Scavenger Hunt: An Embedded Wireless System Approach

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Categories and Subject Descriptors
D.4.4 [**Software Engineering**]: Communications Management—*message sending*; K.3.1 [**Computers and Education**]: Computer Uses in Education—*outreach*

General Terms
Experimentation

Keywords
outreach programs, K-12 computer science education, embedded wireless systems, TinyOS, nesC, computer games

ABSTRACT
Recent statistics have shown the decline in the number of students choosing computer science as an undergraduate degree in the United States of America. This problem is pressing as the supply of qualified computer scientists is decreasing while demand for computer scientists in industry and academia is increasing. Accordingly, many universities and organizations have been engaged in outreach activities to recruit K-12 students in computer science. As part of this effort, we have organized three workshops to introduce K-12 students to concepts of computer science and computer science as a career.

In this paper, we provide an overview of three outreach workshops conducted at Clemson University over the past year. Participants of the workshops varied from elementary to high school students. We focus on one of the activities included in the workshop, a scavenger hunt using embedded wireless systems. We also discuss the technical aspect of the activity. We conclude with an evaluation of the activity in terms of the impact it had on the success of the workshops, and provide pointers to future outreach efforts.

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1. INTRODUCTION
It is not a surprising fact that the number of women in engineering and science, including computer science, is significantly less than that of men. Women, such as Grace Murray Hopper, Anita Borg, and Frances Allen, have had a profound impact on the field of computer science. However, the number of women in the field is still small. According to the National Center for Women & Information Technology, only 17% of computer science degrees obtained in USA in 2008 were obtained by women, compared to 37% in 1985 [7]. This problem stems from the declining recruitment of undergraduate students in general and female students in particular in computer science over the last several years [21]. Although the recruitment of students in computer science has started increasing since 2009 (5.5% increase in enrollment from 2008), the number of degrees awarded in 2009 has decreased by 12% since 2008 [22]. To increase the severity of the problem, the demand for computer scientists is increasing. According to the U.S. Department of Labor, the demand for computer scientists is expected to increase by approximately 24% within the next few years [1]. This in turn increases the gap between the supply of and demand for computer scientists.

In an attempt to increase the recruitment of students in computer science, many universities and organizations all over the U.S. have developed outreach programs. Such programs include introduction to concepts of computer science, programming, hardware, and robotics, to mention a few. Universities involved in outreach activities include University of Central Florida, Purdue University, Clemson University, and Carnegie Mellon University, among others. Organizations involved in similar activities include Google, Microsoft, Intel, and IBM, to mention a few.

In an attempt to increase the recruitment of students in computer science, we developed three workshops held at Clemson University for K-12 students over the past year. The goal of the workshops was to introduce K-12 students to concepts of computer science and get them interested in choosing computer science as a major of study and career. The workshops included activities, such as disassembling and reassembling a desktop CPU, introducing students to principles of programming through Scratch [10], and introducing students to networking concepts through an in-house scavenger hunt game using embedded wireless networks.

In this paper, we provide a brief summary of each workshop hosted at Clemson University. We focus on the scavenger hunt activity. Specifically, we provide implementation details of our scavenger hunt application along with the activity setup. We evaluate the activity as well as the various workshops based on our observations and the feedback we have received from participants.

Paper Organization. The remainder of the paper is organized as follows. Section 2 provides an overview of similar outreach activities discussed in the literature. Section 3 details the three workshops conducted at Clemson University. Section 4 discusses the implementation details of the scavenger hunt activity. Section 5 describes the setup of the activity. Section 6 provides an evaluation of the workshops in general and the scavenger hunt activity in particular. This section also discusses lessons learnt from the workshops. Finally, Section 7 concludes and provides pointers to future outreach activities.

2. RELATED WORK

A scavenger hunt is a popular activity among organized groups of any age. A simple internet search of "scavenger hunt", on Google nets 2,160,000 results. In the first ten results, we find scavenger hunt party ideas for all ages, variations of classic scavenger hunts, multiple definitions of scavenger hunt, team building scavenger hunts, free downloads for different scavenger hunt ideas, book results for scavenger hunt, and news result for scavenger hunts. A narrower search of "high tech scavenger hunt" reveals several articles that discuss geocaching [18, 12]. Geocaching is an outdoor scavenger hunt that involves finding a hidden object or other clue using a global positioning system (GPS) device along with latitudes and longitudes posted on the internet.

In addition to geocaching, there are many outreach programs associated with various universities that use scavenger hunt activities with students. For example, Pennsylvania College of Technology provides a career scavenger hunt for K-12 students [11]. The hunt starts when students are asked to choose a career of interest. Using the internet, the students are then directed to research and answer a list of questions about the chosen career.

Washington State University also has a program called Early Outreach in which scavenger hunts are used with middle school students [16]. These students participate in an all-day scavenger hunt that takes them to various locations at Washington State University. This event allows the students to interact with professors and college students. Through this activity the students have an opportunity to gain real-life experience on a four-year university campus.

The University of Maine has a K-12 outreach program that helps students learn the Canadian provinces and territories by a means of an online scavenger hunt. The students are directed to a website that contains a province/territory and questions related to that province/territory. By following the various links provided in the website, the students are instructed to answer each question pertaining to the particular province/ territory [15].

The University of Illinois at Urbana-Champaign conducts a scavenger hunt during orientation for incoming freshmen in the Department of Computer Science [13]. This orientation scavenger hunt uses handheld computers to aid students in exploring the university campus. One of the goals of this research is to increase the enrollment and retention rates of the students in the department. The authors of [13] found that 54% of the students indicated they made friends during the activity and they felt a connection to the department. The authors have previously found that the lack of social networks was a contributing factor in many cases where students transferred out of the department. The authors conclude that the scavenger hunt has had a positive impact on the retention of students, which was 4.6% higher than the previous five-year historical average.

Finally, the American Association for Artificial Intelligence (AAAI) has incorporated a scavenger hunt in their annual conference [2, 6, 19]. In this scavenger hunt, participants create a robot that must be able to identify and record the location of items on a predefined list. A few of these items include a bright yellow beach ball, a multicolored soccer ball, and a plush dinosaur doll.

At Clemson University's School of Computing, we developed a scavenger hunt that involves embedded wireless systems. We used this activity with students ranging from fifth to twelfth grade. None of the above scavenger hunts were implemented using an embedded wireless systems approach. A detailed description of this system will be further discussed in Sections 4 and 5.

3. WORKSHOP DESCRIPTION

As described earlier, we have conducted three outreach workshops at Clemson University over the past year. This section provides a brief description of each workshop.

3.1 Emerging Scholars Program

Clemson's Emerging Scholars Program is a nationally recognized outreach program that targets students from rural counties with significant economic, educational, and social impediments with respect to technology. These impediments make the transition from high school to higher educational institutes more difficult. Clemson's Emerging Scholars program attempts to address these issues by working with high schools to identify students with the potential to succeed in higher education but need additional support. These students are identified during their freshman year of high school and enter the program as rising sophomores. The students can continue in the program through their senior year. During these years, the students attend Clemson University for 1 to 3 weeks, depending on their class year in high school. While attending Clemson for the first two summers, these students are exposed to team building activities, collaborative learning, and basic reading and writing. Math and science skills are further reinforced. During their last summer, the students are introduced to a schedule that closely mimics a first semester freshman schedule. They attend math, science, social science, and art classes.

Clemson's School of Computing has participated in this program for several years. We provide participating high school students with engaging, hands-on interactive activities designed to give them a better understanding of the field of computer science and its many career opportunities. One such activity is a scavenger hunt. These students participated in two types of scavenger hunt: one involving binary numbers and the other involving embedded wireless devices. The binary number scavenger hunt entailed a campus wide outdoor search. The students had to convert binary to decimal numbers to determine their next destination. The wireless network scavenger hunt was held indoors and required the students to find hidden embedded devices as described later in Section 5.

3.2 STEM-ICT 3D

Science, Technology, Engineering, and Math – Information Communications Technologies (STEM-ICT) 3D is a project funded by the NSF Innovative Technology Experiences for Students and Teachers (ITEST) program. This project is a collaborative effort between Appalachian State University and Clemson University and was funded with the goal of motivating under-represented, middle school students to study and pursue careers in one of the STEM disciplines. Participating students in this program are identified during their sixth grade by their teachers and their school guidance counselor. The students attend a two-week summer academy. During the first week, they learn to design, build, and use a 3D virtual environment. During the second week of the summer academy, the students are joined by their rising seventh grade teachers. During this time the students become the "technical experts" and they are tasked with teaching the teachers the 3D technology they learned the previous week. Working together, teachers and students create virtual environments which will be used in the classroom to teach STEM curriculum in the future.

During the two week summer academy students were provided with several field trips and other activities related to STEM areas. One of these activities was our scavenger hunt using embedded wireless devices as described in Section 5.

3.3 Girl Scouts

To introduce young girls to the field of computer science and the careers computer science has to offer, three Girl Scout troops were invited to a computer science workshop at Clemson University. The grades of these girls ranged from fifth to eighth grade with 19 girls and 5 leaders attending the workshop. Basic programming was introduced through MIT's Scratch programming language [10]. After a short amount of instruction the girls were given time to create a program using Scratch and then demonstrate their creation to the group. The girls were also taught basic computer science concepts, such as networking, binary numbering system, and sorting through CS Unplugged activities [17]. In order to better understand the innerworkings of a computer, they were allowed to disassemble and reassemble a desktop personal computer.

Figure 1: Tmote Invent

As the girls signed in for the day's workshop they were given an embedded wireless device, and instructed to find other hidden devices as we will further discuss in Section 5. The other devices were hidden in the building that housed the workshop prior to the girls' arrival.

4. SCAVENGER HUNT: THE SOFTWARE APPLICATION

Typical applications of embedded wireless systems are those reacting to stimuli in the environment to solve a certain problem. Embedded wireless systems have been used in a variety of scenarios ranging from social networking to saving lives on the battlefield. We are adding a new class of applications to the field: computer science outreach. In this section, we describe the design and implementation of the scavenger hunt application.

We implemented the application using the nesC programming language targeting TinyOS as the operating system of choice. TinyOS [14] and nesC [5] are the defacto operating system and programming language for embedded wireless networks, respectively. nesC is a dialect of the C programming language. nesC is an event-based and interrupt driven programming language for TinyOS. This language is suitable for the class of applications embedded wireless systems are targeting.

Devices (nodes) used in the scavenger hunt application act as either senders or receivers. The software for the receiving devices was installed on 16 Tmote Invent sensor nodes [3]. A Tmote Invent node is a wireless senor node, which commonly integrates on-board light, accelerometer, and microphone sensors. It is also equipped with a CC2420 wireless communication chip [9] that uses IEEE 802.15.4 [8] protocol. These nodes are powered by 2 AA batteries and include three LEDs (typically red, green, and blue). Tmote Invent devices support the TinyOS operating system.

The software for the sender devices was installed on 6 Tmote Sky nodes [4], which use the same wireless communication

Figure 2: Tmote Sky

chip as the Tmote Invent nodes. Figure 1 represents the Tmote Invent node, while Figure 2 represents the Tmote Sky node.

Sender nodes periodically broadcast beacon messages. When receiver nodes receive the beacon messages, they blink one of the LEDs. The receiver nodes use the received signal strength indicator (RSSI) metric to determine which LED to blink. RSSI is a metric that can estimate the distance between senders and receivers [20]. The red, green, and blue LEDs blink if the RSSI value is too low, medium, or high, respectively. In other words, a receiver node blinking the red LED indicates that there are no sender nodes nearby, while a receiver node blinking the blue LED indicates that there is a sender node within close vicinity. Although RSSI is generally not reliable to compute the distance between transmitters and receivers, it was a good enough metric to guide the students to find the hidden nodes.

To make the activity more challenging for the participating students, sender nodes transmit their beacon messages using a radio transmission power of value 5. The radio transmission power ranges in values from 1 to 31 units. The higher the radio power is, the longer the communication range becomes. This requires the students to be close enough to the sender nodes, for the receiver nodes they are carrying to blink the blue LED.

5. SCAVENGER HUNT: THE GAME BEGINS

In this section we describe the setup of the nodes used in the scavenger hunt activity. We also describe our introduction of the activity to the student participants.

5.1 Activity Set-up

The sender nodes were hidden in the building where the workshops were held. The nodes were hidden under water fountains, behind posters, under furniture, behind trash cans, and inside open faculty and student offices. These locations are not directly visible to the participants, which makes the hunt for the nodes more exciting. Along with the sender nodes, we hid candy bags as an incentive for the students to find the missing nodes. Each bag had a different type of candy, and the students who collect the largest variety of candy win the scavenger hunt. Participants were provided with sheets to write down where they find each node. To find the hidden (sender) nodes, each student was

Figure 3: Students participating in a discussion about networks

Figure 4: Students searching for a sender node

given a Tmote Invent node (the receiver node). When students are walking throughout the building, their node would blink the right color indicating their proximity to a hidden node. As a student becomes closer to a hidden node, the color of the blinking LED would change until the student finds the hidden node and gets a piece of candy from the hidden candy bag. Elementary school students were especially excited about the candy.

5.2 Activity Introduction

The scavenger hunt application was not intended to be just a game for the students to play to kill time. Through this activity, we were able to introduce students to the field of networking. Before the game began, one of the workshop moderators explained what networks are. We used cell-phones as an example to illustrate networking concepts. Cell-phones represented receiver nodes, while cell-phone towers acted as sender nodes. We chose cell-phones as students in that age group can easily relate to cell-phones to grasp the concepts of networking. We explained how cell-phones receive signals from a satellite or a cell-phone tower. The closer the cell-phone is to the tower, the stronger the signal becomes. This example helped us explain wireless networking as well. We then passed Tmote Sky nodes around to show students another example of devices that form a network and communicate wirelessly. We also explained how such nodes can be used in various real-world applications, such as intrusion detection, traffic monitoring, and structural monitoring. Through these real world applications, we explained the concept of wireless sensor networks, where nodes monitor the environment and send data wirelessly to cooperatively solve a certain problem. The amount of technical details depended on the age group of the students. Students participated in the discussion and asked a lot of insightful questions. Figure 3 shows one of the moderators having a discussion with the participants at one of the workshops. When students asked all the questions they had, we handed out the receiver nodes (Tmote Invent nodes) to each student. We explained the game and mentioned that the nodes they obtained are like the cell-phones and they are required to find the sender nodes, which act like the cell-phone towers. The students were then given 15 minutes to find the hidden nodes. Figure 4 shows some of the students as they were trying to find one of the sender nodes.

6. EVALUATION

In this section we provide an evaluation of the workshops in general and the scavenger hunt activity in particular. We also highlight the lessons learnt from our experiences.

6.1 Workshop Evaluation

Table 1 illustrates the number of participants in each workshop divided by gender. The table also includes the lowest and highest school grade of the participants. The number of participants in each workshop varied from 12 to 66 participants. The youngest participants were fifth grade students, while the oldest participants were twelfth grade students. The three workshops were very successful. Participation among the students was extremely high. Students were particularly engaged in hand-on activities, such as disassembling and reassembling desktop PCs, developing their own animation using Scratch, or walking throughout the building looking for hidden nodes in the scavenger hunt game. The parents were also very satisfied with what the students learnt. Parents and participants contacted us after the workshops indicating that the participants went home and started applying some of the concepts they learned at the workshop.

6.2 Scavenger Hunt Evaluation

The scavenger hunt activity was very well received among the students. The students asked a lot of questions when we explained the concepts of networking, wireless networks, and wireless sensor networks. For example, students asked about how different a sensor node is from a regular computer, how to install software from a desktop computer to a sensor node, and what display sensor nodes offer to users. The students participated by indicating what real-life applications networking can be used for.

The elementary school students were especially excited about the candy hidden along with the sender nodes. Hiding a different kind of candy along with each node made the activity competitive and more fun for the students as they were looking for the nodes to find what kind of candy was hidden.

When compared to the binary scavenger hunt activity conducted with the participants of the Emerging Scholars workshop, the participants overwhelmingly preferred the wireless network scavenger hunt. Part of this response was due to the controlled environment of indoors; however, they also indicated that they enjoyed learning about the field of networking and how it relates to their daily lives, such as when they use cell-phones.

When the girl scouts played the scavenger hunt, they were so focused on finding the hidden nodes that it became clear the schedule was going to have to be rearranged to allow more time for this activity. Even after extending the activity time, many of the girls asked if time permitted we could hide the nodes and repeat the activity at the end of the day.

From this activity, we learnt that the age group played a role in determining which part of the activity the students were interested in. Elementary school students were enthused by the candy and the fact that they will be running throughout the building looking for the hidden nodes. Middle and high-school students, on the other hand, were more interested in the technical explanation and experimenting with RSSI, as they can relate more to the concepts of networking since this age group uses cell-phones the most.

6.3 Attendees' Feedback

The workshop organizers received multiple emails after the workshops indicating how much the participants enjoyed the workshops and that they learned a lot about computer science. Below are snippets from some of the received emails:

- “The girls and moms had a great day and learned a lot.”
- “[T]he girls seemed really interested and engaged and came home very happy... I think she looks at computers ... a little differently now that she knows more about them.”
- “The girls have raved about it. Thank you so much for supporting the Girl Scouts and giving them this wonderful opportunity to learn and grow.”
- “We really enjoyed the activities and learned a lot. I loved ... the scavenger hunt.”
- “I esp[e]cially loved the scavenger hunts.”
- “We hope we can do another computer day with you sometime!”

7. CONCLUSION

We started with the fact that recruitment of students in computer science is declining. Efforts to increase student recruitment is increasing. Outreach activities are carried out by various universities and organizations. In this paper, we presented three outreach workshops for K-12 students. The workshops introduced the students to concepts of computer science. We focused on one of the activities, scavenger hunt. We discussed the implementation details, the setup, and the teaching aspects of the activity. We then provided an evaluation of both the workshops and the scavenger hunt activity and highlighted the lessons learnt from these activities.

In the future, we are looking into hosting more workshops at Clemson University. We are also currently involved in a

Workshop	Females	Males	Total Participants	Lowest School Grade	Highest School Grade
Emerging Scholars	42	24	66	11	12
STEM-ICT 3D	5	7	12	7	7
Girl Scouts	19	0	19	5	8

Table 1: Workshop Participants Statistics

year long outreach program at a local high-school, where we are introducing computer science concepts to first-year high school students. Looking into the future, we are considering incorporating the scavenger hunt activity in the orientation session for incoming computer science freshmen. Through this activity, the students will be able to tour the computer science building, visit various labs, and meet the professors in the department. Additionally, we plan to include this activity in our weekly departmental tours for prospective students along with their guardians. Finally, we plan to modify the scavenger hunt application to increase the communication range. This way, we can add this activity to the freshmen orientation, where the scavenger hunt will cover the entire campus. The students will be going around campus looking for the sender nodes. This activity will allow students to discover the various parts of campus, meet with current students, and get accustomed to campus life.

8. ACKNOWLEDGMENTS

This work was supported in part by an award from the NSF (CNS[CAREER]-0745846). The authors would like to thank the staff members as well as the student helpers, who provided invaluable aid, input, and feedback during the workshops we conducted over the past year.

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