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From Idea to Impact: A Case Study for Sustainable Innovation

Dr. Daniel Raviv, Florida Atlantic University

Dr. Raviv is a Professor of Computer & Electrical Engineering and Computer Science at Florida Atlantic University. In December 2009 he was named Assistant Provost for Innovation and Entrepreneurship.

With more than 25 years of combined experience in the high-tech industry, government and academia Dr. Raviv developed fundamentally different approaches to ”out-of-the-box” thinking and a breakthrough methodology known as ”Eight Keys to Innovation.” He has been sharing his contributions with professionals in businesses, academia and institutes nationally and internationally. Most recently he was a visiting professor at the University of Maryland (at Mtech, Maryland Technology Enterprise Institute) and at Johns Hopkins University (at the Center for Leadership Education) where he researched and delivered processes for creative & innovative problem solving.

For his unique contributions he received the prestigious Distinguished Teacher of the Year Award, the Faculty Talon Award, the University Researcher of the Year AEA Abacus Award, and the President’s Leadership Award. Dr. Raviv has published in the areas of vision-based driverless cars, green innovation, and innovative thinking. He is a co-holder of a Guinness World Record. His new book is titled: ”Everyone Loves Speed Bumps, Don’t You? A Guide to Innovative Thinking.”

Dr. Daniel Raviv received his Ph.D. degree from Case Western Reserve University in 1987 and M.Sc. and B.Sc. degrees from the Technion, Israel Institute of Technology in 1982 and 1980, respectively.

Dr. Alex Kotlarchyk

From Idea to Market:
A Case Study for Sustainable Innovation

Abstract

This paper describes an on-going non-traditional educational experience of working on an intelligent water-conservation project at Florida Atlantic University. It is unique in the sense that the working settings are different from an ordinary research and development project. We have been working with a private investor and entrepreneur who came up with the original idea. He has been very involved in the project with business, humanitarian, environmental and educational goals in mind.

In addition to providing students a rich academic experience, a goal of this project is for the students to gain practical, "hands-on" knowledge of how to create a commercial product, both from a technical and business perspective. We follow the project as it progresses from inception to commercial promise and share experiences of technical ups and downs, teamwork and communication issues, problem-solving activities, the overlap between academic and non-academic interests, benefits to students, and lessons learned. The paper includes discussion of innovative, entrepreneurial, and practical components of the project.

Students were engaged in both technical and business development, including prototyping, customer relations, product testing, and financing. We discuss the difficulty of academic assessment of this project and share observations and suggestions for improvements to future projects of this type.

The ultimate goal of the project is to develop a new intelligent residential and commercial water sprinkling system that uses readily available internet-based weather information, and with no local sensors. We foresee that the eventual product will be of significant value to society at large by conserving a significant amount of fresh water.

1. **Motivation and Goal**

The goal of this project is to provide students a real-world learning experience and have them gain or improve innovation and business skills not normally taught in a typical engineering classroom environment (Fig. 1).

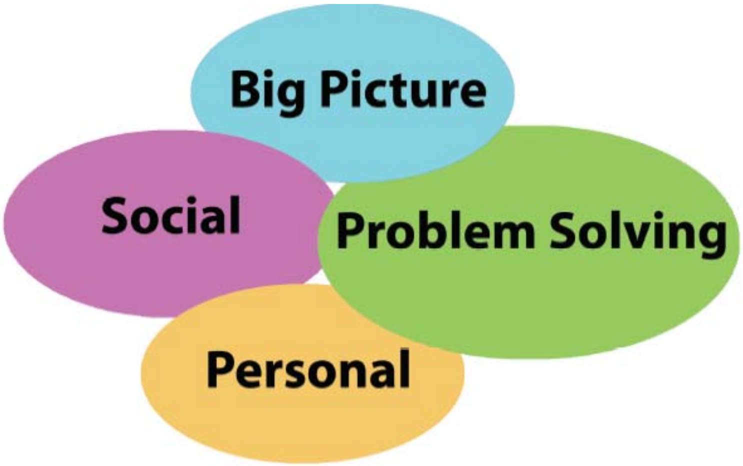

Figure 1: Innovation/Business Skills

These skills include, but are not limited to:

- **Problem solving and entrepreneurial skills,** such as explorative, divergent, convergent and critical thinking. Other examples are intuition, inquiry, estimation, knowledge integration, the ability to act on ideas, and direct, no-nonsense communication.
- **"Big picture" and entrepreneurial skills,** such as the observation of problems in wider contexts, and familiarity with non-engineering disciplines. Concepts include economic, political, cultural, ethical, and environmental awareness.
- **Personal skills,** such as persistence, imagination, curiosity, risk taking, reading and comprehension, the cultivation of a positive can-do attitude, clarity of thought, goal oriented thinking, as well as life-long, lateral learning and artistic abilities.
- **Social skills,** such as teamwork, communication and humor.

Students engage in business-like experience apart from the traditional classroom environment. They work as a team, take risks, push past failures, interact with prospective customers and are exposed to business, as well as technical issues. As in a typical business environment, the students attend regular meetings and are expected to actively participate and produce in a timely manner. They learn to add value and see that their efforts directly contribute to the success or failure of the product. They realize that they must be good communicators to be effective team members since they need to rely on each other for the entire project to be successful. In general, they learn to observe, question data, synthesize, ideate, rapidly prototype, and iterate these steps to improve the product.

The business and environmental motivation for the project is that water use has been growing at more than twice the rate of population increase in the last century. By 2025, it is estimated that 1800 million people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions[1]. One study in Wellington, Florida, showed that of the metered potable gallons that were delivered from the public water supply to the study area during the study period, an estimated 48% were used outdoor for lawn watering[2] Water restrictions are commonly in effect in many locations. Given this dire need to conserve water, it is indeed frustrating to see lawn sprinklers operating during a downpour. Wouldn't it be great to make use of weather information freely available on the web to intelligently control water sprinkling at the local level and be able to conserve as much precious water as possible? Such a system would also be of economic benefit to the owner of the sprinkler system by significantly reducing water usage and cost. Most current water sprinkling systems are pre-programmed (mechanically or otherwise) by the end users. They take into account neither past and present local weather conditions, nor weather patterns and predictions. This leads to waste of water, in particular during rainy seasons. Simple calculations show that in many regions in the US, the use of internet-based information could save more than 30% of fresh water.

The technical project goal is to create a low-cost, intelligent water sprinkler system that is simple to install and operate. To be of practical utility and to appealing to the greatest number of consumers, it needs to be compatible with the installed base of electromechanical and electronic sprinkler systems. This seems to be an important feature that is lacking in proposed and existing systems. The system will improve on existing sprinkler systems[1] by using historical and forecast weather data to delay or expedite sprinkling events. It will be created from inexpensive, "off-the-shelf" components so that manufacturing costs are minimized.

The new system regularly extracts past and predicted rain fall data, from multiple web sources, along with other weather conditions such as humidity and temperature. Additional data are provided by local weather stations. This information, along with customer location, soil information, grass data, mandatory water restriction schedules, etc., is fed into an algorithm that determines whether or not to turn on the sprinkling system. The decision is communicated to the client location via the internet and forwarded via local wireless communication to control the local water sprinkler unit. The process is estimated to be meaningfully more efficient and less expensive than existing technologies that use on-site sensory data. It is environmentally friendly, simple to operate and maintain and can be constructed using low-cost components.

2. About the Project

Project participants

The original idea is the brainchild of Michael Levine: inventor (70+ patents), investor, and entrepreneur. He had previously been the motivating force behind an award-winning project at Florida Atlantic University (FAU) for water desalinization (*"Low Energy Vacuum Distillation Method and Apparatus"*). Due to the success of that project, the current project is based on a similar collaboration between him and a group of students studying at Florida Atlantic University under the guidance of the first author. The project falls under the "Campus 2020" initiative at Florida Atlantic University, designed, in part, to stimulate engineering innovation at the university. A recent Ph.D. alumnus also became involved as a mentor and collaborator through his professional and academic relationships with the other project participants. He has an academic background in biology and the environment, as well as computer science and engineering experience. The project included both graduate and undergraduate students so that all could benefit at an early stage in their careers. The photo (Fig. 2) shows participants at an early stage of the project gathered at the inventor's residence for early experimentation.

Figure 2. Early project participants

Academic vs. Business Environment

Michael Levine brings his entrepreneurial background to the project. As such, he is accustomed to being surrounded by people devoting their full attention to his projects. In an academic environment such single-mindedness is unrealistic to expect. Student participants often are unavailable between semesters and the project is delayed until they return. The professor's primary duty is to educate and is obligated to satisfy the needs of many students outside of the project. Although most students involved in the project are excited and want to do a good job for the project, their main academic objective is to fulfill their requirements for graduation. In fact, students came and went on the project until a dedicated group of students was assembled. Although many (especially the undergraduates) do not yet have the experience to know how to be proactive at all times, they gain a valuable learning experience. This should give them a better understanding of what it takes to succeed in a business environment.

The students had the opportunity to learn from an entrepreneur and inventor who has had success developing successful commercial products and building companies. Students received partial monetary compensation for their efforts, including occasional incentive bonuses for extra efforts. As in the workplace, they worked as a team with people of different ages from diverse experience and nationality backgrounds. Similar to working with people from different departments, the project included students from different majors.

We first present an overview of the project. Since the project had a mixture of technical, business, and educational goals, the next sections discuss technical and business details and identify examples of related and embedded student learning.

The idea

Note: the following information is contained in a provisional patent filed by Michael Levine.

The invention is a device that will use rainfall information from radar and other weather information obtained from the internet to control a sprinkler system. If available, rain gauge measurement information may be incorporated to correct to actual rainfall amounts. The user's Zip Code can be used to identify the user's location and default soil/grass type. The device will be able to inhibit or allow power to a sprinkler system with a pre-existing electronic or electromechanical sprinkler timer. The device will connect to the sprinkler system through the rain sensor connection, if available. Otherwise, the device will be connected to the sprinkler system through standard home circuitry wiring. The sprinkler timer itself will be set to water every day, regardless of whether the timing is set mechanically by pins (e.g., Intermatic: [4]) or electronically (e.g., RainBird: [5]).

By default, there is power supplied to the sprinkler system. The device will be able to automatically inhibit watering by the sprinkler for any 24-hour period by interrupting power to the sprinkler system based on rainfall information obtained from the internet. The device will be able to sense current, such as by an ammeter, and will therefore be able to correct for any power outages to remain synchronized with the existing 24-hour sprinkler timer cycles. If a power outage at the sprinkler location occurs, then the time that power to the sprinkler is inhibited by the invention would be decreased by the power outage time. Similarly, communication outages to the device will be monitored and corrected for, so that the correct 24-hour cycle stays synchronized with the existing sprinkler timer. As with many existing electronic sprinkler timers, the device will have the ability to be programmed for any local water restrictions that are in effect. The invention will be able to be controlled via commands entered into a device app, such *as Google Calendar or the like. The commands may be entered into the app manually by the user or automatically by the invention's algorithm which makes use of the internet rainfall data. Google Calendar control of devices has previously been demonstrated by, for example, the Belkin WeMo using the IFTTT interface [6]. User information and default settings may be entered or modified via a web page or the device apps (including mobile device apps).*

System components

In addition to the existing sprinkler system, the major components of the Smart Sprinkler System project are:

- weather data (historical and forecast, primarily precipitation), e.g. Wunderground,
- data collection and processing
- a data store for weather history, algorithm decisions, and user-specific information
- a decision algorithm to delay or expedite sprinkling, based on the weather data,
- a website for customer registration
- a client receiver/transmitter
- a device that acts as a sprinkler controller by interrupting power to the pre-existing sprinkler system
- communication between the aforementioned components (wireless, where feasible)

Figure 3 shows the basic layout of the current structure of the Smart Sprinkler System. Weather data is provided by the Application Programming Interface (API) that is available from Wunderground [7]. In the Data Collection/Processing section data preparation is performed. The Data Store section centralizes all of the data in one location so that each of the components that require access has available data. The output of the Decision Algorithm is to determine whether or not to sprinkle. Next, the Client Receiver/Transmitter handles the communication for passing that decision on to the Sprinkler Controller. Finally, the Sprinkler Controller handles the activity of enabling/disabling power to the on-site sprinkler system.

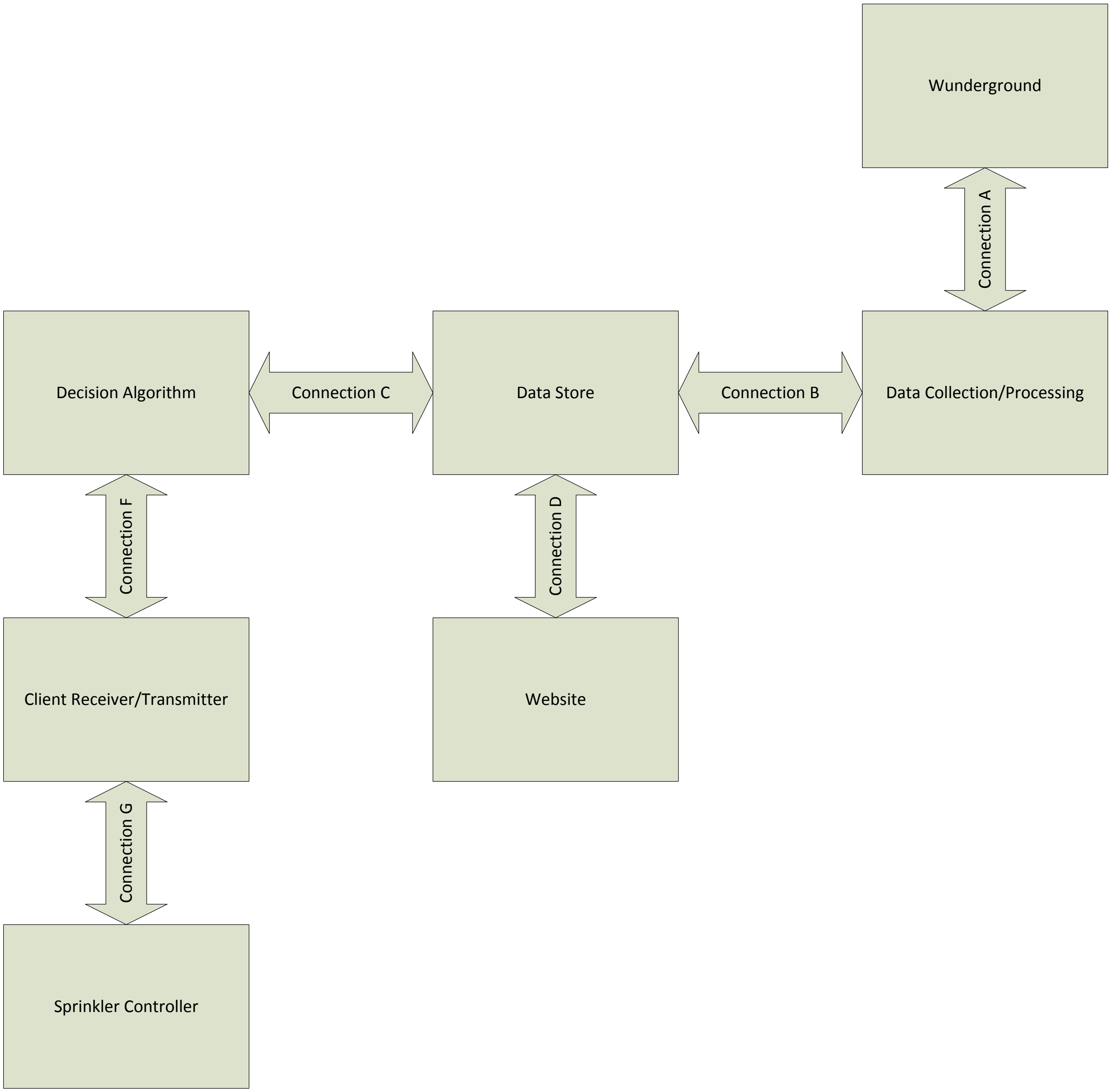

Figure 3. Smart Sprinkler System overview

Initial implementation

This implementation helped students understand a system level approach to the project and to experience the creation of a rapid prototype in a multidisciplinary environment.

The initial implementation of the Smart Sprinkler System was built around an Arduino microprocessor (Fig. 4).

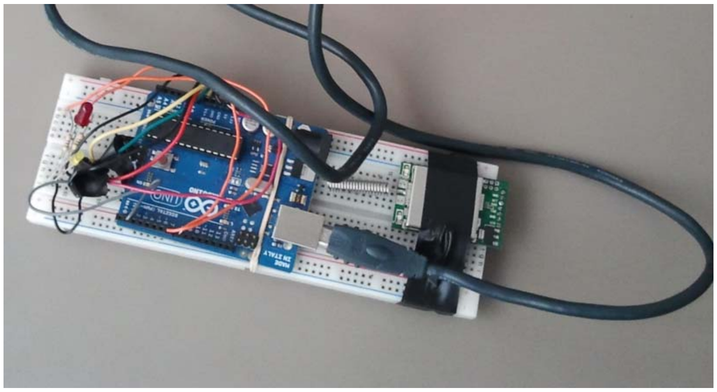

Figure 4. Arduino-based system prototype

The following sections discuss the various components that comprise the Smart Sprinkler system. Issues encountered during the project that project members were forced to confront are discussed in the appropriate section.

- Wunderground

This is the source for weather information. This data from the site comes in two forms: radar images and actual rainfall data. The API that is provided allows the system to gather the data using a web request. In the case of the radar data, location latitude and longitude are used as parameters. In our requests, the longitude and latitude values that are supplied determine the center point for the image we are requesting. Other parameters that are passed are the radius of the scope of our image, the width and height of the image, and whether or not the image should include the underlying satellite image. Fig. 5 was the result of a query that passed the following parameters: Center Longitude (-80.277966), Center Latitude (26.254142), Radius (100), Width (280px), Height (280px), and to show the underlying satellite image.

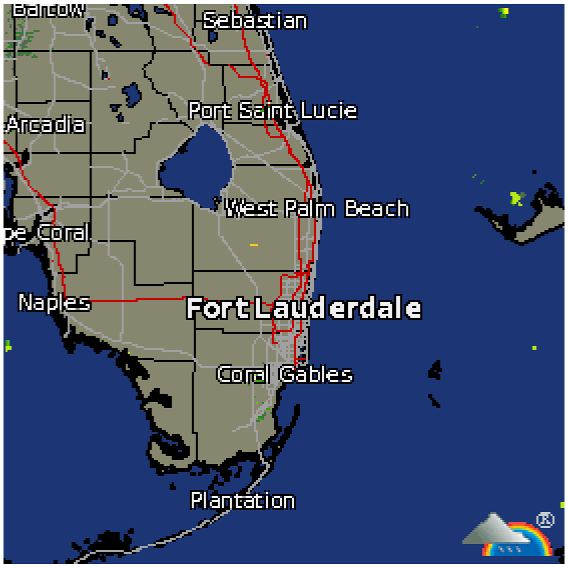

Figure 5. Image result from Wunderground.

The same process can be used to then find the closest Weather Stations for which the API has available data, based on the latitude and longitude values that are supplied as parameters. The result from such a query can be formatted as JSON or XML, which can be interfaced with many programming languages. Finally, from the data that was provided by this query of individual weather stations, the actual rainfall measurement at each of these sources can be retrieved.

- *Student learning*: The students learned to explore information sources and the reliability, accuracy, and timeliness of the data. In addition to paid weather services on the internet, much of the data is available for free. They learned to use free resources whenever possible. Obviously, any additional costs that are incorporated into the system would decrease profit margin and lower the chances for a viable business. Various sites offer rainfall information in 5-minute, 15-minute, hourly, daily, monthly, or yearly totals. A problem with reliability of data occurred when the data service obtained from Wunderground was inconsistent and contact with their support personnel was found to be difficult and frustrating. Many unproductive hours were used up trying to resolve this problem.

- Data Collection/Processing

At this point, the Wunderground API querying takes place. The desired data is gathered and temporarily stored until ready for processing. For now, station selection is performed manually. The radar images are downloaded from the API at five-minute intervals for the entire day and are stored temporarily awaiting processing at the end of each day. The processing of the images at the end of each day consists of taking the color of the pixel and converting it to the decibel value that it should represent as anticipated rainfall. This processing is completed on each of the nearest weather stations, as well as the customer's location. The value calculated through this processing represents the estimated precipitation at the sprinkler system's location. This value is then stored daily in the Data Store for use by the rest of the system.

- *Student learning*: The students learned how to assemble experimental equipment, measure data, communicate the data, store it, and verify it with ground truth. They needed to verify that precipitation values calculated by converting radar images to rainfall amount accurately reflected ground truth. If this could not be accomplished, then the project would be a non-starter. Therefore the students matched actual rain collected by rain gauges to our calculated precipitation values from the radar images. They discovered that there are not only "official" governmental weather stations (often located at airports), but also an ad hoc network of rain gauges reported on by volunteers. The students had an opportunity to travel and see the data collection process of the volunteer network first-hand (Fig. 6). They discovered that some municipal sites apply quality control measures to their data, whereas less scrutiny is applied to the volunteer reports. They realized that there is a varying amount of delay in reporting values, depending on the particular service or website. For additional verification, the students set up a rain gauge located on the patio of the fifth floor of the university's Engineering building that automatically collected and logged rainfall amounts. They also observed how rainfall affected grass growth in different soil types.

- Data Store

All the data that is gathered and used throughout the system is stored here. This includes historical and predicted weather, user account information, and a history of the water sprinkling decisions. The structure of the data is a series of text files that are generated by other processes and stored in a common Dropbox directory. As the number of users grows, we will probably use a commercial database system to manage the Data Store. Such a database system will also aid in the ability to mine the collected data for product improvement.

Figure 6. Data collection at a field weather station

- Decision Algorithm

"To sprinkle or not to sprinkle on the current day, that is the question." The binary response of "yes" or "no" is the output of the Decision Algorithm. The current implementation of our algorithm is quite simple. If there has been no watering event (i.e., significant rainfall or mechanical sprinkling) at the customer site for the two previous days, then watering is scheduled for the current day (i.e. power is not interrupted). Otherwise, a signal is sent that will cause the sprinkle controller to interrupt power to the existing sprinkler system, thereby preventing mechanical watering. In addition, watering will be prevented for the current day if significant rain is forecast for the next day. We will be able to calculate the amount of water saved by implementing our algorithm compared to the typical repetitive sprinkling schedule normally followed by the existing sprinkler when in Automatic mode. We can later improve the sprinkling algorithm by incorporating more weather and climate data.

- *Student learning*: The students learned to predict the need for water sprinkling based on observed historical data, predicted rainfall, and soil type by applying their STEM (Science, Technology, Engineering and Math) knowledge to the problem at hand. They first had to determine how much watering is provided by a typical sprinkler system in order to determine what would be a "significant" rain event that would allow us to delay sprinkling. An experiment was performed in which water was collected from an actual sprinkler system. The water output provided by the sprinkler system was surprisingly low, only one tenth of an inch in an hour. When we thought about it, it made sense in that grass has very shallow roots and watering serves to keep the plant moist and only the top level of the soil saturated. Therefore the sprinkler system only provides 0.03 inches of watering for a typical 20 minute sprinkling event.

- ➢ Website

The website currently has a basic registration page that allows users to register for the system. Once there is a database structure that allows for the storage of the information, the registration will allow the user to input specifics about the client's location that will be used to make the best sprinkling decision. The currently stored user attributes are the following: First Name, Last Name, Address, Email, Device ID, Grass Type, and Soil Type. A more complete list of user attributes will develop as we determine their affect on system performance. Again, free information provided by the Zip Code to quickly locate nearby weather radar stations and rain gauges.

- *Student learning*: Students learned to explore alternative solutions to a given problem. Rather than entering and displaying the user's sprinkling schedule through a separate app, these events could be automatically entered into a familiar user app, such as the Google Calendar. The students were able to demonstrate this capability after creating an interface using the Google Calendar API. However, they were frustrated to discover that the IFTTT web service that triggers events based on entries in the Google Calendar are not immediate, but only guaranteed to occur 15 minutes before or after the scheduled time of the event. To overcome this, they plan to trigger events using email notifications for sprinkler start and stop times, since the IFTTT email interface triggers events immediately.

- ➢ Client Receiver and Transmitter

This portion of the system is set up to receive signals from a server application and uses the decision that it receives to either interrupt the sprinkler system or not. In either case, it will communicate the result of the Decision Algorithm to the Sprinkler Controller.

- *Student learning*: Students learned that "official" channels are not always the most efficient method of getting a task done in a timely manner. We initially were thinking of using the server on the university to implement our system. However, communications issues arose trying to get through the university's firewall. This difficulty is good news for the university from a security standpoint, but is an inconvenience that would delay productive product development. Therefore, it was decided to create a dedicated project server. The initial implementation used radio communication to send the decision to the customer location and then through Wi-Fi to the Sprinkler Controller. We are currently developing the system to use the commercial Belkin WeMo device that will obtain the decision over the internet and send it via Wi-Fi to the Sprinkler Controller. Why develop a communication pathway from scratch when there is an existing commercial product that already has an implementation of the necessary path available for relatively low cost? The students learned to quickly change course and use COTS (commercial-off-the-shelf) products whenever available.

➢ Sprinkler Controller

This device actually does the interrupting of power to the customer's Sprinkler system based on the decision that was passed to it by the Client Receiver/Transmitter.

➢ Communication System

– Connection A

Data Collection/Processing issues web requests to Wunderground and processes the data retrieved from the responses to its queries.

– Connection B

A series of calls for reading and writing to the text files located in the Data Store by the Data Collection/Processing section.

– Connection C

A series of calls for reading the text files located in the Data Store by Decision Algorithm.

– Connection D

The website was not created for the initial implementation. Therefore, there is currently no communication involving website access to the Data Store.

– Connection E/F

The output of the Decision Algorithm is communicated via the internet to the Client Receiver/Transmitter.

- *Student learning*: Students learned to dig into the benefits and drawbacks of alternative solutions. Ultimately, is it more efficient for clients to *pull* the result of the Decision Algorithm, or should the sprinkling decisions be *push*ed to the clients? This was a lively subject for debate between group members. The students created implementations of both mechanisms so that we can further investigate which is ultimately the best method to choose.

– Connection G

This connection uses wireless communication in order to pass the decision from the Client Receiver/Transmitter to the sprinkler controller.

Demonstration

The initial implementation was demonstrated as a proof-of-concept exercise. For maximum effect, an actual sprinkler outside the Engineering building at FAU was controlled by the system during the university's annual collaboration with industry meeting. The attendees were very interested to see it and seemed quite impressed.

3. Student Innovation/Business Skills

A goal of this project is to develop student innovation and business skills, as identified in the 'Motivation and Goal' section of this paper. Although we have given examples of student learning in the previous sections, we now emphasize some experiences from the project which exemplify student learning of innovation and entrepreneurial skills.

Problem solving and entrepreneurial skills

Rapid prototyping – Students created a prototype of a functioning system using an Arduino board that communicated via radio frequencies and operated a custom-built, portable, sprinkler system (Fig. 7).

Interpretation of rainfall from radar images – Rainfall was estimated from radar images obtained at no cost via the web.

Minimalistic approach – The system uses low or no-cost components such as Outlook, C#, COTS hardware (e.g., Arduino board, Belkin WeMo, private small-scale weather stations), available home WiFi, Excel spreadsheet, IFTTT (if-this-then-that) software.

Estimation of sprinkled water – What is the actual moisture requirement? This experiment was performed at the inventor's house. We collected the amount of water that was sprinkled per unit area from the home sprinkling system. From this we were able to estimate the amount of water necessary for the lawn to stay green (i.e., the minimum necessary sprinkling requirement).

Overcoming obstacles – During product development, the project members had to solve hardware problems, such as insufficient water pressure to our test sprinkler and shielding electrical equipment from moisture.

Figure 7. Portable sprinkler system

"Big picture" and entrepreneurial skills

Ability to change course due to economic considerations – We constantly framed our engineering solutions in terms of practical business solutions, keeping in mind the customer point of view. This includes cost, pricing, marketing, sales, etc. There were also issues to consider regarding scaling for production and infrastructure growth. To save time for rapid prototyping, we switched from the Arduino-based system to using the already commercially available Belkin WeMo. Eventually, we may build our own hardware to save on production cost.

Ability to look at products from customer perspective and how this is done – Students conducted a on-site walk-through to explore customer installation issues.

Consideration of environmental impact – A study was conducted that applied our sprinkling algorithm to historical data to estimate the percentage of water that would have been saved using our system.

Dealing with water restrictions – Many municipalities restrict days and times that sprinkling can occur. We needed to research how strictly these are enforced and if any accommodations could be made with governmental agencies.

Addressing reliability issues – Beyond the prototyping stage of the project, we needed to continually test our system for reliability, since this is a major consideration when going to market.

Understanding that "time is money" – Whenever possible, we have tried to use the "official" university channels to purchase necessary equipment, but at times we have received funds directly from our sponsor when we could not wait for the proper channels to come through.

Personal skills

Time management – The university is a commuting school. We needed to accommodate differing schedules and use the time that we were all together efficiently. Meetings were organized so that the most important issues were discussed first.

Can-do attitude – Students learned that any obstacles must be overcome in a timely manner for the project to succeed. An example of persistence in finding a solution to WiFi signal problem. One of the test houses had WiFi signal problems due to multiple concrete walls separating the sprinkler system unit from the WiFi source. We initially attempted to solve the problem by adjusting the location and orientation of the WiFi unit and the receiver, but this did not succeed. In the end, a signal enhancer was purchased to amplify the signal to solve the problem.

Imagination – We were able to conceive and implement a system that collect rainfall data without using local sensors.

Social skills

Conflict resolution – There was a lively debate about the conceptual approach to the communication system in regard to whether the system should perform active polling by the server or wait for interrupts from the clients. This question was ultimately resolved once we found a COTS solution.

Teamwork and sharing credit – Any ideas were given due consideration by the team, regardless of which team member made the suggestion. Ideas from every team member were eventually incorporated into the project and any success was considered a team success.

4. Observations and Suggestions

Although the overall experience of the project was overwhelmingly positive, nonetheless, there were issues to overcome. We tried to create an environment in which the students were motivated to work hard, but at the same time enjoy the successes of the project and the social interaction. The photo in Figure 8 was taken at the inventor's residence in Michigan where the student's had the opportunity to engage in relaxing and fun activities, such as boating and swimming.

We tried to create an environment that closely resembled that of a startup company. However, the reality is that the students have competing agendas in that they have academic commitments outside of the project. Not only was this a time management problem for the students, but also a source of frustration for the inventor/entrepreneur mentor of the team.

Some of the initial student project members worked full-time elsewhere. This turned out to be a mistake. Later, we added students to the project that had less of an outside commitment so that they could be more dedicated to the project and to accommodate project meetings. We would suggest that be the case for future implementations of this type of project.

There were a few students that were assigned to the project who showed a lack of commitment. To maintain enthusiasm for the project and to ensure that everyone was "pulling their own weight," these members were replaced once this became evident. We suggest that commitment to the project be emphasized as a priority before prospective team members agree to join.

Although there were students on the project from different engineering majors (Computer Engineering, Computer Science, and Electrical Engineering), it probably would have also been mutually beneficial to have some student members from the College of Business.

Once we defined the project, we were perhaps too eager to jump right in and start prototyping. In hindsight, perhaps more initial research, both academic and in the marketplace, would have saved us time and money.

5. Learning Assessment Issues

Since this was not a classroom experience and with the limited number of students involved in the project, the traditional methods of assessment of student learning (exams, homework, formal presentations, etc.) may not apply. Rather, we believe that the students benefitted from their experience participating in a dynamic, entrepreneurial environment. They were active participants in what it takes to compete in the real world. They learned that it is not only technical skills that will contribute to the success of their careers, but their ability to innovate, work well in teams, and resolve differences in a productive manner. Above all, they needed to be persistent in moving the project forward to achieve its ultimate goal.

Although we cannot point to any metrics that prove what the students learned, the actions of the students and the results they achieved are indications of learned skills. They were usually willing to work many hours more than were required. They were able to work as a team to find alternative ways to solve problems and see first-hand what it takes to build a product for the marketplace. We cannot say that all the students that participated were able to obtain all of the innovation/business skills, but whether through participation or observation, we are confident that their experience in the project has better prepared them for the real-world challenges that await them in the future.

Figure 8. Not all learning takes place in the classroom!

6. Future Work

We have currently changed courses from the Arduino-based system to show that the system can be built around a popular, commercially available product, the Belkin WeMo. There is a mobile app already created by Belkin for the WeMo and we plan to take advantage of its ability to use the IFTTT (If-This-Then-That) web service to respond to events from other services and devices, such as from a calendar or email event.

We will continue to gather historical weather data to determine how it may be used to improve the Decision Algorithm. Even with the simple algorithm previously described, preliminary analysis of the data indicates that we would see a 30% reduction in water usage by the sprinkler system.

Soon, we plan to have a dozen or so systems in the hands of users willing to act as beta test sites. Many issues still need to be investigated. We need to prove that we can maintain performance once as the number of customers grows. Does our algorithm for converting radar image to rainfall level have dependencies on geographic features? Will we have a problem adapting to existing sprinkler systems outside the United States? One of the important lessons that all on the project have learned is that, especially in the business world, time is of the essence.

Acknowledgements

We wish to thank NCIIA and Last Best Chance, LLC for their partial sponsorship of the project. Our project is part of a larger effort underway at Florida Atlantic University, the Campus 2020 initiative, a human-centered project for an efficient, user-friendly campus.

This paper is focused mostly on the educational experience of the students, with less emphasis on the technical work. It should be noted and acknowledged that elements of the technical description were obtained from multiple reports by students. Specifically we would like to acknowledge Dr. Aalo, and the students Richard Bagley, Patrick Green, Zack Strulovitch, Henley Wright, Pablo Pastran, and Armando Leon.

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[4] Webref 2: http://www.youtube.com/watch?v=xTONP3Z1Bf8

[5] Webref 3: http://www.youtube.com/watch?v=kHqsHSYWTu4

[6] Webref 4: http://www.youtube.com/watch?v=fQMYAhY-e9c

[7] Webref 5: www.wunderground.com