COVER SHEET FOR GRANT PROPOSALS

State Board of Education

SBOE PROPOSAL NUMBER: (to be assigned by SBOE)	AMOUNT REQUESTED: $50,000

TITLE OF PROPOSED PROJECT:

SAVE: Self-organizing Air VEnt System

SPECIFIC PROJECT FOCUS:

The ***SAVE*** proposal was awarded in the amount of $46,000 for HERC FY 2014. This project is to specifically resolve **THREE KEY COMMERCIALIZATION CHALLENGES** of the ***SAVE*** system which we encountered during FY 2014,

i. How to reduce the liability of icing HVAC (air-compressor) coils?

ii. How to measure the HVAC airflow rate and detect overall HVAC system health?

iii. How to prolong ***SAVE*** battery life and energy efficiency through the use of energy harvesting and enhanced wireless communication protocols?

PROJECT START DATE: 7/1/14	PROJECT END DATE: 6/30/15
NAME OF INSTITUTION: Boise State University	DEPARTMENT: Office of Sponsored Programs
ADDRESS: 1910 University Dr., Boise, ID 83725-1135	
E-MAIL ADDRESS: osp@boisestate.edu	PHONE NUMBER: 208-426-4420

	NAME:	TITLE:	SIGNATURE:
PROJECT DIRECTOR/PRINCIPAL INVESTIGATOR	Dr. Gang-Ryung Uh	Associate Professor	
CO-PRINCIPAL INVESTIGATOR			

NAME OF PARTNERING COMPANY: FAMCO	COMPANY REPRESENTATIVE NAME: Martin A. Artis, Presdent

	NAME:	SIGNATURE:
Authorized Organizational Representative	Karen Henry	

SAVE: Self-organizing Air VEnt System

1. **Boise State University**
2. **Principal Investigator (PI): Gang-Ryung Uh**
3. ***SAVE* was submitted to the HERC RFP FY 2014**

The ***SAVE*** proposal was awarded in the amount of $46,000. This project is to specifically resolve **THREE KEY COMMERCIALIZATION CHALLENGES** of the ***SAVE*** system which we encountered during the HERC FY 2014,

i. How to reduce the liability of icing HVAC (air-compressor) coils?

ii. How to measure the HVAC airflow rate and detect overall HVAC system health?

iii. How to prolong ***SAVE*** battery life and energy efficiency through the use of energy harvesting and enhanced wireless communication protocols?

4. Executive Summary

U.S. households rely primarily on electricity and natural gas for HVAC. The Department of Energy (DOE) reports that air conditioning and space heating make up the greatest share of household utility bills. For this reason, the DOE strongly recommends U.S. households install programmable thermostats, e.g., *NEST* thermostats, to save around 10% a year on cooling and heating bills. However, a critical drawback of these programmable thermostats is they can only accurately control the temperature for a localized zone, and room-to-room temperatures can vary significantly. In a poorly insulated zone, programmable thermostats can over-cool or over-heat the space. This often impairs the comfort level of the household and results in an unexpected increase in utility bills.

There are over 130,000,000 homes in the US. In addition, an average of one million new US homes are built every year. It is notable that most houses were typically built with cheap HVAC

products, and therefore, an average household commonly experiences the overcooling and overheating problem. The business opportunity (over $20B/year US home upgrade industry) is to develop an economical and non-invasive consumer product to solve overcooling and overheating problem in a residential building. The main market solutions for overcooling and overheating are either costly with extensive retrofits (e.g., *Lennox*), or far from being satisfactory (e.g., *Activent* and *Airflow*). This project aims to enhance the ***SAVE*** SYSTEM, which we developed during HERC FY 2014, in both safety and energy efficiency. Thus, we can penetrate the US residential HVAC upgrade industry with the enhanced ***SAVE*** system, ***WHICH CAN ECONOMICALLY AND EFFECTIVELY SOLVE OVERCOOLING AND OVERHEATING PROBLEMS WITHOUT RETROFIT AS AN ATTRACTIVE CONSUMER PRODUCT.***

5. Project Objectives and Total Amount Requested

For overcooling and overheating, multi-zone HVAC systems (e.g., *Lennox*) have been used. Yet, these systems require extremely high initial installation costs and expensive retrofits to convert an existing single-zone to a multi-zone system (well beyond $10,000). Nevertheless, overcooling and overheating problem within a given zone still remains. Another market solution is the programmable vent registers (e.g., *Activent* and *AirFlow*). However, to solve the overcooling and overheating problem with these programmable vent registers, a homeowner is required to manually program each register, which can be quite difficult to do correctly when programming more than two registers. The ***SAVE*** proposal for the HERC FY 2014 was targeted to develop a consumer solution to achieve a similar outcome of traditional multi-zone HVAC systems such as *Lennox*, at an affordable *Activent*'s (or *Airflow*) register price.

The ***SAVE*** project was selected for funding and we developed a prototypical system that incorporated automated zone-to-zone temperature distribution during FY 2014. This

accomplishment included creating customized development boards (Figure 1) and an HVAC simulation testing chamber (Figure 2) to enable rapid system testing and design. In addition, we invited Mark Rudin (VP for Research and Development at BSU), Harold Blackman (Associate VP for Research and Development at BSU), John Gardner (Director of the CAES Energy Efficient Research Inst), and other local industry key members to our lab and we successfully demonstrated (proved) that the ***SAVE*** system can solve the overcooling and overheating problems in a residential house setting.

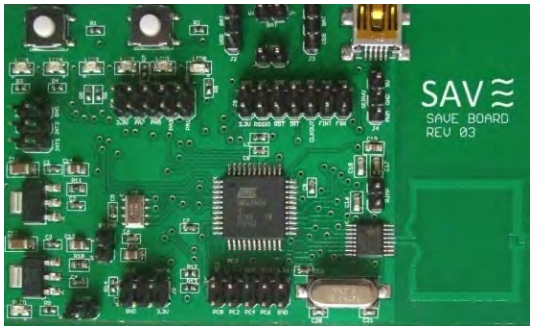


Figure 1: Electrical Development Board

Figure 2: Testing Chamber

While actively interfacing with local software companies and HVAC manufacturer FAMCO for the ***SAVE*** commercialization, we identified three key system challenges that would be imperative to the success of the project when going to market. The **first** of these challenges is to reduce the probability of damaging the HVAC (air compressor) coils by putting too much stress on the HVAC system. It is found that most residential HVAC systems are installed as cheaply as possible, meaning that any additional components added to the system run the risk of damaging the HVAC coils. The ***SAVE*** system should be able to detect these conditions and either warn the users, or take immediate action to eliminate the risk.

The **second** challenge identified was to additionally detect and measure airflow rate at the vent registers. This allows for a wide variety of analytical possibilities, but also enables the

SAVE system to better measure the health of the HVAC system. To detect airflow rate, we will incorporate a miniature wind turbine to measure airflow.

The **third** challenge in conjunction with the first is how to use the miniature wind turbine for energy harvesting to increase the life span of the battery-powered ***SAVE*** system vent registers. It is important for the ***SAVE*** project to reduce the power requirements and increase battery life as much as possible, and energy harvesting is an attractive solution. We will also continue to work on improving the ***SAVE*** wireless communication protocols for system reliability and energy efficiency.

To address three challenges (objectives) described above, we are requesting $50,000**,** which supports two CS and ECE graduate research assistants for FY 2015, one month of PI Uh's summer salary, electronic parts and materials to enhance the system, and travel costs to introduce the system during the annual HVAC trade show in Las Vegas (March 2015).

6. Resource Commitments that Reflect Boise State's Priorities

Since 2005, the University has dedicated resources to the Office of Campus Sustainability led by Dr. John Gardner. In 2010, Boise State became the leading institution in the new Energy Efficiency Research Initiative at Center for Advanced Energy Studies (CAES). The mission of the new Initiative is to increase education and research in energy efficiency, which represents the ultimate objective of the **SAVE** System.

7. The SAVE System's Potential Impact to the Economy of Idaho

There are several significant ways in which ***SAVE*** will positively affect the economy of Idaho. First, the ***SAVE*** system can be supported by the State Legislatures for energy efficiency, and it can be supported by Idaho local utility companies as a consumer commodity for the same reason. Second, as long as the ***SAVE*** system implementation, testing and market acceptance look

promising, it can easily augment various HVAC products from the *Nest*, *Lennox*, *Activent*, *Airflow* and other suppliers, which will help U.S households save cooling and heating bills. By approaching existing manufacturers with enhanced and working versions of their own products by the ***SAVE*** system, we can make it easy for them to visualize the ***SAVE*** system's Intellectual Properties (IPs) in their product line. Third, a provisional/non-provisional patents for the ***SAVE*** system also gives Boise State University a sellable piece of IP.

8. The *SAVE* Market Opportunity

a) Describe need the project address: There are over 130,000,000 homes in the US. In addition, an average of one million new US homes are built every year. It is notable that most houses were typically built with cheap HVAC products, and therefore, an average household commonly experiences the overcooling and overheating problem.

b) Describe market size and demand projections: The US home upgrade industry is estimated to exceed $20B/year. The main market solutions for overcooling and overheating are either costly with extensive retrofits, or far from being satisfactory. This project aims to penetrate the US residential HVAC upgrade industry to effectively address overcooling and overheating problems by enhancing the ***SAVE*** system a consumer product. For the ***SAVE*** demand projections, we set the goal as the initial sales of 10,000 vent registers. This equates to 500 houses (average of 20 vent registers per a single home house) in the first year. If the sales grow at 75% for 5 years, we anticipate that the ***SAVE*** system will be distributed to just under 5,000 homes (quite conservative considering the market size). The ***SAVE*** system's financial projection goal is to achieve $1,000,000 operating profit by FY 2020.

c) Describe the barriers to market entry: One of the more challenging aspects of bringing the ***SAVE*** system to market is how to best package and distribute the system to consumers.

SAVE would like to position itself to be sold in piecemeal, allowing a greater flexibility for consumers to tailor the system to their needs and or budgetary requirements. However, the ***SAVE*** system is most effective when installed as a complete system, which then necessitates higher upfront costs. This dichotomy between effectiveness and flexibility will be an area of concentration for the ***SAVE*** project to solve when looking for a balance between the two.

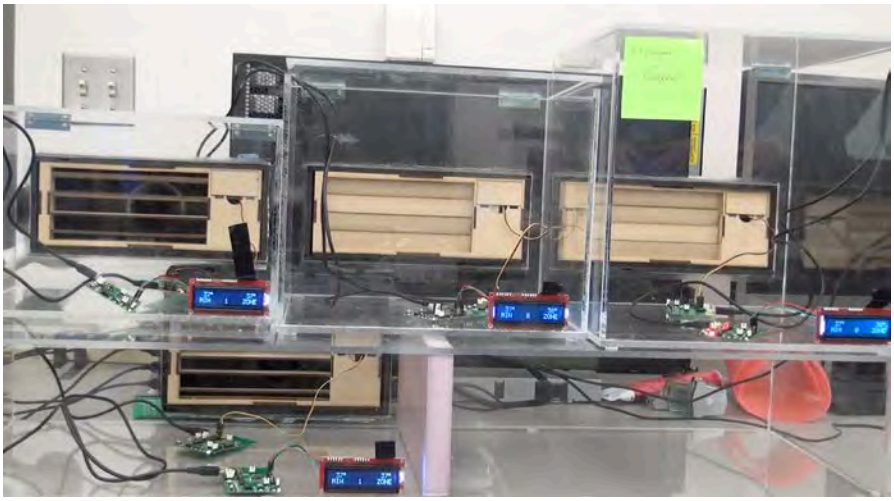
9. The Technology and Path to Commercialization

i. *What stage in the process SAVE project is currently at*

- July 2013: Kyle Hoff (Mechanical Engineering undergraduate student) joined the ***SAVE*** research team to design ***SAVE*** Registers which are closer to the final air vent product.
- August 2013: The ***SAVE*** was selected for presentation in Business Venture Challenge at UKC 2013 conference. Kyle Schwab (CS graduate student) presented the ***SAVE*** and the project was selected as a runner-up among the 50 research/business teams competition.
- September 2013: We created a Xtapped loop PCB antenna on 933 Mhz spectrum to enable wireless communication across ***SAVE*** Zone Controller (ZC) and Registers. We have achieved wireless communication over a 150 feet non-line-of-sight distance.
- October 2013: We designed and sourced method for the ***SAVE*** custom electrical board, which is small to fit inside the air vent register developed by Kyle Hoff.

- December 2013: We fully tested the ***SAVE*** electrical board and developed a task-based software stack (abstract layers) for the firmware (program) on the ***SAVE*** electrical board. Figure below demonstrates wireless communication between two ***SAVE*** electrical boards programmed with our task-based firmware.

- January 2014: We created partnerships with local software companies IdeaRoom Technologies Inc (CEO Russ Whitney) and SMARTdwell Inc (CEO Steve Taylor) to create a new venture and smart home service business.
- March 2014: Designed new mechanical prototype to be dimensionally accurate as the desired finished product (under 1" thick).
- April 2014: we built an HVAC simulation environment to test whether the programmed ***SAVE*** system can regulate air vent registers to achieve even distribution of air temperature throughout the entire house.



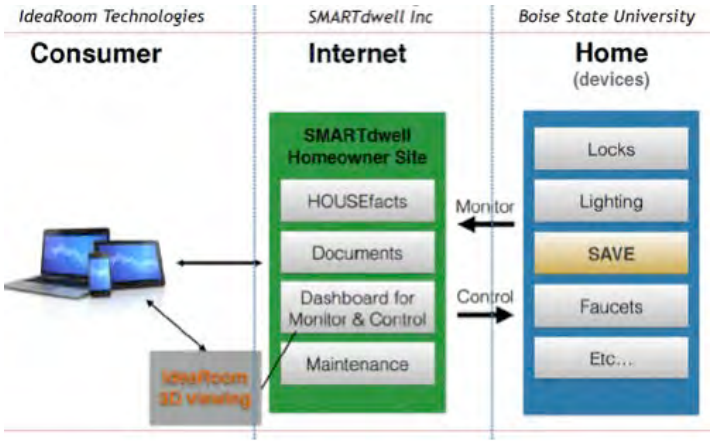
- May 2014: We created partnership with a local HVAC manufacturer FAMCO (CEO Marty A. Artis) to find a way to commercialize the ***SAVE*** system.

ii. What this funding will accomplish

- Support the research team to develop hardware/software to measure CFM at the ***SAVE*** air vent registers to reduce the liability of icing HVAC (air-compressor) coils.
- Support the research team to optimize system to prolong ***SAVE*** battery life and energy efficiency through the use of energy harvesting (using a small wind turbine) and enhanced wireless communication protocols.
- Support the research team to meet HVAC manufacturers for the system commercialization and to participate HVAC trade show(s).

iii. What tasks are required to move the SAVE project to the next stage and the intended outcome

- Task: Filing provisional/non-provisional patent for ***SAVE*** project.
- Task: Thorough testing and benchmarking.
- Task: Update mechanical and electrical prototypes to incorporate miniature wind turbine for energy harvesting and air flow measurement.
- Task: Implementing Market strategy and planning.



The ***SAVE*** team has been actively interfacing with the local software companies *IdeaRoom Technologies Inc* (CEO Russ Whitney) and *SMARTdwell Inc* (CEO Steve Taylor) to create a new venture on smart home service business.

- Intended Outcomes: (1) **completion of the provisional/non-provisional patent filing** on the ***SAVE*** system invention, (2) **production of *SAVE* systems that can be deployable in houses,** and (3) **collaboration with industry partners to submit an NSF proposal (**either PFI or SBIR programs**) to secure continuous funding to enhance the *SAVE* to next level(s).**

10. Commercialization Partners

Martin A. Artis, the president of **FAMCO** (http://www.famcomfg.com/) will be the ***SAVE*** system's commercialization partner during HERC FY2015. In particular, Martin Artis and his engineering team director (David Davis) will help us (1) design and implement safe (as a consumer product) and energy efficient mechanical and electrical prototypes of the ***SAVE*** system and (2) commercialize the ***SAVE*** system as a consumer HVAC supplement.

11. Specific Project Plan and Detailed Use of Funds

For the tasks in Table 1, PI Uh will lead the research team of three graduate CS/ECE students – Kyle Schwab, Jared Law and Paul Molloy (Low power system engineer at Micron). All the ***SAVE*** team members have prior industry and academic experience in design and implementation of embedded systems.

Tasks	1st quarter 7/1/14-9/30/14	2nd quarter 10/1/14-12/31/14	3rd quarter 1/1/15-3/31/15	4th quarter 4/1/15-6/30/15
Electronic prototype				
firmware development				
mechanical prototype				
testing and benchmarking				
patent preparation & filing				
project demonstration				
HVAC trade show				

Table 1. *SAVE* Project Plan for HERC FY 2015

First, the research team will prepare the electronic and mechanical prototypes for the ***SAVE*** system described above by the end of the 2nd quarter. The mechanical and electrical prototype upgrades for the first two quarters involve the necessary changes needed to incorporate the miniature wind turbine for energy harvesting and air flow measurements. This scheduled work also includes the firmware enhancements needed for incorporating the management of the updated rechargeable battery and wind turbine interactions.

Second, we will then install the ***SAVE*** system in team member houses to test, benchmark, and validate the ***SAVE*** system design during the 3rd and 4th quarters. Specifically, the ***SAVE*** team will be focusing on firmware based power optimizations and wireless protocol design for real world conditions. A large focus will be placed on stabilizing the system reliability and getting the firmware base to pre-production quality. Validation will also include data mining for ***SAVE*** system characteristics and the impact on household energy savings. In addition, PI Uh will prepare the required documentation for provisional/non-provisional patent filing with the Boise State University. Lastly, in the 4th quarter we will begin public ***SAVE*** system demonstrations.

The requested ***$50,000*** will be used to support (1) two CS and ECE graduate research assistants during HERC FY 2015, (2) one month of PI Uh's summer salary, (3) electronic parts and materials, and (4) travel costs to introduce the ***SAVE*** system during the annual HVAC trade show at Las Vegas in 2015.

12. Institutional and Other Sector Support

Computer Science Department and College of Engineering at Boise State University will support the ***SAVE*** project by offering the lab space and computer systems in MEC 302-R for the proposed research activities.

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. Use additional pages as necessary.

Laboratory: Micron Engineering Center 302 R - Computer Science Research Lab

Clinical:

Animal:

Computer: PI Uh has one 24-core Intel Xeon CPU (2.4Ghz) server and two Core I7 servers to manage the project development source code and report the progress of the proposed SAVE development. Two Windows 7 workstations and two Linux workstations for firware development.

Office: Micron Engineering Center 302-N

Other: PI Uh has two floating licenses of IAR WorkBench to develop firmware on Atmel 8-bit microcontrollers and Carbon Systems's cycle accurate ARM Cortex A8 pipeline simulator.

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate, identifying the location and pertinent capabilities of each.

20 Atmel XMEGA-B1 XPLAINED Evaluation Kits, 60 SAVE custom electrical boards, 15 ethernet development boards and a router for SAVE debugging, 8 Atmel JTAGICE3, 5 BeagleBoardXM, 1 Pandaboard, and 15 Raspberry pi to develop gateways for the SAVE.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

Geared motors and drivers, temperature/pressure sensors, acceRFM12B (433Mhz) radio modules, acclerometers, Atmel Raven, 4 Activent vent registers and TI CC2530 ZigBee network processor development kits

---

Gang-Ryung Uh, PI, Boise State University

Professional Preparation

B.A.	1987	Economics, *Hankuk University of Foreign Studies*, Seoul, Korea
M.S.	1992	Computer Science, *Florida State University*, Tallahassee, FL
Ph.D.	1997	Computer Science, *Florida State University*, Tallahassee, FL

Appointments

08/2008 - present:	Associate Professor, Dept. of Computer Science, *Boise State University*.
08/2010 - 07/2011:	Research Associate (sabbatical), *Static Pipelining* Project, *An Approach for Ultra-Low Power Embedded Processors* Dept. of Computer Science, *Florida State University*, Tallahassee, FL.
08/2002 - 07/2008:	Assistant Professor, Dept. of Computer Science, *Boise State University*.
06/2007 - 12/2007:	On-line Race Detection Tool Developer (Intel Contract), *Intel Performance, Analysis and Threading Lab*, Champaign, IL.
05/2005 - 08/2005:	Research Associate, EECS, *Seoul National University*, Seoul, Korea.
01/1998 - 07/2002:	Embedded System Tools Developer, *Lucent Technologies*, Allentown, PA.

Publications (student author names shown in italic font)

- I. Finlayson, *B. Davidson*, *P. Gavin*, **G. Uh**, D. Whalley, Magnus Sjalander and G. Tyson, "Improving Processor Efficiency by Statically Pipelining Instructions," *2013 ACM SIGPLAN/SIGBED Conference on Languages, Compilers and Tools for Embedded Systems* (LCTES'13), ISBN: 978-4503-2085-6, pages 33-44, May 2013.
- *I. Finlayson*, **G. Uh**, D. Whalley and G. Tyson, "An Overview of Static Pipelining," *IEEE Computer Architecture Letters* (CAL), ISSN: 1556-6056, Vol. 11, No. 1, Jan 2012. This paper was selected as the BEST paper and presented during the 19th IEEE International Symbpsium on HPCA.
- *I. Finlayson*, **G. Uh**, D. Whalley and G. Tyson, "Improving Low Power Processor Efficiency with Static Pipelining," *15th Workshop on Interaction between Compilers and Computer Archi- tectures* February 2011, San Antonio, TX.
- **G. Uh**, R. Cohn, B. Yadavalli, R. Peri and and *R. Ayyagari*, "Analyzing Dynamic Binary Instrumentation Overhead," *Workshop on Binary Instrumentation and Application*, October 2007, San Jose, CA.
- *D. Cho*, *R. Ayyagari*, **G. Uh** and Y. Paek, "Preprocessing Strategy for Effective Modulo Scheduling on Multi-Issue Digital Signal Processors," *Proc. of the 16th International Conference on Compiler Construction*, March 2007. Braga, Portugal.

Synergistic Activities

- **2013 Business Venture Challenge Runner-up - *"SAVE: Self-organizing Air VEntilation system*"**: This invention was selected as a runner-up among 30 business team competition and

awarded during UKC 2013, New York/New Jersey.

- **2012 Google Faculty Research Award - Open-Source ARM Cortex A8 Compiler:** An optimizing ARM Cortex A8 compiler development via streamlining LLVM and VPO compilers to generate high performing ARM Cortex A8 machine code, which can match the performance of Cortex A9 with significantly reduced power consumption.
- **Pin-based Dynamic Cache Simulator Development for Shared Address Space (SAS) Multiprocessor Architectures:** On-line PIN cache simulation tool that reports cache performance for x86 multi-threaded applications with various cache coherence strategies, i.e., MSI, Dragon, and Directory-based.
- **LejOS Robotics Activities Development for Undergraduates and High School stu- dents:** (1) Intiation of Computer Science Robotics Club (2009) and (2) creation of Robotics activities during e-Day (K12 under-represented students) and e-Girls (9th–10th grade female students) to broaden under-represented students' participation into STEM.
- **Conference:** (1) Programming Committee members for INTERACT-15 and INTERACT-16, (2) Local chair ACM SIGPLAN Conference on Languages, and Compilers and Tools for Embedded Systems (LCTES 2005), and (3) Programming Committee members for ICPP'03, and LCTES'02–LCTES'05.

Current Support

Sponsor	Project Title	Amount	Project Period	Months Committed
Moneual Inc.	Development of Virtual Machine of Smart Sensor Network Access Control Based on Smart Platform	$130,954	6/1/11–9/30/14	2 months
Google, Inc.	Preprocessing for Modulo Scheduling within Open Source ARM Cortex-A8 Compiler	$37,400	8/1/12-9/30/14	0 months
Idaho Board of Education	SAVE: Self-organizing Air VEnt System	$45,800	7/1/13–6/30/14	1 month

GANG-RYUNG UH, Ph.D. – CURRICULUM VITAE

A Contact Information

Department of Computer Science, Boise State University,
1910 University Drive, Boise, Idaho 83725
E-mail: uh@cs.boisestate.edu,
Home page: http://cs.boisestate.edu/∼uh,
Phone: 208.426.5691

B Research and Teaching Interests

Optimizing compilers, OS and computer architecture interactions, dynamic performance evaluation, and embedded systems.

C Formal Higher Education

1997	Ph.D	Major: Computer Science. Florida State University, Tallahassee, Florida. Dissertation: *"Effectively Exploiting Indirect Jumps"*
1993	M.S.	Major: Computer Science. Florida State University, Tallahassee, Florida. Thesis: *"Predicting Consumer Expenditure Behavior with Neural Nets"*
1987	B.A.	Major: Economics. Hankuk University of Foreign Studies, Korea.

D Professional Employment

2008 – present	Associate Professor, Computer Science Department, Boise State University.
2010– 2011	Research Associate (sabbatical) for the NSF grant CNS-0964413, *Static Pipelining, an Apporach for Ultra-low Power Embedded Processors*, Dept. of Computer Science, Florida State University, Tallahassee, FL.
2002 – 2008	Assistant Professor, Computer Science Department, Boise State University.
2007 (Jun–December)	Consultant, Intel Performance, Analysis and Threading Lab, Champaign, USA.
2006 (May–August)	Consultant, Intel System Software Lab, Hillsboro, USA.
2005 (Dec)	Research Faculty, Seoul National University, Korea.
2005 (May–August)	Research Faculty, Seoul National University, Korea.
2000 – 2002	Research Scientist, Agere Systems, USA.
1998 – 2000	Research Scientist, Lucent Technology, USA.
1990 – 1997	Research/Teaching Assistant, Department of Computer Science, Florida State University, USA.

E University Level Teaching

E.1 Courses taught

1. Quantitative Computer Architecture	(grad)	Boise State University, Boise, Idaho
2. Advanced Topics in Compilation	(grad)	Boise State University, Boise, Idaho
3. Introduction to Computer Science I	(undergrad)	Boise State University, Boise, Idaho
4. Introduction to Computer Science II	(undergrad)	Boise State University, Boise, Idaho
5. Embedded Systems Design in C	(grad)	Boise State University, Boise, Idaho
6. Programming Language & Translation	(undergrad)	Boise State University, Boise, Idaho
7. Problem Solving in C	(undergrad)	Florida State University, Tallahassee, Florida

E.2 Courses created

1. Quantitative Computer Architecture	(grad)	Boise State University, Boise, Idaho
2. Advanced Topics in Compilation	(grad)	Boise State University, Boise, Idaho
3. Embedded Systems Design in C	(grad)	Boise State University, Boise, Idaho
4. Problem Solving in C	(undergrad)	Florida State University, Tallahassee, Florida

E.3 Courses revised in large

1. Introduction to Computer Science I	(undergrad)	Boise State University, Boise, Idaho
2. Introduction to Computer Science II	(undergrad)	Boise State University, Boise, Idaho
3. Programming Language & Translation	(undergrad)	Boise State University, Boise, Idaho

F Publications

F.1 Refereed Journals

1. I. Finlayson, **Gang-Ryung Uh**, D. Whalley and G. Tyson. *"An Overview of Static Pipelining,"* IEEE Computer Architecture Letter (CAL), ISSN:1556-6056, Volume 11, No. 1, Jan 2012. The paper was selected as the BEST paper and presented during the 19th IEEE International Symposium on HPCA.

2. **Gang-Ryung Uh**, Yuhong Wang, David Whalley, and et al. *"Compiler Transformations for Effectively Exploiting a Zero Overhead Loop Buffer,"* In the journal of Software Practice & Experience, Volume 35, pages 393-412, 2005.

3. W. Kreahling, D. Whalley, M. Bailey, X. Yuan, **Gang-Ryung Uh**, R. Van. *"Branch Elimination via Multi-Variable Condition Merging,"* In the journal of Software Practice & Experience, Volume 35, pages 51-74, 2005.

4. Jinhwan Kim, Yunheung Paek, **Gang-Ryung Uh**. *"Code Optimization for a VLIW-style network processing unit,"* In the journal of Software Practice & Experience, Volume 34, pages 847-874, 2004.

5. Minghui Yang, **Gang-Ryung Uh**, David Whalley. *"Efficient and Effective Branch Reordering Using Profile Data,"* In ACM Transactions on Programming Languages and Systems (TOPLAS),Volume 26, Number 6, pages 667-697, 2002.

6. **Gang-Ryung Uh** and David Whalley. *"Effectively Exploiting Indirect Jumps,"* In the journal of Software Practice & Experience, December 1999, pages 1061-1101.

F.2 Refereed Conferences

1. K. Schwab, J. Law, G. Cook, K. Hoff and **Gang-Ryung Uh**. *"SAVE: Self-organizing Air VEntilation system,"* In the proceeding of UKC 2013, New York/New Jersey, August, 2013. This work is selected one of 10 finalists for the Business Venture Challenge (BVC) competition program and will be presented during the conference for $10,000 cash award competition.

2. I. Finlayson, B. Davis, P. Gavin, **Gang-Ryung Uh**, D. Whalley, M. Sjalander and G. Tyson. *"Improving Processor Efficiency by Statically Pipelining Instructions,"* In the proceeding of ACM SIGPLAN/SIGBED Conference on Languages, Compilers and Tools for Embedded Systems (LCTES), June 2013, Seattle, WA.

3. Doosan Cho, Ravi Ayyagari, **Gang-Ryung Uh**, and Yunheung Paek. *"Preprocessing Strategy for Effective Modulo Scheduling on Multi-Issue Digital Signal Processors,"* In the Proceedings of the 16th International Conference on Compiler Construction, March, 2007, Braga, Portugal.

4. Wankang Zhao, Prasad Kullkarni, David Whalley, Christopher Healy, Frank Mueller, **Gang-Ryung Uh**. *"Tuning WCET of Embedded System,"* In the Proceedings of IEEE 10^{th} Real-Time and Embedded Technology and Applications Symposium, May 2004, Toronto, Canada.

5. W. Kreahling, D. Whalley, M. Bailey, X. Yuan, **Gang-Ryung Uh**, R. Van. *"Branch Elimination via Multi-Variable Condition Merging,"* In the Proceedings of European Conference on Parallel and Distributed Computing (EuroPar03), August 26-29, 2003, Klagenfurt, Austria.

6. J. Kim, S. Jung, Y. Paek, and **Gang-Ryung Uh**. *"Experience with a Retargetable Compiler for a Commercial Network Processor,"* In the Proceedings of the 2002 International Conference on Compilers, Architecture and Synthesis for Embedded Systems, 2002, Grenoble, France.

7. **Gang-Ryung Uh**, Yuhong Wang, David Whalley, and et al. *"Techniques for Effectively Exploiting a Zero Overhead Loop Buffer,"* In the Proceedings of the 9th International Conference on Compiler Construction (CC'2000), pages 157-172, March 2000, Berlin, Germany.

8. Minghui Yang, **Gang-Ryung Uh**, David Whalley. *"Improving Performance by Branch Reordering,"* In the Proceedings of ACM SIGPLAN Conference on Programming Language Design and Implementation, pages 130-141, June 1998, Montreal, Canada.

9. **Gang-Ryung Uh**, David Whalley. *"Coalescing Conditional Branches into Efficient Indirect Jumps,"* In the proceedings of International Static Analysis Symposium, pages 315-329, September 1997, Paris, France.

10. **Gang-Ryung Uh**, Daniel Schwartz. *Predicting Consumer Expenditure Behavior with Neural Nets,"* In the Proceedings of IEEE'93 World Congress on Neural Networks.

F.3 Refereed Workshops

1. R. Baird, B. Davis, **Gang-Ryung Uh** and D. Whalley. *"Improving Machine Code Generation Quality by Interfacing VPO with LLVM Pipelining,"* this draft was accepted for poster presentation during the the European LLVM Conference, April 2013, Paris, France. R. Biard received $1,000 travel grant for the Boise State Unversity's contribution to the LLVM compiler infrastructure. The LLVM compiler is awarded 2012 ACM Software System Award, which is given by ACM to *one* software system wordwide every year.

2. I. Finlayson, **Gang-Ryung Uh**, D. Whalley and G. Tyson. *"Improving Low Power Processor Efficiency with Static Pipelining,"* In the proceeding of 15th Workshop on Interaction between Compilers and Computer Architectures (INTERACT), Feburary, 2011, San Antonio, TX.

3. **Gang-Ryung Uh**, Robert Cohn, Bharadwaj Yadavalli, Ramesh Peri, and Ravi Ayyagari. *"Analyzing Dynamic Binary Instrumentation Overhead,"* In the Proceedings of the Workshop on Binary Instrumentation and Applications, October, 2006, San Jose, USA: **appeared in the ACM SIGARCH Computer Architecture News, ISSN:0163-5964.**

4. Doosan Cho, Ravi Ayyagari, **Gang-Ryung Uh**, and Yunheung Paek. *"Instruction Re-selection for Iterative Modulo Scheduling on High Performance Multi-issue DSPs,"* In the Proceeding of the 1^st International Workshop on Embedded Software Optimization, August, 2006, Seoul, Korea: **published in Lecture Notes in Computer Science (LNCS), ISSN:0302-9743.**

5. **Gang-Ryung Uh**. *"Tailoring Software Pipelining for Effective Exploitation of Zero Overhead Loop Buffer,"* In the Proceedings of the 7^{th} International Workshop on Software and Compilers for Embedded Systems (SCOPES 2003), September 24-26, 2003, Vienna, Austria: **published in Lecture Notes in Computer Science (LNCS), ISSN:0302-9743.**

6. **Gang-Ryung Uh**, Yuhong Wang, David Whalley, and et al. *"Effective Exploitation of a Zero Overhead Loop Buffer,"* In the Proceedings of ACM SIGPLAN Workshop on Languages, Compilers, and Tools for Embedded Systems, pages 10-19, May 1999, Atlanta, USA: **published in ACM SIGPLAN Notices, Volume 34, Issue 7, ISBN:1-58113-136-4.**

F.4 Patent

1. **Gang-Ryung Uh**, Kyle Schwab, Gang-Ryung Uh, and et. al. *"SAVE: Self-organizing Air VEntilation system"*, Boise State University filed a provisional patent appplication for the SAVE technology on June 14, 2013 (61/835,276). This invention is nominated for 2013 Idaho Innovation Awards by the Boise State University's Office of Sponsored Program (OSP).

2. **Gang-Ryung Uh**, David Whalley, and et. al. *"Compiler Optimization for Exploiting Zero Overhead Loop Mechanism"*, Inventor Number: 2083757, Patent Number:6367071, Approval Date: April 2, 2002.

G Invited Talks/Presentations

1. *"Improving Processor Efficiency by Statically Pipelining Instructions',"* KOCSEA Technical Symposium, Atlanta, Georgia, 2012.

2. *"LLVM-VPO Compiler Infrastructure for a Low Power Embedded Processor,"* Seoul National University, Seoul, Korea, 2012.

3. *"Overview of Statically Pipelined Processor,"* ETRI, DaeChun Korea, 2012.

4. *"Compiler Optimization Strategies for Mobile Processors,"* ETRI and Monuel ELFWAND Project Workshop, DaeChun, Korea, 2012.

5. *"Architecture and Compiler Techniques to Improve Processor Energy Efficiency,"* Samsung System-On-Chip (SOC), Seoul, Korea, 2012.

6. *"PIN - Dynamic Binary Instrumentation,"*, NASA Advanced Supercomputing Division, Ames, CA, USA, 2006.

7. *"StarCore VLES SC1400 DSP and Compiler Optimization,"* Samsung Electronics, Seoul, Korea, 2005.

8. *"Effective Modulo Scheduling for VLES SC1400 DSP,"* Seoul National University, Seoul, Korea, 2005.

9. *"Compiler Optimization Strategy to Reduce Power without Degrading Performance,"* NASA Advanced Supercomputing Division, NASA Ames, CA, USA, 2004.

10. *"Compiler Optimization Strategy to Reduce Power without Degrading Performance"*, Agere Systems, Allentown, PA, USA, 2004.

11. *"Tailoring Software Pipelining for Effective Exploitation of Zero Overhead loop buffer,"* SCOPES, Vienne, Austria, 2003.

H Funding

1. Principle Investigator, Idaho State Board of Education, Higher Education Research Council, Idaho Incubation Fund Program FY 2014 RFP, *"SAVE: Self-organizing Air VEntilation system"* $45,800, July 2013 – June 2014.

2. Principle Investigator, Google Faculty Research Award, *"Preprocessing for Modulo Scheduling within Open-Source ARM Cortex-A8 Compiler,"* $37,400, August 2012 –.

3. Principle Investigator, Korea Evaluation Institute of Industry Technology (KEIT), Grant NO.10041725, *"ELFWAND: Building the Service and Software Foundation for Personalized Smart Device Sensor Applications,"* $210,000 (for Boise State University), Jun 2012 – May 2015.

4. Co-Principle Investigator, Korea Small Medium Busines Adiministration, Grant NO. 0004537, *"Development of Virtual Machine for Smart Sensor Network Access Control-based Platform,"* $130,594 (for Boise State University), Jun 2011 – May 2013.

5. Principle Investigator, NASA Idaho EPSCoR, *"PIN Based Non-Uniform Memory Access (NUMA) Memory Simulator,"* $30,000, May 2009 – August 2010.

6. Principle Investigator, INTEL Corporation, *"Multi-threaded PIN Simulator Desgin,"* $25,000, Jan 2007–Oct 2011.

7. Principle Investigator, NASA Idaho EPSCoR, *"Compiler Optimization for Ultra-Low Power Wireless Sensor Signal Processor,"* $8,000, Nov 2005–Nov 2006.

8. Principle Investigator, Brain Pool (Korean Federation of Science and Technology Societies) *"Compiler Infrastructure Development,"* $20,000, *Period*: May 2005–Dec 2005.

9. Principle Investigator, NASA Idaho EPSCoR, *"Optimizing Compiler Benchmark Infrastructures for Ultra-low Power Embedded Processors,"* $60,294.00, *Period*: Oct 2003–Aug 2004.

10. Principle Investigator, NSF Idaho EPSCoR, *"Instruction Selection Sensitive Software Pipelining for Effectively Exploiting Zero Overhead Loop Buffer,"* $50,800, Mar 2003–Dec 2003.

11. Principle Investigator, Dean's Office, *"Automatic Code Generator for Embedded Processors,"* $30,000, Jan 2003–.

H.1 Equipments awarded

1. Texas Instrument, 3x BeagleBoard ARM XM, $450, May 2013.

2. Intel Corporation, one LittleFe portable teaching cluster and 2011 NCSI parallel workshop travel support, $5,000, August, 2011.

3. Texas Instrument, 20x CC2530 ZDK-ZNP ZigBee development boards and 2x TMDSCCS-ALLF01, $7,970, November 2010.

4. INTEL Corporation, 2x Intel Itanium IA64 MP 1.3Ghz Rackmount server, $11,655.00, Mar 2007.

5. INTEL Corporation, 4x Intel Xeon MP 2.7Ghz Rackmount Server, $28,159.00, Oct 2006.

6. AGERE SYSTEMS Corporation, DSP16000 software tools and DSP16410 development boards, $36,000.00, Dec 2005.

7. CYPRESS SEMICONDUCTOR Corporation, PSoC development kits, $10,000.00, Oct 2005.

I Mentoring

I.1 Graduate Students

- MS student: Lakshmi Peri, Topic: *Evaluating the presence of a Victim Cache on an ARM processor*
- MS student: Kyle Schwab, Topic: *SAVE: Self Organizing VEnt Control*
- MS student: Jared Law, Topic: *SAVE: Self Organizing VEnt Control*
- MS student: Nathan Riskey, Topic: *SAVE: Self Organizing VEnt Control*
- MS student: Gregory Cook, Topic: *LLVM-VPO Compiler for ARM*
- Ph.D committee: Doosan Cho, Dept of ECE, Seoul National University

- MS Chair: Jaremy Creechley, Topic: *LAZYCAT: A Lazy XMLPL Compiler and Runtime System*, October 2012
- MS student: Pallayya Sarma Karra, Topic: *Visualization of Dynamic Loop Profiling Information*
- MS committee: Kevin Nuss, Topic: *A Tool to Aid in the Parallelization of C and Fortran Programs*
- MS Chair: Samatha Guttala, Topic: *Simulator for Dynamic Branch Prediction Unit Access*, October, 2008
- MS Chair: Ravi Ayyagari, Topic: *A Dynamic Loop Profiling, Optimization and Detection Tool*, August 2007
- MS Chair: Arpita Ghosh, Topic: *Retargeting MPEG Decoder to Digital Signal Processor*, May 2007
- MS committee: ChokSheak Lau, Georgia Institute of Technology, Topic: *An Optimization Framework for Embedded Processors with Auto-Modify Addressing Modes*, Nov 2004

I.2 Undergraduate Students

- Kyle Hoff (MB&E), Topic: *SAVE: Self Organizing VEnt Control*
- Ryan Baird (CS), Topic: *LLVM-VPO Compiler for ARM Cortex A8*
- Jason Wall (CS), Topic: *3D NBody Gravitational Simulation*
- Mark Stewart (CS), Topic: *3D NBody Gravitational Simulation*
- Paul Turner (Physics), Topic: *3D NBody Gravitational Simulation*
- Dan Crow (CS), Topic: *Visual Interactive Assembly Level Optimizer for DSP16000*, August 2005
- Steve Mathie (CS), Topic: *Visual Interactive Assembly Level Optimizer for DSP16000*, August 2005
- David Zuercher (CS), Topic: *Automatic Code Generator for Embedded Processors*, Dec 2004
- Charles Paulson (CS), Topic: *Automatic Code Generator for Embedded Processors*, April 2004

J Professional Service

2012–	Vice president of Korean American Scientists and Engineers Association (KSEA) Idaho Local Chapter
2010-2011	Program Committee Member, Workshop on Interaction between Compilers and Computer Architectures (INTERACT)
2004–	Chair of Board of Directors, Idaho Korean Community Association
2002–	Reviewer of numerous journal and conference articles, approx. 40.
2005	Local Chair, ACM SIGPLAN/SIGBED 2005 Conference on Languages, Compiles, and Tools for Embedded Systems (LCTES).
2005	Session Chair, ACM SIGPLAN/SIGBED 2005 Conference on Languages, Compiles, and Tools for Embedded Systems (LCTES).

2003 Student Poster Session Chair, ACM SIGPLAN/SIGBED 2005 Conference on Languages, Compiles, and Tools for Embedded Systems (LCTES).

2003 Program Committee Member, ACM SIGPLAN/SIGBED 2005 Conference on Languages, Compiles, and Tools for Embedded Systems (LCTES).

2003 Program Committee Member, International Conference on Parallel Processing (ICPP).

2002 Program Committee Member, ACM SIGPLAN/SIGBED 2005 Conference on Languages, Compiles, and Tools for Embedded Systems (LCTES).
Tenure period.

K References

References available upon request.

SUMMARY PROPOSAL BUDGET

Name of Institution: Boise State University

Name of Project Director: Dr. Gang-Ryung Uh

A. PERSONNEL COST (Faculty, Staff, Visiting Professors, Post-Doctoral Associates, Graduate/Undergraduate Students, Other)

Name/ Title	Salary/Rate of Pay	Fringe	Dollar Amount Requested
Dr. Gang-Ryung Uh, Associate Professor, 1 month	$95,166 for 9 mos.	32%	$13,968
Graduate Research Assistant, approximately 600 hours at $20/hour	$11,960 for 12 mos.	9%	$13,016
Graduate Research Assistant, approximately 600 hours at $20/hour	$11,960 for 12 mos.	9%	$13,016

% OF TOTAL BUDGET:	80%	SUBTOTAL:	$40,000

B. EQUIPMENT: (List each item with a cost in excess of $1000.00.)

Item/Description	Dollar Amount Requested
SUBTOTAL:	$0

G. TRAVEL:

Dates of Travel (from/to)	No. of Persons	Total Days	Transportation	Lodging	Per Diem	Dollar Amount Requested
Las Vegas, NV for HVAC trade show	3	3-4	$900	$2,320	$780	$4,000
SUBTOTAL:						$4,000

H. Participant Support Costs:

	Dollar Amount Requested
1. Stipends	
4. Other	
SUBTOTAL:	$0

I. Other Direct Costs:

	Dollar Amount Requested
1. Materials and Supplies: Custom boards, sensors, radios	$6,000

2. Publication Costs/Page Charges	
3. Consultant Services (Include Travel Expenses)	
4. Computer Services	
5. Subcontracts	
6. Other (specify nature & breakdown if over $1000)	
SUBTOTAL:	$6,000
J. Total Costs: (Add subtotals, sections A through I) **TOTAL:**	$50,000
K. Amount Requested: **TOTAL:**	$50,000
Project Director's Signature: [signature]	Date: 6/11/2014

INSTITUTIONAL AND OTHER SECTOR SUPPORT
(add additional pages as necessary)

A. INSTITUTIONAL / OTHER SECTOR DOLLARS	
Source / Description	Amount

B. FACULTY / STAFF POSITIONS
Description

C. CAPITAL EQUIPMENT
Description

D. FACILITIES & INSTRUMENTATION (Description)
Fully equipped laboratories (see Appendix 1)

FAMCO™
FRESH AIR MANUFACTURING CO.

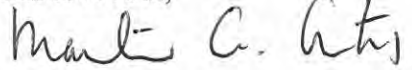
6/10/14
Boise State University
Attn: Dr. Gang-Ryung Uh

Dear Dr. Uh,

We are writing to express our support for your proposal for funding under the HERC Idaho Incubation Fund program towards developing S**elf-Organizing VEnt (*SAVE*)** System.
The purpose of your proposed scope of work is important to the HVAC industry and we are interested in research and development opportunities that will assist in moving the SAVE technology to a stage that can be commercially marketed. In addition, FAMCO is also interested in potential opportunities of applying innovative electronic and firmware used in SAVE to our innovative FAMCO IAQ Economizer.
Fresh Air Manufacturing Company (FAMCO) was established in 1989 and is headquartered in Meridian Idaho. We are one of the Pacific Northwest's largest manufacturers of HVAC sheet metal and plastic, air ventilation products. FAMCO currently manufactures and distributes from three plants located in Meridian, Nampa and Caldwell Idaho to thousands of wholesalers across the United States and Canada. FAMCO products are used in HVAC to Roofing, and Building Materials. Using Lean Manufacturing, every procedure is measured, analyzed and checked for quality, efficiency and customer satisfaction. FAMCO consists of the forward-thinking veteran management team focused on bringing innovative HVAC projects and designs to market. We pride ourselves on the guarantee of quality ventilation and building products at FAMCO with over 25+ yrs. of manufacturing and design of electrical/mechanical components.
In particular, FAMCO management team and engineering will provide the expertise, technology and experience in researching and designing the mechanical components of the ***SAVE*** Registers that best suits the intended market and meets the performance expectations. FAMCO will support the SAVE project team by providing the basis for bridging the gap between R&D and full-scale manufacturing. We are prepared to provide the following support towards the SAVE project. Specific experience/expertise includes:

1) Full Mechanical Design of VENT Register Components; to include wide variety of materials analysis.
2) Electrical Component Design; to insure survival in the residential world.
3) Business Model Development: determine whether retail, wholesale, or internet sales will find customers.

We are committed to providing industry with the most current technology and see the opportunity to partner with Dr. Uh's research at Boise State University to be extremely valuable.
FAMCO looks forward to our involvement and potential for interaction leading to the development and commercialization of Dr. Uh's ***SAVE*** system as a consumer product.
Best regards,
Martin A. Artis,



President

649 N. Ralstin St. Meridian, Idaho
(208) 884-8931 • 1-800-234-1903 • Fax (208) 884-8943 • E-mail famco@famcomfg.com • www.famcomfg.com