Naut DB: Towards a Hybrid Runtime for Query Processing Samuel Grayson¹, Kyle Hale², Boris Glavic²

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Abstract

With the explosion of "big data", executing queries on vast amounts of data in parallel has become a bottleneck in many HPC systems. Complex towers of abstractions behind generic interfaces in the traditional software stack are getting in the way of better performance from multi-core systems.

To mitigate this inefficiency, we built hybrid runtime kernel (based on the Nautilus Aerokernel) for the paralel execution compiled queries. We evaluate the performance of our specialized runtime against a general-purpose runtime, for which Linux will serve as our examplar.

Motivation

The goal of this research is to integrate the improvements specialized systems (unikernels) with the improvements in specialized DB (compiled queries) to achieve high-performance.

- Status quo
- Too many abstractions makes high-performance difficult.
- OS is not aware of the workload; app-programmer is.
- DB systems already have specialized scheduling abstraction, mem. management abstraction.
- Give up the flexibility and generality in exchange for performance.
- Specialized Hybrid Runtime
- Kernel + Dataflow Runtime run in ring 0 (unikernel-like).
- Advances in multi-kernel environments allow physical TODO: (cite pisces) resources to be split between a full-weight kernel and our specialized runtime.
- Unikernel-inspired design allows the app-programmer fine-grained control over the execution environment.
- Control over scheduling \implies no context-switches.
- Control over OS \implies avoid interrupts \implies faster and more predictable.
- No virtual memory \implies huge page-sizes (1Gb) \implies no TLB misses.
- Control over memory \implies specialize memory-allocator for workload (by app-programmer). See Fig 1
- Compiled Queries
- Could be pre-compiled or JIT-compiled.
- The app-programmer writes compiled code in the unikernel, giving them unfettered access HW.
- Compose operators within a block \implies avoid function-call overhead.
- Control HW \implies NUMA-aware code.

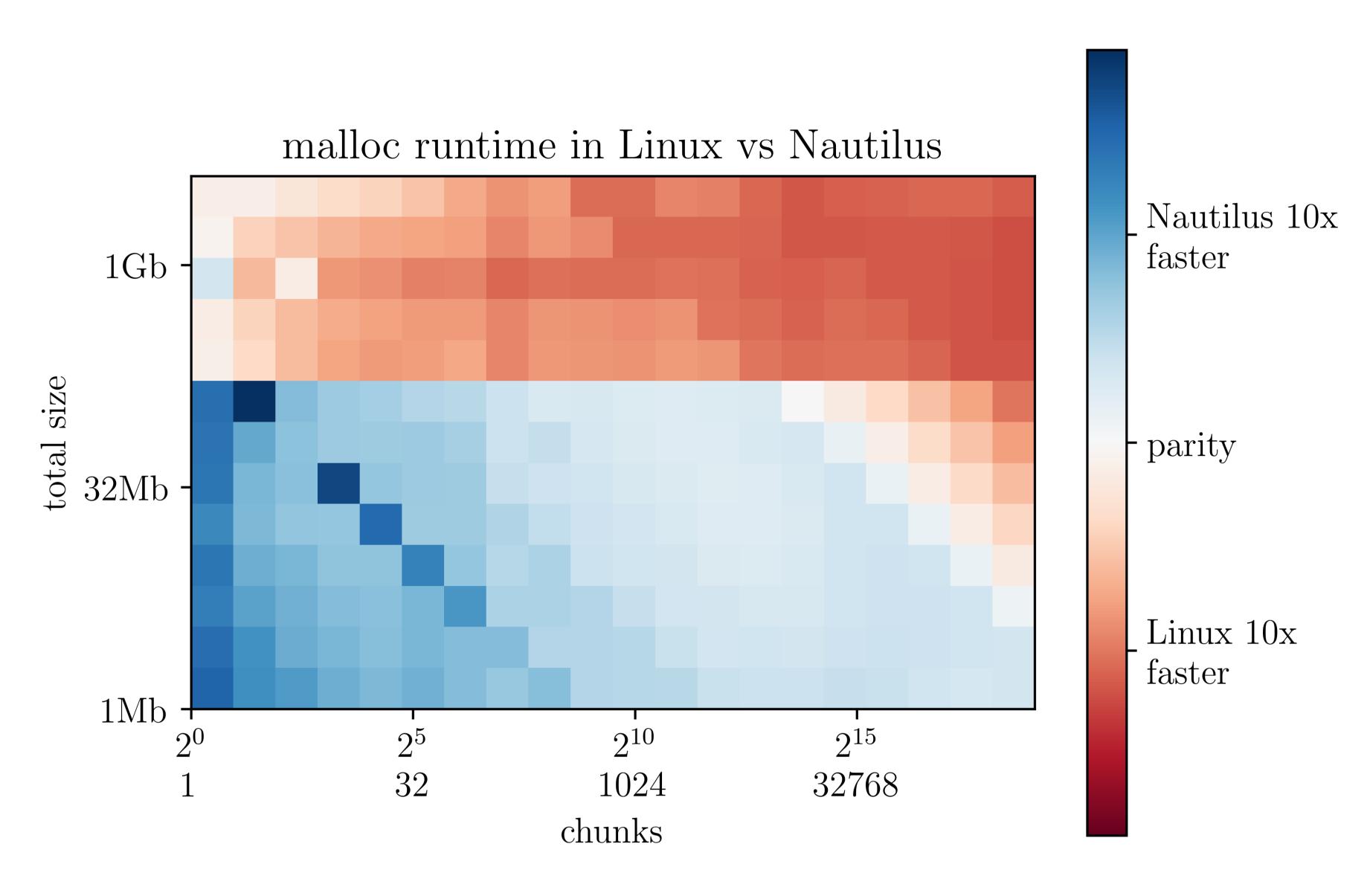


Figure 1:An alternative memory allocator can have a better performance for certain workloads.

Previous Work

- Customized OS support for data-processing[?]: TODO: I am not sure what specific improvements we have over this paper.
- A Case for Transforming Parallel Runtimes Into Operating System Kernels[?]: the authors use a specialized runtime and show performance benefit for runtimes such as Legion.
- System-Level Support for Composition of Applications [?]: the authors introduce Pisces which allows multiple kernels to run on the same physical node, partitioning the resources. This makes it more convenient to run an single-application OS alongside a general-purpose OS for other applications.
- TODO: get a paper on Compiled Queries

Testing prototype

- in-memory, columnar, chunk-oriented operators
- embedded in Nautilus or as application in Linux
- 16-core x86 64 AMD EPYC with 4 NUMA nodes
- TODO: version of linux kernel

Preliminary results I

Basic array operations (within a chunk) perform better in the specialized run-

Placeholder lmage

Box-and-whisker graph showing the performance (measured in cycles) and uncertainty

Figure 2:Nautilus can run array operations faster than Linux.

Preliminary results I (determinism)

Placeholder

lmage

TODO: Line plot with $\pm \sigma$ region shaded.

Operation	Linux	Nautilus
TLB miss		1
Page fault		0
Context switches		0
Interrupts		0
TODO: measure	linux	with perf.

Table 1:Nautilus can run array operations faster than Linux.

Preliminary results II

Some operator implementations perform worse in the specialized runtime. We are researching why this is, and if there is a way to beat Linux's performance.

TODO: Sort vary chunk size and num columns, parameters favorable to Nautilus

TODO: Select vary chunk size and num columns and domain size, parameters favorable to Nautilus

TODO: Create vary chunk size and num columns, parameters formula to Nontilue

Discussion

TODO: Since we are specialized we can improve the performance for specific workloads. If we are not better, we could switch to different customizations (chosen by the applicationprogrammer).

Future Work

- Implement performance counters (hardware-specific).
- Test more operators.
- Test parallel operations.

Conclusion

The research is promising, but more work needs to be done. Future work should seek to understand and improve the preformance details such as TLB misses and data cache misses in order to beat a general purpose OS.

Making the process simpler from the application-programmer's perspective is an active topic of research.

References