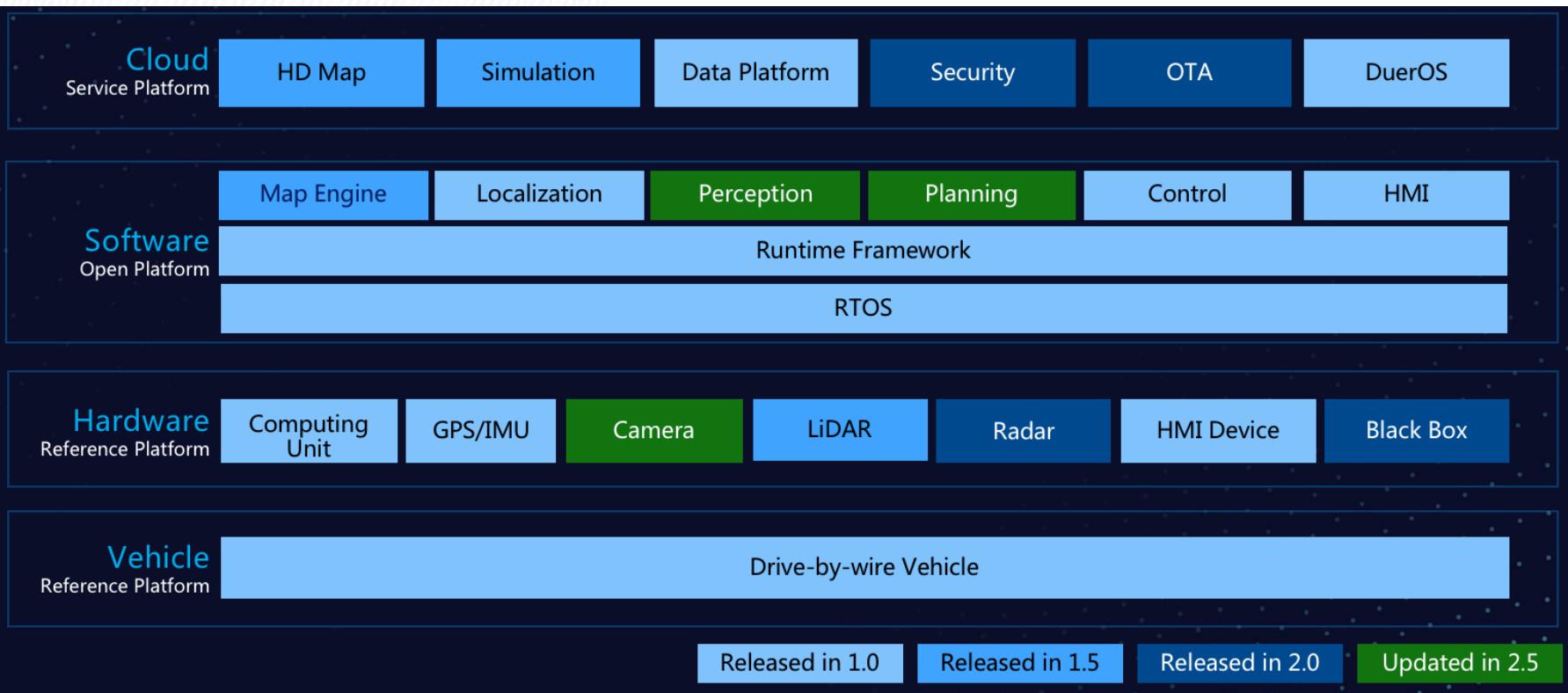
Cloud Service Platform	HD Map	Simulation	Data Platform	Security	OTA	DuerOS	Volume Production Service Components	V2X Roadside Service		
Open Software Platform	Map Engine	Localization	Perception	Planning	Control	End-to-End	HMI	V2X Adapter		
	Apollo Cyber RT Framework									
	RTOS									
	Computing Unit	GPS/IMU	Camera	LiDAR	Radar	Ultrasonic Sensor	HMI Device	Black Box	Apollo Sensor Unit	Apollo Extension Unit
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)



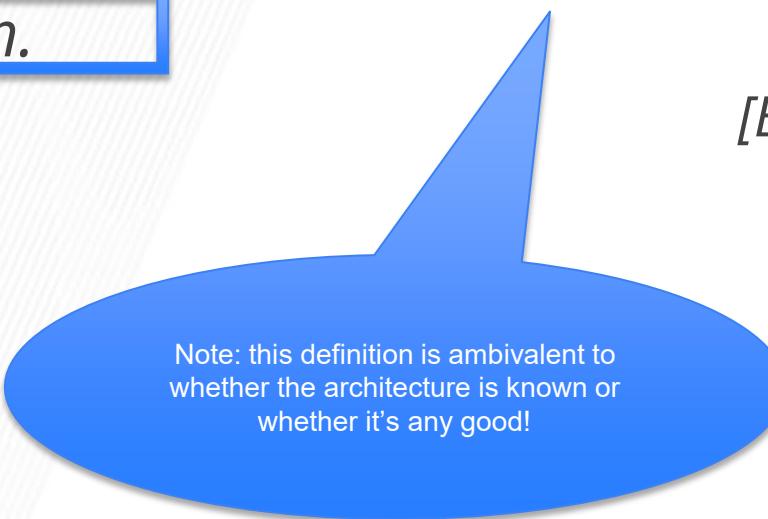
Source: <https://github.com/ApolloAuto/apollo>



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 NodeBB?
- How can I make it easy to create posts in NodeBB?
- What lock protects this data?
- How does Google rank pages?
- What encoder should I use for secure communication?
- What is the interface between objects?

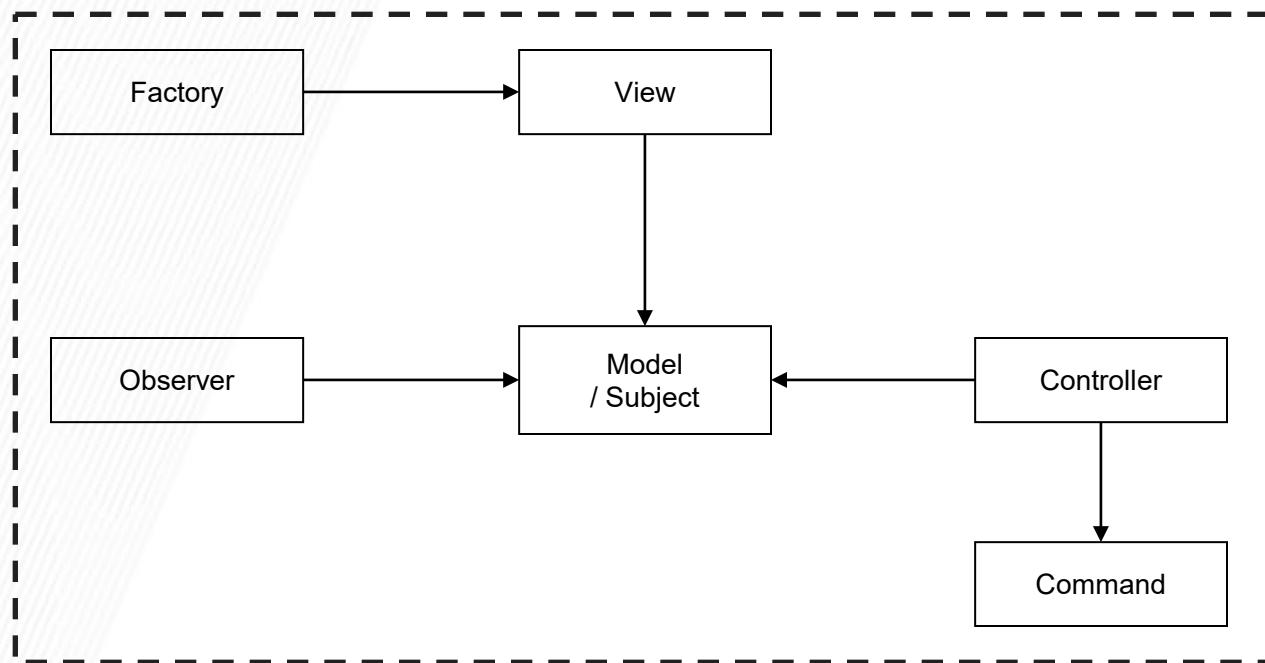
Architectural Questions

- How do I extend NodeBB 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?

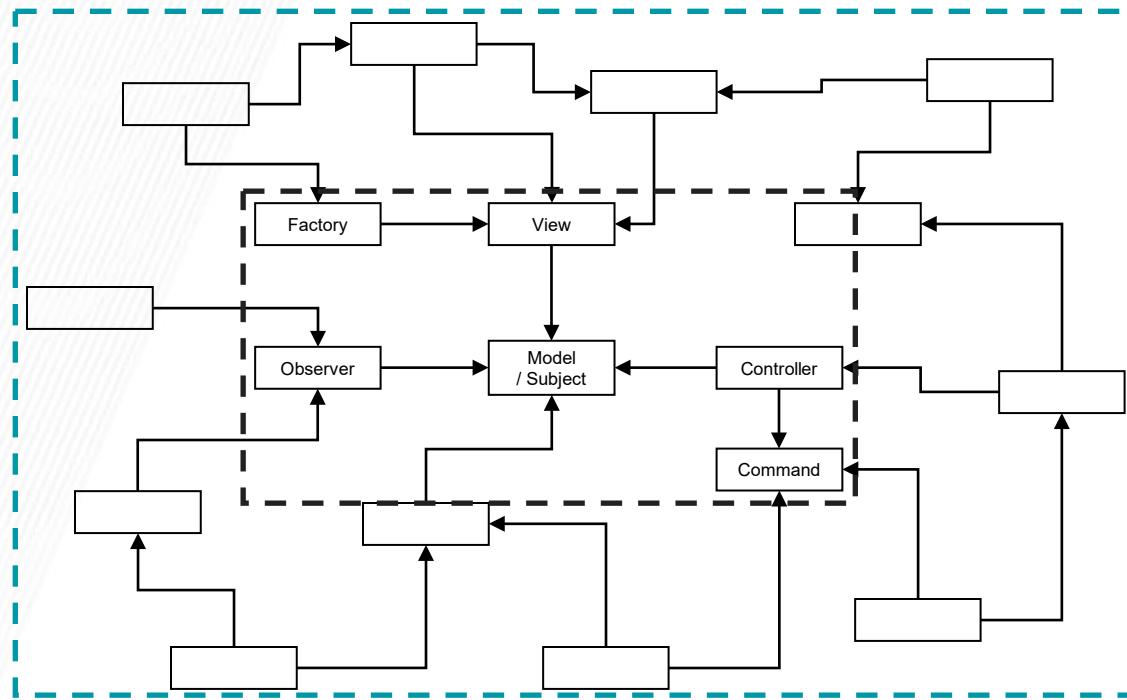
Objects

Model

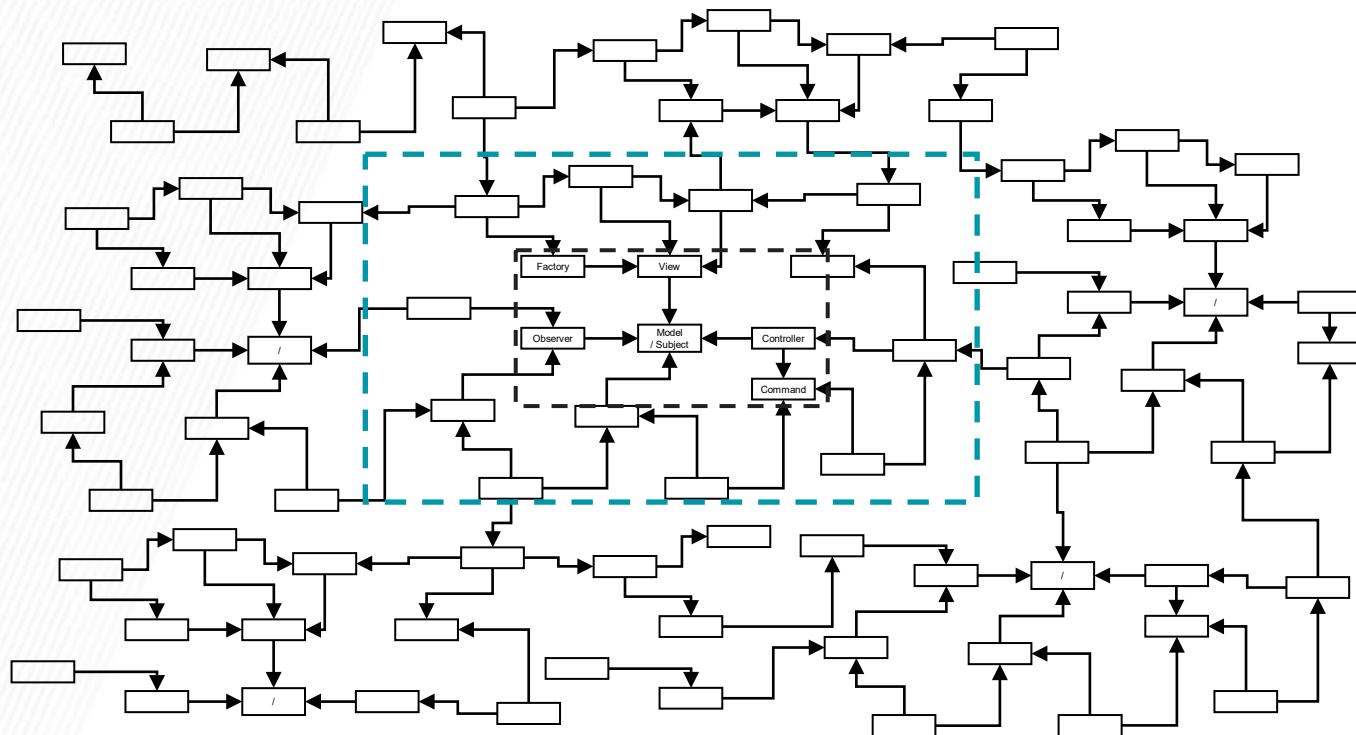
Design Patterns



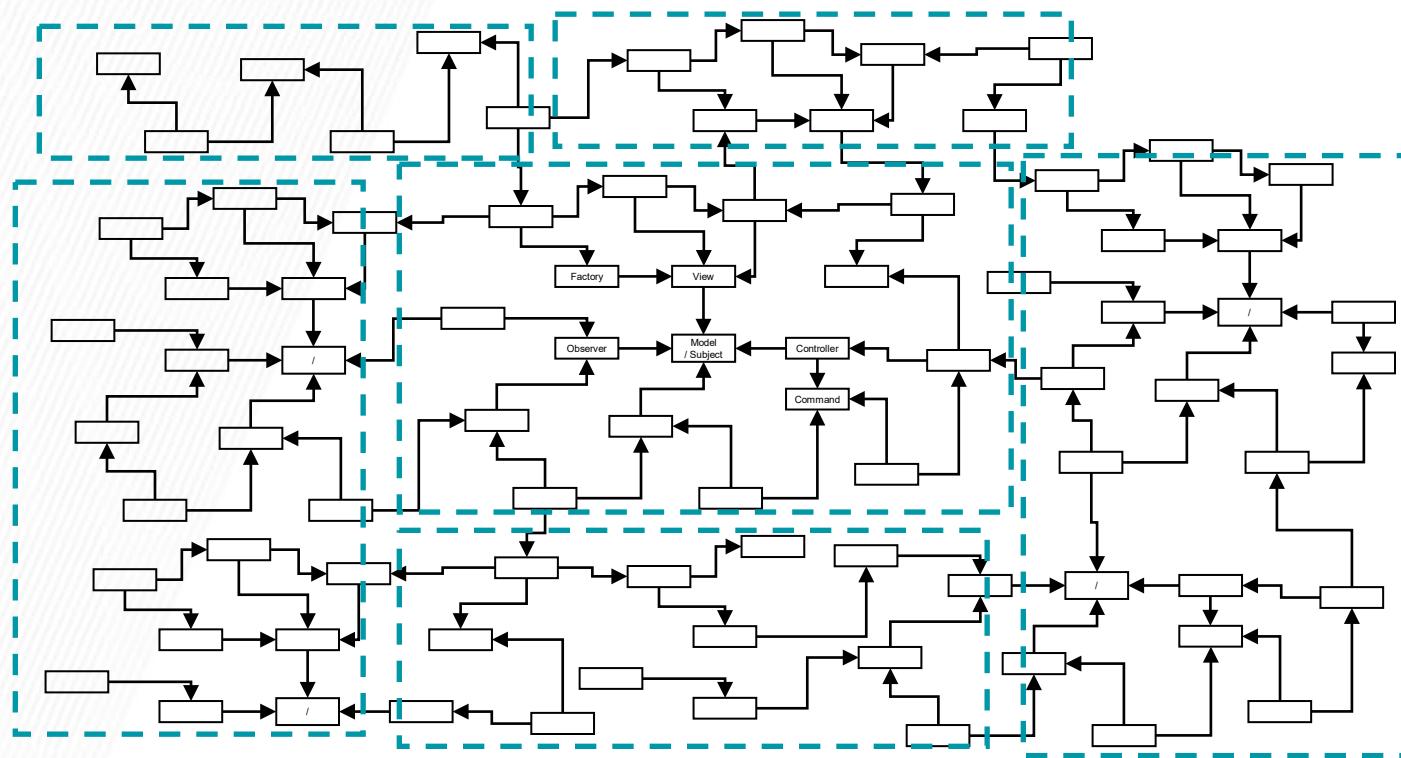
Design Patterns



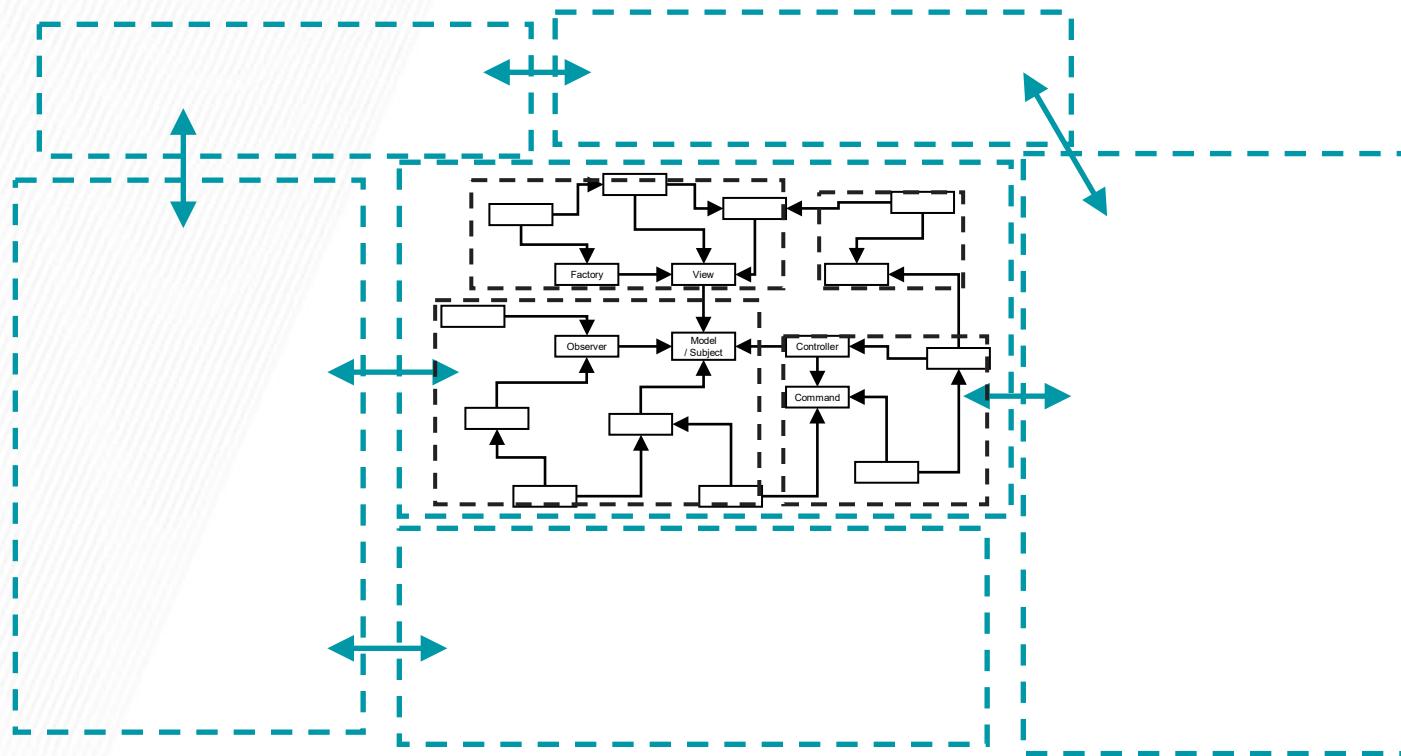
Design Patterns



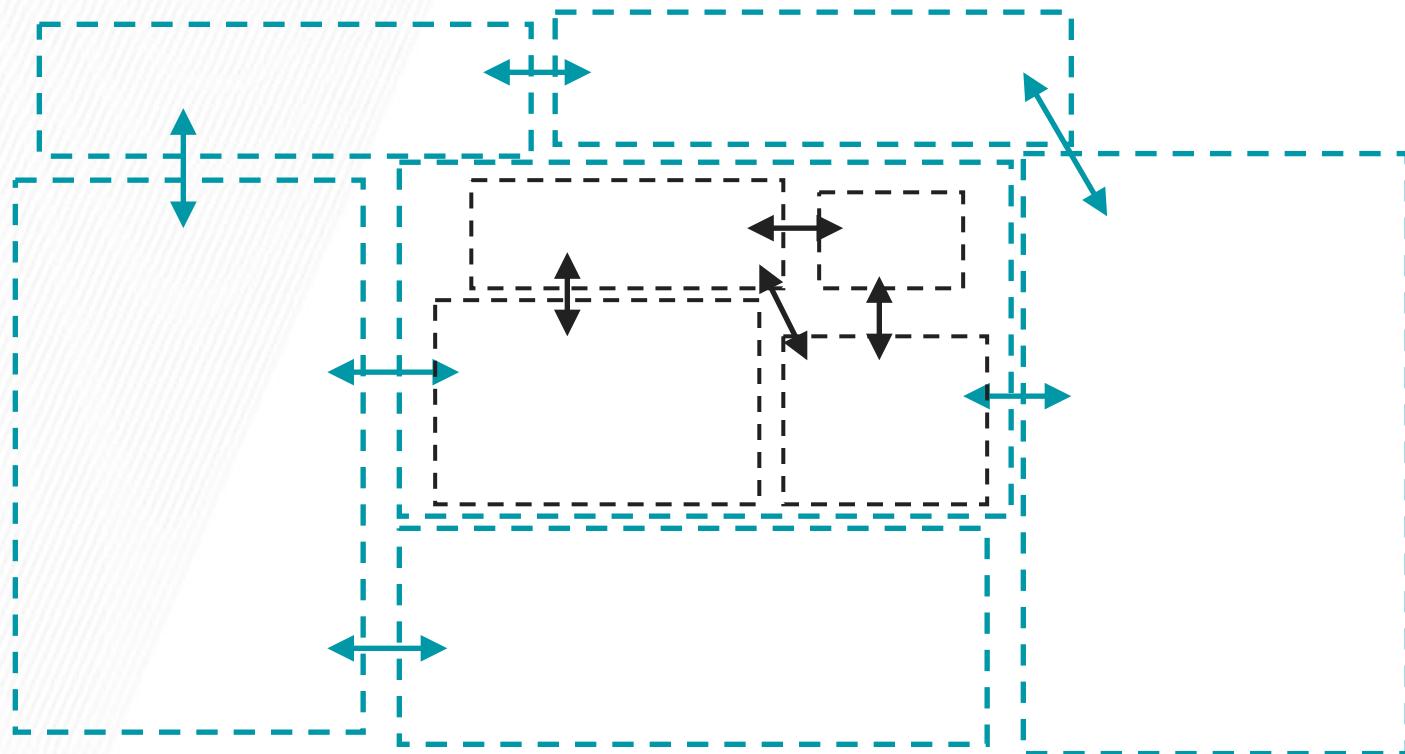
Architecture



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

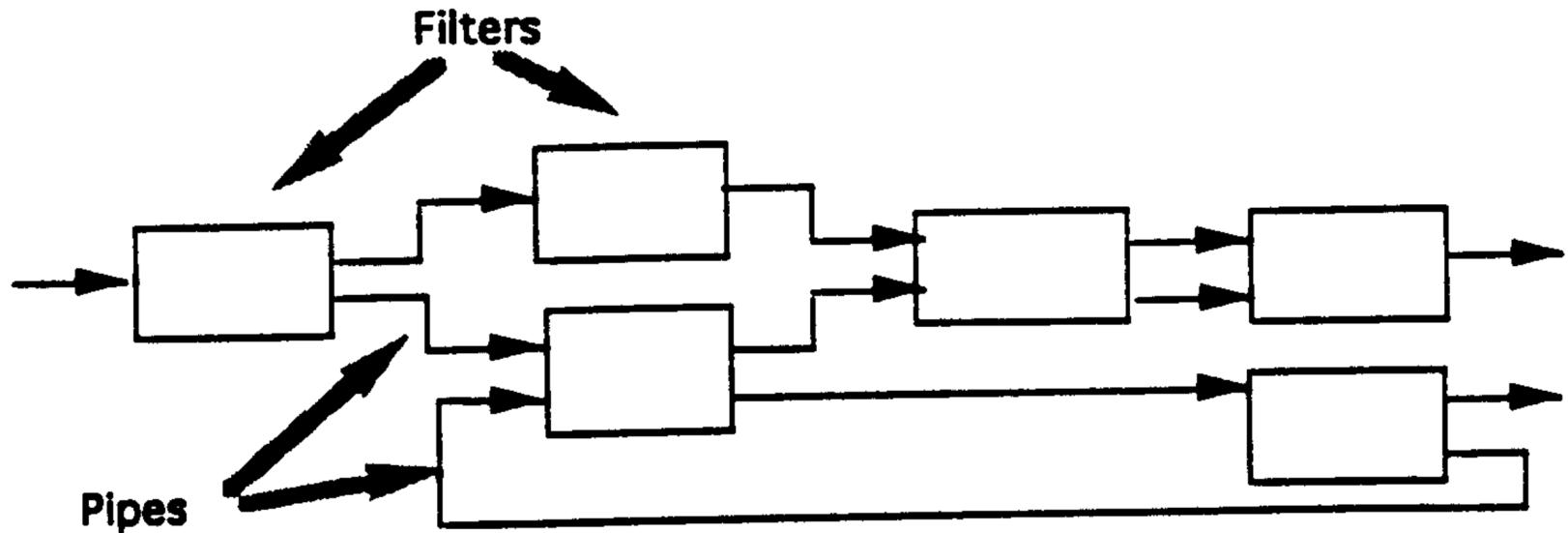
- Every view should align with a purpose
- Views should only represent information relevant to that purpose
 - Abstract away other details
 - Annotate view to guide understanding where needed
- Different views are suitable for different reasoning aspects (different quality goals), e.g.,
 - Performance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

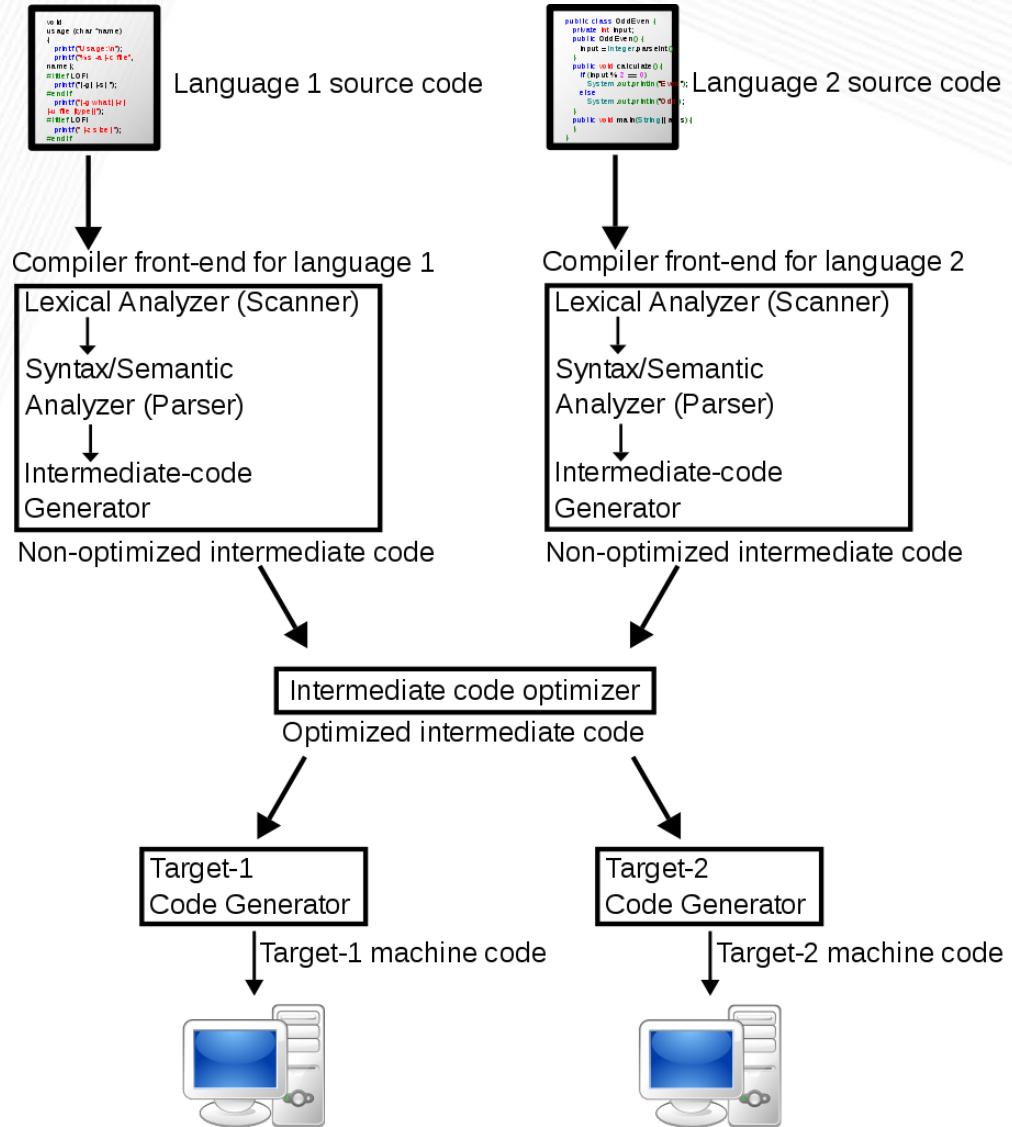
Common Software Architectures

1. Pipes and Filters

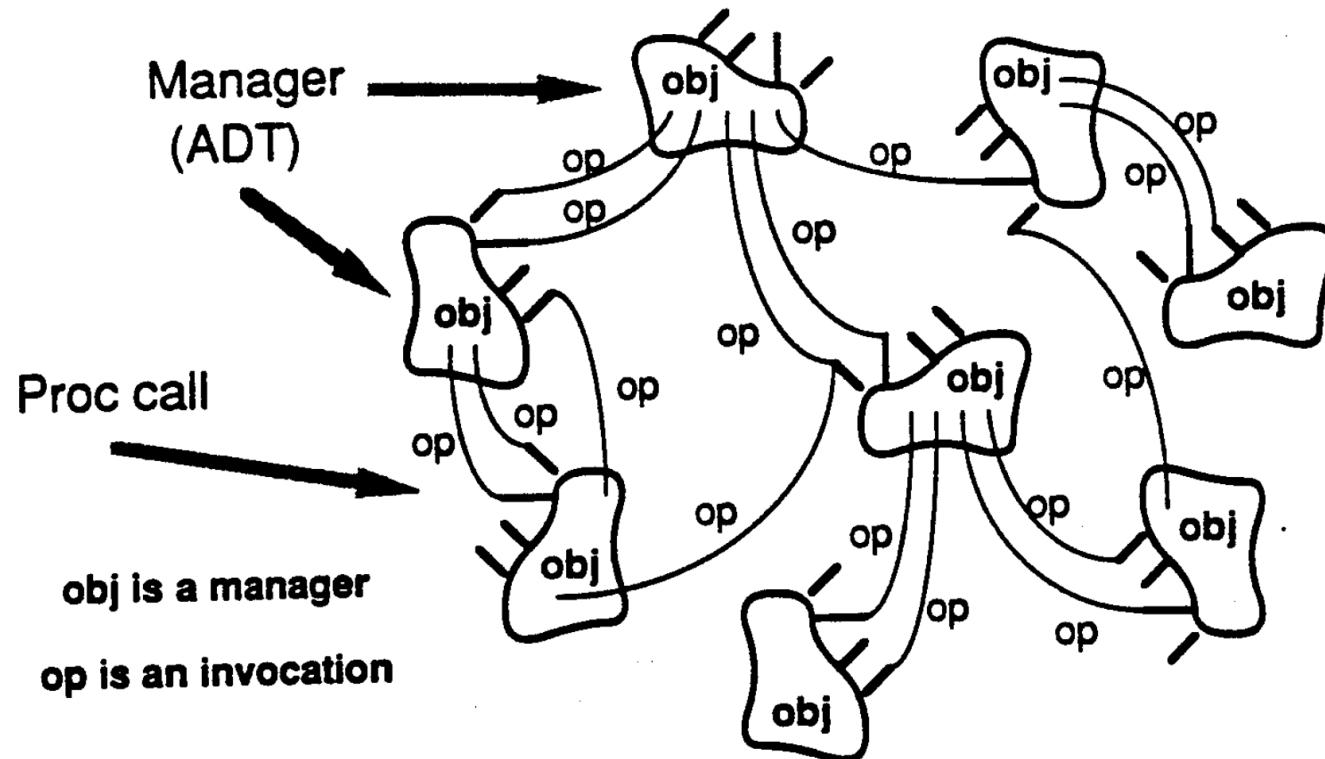


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Example: Compilers

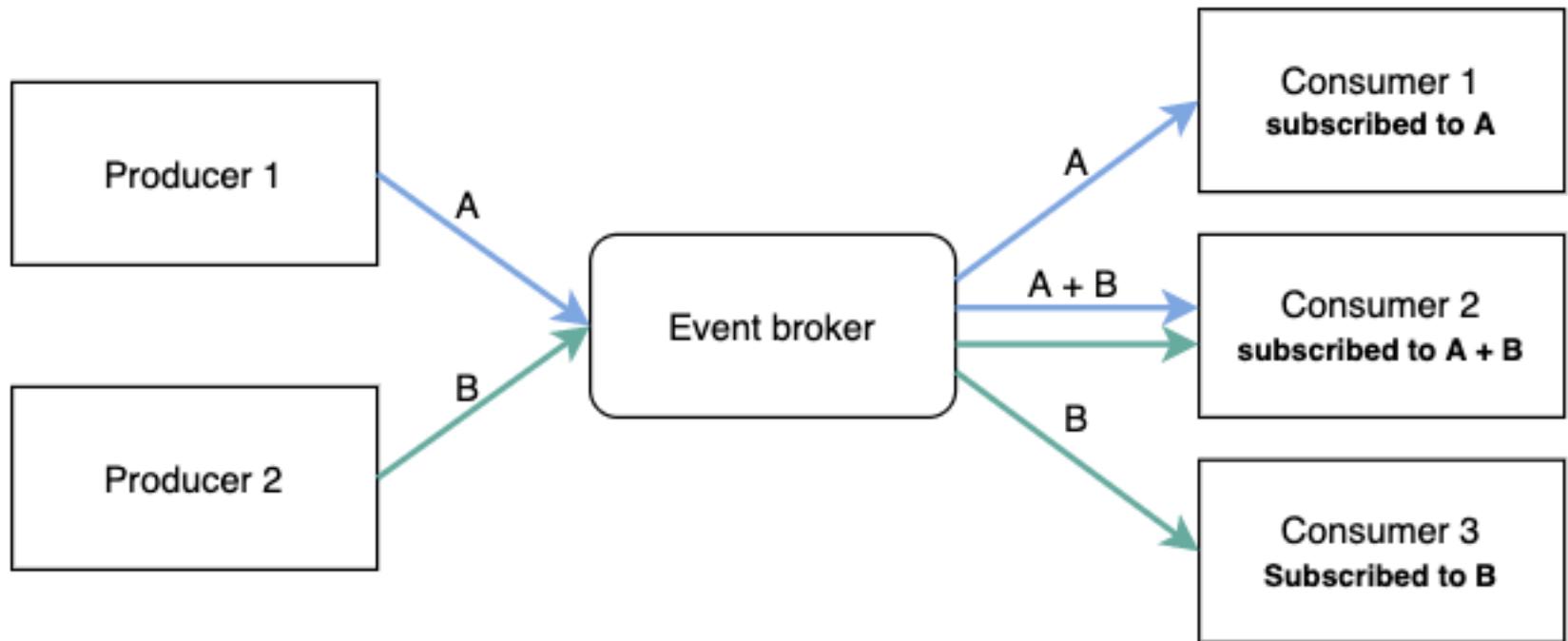


2. Object-Oriented Organization



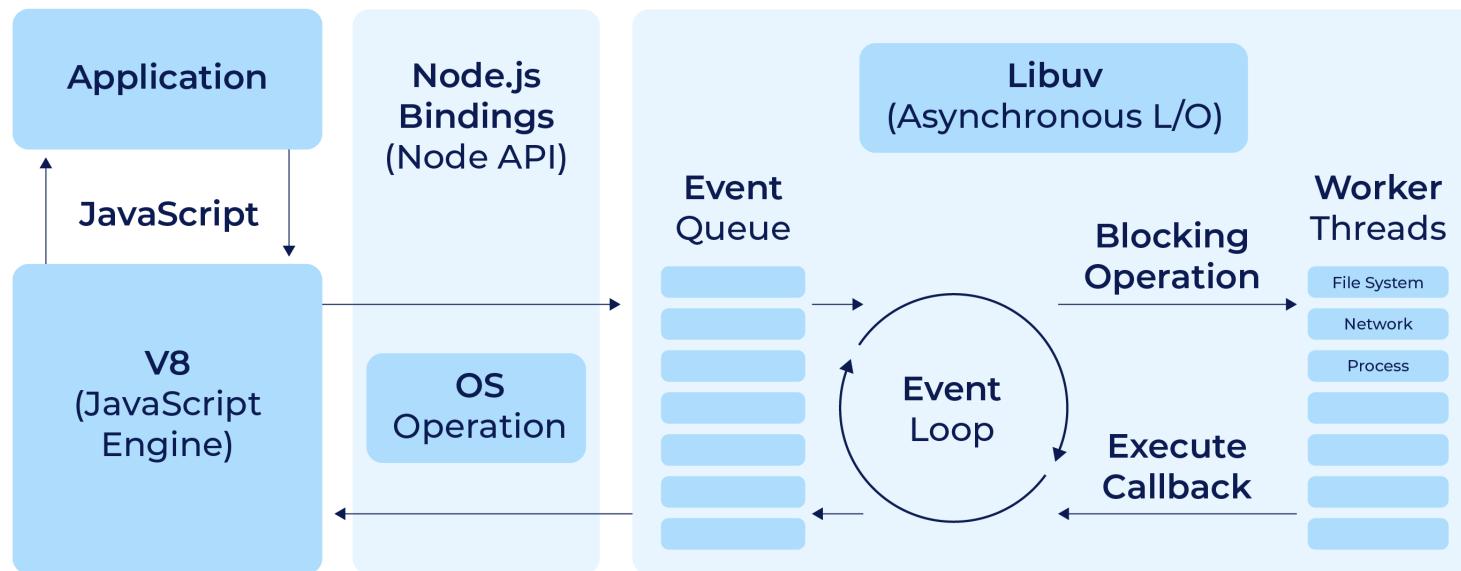
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3. Event-Driven Architecture

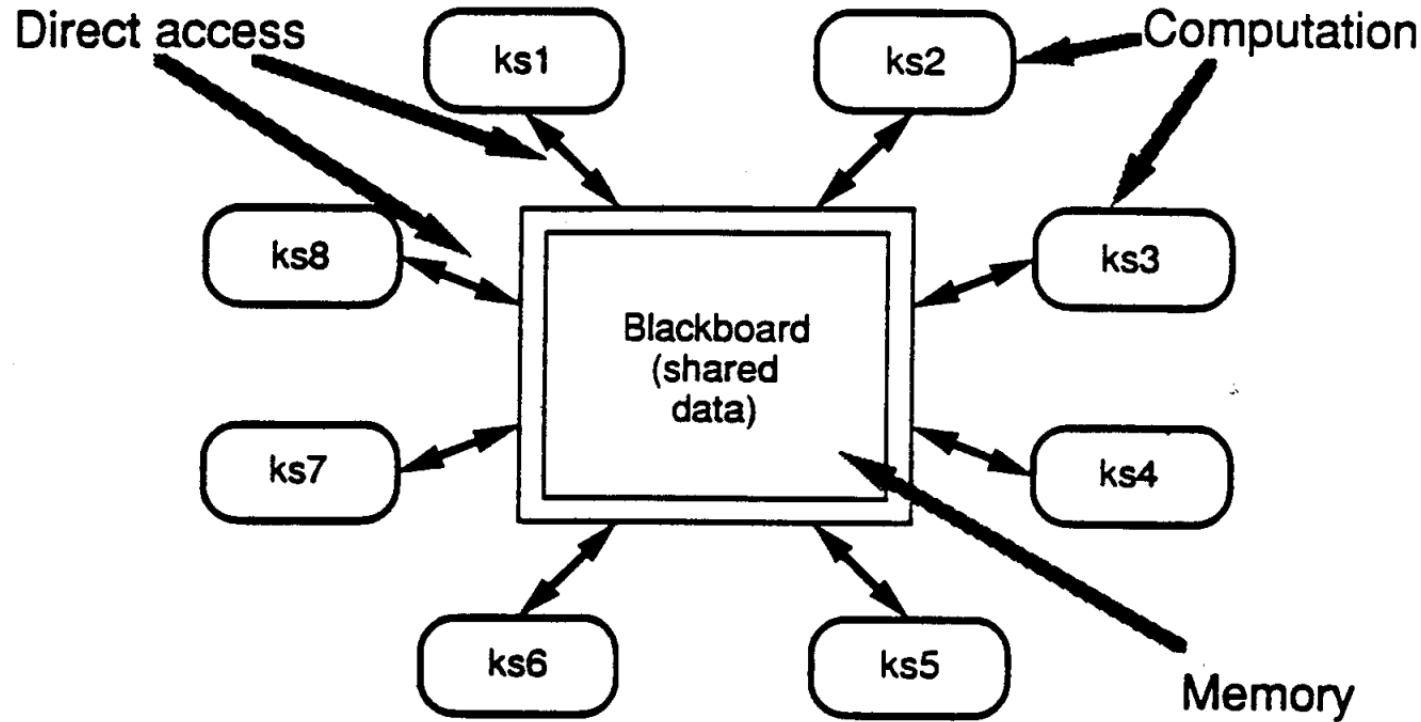


Example: Node.js

Node.js Architecture

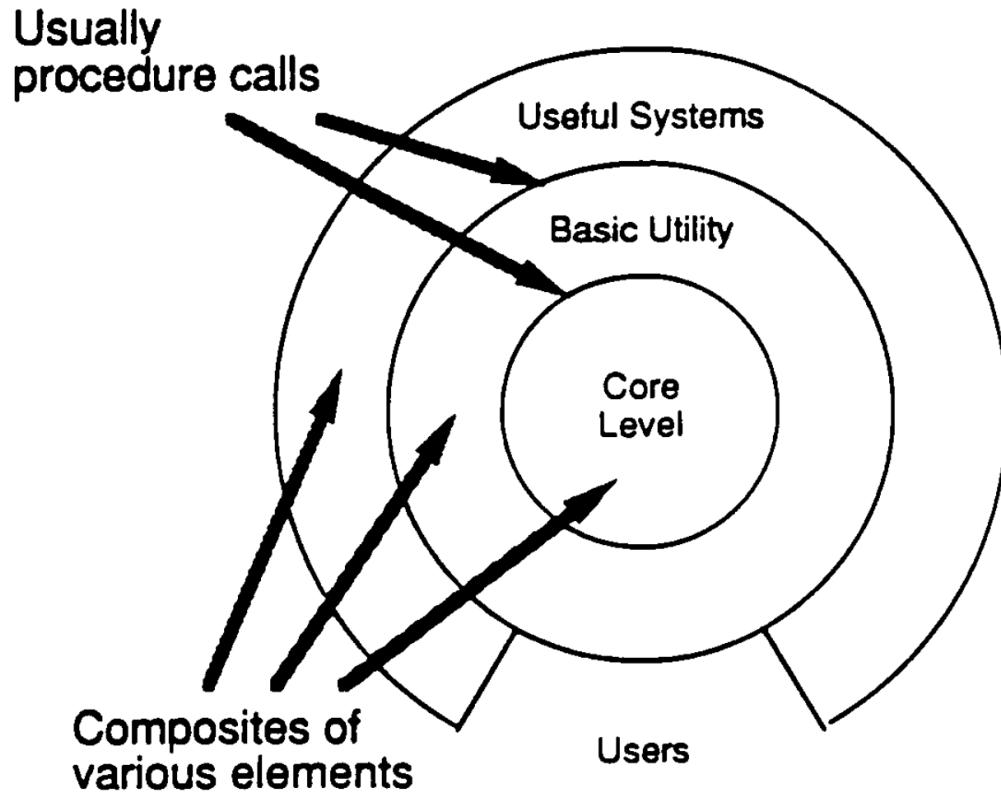


4. Blackboard Architecture



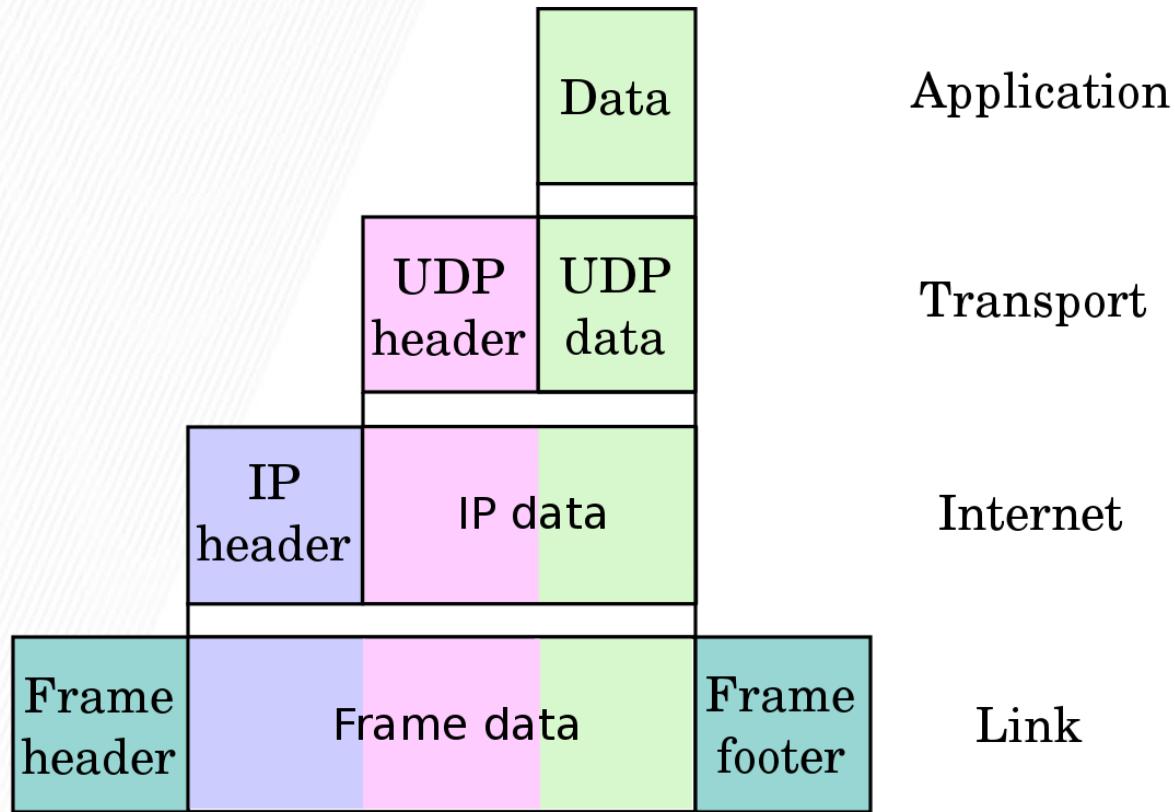
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5. Layered Systems



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Example: Internet Protocol Suite





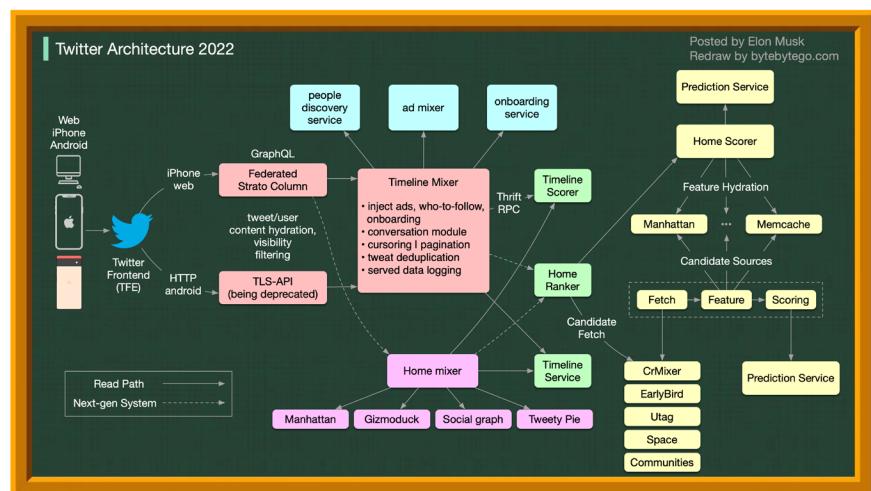
Elon Musk 
@elonmusk

Just leaving Twitter HQ code review



4:28 AM · Nov 19, 2022

36.9K Retweets **16.1K** Quote Tweets **464K** Likes



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

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

Next Up

- Microservices