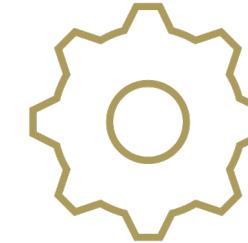




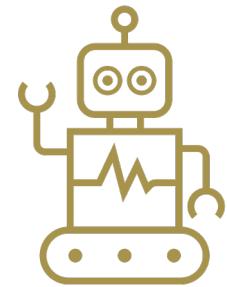
Smart



Fast



Systems



Machine Learning



Computer Vision

Building Smart and Fast
Systems using
Machine Learning
and Computer Vision.

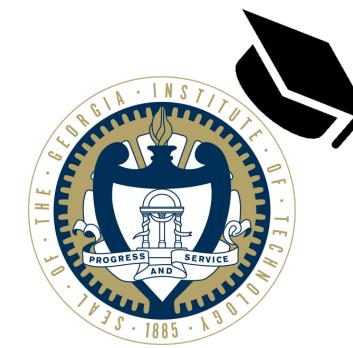
Thaleia Dimitra Doudali

Assistant Research Professor @IMDEA Software Institute

About Me



2015



2021



Start: October 2021

Born and raised
in Greece.

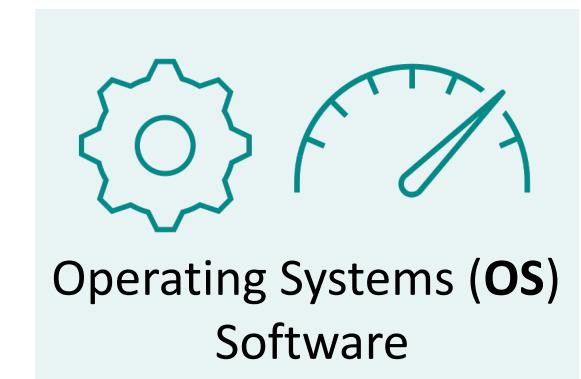
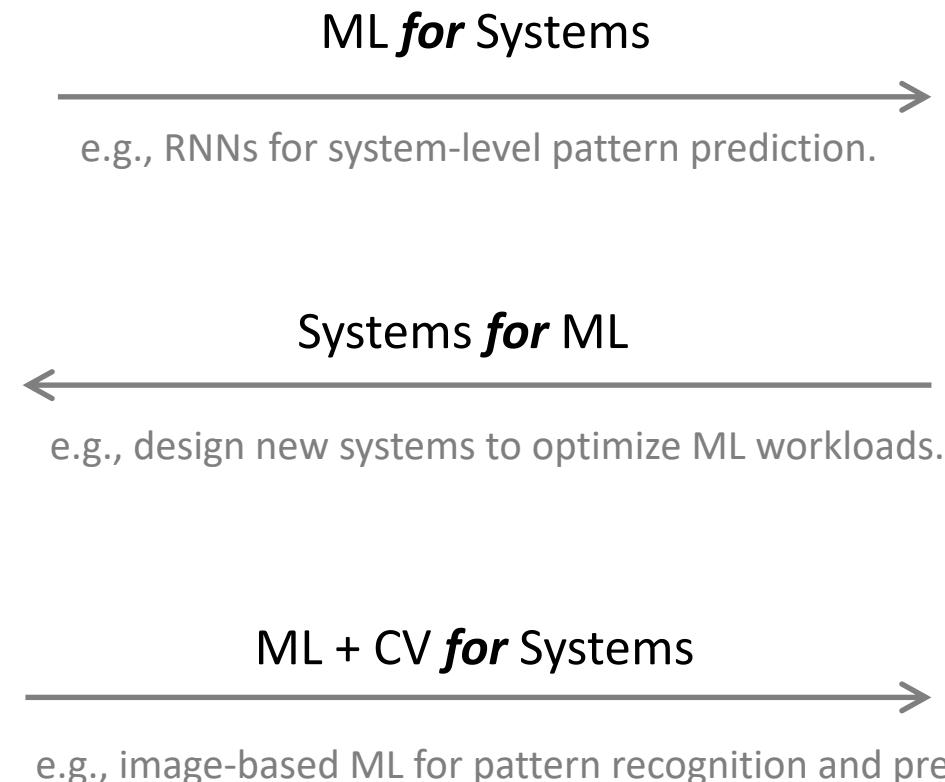
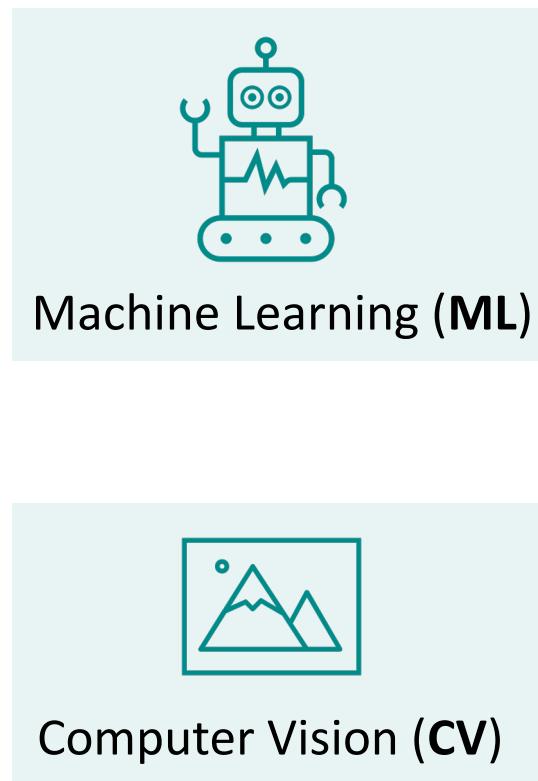
Undergrad in ECE at
NTUA, Athens, Greece.

PhD in CS at
Georgia Tech, Atlanta, USA.
Advised by Ada Gavrilovska.

Assistant Professor at
IMDEA, Madrid, Spain.

About My Research

My research lies at the intersection of Machine Learning and Systems.

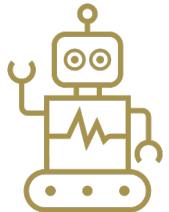


Talk Outline



Why do we need Smarter and Faster Systems?

The evolution of the hardware technologies, calls for software improvements.



Building Smart Systems

Using machine and human intelligence to build practical ML-based systems.



Building Fast Systems

Reducing ML-based management overheads with visualization.

Building image-based system pipelines.



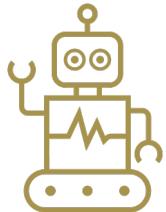
Future Research Directions

Talk Outline



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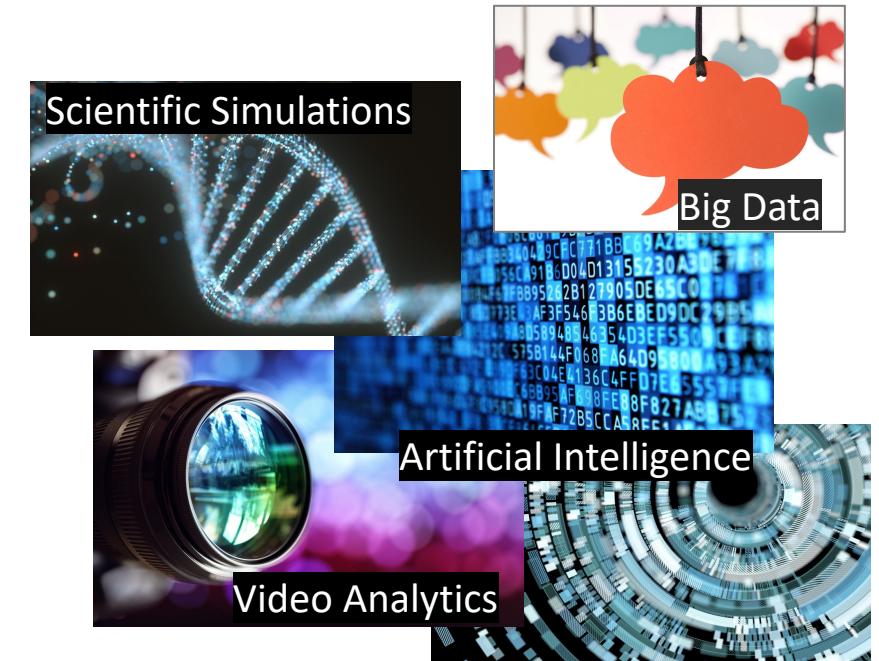
Future Research Directions

The Era of Data

“More than **65 ZB** of data will be created, captured, copied, and consumed in the world this year.”

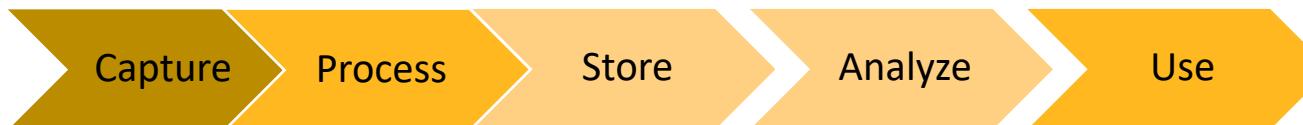
Source: International Data Corporation, March 2021.

Exploded
Data Sizes



Data Analytics Pipeline

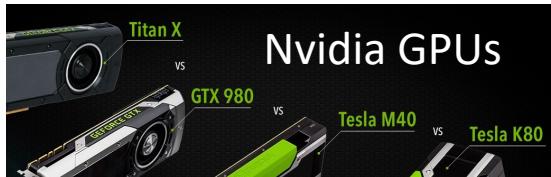
ZBs of data



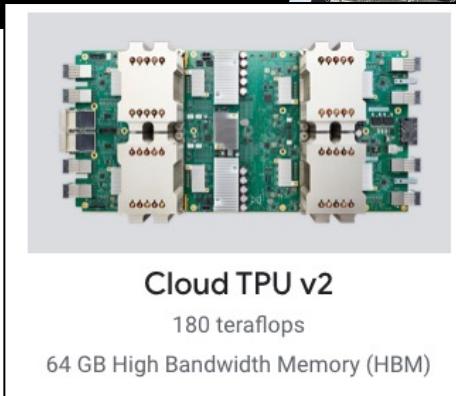
Need for speed and massive storage capacities!

The Era of Heterogeneous Hardware

Compute Acceleration



ARE DPUS THE
NEXT DATACENTER
REVOLUTION?



Google

Data Storage Acceleration



Network Acceleration

Mellanox Innova™-2 Flex
Open Programmable SmartNIC



Interconnection Standards

CXL Compute Express Link™

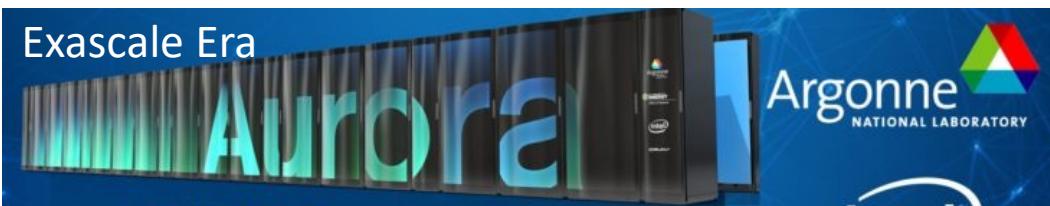
Gen-Z Consortium

- Industry Leaders developing a memory-semantic interconnect



Heterogeneity Across Computing Platforms

Supercomputers



HPC wire

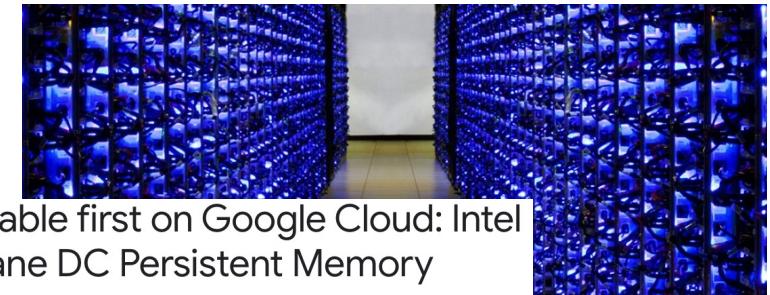
Since 1987 - Covering the Fastest Computers
in the World and the People Who Run Them

- ✓ Home
- ✓ Technologies
- ✓ Sectors



Application Performance	200 PF
Number of Nodes	4,608
Node performance	42 TF
Memory per Node	512 GB DDR4 + 96 GB HBM2
NV memory per Node	1600 GB
Total System Memory	>10 PB DDR4 + HBM2 + Non-volatile
Processors	2 IBM POWER9™ 9,216 CPUs 6 NVIDIA Volta™ 27,648 GPUs
File System	250 PB, 2.5 TB/s, GPFS™
Power Consumption	13 MW
Interconnect	Mellanox EDR 100G InfiniBand
Operating System	Red Hat Enterprise Linux (RHEL) version 7.4

Datacenters



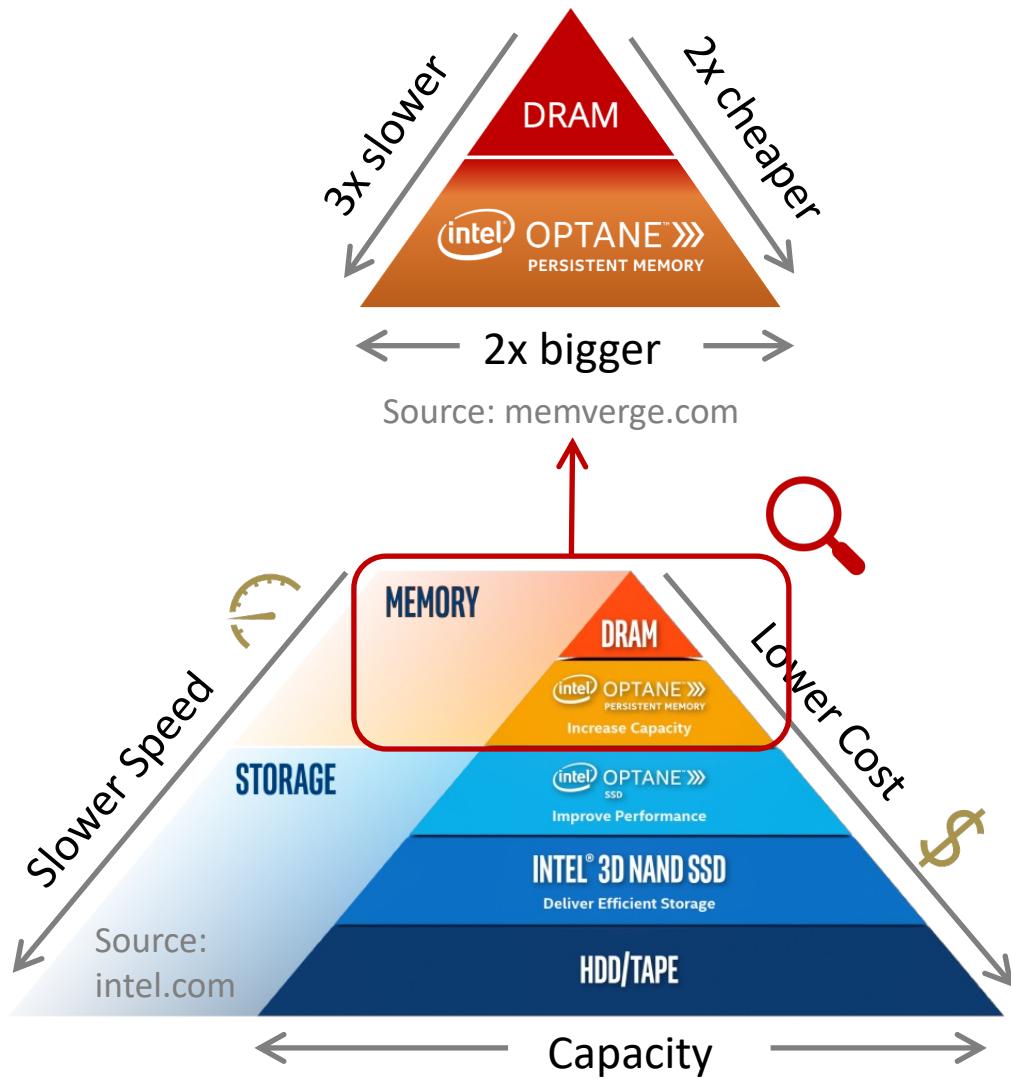
Available first on Google Cloud: Intel Optane DC Persistent Memory

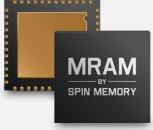
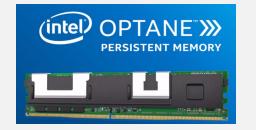


Personal Devices



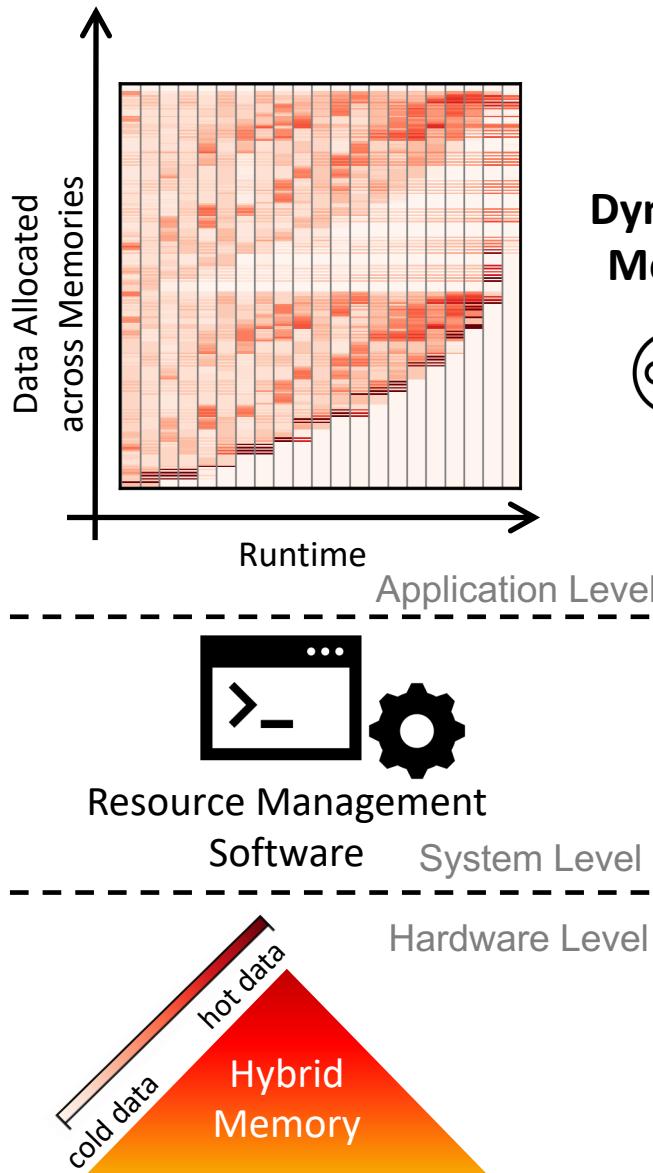
Heterogeneity Trade-offs



Characteristic	Technology	Hardware Vendors
Low Latency	MRAM	 Everspin Announces 1Gb ST-MRAM
High Bandwidth	HBM	
Persistence	PMEM	

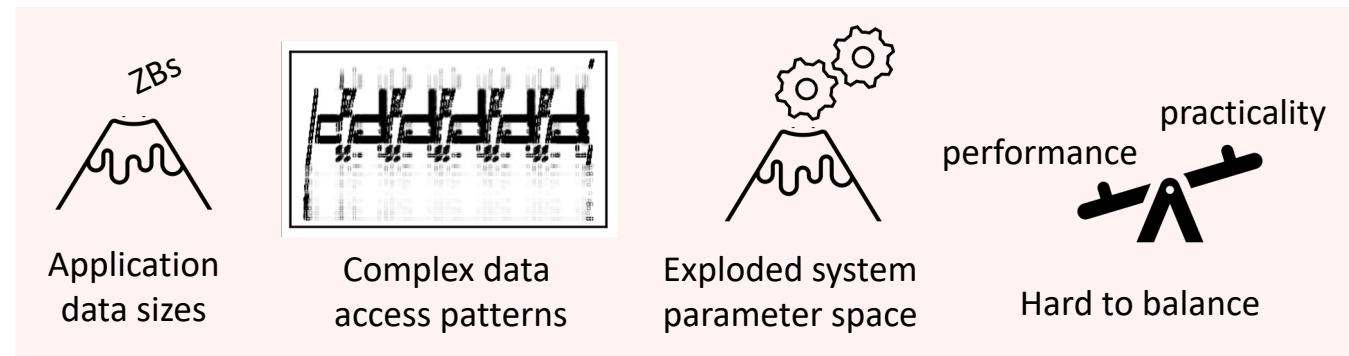
Examples of other heterogeneous memory technologies.

Building Software to Maximize the Hardware Efficiency



It is a **complex decision mix** to manage the data allocated across memories.
E.g., Which / How much / Where / When to move data?

Why do we need smarter and faster systems?

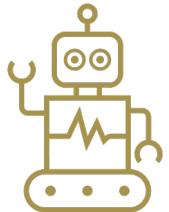


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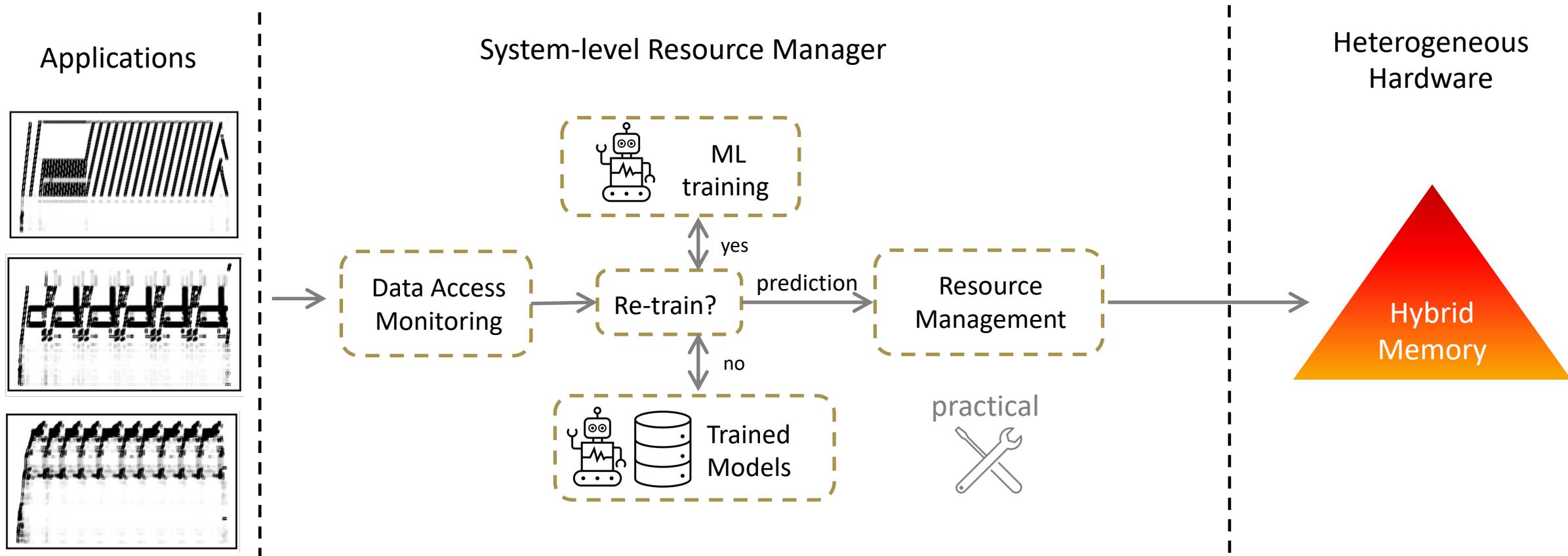
Building image-based system pipelines.



Future Research Directions

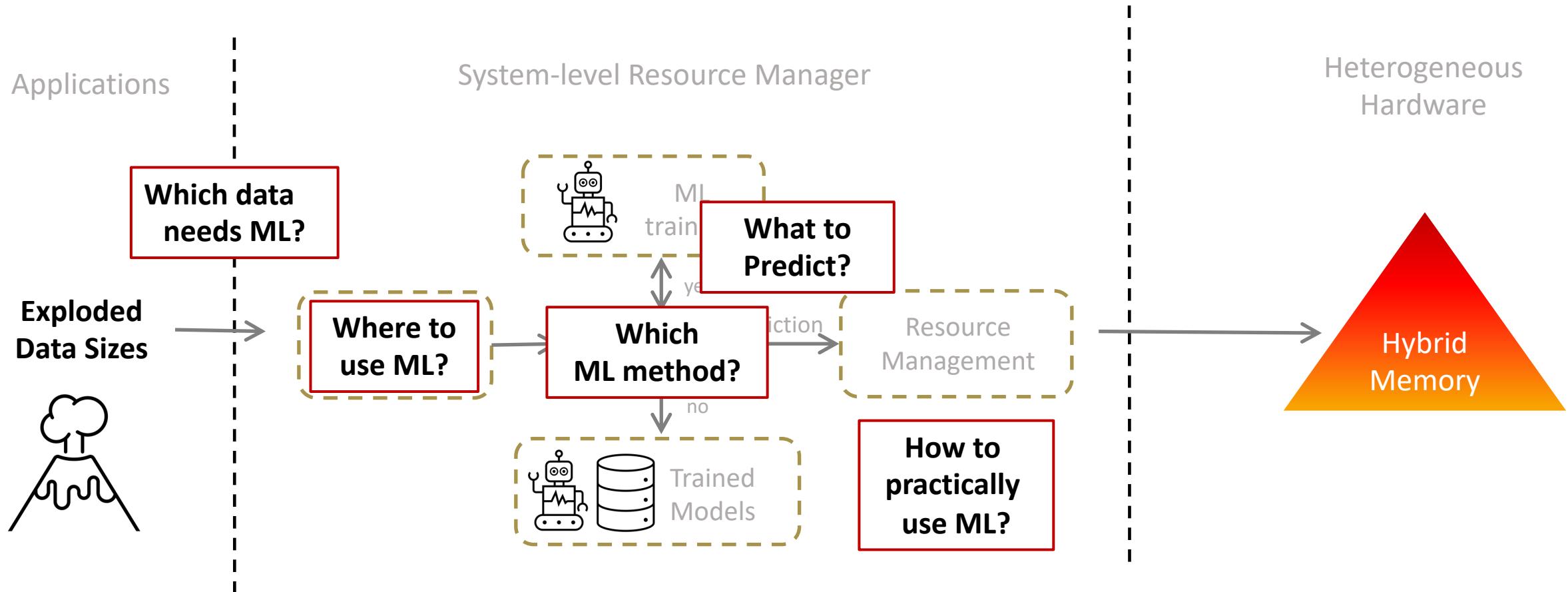
The Vision

ML-augmented heterogeneous resource manager.



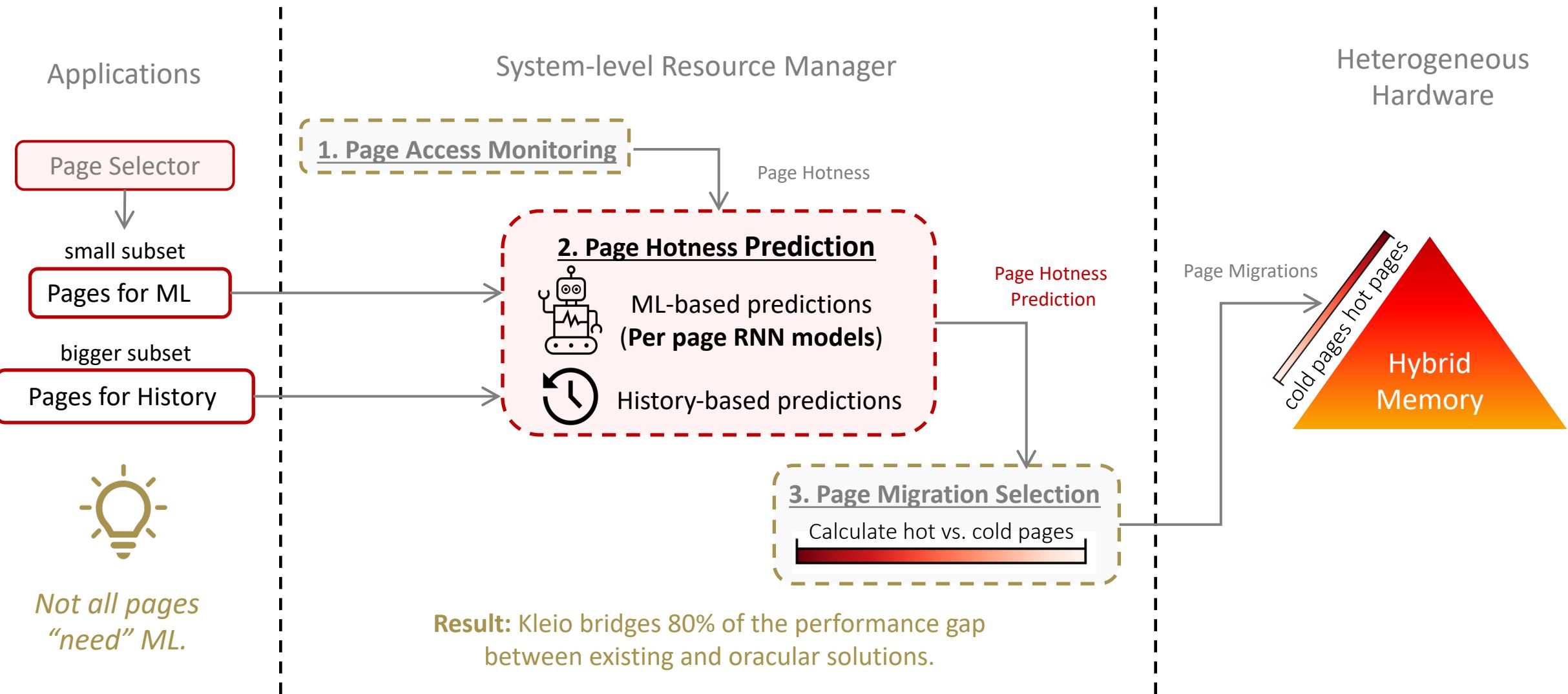
Contributions Towards the Vision

Laying the grounds for the *practical* integration of ML.



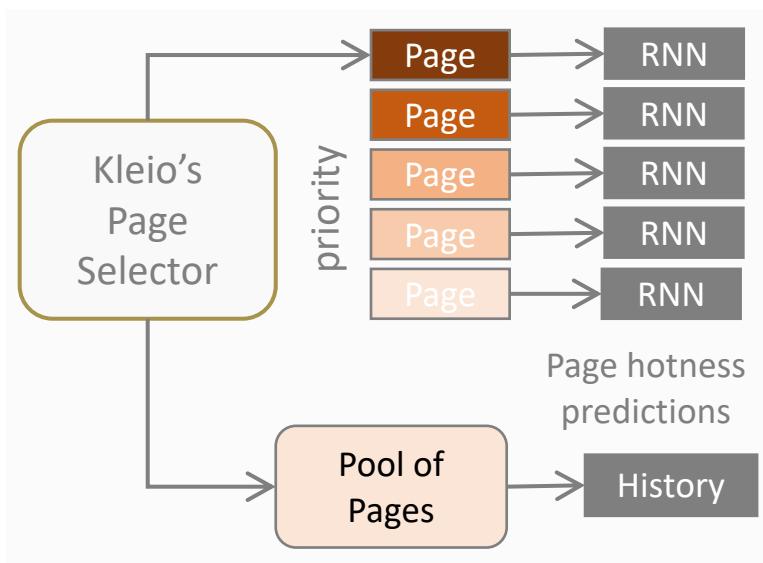
System design of Kleio

Kleio: a hybrid memory page scheduler with machine intelligence. [HPDC 2019]



The Key(s) to a Practical and Efficient ML-based System Design

Apply ML **when** and **where** necessary.



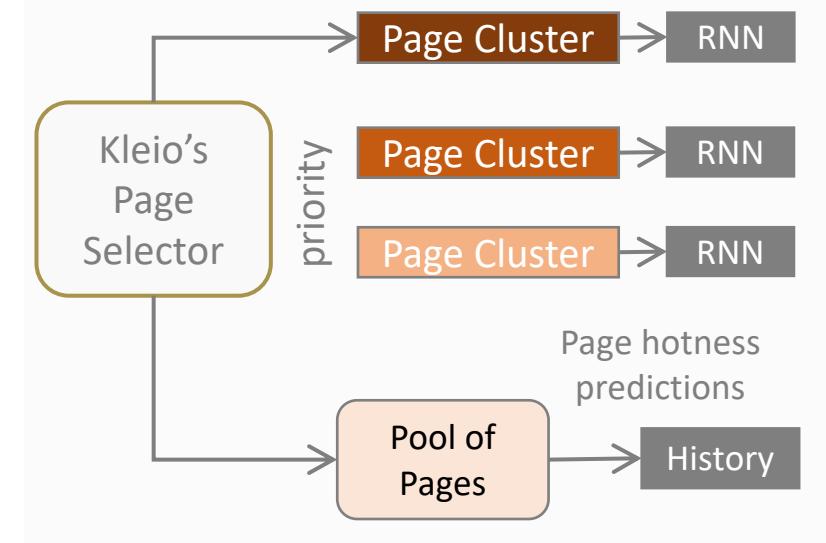
Apply ML on a small page subset.



↳ Foundations for practical use of ML.

Carefully select pages for ML.

↳ Application performance boost.

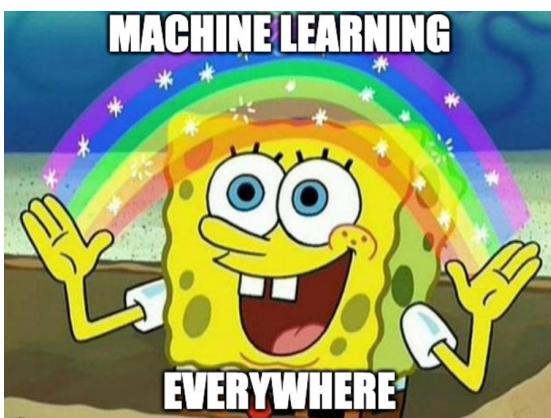


Small can still mean thousands of pages, because of the massive memory footprints of modern workloads.

Can we reduce the number of pages via clustering?

Insights from the System Design of Coeus

Coeus: Clustering (A)like Patterns for Practical Machine Intelligent Hybrid Memory Management . [CCGrid 2022]



Clustering? Let's use ML!

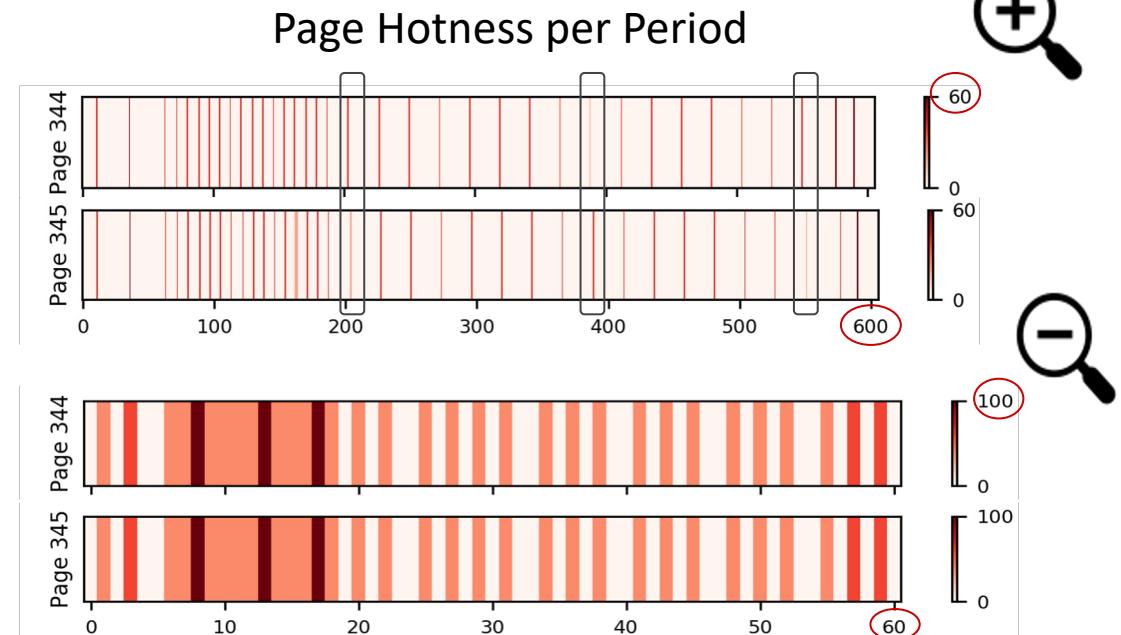
For example, K-means.

- How many clusters?
- Clustered input to ML?

Not trivial to configure.

Let's use our human intelligence..

.. Kleio learns the patterns of page hotness across time periods.



So what if I increase the duration of the period?



Key Idea

Group pages with *identical* patterns under a *single* ML model.

↓ 3x less RNNs

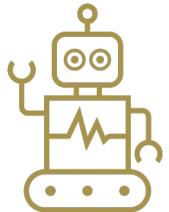
↑ 3x more performance

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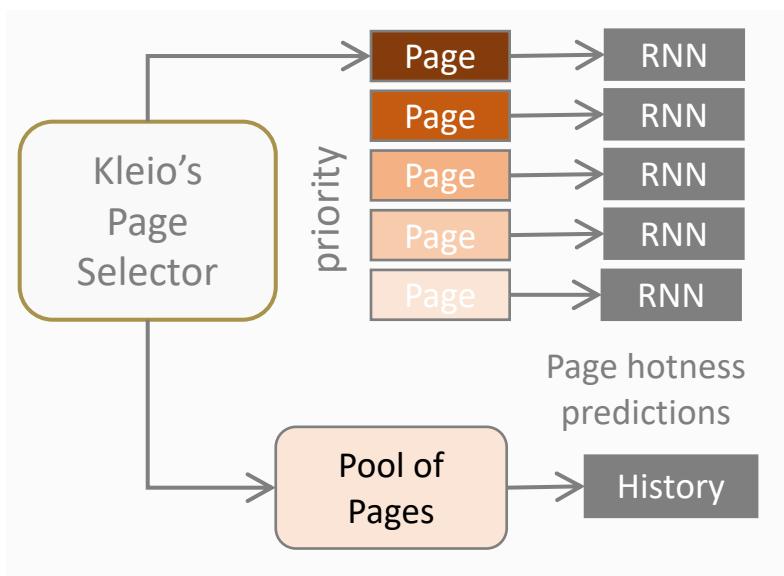
Building image-based system pipelines.



Future Research Directions

The Key(s) to a Practical and Efficient ML-based System Design

Apply ML **when** and **where** necessary.

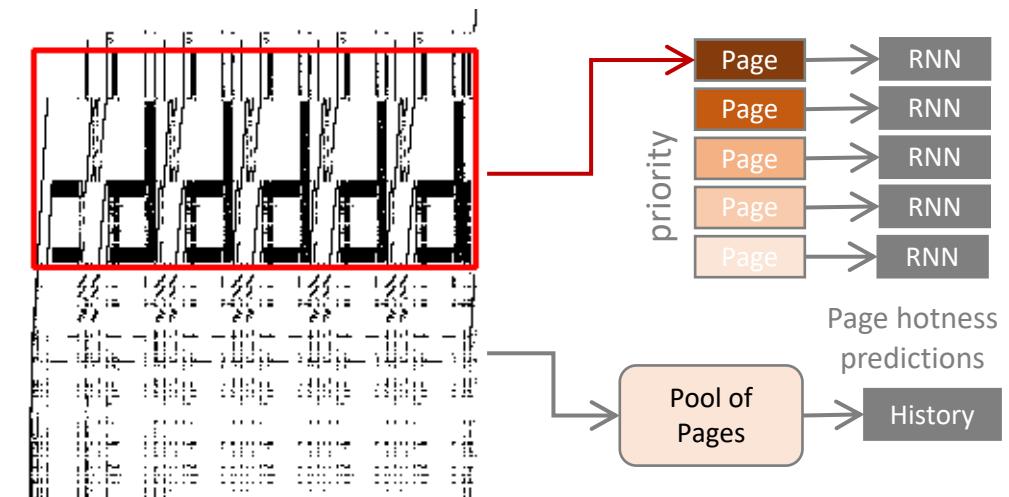


Apply ML on a small page subset.

↳ Foundations for practical use of ML.

Carefully select pages for ML.

↳ Application performance boost.



The page selection is not a lightweight process.

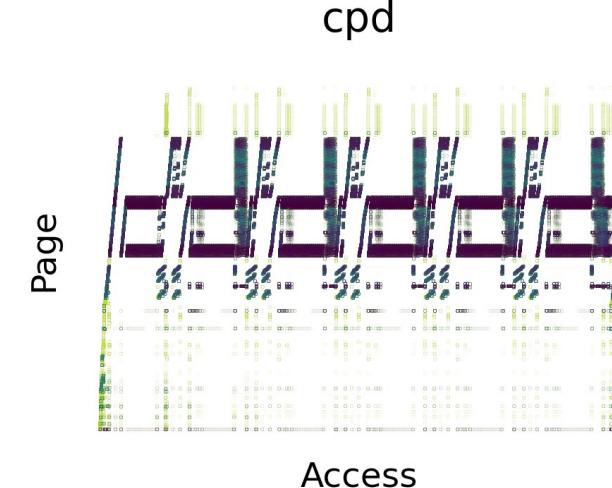
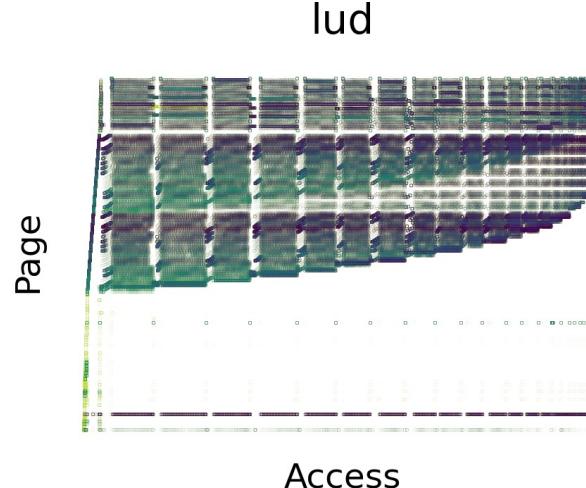
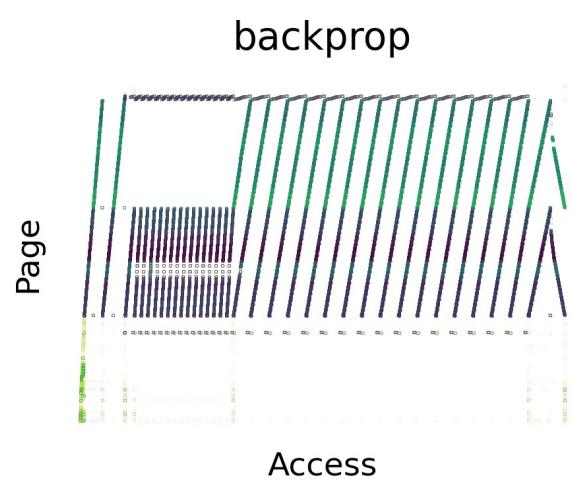
Performance modeling and estimations are used to maximize the effects of ML on application performance.

Can we accelerate the page selection process?

Insight from Visualizing Pages Selected for ML

High Priority

Low Priority

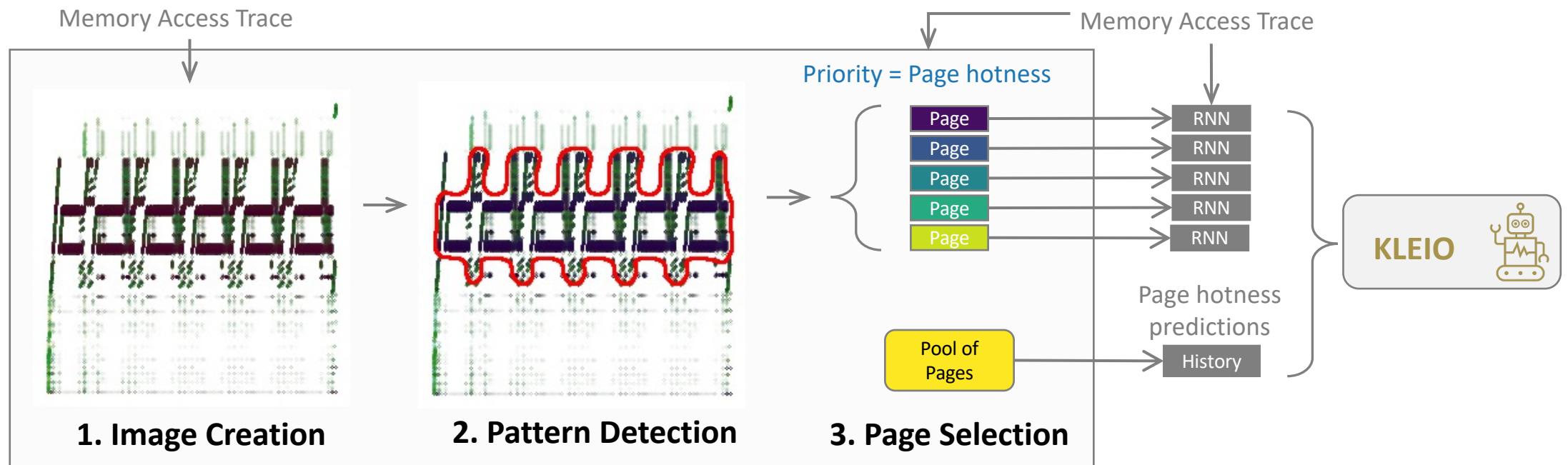


Neighboring pages that are part of distinct access patterns across time receive similar priority for ML.



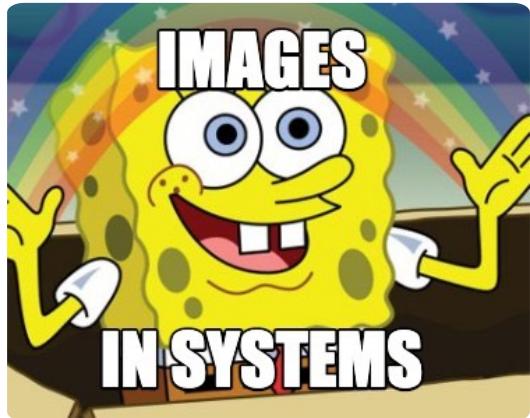
Towards Image-based Page Selection

Cronus: Computer Vision-based Machine Intelligent Hybrid Memory Management. [MEMSYS 2022]



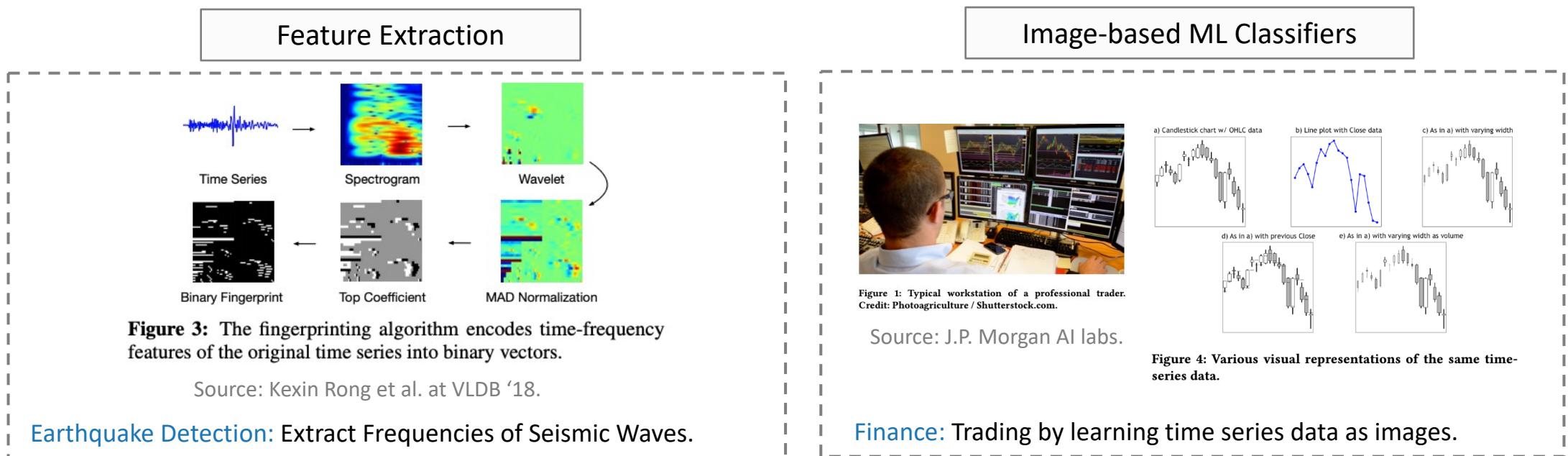
Cronus reduces by **400x** the page selection times, from minutes down to seconds.

Why Use Images Inside Operating Systems?



Creating images helps:

- Another way to represent data, reducing their dimensionality to a 2D / 3D space.
- Captures spatial and temporal correlations.
- Leverage computer vision and image-based algorithms.



Computer Vision + Machine Learning for Systems (1)

What can an image-based system pipeline look like?

E.g., predicting future resource utilization.

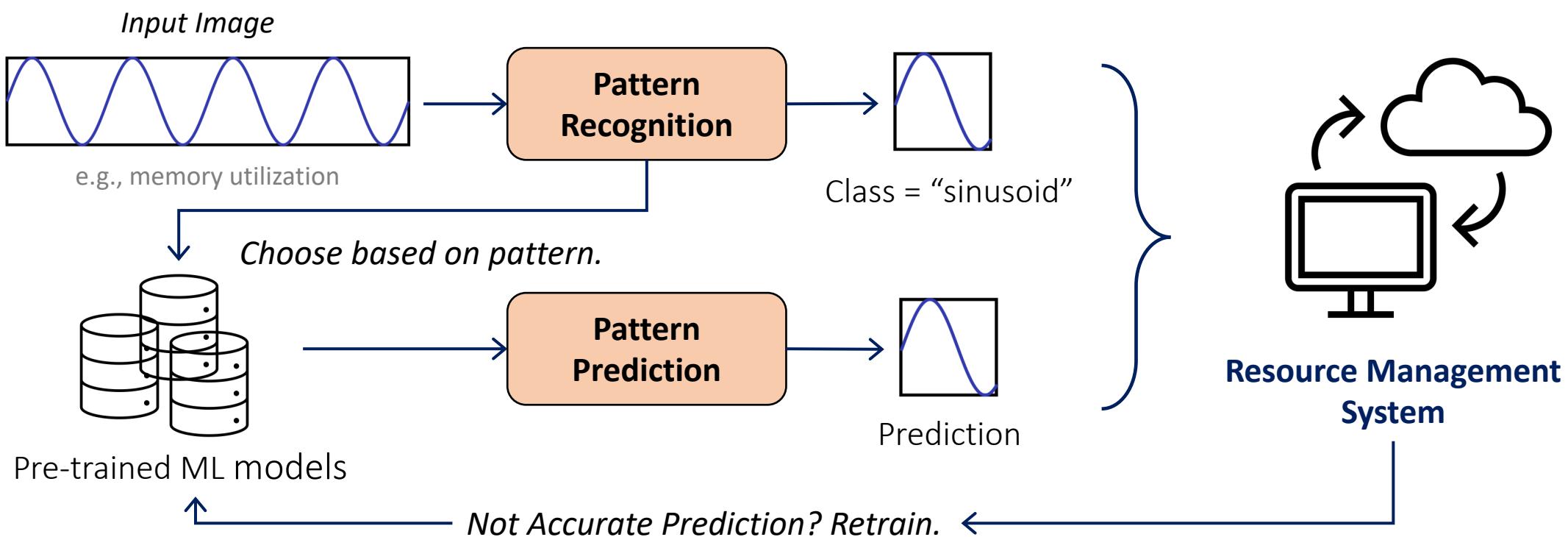
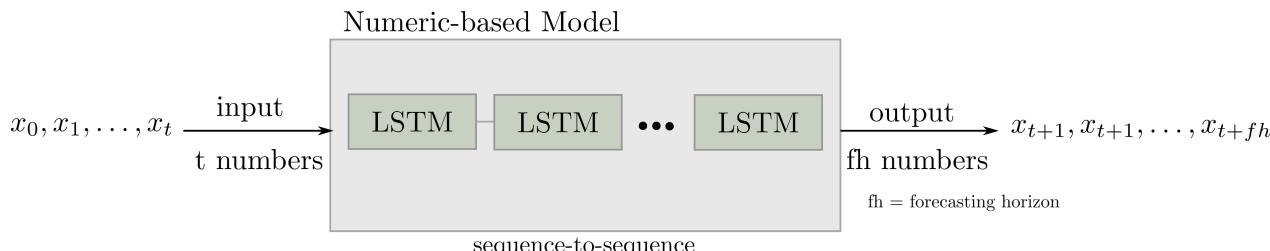


Image-based vs. Number-based Machine Learning

Research paper under submission.



Number-based LSTM model

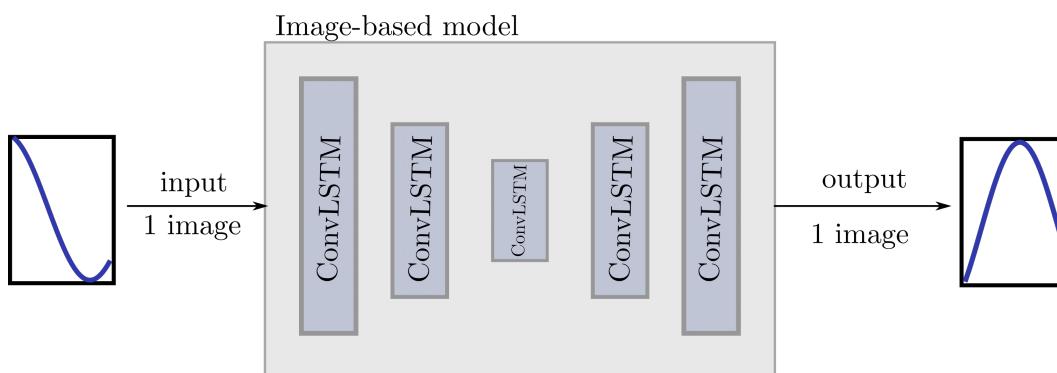
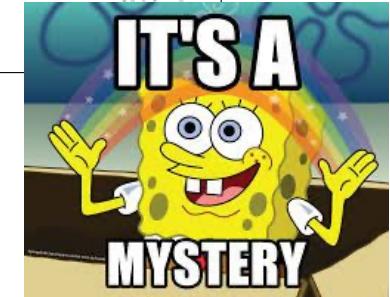
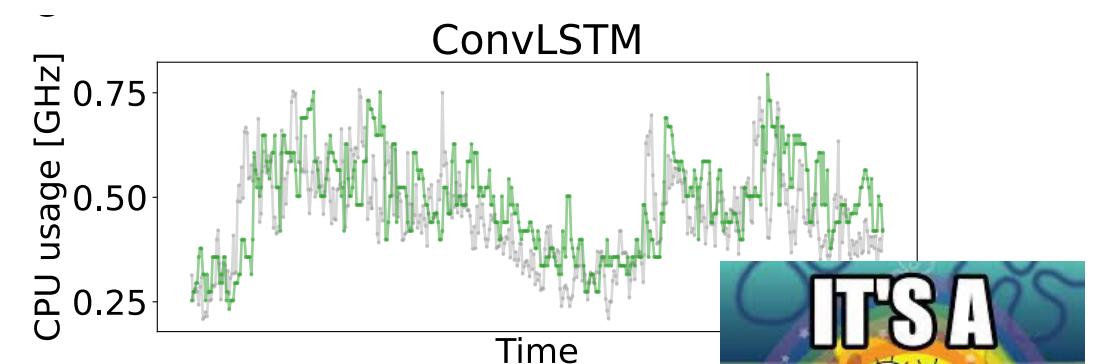
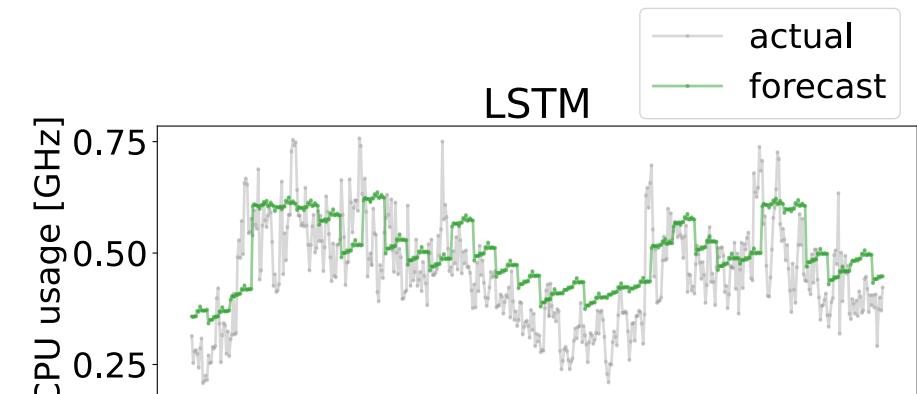


Image-based ConvLSTM model

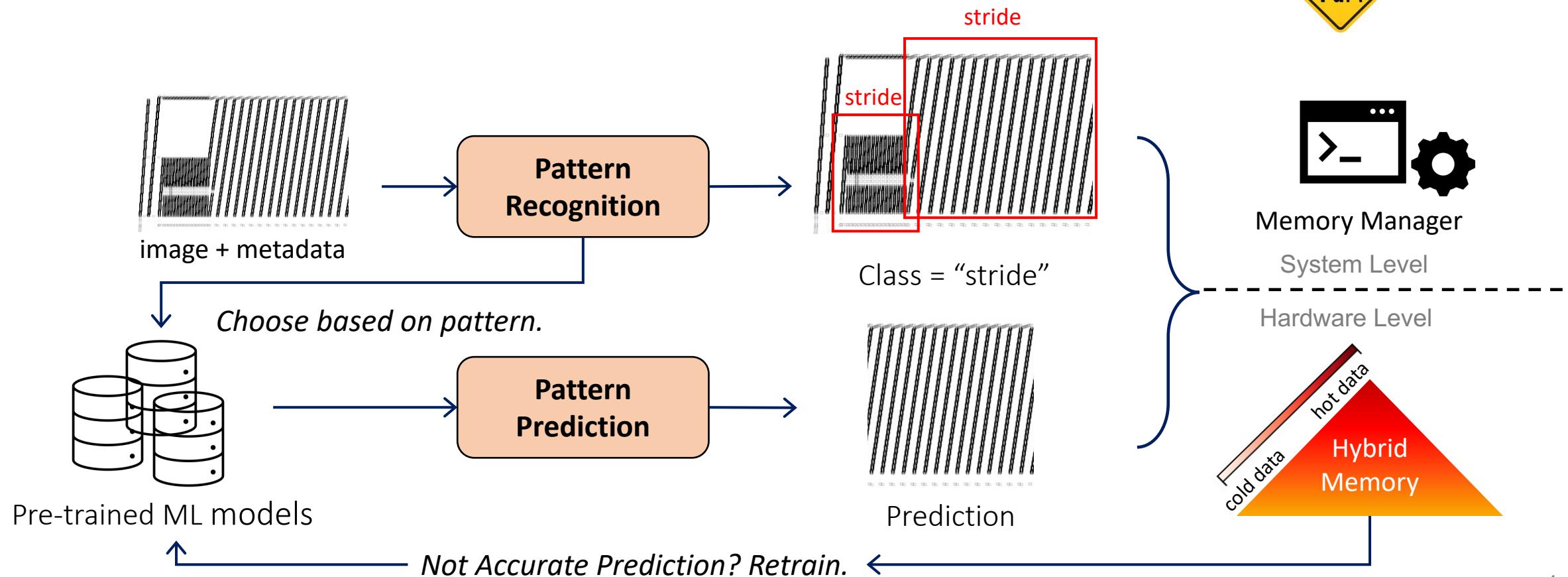


The image-based ConvLSTM makes more accurate predictions.

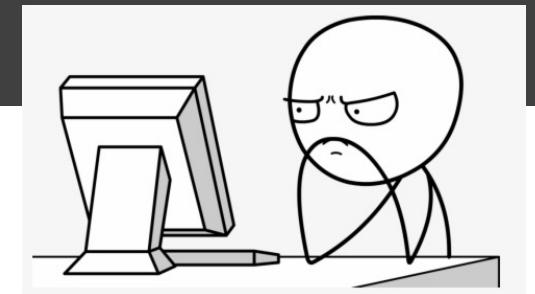
Computer Vision + Machine Learning for Systems (2)

What can an image-based system pipeline look like?

E.g., learning memory access patterns.



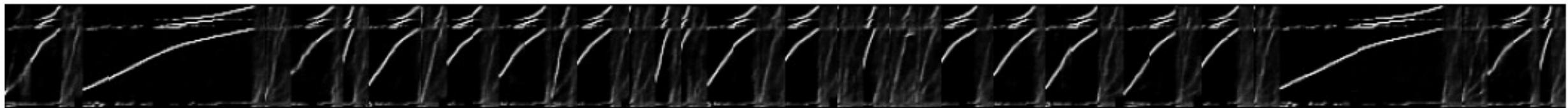
Early Results on Image-based Pattern Prediction



Ground Truth



Prediction



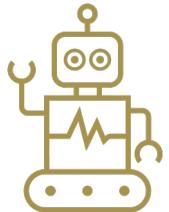
More challenging, since the data access patterns are more complex.

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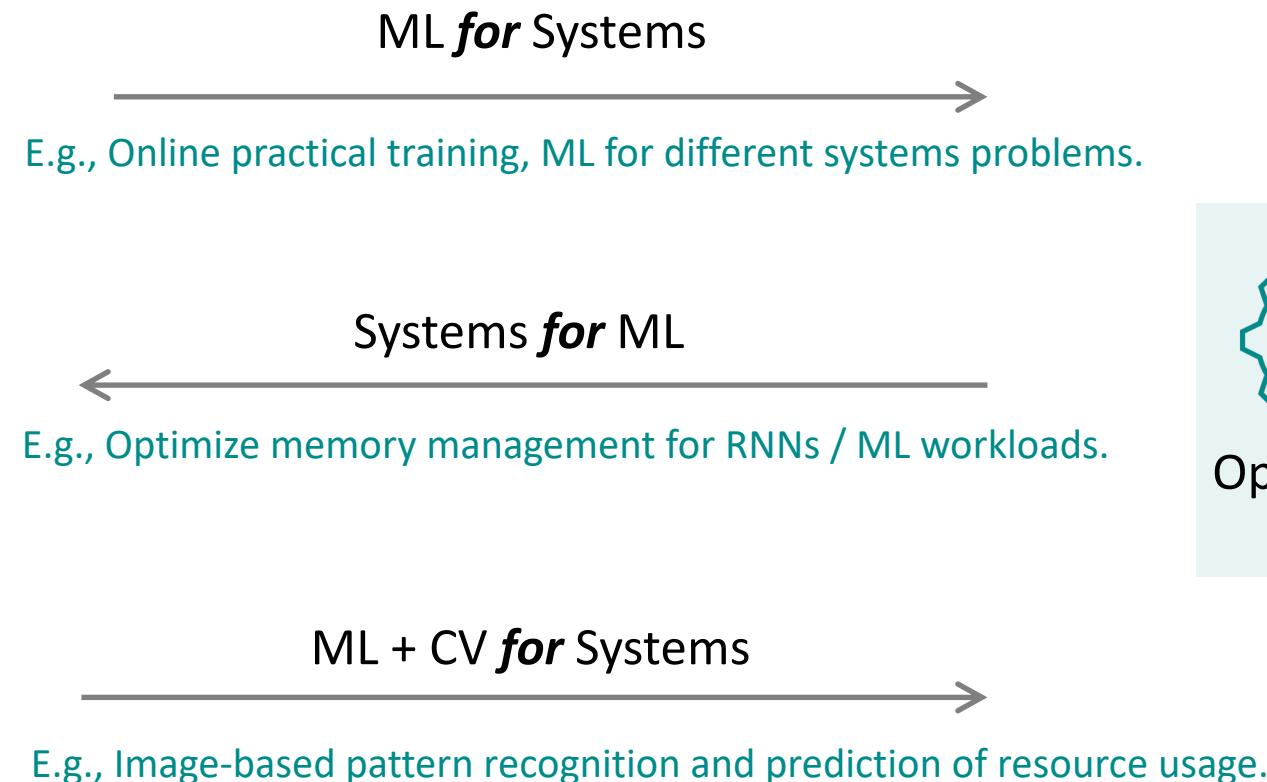
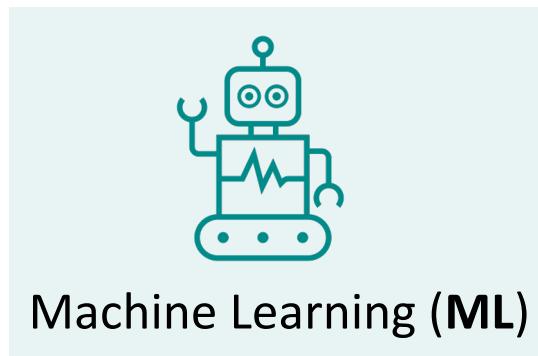
Building image-based system pipelines.



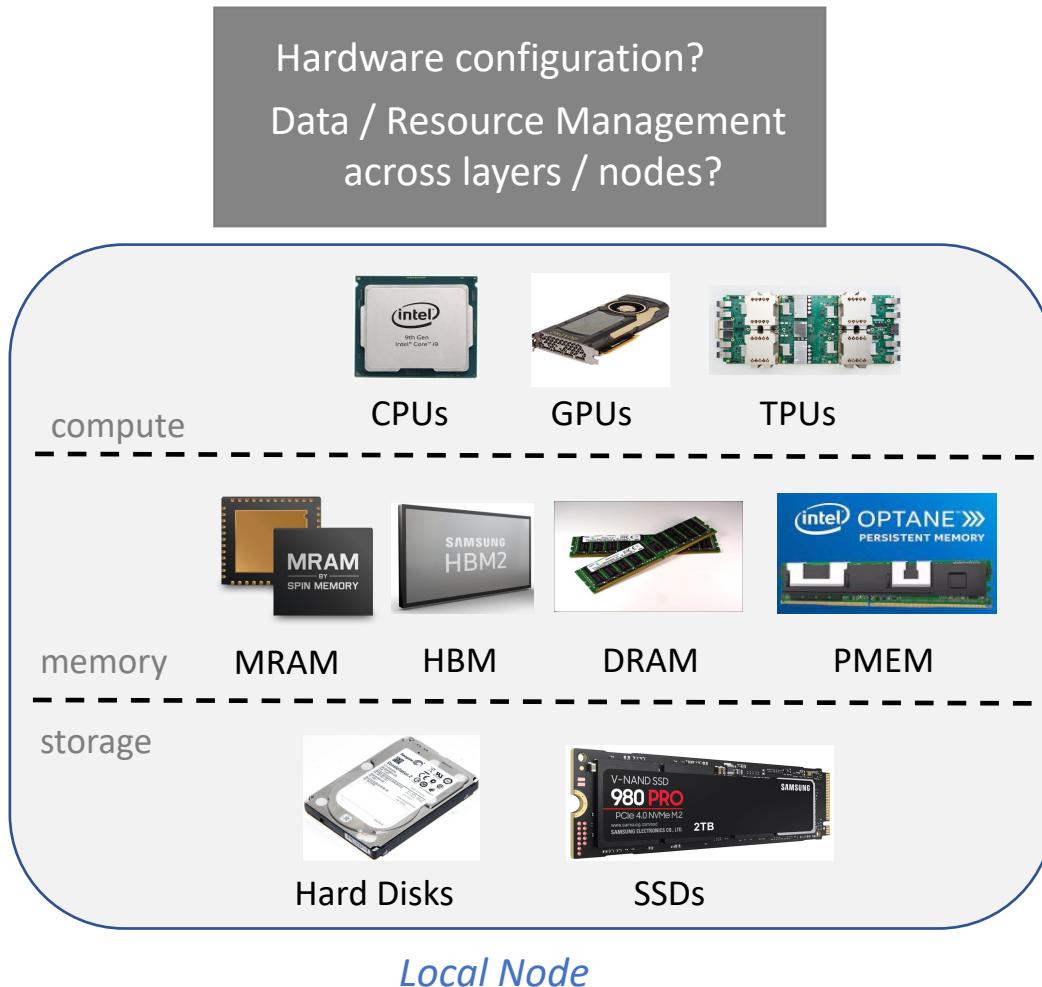
Future Research Directions

Future Research Directions

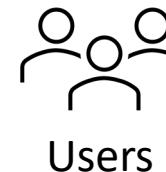
My research lies at the intersection of Machine Learning and Systems.



Intelligent Management of Extreme Heterogeneity



System vs. HW / SW co-design?

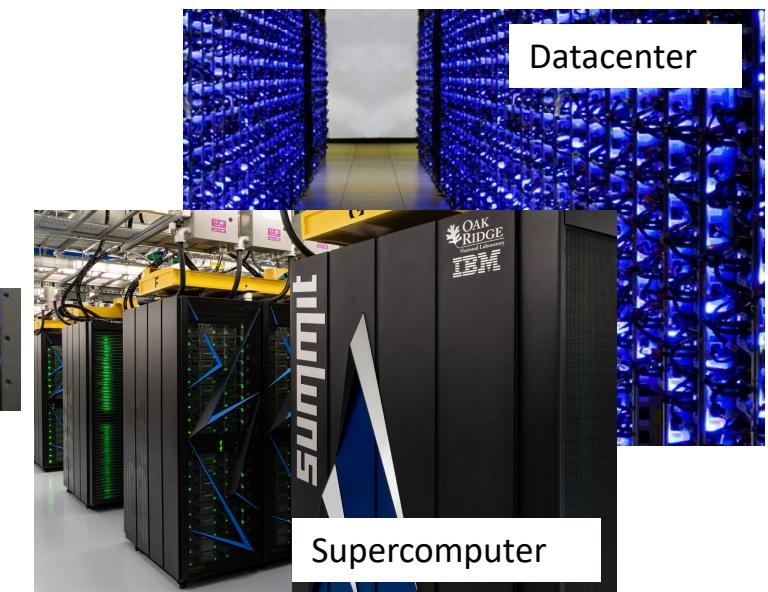


Multi-tenancy?
Isolation?

Performance?
Cost / Energy /
Resource Efficiency?



High-Speed Interconnects



Massive Node Clusters
Disaggregated Resources

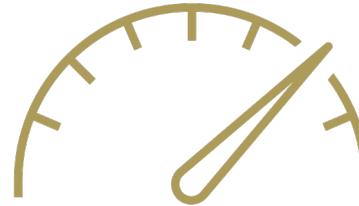
ML integration Aspects:
Necessity Effectiveness Practicality Interpretability



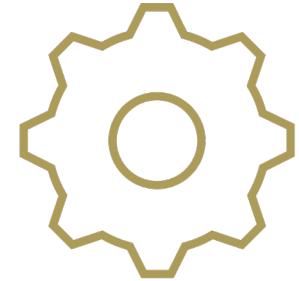
Scan this to find more
about my work.



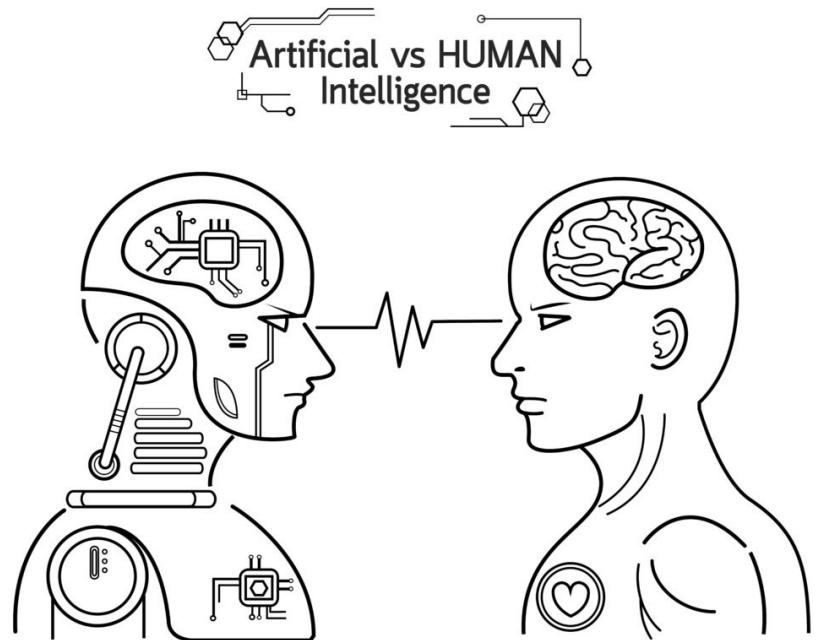
Smart



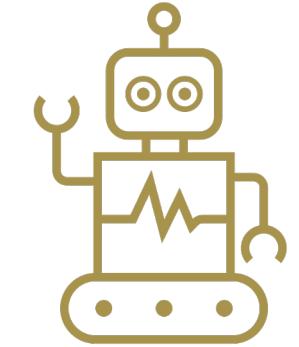
Fast



Systems



How can we use our human
intelligence to build **practical**
systems that leverage
machine learning and
computer vision?



Machine Learning



Computer Vision