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EXTENDING DISCRETE-EVENT SIMULATION FRAMEWORKS FOR NON-STATIONARY PERFORMANCE EVALUATION: REQUIREMENTS AND CASE STUDY

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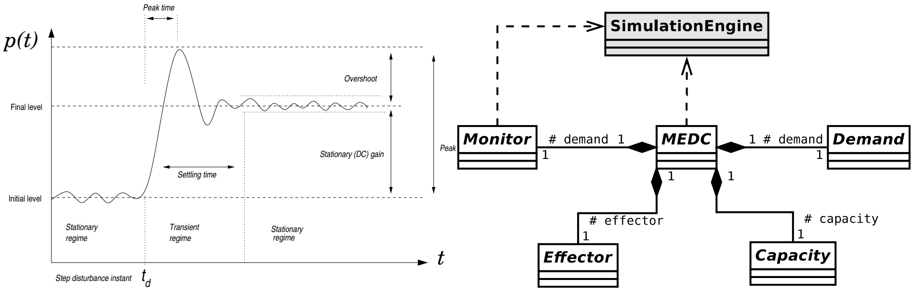
ABSTRACT

This paper introduces an approach to obtain an empiric analytical model of the performance dynamics of computer systems out of discrete-event simulation (DES) experiments. To that end, the proposed methodology elicits the requirements for extending conventional stationary DES frameworks so as to meet the needs of transient performance analysis. The work goes through the rationales for the conceptual formulation of dynamic (as opposed to static) capacity and summarizes a methodology for system identification. Results of on going research are reported and conclusions illustrated by case study.

1 NON-STATIONARY PERFORMANCE EVALUATION FROM DES EXPERIMENTS

This present study relies on the abstract notion of *performance* as a quantitative assessment of how well one system's *capacity* is capable of absorbing the incoming *demand* — all quantities generically defined. Concerning many engineering purposes, the system capacity $C(\cdot)$ can therefore be conceptually formulated as a function relating the signals demand $d(t)$ and and performance $p(t)$ such that it can be denoted $p(t) = C(d(t))$. While not often expressly distinguished, *stationary* analysis is hereby implied. Under a typical stochastic workload, a suitable experimental approach for this goal consists in sampling the input and output signals for some time, discarding initialization effects, and then applying regression techniques to parametrize a proper analytic model. The underlying reason to ensure a stable operational point is that, during initialization, system *dynamics* may be expressive, e.g. due to buffers filling, resources instantiation etc. Capturing the dynamic properties, in turn, is precisely the aim of *transient* (non-stationary) analysis. Under this approach, capacity is to be modeled as a *dynamic system*, mathematically corresponding to a differential (or difference, in discrete time domain) equation. Formally, we may then denote capacity $C(\cdot,t)$, and thereby $p(t) = C(d(t),t)$, to imply that performance at any instant does not depend solely on the immediate demand, but also on time, since the inertial behavior causes the input changes to show up at the output with certain delay and varying with time even if demand is constant. For instance, starting at an initial stationary level (Figure 1a), an abrupt step disturbance at the input may yield a monotonic increase, dumped oscillation or even catastrophic instability at the output. In addition to the stationary gain (Figure 1a), transient analysis reveals *dynamic performance parameters* such as peak performance degradation, transitory overshoot, output settling time, and other metrics of interest.

In a great extent, existing DES frameworks for computer systems performance evaluation are originally meant for stationary analysis. The present research work investigates approaches to extend methodologies and tools for use in non-stationary performance evaluation. One of the proposed contributions in this area is a systematic approach to extracting empirical-analytic dynamic models of computer systems's performance out of DES experimental data. Concisely, the approach consists in a concern-based reference model for non-stationary DES, an experimental protocol to acquire identification data, and a time-analysis method



(a) Dynamic performance metrics (b) A concern model for non-stationary DES

Figure 1: Dynamic performance metrics and a non-stationary DES architecture

to obtain an empiric-analytical dynamic model. The reference model separates the simulation designer's concerns into a set of responsibilities comprising the capabilities of modulating demand and capacity in the course of simulation, timely monitoring variables and modeling the dynamics of the system's effectors. The proposed MEDC (monitor, effector, demand, capacity) architecture is depicted in the class diagram of Figure 1b and further detailed in (Mamani, Júnior, Santana, Santana, Nobile, and Monaco 2015). The identification protocol relies on the hypothesis of a valid (stable) linear time-invariant (LTI) approximation and on classical frequency-domain analysis. The procedure must be able to expose the system dynamics by applying it a controlled disturbance and then observing the elicited transient regime. The protocol consists in a sequence of steps: a) choose demand and performance parameters (SISO); b) bring the system to the quiescent operational point; c) ensure linearity by causing the basal stationary demand to excursion at the vicinity of the operational point (small-signal analysis); d) apply the system a step disturbance (Figure 1a) and sample the performance measurement; e) apply offsets and normalization so that performance signal represents the response to a unitary step input at the zero initial-condition; f) generate a frequency-response vector (bode plot) to identify the cut-off frequency f_c; g) apply the discrete signals a sharp low-pass filter to remove stochastic noise beyond f_c (signal as averages); h) select the lowest-order dynamic model (parsimony) capable to capture the system dynamics (1^{st} order if transient is monotonic, 2^{nd} order if it exhibits stable oscillation); i) use the filtered signals to fit an auto-retrogressive model with exogenous input (ARX) model; j) from the ARX model derive a transfer function (TF). The TF is an empirical analytic approximation of the system dynamics which can be validated by comparison its with DES simulations.

2 RESULTS AND ONGOING RESEARCH

The introduced approach grounds the design of OnlineBroker (Júnior, Mamani, Santana, Santana, Nobile, and Monaco 2015), an extension of the known cloud computing simulation framework CloudSim (www.cloudbus.org/cloudsim/). The implementation by the authors has been explored in control-theoretical approaches for resource allocation in cloud computing (under FAPESP, CNPq, CAPES, NAPSoL support). Results have shown that the ability to model the transient behavior through the herein introduced technique yielded observable performance gains (Mamani, Júnior, Santana, Santana, Nobile, and Monaco 2015).

REFERENCES

Júnior, L. A. P., E. L. C. Mamani, M. J. Santana, R. H. C. Santana, P. N. Nobile, and F. J. Monaco. 2015, Oct. "Non-stationary simulation of computer systems anddynamic performance evaluation: a concern-basedapproach and case study on cloud computing". In *The 27th SBAC-PAD.*, (in print).

Mamani, E. L. C., L. A. P. Júnior, M. J. Santana, R. H. C. Santana, P. N. Nobile, and F. J. Monaco. 2015. "Transient performance evaluation of cloud computing applications and dynamic resource control in large-scale distributed systems". In *Proceedings of the 2015 International Conference on High Performance Computing & Simulation — HPCS*. Amsterdam, The Netherlands.