AC 2010-122: BEYOND SIMULATION: STUDENT-BUILT VIRTUAL REALITY GAMES FOR CELLULAR NETWORK DESIGN

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Beyond Simulation: Student-Built Virtual Reality Games for Cellular Network Design

Abstract

This paper reports on experience with modifications to National University’s “Wireless Engineering Software” and “Radio Systems Modeling” courses to enable students to gain experience in wireless communications engineering through designing, building and then using simulation games for network design and radio design. Game design has been incorporated as a primary learning tool into these courses in the Master of Science in Wireless Communications degree program.

Laboratory experiments and simulations are already used in some engineering curricula. The introduction of interactive simulation games in virtual environments goes a step further. The games simulate real world engineering dynamics and improve retention of complex concepts. Furthermore, the depth of learning increases as the students design and build the games, instead of just playing them.

The processes and principles of game design have been adapted from National University’s School of Media and Communications (SOMC). SOMC currently uses this approach to successfully teach game design in its digital entertainment and interactive arts program, with the core objective of creating “playcentric” video games.

To expand this process to engineering courses, faculty from SOMC and the School of Engineering and Technology (SOET), collaborated to combine engineering processes with game design techniques to teach interactive games for designing a cellular communications network and digital radio design to engineering students. Game rules, built by the students, must incorporate principles of mathematics, physics, and engineering, including the dynamics of wave propagation, binary logic, and the architecture of wireless systems. Students become game designers as they create original games including content from the STEM (Science, Technology, Engineering and Math) curriculum. This process makes students more effective system designers by bridging experience to the real world.

Teams of students design and build the games on HP Tablet computers. They then “play” the games in teams, as they compete to design the “best” network and radio receiver for a particular set of conditions. This approach changes student focus from learning of theory to practical application of the theory. The introduction of constructive competition provides an additional element of motivation, as it enhances realism and amplifies student ideas.

Introduction

This paper reports initial findings from taking existing video game design techniques and processes and integrating them into the wireless communication engineering curriculum. Using
games to teach and inform has been the subject of many studies, due to the engaging nature and apparent concentration of playing games in order to achieve goals and entertain\textsuperscript{1}. This project originated in the desire to enhance learning in the Wireless Communications Masters (WCM) degree program at National University, using Hewlett Packard (HP) Tablets received as part of an HP Technology for Teaching Leadership Grant in conjunction with powerful interactive DyKnow® instructional software. Upon receipt of the grant, faculty in the National University’s School of Engineering and Technology and School of Media and Communication began the process of creating “virtual apprenticeships” in wireless communications engineering through video game design.

The use of games in teaching is not foreign, especially in computer science degree programs, where video games are used primarily to motivate students by introducing an interesting project or series of assignments\textsuperscript{2}. However, this study was unique in the implementation of video game design by students (students create entirely new games) in order to enhance the learning of wireless communication systems and technologies through experience with real world relationships, theoretical and physical, within the game systems and simulations.

Marrying course methodologies from the Video Game Design curriculum in the School of Media and Communication with the content and subject matter of the School of Engineering and Technology seemed both novel and challenging, and offered the promise of unique outcomes that would significantly enhance learning by providing “virtual apprenticeships” to engineering graduate students. The overarching concept was influenced by Shaffer’s\textsuperscript{3} work on epistemic games, but, this project went further by introducing the concept of video games designed by the students, rather than using games designed by others. In other words, students would be commissioned to understand a specific perspective within the discipline by creating a unique game to describe a real life situation within the wireless communications field.

The courses targeted for this study were WCM 608 Wireless System Design and WCM 609 Radio Systems Modeling, each of which was considered a separate phase of the study, labeled phase 1 and phase 2 respectively. The courses were taught in series and students were largely the same for both courses, allowing students to grow in the program discipline as well as the concept of video game design. This continuation of the study allowed for the added benefit of leveraging existing knowledge of game concepts and building upon prior knowledge of wireless communications.

Researchers and faculty were initially apprehensive of the coupling of game concepts with the science of wireless technologies. The apprehension was largely due to possible disconnect with content knowledge for students in a disparate field, i.e. game design vs. engineering, coupled with concerns for excessive overhead in teaching game concepts in an already accelerated course format. However, the study results and impact on student learning proved surprising and they offer promising results for enhancing the engineering teaching and learning process, while alleviating initial concerns with overhead and the disparate fields of study.
Video Game Design Methodology and Integration with Engineering

The objective of facilitating the education of engineering graduate students to include becoming game designers, while not overwhelming the amount of content in a particular course, was based on the idea that coupling core elements of game theory with highly practical examples would provide an appropriate vehicle. At National University, classes are taught in an accelerated format, requiring class times of 4.5 hours per meeting. In each class, the faculty instructor was joined by a researcher for the game design component of the class, which the research team (including the faculty member) agreed should only take approximately 2 hours of lecture, interaction, and discussion time.

In order to achieve the highest level of immediately applicable game design knowledge in the shortest amount of time, the researchers coupled theory and play into an initial example using an existing paper and pencil turn-based game, BattleTech. Using the basic rules of play for this multiplayer game, facilitated on physical hexagonal maps, with 2” plastic player characters, and multi-sided dice, students were introduced to the foundations of simple game structure and design (see Figure 1). Students saw, for the first time, how each element of the game worked together and that the players’ decisions were based on balancing competing forces to build strategies of play⁴.

Figure 1: The turn-based paper and pencil game, BattleTech

According to Fullerton⁵ and Prensky⁶ the key elements of game structure are players, objectives, procedures, rules, resources, conflict, boundaries, outcomes and feedback, and formal elements. Fullerton further explains that considerations for engaging players of the designed game include challenge, play, premise, characters, story, and dramatic elements. For this study, students were
presented with an adaptation of the Fullerton model in order to achieve a few key elements without the intricacies of a full-fledged game design education. Researchers in this study used the following adaptation for basic game structure and throughout the two classes, as a starting point for student construction:

Initial Game Design Considerations (Idea Generation):
- Characters and Objects
  - Define possible characters, world, and objects
- Procedures and Game Flow
  - Create a game flow diagram showing the players options, decision points, and overall game process
- Rules, Relationships, and Boundaries
  - Describe possible interactions and influences on objects
- Objectives and Challenges
  - Define overarching game-play incentives and obstacles
- Dramatic Elements and Back-story
  - Consider intrinsic rewards and possible player incentives that can be enhanced by adding pre-game-play detail and prescribed motives for strategies of play

This initial game design considerations component allowed students to explore the overarching game structure and play test (actually play components of the game), while building further elements based on feedback from student team members, faculty, and researchers. Students were asked to present the early game ideas to the entire class in a formal presentation and game demonstration, using working physical prototypes (mimicking the BattleTech game-play with paper, pencil, physical maps, and dice), in order to work out the relationships and interactions within the proposed game. Once the basic core game was established, the students were commissioned to create a digital interactive prototype of the game, using a series of tools discussed later. The procedure for moving the individual game projects forward revolved around the construction of digital game assets, while working out the specifics of game-play, system dynamics, and playability of each team’s game. The suggested procedure was as follows:

Development of Digital Game Assets and System Dynamics
- Development of Character and Object Explanations
  - Character sheets, object inventories, and outline of attribute categories
- Asset Specifications
  - Detailed description of player options, constant game object attributes, and object properties
- Game rules and system dynamic integration
  - Integrated rules and interactions directly into objects on character sheets and object inventories
- Character, Objects, and World Representation
  - Game Art and Representation in and of World
  - Tool selection for Game Art and transfer to actual game asset
• Game Status and Procedure Tracking
  o Game play sheets, playing cards, score keeping, and interactive game elements

Students then took the procedures suggested for general game creation and development of detailed mechanics and began to explore the creation of their unique game simulations to explain course topics and outcomes in this new medium. Once they completed the groundwork of playing semi-complex turn-based games, instruction in game elements, and seeing how the systems for games are developed and defined, students quickly bridged the gap between these examples and their commission to transform course content, derived from lecture, text, and research, into game-based facsimiles of real-world equipment, organizations, and the science that drives wireless technology. This transformation of the theoretical to practical and engaging interactions culminated in playable epistemic games, where students would consider detailed perspectives of the stakeholders and simulate the decision-making process of each, in real-world situations.

Game Development Tools and Hardware for Building Digital Games

PowerPoint as a Graphic Design Tool for Non-graphic Design Students

When building the game boards, the researchers utilized Microsoft PowerPoint (PPT) as the primary design tool for a number of reasons. Traditionally, not considered a graphic design application, PPT has the capability of designing simple objects and integration (composition) of graphics into a single interface, while requiring little time to learn how to use for non-graphic

Figure 2: The use of PowerPoint templates to create game maps
design students. The use of layers on a single PPT slide allowed for maps, hexagonal grids, and in context individual game assets to be constructed.

Students were provided a template file with a transparent hexagonal grid on a single slide (see Figure 2). The researchers then instructed students to select the grid image, access the Picture ribbon, and open the selection pane. These steps allow the student to use PPT as a composition tool for creating multilayer images or slides.

The researchers then demonstrated how to capture maps from outside sources, such as Google maps, in order to give an underlying graphic (representing a “world”) for which the game would be played (see Figure 3). This gave the added benefit of relating the game to the real world by using actual maps. Students were given the option of creating their own hypothetical maps or game boards in order to demonstrate the “world” in which their games take place. The development of game boards gave the faculty opportunity to discuss and students the opportunity to research environmental factors, such topography, population density, traffic, and various factors, related to wireless technology and signal propagation.

Figure 3: Demonstration of the addition of real world maps and construction of game assets in PowerPoint

Lastly, the PPT component allowed the students to create individual game assets or characters for moving and playing in the game board. This functionality was facilitated through PPT’s drawing tools and “save image as” property in the context menu. Students were able to design appropriately proportionate game assets, like base stations or icons, group the drawings, and
export the individual elements as transparent .gif files (see Figure 4). The .gif file is the image extension that is supported in the DyKnow® software (see www.dyknow.com), which acts as the gaming environment.

![Diagram](image-url)

Figure 4: Demonstrates the ability in PowerPoint to export drawn game objects to .gif format

**DyKnow® and Tablet PC HP Grant Hardware**

Dyknow® and the HP Tablet PCs acted as the game platform and online synchronous connectivity tool. The Dyknow® software allowed for synchronous interaction between student HP Tablet PCs and, according to the literature, facilitated out of class review by recording annotations made by students which was useful for reviewing game-play. Research has shown that using digital inking and digital social interaction support more permanent retention of learned skills and knowledge.

In this study, students loaded their game boards as PPT slides into the Dyknow® system and synchronized with other HP Tablet PCs running Dyknow® in the classroom or online. Once the game board was loaded, the Dyknow® facilitator (one of the students acting as instructor) can turn on sharing, which enables all connected users to control assets, using the HP Tablet PC’s stylus, within the game board (see Figure 5). At that point, the student will open a Palette Object panel, allowing assets to be imported (transparent .gifs) and used in the gaming environment.

**Matlab® and Radio Design**

Student Teams utilized Matlab® from The Mathworks™ as the game engine and game object within the game. Designed as mathematical software for calculation, programmed simulation,
and many professional level analyses, Matlab® provides a platform for signal processing and system simulation within the WCM and other academic programs. In this case, Matlab® was introduced in Phase 2 of the study, as a software program to be used as the backbone of the student games. In other words, the students would build assets in PPT, use Dyknow® as the game board, and Matlab® to act as the game engine. Specifically, players could input player data, generate random numbers, maintain persistent variables, analyze signals, program the simulated radio systems, and receive output and status from the student developed Matlab® functions.

Figure 5: Shows game maps imported into DyKnow running on HP Tablet PC

Implementation in the Classroom

Classroom implementation of the game design into the WCM608 Wireless System Design (Phase 1 of the study) was comprised of teaching the graduate students game design, while covering the traditional content for the course. As discussed earlier, the researchers overcame the obstacle of adding new material (i.e. game theory and design) by minimizing the amount of time and curriculum dedicated to the game design process. This was accomplished by demonstrating real examples of similar games and the constructs that make them work. Additional lessons on game design were always taught in context to the actual building of the individual student team projects. In other words, students were coached on specifics of game structures and playable game design, as they developed their plans, presentations, implementations, and delivery of their own games. This technique of “in-the-build” training kept the students teams moving forward in course curriculum and game integration, while new or revised concepts in production of their games could be added. It was noted by faculty and the
researchers that the students almost immediately took ownership of the process and project; they demonstrated an inherent ability to understand the functions and components of games.

Having surprisingly observed the students’ enthusiasm, dedication and engagement in game design in WCM608 and their impressive work, it was decided to move to Phase 2, continuing to integrate game design into WCM609 to motivate students’ learning, grab their attention and enhance their critical thinking. This satisfied the creative and intellectual nature of the students, and achieved better learning outcomes than did the previous version of the course. Advantageously, WCM608 and WCM609 were taught back to back, allowing students to leverage existing knowledge and lessons learned in game design to the new subject matter and project criteria.

The course WCM609 Radio Systems Modeling (phase 2 of the study) focuses on modeling and simulation of wireless communication systems. The goal of this course is to explore all the components of a radio communication system and simulate using MATLAB® and its simulation tool SIMULINK®. Throughout the course, via the instructor guided laboratories, the students learned to analyze, build and design components of a real radio receiver. The course has been offered several times in the Master of Science in Wireless Communication program at National University. A course project is given to the students at the end of the design course, in which the students are required to design and simulate a complete digital radio that includes each part of a typical digital communication system using MATLAB® with SIMULINK®.

Similar to WCM608, the instructor of the course, a professor in the School of Engineering and Technology along with a professor from the School of Media and Communication collaborated to combine digital radio systems simulation and design with video game design. The course project was revised to create a radio model based simulation game. More specifically, the students were required to design video games whose inputs come from the digital radio simulation blocks created using MATLAB®/SIMULINK®; the video game then responds to the inputs, and based on the game interaction, the players make decisions and execute the game strategy. The data generated by the game is fed back as input to the radio simulation blocks. The cycle repeats till the time limit is reached or certain constraints are met. The game procedure cycle is showed in Figure 6.

According to Holliday’s paper, to be most effective in integrating games design into courses, two traits are necessary. First, the final game the students develop should be at a level of sophistication comparable to commercial games. Having such a target maximizes the students’ enthusiasm. Second, the game should be developed incrementally through a series of assignments. Incremental development allows each assignment to be manageable and allows the assignments to start early in the course. Following this approach, the project was divided into four stages, each stage lasting one week.
In the first stage, the students formed teams and chose their project subjects; in the second stage, each team designed game characters, objects, procedures, rules and game flow; the MATLAB® based digital radio simulation blocks were developed in the third stage; and interaction and interfacing between video game and the radio simulation blocks completed in the fourth stage. At the end of each stage the student teams presented and demonstrated their progress, and modified their project according to two instructors’ and other students’ comments and suggestions. The grade of the project was given based on the evaluation of a written report and the final presentation.

Figure 6: Basic Radio Simulation Game Procedure Cycle

Student Game Results and Observations

During the study, one of the immediate observations was the level of concentration and collaboration exhibited by the student teams. The professors were surprised at the intensity and enthusiasm with which the students worked and progressed through course curriculum in the team environment. The level of dedication and engagement was expressed through an apparent desire to learn the wireless communication system components in order to accurately incorporate the combination of technologies into the game simulation. Students recognized the necessity of prior knowledge and background content in order to progressively build the game and explain the wireless technologies used as game assets. In video game design it was imperative to describe each game component as well as the relationship each component has with the others, creating what is known as system dynamics. The same understanding is required in real world implementation of wireless and radio system design and construction. As a result, an engineering epistemology or method of creative thinking was developed, while game simulation progressed toward the goal of a working representative project deliverable.
During Phase 1, the WCM 608 Cellular System Design component of the study, one team, who chose the name “Tigers”, developed a game based on cellular hand-off, types of service, user equipment, and power management. In the game each student owned multiple base stations as a service provider, and then game characters (cell phone users) would move around the digital map based on random numbers generated by dice rolls, connecting to towers, using power, and going through hand-offs as they moved. Each player would mark the efficiency of their tower configuration, while attempting to move to higher generations of technology (for example: moving from 2.5G to 3.0G networks). The students designed a measurement of cost, resources, and utility in which players were forced to decide between base station location, service offerings, supporting customers, and upgrading to new technologies. Winners were based on profitability over a set numbers of turns in the game.

Observations for this team focused largely on the ability of the game simulation to engage the players in random situations for base station selections, while teaching the fundamental concepts of wireless network design. The faculty response to this game design process was observed and recorded as one of surprise at the motivation of students to work in teams, while demonstrating greater depth of conversation and debate on course content and concepts. Faculty observed the increase in hours spent working on the game project and levels of collaboration both during and out of class versus previous courses where game design was not employed. For the team “Tigers”, their responses indicated a greater level of intensity and depth of learning of course material, coupled with increased interest in the course content due to the excitement of incorporating class work into a playable game.

The second team, which chose the name “Hunters” provided a similar game model in which cellular networks were designed by players, but instead of selecting stations over a broad area, players were allowed to select individual areas within a town and battle for customer retention and profitability. Dice rolls decided the movement of large numbers of customers throughout the game board and introduced the concept of “roaming”, all while sharing customers and maintaining capacity within the players’ territories. Winners were able to maintain large customer bases while supporting the migrating cell phone users throughout game play.

The observations of team “Hunters” yielded similar results to the “Tigers” team, with the addition of increased complexity in their game elements and interactions. The explanations and presentations by the team were found by faculty to be both sophisticated in design and approaching professional levels in demonstration of wireless network design and concepts. Furthermore, researchers observed many examples of spirited competition between the student teams, derived from the overall culture of games that grew in the classroom, which continued to raise the quality of work produced.

During Phase 2, the WCM 609 Radio Systems Modeling component of the study, one team, which chose the name “Dragons”, constructed a game simulation for a battlefield scenario involving weapons, vehicles, signals, transmitters, and receivers. In the game simulation,
opponents assumed roles of attackers and defenders, giving each a chance to choose attacks, send encoded signals, and order the destruction of the opponent assets. Meanwhile, the defender could intercept signals, and cause the scrambling of orders to defeat the attack. All of these interactions took place on a digital game board in DyKnow®, using pre-constructed game assets developed in PowerPoint, and facilitated by a mathematical game engine in Matlab®, creating a rich gaming environment to demonstrate the concepts of the WCM course. The details of this phase are to be covered in a future paper.

The second group in phase 2 of the research, which chose the name “Spicy”, created a game based on the placing of radio components around the game board. The objective of the game was for each player to locate the necessary components to build a complete simulated digital radio. The challenge was that every radio component, represented by a Matlab® program, would be “bugged” by the opposing player (attacker). The defending player (player commissioned to debug) would then examine the code and attempt to fix all the errors successfully within a particular time period. The idea for the game came from the student’s own experience with debugging Matlab® code and the team decided to create a game out of the classroom activity. Once all components of the radio were captured, the player would then receive and decode signals sent by the other players. All of this interaction was dictated by cost of time (players could purchase time to debug), and the ability of players to successfully build and decode with their radios.

The researchers and faculty utilized specialized grading criteria based on an existing rubric for assessment of video game design students and game design documents.

Basic grading criteria included:

- Map Detail/Description of Play
- Character and Game Object Description
- Game Challenges and Objectives
- Telecommunication Concepts and Implementation
- Procedure/Rule Design

Students delivered their group projects in video game project written reports, class presentations, and play testing of the actual student designed games. Student deliverables and assignment scores revealed many significant and successful outcomes in this preliminary study. Some of the most interesting observations, based on student grading revealed the apparent increase in depth of learning and a unique knowledge transfer associated with the game design methodology, demonstrated in explanation and actual game play by each student.
The faculty for WCM609 also observed the enthusiasm and creativity demonstrated by the students in the creation of simulation games by both teams. To the researchers and faculty the students appeared to be highly motivated and legitimately enjoying themselves both in and out of classroom as they built their games. Faculty further observed and commented that designing and playing these games helped the students understand the communication signals processing theories and radio systems fundamentals, better than students in previous classes who had experienced difficulty in absorbing these concepts.

Both researchers and faculty agreed that students exhibited signs of greater cognition and meta-cognition, or understanding the way in which they were learning. This meta-cognitive benefit was demonstrated in the approach toward MATLAB® coding, especially with the game developed by team “Spicy”, in which the ability of debugging and creating bugs in MATLAB® code was crucial to playing the game successfully. Clearly, team “Spicy”, as game designers had to think deeply about how players would perceive and execute the code manipulations and how their opponent players would then think through the reverse of the manipulation in order to correct the damage. This component of their simulation game demonstrated the understanding of thinking about how they and others would solve complex issues in wireless communication, approaching a professional epistemology toward engineering.

Conclusions

This exploration into using game design as a catalyst for student learning and virtual apprenticeships in the wireless communication program showed many promising results. First and foremost were the observations and recorded comments from the researchers, faculty, and directly from students that demonstrated an apparent increase in engagement, depth of learning, and practical experience with course content and concepts. Faculty, in particular, during both phases of the study remarked that students genuinely appeared to demonstrate greater practical knowledge of course topics and were consistently impressed with the level of discussion between student teammates, as well as level of complexity with questions being asked of them in regards to wireless communication theory and application. Students clearly demonstrated increased enthusiasm toward the subject matter and increased desire to collaborate in student teams, in order to see the fruition of their proposed games.

The limited number of students participating in the overall study, including both phases, prohibited the collection of concrete quantitative results. However, the study’s purpose and execution yielded significant results in terms of successful proof of concept, coupled with meaningful qualitative data allowing for further process improvements and act as a starting point for additional study. The researchers observed that the cautionary elements and perceived obstacles, such as overhead for cross-disciplinary content for implementing game design as a legitimate vehicle for teaching and learning could not only be realistically overcome, but that, when properly executed, could be near negligible. In other words, engineering students could be taught to become game designers and creators (albeit in a limited scope) without compromising
the existing curriculum. These initial findings, of developing virtual apprenticeships through game design for engineering students, were viewed by the research team as encouraging and certainly meriting for further research.
Bibliography


