# Leveraging CloudLab to Better Quantify the Impact of Cloud Computing on Robotics

S.L. Remy – Clemson University – Usable Interactive Systems Group

In the past four years there has been increased access to Cloud Computing technologies that are quite relevant to the development of networked robots and other connected devices. Specifically focusing on Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) models, there are now scores of providers, many of which provide comparable services. While there are few formal cloud standards, several de facto standards exist. In the PaaS domain, when considering Python, several vendors make use of virtual environments, and also use git repositories. There may be variation of terminology; however, whether you call them dynos, gears, or use some other creative metaphor, there is consistency in the resources that are provided to research developers. Such similarities also exist in IaaS offerings. We researchers have ready access to commercial cloud offerings; however, there is little work that provides us with assurances about performance. Vendors are locked in a battle to drive cost down so that they can capitalize market share, and they have little interest in sharing details that will help a scholar develop repeatable results. At present, only with access to private cloud infrastructures can the impact of particular technologies truly be understood. This is the reason why the CloudLab project is so exciting to us in the Usable Interactive Systems group at Clemson University.

Over the past two years we have performed experiments that bridge the domains of cloud computing and robotics. Unlike many other facets of computing, in robotics, time and other physical properties like distance and momentum are *significant*. It is not enough to that code compiles and runs, or that a service composition is possible, but in robotics, subtleties like latency or jitter can impact performance, and in extreme cases can cause instability. Whether considering “robot brains” in the cloud, or simulating robot in the cloud, making decisions on millisecond scale is critical. The variability associated with assessing time on virtual clocks on operating systems which run on virtual machines, and the variability associated with multiple virtual machines sharing the same physical network interfaces, are just two sources of concern when we consider cloud computing and robots. Out of fear, many seek to avoid the Cloud at all cost, but such an approach is not truly viable.

To date, our focus has been to quantify the impact of the use of Cloud and Web technologies on performance, and we would like to leverage CloudLab to better evaluate the ecosystem. If given the opportunity, our group will perform work in three synergistic areas: the impact of IaaS on the simulation of real-time robot models and robot control, the impact of PaaS frameworks on real-time interaction with robots (over short durations), and finally, the user experience for developers configuring the IaaS or PaaS infrastructures that are used for this purpose. CloudLab promises transparency and control all the way to bare metal and this presents opportunities to better characterize the impact of the cloud. Initially we intend to use Openstack for IaaS, and to use Openshift for PaaS. If successful, we will consider other infrastructures as well. We use open source robotics frameworks (ROS, Gazebo, Stage and Morse) to simulate whole robotic infrastructures and we also use dynamical models of robots simulated in C or Python. Control is implemented in C, Python and Java. To evaluate the user experience for developers, we consider the task of applying the cloud-hosted robotics to support one-week computer science education/outreach activities.


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Under review:

- Quantifying the Impact of Network Standards on Control of an Aerial Robot
- Counting the Cost: Assessing the Impact of Programming Approaches on Closed-Loop Networked Control
- Work-in-Progress: Leveraging Cloud Computing and Web Standards to Support Learning Objectives in Multiple Classrooms
- Evolving Large Populations of Controllers in the Cloud: Investigating General Runtime Behavior of PaaS