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High Performance Optimization of Civil Infrastructure Systems on Cloud

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Summary

Infrastructure system analysis is a computation-intensive task. Equipped with the software tools, engineers are able to analyze a handful of alternative solutions, but often end up with a workable alternative far from the optimized solution. Effectively optimizing an infrastructure system is a challenging task. Undertaking such a task requires not only well-developed optimization software tools, but also powerful computing facilities. Therefore, infrastructure system optimization is highly desirable to be conducted on cloud.

Infrastructure system optimization is usually an implicit and nonlinear programming problem. The problem has to be carefully formulated in the way that classic mathematic programming can be applied to. In comparison, a genetic algorithm (GA) based on natural evolution mechanics and genetic reproduction is found flexible at solving the engineering problem as is, namely without special mathematic treatment. A competent GA has been successfully applied to water distribution optimization problems including model calibration, network design and pump scheduling. It has been decoupled and generalized as Darwin optimization framework, incrementally developed as a general parallel optimization solver for infrastructure system analysis. The framework is further developed and deployed as thin-client architecture on a high performance computing (HPC) cloud.

The HPC cloud computing platform is comprised of a HPC cluster and the parallelized optimization framework. It enables engineers to efficiently and cost-effectively undertake computation-intensive tasks of large infrastructure system optimization. Based on the outcomes of the previous research projects, a wide range of optimization problems, including, but not limited to, water pipeline leakage detection, pump scheduling, geometry design, structure damage detection and building performance-based design optimization, have been solved by applying the HPC optimization.

Both water pipeline leakage detection and structure damage detection are the problems of system identification. It is formulated to solve for a set of system parameters by integrating the Darwin with each of the domain analysis models, hydraulic simulation and finite element analysis respectively. The optimal set of parameters was found by minimizing an objective function representing the pre-defined distance between the observed and simulated attributes. Geometry design and building performance design are multi-disciplinary optimization problems, which are

solved by integrating Darwin with parametric geometry modeling tool, structure analysis model and building energy analysis. A number of case studies have been conducted to demonstrate the successful applications and benefits of Darwin optimization framework for civil infrastructure high performance analysis.