Student Control of Engineering Mall

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During the 1993-94 academic year a fountain included in an associated park-like structure, covering an area 115 ft. by 300 ft. designed by sculptor William Conrad Severson, was constructed in front of the University of Wisconsin Engineering Hall, becoming part of the larger campus complex, Henry Mall. This extends from the engineering campus well into the entire campus and builds a visual link to the College of Agriculture and Life Sciences.

At the south end of this park-like area stands a dynamic piece of art, the Maquina, consisting of a pair of what many of us see as large calipers standing the order of 25 ft. high and wide, which include several arrays-of-nozzles and individual nozzles each fed through electrically controlled valves. A photograph of this sculpture is presented in Figure 1.

Figure 1 UW College of Engineering Maquina Fountain

This structure and support equipment has become a very tantalizing and productive laboratory environment in which our students carry out a wide range of design and development projects. From the original conception through construction completion, Dean John Bollinger saw this facility as a hands-on laboratory for the students and the faculty of the entire College of Engineering. The entire cost of this structure was met with alumni gifts of cash donations and corporate gifts in kind. It provides a valuable and elegant hands-on on-line experiment for our students. It has also begun to provide a focal point of cooperation and team projects with students in the arts.

Students have been involved in programming computers that control the system since the construction personnel finished their work in the fall of 1994. The student involvement continues to grow, with them suggesting and implementing extensive additions to the system operation, a good part of this supported by the College. This is certainly a part of the new program in the College of Engineering, centered on "Improving Undergraduate Engineering Education" at the University of Wisconsin as reported by Corradini [1].

Layout

Figure 2 provides general, though not detailed, layout of the fountain system. There is extensive landscaping and other facilities not detailed thereon. As noted in the figure, the structure within which the students confine their work covers a land area of 90 ft by 250 ft. Near the south end of this structure is the pool in which the Maquina is mounted. The picture of this sculpted fountain, which has tended to become our college logo, can be seen on our Internet web page at http://www.engr.wisc.edu/. That photograph, much like that of Figure 1, was taken looking to the south from an area just north of the Maquina.

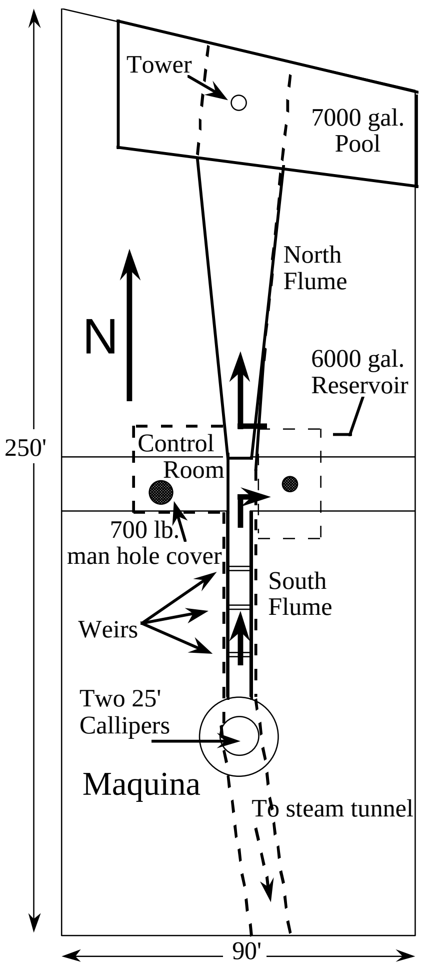

Figure 2 Mall Layout

The Maquina includes extensive plumbing, primarily providing a vigorous source of water, compressed air, and potentially, steam. There are 32 pilot-controlled solenoid valves controlling supply of water to a wide variety of individual nozzles and arrays of nozzles in the Maquina. Water fed to the various nozzles included in the Maquina over-fills the pool below it. This water flows down the south flume to the north, across three pneumatically controlled weirs, then turns east dropping into a 6000 gallon underground reservoir. The water is drawn from this reservoir and returned to the Maquina. This is one of two water circuits.

A second water circuit exists at the north end of the complex. A vigorous flow of water enters the north flume, filling the south end of that flume approximately two inches deep, then flows down the widening flume into the north-end pool of 7000 gallon capacity, which serves as a second reservoir in this system. Water is pumped from the pool to serve as the supply for the flume. A columnar structure of height approximately 20 ft. made of a lattice work of half-inch square stainless steel serves as a tower in the north-end pool. Water is discharged from the top of the tower through vertically upward facing nozzles, which falls into the pool in the summer and leads to large ice structures in the winter months.

By spring of 1997, there are plans to place 3 ft square concrete slabs around the entire inner perimeter of the north-end pool, with jet nozzles in the centers of 24 of these slabs. This requires the addition of 24 more pilot-controlled valves and a new pump system to supply high-pressure water to the nozzles.

Beneath the two water loops, in the basement laboratory, sometimes referred to as “the tunnel” or “the dungeon”, is the control room for the fountain. This is indicated with the dashed lines, extending from the area under the middle third of the north-end pool, south through what is labeled the control room, then continuing further south under the Maquina and its pool. The underground passageway is seen to continue further south, but this ties only into to the underground steam tunnels serving the entire campus heating system. This does not provide entry into the tunnel control room. Our only entry into this control room is via a 700 lb. man-hole lid lifted from the sidewalk above the control room with a special piece of equipment designed for just this purpose. This entry gives the students a real feel for a process-control plant underground-services facility.

In the control room there are two 20 hp main pumps and two 5 hp auxiliary pumps. Soon after completion of the main construction of this project in the fall of 1994, Allen-Bradley Corporation presented us a gift of a PLC controller to control a variety of signals in the structure. This PLC has been interfaced to the electrically controlled valves through solid-state relays. More than 32 valves within the Maquina control the flow of water supplied to a variety of nozzles. Air supplied to the three pneumatically controlled weirs in the south flume is likewise controlled by electrically actuated valves which are in turn controlled by the PLC. Similarly, there are several valves that are under PLC control for the north-end pool. The water depths in both the north-end and south-end pools are automatically controlled. The PLC is also used to control grounds lighting.

The PLC can sense wind speed based on an anemometer placed on the roof of an adjacent building. At the time of the preparation of this document, temperature sensors are being installed that will be used in making sure no damage takes place as ice displays are created. An additional consideration is the safety of the walkways in the winter months. The ice-making sprays must be shut off when the wind exceeds approximately seven miles per hour to prevent water spray from creating ice deposits on the sidewalks. Another external input array, sensed by the PLC, are photo-optical switches mounted on five bollards that visitors activate as they walk by, viewing the fountain. These are intended to provide a variety of special water displays or sound effects. This "push-button" input allows interested parties to casually control aspects of the fountain display.

The PLC is mounted in the south-west corner of the underground control room, near the entry man-hole. This room is supplied with city water (70 to 90 psi) through a 1-1/2 inch supply; with campus compressed air at 90 psi through a 1-1/4 inch supply; and 10 psi saturated steam through a 1-1/4 inch line, primarily for heating the control room. When one considers that a combination of water, air and a little steam vented into cold air can result in man-made winter effects, including snow, steam and ice formation, it is easy to imagine why students get excited about the possibilities.

There are really two aspects to the fountain control system as shown in Figure 3. The first one is the control and monitoring of the fountain hardware itself. This includes the various valves, motors, and switches that are part of the fountain structure. This portion of the system is controlled through the PLC. The PLC can be programmed over the Ethernet using a DOS program developed by Allen-Bradley. This program allows ladder logic programs to be written and stored on the PC and then downloaded to the PLC. The second aspect of the system is the multimedia APTIVA PC equipped with a sound card and CD-ROM drive that students can develop various programs to enhance and augment the basic operation of the fountain. This PC is located in the front of the Engineering Hall in a glass room so fountain activities can be directly observed by the programmer. LabVIEW, because of its availability and relative ease of programming, has become the primary software package that students use for their projects. There are two main interfaces currently in use on the system. A serial fiber optic link between the PC and the PLC allows students (via a third party software package) to control and monitor PLC inputs and outputs from within the LabVIEW program on the PC. The other interface is the analog output from the PC's sound card, through which the fountain mall can be bathed in audio. In the penthouse at the top of Engineering Hall, just to the south of the fountain are three 400 Watt audio amplifiers, driving four 24 inch loud speakers and two speaker systems dedicated to the mid and high frequency end. This audio equipment is positioned in a large (30 ft wide, 200 ft long, 15 ft high) empty, concrete-walled air intake plenum that serves as a tremendous bass reflex chamber. This audio system provides sound that can flood the entire Engineering Campus Mall area. This audio is under control of the APTIVA computer and associated audio mixers.

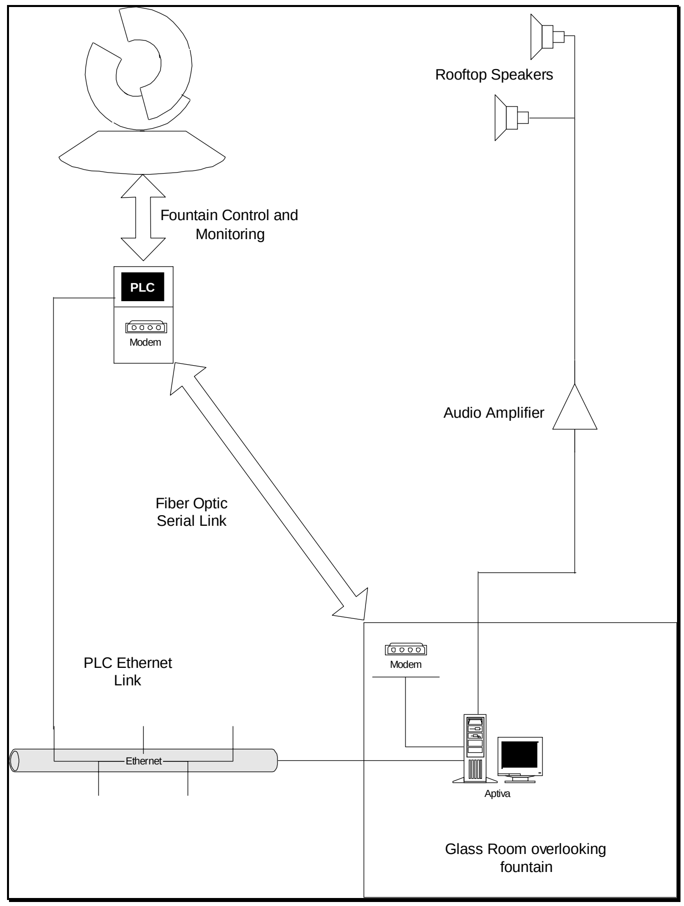

Figure 3 PLC/ APTIVA Configuration

A cross section of students have been invited to incorporate the above facilities into a hands-on, on-line, real-time control laboratory. The response has been rewarding. This has served many students to date, and we expect many more in the future. Serving these students as instructors places a great demand on professors, shop managers and the College resources This has lead to significant rewards for the students. Many have indicated that having been involved with this laboratory having opened the door for them in securing an entry level professional position that they desired.

Student Activities To Date

During the fall of 1994, students were asked to make proposals regarding how they might carry out a project to present a dynamic show centered on the fountain for the Colleges 1995 Engineering Exposition, an event that takes place every second year. The Society of Hispanic Professional Engineers won this competition, having prepared a proposal involving design and installation of the above mentioned audio system, the purchase and inclusion of the personal computer into the system, extensive programming of the PLC and APTIVA, as well as bringing in a professional dance group. This formed a centerpiece for those attending the Engineering EXPO and provided an enlightening program dealing with Mexican history and heritage. These Hispanic engineers were essentially in an independent study program, thus received credit for their very significant contribution to the fountain system.

Professor Marleau has been offering the course ECE 468 , Digital Computer Projects in Control and Instrumentation since 1971. This course has always stressed hands-on, on-line, real-time application of computers. In recent semesters many of the students in this course have chosen the fountain as their project. There are also a number of students taking ECE 699, Independent Study, involved with the fountain. During both the summers of 1995 and 1996, Professor Marleau led SURE (Summer Undergraduate Research Experiment) students, one in ‘95 and two in '96, putting in eight hours per day for the entire 8 weeks of summer school working on mall project implementation. These summer efforts have centered primarily on the programming of the computer control of the fountain. These students have had to learn the PLC programming, and LabVIEW independently. These three SURE students have all made significant contributions to the fountain operation, and all have indicated that their summer efforts have significantly contributed to their academic/professional life. These students tend to leave their signatures on the fountain. In the summer of 1995 one student used the computer time program to play the preamble to the Westminister Chime theme prior to every hour. On the hour he played the appropriate number of gongs and sent a 30 ft jet of water vertically upward with each gong. He had to take care to slow the audio presentation, in that the pilot-controlled irrigation valves used on the fountain are relatively slow responding.

Similarly, the students in 468 or 699 must familiarize themselves with the computer programming involved which is not often covered in classes. This does not tend to be dealt out in routine classroom presentations. When the students are first alerted to the opportunity to work on the fountain, they tend to be very eager. As they learn of the potential scope of the project in which they may be involved, on many occasions a significant anxiety results. They soon realize that they cannot do their thing alone, but must depend on colleagues or skilled tradesmen and technicians to aid them in taking their next step. They have been pleasantly surprised to see that the College is willing to provide such expertise.

Setting up this interactive display has required a great deal of student engineering effort. Programming the PLC requires that the programmer be familiar with the associated ladder logic. The SHPE students suggested that an IBM APTIVA be purchased to communicate with the PLC from a room in Engineering Hall, over-looking the fountain. Such was purchased by the College and installed by the students. Extensive wiring was handled by campus electricians. Further student groups suggested the use of LabVIEW software to provide a user-friendly interface between the APTIVA and the PLC. This required further purchase of third-party software to provide this tie. Mr. Schowalter called on his experience with computer communication to aid the students in various aspects of software development as well as the computer networking.

Current And Future Projects

There are students currently involved in 468 and 699 this semester making definite contributions to the fountain project, but they are also involved in establishing a large project team preparing for Engineering EXPO in the spring of 1997. They plan to provide a more user-friendly and very dynamic interface. They plan to supply music from a variety of sources, directly from CD or tape, from a MIDI music generator system, possibly from a conventional electronic keyboard, or possibly from a "jump-on-the-keys" keyboard as seen in the movie "BIG". Such signals will be sent to a spectrum analyzer breaking the spectrum into the order of 24 bands which would be then supplied to amplifier-speaker systems. Given sufficient power in any given band, this will cause a different combination of water jets to spray in the north-end pool corresponding to a given key being pressed. This hopefully will stimulate further user interaction.

The students are also planning to have a touch-screen input provide fountain control. They are further planning to present a “live” video camera image of the fountain to the Internet, thus allowing viewers from around the world to view the fountain action. They also indicate that they will invite such viewers to modify fountain action from remote locations via the World Wide Web, and take note of the results. This must be approved by a hierarchical decision maker to make sure that no local user is using the system at the same time. This hierarchical system will also need to decide which local participant really has control of the fountain.

Conclusion

Students involved with various aspects of this Maquina Fountain project benefit in many ways. First is the experience of working on a “real” system. So often, student design experience is limited to a paper design exercise or simply breadboarding a prototype. In this case, students are contributing to an actual working part of the campus landscape. Secondly, after being introduced to the project and keenly stimulated, students soon learn how complex and many-faceted the system is. Many times grandiose project proposals are regularly scaled down during the course of the semester as unforeseen delays and problems start to crop up. While the faculty and staff provide solutions to some of these problems, it is usually up to the students themselves to solve these problems on their own. For some students, the concept of “no one right answer” is sometimes difficult to grasp. Another benefit arises when it becomes obvious to the student how important it is to work together as a part of a tightly integrated team. A given person realizes that they can fill voids in their knowledge and experience by calling on colleagues with special strengths. This is facilitated somewhat by email and a “mall” email list where anyone working on (or even just interested in) technical mall activities can broadcast a message to all list members by simply sending a message to the alias for the group. Also in this environment, the students learn how to interface with a wide variety of highly-skilled tradesmen. Finally, the students learn the value of good documentation. Since most of these projects are built upon past work that has been done by others, students spend a good portion of their time at the beginning of the semester simply learning how the system works. They quickly see that well documented software, cabling and hardware significantly decrease the amount of time needed to understand how a particular part of the system works. They also see how some poorly documented projects do just the opposite. In several cases, students have redone documentation of a past project, just to make things easier for the next person. However this is the exception rather than the norm. Most of the regular University of Wisconsin students take a senior year report writing class. The fountain complex is often the subject of such reports. Although such reports are written, they seldom take a form that well serves the person(s) picking up where they left off.

The faculty and staff involved in the Maquina Fountain project find it to be very demanding of their time and efforts, but we also find great reward in watching the students advance their skills and finesse. Many of the students so involved have mentioned to us that they felt the fountain project experience is what interested interviewers and resulted in job offers. We see this fountain project continuing, drawing interested students for many years to come. Our concern is that only a few faculty have shown interest in supporting this project and the learning environment that it creates. It is clear that we will have to broaden the faculty base in order to support the growing number of students who wish to participate.

1. Innovations in Improving Undergraduate Engineering Education, Michael L Corradini, Proceedings of the 58th Annual American Society of Engineering North Midwest Section Meeting, 3-5 October 1996, North Dakota State University, Fargo North Dakota.

Dr. Richard Marleau, P.E. has dedicated much of his professional life to courses and projects centered on real application of computers in support of real-time on-line control and instrumentation in both his regular course dedicated to such efforts and many independent study programs. The topic of this paper has involved over 25 students so involved.

Jeffrey Schowalter is a Faculty Associate in the Department of Electrical and Computer Engineering. His current responsibilities include the supervision of several undergraduate laboratories. His previous experience includes engineering positions at McDonnell Douglas Space Systems Company and as an active duty officer in the United States Air Force.

John Bollinger is Dean of the College of Engineering, a consultant and a director of several corporations. His academic work is in the field of automatic controls, computer control of machines and processes and the design of automation machinery.