From Supercomputer to Smartphone: Visualizing High-Performance Computing Resources on Mobile Devices

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Abstract
The Argonne Leadership Computing Facility provides supercomputing capabilities that are 10 to 100 times more powerful than systems typically used for scientific research. By providing effective visualizations designed specifically for mobile devices, we hope to bridge information gaps that occur when users do not have terminal access to these supercomputing resources. We introduce ALCF on the Move (AOTM), a mobile productivity application that provides real-time status of ALCF supercomputing machines at any time, from anywhere. With AOTM, the user can navigate a dashboard that summarizes ALCF supercomputing resources to job-level information. We believe that this progressive level of detail will create a meaningful story about the state of each resource and the status of users' activities on the resources.

Author Keywords
Supercomputing; visualization; dashboard; mobile device; push notification.

ACM Classification Keywords
H.5.2 [User Interfaces]: User-centered design, Screen design (e.g., text, graphics, color).

Introduction
The Argonne Leadership Computing Facility (ALCF), located at Argonne National Laboratory, is one half of the Department of Energy (DOE) Leadership Computing Facility in the United States dedicated to open science. Along with its partner site at Oak Ridge National Laboratory, the ALCF provides substantial awards of supercomputing time and user support services that enable large-scale modeling and simulation research aimed at solving some of the world's largest and most complex problems in science and engineering [1].

ALCF users access ALCF supercomputing resources on a traditional computer, where they can remotely log in to a machine from a command line terminal. While this approach is necessary to address the unique execution requirements of each project, it also can result in wasted machine time. For example, a user may miss a window to run a simulation if he or she is unaware of the state of a remote resource.

Mobile devices can be leveraged to bridge this gap. These ubiquitous devices (studies estimate 6 billion smartphone users in 2020 [7]) can be used in a diverse range of environments and contexts [2] as opposed to traditional computers that are associated with a particular location or setup [4]. Unfortunately, desktop visualization applications do not scale well to mobile devices due to factors such as reduced screen space, lower performing onboard hardware, and different input techniques [3]. Additionally, users may have limited cognitive resources while using mobile applications. These considerations place an emphasis on providing effective, easily understandable visualizations developed specifically for the characteristics and interaction methods of mobile devices [5].

We have developed AOTM, an iOS mobile companion application ("app") that provides real-time information about the state of ALCF supercomputing resources. With AOTM we hope to maintain the connection between the user and ALCF supercomputing resources outside of terminal access by providing visualizations that directly address the form factor, interaction methods, and contexts of mobile devices.

ALCF on the Move
System Overview

AOTM is an iOS app with a backend service that enables the user to monitor the status of computing resources and to configure notifications on specific status events (Fig. 1). It also highlights the latest facility news and announcements. In AOTM, the user navigates from a dashboard screen that displays all of the supercomputing resources down to a screen that contains job-level information. While the app cannot directly connect with supercomputing resources, it does keep track of limited user-specific data and settings.

Development

There are about 1,000 users in the ALCF community, of which roughly 300 own an iPhone. This community includes technical support staff, researchers consuming awarded computing time, and high-level management. We conducted numerous interviews across this spectrum of users to gather requirements. We then devised new functionality that would be tuned to mobile devices. Finally, we iteratively constructed visualization

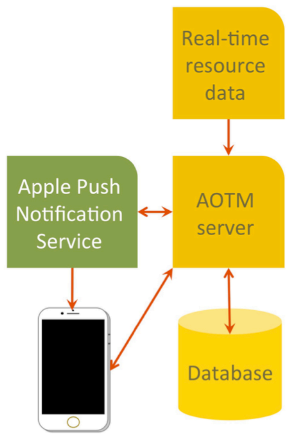

Figure 1: The AOTM server tracks each device that has registered for push notifications and that device's app settings. It organizes the real-time resource data in its database and determines when push notifications need to be sent to a device. When it has determined that a notification needs to be sent, the AOTM server asks the Apple Push Notification Service (APNS) to execute the push notification. The APNS also lets the AOTM server know when a device has been unregistered.

and interaction prototypes and solicited feedback to find the most effective techniques for presenting this data.

Push Notifications
Our objective was to not simply translate the command line interface to a mobile application; rather, our goal was to provide a completely different way to monitor ALCF supercomputers and the jobs that they run. The ability to track specific jobs was a key factor in our departure from typical methods; namely, we wanted to relieve the user of having to actively monitor his or her jobs. The push notification feature that is available on mobile devices plays a crucial role in sending timely information to users. We use this feature to lessen the cognitive load on our users so they can focus on other tasks.

ALCF Dashboard
The idea of making information available at a glance is extremely useful in the context of mobile-based visualization [6]. With AOTM, a user can quickly obtain a summary of a computing resource. Then, depending on his or her objective, her or she can either navigate deeper or choose to check the app later.

The opening screen of the app is the ALCF Dashboard (Fig. 2), which displays an overview of each ALCF resource arranged in a table. The user can tap on any cell of the table to navigate to more detailed information about each machine. Each machine cell has a single-measure doughnut chart indicating the percentage of the machine that is currently in use. We have used redundant color encoding (green vs. grey) to show qualitative information or state (i.e., activity vs. inactivity, presence of jobs to be run vs. no jobs, etc.). The green region reflects the percentage used and the numerical percentage is displayed below the name of the machine.

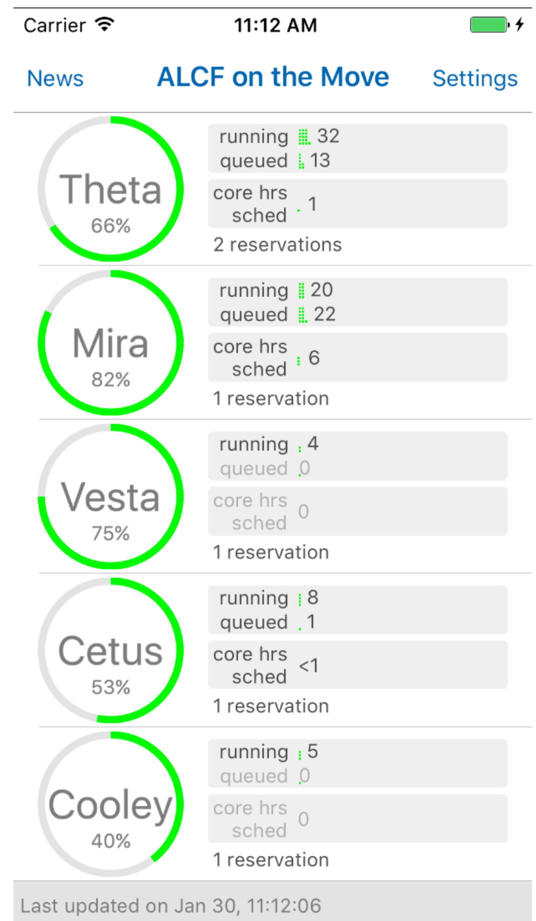

Figure 2: The ALCF Dashboard gives users a glanceable overview of the state of ALCF supercomputing resources, in real time.

In order to visualize other meaningful data points, we have devised a variation of the bar chart. Each horizontal bar is comprised of zero or more vertical columns of dots, with each dot representing a fixed amount of data. In this way, we can convey a finer granularity of statistics that may span a wide range of values.

To the right of the doughnut chart are several sections providing data on how computing time is being scheduled. This includes the number of running jobs and jobs scheduled to run on the machine. Additional information includes core-hours scheduled, which shows the combined wall time (maximum run time) of all queued jobs divided by the total number of machine cores. This quantity can be roughly translated as the number of hours the entire machine is scheduled to be utilized. Lastly the number of scheduled reservations is displayed.

Map

The Map screen displays a 2D visualization of the physical layout and current utilization (nodes running processes) of a machine (Fig 3). Each running job is assigned a color and nodes are colored accordingly.

Nodes that are white (clear) are not currently processing any jobs. Tapping on a node will select the job it is executing and highlight all nodes that are processing that job. Double-tapping a node will open a job detail pop-up window which displays the following information:

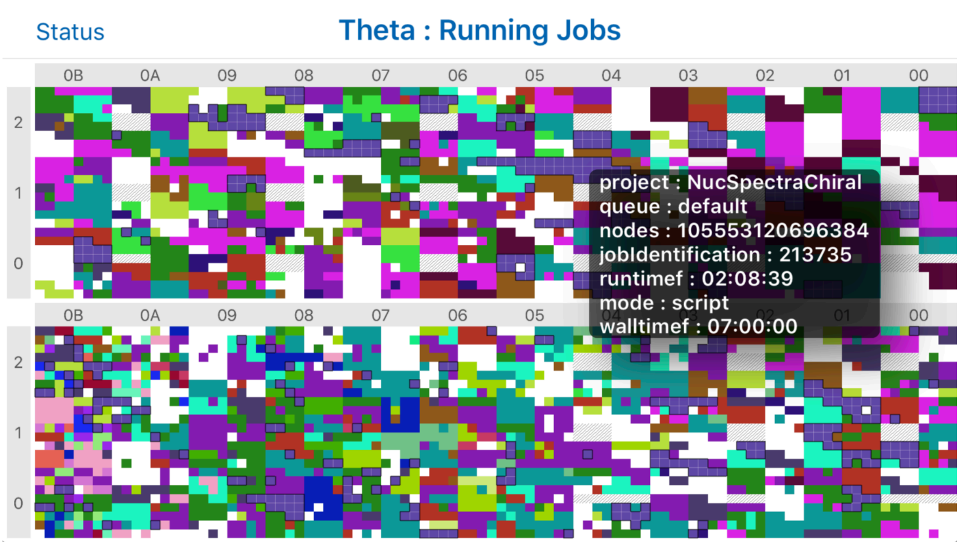

Figure 3: Snapshot of the Map screen showing jobs running on Theta. The Map tool [OK?] helps users see the current utilization of a specific resource. Job information can be displayed by selecting any nodes running that job.

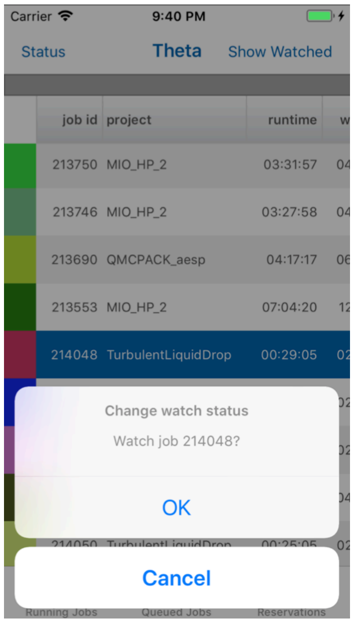

Figure 4: The Jobs Table displays all running jobs, queued jobs and reservations for a machine. Users can select jobs to track, or "watch."

- nodes: the number of nodes running the job
- walltimef: the maximum amount of time the job may run
- jobIdentification: the job id
- project: the project that the running job belongs to
- mode: the mode in which the job is run
- queue: the queue that the job belongs to
- runtimef: the amount of time the job has already run

Jobs Table

The Jobs Table is a tabbed pane that displays sortable tables of running jobs, queued jobs, and machine reservations. A user can select any jobs he or she is interested in tracking, or "watching" (Fig 4). The user will receive push notifications when a watched job changes status (e.g., when a job's status changes from queued to running). The right navigation bar button toggles between displaying all jobs and only watched jobs. Jobs that are selected on the Jobs Table or Map persist when navigating between these two screens.

News, Events and Announcements

The News, Events and Announcements screen shows a brief summary of major news, events, and announcements to keep users informed of activities happening at the ALCF. Links are provided to the corresponding webpage, where available.

Settings

The Settings screen allows the user to customize his or her app. If activated, push notifications can be set for each machine to let the user know when the job queue drops below a specified number of jobs. The refresh interval to upload new data can also be set.

Interaction Scenarios

Scenario A

An astrophysicist has queued a simulation job that should consume seven hours of computing time and configures AOTM to notify him when the job changes status. He receives a notification at work that the job has changed status from queued to running. However, while commuting home 45 minutes later, he receives a push notification that his job has stopped running. He uses this information to log in when he gets home to investigate why the job terminated prematurely.

Scenario B

A principal investigator at a university opens the app while on a lunch break and with a quick glance sees a machine at 4 percent utilization. She knows that her team has been queuing jobs to meet a deadline for a conference they need to provide results for. She wonders why none of her team's jobs are running when the machine is so empty. Upon closer examination, she notices that there are two reservations scheduled and realizes that the machine is draining its nodes so that it can perform maintenance jobs on the entire machine.

Scenario C

An ALCF staff member sets her app to notify her when the queue is low for the visualization cluster. She has changed her app settings to configure the queue threshold to be set at 3. She is composing an e-mail when she receives a push notification on her phone that the queue is low (i.e., the number of jobs waiting in the queue is lower than 3). She checks the app and sees that no reservations are scheduled and that the Map view does not show any of her users' jobs running. She quickly contacts her clients who need visualization work and recommends that they schedule jobs due to low activity on the cluster.

In each example, users are able to act quickly on real-time information, rather than waiting until they have a moment to access a laptop or time to scan the web for the information they need.

Discussion

The Map and Jobs Table were adapted from a large format version that included both visualization and table information on same screen. Due to the disparity in screen space, it was necessary to make several adjustments to the design. Our first step was to separate the map and table. For the map, we stripped out all unnecessary design elements, such as redundant labels and space between hardware components. Without the jobs table on the same screen, it was also important that users have the ability to associate nodes with the jobs they were running. The Job Information popup window ties running jobs to computing nodes in the Map. Additionally, we needed to plan the navigation between the Map and Jobs Table carefully so that the user state was preserved. Selecting a job on the Map meant it need to also be selected on the Jobs Table and vice versa, or the user would have no way to connect the information between the two screens.

While the HPC community is relatively small and highly specialized, we hope that AOTM will help cast a wider net in the larger scientific community. Depending on the user, the functionality and information presented on each screen may serve different purposes. For instance, domain experts rely heavily on the Map to monitor their users' jobs and determine which nodes might be available for processing. For high-level management, this visualization will provide a quick overview of a machine's utilization, as well as a presentation aid. For this reason, user surveys and interviews will be conducted after each major release to evaluate the myriad ways the app is being used as well as to provide us with data in areas such as usability, design, and interaction. We will also collect anonymous statistics of push notification and job monitoring activity. Finally, AOTM will be incorporated into our facility's helpdesk and report tracking system so that issues and feature requests can be organized and prioritized.

Conclusion

We have introduced ALCF on the Move, a mobile application that will provide the HPC community with up-to-date information on our resources. AOTM will enable users to plan more effectively, which could have a potentially significant productivity impact.

On AOTM, access to resources is static and archival data is not available. Future work includes incorporating statistics for short windows of time and access to user accounts as well as some resource-level interactivity. While each running job is assigned a color randomly, future prototypes may involve a more categorical color mapping based on the area of science the job belongs to. We also plan to develop AOTM on other operating systems, such as Android. AOTM will be available on the Apple iTunes store for iOS.

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