WiP Abstract: Can Cyber-Physical Systems be Predictable? Inferring Cyber-Workloads from Physical Attributes

Junsung Kim†, Young-Woo Seo¬, Hyoseung Kim†, Ragunathan (Raj) Rajkumar‡
†‡Electrical and Computer Engineering, Carnegie Mellon University, Pittsburgh, PA
¬‡The Robotics Institute, Carnegie Mellon University, Pittsburgh, PA
†{junsungk, hyoseung}@cmu.edu, ¬young-woo.seo@ri.cmu.edu, ‡raj@ece.cmu.edu

ABSTRACT

We present a new framework that can predict workloads of cyber-tasks based on their physical inputs.

1. INTRODUCTION

Cyber-Physical Systems (CPS) enable a wide range of application domains, including embedded medical devices, smart cars, distributed transportation systems, smart grids, and planetary robots. Since CPS are tightly coupled with the physical world, CPS must satisfy strict timing constraints based on operating characteristics.

Real-time theories applicable to CPS have been well-studied and used in practice to guarantee system timeliness; however, conventional ways of dealing with real-time systems become less appealing to CPS. The pessimism in the traditional analyses [2] does not give enough room for flexible CPS design options for dealing with space and cost constraints. For example, extra hardware caused by pessimistic timing analysis might not be desirable in the cost-sensitive automotive industry. Space taken by additional hardware is undesirable in space-sensitive systems like implantable medical devices.

It is challenging to reduce the pessimism about system timeliness particularly when we use conventional real-time analysis techniques assuming the worst-case execution times of tasks. This challenge comes from the fact that CPS tend to have more variations on their workloads. For example, the authors in [2] showed that there could be 47% difference on the utilization of an engine task unless we capture the engine states. Hence, the lack of understanding of the proper engine (task) behavior can end up requiring more hardware, and correspondingly additional cost and space.

2. METHODS

Understanding CPU consumption of generic tasks is not trivial, and it is still an active research area. Unlike generic tasks, however, CPS tasks have strong correlations between the CPU resources consumed by the tasks and the internal state and external physical conditions. We aim to find how much resources should be allocated to cyber-tasks by leveraging 2D classifications of physical attributes based on inputs' origin and the degree of their variability: (*endogenous*, *exogenous*) and (*static*, *dynamic*). The 2D classification enables us to categorize inputs that affect tasks on CPS into four different cases. Depending on how inputs affect tasks, we classify each task as either a *uni-modal task* or a *multi-modal task*. We apply a conventional workload analysis [1] to uni-modal tasks. We use three *regression* methods (linear and logistic regression, and robust fit) to figure out how each multi-modal task behaves depending on its physical inputs.

We apply our proposed framework to the self-driving car [3] developed at CMU to illustrate our findings. To effectively and accurately profile both types of tasks, we have developed a lightweight kernel module and deployed it on the self-driving car. Hundreds of hours of real-world data are collected and leveraged. We also design a feature space to predict cyber-tasks' workloads.

3. PRELIMINARY RESULTS

Our preliminary results show that the traditional workload analysis works well for uni-modal tasks and the regression methods are suitable to predict multi-modal tasks. In particular, the linear regression outperforms the other two regression methods by up to 12.6 times in terms of the mean squared error between the predicted and the true CPU utilization values.

4. REFERENCES

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