2006-600: THE GAME OF LIFE WORKSHOP - REACHING OUT TO HIGH SCHOOL STUDENTS WITH DISABILITIES

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The *Game of Life* Workshop - Reaching Out To High School Students With Disabilities

Abstract

Since engineers and computer scientists build tools and provide solutions for diverse audiences, those who practice engineering should represent a diverse population. Among the several underrepresented groups in engineering and computer science are people with disabilities. Furthermore, people with disabilities pursue post-secondary education at a lower rate than their non-disabled peers. The combination of these factors suggest the importance of outreach efforts to help students with disabilities transition to and succeed in college and careers related to engineering and computer science.

This paper describes a week-long workshop related to computer science that is part of a one-week-long summer session of a multiple-year program for high school students with disabilities. The program and specific workshop have been offered every summer since 1994. The overall goal of the computer science workshop is to build confidence in the students as they create and build successful programs to solve specific problems. We evaluate the program by answering the questions: Can high school students with disabilities, and with little or no programming experience, be successful innovators and implementers of a week-long programming project? *and* How does workshop participation impact students' futures and confidence? We demonstrate success of the computer science workshop by providing examples of students' projects, a report from one workshop participant who is currently enrolled in college and a co-author of this paper, and data collected from participants over time.

The computer science workshop focuses on programming cellular automata, in the form of the Game of Life. Most workshop participants had no prior programming experience, yet many have used computers and assistive technologies. The Game of Life platform is appropriate for a program like this for several reasons: *(i)* it is not a typical introduction to programming, so even students who have programmed before learn something new, *(ii)* few actions need to be programmed but the reasoning can be challenging, *(iii)* the platform can be used for diverse projects related to games, simulations, graphics, and image processing.

In addition to describing the structure of the programming projects, the paper addresses several key aspects for making the workshop a success. First, the ratio of staff to students is one-to-one, giving each student direct access to a mentor and guide. Second, the Game of Life platform is flexible enough to provide every student the opportunity to work on a self-directed project. In the past, students have completed projects related to cellular automata theory, predator-prey games, image processing, and creating tactile maps for blind students. Letting students set their own course gives them ownership in their projects while relieving competition among students. Finally, students present their work to their peers and families during the final day of the workshop which provides external motivation for completing projects.

This paper serves to disseminate the workshop model and key properties to other colleges and universities so that engineering and computer science may attract a more diverse population. We

provide evidence regarding the success of the workshop through students' work, a case study, and analysis of program evaluation data.

1. Introduction

Engineers and computer scientists build products for use by a diverse population; therefore, it is sensible and necessary that engineers form a diverse population. Unfortunately, the demographics of US students earning engineering degrees and those practicing as professional engineers do not reflect the US population[1]. Among the underrepresented groups are women, Black men and women, Hispanic men and women, Native American men and women, and men and women with disabilities. The focus of this paper is an outreach program to encourage high school students with disabilities to pursue post-secondary education and consider careers in science, math, technology, and engineering. In addition to providing an overview of the outreach program, the paper provides answers to the following questions: Can high school students with disabilities be successful innovators and implementers of a week-long programming project? *and* How does participation in the summer workshop impact students' futures and confidence?

DO-IT (Disabilities, Opportunities, Internetworking, and Technology) is a collaboration of the College of Engineering and Computer Science, the College of Education, and Computing and Communications at the University of Washington. This Center undertakes a variety of activities that lead to college and career success for people with disabilities. One of these programs is called the DO-IT Scholars program. DO-IT Scholars are high school students who want to pursue postsecondary studies and careers but face significant challenges due to their disabilities. The program has three key components: (a) residential Summer Study on the university campus, (b) year-round computer and Internet activities, and c) work-based learning.

While participating in the program, DO-IT Scholars develop social, academic, and career skills in preparation for postsecondary studies and careers. A goal of the program is for Scholars to lead self-determined lives. Since the inception of the DO-IT Scholars program in 1992, more than 250 students with a variety of disabilities have successfully transitioned from secondary schools to postsecondary education and employment settings.

The following sections of this paper describe in more detail the DO-IT Scholars Program and evidence of its efficacy, followed by a description of the DO-IT Summer Study and the Game of Life workshop to introduce students to computer programming. We also offer a summary of data collection and analysis to answer the research questions. Our results showcase the success of the Game of Life Workshop. Finally, we address specific components that are keys to the success of the program so that readers may develop similar outreach programs.

2. DO-IT Scholars Program

2.1 Computers and the Internet

DO-IT Scholars make substantial use of computers, assistive technology, and the Internet. Assistive technology used by scholars includes speech output systems for those who are blind or have disabilities that affect their reading ability, and speech input and alternative keyboards for those who do not have full use of their hands. Hardware and software is loaned to Scholars throughout their participation in the program.

Ongoing online support includes e-mail messages that provide academic, career, and technical information, and lively discussions between peers and mentors about issues that impact college and career success. Mentoring in DO-IT is primarily done in an online group context rather than one-to-one. Although proximity is important to developing peer and mentor networks in most settings, such as in Summer Study activities, online communication has proven to be invaluable in building and sustaining relationships for many years over great distances[2].

2.2 Summer Study

Most DO-IT Scholars attend their first two-week Summer Study session after their sophomore years in high school. They reside in dormitories at the university campus. They meet other Scholars as well as adult mentors while becoming involved in a wide variety of activities to prepare for college, careers, and other aspects of adult life. Activities include participation in lectures, group work, science labs, mock interviews with professors and employers, career exploration on the Internet, electronic communication, résumé writing, and disability services presentations. Scholars expand their skills in Internet and computer use in a computer lab equipped with assistive technology identical to the systems DO-IT provides for their homes.

After their first Summer Study, DO-IT Scholars communicate online with each other and their adult mentors throughout the year. Scholars return for a second Summer Study session the following year. Their session overlaps with the next group of Scholars, so they have a chance to make new friends and expand their network of peer support. It is during this second Summer Study that Scholars participate in small group workshops with a professor as the lead. They have a chance to choose from a variety of topics that have included accessible web design, technical communication, computer science, virtual reality, and the design of accessible parks. One such workshop is called the Game of Life workshop, which introduces students to the art of computer programming.

2.3 Work-based Learning

Scholars have the option of returning for a third-year Summer Study session as interns. The interns help with the coordination of academic and recreational activities. They learn about program operations and how to work effectively with supervisors and co-workers. Scholars also practice disclosing their disabilities as well as negotiating and testing the effectiveness of adaptive computer technology and specific accommodations in job settings. Scholars have reported that their work-based learning experiences through the program proved valuable in preparing them for careers, especially in the areas of clarifying career goals, developing accommodation strategies, gaining work skills, and learning to work as part of a team[3].

2.4 Efficacy of Scholars Program

Transition Interventions for Students with Disabilities National Science Foundation (NSF) projects and other programs for racial/ethnic minorities, women, and people with disabilities have identified promising practices for bringing students from underrepresented groups into STEM fields. Key among these activities are (1) hands-on science experiences in pre-college environments, (2) work-based and research experiences, (3) bridge programs between academic levels, (4) tutoring, and (5) mentoring.[2, 13, 14, 15, 16, 17] Summer camps nationwide have provided young people with opportunities for peer and mentor support, to learn self-advocacy skills, and/or to prepare for college.[19, 20] In addition, programs that offer work experiences give students opportunities to explore their own interests, develop skills, apply computer skills, and learn to work with supervisors and co-workers.[3, 20, 21]

The DO-IT Scholars Program was created based on previous research results as stated in the paragraph above. The longevity of the program for over a decade and its numerous awards provide evidence for the overall success of the program. The DO-IT Scholars Program has won several prestigious awards, including the President's Award of Excellence for Mentoring in Science, Engineering, and Mathematics; an outstanding program award from the Association of Higher Education and Disability (AHEAD); and the National Information Infrastructure Award for exemplary use of the Internet to further education. It has sustained operations for more than a decade. It was initially funded by the National Science Foundation (NSF) as an experimental program to increase participation by students with disabilities in higher education programs and careers in science, engineering, mathematics, and technology. After the initial six years the state continued to fund ongoing efforts with residents and increased the scope of the program to include other challenging academic and career fields, such as business.

The success of the DO-IT Scholars Program is illustrated by number of articles in magazines and newsletters, the total number of Scholars served, and its ability to attract funding. For example, over 80 articles have been written by authors who are not DO-IT staff members. [22, 23, 24] More than 270 Scholars with a wide range of disabilities have transitioned successfully from secondary schools to postsecondary schools and employment. The government has supported the program with financial resources and corporate and private sources continue to provide money.

The success and key principles for success of the DO-IT program are highlighted by the research results in the following sections, which illustrate perspectives of the Scholars, parents, and mentors.

2.4.1 Scholars' Perceptions

Retrospective Survey: In a study[25] undertaken to assess former Scholars' reflections on the value of DO-IT participation, computer and Internet support were perceived as the most valuable activities, benefiting them through improving academic, social, and career skills. Former Scholars reported growth in the following specific areas as a result of their participation in DO-IT, listed here in descending order:

1. Preparation for college
2. Internet skills
3. Preparation for employment
4. Self-advocacy skills
5. Computer skills

6. Independence
7. Perceived career options
8. Social skills
9. Self-esteem
10. Perseverance

A follow-up study compared the perceived benefits of DO-IT Scholars with initial interest/aptitude to those without the initial interest/aptitude in STEM. For example, participants not initially interested in STEM valued social life to a greater extent than those interested in STEM and the STEM group expressed more interest in technology-related activities. Non-STEM participants consistently rated themselves higher in self-advocacy skills and perceived that program participation improved their social skills more than did STEM participants.[28]

Focus Groups: Focus groups also provide perspectives of Scholars. Scholars participating in focus groups and follow-up surveys on focus group questions reported positive aspects of email—being able to stay close to friends and family; to communicate with many people at one time; to get answers to questions; to meet people from around the world; to communicate quickly, easily, conveniently, and inexpensively; to allow people with speech impairments, deafness, mobility impairments, and other disabilities to communicate independently; and to make a disability a private matter while communicating with others.[2] Scholars who had difficulty accessing printed materials as a result of disabilities reported that the Internet provided a way for them to independently access information. All high school participants predicted that Internet access would contribute to their college and career success.

Email Messages: The analysis of the content of more than 10,000 email messages exchanged between DO-IT Scholars and adult mentors[2] revealed that peer-peer and mentor-protégé relationships sustained on the Internet provide participants with psychosocial, academic, and career support. However, the content of peer-peer messages are more personal in nature and a higher percentage of messages between mentors and protégés than between peers related to academics, careers, disabilities, technical issues, program activities, and college transition.

Survey of Scholars: Scholars responding to a survey expressed high interest, activity, and enjoyment in using their computers and email and in communicating with DO-IT mentors and Scholars. Respondents reported a high level of email use and their expectation that access to the Internet would contribute to college and career success. Ninety percent of the Scholars reported that they enjoyed communicating with other Scholars, and 80% indicated that they enjoyed communicating with mentors.[2] Respondents suggested that DO-IT mentors are valuable resources for furthering their academic and career interests. Regarding mentor contacts, 66% said they felt better prepared to make the transition from high school to college, 33% reported that contact with mentors helped them believe they could achieve a lot in spite of their disabilities, 77% said contact with DO-IT mentors stimulated their interests in science, technology, engineering and mathematics fields, and 66% reported having learned more about different careers in science as a result of email exchange with mentors.

Survey of DO-IT Scholar Interns: In a survey, participants reported considerable benefit from their work-based learning experiences. They gained motivation to work toward a career, learned about careers and the workplace, gained job-related skills, learned to work with supervisors and co-workers, and developed accommodation strategies.[3, 26]

2.4.2 Parents' Perspectives

Survey: When parents were asked to what degree DO-IT enhanced their children's lives, the items ranked in order, beginning with the highest, are: (1) interest in college, (2) perception of career options, (3) self-esteem, (4) self-advocacy skills.[27] They reported that DO-IT participation helped their children develop social, academic, and career/employment skills. One parent summarized: "My son was able to realize that many other students had to struggle through school. DO-IT camps allowed students to bond and the computer networking allowed them to continue to support each other through the year. He did not dwell much on the future until he attended a DO-IT camp. He came home talking about his college plans, with confidence that he could manage it. DO-IT has also helped my son get a part-time job for his first year of college. He has achieved a level of independence we never thought possible." [27]

2.4.3 Mentors' Perspectives

Survey: Results from a survey distributed to DO-IT mentors indicate that mentors discussed a wide variety of topics with Scholars, including academic and career fields in science engineering, mathematics and technology; college issues; disability-related issues; careers; computers; adaptive technology; and the Internet. Mentors reported that they felt satisfied knowing they could be of assistance to Scholars and enjoyed the mentoring relationship.[2]

3. DO-IT Summer Study and the Game of Life Workshop

3.1 Objectives

The ultimate goal of the DO-IT Scholars program is to increase the success of people with disabilities in postsecondary education and careers. To reach this goal, the program undertakes activities to increase independence, self-confidence, and self-determination. Program staff members provide assistive technology that gives Scholars access to computers and the Internet and trains Scholars in how to use technology. For example, students who are blind receive text-to-speech technology that reads aloud text that appears on a computer screen. Students use technology to complete school work, research, and correspond via e-mail more effectively and efficiently. Furthermore, living in the dorms and taking part in the various organized activities allows the participants to learn what tools they might need to participate more fully in non-academic life. The program also offers workshops on how to ask for accommodations in school and in the workplace and how to prepare for a job interview. A large network of mentors, both with disabilities and without, is also available to the Scholars to answer questions about college and career life. Finally, through the planned outings and activities social skills are advanced, and self-confidence is built. The ultimate goal of the program is for Scholars to use their new found independence and self-confidence to pursue college educations and challenging careers.

3.2 Summer Study Schedule

These goals are achieved through a highly structured schedule which spans two weeks for first-year Scholars and one week for second-year Scholars. During the week, Scholars attend classes, workshops, and keynote speeches, and on the weekends they take part in field trips to places such as the zoo, the science center, and the aquarium. Second-year Scholars attend small group workshops (ex: The Game of Life) every morning. In these workshops they develop a project under the guidance of an expert in that field. After lunch they attend classes about using technology, building resumes and interviewing skills, improving study skills, being successful in college, and introducing a career field such as bioengineering or social work. In the evenings Scholars play games and socialize, sometimes at organized activities such as karaoke, tie-dying, and dances. The summer program culminates at a public closing ceremony in which the second year Scholars present their workshop projects to peers and family members.

3.3 Game of Life Workshop

3.3.1 Objectives

The Game of Life Workshop has been held every summer since 1994. The goals of the workshop have remained the same since the first offering. The first goal is to introduce Scholars to some basic computational concepts that can be applied immediately to solve problems. The vast majority of high school students who have participated in the workshop have had little or no programming instruction. Hence, a brief introduction to programming is given before the Scholars move forward to solving problems. The second goal of the workshop is to build the Scholars' confidence by actually solving interesting problems and showing what they have accomplished to their peers, friends, and family at the closing ceremony.

3.3.2 History of the Workshop

The original title of the workshop was "The Game of Life and Parallel Computing". At the time, the Department of Computer Science and Engineering had a 1,024 processor parallel computer called the Maspar. The processors were arranged in a 32×32 grid with wrap-around. The Maspar system supported a C-like language, MPL. For example, a single integer variable X can represent a 32×32 gray scale image. The single instruction X = W.X shifts the image to the right (east). More generally, a single integer variable X can represent the state of a 32×32 two-dimensional cellular automaton.[4,5] Very simple conditional statements can represent the transition function of the cellular automaton. The Game of Life, invented by mathematician John Conway, and popularized by *Scientific American* writer Martin Gardner[6], can be defined in MPL as follows.

```
// counts how many neighbors are alive (X=1 for alive, X=0 for dead)
AliveNeighbors = N.X + NE.X + E.X + SE.X + S.X + SW.X + W.X + NW.X;
// if there are too few or too many live neighbors then cell dies
if (AliveNeighbors < 2 || alive > 3) {X = 0;}
// exactly three live neighbors gives birth
else if (AliveNeighbors == 3) {X = 1;}
//exactly two live neighbors yields no change
```

A graphical user interface displayed arrays of colors that represented the state of the 32 × 32 grid. The beauty of this approach was that there was no need to define arrays and there were no loops to control processing through the array. The MPL rules looked like cellular automata rules.

In the first two years we had just two or three Scholars attending the workshop and we employed an undergraduate student as an assistant. The projects were somewhat limited due to the grid size. Over the years, the implementation moved to the C programming language and then to Java. The workshop title changed to "The Game of Life and Image Processing". The updated infrastructure supported more Scholars and we moved to a one-to-one staffing model, utilizing undergraduate and graduate students to assist the Scholars.

In 2002, Stephan Wolfram published his book *A New Kind of Science*[7,8] that touted the importance of the cellular automaton in general science. The book describes several interesting problems Scholars can tackle. For example, a two-state, one-dimensional cellular automata can be defined using an 8 bit binary number. For example the rule 90 is defined by Figure 1:[9]

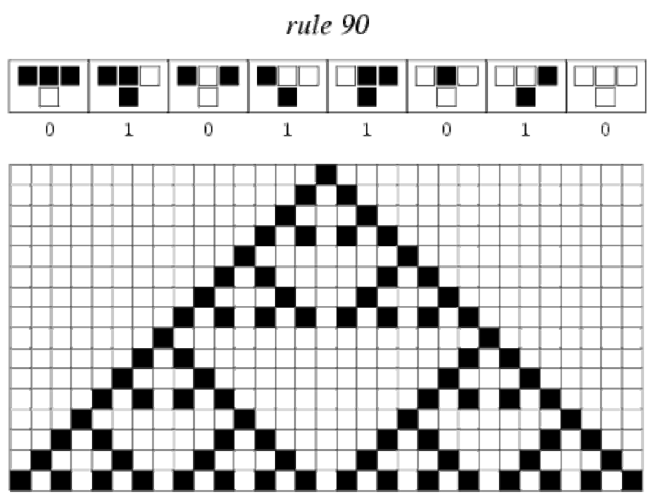

Figure 1: Rule 90 from Wolfram's book, *A New Kind of Science*. The rule determines the state of the cell in the next generation. The bottom half of the figure shows the resulting configuration from applying the rule 15 times (or 15 generations).

In recent years, we have taken small research problems and had Scholars tackle them. For example, one of our research problems is classifying images of proteins as to whether the protein solidifies to be a crystal. Scholars developed strategies to enhance the image to improve classification accuracy. A second research problem involves automatically creating tactile maps to assist blind students. Scholars created programs to simplify map images so they could be transformed to Braille. The cellular automaton approach provides a rich environment for solving computational research problems.

3.3.3 Workshop Format

The workshop spans five days, usually from 9 AM until noon. The workshop is held in a computer lab, with one Scholar per workstation. The stations are far enough apart to allow the

Scholar and the assistant to sit next to each other. Each Scholar is given an electronic folder containing the complete Game of Life program. On the first day, the instructor gives a half-hour lecture on some Java basics and demonstrates the Game of Life program. He/she then gives all the Scholars the same problem: shift the entire image to the right by one cell. The solution is a one line program, which most Scholars succeed in finishing within a short time. For many Scholars it is exciting to see images change at their commands. It seems so simple, but for someone who has never programmed before, the power of programming becomes immediate. On the first day, Scholars tackle the same set of problems, but they solve them at their own paces. During that first day the instructor circulates to see how Scholars are doing and to assess their interests and capabilities. After the Scholars leave, the instructor meets with the assistants to discuss the assignment of week-long projects to each Scholar.

On the second day Scholars are given their problem for the rest of the week. Each Scholar, with the help of his or her assistant, has ownership of the problem and its solution. In some cases, Scholars work as a team to tackle a common problem. A solution is cellular automata "behavior" defined by a Java method. As one would expect from novice programmers, it is often the case that there are both syntax errors and logical errors in their programs. The assistant is helpful to the Scholar in deciphering the compiler error messages. We do not expect Scholars to understand Java syntax in a few days, so they are not left alone to suffer. Logical errors are another matter. When a new behavior does not perform as expected, the Scholar and the assistant engage in a discussion with the goal of leading the Scholar to discovering a correct solution.

On days three and four Scholars continue with their projects. At the end of each day of Summer Study they share their progress and working solutions with their peers. In most cases seeing what others have been doing inspires the students to do more on their own projects. On the final day Scholars prepare for the closing ceremony presentation. Each Scholar chooses two to three of their solutions (programs) to demonstrate. These behaviors are installed in a single demo program, so the menu of behaviors includes programs from all Scholars. One Scholar serves as a master of ceremonies to introduce the workshop and other Scholars at the final ceremony. The Scholars rehearse the presentation to perfect what they will say and figure out the timing. The final ceremony is held in the afternoon of the final day. In about 15 minutes, other students, family, and friends learn about the Game of Life workshop and the programs created by the Scholars.

3.3.4 Game of Life User Interface

The current version of the Game of Life platform is shown in Figure 2. The program infrastructure allows Scholars to write classes to define new behaviors. These behaviors then appear on the behavior menu. Different grid sizes from 16 × 16 to 512 × 512 cells can be chosen. When the grid size is large, the grid lines dominate the image. Using another menu the grid lines can be removed. Each cell is capable of holding 101 different colors. By selecting a color from a slider, the cursor is activated with that color. Clicking on a cell turns the cell the color of the cursor. The value 0 is reserved for black, and the value 100 for white. There is a second slider for the "level" color. The level is useful for various tasks. For example, it can be used to solve the problem of erasing lettering from an image if the lettering is of a specific color.

There are three indicators in the game of life: the row and column coordinates and color of the cell under the cursor. There are menu options to save an image that has been created, to load a previously saved image, and to load and existing JPEG or GIF image.

Once a behavior is chosen, the program can be run in slow, normal, or fast mode. Clear and reset buttons allow the user to either start with a clean slate or start from the last time the behavior was started.

In our experience the user interface can be learned in just a few minutes by any student who has had experience with common applications like e-mail, Microsoft Word, and Paint.

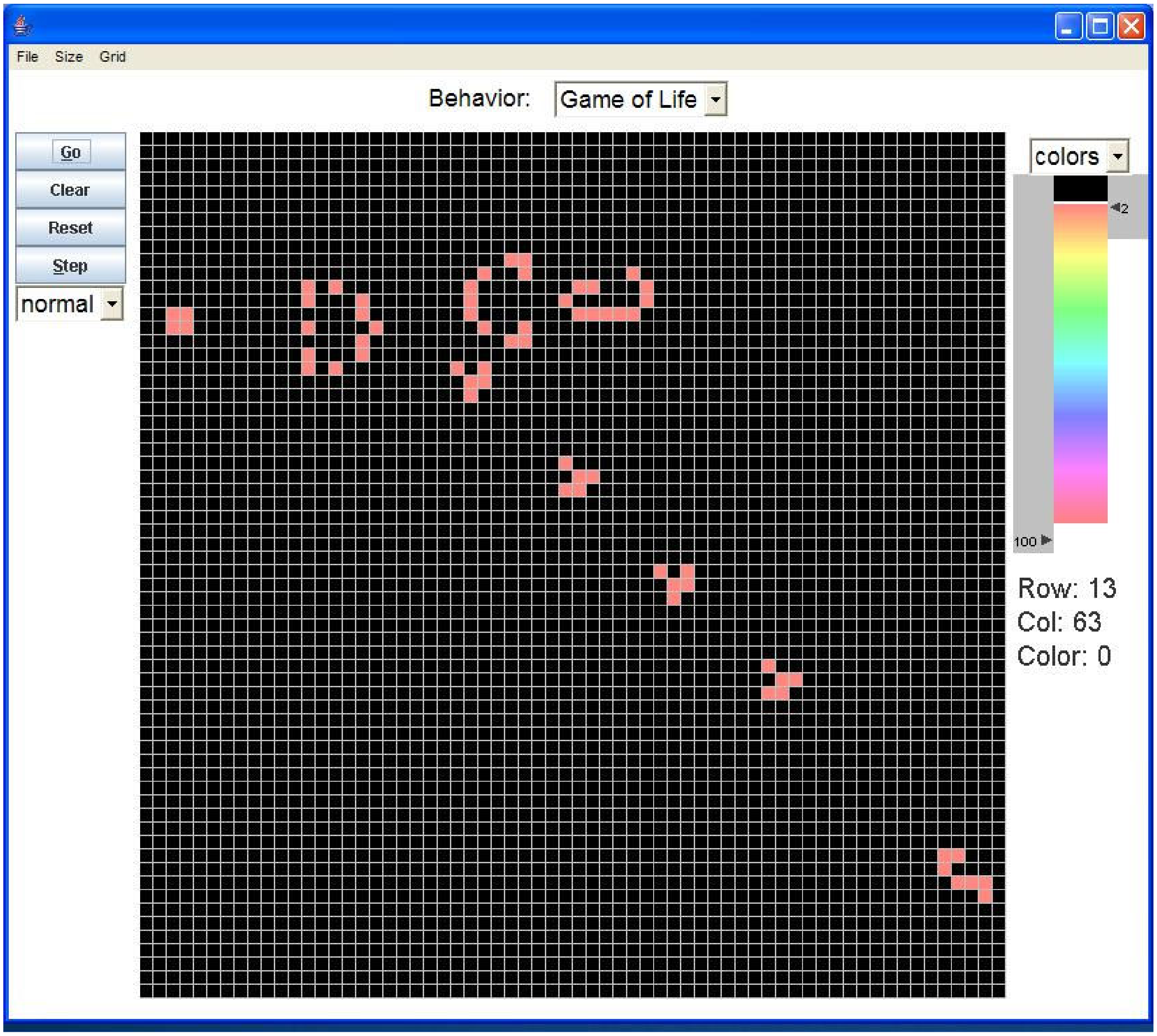

Figure 2: Game of Life User Interface

3.3.5 Project Examples

Each project is actually posed as a problem to solve. We do not disclose the solutions to these problems, but every one of them was solved by at least one Scholar. Scholars have access to a resource library of books in addition to the ample resources available on the Internet when forming solutions to problems.

- Game of Life Configurations: Martin Gardner describes several configurations, such as the glider, glider gun, and glider eater. The behavior determines the motion of "gliders" on the screen.
- Game of Life with Aging: In the basic Game of Life there are only two colors: 0 (black) for dead and 1 (orange) for alive. Create a game of life with aging. If a cell persists as alive, then its color value increases.
- Shadow: Write your name by creating white cells. Create a behavior that places a shadow of a specific color so that the letter appears to have 3-dimensional depth. A variant is to use the level to select the shadow color.
- Fill: Create a black area with a white boundary. Choose a cursor color and click in the black area. Create a behavior that fills the enclosed area with the cursor color.
- Power Fill: Again create a black area with a white boundary. Choose a cursor color and click in the black area. Do that again with a second cursor color. Fill the area enclosed by the white boundary by having one color dominate.
- Connected Components: Create several black areas with white boundaries. Create a behavior that automatically fills the areas with different colors, one color per enclosed area. This can be quite challenging, but by introducing the student to a hash function, then a version of power fill can do the job.
- Image Reversal: Create a behavior to reverse the gray level of an image so that, for example, gray level 20 become gray level 81. Although this is relatively simple, it is a good starter problem for image processing.
- Fade Out: Create a behavior that after repeated steps fades a gray scale image to a solid gray image.
- Edge Detection: Create a behavior that finds the edges in a gray scale image and makes them white. Student can use the level to make adjustments to the edge detector.
- Threshold: Create a behavior that changes a gray scale image to black and white by choosing a level (threshold) where cells above the threshold are white and below are black.
- Dithering: Students will discover that using a threshold does not yield a very good effect. Introduce the concept of 2×2 dithering, where one of 0, 1, 2, 3, or 4 cells of a 2×2 grid are black and the others white. These patterns essentially define 5 levels of gray. The problem is to dither an entire image. This can be expanded to 3×3 or 4×4 dithering. Students can discover what kind of dithering works best on their images.
- Firing Squad Problem[10]: The firing squad problem is a classic problem in one-dimensional cellular automata. A general stands at one end of a line of officers. Each officer can communicate left and right. All officers start in the same state with the general in a different state. Design a cellular automaton so that after some time all officers end up in the same state, the firing state. There is a classical solution, called the "Signal Solution" that goes back to 1962 by Moore[11]. The Signal Solution takes 3N steps for N

officers. There is a more modern solution by Mazoyer[10] that takes 2N steps. Students are not expected to come up with these solutions themselves, but to look them up on the Internet and translate what they find to a behavior in Java. This is not as straightforward as it appears because the solutions found on the Internet are rather cryptic.

- Self-reproducing Automata: Construct small two-dimensional cellular automata that exactly reproduce themselves. Modern very small solutions with 6 and 8 states can be executed in a reasonable amount of time.
- *A New Kind of Science* Designs: Wolfram's book, *A New Kind of Science*[7,8], is full of hundreds of cellular automata that can be made into interesting behaviors. As mentioned earlier, to actually program a behavior it takes an understanding of Wolfram's numbering system for two state automata. There are many beautiful designs that can be created from very simple rules.
- Tactile Maps: One of the more interesting projects in recent years is taking color maps of the university campus and processing them for printing on an embosser so that they can used by blind students and visitors to the campus. This is actually a very large research project, but pieces of it were done in the Game of Life workshop. Types of processing that had to be done include replacing one color by black or white, replacing one color by its background color, and finding edges to make them black. In the end, black cells are raised dots, while white is not.
- Protein Crystal Enhancement: In one of our research projects we classify images as to whether they have protein crystals in them. Students were given the problem of finding ways to enhance the images to make the crystals more recognizable. Actual images from the research project were used.
- Various Games: Some students have been interested in creating games. One successful game implements the behavior of spreading the scent of food around obstacles with another behavior used by a creature to search for the food by following the scent. This game used a random number generator to randomly search until the scent was located. In another variant the food was a large blob at which the creature ate away. When the creature was not eating, it would randomly search for the blob.

4. Evaluation

In addition to creating and supporting the DO-IT outreach program, the authors investigated the following questions: (1) Can high school students with disabilities, and with little or no programming experience, be successful innovators and implementers of a week-long programming project? *and* (2) How does workshop participation impact students' futures and confidence?

The data used to answer our questions includes students' programs and slides from final presentations from each summer's Game of Life workshop. In addition to the artifacts produced by Scholars, we have tracked 48 participants in the Game of Life workshop in terms of high school graduation rates, college/university attendance, and college/university graduation rates. Finally, one of the authors of this paper provided insight into her experiences as a Game of Life Scholar and Summer Study Scholar through an interview.

5. Workshop Evaluation Results

5.1 Scholars' Projects

During the process of leading the Game of Life workshop, two of the authors have observed that *every* Scholar successfully completed a week-long programming project. *Every* Scholar successfully presented to peers, friends, and family the final day of the summer program.

Scholars completed the problems described in Section 3.3.5, so they were successful innovators of week-long programming projects. Again, Scholars worked with assistants to get the programming language syntax correct, but the ideas and problem-solving strategies were directed by the Scholars. Figures 3 through 7 show artifacts produced by programs created by Scholars during the summer 2004 workshop. As the reader can see from the figures, the projects are quite varied. Appendix A shows the Java class file created by a Scholar to produce the dither behavior shown in Figure 7. As the Java code in Appendix A shows, Scholars made use of variables, arithmetic, and conditionals. Because the infrastructure uses cellular automata, loops and arrays are not necessary.

The following excerpt from an article shares Scholars' experiences from the 2004 Game of Life workshop. It provides an overview of the workshop projects[12] from the perspective of the Scholars and was published in a DO-IT News newsletter.

> "As frequently as we all use computers, rarely do we realize the complex problem-solving skills necessary to create the programs. In August 2004, we touched the surface of such programming in the "Game of Life" Summer Study workshop. Instructed by Professor Richard Ladner, several undergraduate and graduate assistants, and a DO-IT intern, Scott, we worked on separate projects for a week that demonstrated a few of the different uses for computer programming.
>
> Scott created several "hunter and prey" and "maze" games. He had to work through the difficulties of "debugging," or finding errors in the program code, and use logic to create the appropriate behavior for the characters of his games.
>
> Creating programs for an entirely different use, Scholars Tasha and Jamie developed maps of the University of Washington campus for blind students and visitors. They had to first simplify the visual maps through image processing and then add Braille text to the resulting images. These maps were printed on a tactile printer that has the ability to punch bumps into paper.
>
> Annemarie used image processing for a slightly different application. She configured gray-scale images into black-and-white images using a process called dithering, which is like pointillist art. Additionally, she applied sharpening programs, edge detections, and background filters to find crystallized proteins automatically from images.

Jessie worked with Stephen Wolfram's *A New Kind of Science* as a basis for using more classical programs. Several of these resulted in complex and beautiful patterns and shapes.

The workshop revealed the wonders of computer programming as well as the frustrations. All of us experienced many instances of satisfaction, but they were all preceded by diligence and intense problem solving."

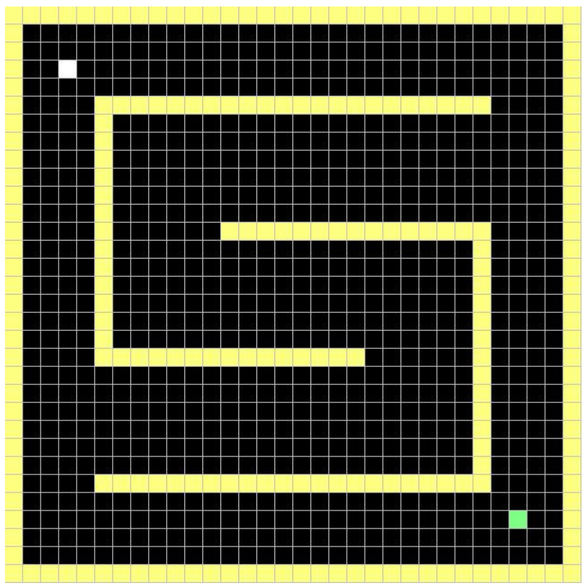

Figure 3: Screen shot of predator-prey game behavior implemented by a Scholar.

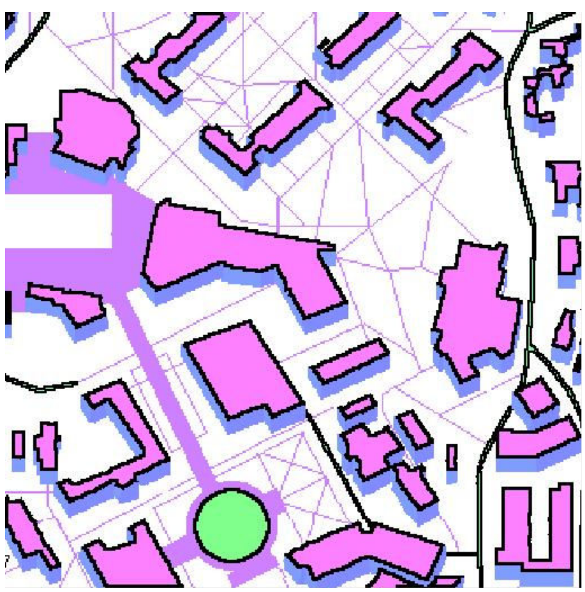

Figure 4: Image of the university campus produced by color filling behavior implemented by a Scholar. The image was used to create a tactile map which helps blind students and visitors navigate the university campus.

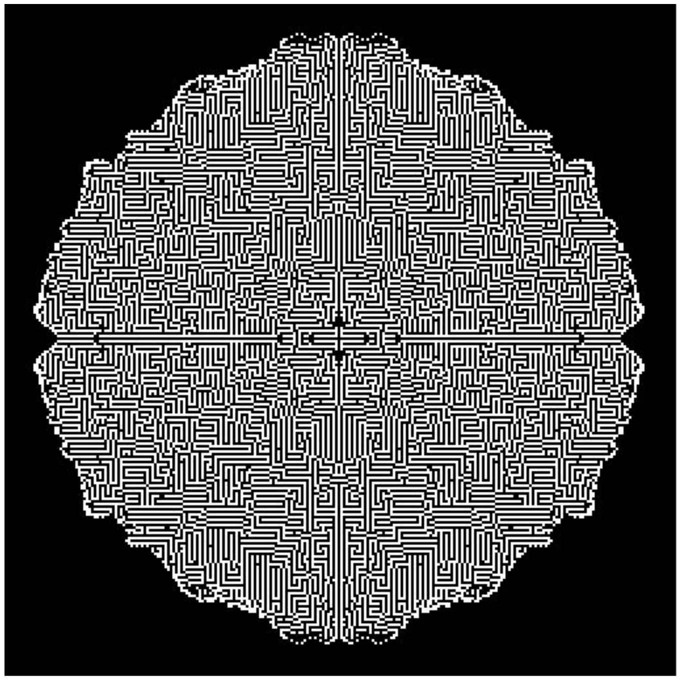

Figure 5: Image produced by Game of Life behavior implemented by a Scholar.

Figure 6: Image produced by edge detection behavior implemented by a Scholar.

Figure 7: Image resulting from a 4x4 dither behavior implemented by a Scholar.

5.2 College Enrollment and Graduation Data of Workshop Participants

48 Scholars participated in the Game of Life workshop between the years 1996 and 2005. Table 1 lists the number of Scholars who participated in the workshop per year. Of the 48 Scholars, 15 were females and 33 were males. 45 of 48 Scholars have graduated from high school while 3 Scholars are planning to graduate in 2006. Table 2 shows information regarding college attendance and graduation. As the table indicates, most Scholars attended college or are currently attending college. Of those who are in or who have graduated from college, 6 Scholars are/were Computer Science majors. 18 Scholars studied or are currently studying a major in science, math, or engineering while 18 Scholars studied or are currently studying in a major outside those fields. We do not have major information for 7 Scholars. Four Scholars went on to graduate school, one in each of the following disciplines: Computer Science, Physics, Political Theory, and Law.

Table 1: Number of Game of Life Workshop Scholars Per Year

Year	# of Scholars
1996	4
1997	6
1998	4
1999	5
2000	5
2001	5
2002	4
2003	5
2004	5
2005	5

Table 2: Information regarding college attendance and graduation of the 48 Game of Life (Data from Scholars as of January, 2006)

Description	# of Scholars
Graduated from college	17
Currently in college	26
Did not attend college	1
No data about college	1
In high school	3

5.3 Report from a Workshop Scholar

To provide a glimpse into how the DO-IT Scholars Program and Game of Life Workshop personally impacted one Scholar, we include a report based on an interview with a paper author. The interview was conducted approximately 1.5 years after attendance in the Game of Life summer workshop.

This participant is currently a freshman in college, majoring in Biology with a minor in Spanish. She first attended the DO-IT summer program to learn about the living accommodations she would need while attending college. She had not programmed a computer prior to attending the Game of Life workshop, yet she was comfortable using computers and reported spending about 15 hours using a computer per week. Her career interests before attending the Game of Life workshop included publishing and editing, since writing came naturally to her. She knew technology would be a part of her life in terms of email, word processing, correspondence, but she had no desire "to work in front of a computer all day long". She rated herself as average to a bit higher than average when assessing her confidence in using technology before attending the workshop as compared to her peers. She was also sure that college would be part of her future.

She says, "Overall, my experiences with DO-IT were good, but I found many of the classes and activities were not as useful to me as they could have been. The experiences of living independently in the dorms, managing getting food in the cafeterias, and traveling around campus were the most valuable to me. I also appreciate the networking with mentors with disabilities and companies that offer internships. However, … I don't feel that the academic classes simulated anything near college level classes until we got into our individual workshops (like the Game of Life) in the second year."

This participant was quite surprised at how much she could learn about programming in just a week while attending the Game of Life workshop. She states: "I found the Game of Life Workshop to be intensive and informative. I was very surprised by the results and programs that I was able to create in only a few days, as well as the fact that we were able to start writing programs within the first hour of the workshop. The problem solving was consistently challenging, and thus, kept my interest and curiosity throughout the entire workshop. Completing the programs to achieve the desired effect was extremely satisfying, so I found the entire workshop engaging and enjoyable."

She was attracted to the Game of Life workshop since she thought it would be the most challenging and furthest from anything she had done before. She had few expectations for the workshop and, therefore, she achieved more than she ever expected. She learned how to problem-solve using methods that made her think “backwards”. She also learned about the diverse uses of computers from image processing to creating tactile maps. She worked on image processing projects during the week, which included clarifying images of protein crystals, reducing noise in images, creating edge detectors, writing dithering programs, and writing image sharpeners. Figure 6 is a result of a programs created by this Scholar.

After attending the Game of Life workshop, she felt a little more confident than her peers when it came to using technology. Other impacts of the workshop include her sharing of and continuous use of programs created in the workshop, her confidence as an independent person, her interest in majoring in biology, and her interest in learning more about technology. For this participant, the Game of Life workshop increased her self-confidence and interest in learning about technology.

She continues to use the programs she created. She states: “I have kept my programs for dithering and finding edges so that I can manipulate photos of friends and family, which they always seem to enjoy.”

Her experiences in the summer program helped her realize just how independently she can live. This enabled her to look at schools further away from home. She felt that she became more confident as a problem-solver and as a person working with technology. She even considered a major in Computer Science, but chose Biology instead. She did become more interested in technology, as evidenced by this quote: “I was interested in learning more about technology after attending the workshop. I realized that all of the necessary problem solving involved in the field would keep it from becoming boring. Furthermore, before attending the workshop I had been operating under the delusion that working with technology meant sitting in front of a computer and having little to do working with others. In the problem solving process I realized that this was not at all true.”

5.4 Conclusions

Our data indicate that students with disabilities can, indeed, complete week-long programming projects. The projects are quite diverse, from games to creating maps to processing images. The Scholars were the innovators in each project, while assistants helped them with the Java syntax. As is the case with most Scholars, those who attended the workshop went on to successfully complete high school and most continued their education in college. Some have even pursued careers related to technology and four continued their education at the graduate level. Many workshop participants are still enrolled in high school or college, so we have yet to learn of their career decisions. For the Scholar interviewed for this article, the Game of Life workshop increased her confidence with technology and changed her perception of how computer scientists work.

6. Key Principles for Success

6.1 Game of Life Workshop

We cannot assess each component of the Game of Life workshop in isolation, but the entire workshop as a whole helped produce the results above. Based on our involvement with the workshop and having organized it for several years, we feel that the following principles enable its success. We intend for these principles to be a guide for readers who want to create outreach programs for high school students, where the target audience may or may not be disabled.

- The Game of Life workshop is not a typical introduction to programming. Even students who have programmed before have little prior exposure to cellular automata.
- Few actions need to be programmed to create behaviors. See Appendix A for the size of a typical program created by Scholars. Also, the idea of loops and arrays need not be introduced to create complex behavior.
- Because such little actual programming (typing) is required, the emphasis in the workshop is on program-solving, reasoning, and algorithmic thinking.
- The infrastructure of cellular automata supports diverse projects, as described above. Because each Scholar works on an individual project, each Scholar can work on what interests him or her and Scholars can take ownership of their projects.
- The final presentation is a good motivator for Scholars, as their friends and family will see what they have done in the workshop.
- The one-on-one Scholar to staff ratio is ideal for Scholars to get the help they need. This structure provides a consistent mentor to each Scholar for the entire week.

7. Conclusions

This paper described a program designed to assist high school students with disabilities and provide experiences to expose them to careers in science, math, technology, and engineering. More specifically, we described a workshop model to introduce high school students to computer programming through the Game of Life. We analyzed data to answer the questions: (1) Can high school students with disabilities be successful innovators of a week-long programming project and (2) How does workshop participation impact Scholars' futures and confidence? We answered these questions by demonstrating students' artifacts, collecting data from Scholars over time, and a case study of a Scholar. We demonstrated the success of the DO-IT Program in Section 2.4, using data collected from Scholars, parents, and mentors. We intend that the principles for success outlined in Section 6 be used as a guide for other faculty and workshop organizers who intend to develop outreach programs, whether or not the target audience includes students with disabilities.

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Appendix A

```
//
// *********************************** Dither1.java
//
// class Dither1  (inherits from class Behavior)
// The negate function will flip the value of the images colors on the
// spectrum.
public class Dither1 extends Behavior {

  public void applyTo(Cell c) {

        //Dithering program first give command so that the computer will
        //deal with the intended cells and leave the others alone
        //Second take the average of the cells and give them a
        // a pattern based on their averages.
        if(c.col%2==0&& c.row%2==0){
              double ave = (double)(c.get()+ c.E.get()+
                                    c.SE.get()+c.S.get())/4.0;
      if(0.0<= ave && ave< 20.0)
      {c.setNext(0);}
      if(20.0<= ave && ave< 40.0)
      {c.setNext(0);}
      if(40.0<= ave && ave< 60.0)
      {c.setNext(0);}
      if(60.0<= ave && ave< 80.0)
      {c.setNext(0);}
      if(80.0<= ave && ave <= 100.0)
      {c.setNext(100);}
        }
if(c.col%2==0&& c.row%2==1){
              double ave = (double)(c.get()+ c.E.get()+
                                    c.NE.get()+c.N.get())/4.0;
      if(0.0<= ave && ave< 20.0)
      {c.setNext(0);}
      if(20.0<= ave && ave< 40.0)
      {c.setNext(100);}
      if(40.0<= ave && ave< 60.0)
      {c.setNext(100);}
      if(60.0<= ave && ave< 80.0)
      {c.setNext(100);}
      if(80.0<= ave && ave <= 100.0)
      {c.setNext(100);}
}

if(c.col%2==1&& c.row%2==1){
              double ave = (double)(c.get()+ c.N.get()+
                                    c.NW.get()+c.W.get())/4.0;
      if(0.0<= ave && ave< 20.0)
      {c.setNext(0);}
      if(20.0<= ave && ave< 40.0)
      {c.setNext(0);}
      if(40.0<= ave && ave< 60.0)
      {c.setNext(0);}
      if(60.0<= ave && ave< 80.0)
      {c.setNext(100);}
```

```
        if(80.0<= ave && ave <= 100.0)
        {c.setNext(100);}
          }

  if(c.col%2==1&& c.row%2==0){
                double ave = (double)(c.get()+ c.N.get()+
                                      c.NE.get()+c.E.get())/4.0;
        if(0.0<= ave && ave< 20.0)
        {c.setNext(0);}
        if(20.0<= ave && ave< 40.0)
        {c.setNext(100);}
        if(40.0<= ave && ave< 60.0)
        {c.setNext(100);}
        if(60.0<= ave && ave< 80.0)
        {c.setNext(100);}
        if(80.0<= ave && ave <= 100.0)
        {c.setNext(100);}
          }
        }
  }
```