Cronus: *Computer Vision-based Machine Intelligent Hybrid Memory Management*

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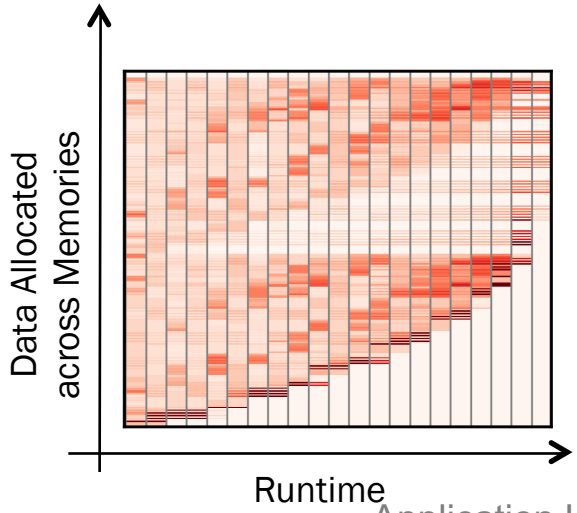
* Work done while at Georgia Tech (PhD).

Hybrid Memory Management is Complex

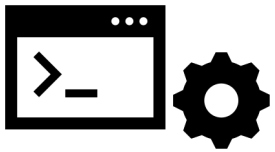


Dynamic Data Movements!

It is a **complex decision mix** to manage the data allocated across memories.

E.g., Which / How much / Where / When to move data?

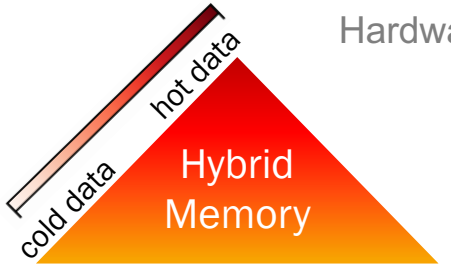
Application Level



Resource Management Software

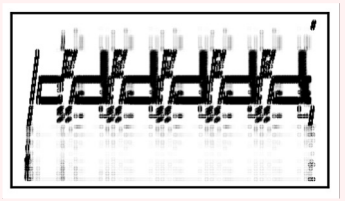
System Level

Hardware Level

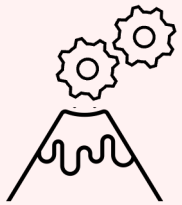


Why do we need more intelligent systems?

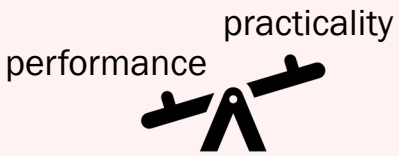
Application data sizes



Complex data access patterns



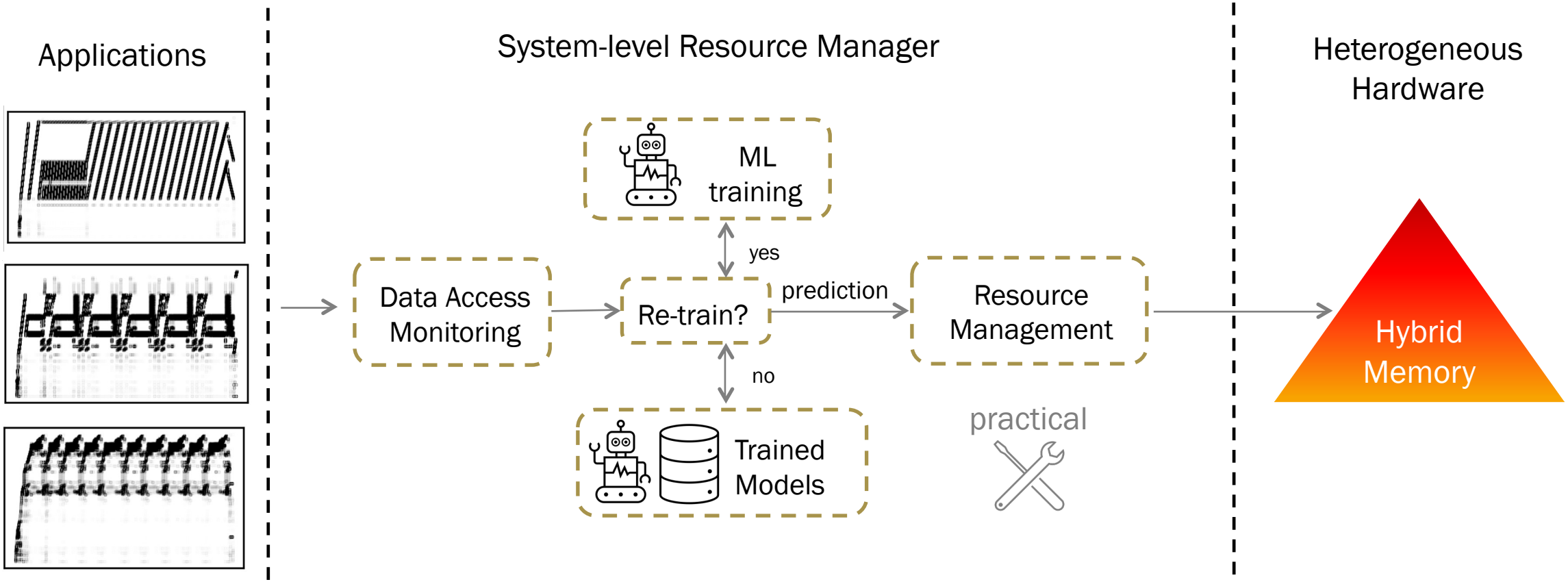
Exploded system parameter space



Hard to balance

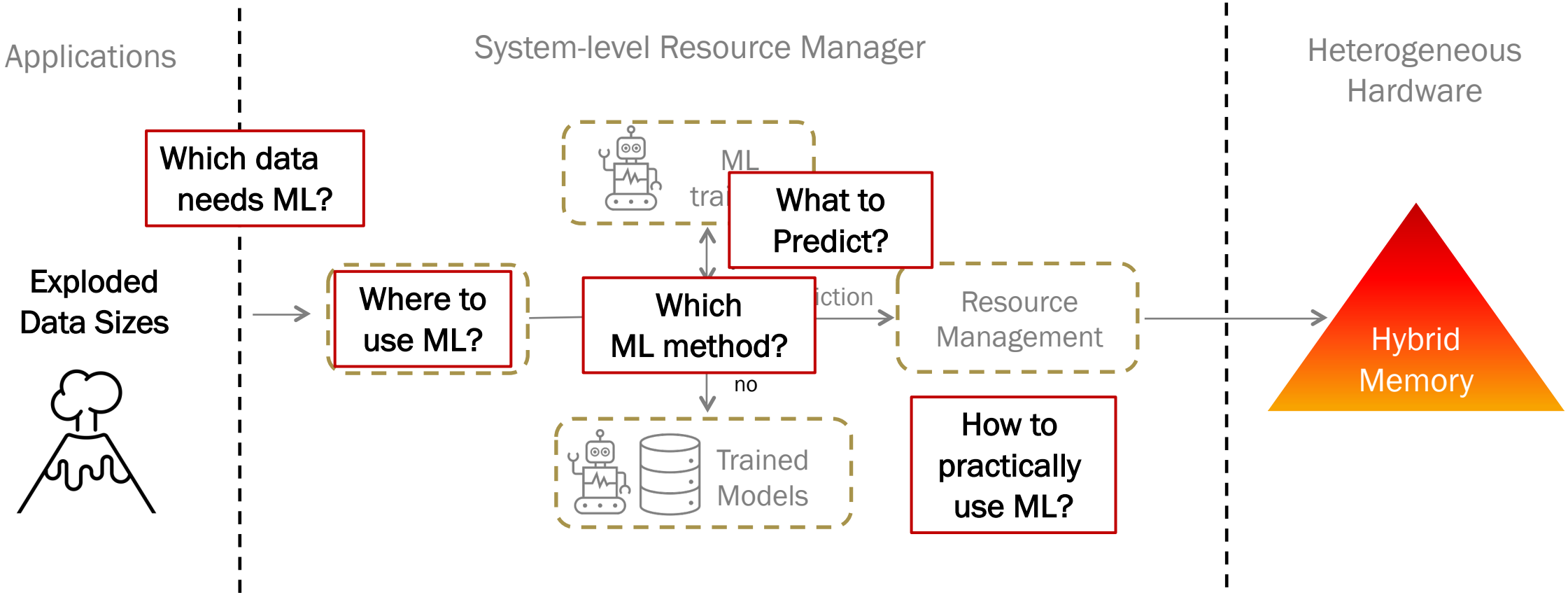
Machine Intelligent Hybrid Memory Management

The Vision.



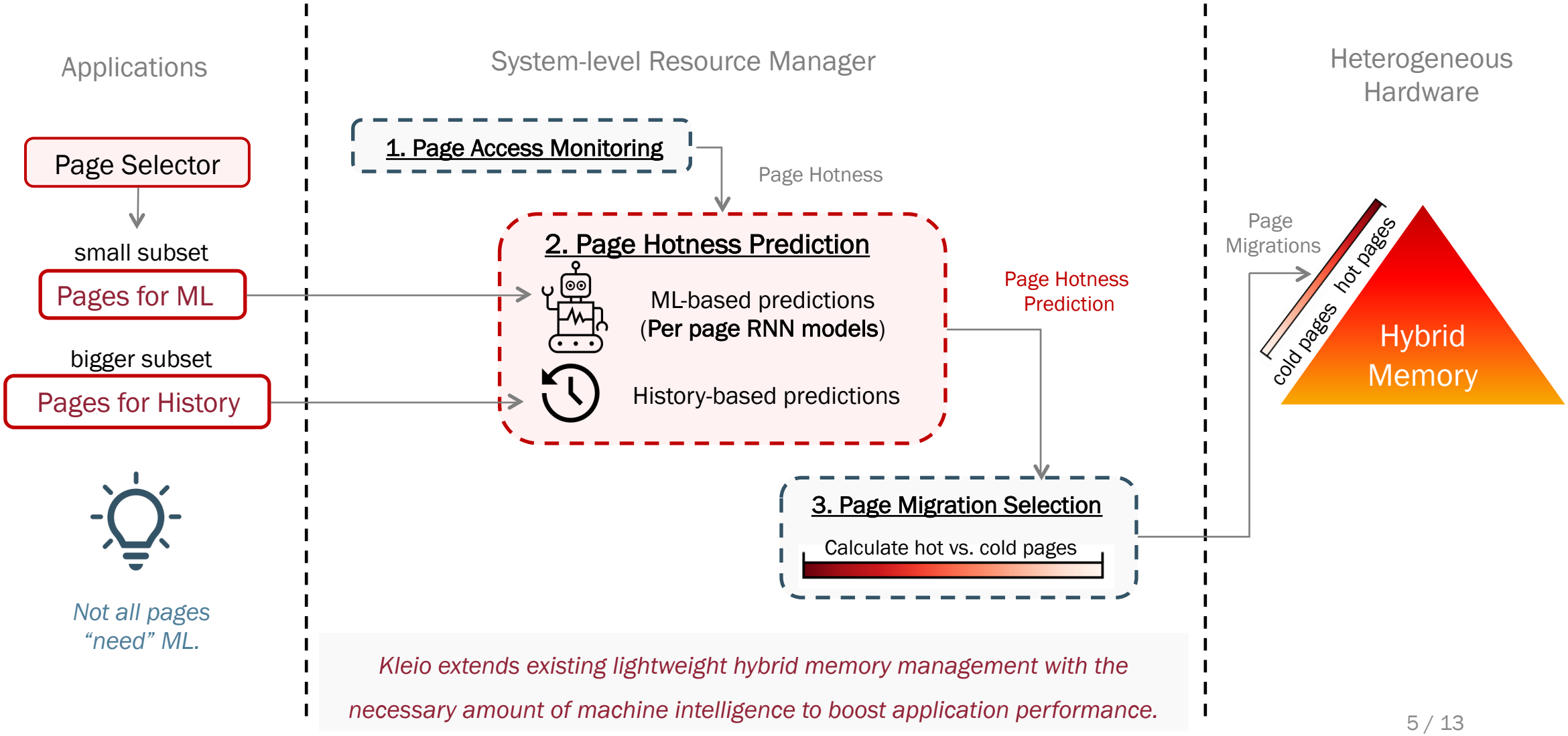
Machine Intelligent Hybrid Memory Management

Laying the grounds for the practical integration of ML.



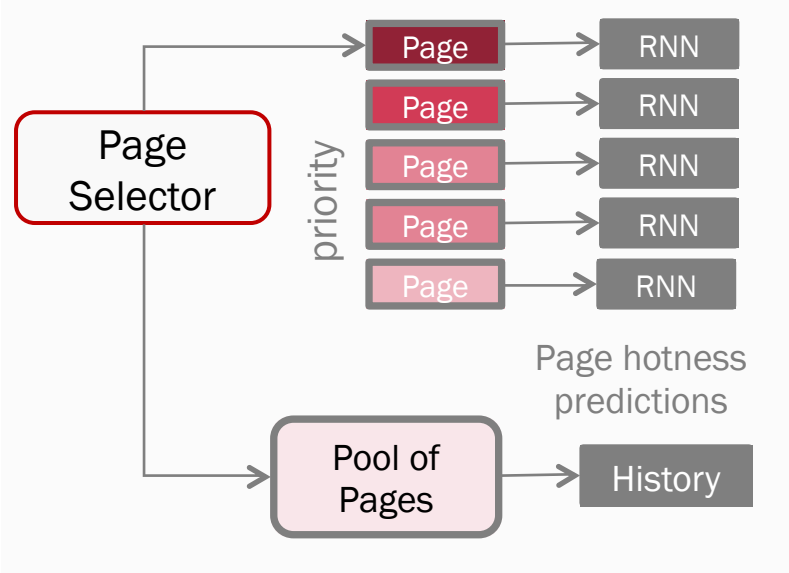
System Design of *Kleio*

Kleio is a hybrid memory page scheduler with machine intelligence. [Best Paper Award Finalist at HPDC 2019.]



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

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

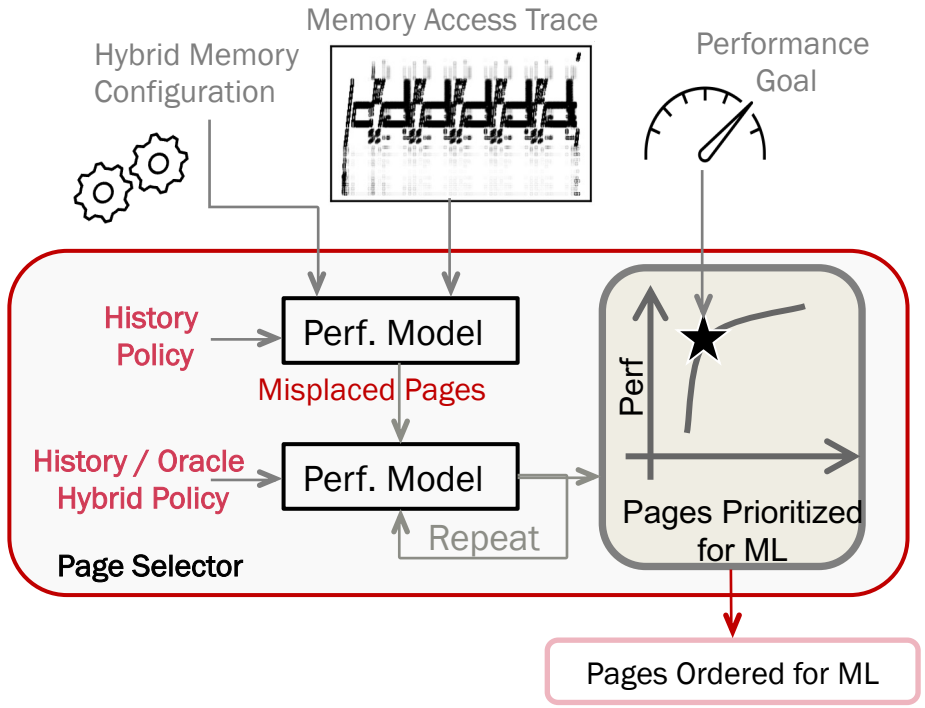


Apply ML on a small page subset.

↳ Foundations for practical use of ML.

Carefully select pages for ML.

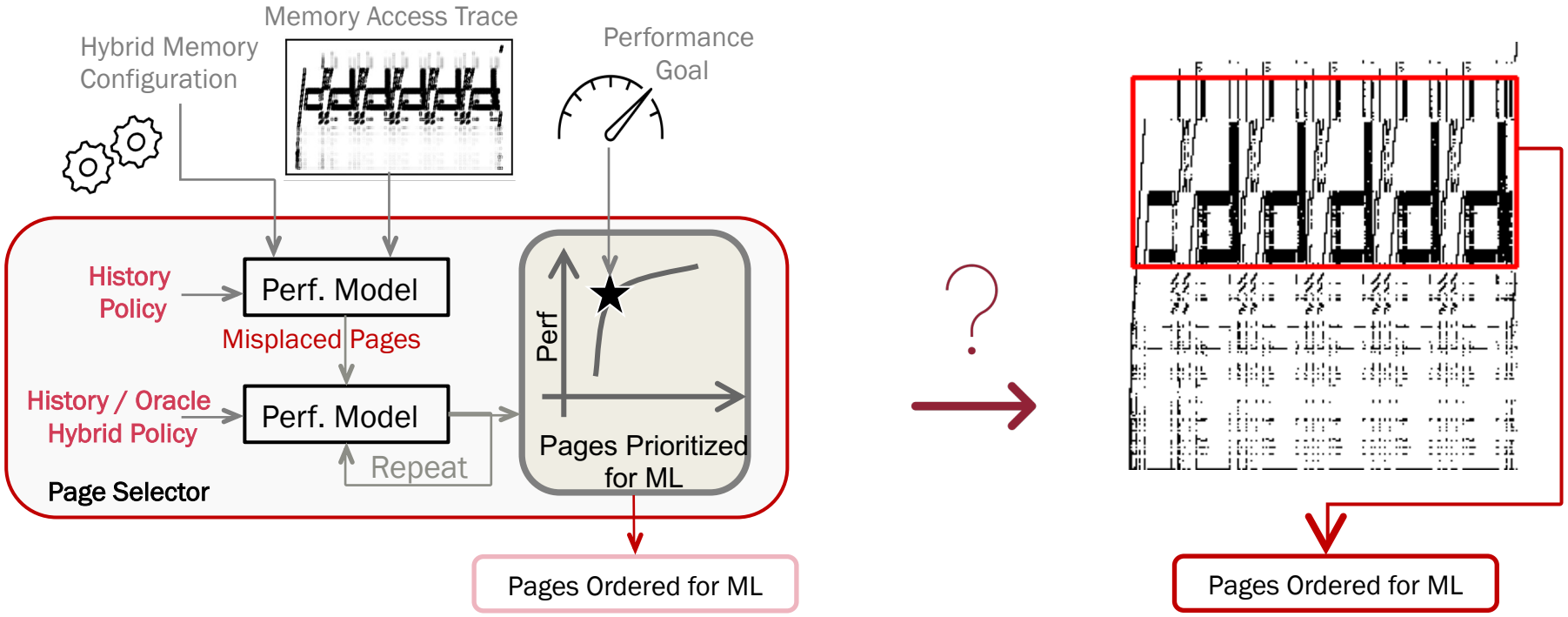
↳ Application performance boost.



The page selection is not a lightweight process.

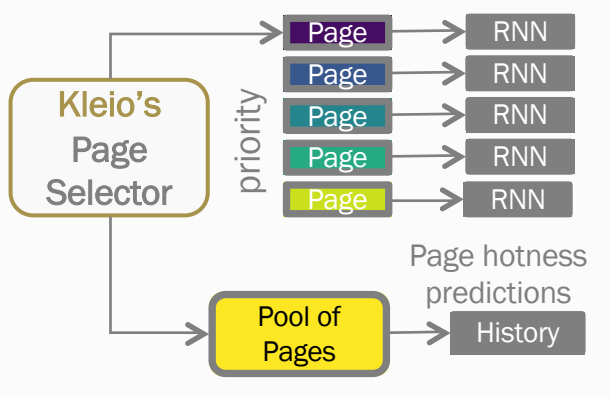
Can we accelerate the page selection process?

Reducing Operational Overheads of ML-based Management

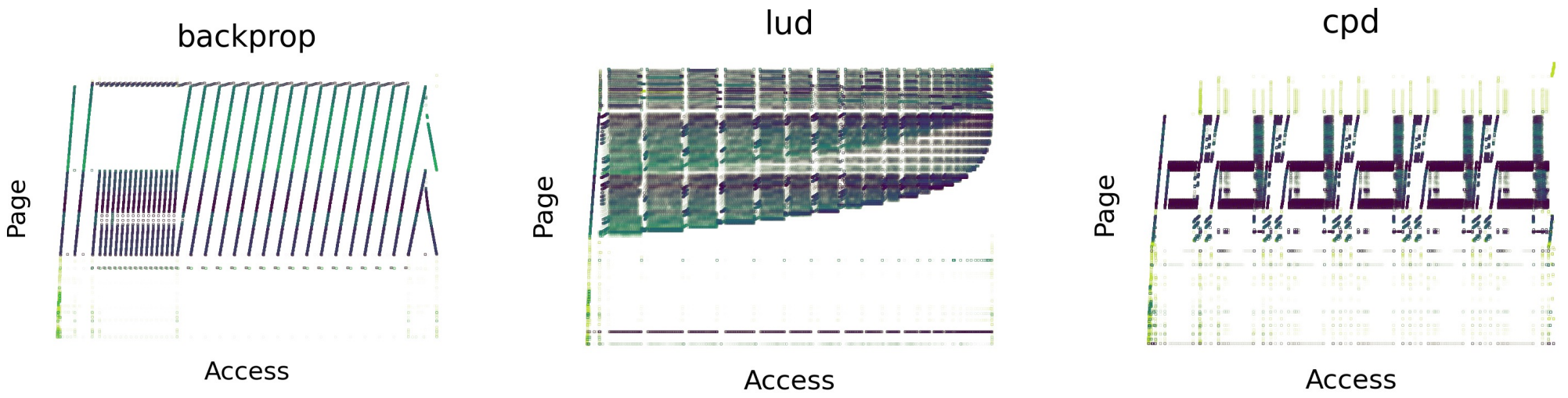


Can we accelerate the page selection process via **image-based** decisions?

Insight from Visualizing Pages Selected for ML

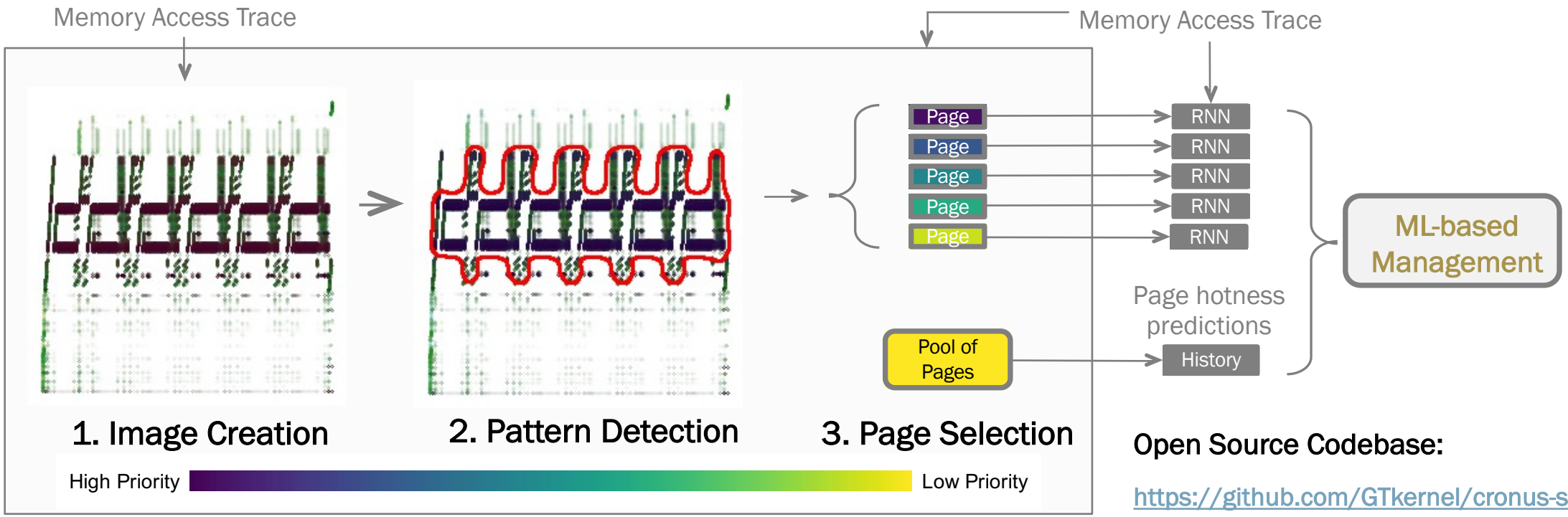


High Priority — Low Priority



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

Cronus: Image-based Page Selection Pipeline



Open Source Codebase:

https://github.com/GTkernel/cronus-sim

1. Image Creation:
   1. 256x256 image size.
   2. Page priority = hotness x hotness variance.
   3. Perceptually uniform colormap.
2. Pattern Detection with automatic color thersholding.
3. Page Selection with reverse pixel-to-page mapping.

Evaluation

Objective: Evaluate the effectiveness of the Page Selection.

Comparison

- **Kleio:** Performance-based Page Selection.
- **Cronus:** Image-based Page Selection in viridis colormap.
- **Grayscale:** Image-based Page Selection in grayscale colormap.
- **Viz-Black:** Image-based Page Selection in black-and-white.
- **Thres-Elbow-Benefit:** Analytical Page Selection with thresholds.

Goals (compared to Kleio)

~ Similar Page Selection Quality.

~ Similar Application Performance.

↓ Reduced Page Selection times.

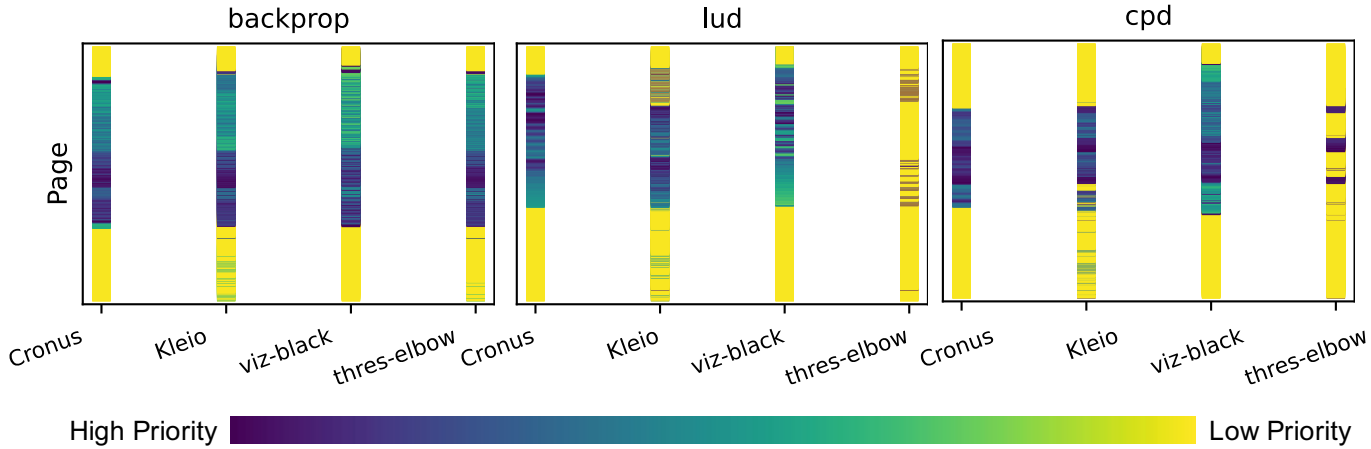
Evaluation

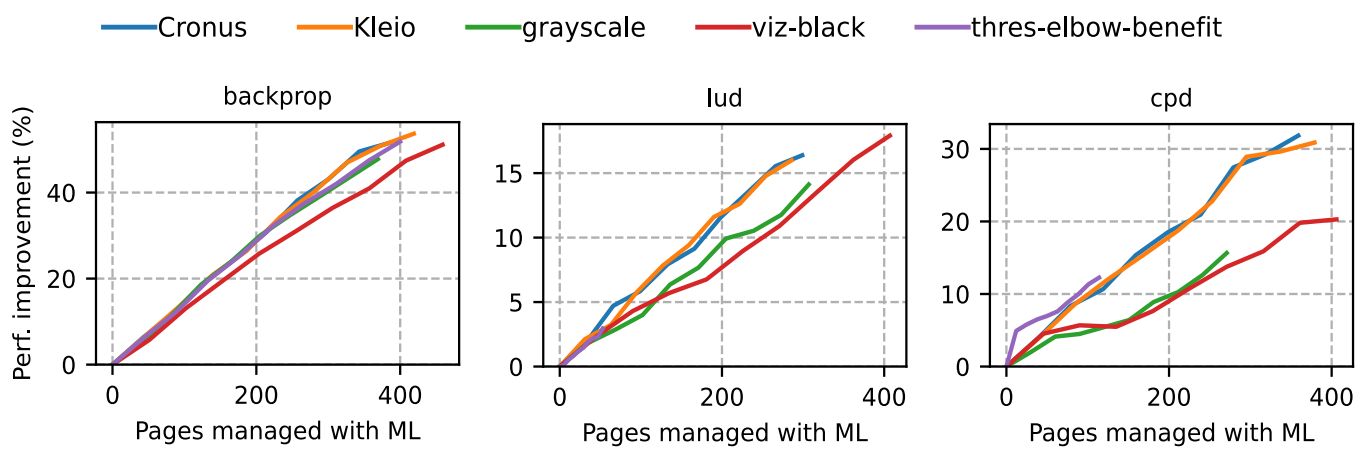
Page Selection Quality.

Cronus ~ Kleio

Application Performance.

Cronus ~ Kleio

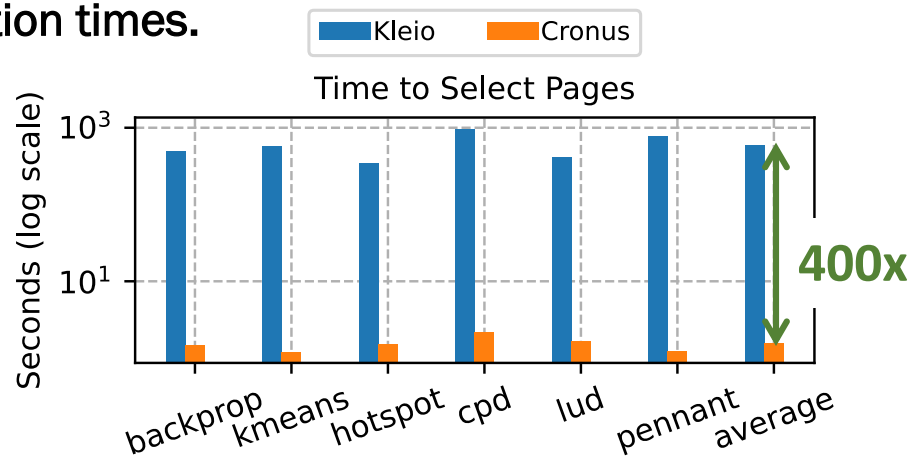




Cronus makes an *image-based* high quality page selection that delivers similar performance to Kleio.

Evaluation

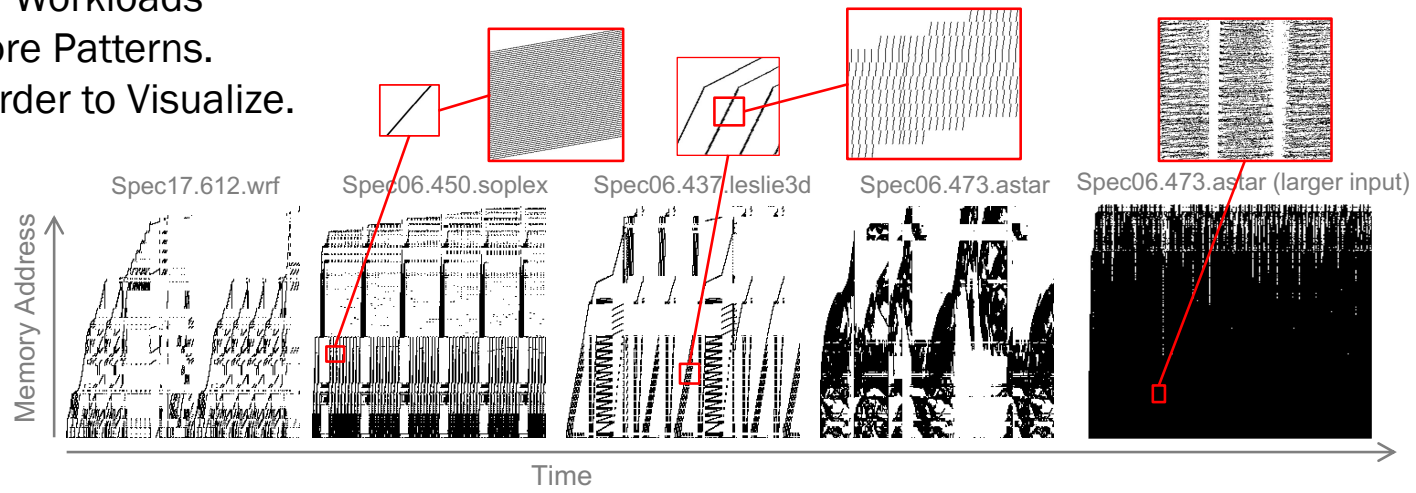
Page Selection times.



Cronus drastically reduces by **400x** the page selection times, down to few seconds.

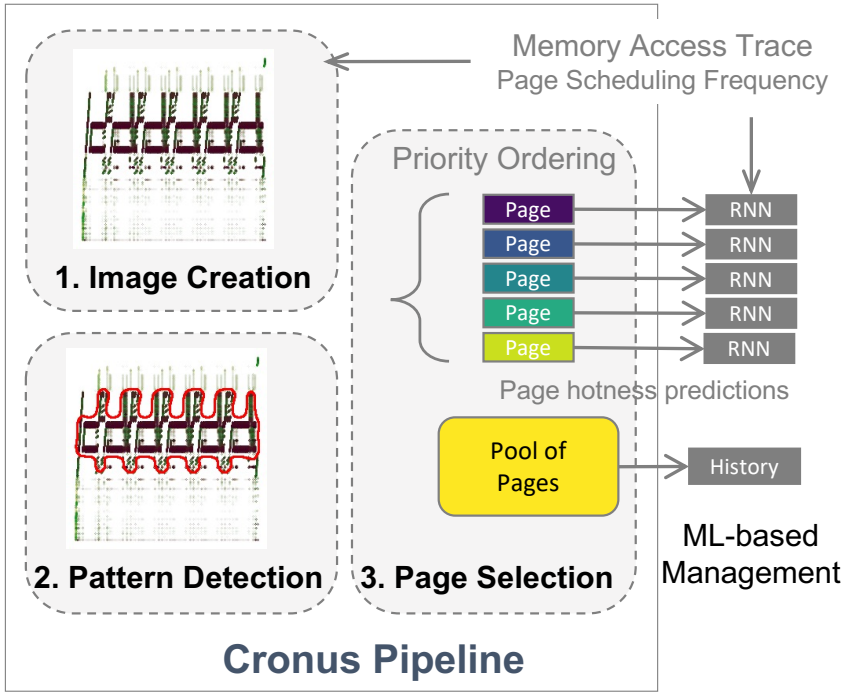
Remaining Challenges.

Larger Workloads
- More Patterns.
- Harder to Visualize.



Summary of Cronus

Greek Trivia: According to the ancient Greek mythology, Cronus (Kronos) was the King of the Titans and the god of time.



Takeaways:

- An image is worth a thousand.. lines of code.
  - Image processing and computer vision methods can unlock new opportunities in reducing system complexity and overheads.
- It is all about the image color and metadata.
  - A perceptionally uniform colormap best captures the most effective page ordering.
  - The metadata enable a standalone image-based pipeline with no need to store huge raw data (memory access trace).

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