

Where Have All The Cycles Gone?

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Artwork by Daniel Mercadante



Adobe is Hiring

https://cppatadobe.splashthat.com





Sand in the Gears

- Memory Latency
- Synchronization
- Expanded Requirements
- Programming Model





Memory Latency

4 Δ ∧ ∧ Δ Δ Δ Δ Δ



Processor-Memory Gap



Computer Architecture: A Quantitative Approach by John L. Hennessy, David A. Patterson, Andrea C. Arpaci-Dusseau

Processor-Memory Gap



Synchronization



Synchronization



Mutex under contention - 1,000 - 1,500 cycles

The last line is the full cost of a context switch 10,000 - 1,000,000 cycles



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Not all CPU operations are created equal

"Simple" register-register op (ADD,OR,etc.)			
Nemory Write ~1	111		
Bypass delay: switch between			
integer and floating-point units			
"Right" branch of "if" 1-2			
Floating-point/vector addition 1-3			
Multiplication (integer/float/vector)			
Return error and check 1-7			
L1 read 3-4			
TLB miss 7-21			
L2 read 10-12			
"Wrong" branch of "if" (branch misprediction)			
Floating-point division 10-40			
128-bit vector division			
Atomics/CAS 15-30			
C function direct call			
Integer division 15-40			
C function indirect call 20-50			
C++ virtual function call 30-60			
L3 read 30-70			
Main RAM read 100-150			
NUMA: different-socket atomics/CAS			
(guesstimate)			
NUMA: different-socket L3 read			
Allocation+deallocation pair (small objects)			
NUMA: different-socket main RAM read			
Kernel call 1000-	-1500		
Thread context switch (direct costs)	000		
C++ Exception thrown+caught	5000-10000		
Thread context switch (total costs,	10000 - 1 millio) 010	
including cache invalidation)			

Distance which light travels while the operation is performed



Amdahl's Law - Cost of Synchronization

Each line represents 10% more synchronization





Expanded Requirements

4 **_** Δ Δ Δ Δ Δ Δ Δ Δ Δ Δ Δ 4 Δ 4 Δ Δ Δ Δ Δ Δ Δ Δ Δ Δ Δ



Background Processes

	\sim		16%	41%	0%	0%	6%	
Nam	e	Status	CPU	Memory	Disk	Network	GPU	GPU engine
Ap	ps (8)							
>	🗧 Windows Explorer		0.4%	93.2 MB	0.1 MB/s	0 Mbps	0%	
>	🔼 Task Manager		0.6%	43.3 MB	0 MB/s	0 Mbps	0%	
>	Slack (7)		0.6%	344.7 MB	0.1 MB/s	0 Mbps	0.2%	GPU 1 - 3D
>	People (2)	φ	1.5%	49.0 MB	0 MB/s	0 Mbps	5.6%	GPU 1 - Video Decode
> (Microsoft Edge (24)		4.9%	1,892.7 MB	0.1 MB/s	0 Mbps	0.1%	GPU 1 - 3D
>	- Mail		0%	64.1 MB	0 MB/s	0 Mbps	0%	GPU 1 - 3D
>	ITunes (7)		0%	64.2 MB	0 MB/s	0 Mbps	0%	
>	Calendar		0%	47.9 MB	0 MB/s	0 Mbps	0%	GPU 1 - 3D
				a second s				

Background Processes

UtilizationSpeed11%3.27 GHzProcessesThreadsHandles37750172757Up time7:01:29:19



	Base speed:	3.10 GHz
	Sockets:	1
	Cores:	4
	Logical processors:	8
76	Virtualization:	Enabled
	L1 cache:	256 KB
	L2 cache:	1.0 MB
	L3 cache:	8.0 MB



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Programming Model



Sand in the Programming Model

- Heap Allocated Objects
 - Lifetime Management Atomic Ops
 - Indirection & Virtualization
- Threads Context Switch
 - Dispatch cost
- Arrays of Structures (AoS)
- Raw loops
- JIT compilation and GC

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100x

8 - 32

10x

- 500 600
- 10,000 1,000,000
- 10 20
- 30 60

200 - 500

Desktop Compute Power (8-core 3.5GHz Sandy Bridge + AMD Radeon 6950)



Digging Out

- Hardware changes
 - Unified and shared memory
- OS changes
 - Managed cores across processes
 - Hints for thermal, memory, heterogeneous core, and cache utilization
 - Coordinated asynchronous, DMA based IO





Language Changes

- Mutable value semantics
 - https://www.val-lang.dev/
- Structured task concurrency model
 - Grain size control
 - Explicit data dependencies for thread affinity
- GPU and SIMD execution model
 - Algorithms and execution abstraction
- Array of structures of arrays (AoSoA) support





About the artist

Daniel Mercadante

American artist and filmmaker Daniel Mercadante creates surreal photographs by painting in camera with a custom-built lighting rig. Inspired by the peace and beauty of the natural world, he shoots multiple long exposures of the same composition, and then animates his images to create meditations on light and nature. Mercadante created this piece using a Canon 5D camera and Contax/Zeiss vintage lens, and then fine-tuning color and exposure in Adobe Lightroom and making final touches to the light path in Adobe Photoshop.

Made with





Ps Adobe Photoshop **Lr** Adobe Photoshop Lightroom



Artwork by Daniel Mercadante

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