Building a serious game for teaching secure coding in introductory programming courses

Nicoletta Adamo-Villani  
Department of Computer Graphics Technology, Purdue University; nadamovi@purdue.edu

Steve Cooper  
Department of Computer Science, Stanford University; cooperes@cs.stanford.edu

David Whittinghill  
Department of Computer Graphics Technology, Purdue University; dmwhittinghill@purdue.edu

Why a game to teach secure coding

- Reports of software-related security breaches are a weekly occurrence in the news.
- There is a tremendous need for computing graduates with a background in Information Assurance (IA)
- Given that the vast majority of practicing programmers do not have advanced degrees, there is a need to give beginning programming students early exposure to secure coding
- The CS2008 document identifies "computer security" (their term for IA) to be one of the three major new focal areas of computing

Background: Secure Coding

Secure coding can be defined as writing code without bugs or vulnerabilities. Many of the most dangerous vulnerabilities result from a reasonably small set of programming errors. Current IA courses and textbooks are targeted at the advanced undergraduate or graduate level. The intent is to "un-teach" students the bad habits they have previously learned.

An approach is needed that is appealing to both students and instructors, and could help to teach beginning programming students secure coding principles.

Background: Serious Games

In Mike Zyda’s definition, a game is “a physical or mental contest, played according to specific rules, with the goal of amusing or rewarding the participants”, while a serious game is “a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training; education, health, public policy, and strategic communication objectives” (Zyda 2005). Serious gaming repurposes the concepts of videogames and videogame technologies that have been used for commercial entertainment, and uses the gaming approach for training, education, advertising, national defense, genetics productivity, and more.

"Play", an important contributor to human development, maturation, and learning, is the main component of serious games (Derryberry 2010). Another fundamental component is “fun”.

The player of a serious game is motivated to play the game, and continues the lesson much longer and with greater attention than he or she would using traditional learning techniques.

The founders of the Education Arcade at MIT stated that there are many intrinsic motivations for learning associated with games. “The threat of failure is lowered. Games allow players to try, make mistakes or fail, and then try again without losing face. Discovery and application of learned skills in new contexts encourages exploration and experimentation. A sense of engagement continues during gaming. Computer games allow players to be stakeholders in the events that occur on the screen” (Riley et al. 2010).

Some research has taken place on serious games from a “new media” perspective (Dovey & Kennedy 2006) from psychological perspectives (Iwase 2007) (Gletscher et al. 2007) as well as from sociological perspectives (Etzkorn et al. 2008). As far as learning, scientific evidence to support the assumption that serious games are educationally effective is still limited. Serious games may have positive impacts on education as tools but relatively little is known about the learning outcomes of the users who play them (Square & Attention 2010).

There is a need to investigate the role and benefits of serious games in the classroom. The long-term goal of our work is to advance the knowledge in the field by evaluating the effectiveness of serious games for teaching computer science concepts to undergraduate students.

Pre-production: concept art and storyboards

Game levels developed so far

Technical Details

The platform for the game is based on Autodesk Maya and Unity3D. We use Maya software to model and texturize the virtual environments, props and characters and to animate their functionality. Interactively with the 3D components is programmed in C# using the Unity game development platform. The choice of the Unity platform was based on the following considerations:

- Unity has an optimized graphics pipeline that supports interactive rendering of complex animated 3D meshes and advanced lighting and textures even on computers with limited graphics capabilities.
- Unity interfaces seamlessly with major 3D animation tools (e.g. Autodesk Maya and 3D Studio Max) and file formats, and allows for instantaneous import and update of assets files and animations.
- It supports a wide range of publishing platforms, including: standalone builds for iPhone OS and Win-Dows, web delivery through the Unity Web Player Plug-in (3 MB), Wii and iPhone publishing.

The game is deliverable via web or as an e-store or app file, and is being designed to run on hardware and software infrastructure that is already widely deployed in universities. Students will be able to use the game on low-end personal computers (PC/MAC) with low-end graphics cards.

Evaluation

The game is being created using an iterative user-centered development approach that includes two forms of evaluation: formative and summative. Formative evaluation focuses on the design features of the game (i.e., usability, fun and engagement, user ability to make correlation between the game level and the related educational concept, and quality of the graphics); summative evaluation tests the efficacy of using the serious game and the accompanying educational modules for teaching IA concepts to undergraduate students in introductory programming courses.

To date, we have conducted 3 formative studies. A detailed report of the findings from these studies can be found in (Adamo-Villani et al 2012) and (Adamo-Villani et al. 2013). Below is a summary of results.

Summary of Findings:

Results of the studies show that the currently developed levels are usable and engaging and the majority of students were able to establish a clear correlation between the game levels and the corresponding IA concepts. While several flaws pertaining to the user interface were revealed within the levels, these flaws did not affect the ability of the participants to play the game. Both quantitative and qualitative data prove that the participants enjoyed playing the levels and were motivated to complete the game. Subjects’ reactions to the quality of the graphics was very positive, and contributed to keeping the players captivated. Findings also show that the two game levels are attractive and engaging to novices and female players. This is an important factor, as the goal of the project is to reach a wide audience by creating a game that is also appealing to females and students who are not avid video game players.

We are currently conducting a summative study with a group of undergraduate students on high school students to determine whether playing the game improves content learning and whether paying the game leads to higher learning gains than traditional learning/teaching methods.

Future work

- Development of all 7 game levels
- Summative evaluation
- Dissemination through three channels: the IA education community, the ATE centers, the CS education community

Publications


http://www2.tech.purdue.edu/cgt/ig3/IAgame/website/