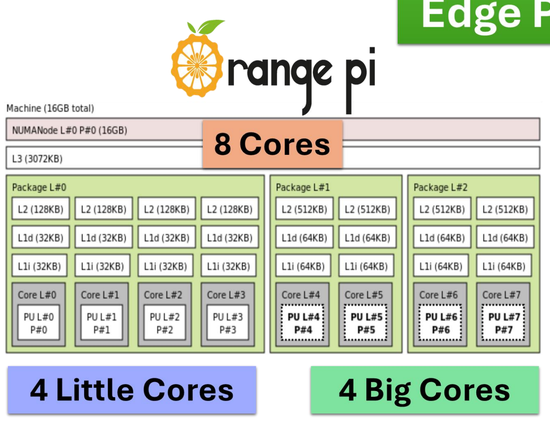
Analysis of Performance-Impacting Factors

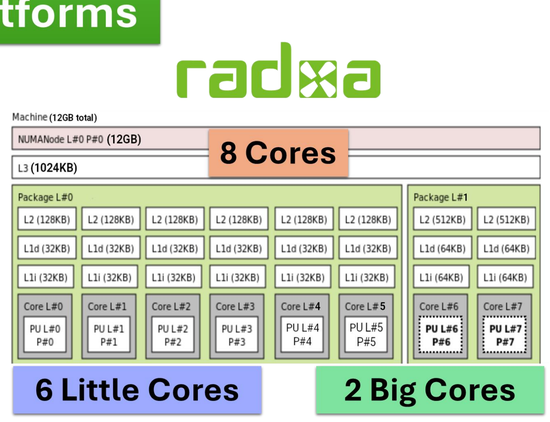
Steven D. Harris, Christopher D. Gill, Roger D. Chamberlain
McKelvey School of Engineering, Washington University in St. Louis

Overview

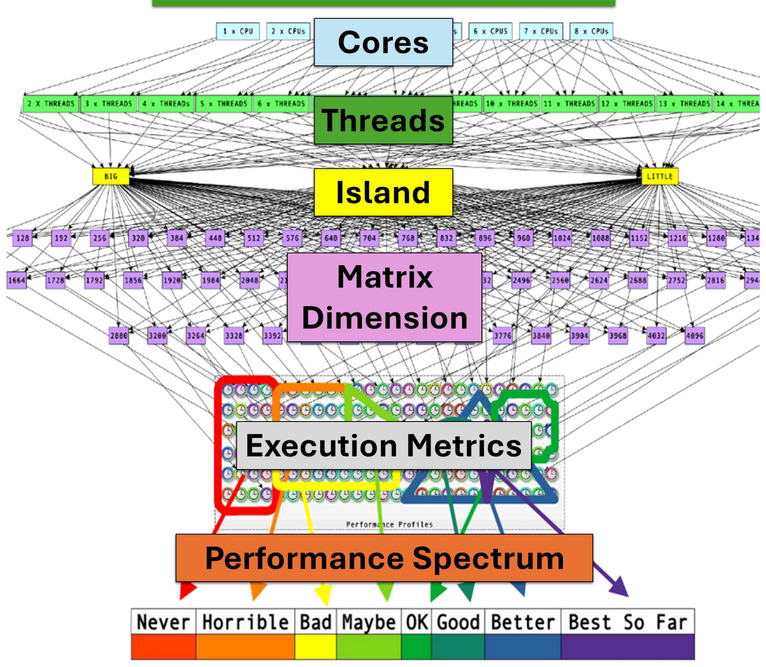
Modern asymmetric multiprocessing (AMP) architectures frequently rely on the heuristic assumption of cluster independence, where cores operate as computationally orthogonal resources. This research provides a rigorous mathematical and empirical disproof of this assumption through the application of the **Boltzmann uniqueness theorem** and **Structural Equation Modeling** (SEM). We identify "architectural entanglement" as a systemic phenomenon which necessitate coupled relational models rather than traditional additive ones. Statistical validation confirms that performance scaling is non-linearly dependent on architectural constitution. These findings support a paradigm shift toward coupled-domain modeling in heterogeneous system design.

Arm Big.LITTLE Edge Platforms

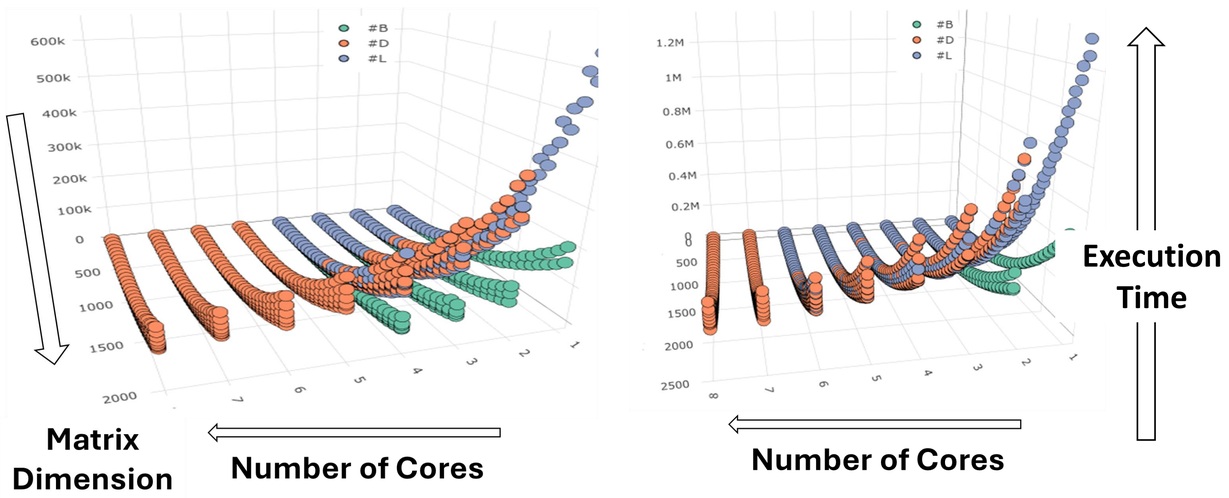




Platform Complexity



GEMM Workloads



Architectural Entanglement

This systemic architectural entanglement manifests as a **failure of convolutional commutativity**, enabling the application of the Boltzmann uniqueness theorem as a formal **measure-theoretic** disproof of **cluster independence** by demonstrating that the joint energy measure is not the convolution of its subsystem parts.

Orange Pi Power Analysis

Target Island	Big0 Power	Big1 Power	Little Power
Big0	**3.213 W**	0.692 W	1.006 W
Big1	0.602 W	**2.560 W**	1.275 W
Little	0.602 W	0.602 W	**1.228 W**

$$\Phi_\beta[\mu_{Big} * \mu_{Little}] \neq \Phi_\beta[\mu_{Big}] * \Phi_\beta[\mu_{Little}]$$

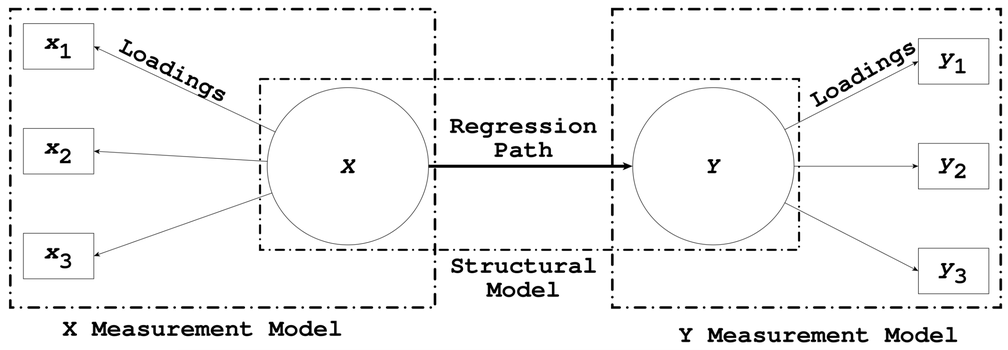
Idle Domain (Parasitic Draw)

Targeted Domain (Power Draw)



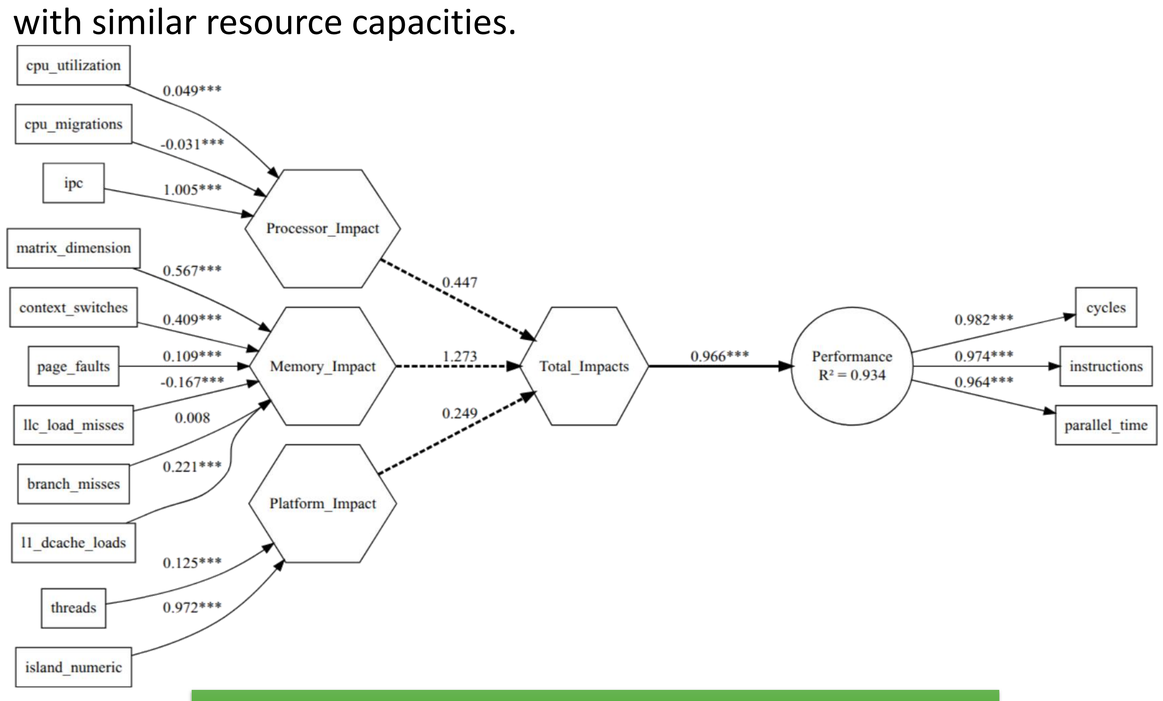
Structural Equation Modeling

SEM provides simultaneous articulation of parameters and their interactions in cohesive and intuitive models that capture important metrics and behaviors.



Comprehensive Models

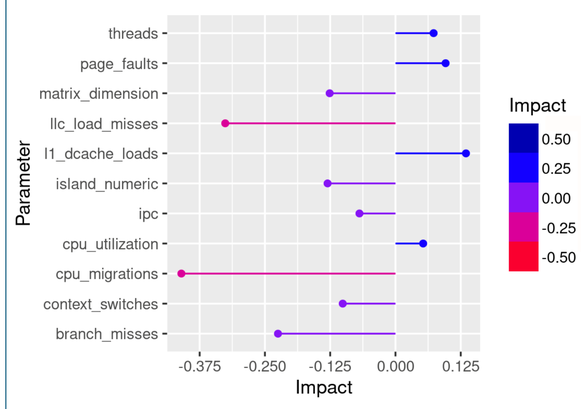
SEM provides targeted performance models applicable to many devices with similar resource capacities.



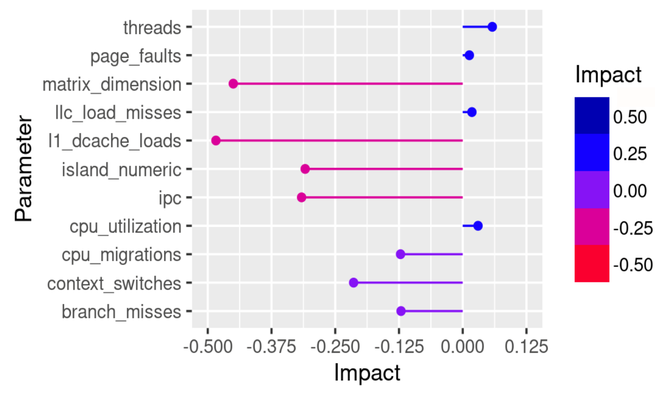
SEM Parameter Impacts

SEM facilitates the formal decomposition of complex microarchitectural interactions, providing targeted quantitative insights into both the magnitude and direction of performance impacts exerted by hardware-agnostic parameters, thereby exposing the underlying structural dependencies within heterogeneous architectures.

Orange Pi 5



Cubie A7A



Conclusion

Heterogeneous fabrics necessitates **Power-Aware** scheduling that acknowledges shared voltage domains in coupled physical systems.
The **Boltzmann equation** bridges measure-theoretic physics with digital architecture enabling quantification of "architectural noise" and "stochastic coupling" previously confined to theoretical physics and quantum systems.
Utilizing **Structural Equation Modeling (SEM)** allows performance variation discrimination from confounding nuisance signals. We move system modeling from additive logic to relational, **matrix-based framework** essential for managing physical fabric interference.

	Homogenous	*Heterogeneous*
Isolation Assumption	Logical Thread Isolation	Physical Voltage/Fabric Coupling
Scaling Approach	Linear Scaling	Non-linear Scaling
Model Type	+ + + Additive (P_1 + P_2)	[M] Relational / Matrix-based