Research Statement

Since joining the University of Hawaii in 1990 and founding the CSDL research group, I have led research projects in a variety of domains: computer-supported cooperative work (Egret, Clare), software technical review (CSRS), software product and process measurement (LEAP, Hackystat, HPC, Zorro), sustainability and renewable energy (Kukui Cup, Makahiki, Open Power Quality), and educational technology (Athletic Software Engineering, RadGrad). This work enabled me to chair 8 completed Ph.D. dissertations, 24 M.S. theses, author or co-author over 60 refereed publications, obtain over 20 grants and awards (including 5 NSF grants), and mentor over 50 graduate and undergraduates in my research group.

A common thread connecting all of these endeavors is a commitment to the engineering of high quality, open source software systems to advance the state of the art. I believe that tool building can provide a variety of benefits to the research community: improved validation, reproducibility, and collaboration. I also think that the chance to develop professional-level software engineering skills is of great benefit to the students involved in these research projects. But if I am to be completely honest, the fundamental reason my research projects usually result in significant software systems is because I enjoy building software. Starting in the 1980s, when I first became proficient programming AI applications using a Lisp Machine, I have continued to refine my software design and engineering skills while migrating from Lisp to Java to Python and most recently to Javascript.

There are excellent researchers who focus on advancing the discipline of software engineering even though they themselves no longer develop software. At this point in my career, I am in some ways the opposite: I remain committed to active practice of software engineering, but now focus on application domains outside of software engineering. Over the past decade, this disciplinary flexibility has led me into research in sustainability, renewable energy, gamification, power quality, and educational technology. I believe my commitment to active practice has also made me a more effective teacher of software engineering.

For information on each of the 33 research projects I have led since coming to the University of Hawaii, please see the CSDL Research Page. For the remainder of this statement, I would like to focus on two current research projects: Open Power Quality and RadGrad.

Open Power Quality

As a resident of Hawaii, an advocate for sustainability and resiliency, and a homeowner with solar panels, I am acutely interested in the technical and political issues surrounding distributed, intermittent energy generation on Oahu's electrical grid. Four years ago, I started the Open Power Quality project along with two graduate students based upon the following observations: (a) community demand for rooftop solar exceeds HECO's limits on installation; (b) these limits are based upon claims about how much solar penetration can be safely added without incurring grid instability; (c) the data behind these claims is not made available to the community by HECO; and (d) there is no currently available, cost-effective means for a community to obtain independent measures of their grid's stability.

The goal of Open Power Quality (openpowerquality.org) is simple: provide inexpensive hardware devices that can: plug into a wall outlet; monitor voltage, frequency, and THD; and upload the results wirelessly to a cloud-based server that can run analytics and report on the occurrence and nature of power quality anamolies. The "open" in Open Power Quality refers to our desire to make the hardware, software, and data all available via open source licensing, in order to encourage the creation of an ecosystem of development, research, and policy making. Such a project could provide an independent, public source of data about the electrical grid that could inform policy making and ultimately support higher penetration of renewable energy.

While the goal is simple, the implementation has been challenging. After working through several major design iterations of both hardware and software, we now feel confident that our current architecture provides

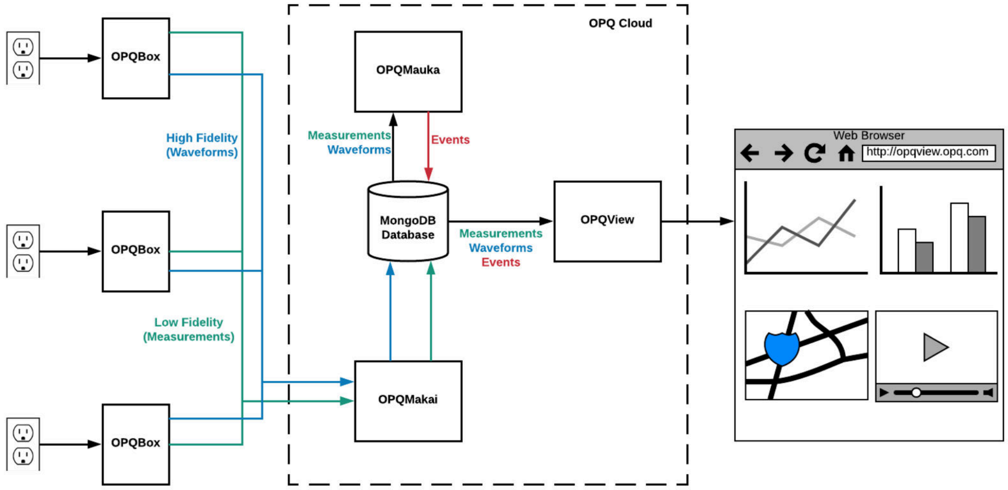

Figure 1: *OPQ System Architecture*

a stable platform with which to begin delivering insights into the grid during 2018. Our current architecture is shown in Figure 1.

One challenge was the design of a hardware box that would be relatively inexpensive to manufacture and configure, could capture electrical data with reasonable fidelity and store it onboard for approximately 60 minutes, and perform enough analysis on the waveform to communicate to the cloud-based services when PQ anomalies occur. The current OPQ Box combines a custom board with a Raspberry PI, and costs under $100 to manufacture.

A second challenge was the design of cloud-based analytics and visualization. We eventually decided on a combination of three services, all backed by a MongoDB database. OPQ Makai receives low fidelity measurements of voltage and frequency from each OPQ Box approximately once a second. Makai is responsible for interpreting these measurements and deciding whether or not to request high fidelity waveform data from one or more OPQBoxes so that deeper analyses of the anomaly can be performed. OPQ Mauka has a plugin architecture for supporting an extensible number of analyses on waveform and/or measurement data. Finally, OPQ View is responsible for presenting these analytics to users.

A third challenge was the design of device synchronization. Device synchronization is vital, because it enables the OPQ cloud-based services to distinguish between PQ anomalies specific to a single location from those that are present across a substation or the entire grid. Most utility-scale PQ monitors use GPS synchronization, which means device clocks will differ by only a few nanoseconds. However, GPS synchronization requires the boxes to be line-of-sight to satellites, which imposes significant constraints on their location. We decided to use NTP-based synchronization, which enables OPQ Boxes to be placed anywhere there is a wireless access point, but with the result that OPQ Box clocks can differ by up to 10 milliseconds. So far, this appears to be "good enough" device synchronization to distinguish local from grid-wide events, especially when we can further analyze the waveforms to see if the detected anomalies are similar across devices as well as co-located in time.

The OPQ project provides research for two Ph.D. students and a half dozen VIP undergraduates. We were part of the Energy Excelerator cohort in 2014, which resulted in the incorporation of a privately held company and a small amount of seed funding.

RadGrad

The RadGrad Project began two years ago with the following observations about the computer science degree experience:

1. CS is experiencing explosive growth in disciplinary areas. For example, "self-driving cars" has matured from "research topic" to "industry growth area" in less than four years–the timespan of a student's degree program. The ICS Department's curricular offerings cannot keep pace with the velocity of change in the field.

2. Extracurricular activities are essential to the development of a well-rounded CS graduate. Even in a high demand discipline like computer science, simply completing university degree requirements with a decent GPA does not by itself create a competitive candidate for high quality jobs or graduate school. Participation and success in strategically chosen extracurricular activities such as hackathons, internships, and other events are critical to development of a professionally attractive graduate.

A key insight underlying the design of RadGrad is that these two issues can be addressed through a single change: elevating selected extracurricular activities to equal status as coursework in the degree experience. If this can be achieved, then: (1) Faculty can introduce interested students to emergent disciplinary areas through "curated" online resources including MOOCs without the delays and scheduling issues associated with curricular offerings, and (2) Students will be incentivized to incorporate a complementary set of extracurricular activities into their degree experience, resulting in better preparation for the workforce or graduate studies.

Obviously, advisors and faculty have stressed the benefits of extracurriculars to students for generations, and generations of students have ignored this advice, only to rue this decision some time after graduation. This is because extracurriculars are seen by students as, well, "extra", not "equal".

While it's easy to state the desired change, it's not straightforward to implement, and we've spent two years iteratively designing and testing various prototypes with students, faculty, and advisors. This research and development process has resulted in a system that is now ready for deployment and assessment in the ICS Department this Fall. Figure 2 shows one of the pages from the RadGrad web application that gives a flavor for the user interface.

RadGrad includes five principal design components: Explorers, Degree Planner, ICE, Levels, and Mentor Space:

"*Explorers*" *for Career Goals, Interests, Courses, and Opportunities.* A student cannot become well-rounded until they have a reasonable understanding of their discipline. RadGrad explorers provide students with high quality, faculty-curated resources for learning about career paths, courses, and "opportunities" (i.e. extracurricular activities). Each of these are tagged with one or more "interest" areas, and the resulting network of relationships enables a variety of capabilities, including recommendations. For example, let's say a student indicates "Graduate School" and "VR (virtual reality) Engineer" as career goals. Graduate school has "research" as one of its associated interest areas, and VR Engineer has "computer graphics". From these two interests, RadGrad can recommend that the student consider a research project in Jason Leigh's Lava Lab (because that opportunity has both interests "research" and "computer graphics"), and join the local Hawaii Virtual Reality Meetup Group (because that opportunity has the interest "computer graphics"). In addition to this "top-down" direction, where choice of career goal leads to course and opportunity recommendations, recommendations can also work "bottom-up": from the courses and opportunities in a student's degree plan, RadGrad can help them determine the career goals for which they will be best prepared.

A discipline-specific degree planner. STAR provides system-wide support for helping students satisfy university and college-level degree requirements. RadGrad is designed to complement STAR, not compete

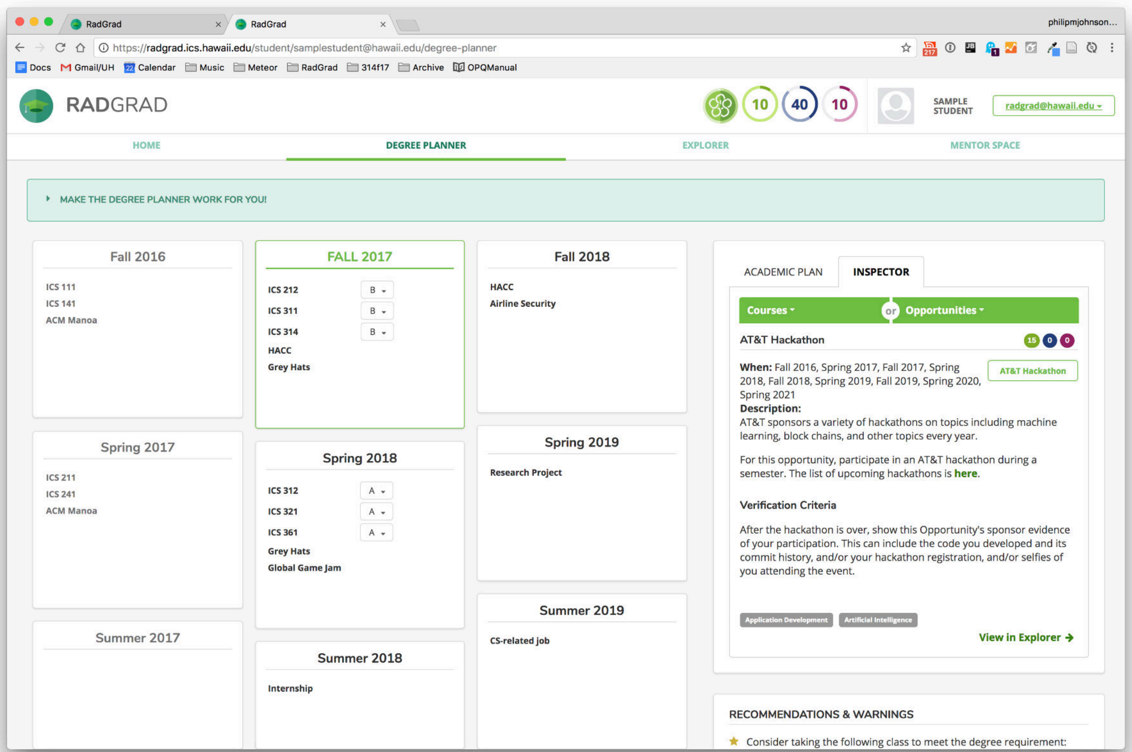

Figure 2: *Sample RadGrad Application Page*

with it, and one desired outcome of this project is increased synergy between the two systems. The RadGrad degree planner is more narrowly focused than STAR, because students only plan their degree program courses (for example, ICS courses). At the same time, it is more general than STAR, because students also use it to plan their participation in opportunities. Providing a degree planner with an equal focus on curricular (i.e. course) and extracurricular (i.e. opportunity) offerings is an important step toward elevating extracurricular activities to equal status as coursework.

Innovation, Competency, Experience: The ICE metric. It's all well and good to provide a faculty-curated resource about extracurricular opportunities as well as a degree planner that enables students to plan their participation, but as long as students view their GPA as their sole metric for success, they are likely to infer that opportunities are not important. In RadGrad, the GPA is never computed or displayed. Instead, RadGrad computes and displays a three component metric called ICE (Innovation, Competency, Experience) as the measure of success. To be "well-rounded", a student must earn at least 100 points for each of the three ICE components by the time they graduate. RadGrad awards 10 Competency points when a student gets an A in a degree program course, and 6 Competency points when a student gets a B. (No Competency points are awarded for grades below B.) In RadGrad, coursework only earns Competency points; to earn Innovation and Experience points, a student must participate in opportunities. For example, participating in a faculty research project for one semester might earn 25 Innovation points. Successfully finishing an internship in a high tech company for a summer semester might earn 25 Experience points. Participating in a short event, such as a weekend hackathon, or in communities like StackExchange, might earn 5-10 points. Completing online MOOCs or other extramural certificate programs can also earn Competency points (as long as the faculty approve them for this purpose.) The ICE metric itself, and the number of points awarded, is a "game mechanic": it creates a way to incentivize students to excel in both curricular and extracurricular activities because it measures achievement for both of them.

RadGrad Levels, or the path to becoming a computer science ninja. While the ICE metric elevates extracurriculars to first class status with curriculars, the mere existence of a metric, especially an online-only one, does not guarantee student buy-in. We designed a second game mechanic called Levels to: (a) make RadGrad participation physically visible within the student community; (b) represent progress with respect to the ICE metric; (c) be cost-effective for a department with hundreds of students; (d) be perceived by students as "cool", and thus incentivize acquisition of ICE points. After several rounds of design and student feedback, we converged on a sequence of six differently colored laptop stickers (similar to a martial arts "belt" progression from white to black) that represent stages toward the ultimate ICE goal of 100/100/100. A student making acceptable progress through the degree program will advance one Level per semester for the first three semesters (each time qualifying for a new laptop sticker, given to them for free by an ICS advisor). The subsequent three levels are more difficult to achieve in a single semester. The stickers were designed by a professional graphic artist (and former ICS student). Student feedback on this game mechanic has been very positive. The laptop stickers can be printed in bulk for approximately $0.50/sticker, making the cost per student a maximum of $3.00.

Pay it forward: Mentor Space. It takes a village to create a well-rounded computer science graduate and a high quality degree experience. We wanted to design a way for graduates of our program and local high tech professionals to engage with our students in a low-cost, high impact manner. The results is Mentor Space, a communication platform within RadGrad that allows students to pose questions about life after graduation and obtain a variety of perspectives from mentors.

Over the past year, we have implemented an instance of RadGrad with information about computer science courses and opportunities, and performed successful pilot studies with approximately 50 computer science students. We are now planning a wide scale deployment to the 400 undergraduate computer science majors in Spring, 2018.

As part of our pilot studies, we became aware that RadGrad has the potential to positively influence engagement, diversity, and retention. To assess this potential, we are designing an empirical study as part of a proposal to the NSF program on Improving Undergraduate Stem Education, to be submitted in Spring 2018.

Future directions

If I join the Department of Electrical Engineering, I would like to continue these efforts and also participate in new initiatives with EE faculty.

The Open Power Quality project is an extremely natural fit with students and faculty in the Department of Electrical Engineering; indeed, most of the undergraduates participating in this project have been part of the Department's VIP Program, headed by Aaron Ohta. The next step for this project is a KickStarter campaign, which we hope to begin in the Summer of 2018.

Issues of engagement, diversity, and retention are widespread in STEM disciplines, including engineering. If the EE faculty are interested, I would like to develop a research project in which we explore the extent to which RadGrad can improve these indicators for engineering undergraduates.

I have participated in a variety of proposals headed by Tony Kuh as part of the Renewable Energy and Island Sustainability group. I have very much enjoyed these projects and look forward to continued involvement in renewable energy initiatives within the Department. I believe there are areas of overlap between the Open Power Quality project and Tony Kuh's Smart Campus Energy Lab, and I look forward to increased interaction between these initiatives.