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ARCADE: Automated Resource Management System for HPC at Petrobras

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Introduction (Font: Arial Bold, 10).

Efficient utilization of high-performance computing (HPC) resources represents a critical challenge for the oil and gas industry, especially in geophysical data processing. At Petrobras, the evolution of seismic imaging algorithms has demanded increasing computational capacity, yet manual management of these resources resulted in suboptimal occupation levels, generating excessive costs and operational inefficiency. Monitoring scientific computing environments is particularly challenging due to the complex triad of stakeholders—users with specific scientific needs, IT infrastructure teams, and software developers—each with different priorities and technical languages. ARCADE was developed as a solution to bridge these gaps and automate monitoring and optimization of computational resources.

Method and/or Theory

ARCADE employs a modular architecture designed to address the multifaceted challenges of HPC resource management. The system integrates several specialized components working in concert to deliver comprehensive monitoring capabilities: automated detection of computational nodes behaving abnormally, predictive analytics for estimating completion times of large-scale jobs, systematic log analysis to verify successful process execution, infrastructure anomaly detection through guided analysis of CPU/GPU/memory usage patterns, and a centralized dashboard for resource monitoring and management. This modular approach addresses the diverse needs of the stakeholder triad: scientific users receive performance insights on their jobs, IT teams gain infrastructure monitoring capabilities, and developers can track application behavior. Development began in 2023 and evolved from initial prototypes to a robust web platform with corporate authentication, enhanced information security, and real-time monitoring of computational resources.

Results and Conclusions

The implementation of ARCADE raised HPC resource utilization levels from approximately 60% to over 90%, representing significant savings for the company - for the Pégaso machine alone, optimization avoided excessive spending of R\$45 million. The system enables real-time visualization of resource usage, automatic anomaly identification, job history tracking, and user-specific configuration customization. By creating a common interface for the user-IT-developer triad, ARCADE has improved communication and reduced troubleshooting time for computational issues. Future developments include more robust AI integration for load balancing based on project deadlines, seasonality forecasting, automatic suggestion of corrections for common failures, and automated user communication, establishing ARCADE as an essential tool for efficient computational resource management at Petrobras.