MLDep: A Testbed for Performance Exploration of Machine Learning Inference Serving

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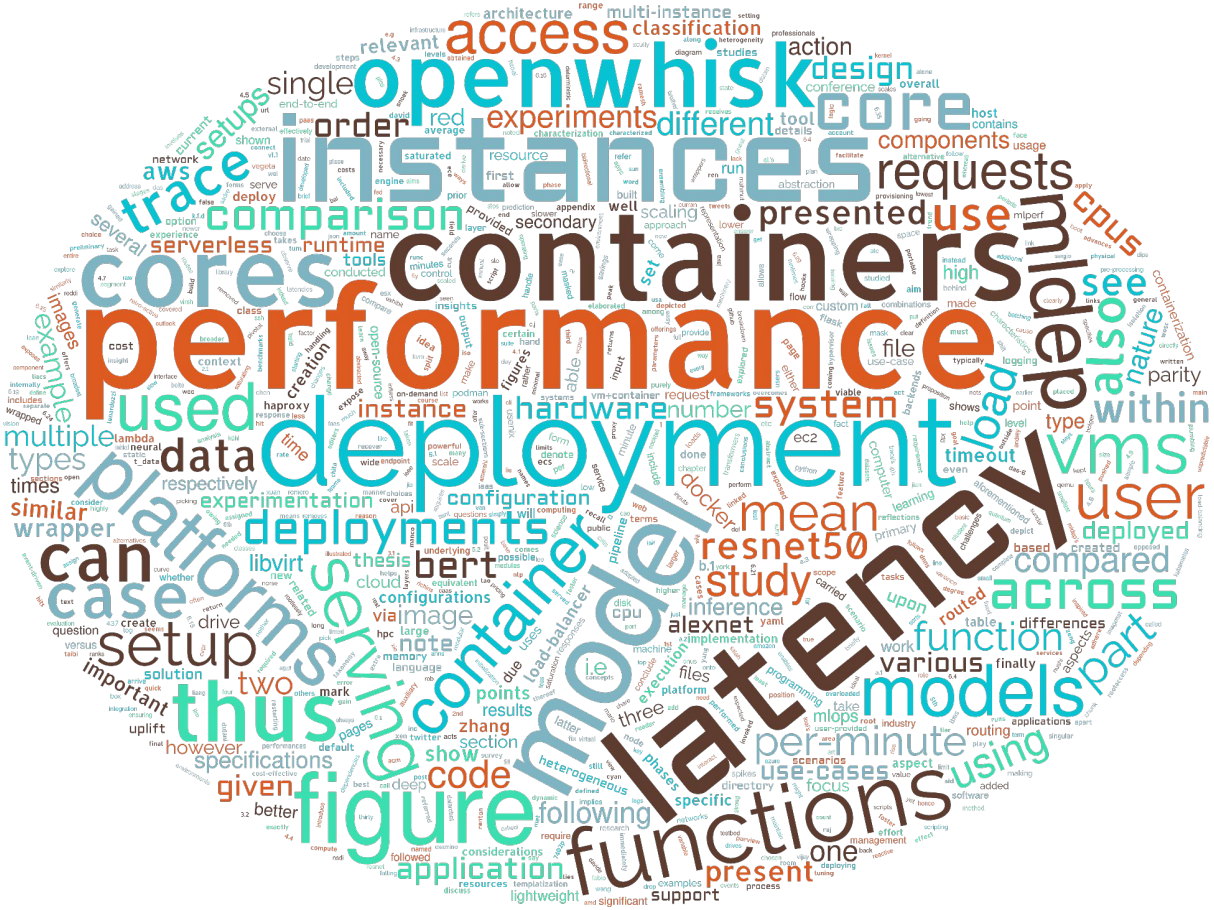
Overview

- Introduction
- Research Questions
- MLDep - Design and Implementation
- Experimentation Approach
- Results
- Conclusion
- Future Work



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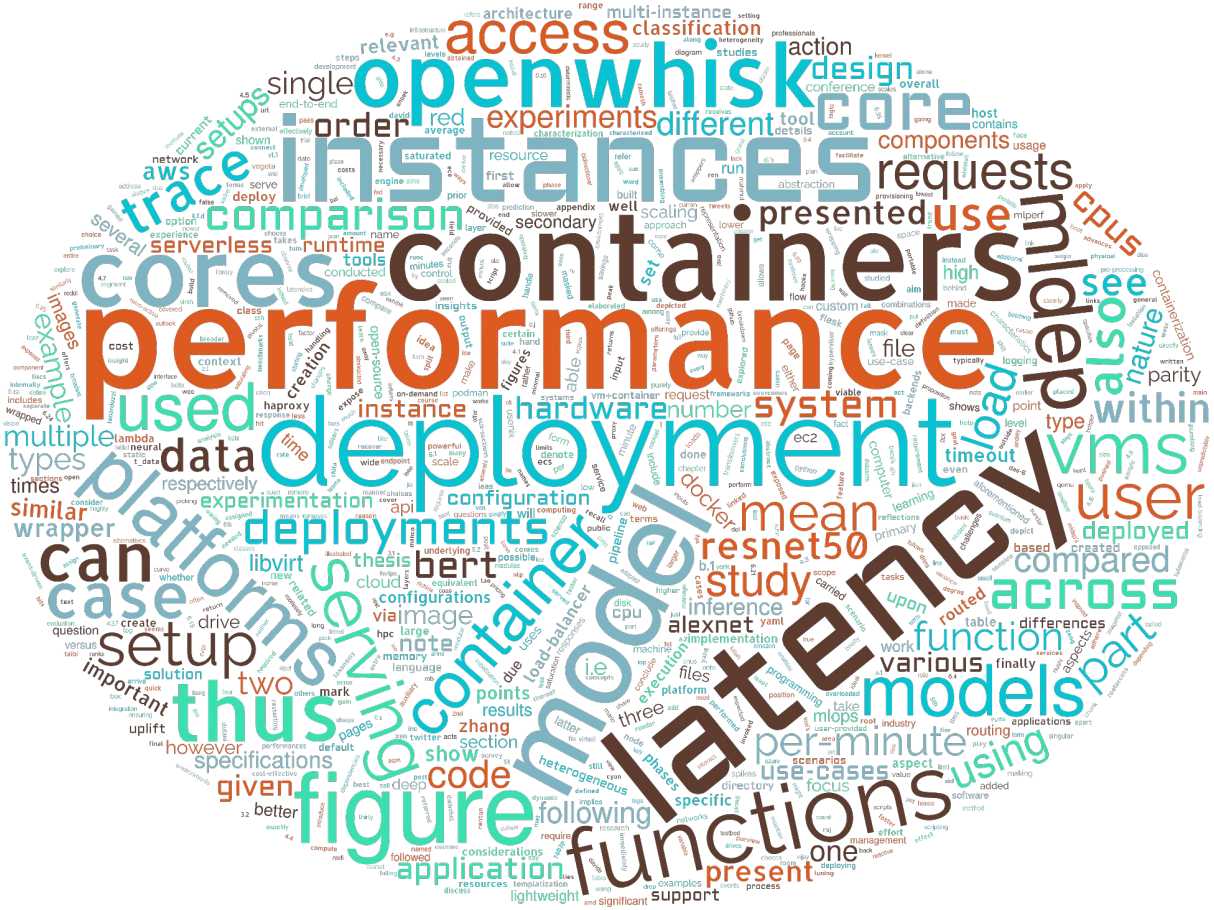
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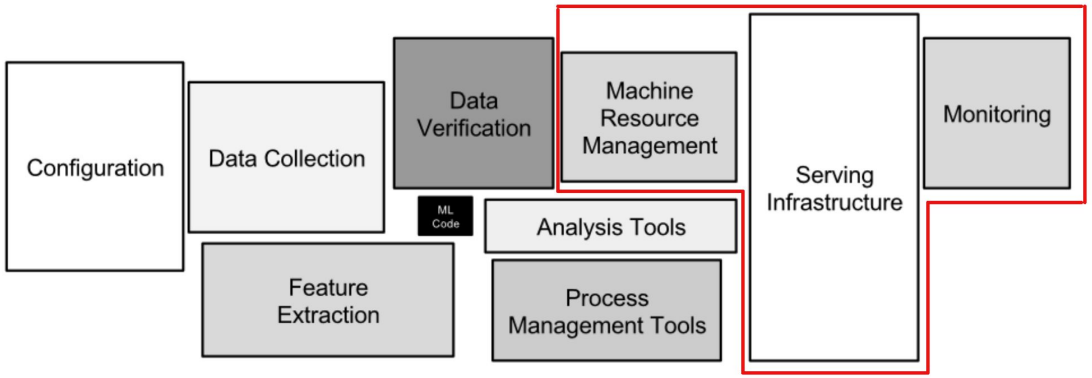
Introduction

- Inference serving
- Deployment
  - MLOps tools
  - IaaS, CaaS, FaaS
- MLDep
  - Fewer layers of abstraction
  - Light-weight, modular and extensible
  - Focus on comparison of deployment platforms
- Study on nature of deployments



Scully et al.

Amazon SageMaker

Kubeflow

H2O.ai

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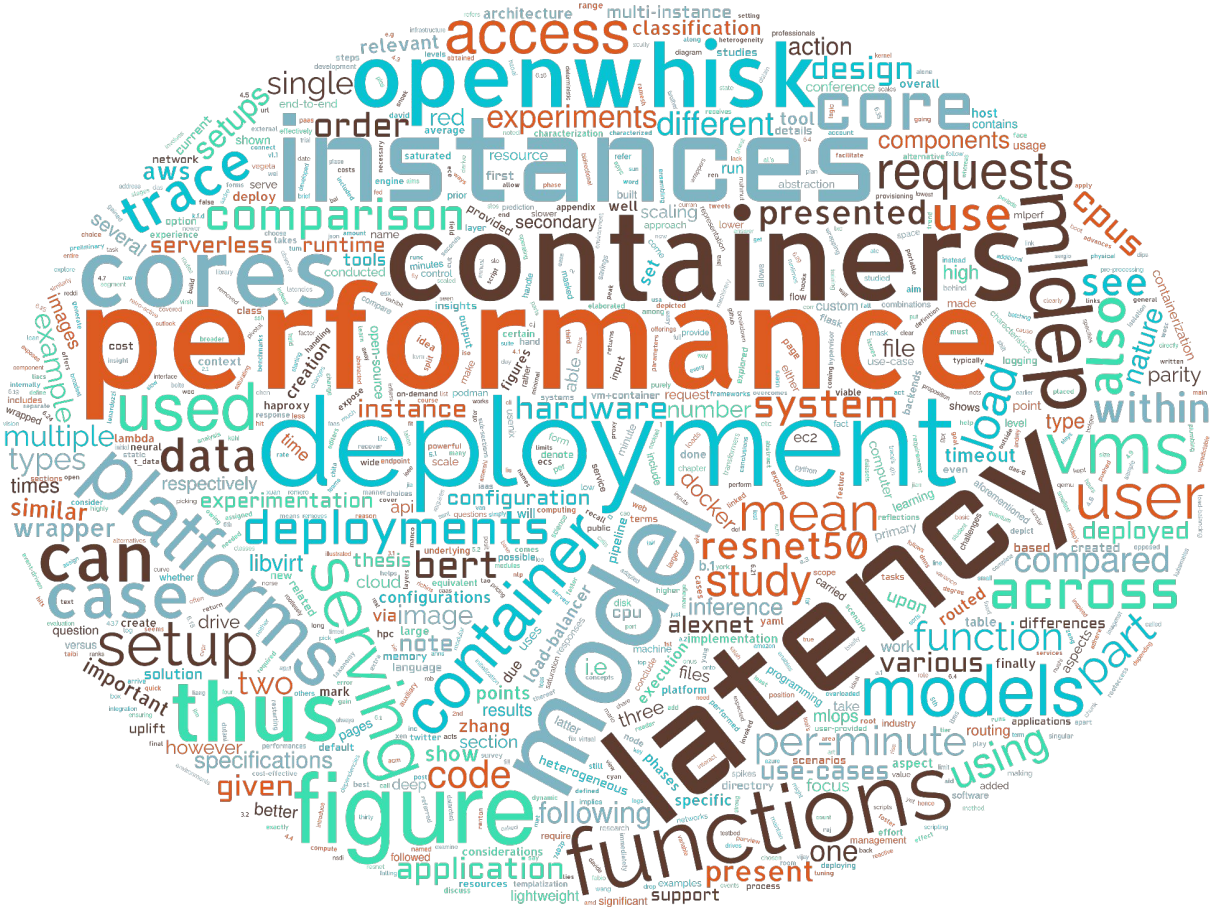

Research Questions

- What are the **potential challenges and pitfalls** associated with different deployment platforms?
- What are the **comparative performance results of the underlying deployment platforms/configurations** for currently relevant ML use-cases?

Contributions:

- Multiple deployment setups tested
- Hardware parity between platforms
- **MLDep** - Fosters **exploration** of deployment characteristics given a model

ML Model	EC2		ECS		Lambda	
	$	t (ms)	$	t (ms)	$	t (ms)
Inception-v3	5.0	210	9.17	217	19.0	380
Inception-ResNet	9.3	398	16.4	411	39.3	785
OpenNMT-ende	51.5	2180	96.3	2280	155	3100

Zhang et al.

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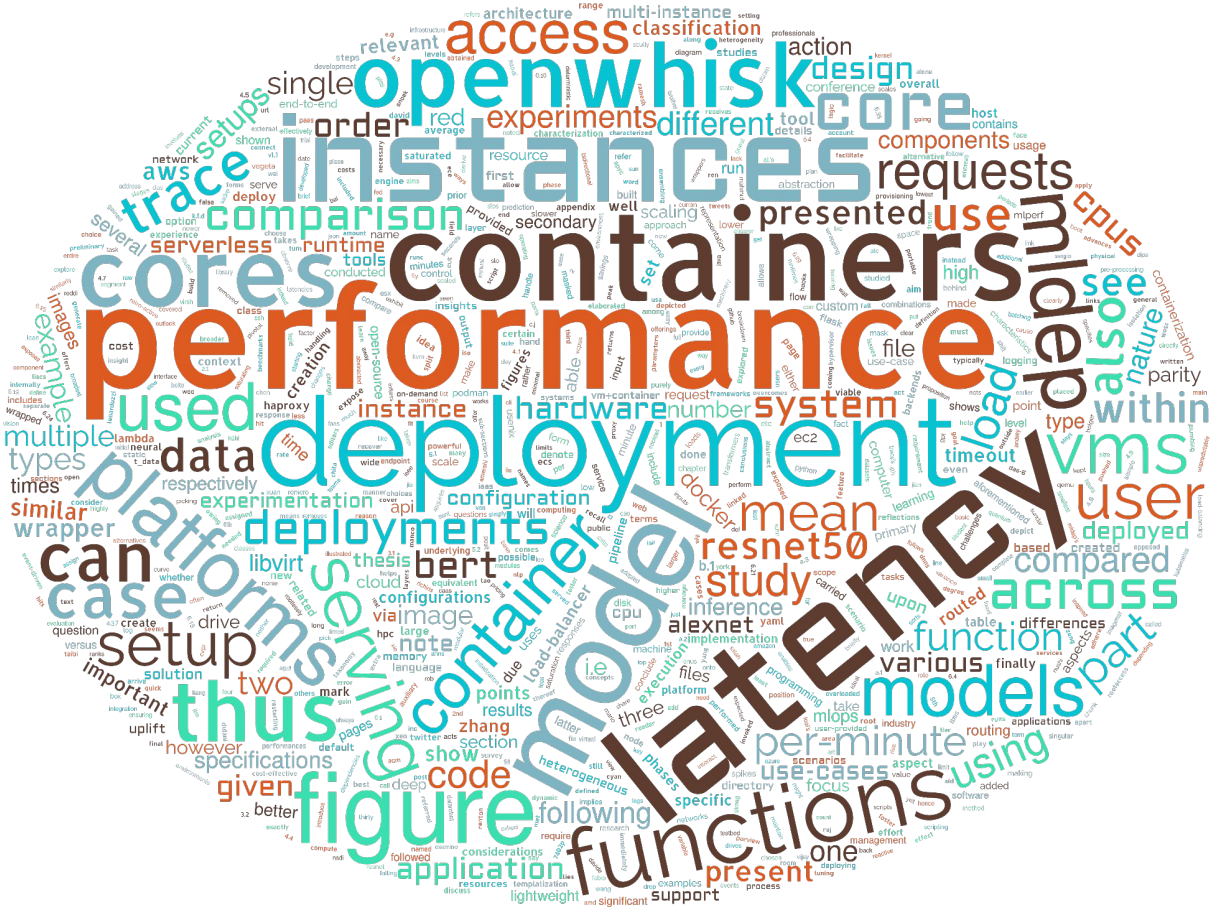
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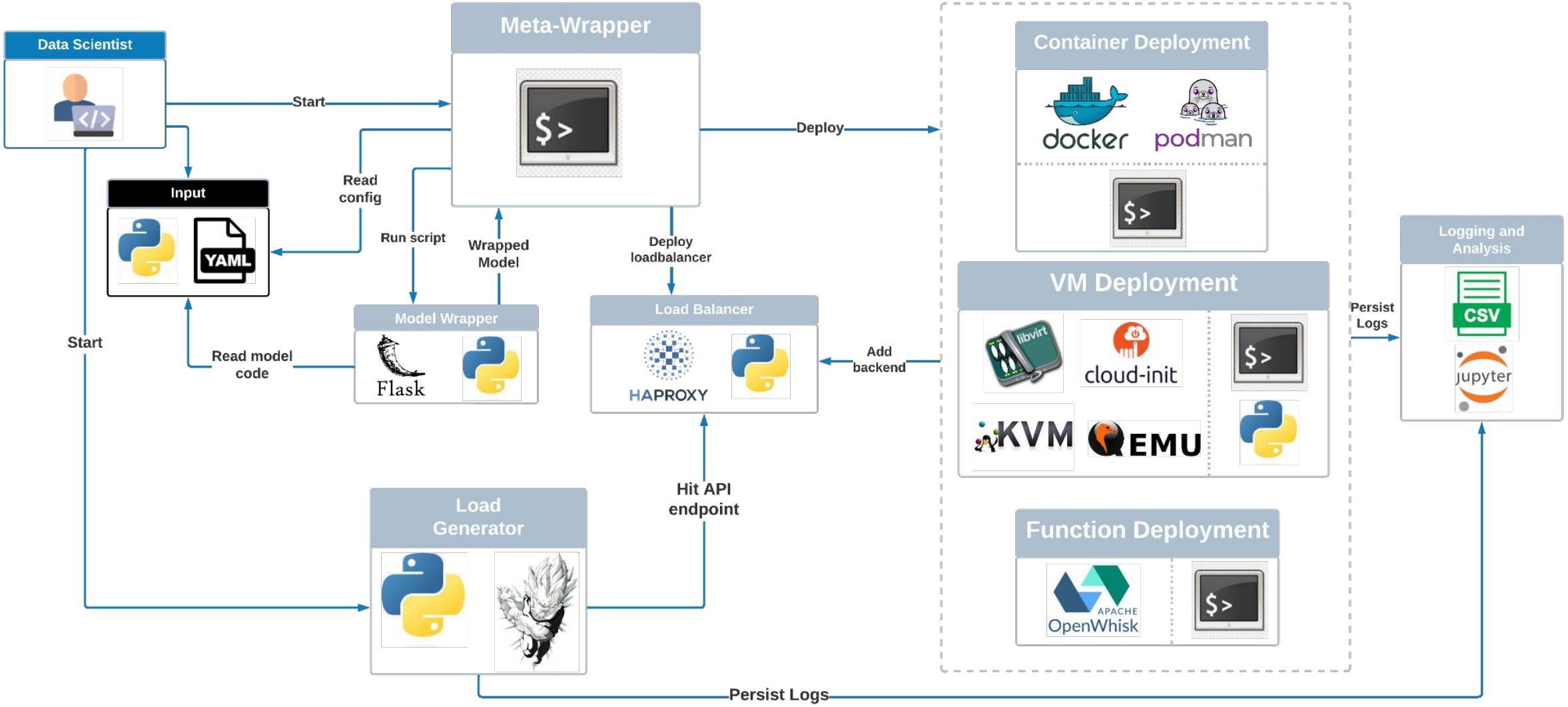
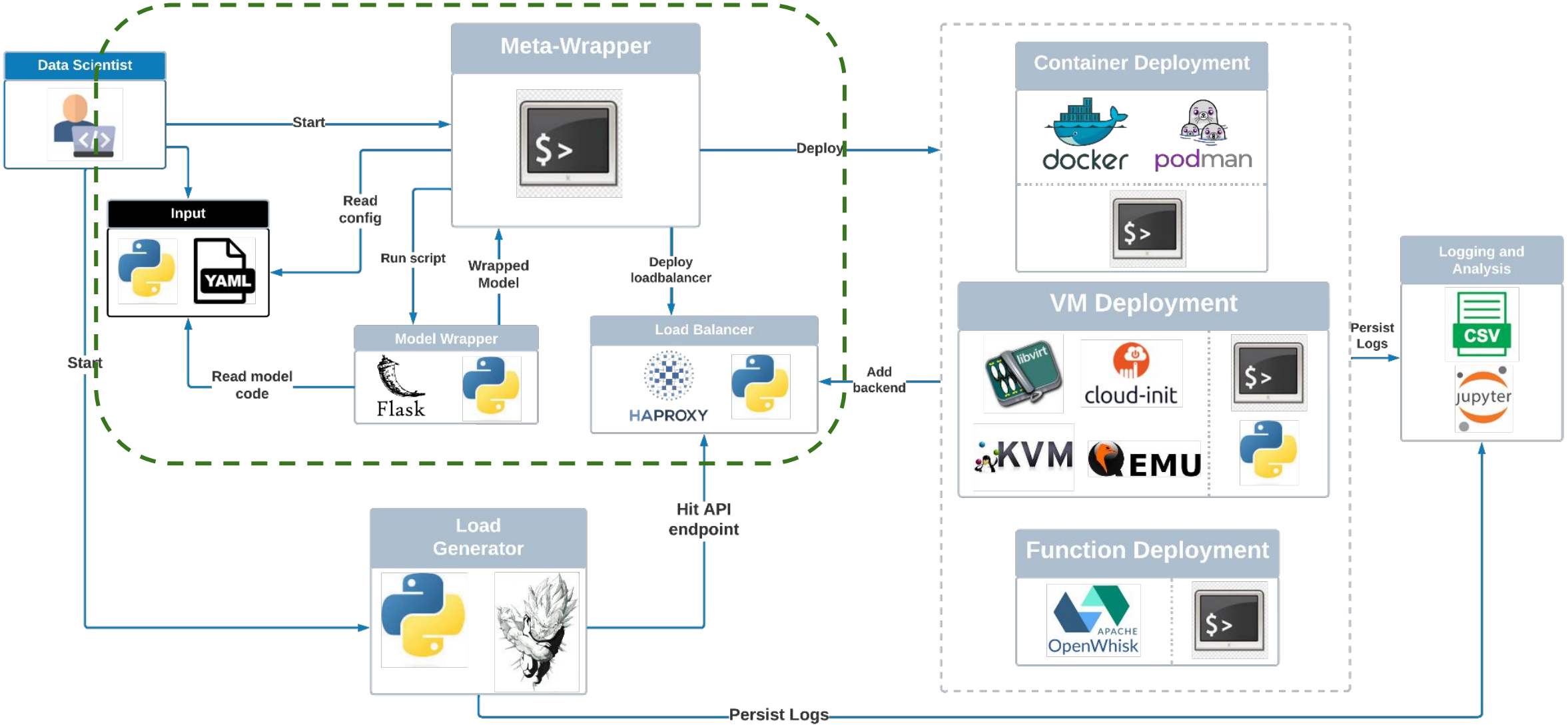
MLDep - Tech Stack

- Bash Script
- Jupyter Notebook
- Python Script or Model Code
- Podman
- cloud-init
- QEMU
- Flask
- HAProxy (Loadbalancer)
- Vegeta Load-testing
- Docker
- Libvirt
- KVM
- Apache OpenWhisk

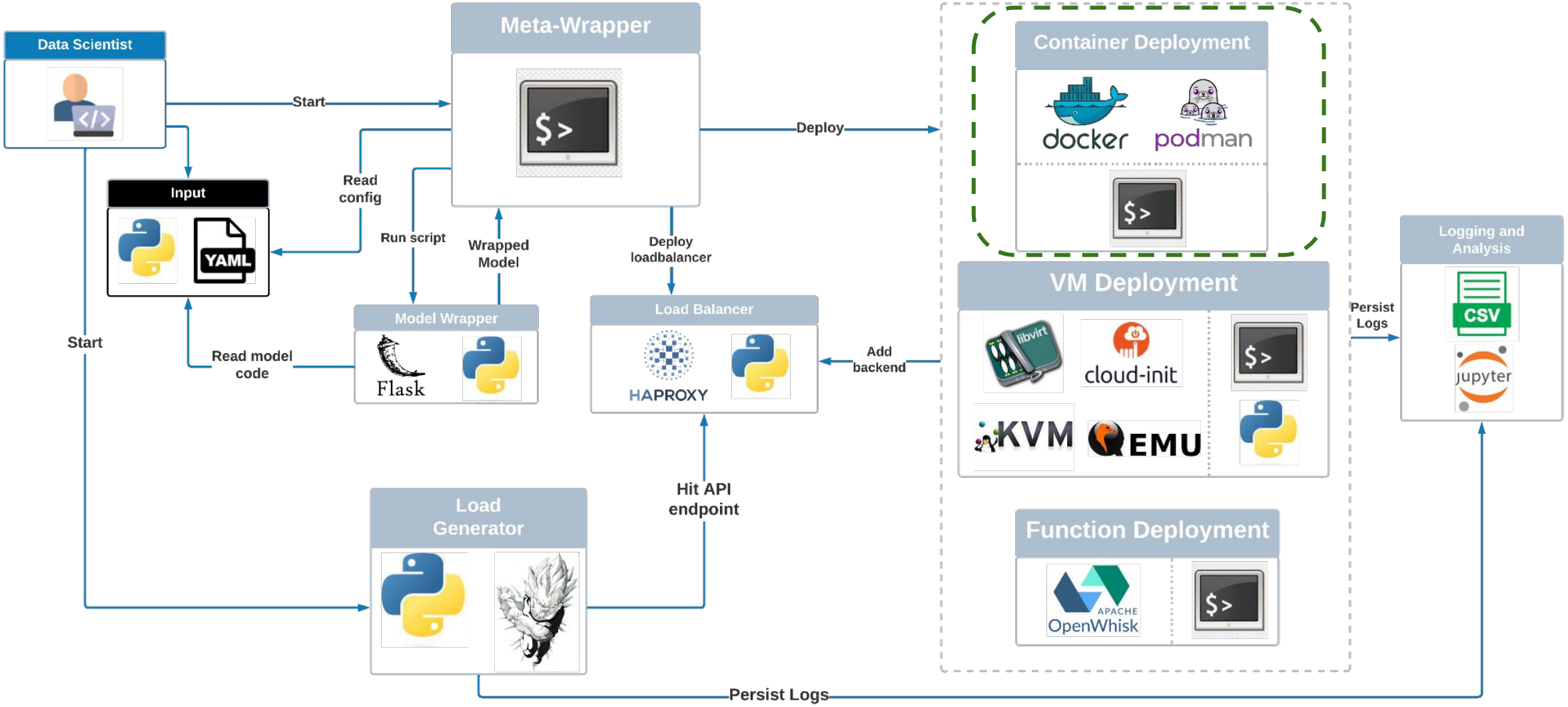
MLDep - Solution Architecture



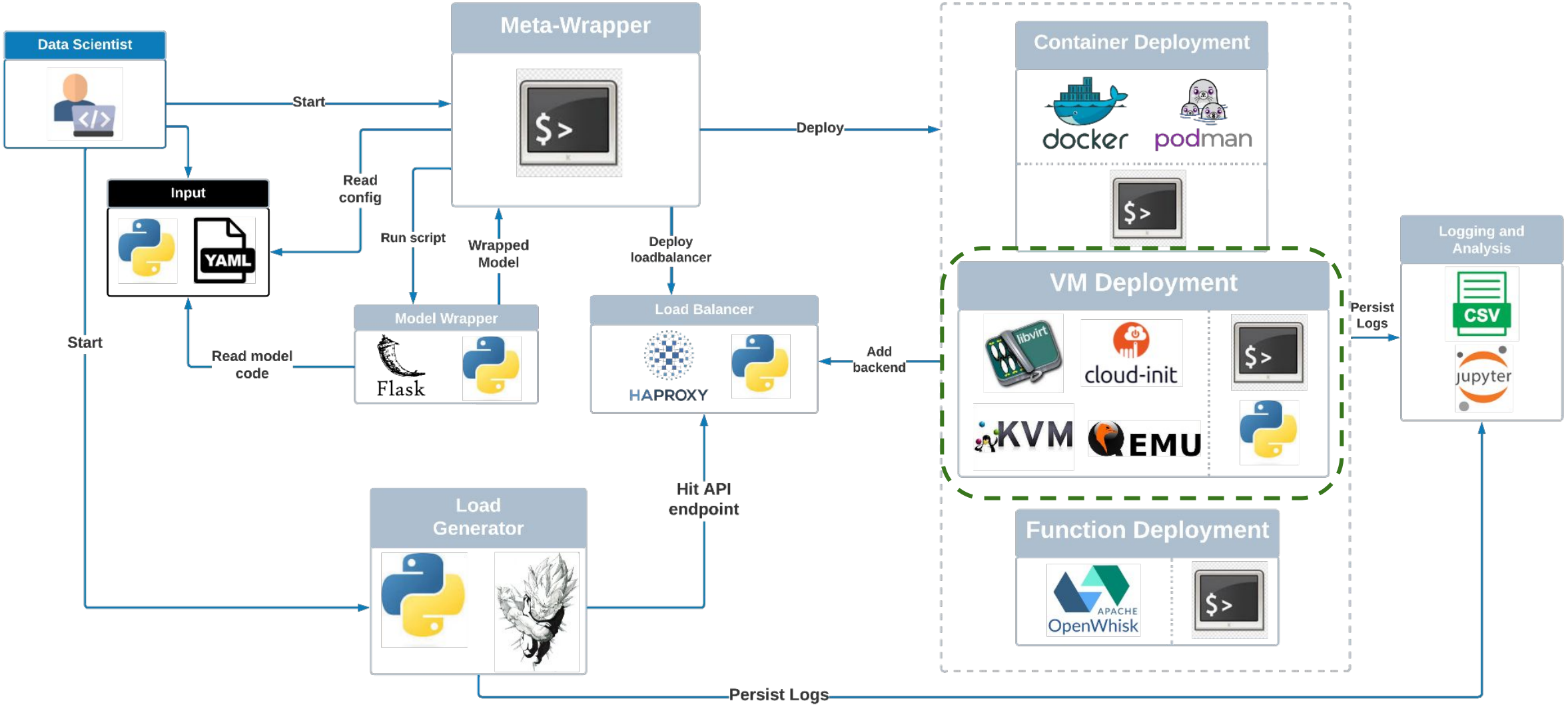
MLDep - Pre-deployment Phase



MLDep - Container Deployment



MLDep - VM Deployment



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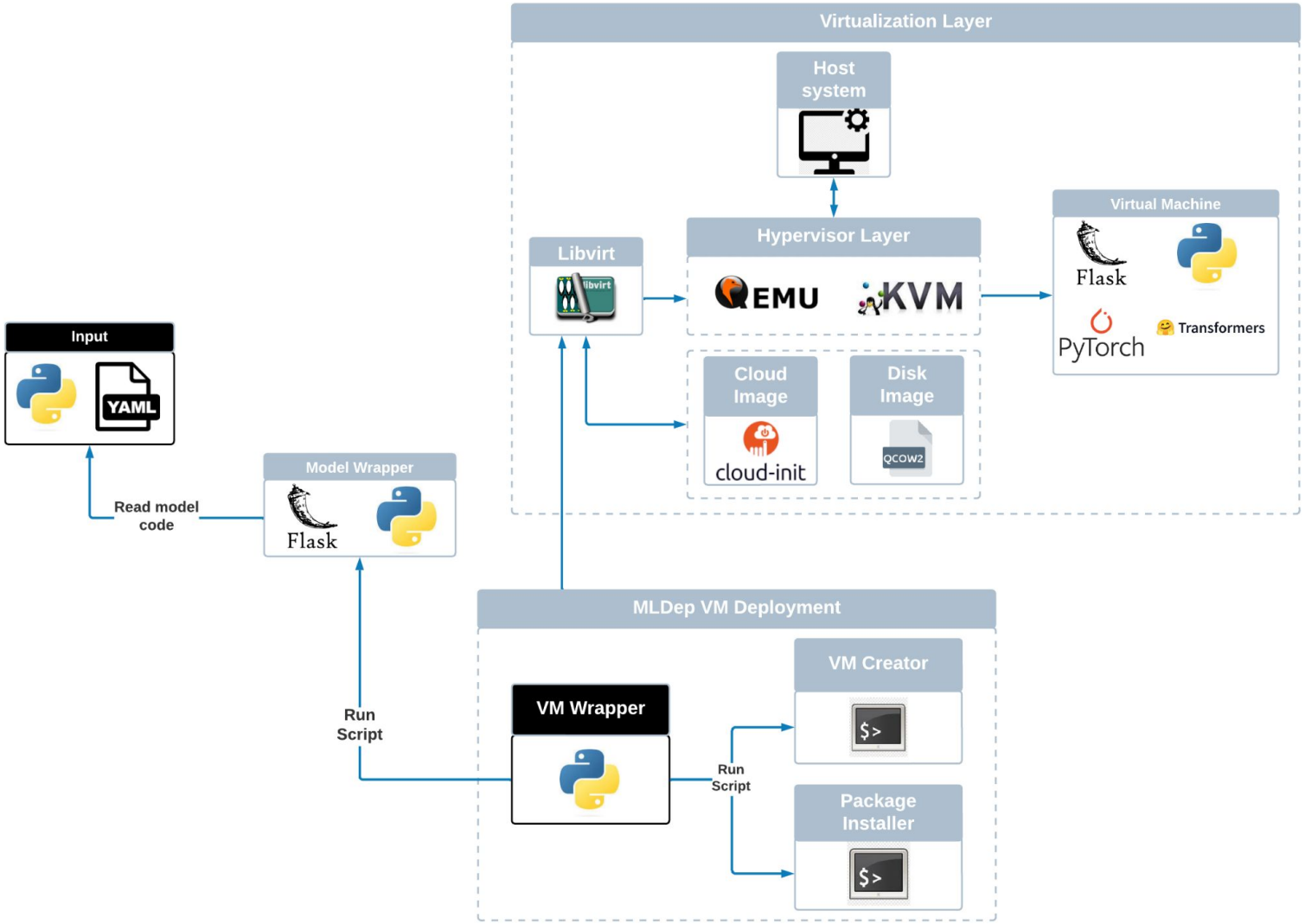
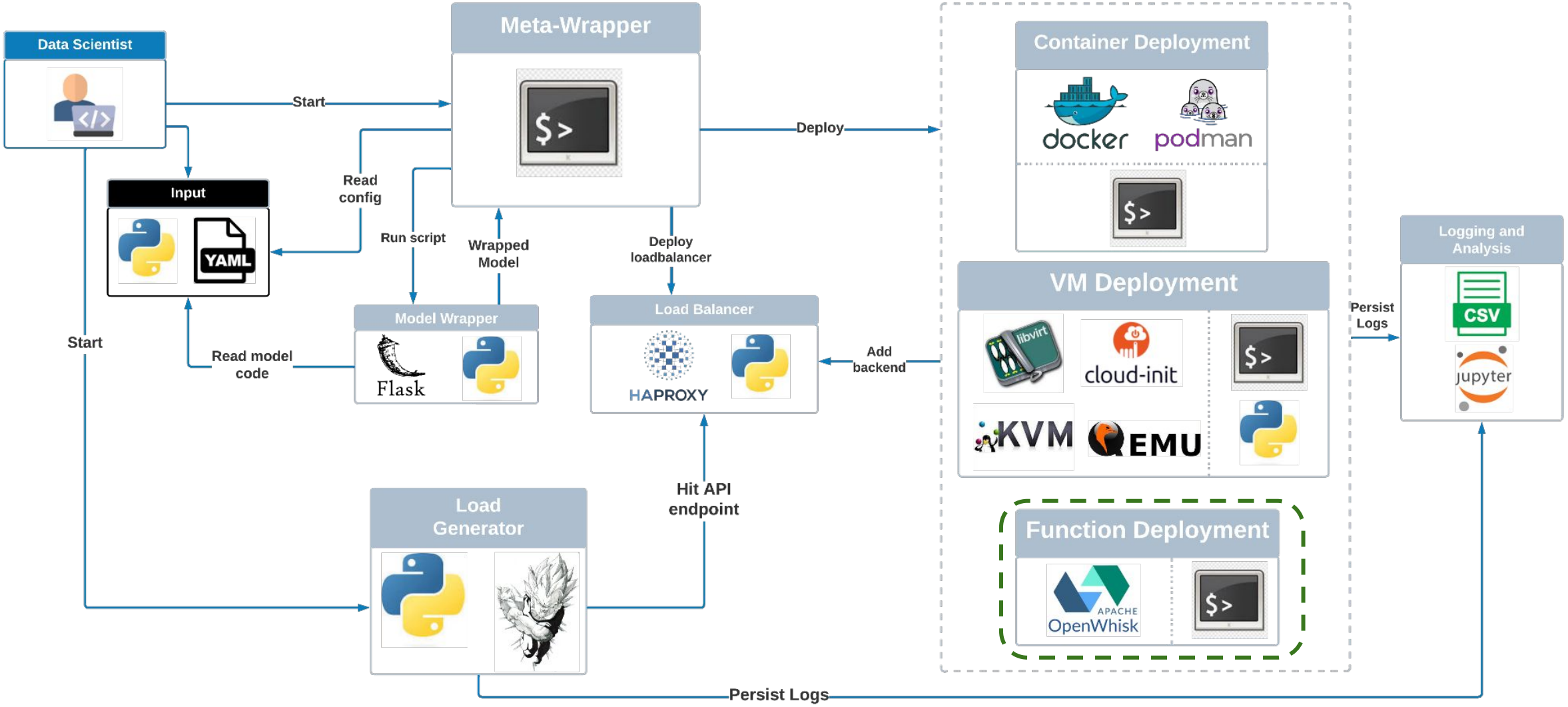
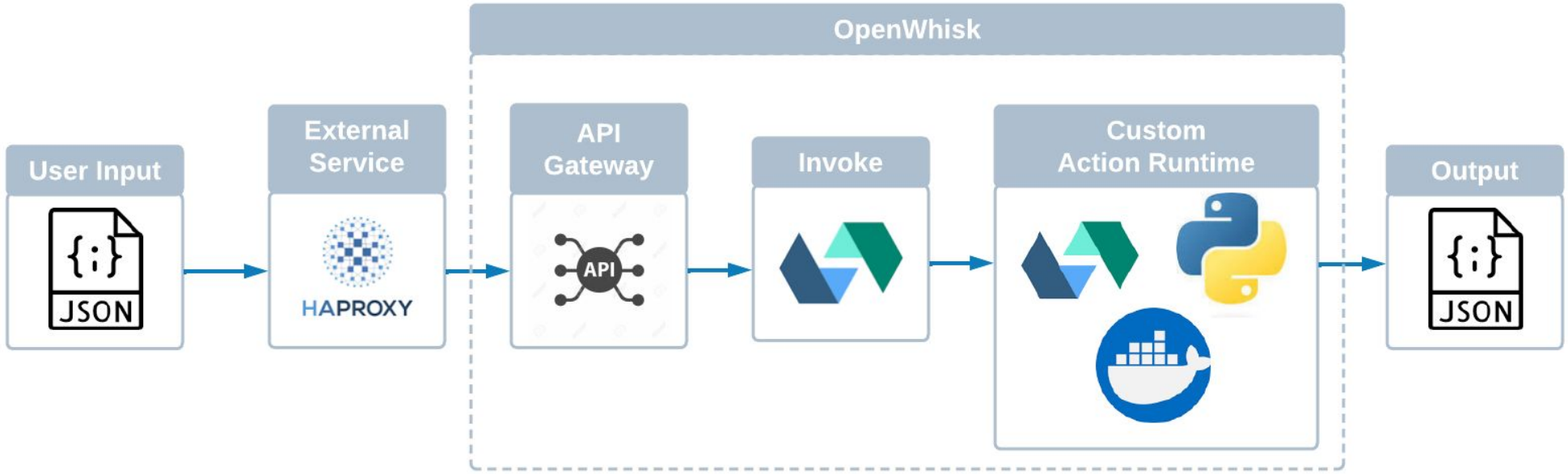


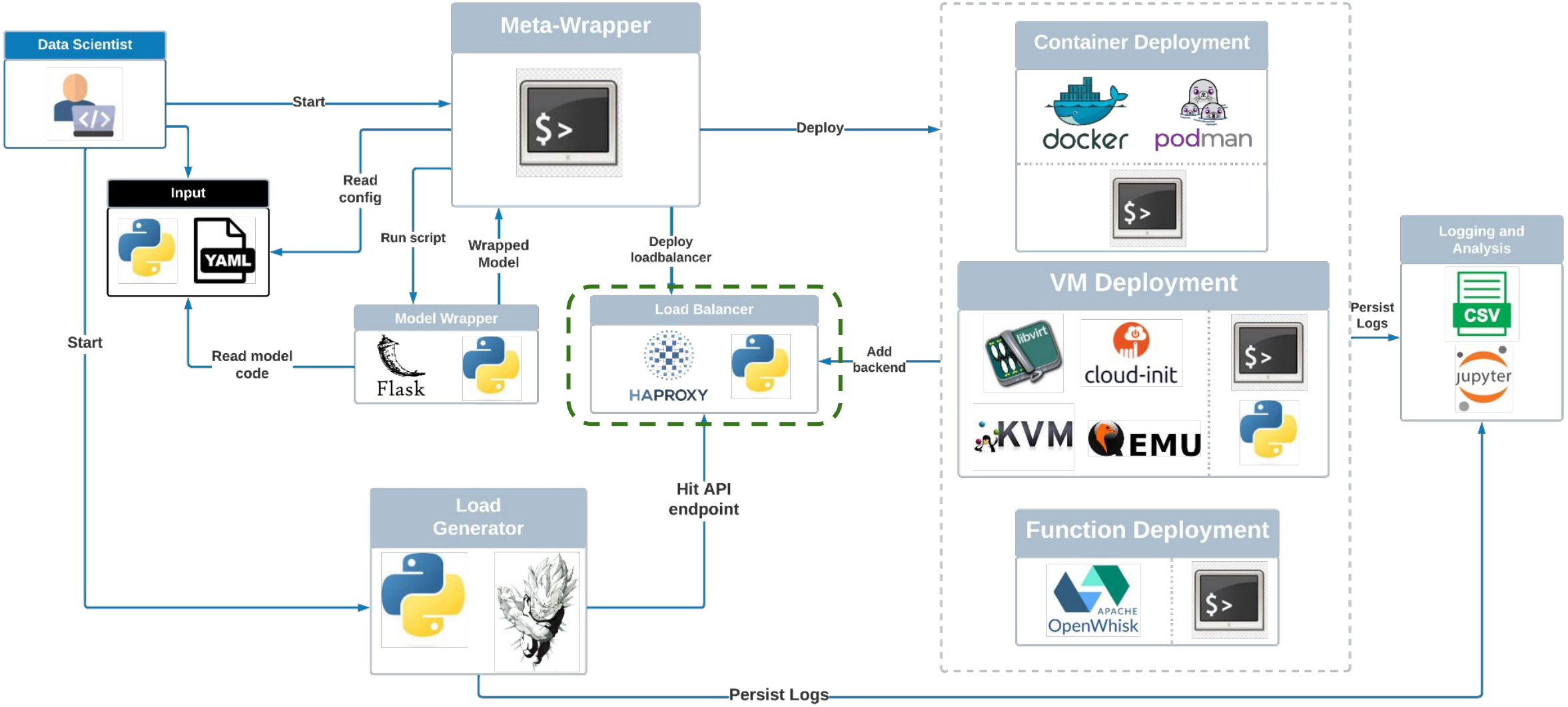
MLDep - Function Deployment



MLDep - OpenWhisk Functions



MLDep - Load-balancer



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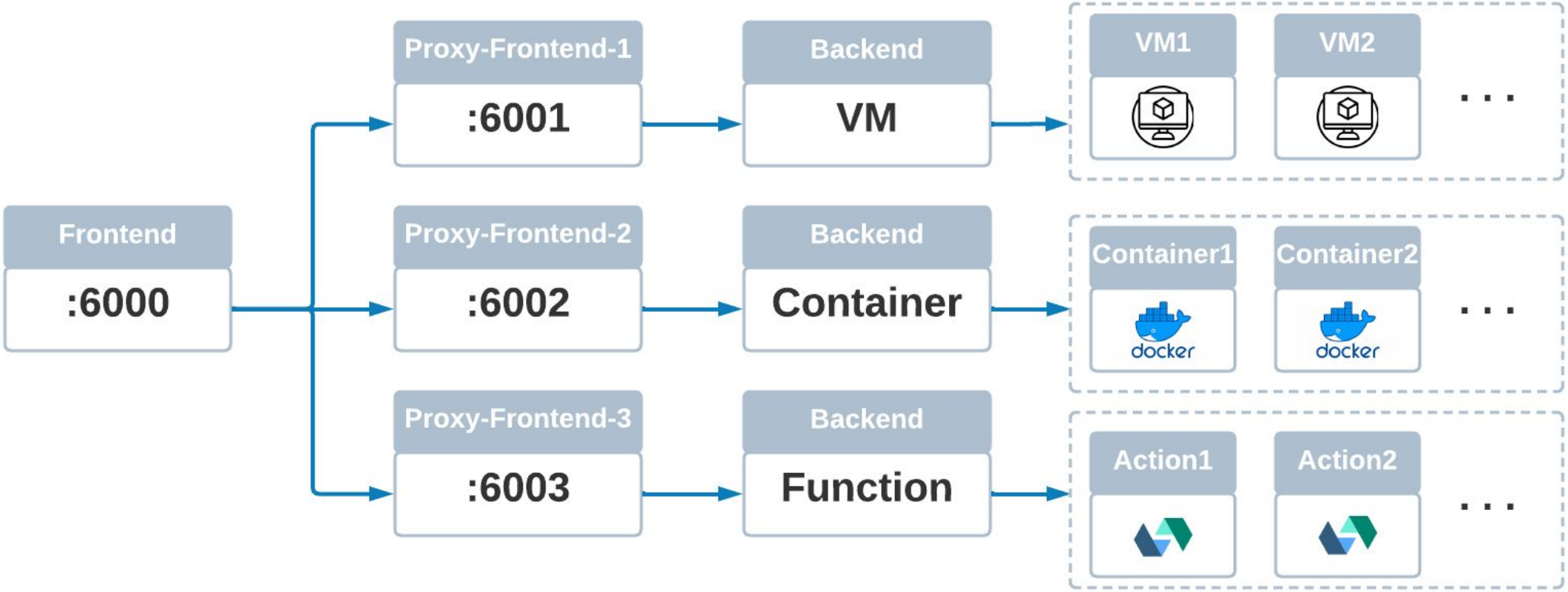

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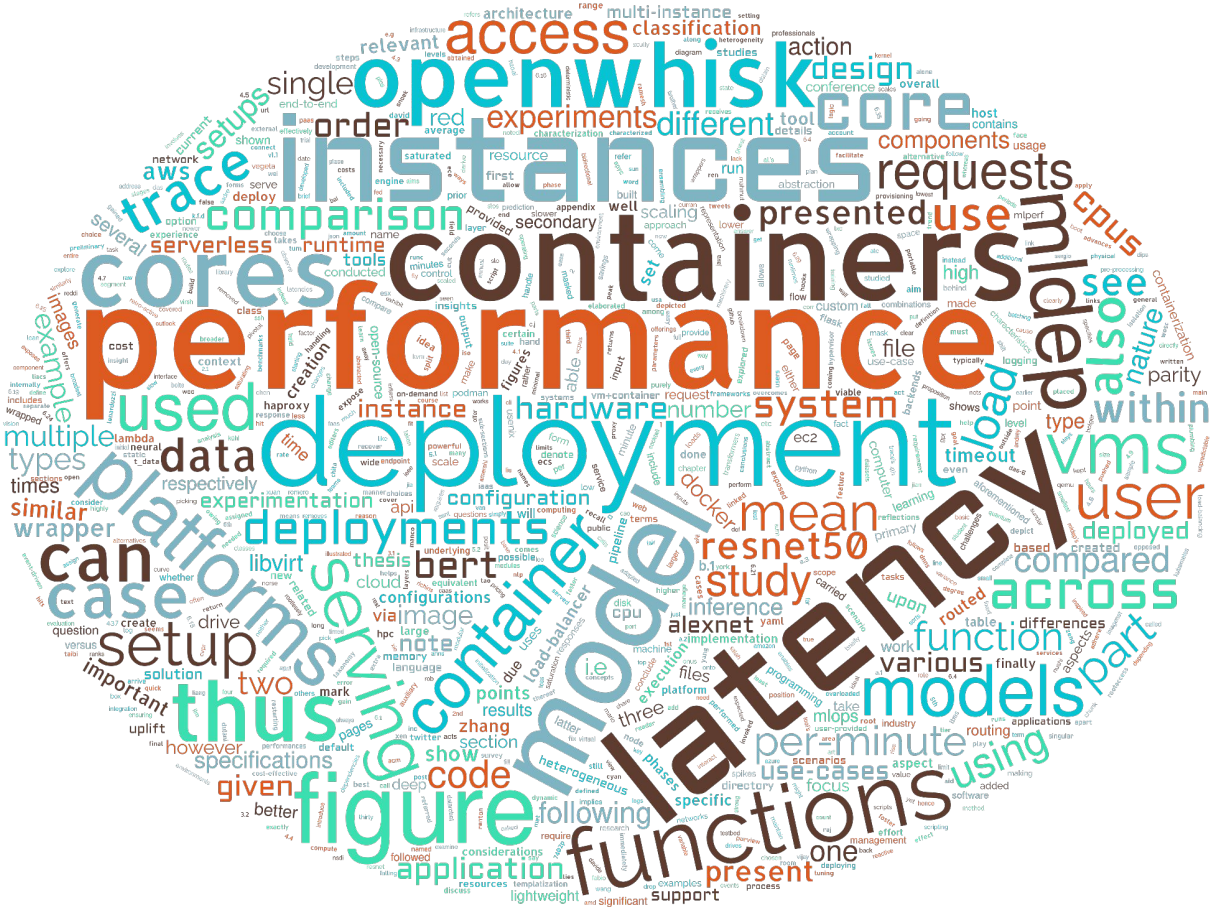
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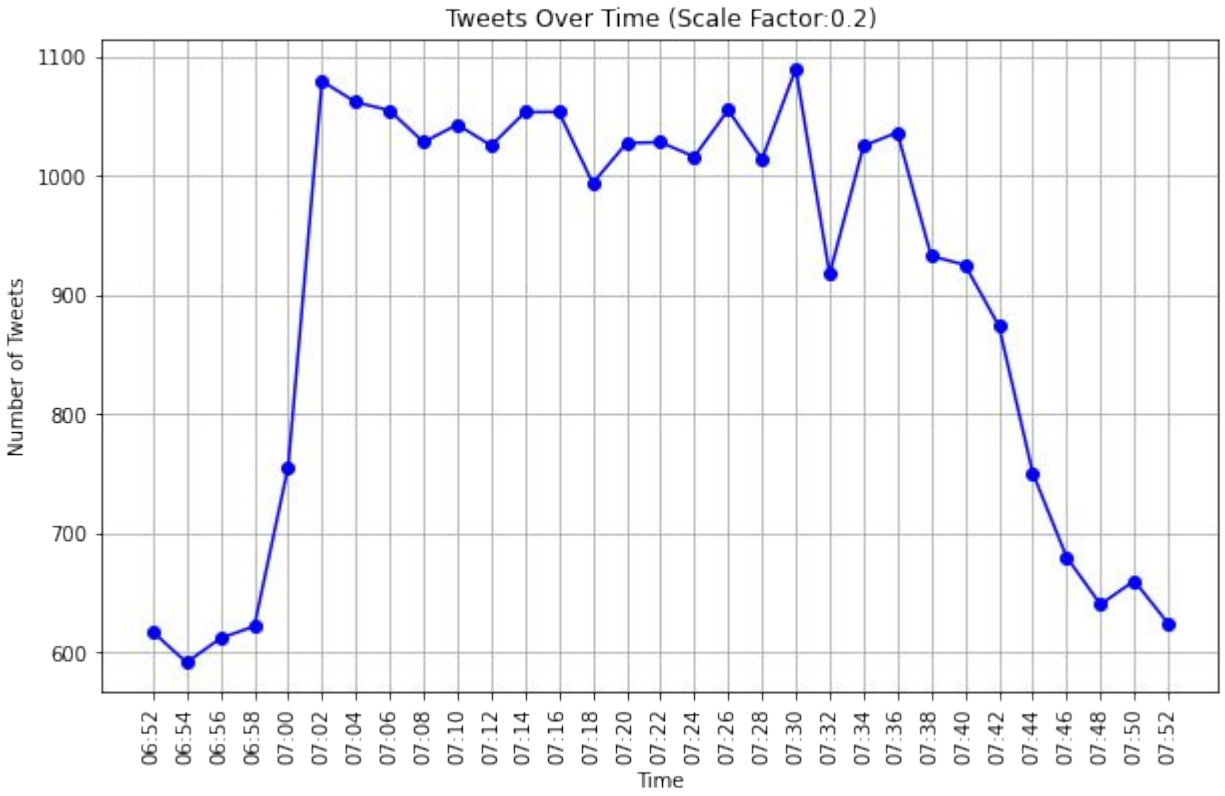
Models and Trace

Model	Use-Case	Framework/ Library	Parameters
AlexNet	Image Classification	PyTorch	62.3M
ResNet50	Image Classification	PyTorch	23.5M
BERT	Bi-directional Context Inference	Transformers	345M

- Load generation with Vegeta
- No repeated requests, uniform order across experiments
- Three phases



Experiments

- Performance across different deployment platforms and **instance types**
  - Single instance, how does performance scale with **increasing cores**?
- Performance Across **multiple instances of a single deployment platform**
  - Multiple instances with access to 2 cores each, how does performance scale with **increasing instances**?
  - Running on the same physical host, no cores shared
  - Instances vs. cores
- **Containers versus functions** in **conjunction with VMs**
  - (VM+Container) vs. (VM+Function)
  - Heterogeneous vs. Multi-Instance

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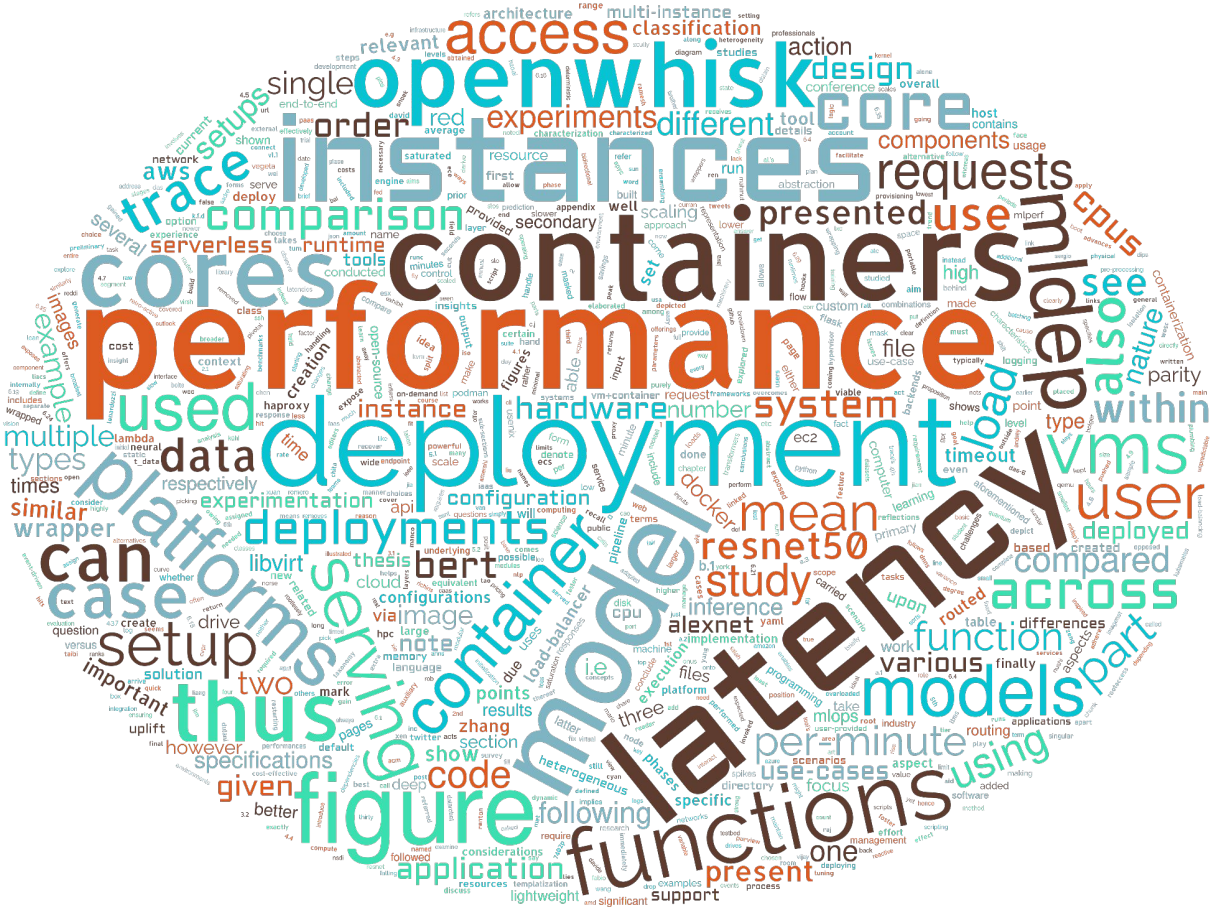
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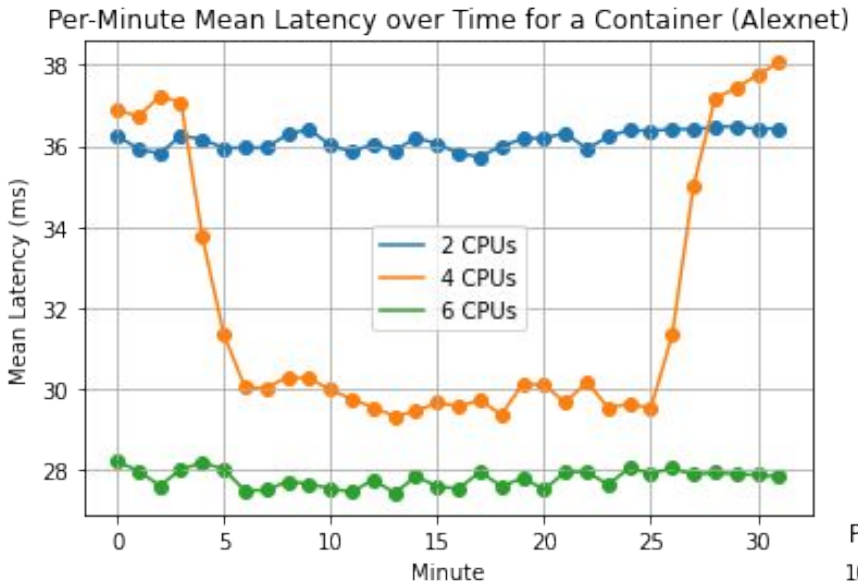
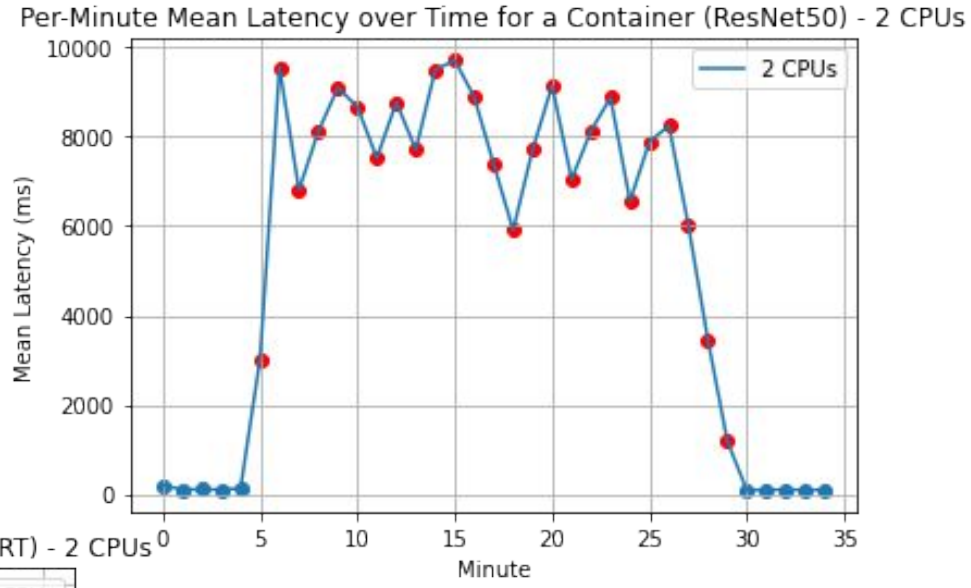
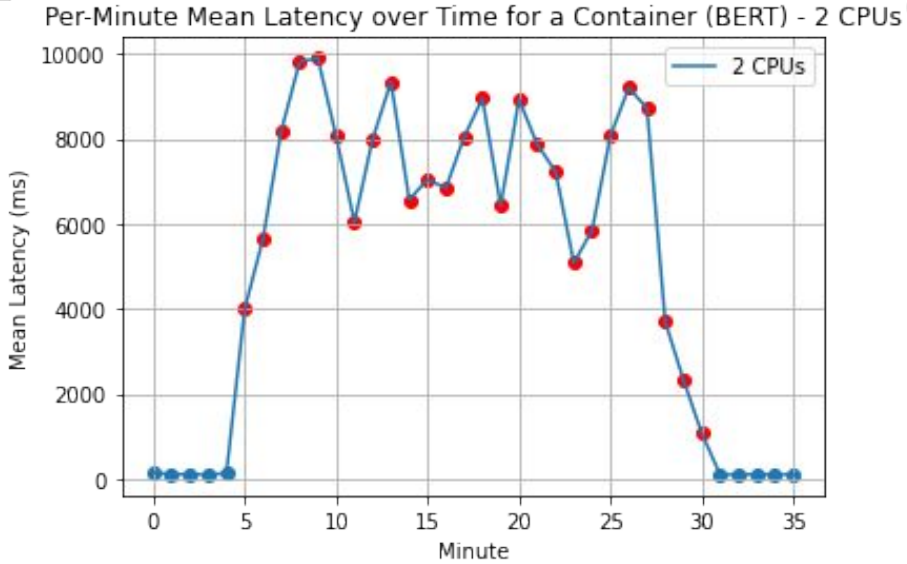
Scaling Across Cores

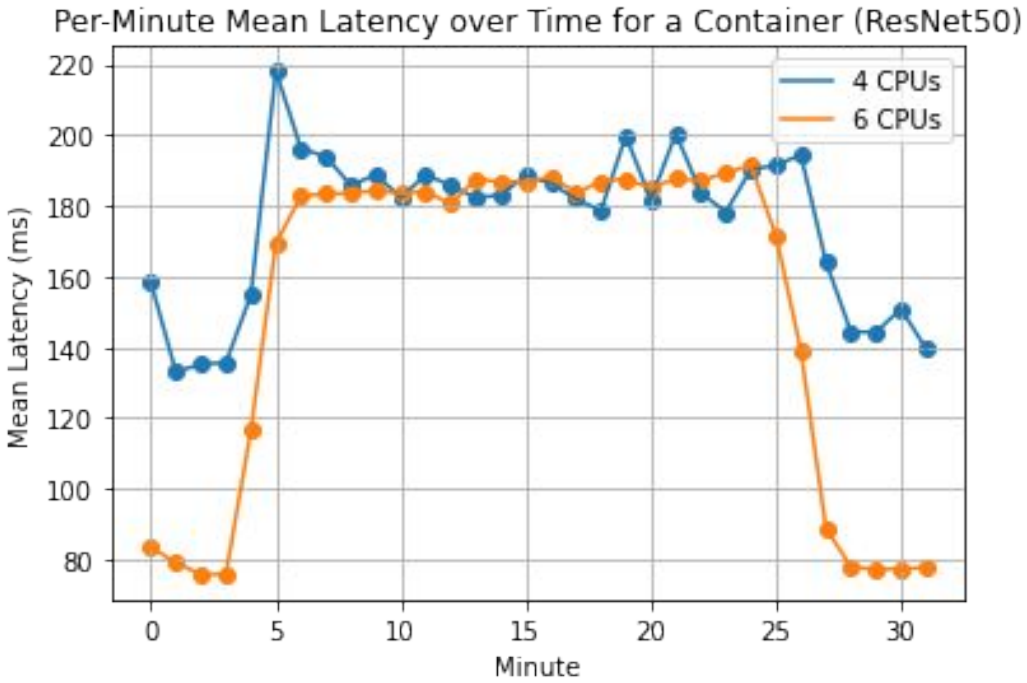
Containers - Scaling Across Cores

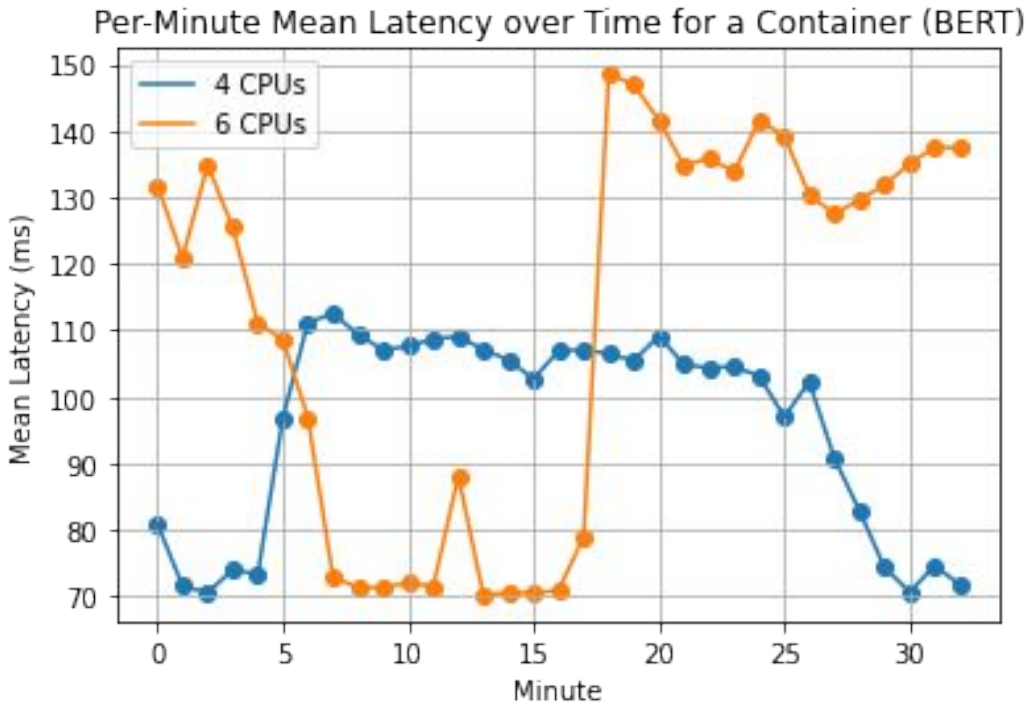






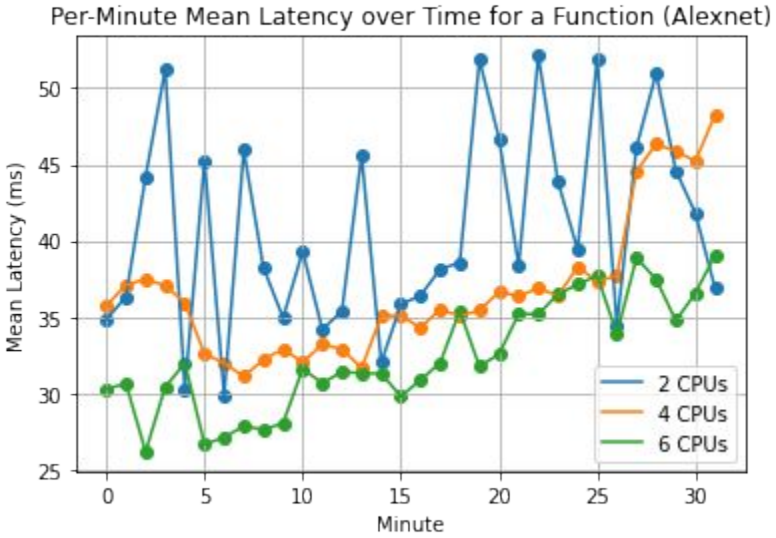
Containers - Scaling Across Cores

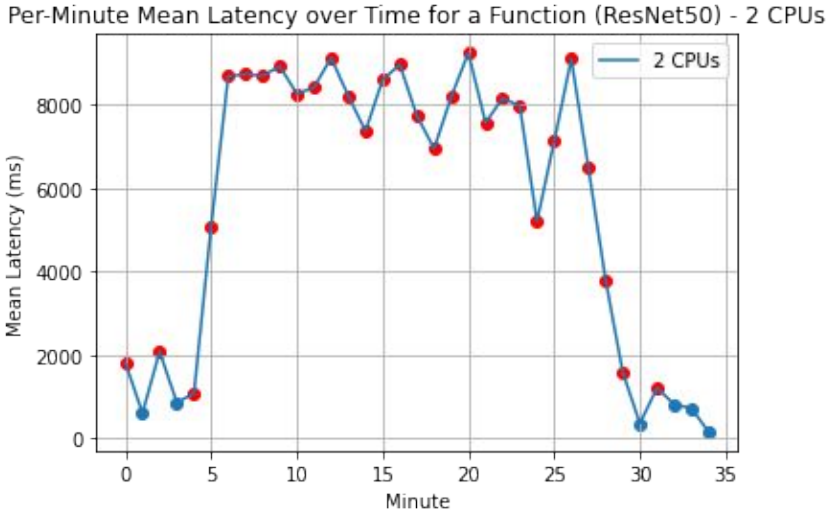


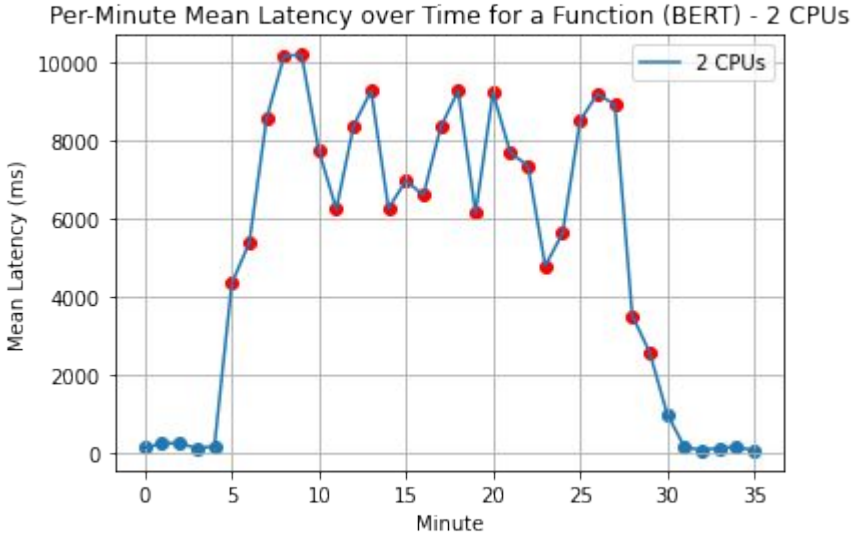


- With 2 cores we do see containers recover in the final third of the trace
- Once saturation is overcome, adding more cores leads to diminishing or no returns
- Averages include timeouts! Without this inclusion, 2 cores do in fact degrade gracefully compared to 4 and 6 cores

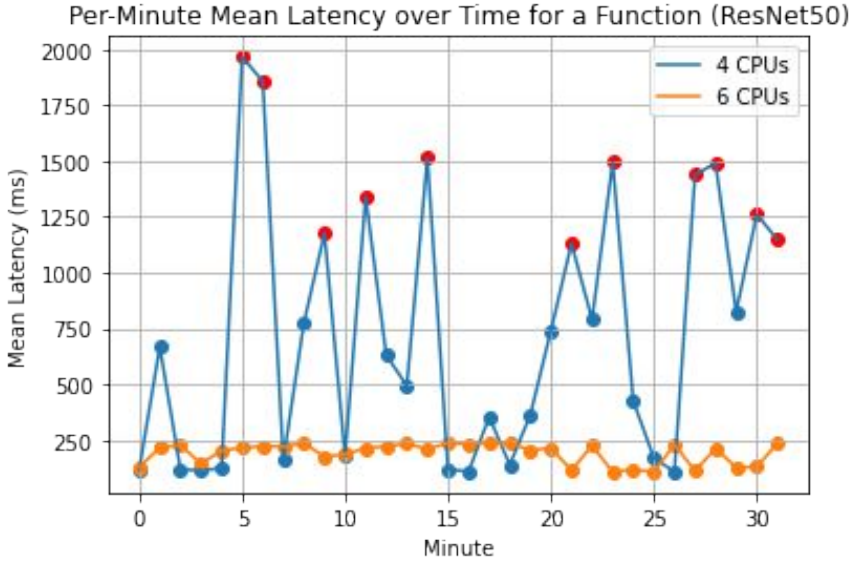
Functions - Scaling Across Cores

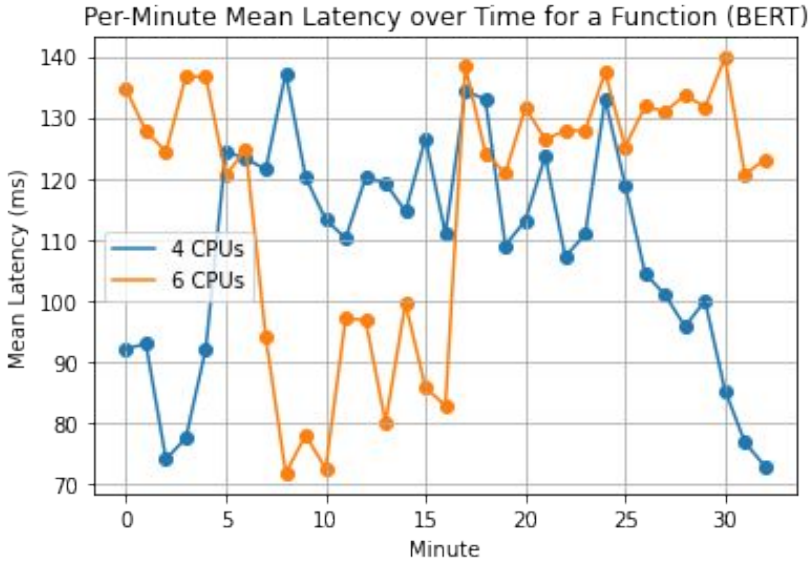




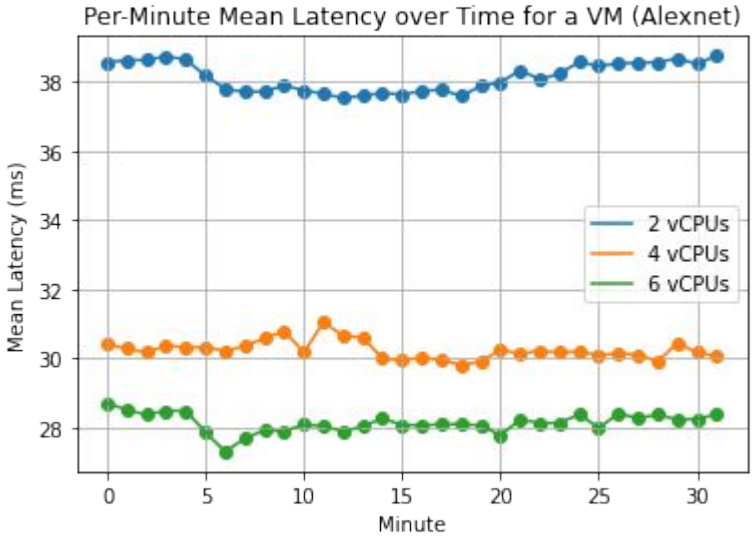


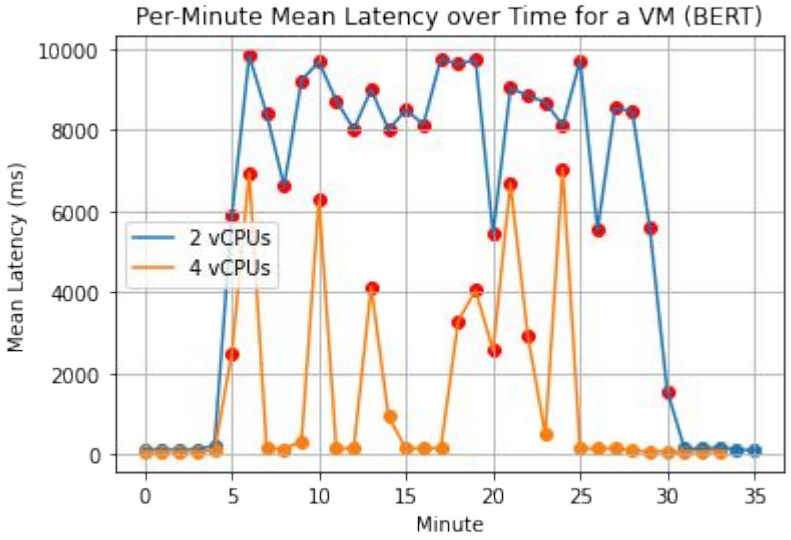
- Functions require more resources than containers
- AlexNet scales to an extent
- Response times more erratic than containers
- Scaling up - inconclusive

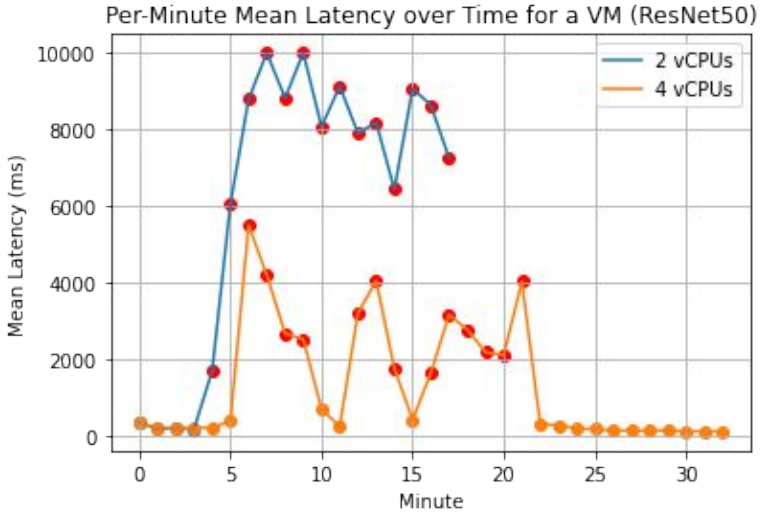




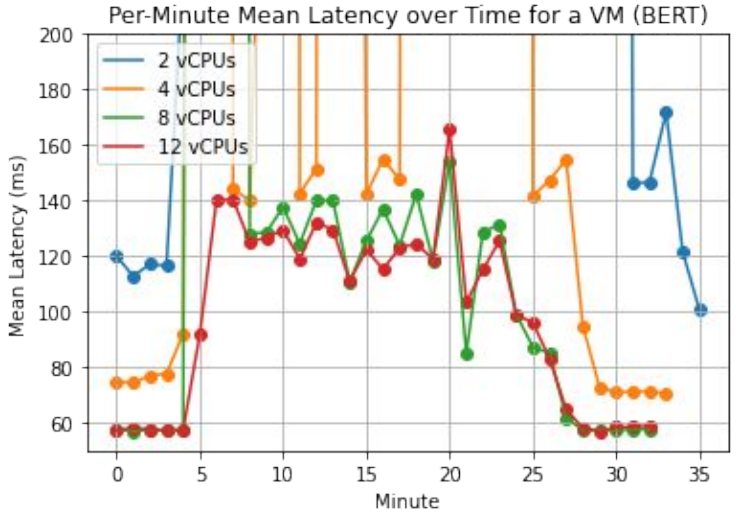
VMs - Scaling Across Cores

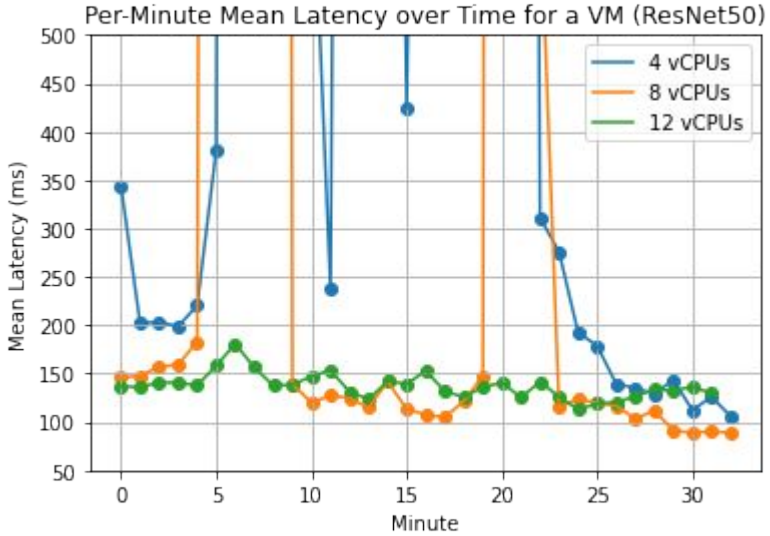






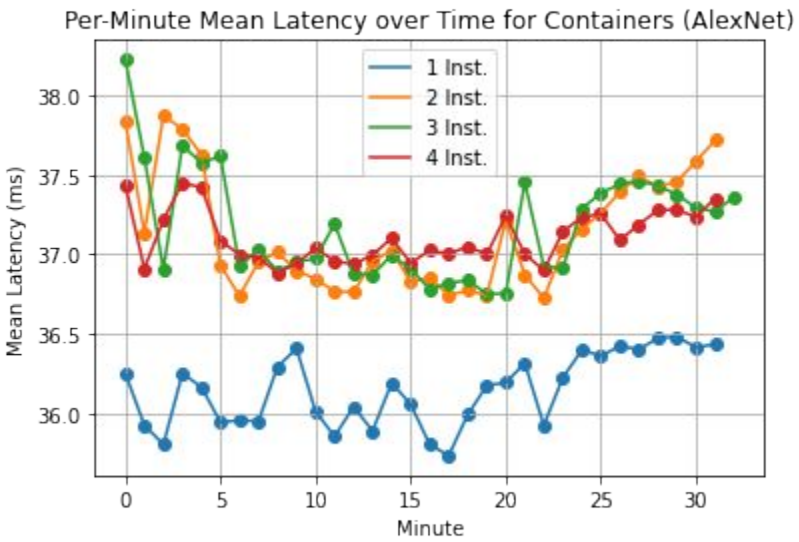
- AlexNet behaves similarly across the 3 platforms
- Even 8 cores seem to get overloaded! Quantum of overloading drops
- Performance uplift inconclusive

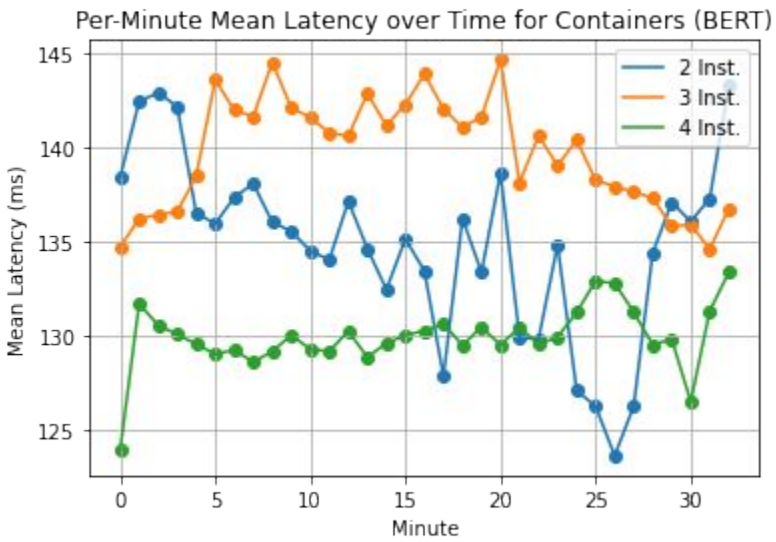


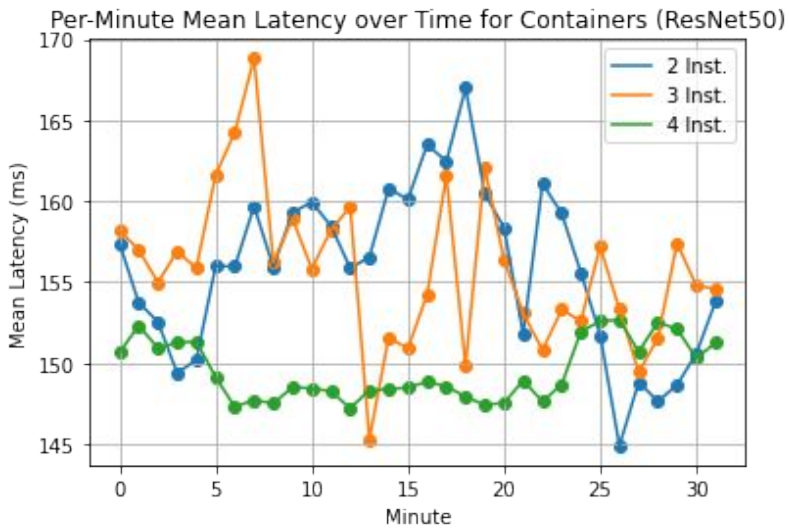


Scaling Across Instances

Containers - Scaling Across Instances

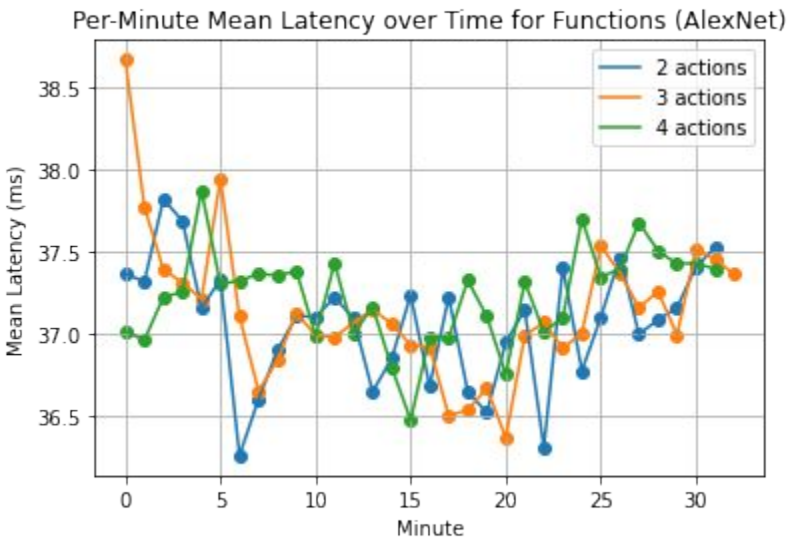


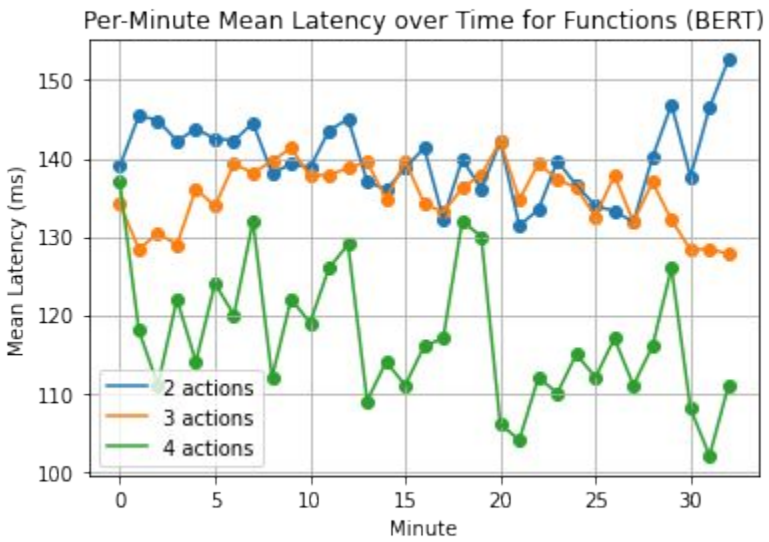


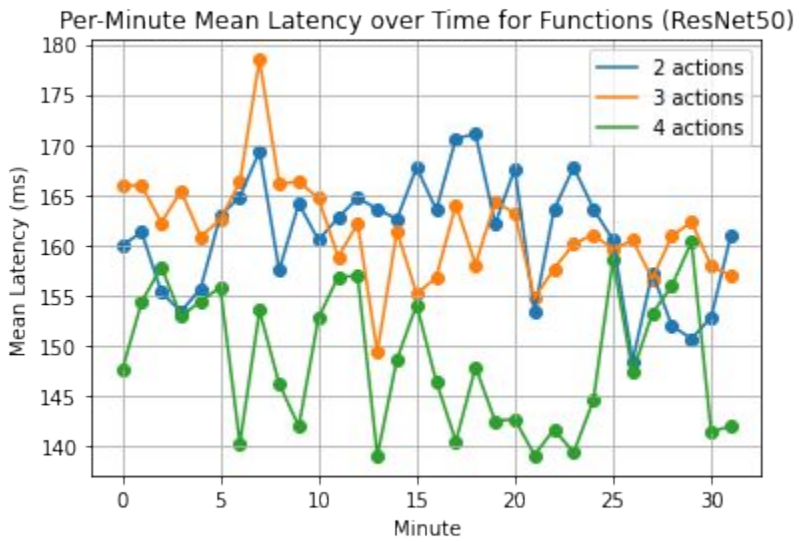


- BERT and ResNet - 4 instances the clear winner, 2 and 3 trade blows
- AlexNet is entirely unintuitive
  - Change in mean latency

Functions - Scaling Across Instances

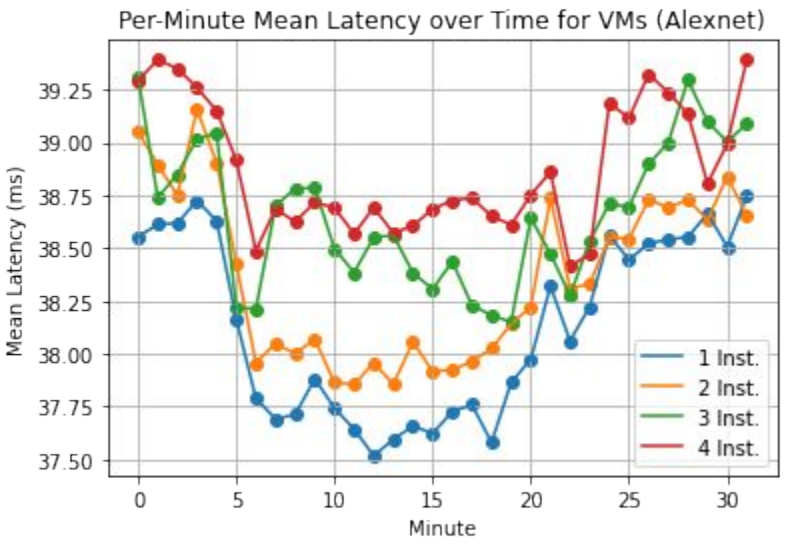


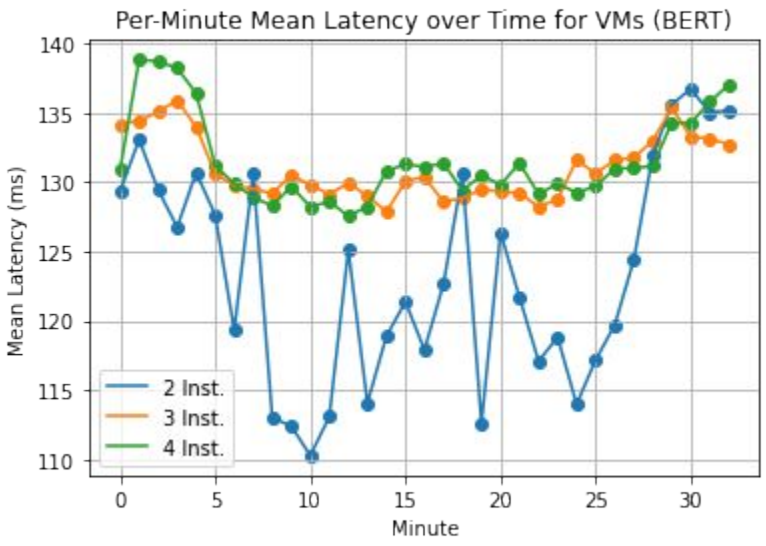


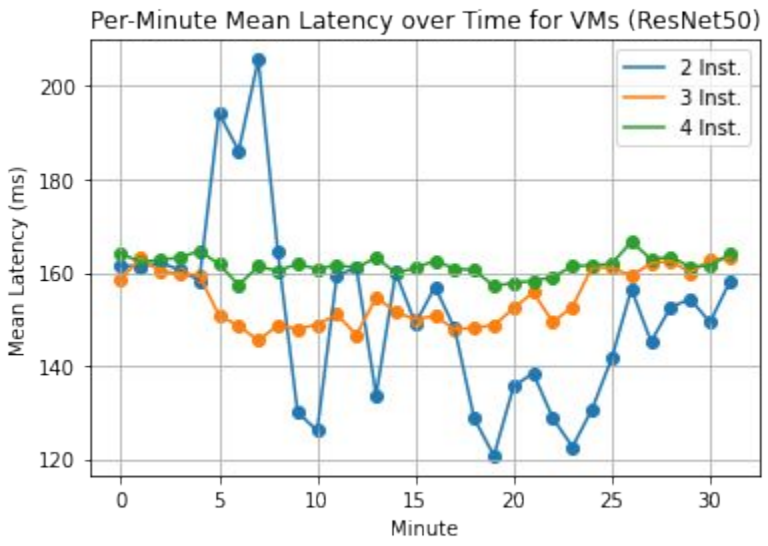


- What do multiple function instances mean? - Multiple containers vs. multiple actions
- With ResNet and BERT, 4 stands apart, 2 and 3 trade blows
- AlexNet does not scale out (Remember containers!)

VMs - Scaling Across Instances







- The setup with minimum number of instances that can effectively handle peak load wins
- 3 and 4 instance setups yield more predictable latencies
- 4 instances of 2 cores each flattens the curve better than a single 8 core instance

Scaling - Cores vs. Number of Instances

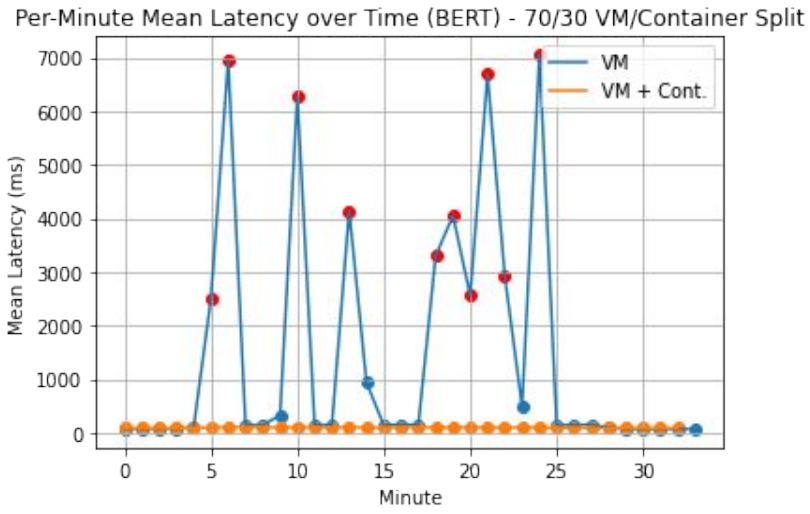
	Setup	Mean Latency (ms)	Setup	Mean Latency (ms)
Container	4 cores	175.7	6 cores	151.3
	2 instances	155.9	3 instances	155.8
Function	4 cores	Overloaded	6 cores	191.7
	2 instances	161.2	3 instances	160.3
VM	4 cores	Overloaded	8 cores	Overloaded
	2 instances	151.3	4 instances	161.5

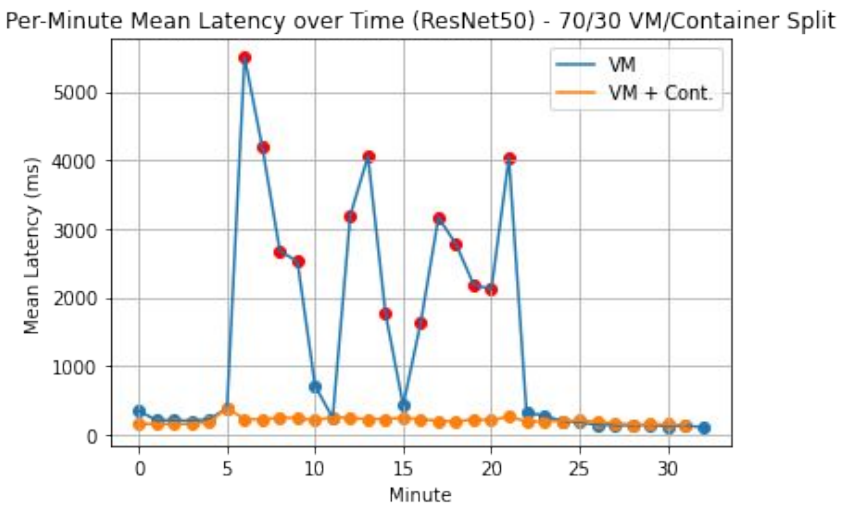
- Learning -
  In the case of equivalent hardware, scaling out less powerful hardware > scaling up
- Caveat - hardware parity, cost benefit
- Increasing number of instances is a good option, but is there another?

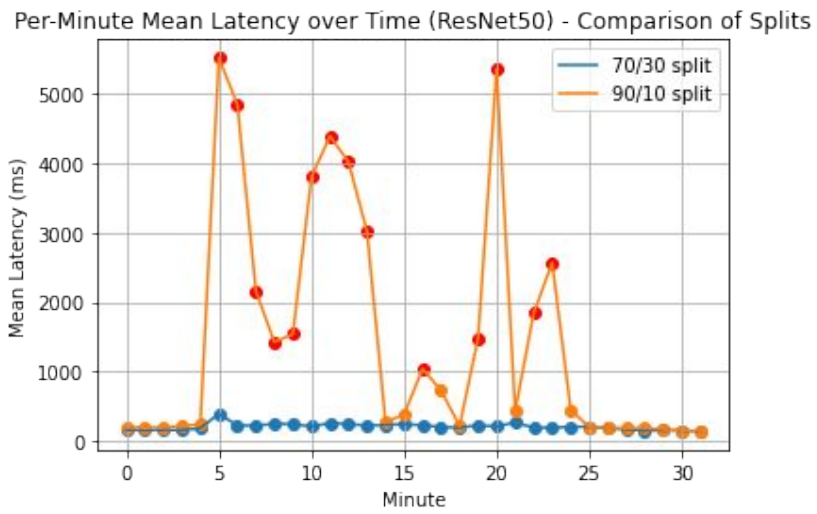
c5.large	$0.062	27%	$0.085
c5.xlarge	$0.123	28%	$0.17
c5.2xlarge	$0.246	28%	$0.34
c5.4xlarge	$0.493	28%	$0.68

Heterogeneous Setups

Heterogeneous Setups - Containers as the Secondary Deployment

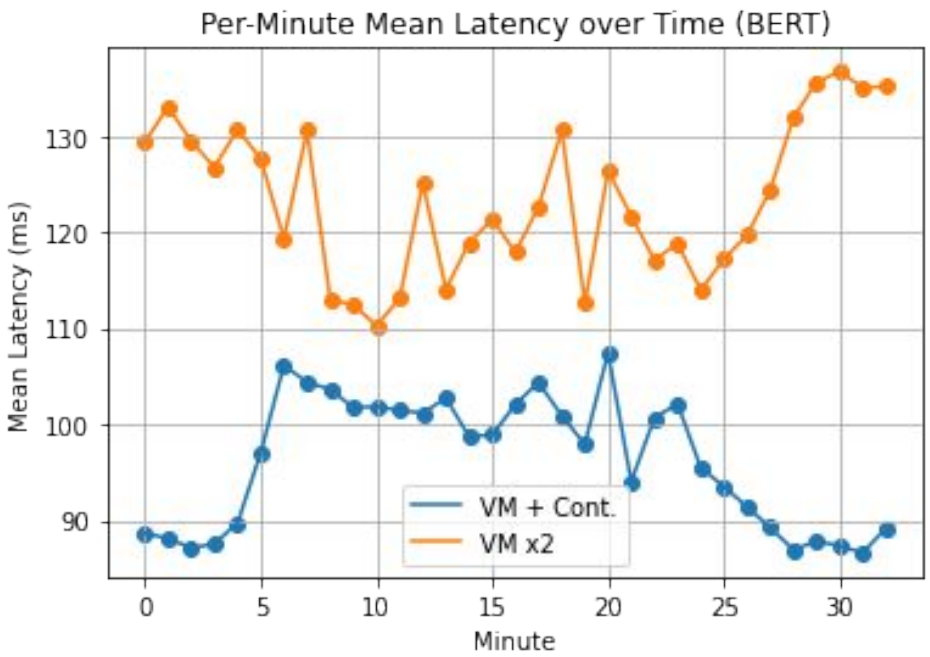


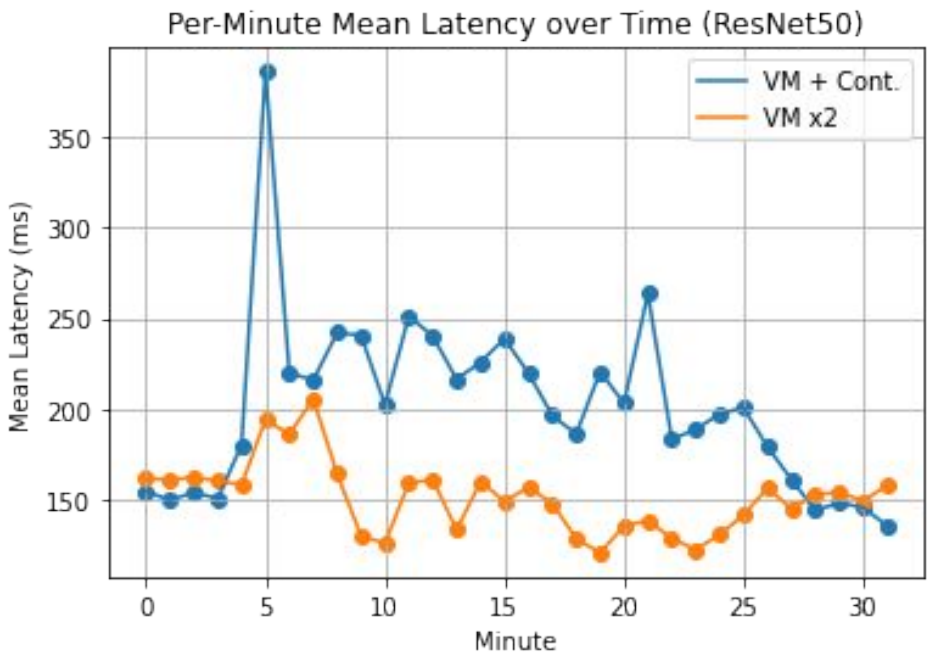




- The secondary deployment helps overcome saturation
  - Push the primary as much as possible, routing
- A 6 core VM would show inferior performance!
- What about comparison against pure VMs or container setups?

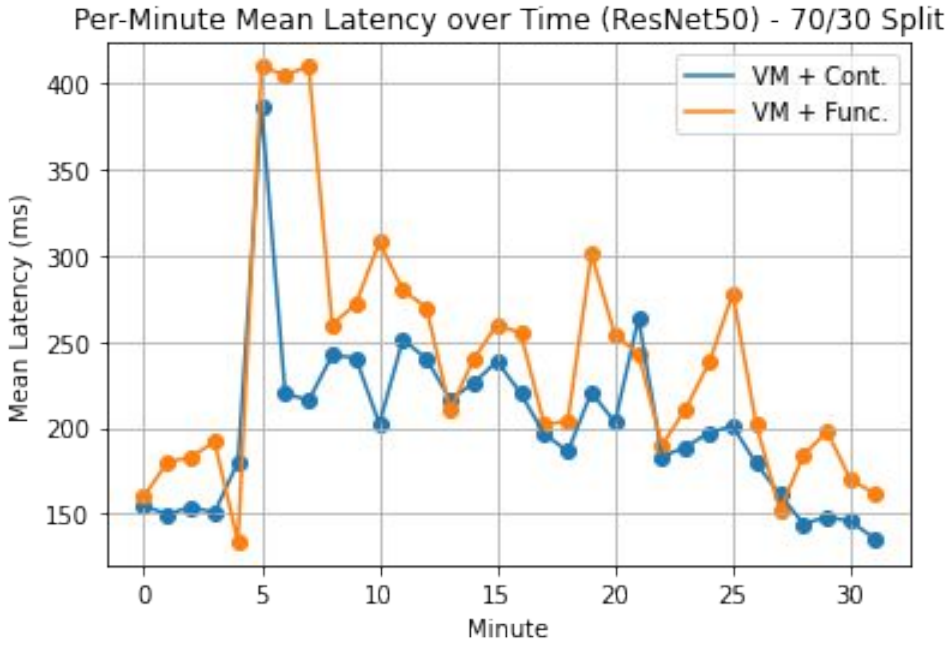
Heterogeneous Setups vs Homogeneous Setups





- A heterogenous setup can compete
- Similar results when compared against a container with 4 cores
- Comes down to cost, further experimentation

Heterogeneous Setups - Containers vs Functions as the Secondary Deployment



- Results are intuitive - container > function
- Cost - Huge caveat! Functions are PAYG. Is the performance uplift of containers worth it?

Discussion

Discussion * Terms and Conditions Apply

- Hardware Parity - not the case with cloud platforms
- Containers, Functions, VMs OR
  Docker, OpenWhisk, KVM
- Costs, pricing models

Discussion

- At parity - VMs require the most resources to drive equivalent performance, Functions require lesser, Containers the least

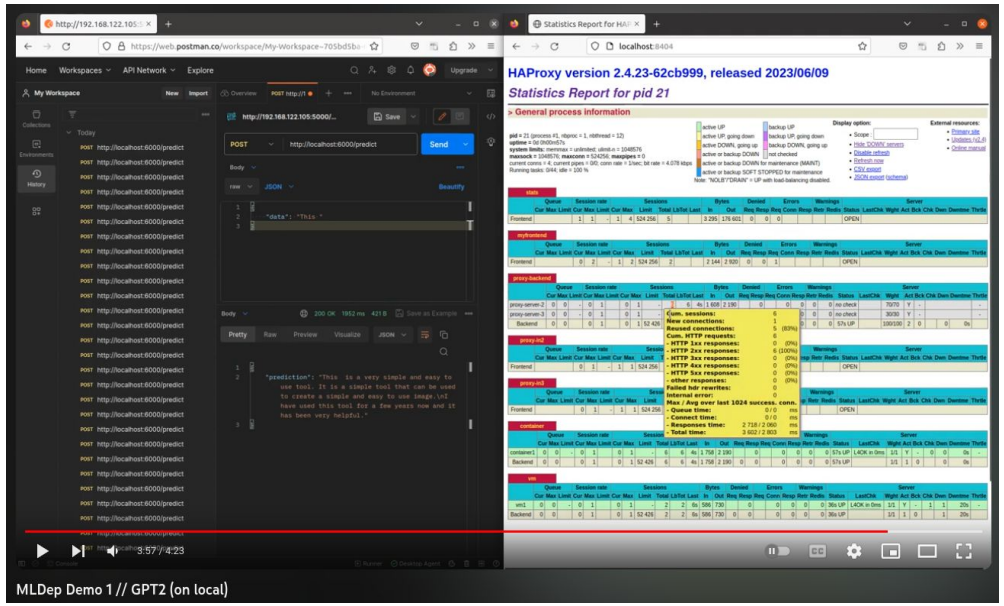
- Settle on a core count that does not get overloaded or saturated
  - Gains are inconclusive beyond this

- For all three platforms, scaling out to multiple instances is highly effective
  - Scaling out beyond a point nets inconclusive gains
  - Flattens the response times, **higher predictability**

- Alternative to multi-instance, route a small fraction of the load to a **secondary deployment**
  - Might not always be better than homogenous setups, but could be more cost-effective
  - Containers act as a better secondary deployment than functions, but pricing model should be considered

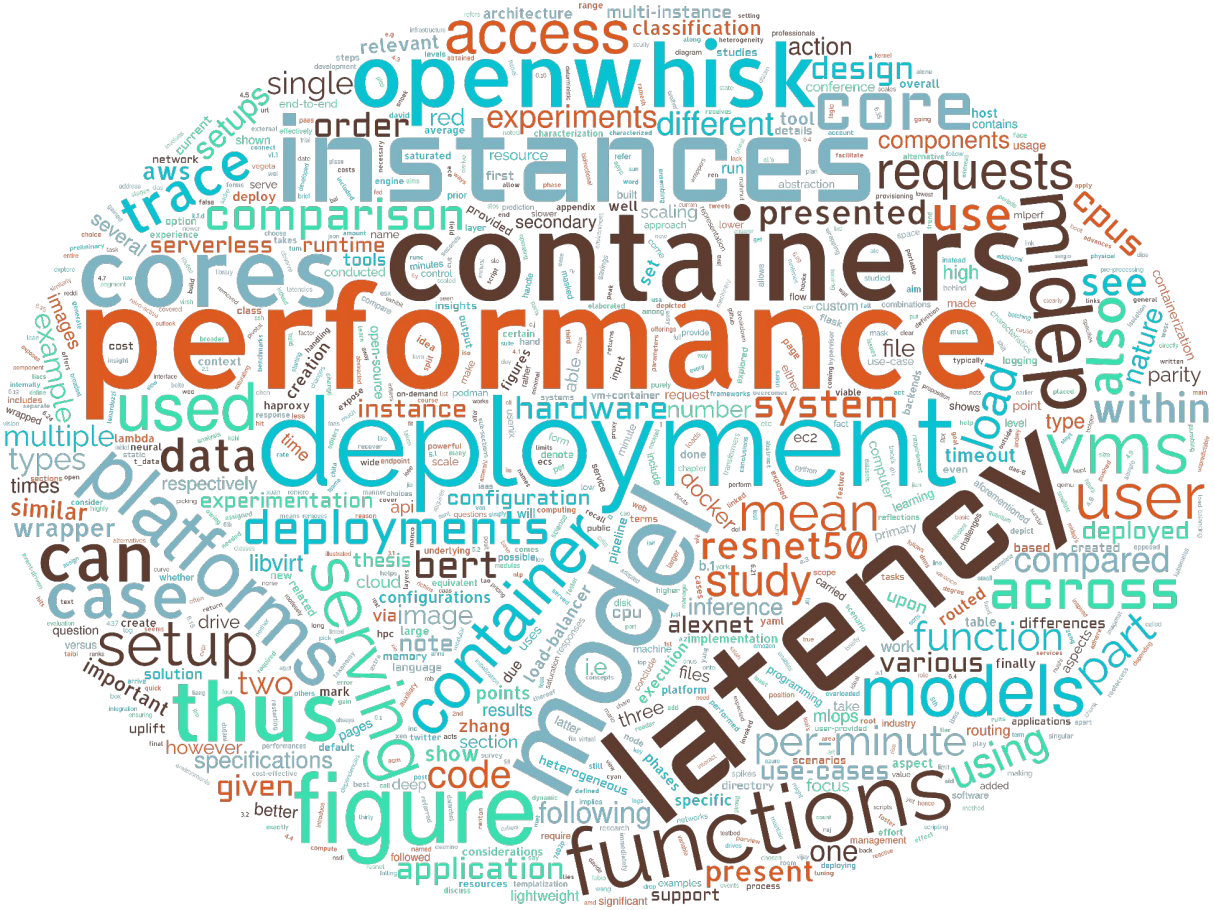
Discussion - What did we miss out on?

- Complete measurement of baseline performances and a no-op measurement
- Wider range of models, heavier models
- Wider range of hardware setups, instance numbers
- Further investigation into performance discrepancies
  - Containers vs. Functions
  - That 4 core AlexNet container!



Overview

- Introduction
- Research Questions
- MLDep - Design and Implementation
- Experimentation Approach
- Results
- **Conclusion**
- Future Work



Conclusion

- Potential challenges and pitfalls, comparative performance
  - VMs require more powerful resources to drive performance
  - Functions show less predictable response times than containers
  - Scaling up and out is very contextual, not always predictable

- Multi-instance and heterogeneous setups are good solutions that each have their own caveats

Overview

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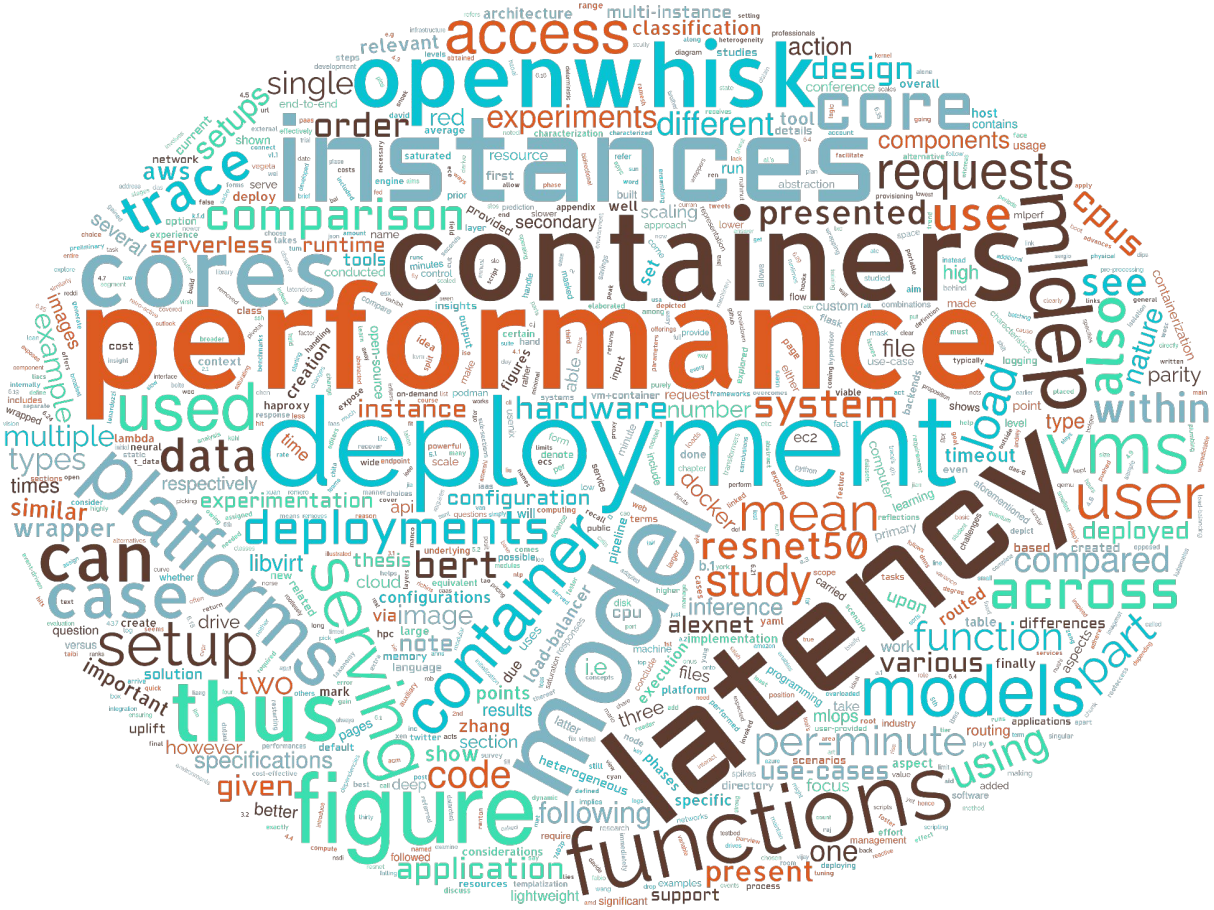
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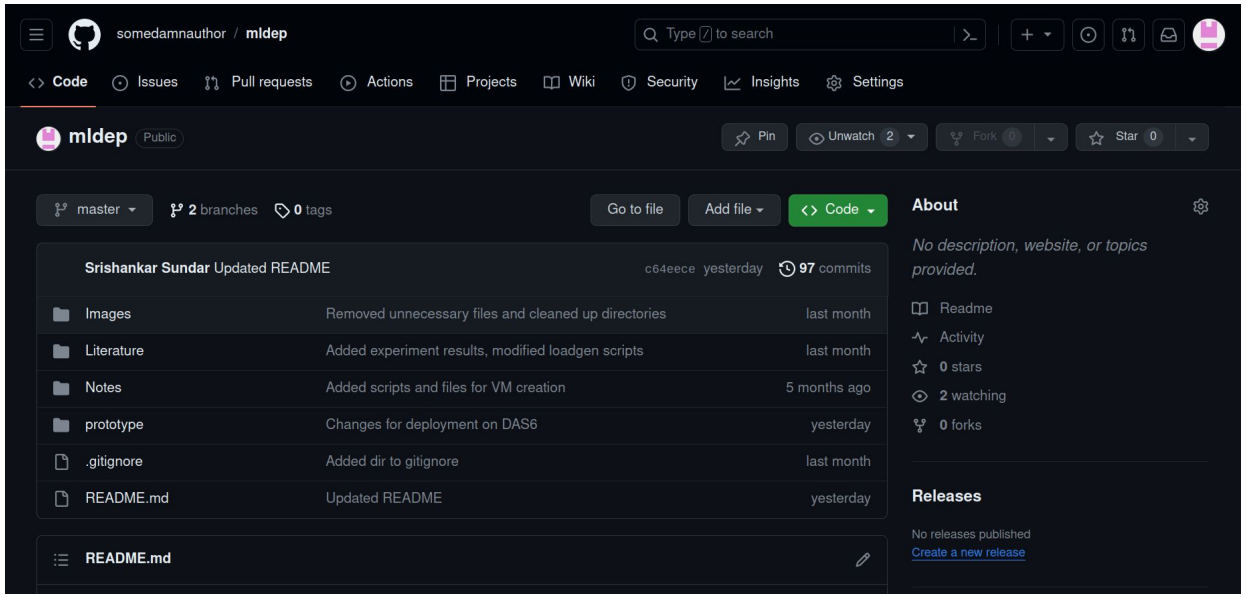
Future Work

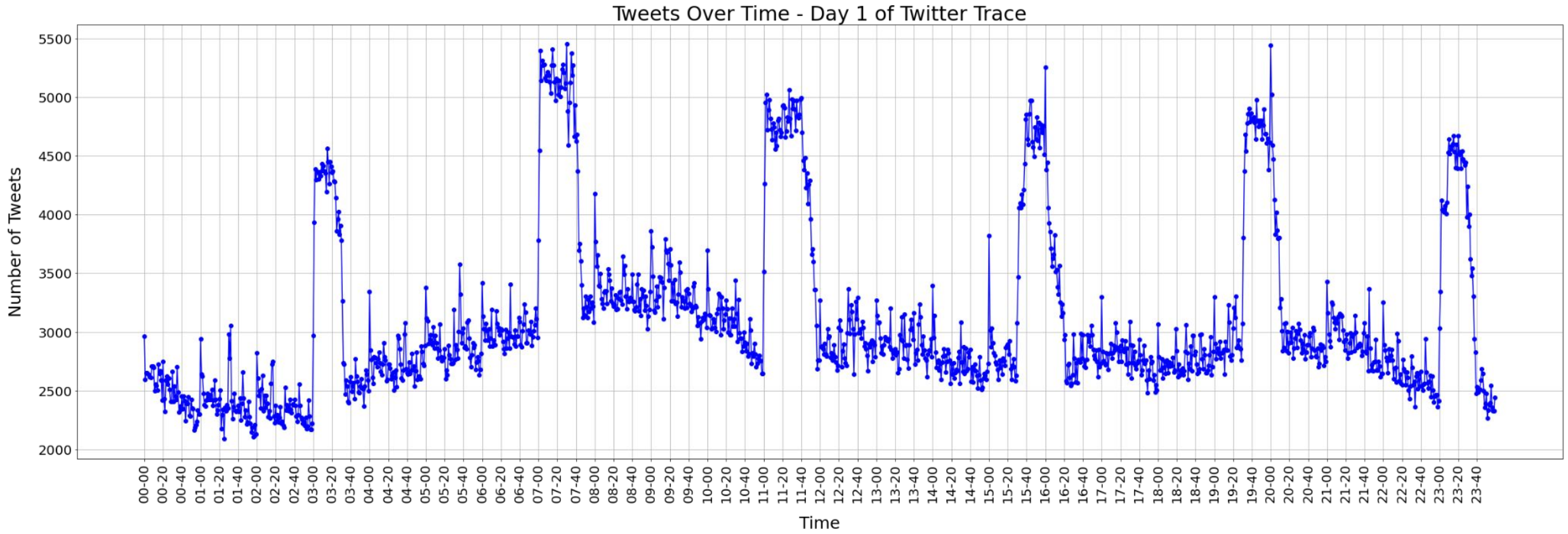
- MLDep as a testbench
  - Maturity in terms of design
  - Extension to cloud offerings
  - Reactive scaling
  - Support for more solutions



Thank You!

Universiteit Leiden
The Netherlands

Appendix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