Augmenting Design Curriculum with Location-Aware Technologies

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Abstract
This paper discusses ways in which emerging interactive augmented reality (AR) technologies are being adopted by designers and extended into areas of tourism, education, entertainment and commerce. It discusses, in detail, project development stages and methodologies used to engage design focused students into, often complex, technological issues. The discussion is contextualized through a number of case studies of mobile and marker-based AR applications developed within the university curriculum.

Categories: Human-centered computing - Human computer interaction (HCI) - Interaction paradigms - Mixed / augmented reality

1. Introduction

Historically, new forms of representation and visualization marked significant conceptual shifts in design thinking and in the very process of ideation. Not unlike the introduction of perspective during the Renaissance, digital technologies in recent years transform the ways design is being conceived and produced. Augmented reality (AR) is one of the recent contributors to this shift, bringing significant new attitudes into already complex digital processes.

Over the last couple of years, AR technology has seen a renewed interest from developers and consumers as well as the emergence of new authoring-friendly platforms with a low learning curve. This new lower authoring threshold attracted increasing interest from design professionals and academics to port this new technology into design and creative disciplines. From architecture and product design to branding and gaming, AR technology expands existing communication frameworks into more user-centered media. The appeal of the AR technology connects with the broader expectation of context-specific and context-aware data sets that respond to user needs.

This paper investigates ways that emerging interactive technologies are being adopted by designers and extended into the areas of tourism, education, entertainment, and commerce. It discusses in detail the project development stages and methodologies used to engage designers into often-complex technological issues. The discussion is contextualized through a number of case studies of mobile and marker-based AR applications developed as part of academic research. These applications include an app for fashion-based social events that allows participants to preview recent collection additions, an info-navigational app for the High Line elevated urban park in New York City, a marker-based sustainable growth game, and an interior decorating interface to visualize various furnishing scenarios.

While a number of case studies are discussed from a developer perspective touching on technical intricacies, the primary focus is on content development, interface design, and user interaction considerations.

2. Augmented Reality Context

Traditionally, AR environments employed two distinct types of data overlay. Marker-based environments employed distinct markers and, more recently, images (image targets) to locate virtual data within the physical world. Markers can be two-dimensional images or in some cases three-dimensional captures/objects. A second, marker-less, approach associated with mobile AR involved GPS, digital compass, and accelerometer sensors to position users and the virtual content around them. The GPS location and the compass direction is checked against a database for location associations. If any dataset point meets user defined criteria, such as proximity or thematic interests, the visual reference to the dataset is displayed on a mobile device as a point of interest (POI).

3. Situated Past

While AR technology is routinely employed in the form of data overlays providing supplementary information for physical objects that are visible with the unaided eye, it is also increasingly used to visualize less tangible structures and concepts such as historical events, cultural phenomena, and scientific processes. This can be seen in a number of research projects and mobile apps developed as part of the academic research, which help users to experience history and facilitate urban explorations. [NF2011b] TimeWarp [HBM*2008], a mobile edutainment application designed as an AR game situated in Cologne, Germany, focuses on virtual reconstruction of historic buildings by superimposing virtual imagery over currently existing structures. The application not only shows no-longer-existing buildings as they originally appeared but also visualizes design changes that occurred over time to still-present structures.

An example of no-longer-existing buildings that continue to function as an urban landmark are the Twin Towers of the World Trade Center in New York. The 110 Stories[1] mobile AR app virtually recreates the silhouette of Twin Towers and presents them overlaid over camera

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images from various locations in the city (fig.1). Once the most prominent landmark in the lower Manhattan, the towers no longer serve as an element of wayfinding. However, for those who want to reconnect with the lost iconography of the towers, the 110 Stories app provides a meaningful interface for the collective memory. Similarly, a number of other AR apps bring to life past events or no-longer-existing buildings and cities. These integrated media elements may no longer be universally recognizable or understood by the community nor contribute to universally shared collective memories of a place.

Figure 1, Manhattan skyline as viewed with 110 Stories mobile AR app.

Similarly, the Immersive Experience of Cultural Heritage project [KSH*2009] uses an AR tour approach to provide tourists with a more realistic experience by placing virtual characters within historical structures. Visitors to the heritage sites of Sajeongjeon and Gangnyeongjeon in Korea can use their mobile devices to access additional facts associated with the showcased physical content.

The Augmented Reality Framework for Architectural Applications project [NF2011a] combines dynamic image tracking of architectural context as a spatial framework for historical reconstruction. While a similar approach is routinely used by many museums, this particular project does not rely on AR markers such as QR codes. It implements visual camera tracking of the rectangular display space to position its virtual actors without a need for visually intrusive markers.

Virtual environment allow for explorations of inaccessible or not-yet-materialized designs. They can be precursors of future physical urban spaces and potent drives in their realization. This is the case with AR environments (fig.2) developed by Tremont Underground Theater Space (TUTS) initiative[2]. This initiative is using AR gamified virtual tourism media not only to popularize ideas of the adaptive reuse of the abandoned public infrastructure but also to build social constituency and connect with general public (fig.3).

The shifting focus from virtual-reality (VR) environments toward mixed-reality and AR frameworks indicates the reexamination of earlier visions of separated physical and digital worlds. The emerging picture fuses both dimensions into a single continuum. The newfound physical context adopted by AR games encourages players to push the boundaries of social conventions and accepted public behavior. Unlike more passive forms of entertainment such as reality TV or even active-yet-confined console-based games, the AR framework incorporates physical activities and social interaction as well as encouraging exploration, learning, and discovery. Furthermore, as activities integrate digital media culture within the built environment—cities—these games provide an insight into our physical-digital selves and better understanding of ourselves and our communities.

Figure 2. *Augmented reality (AR) environment as social and design activism and urban games.*

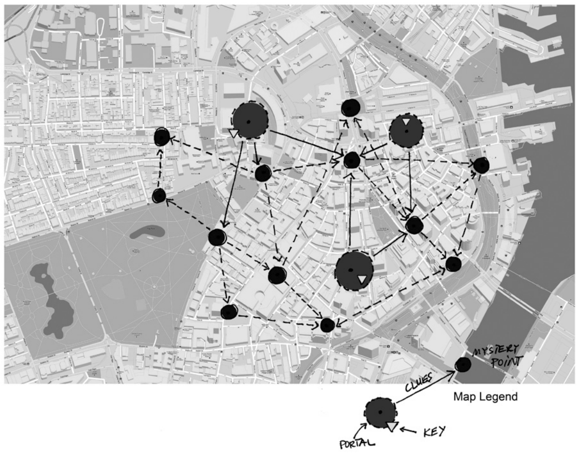

Figure 3. *Mystery Spaces, a map with POIs arranged in the form of the game play.*

4. Engaging Commerce and Tourism

"Let's pretend you're on your way to Manhattan to buy some new clothes. Maybe you're looking to impress someone on a date. Maybe you need an outfit to ace that interview. Maybe you're looking to change your style and try something new. Whatever the case may be, you know New York fashion will not disappoint.

You arrive on 54th Street on Fifth Avenue early in the afternoon. There's a ton of different stores in that five-block radius. There's high end fashion retail and some typical name brand stores. Some stores aren't in your price range, but you might be interested in what they have to offer. You're not sure where to shop first. Decisions, decisions…Luckily, there's an app for that!"

The above shows one of the proposals for a mobile AR application that combines fashion retail experience with location-aware services and electronic social networks. This application not only addresses an interest match between product providers and consumers but also touches on less tangible needs such as the sense of social happening and the excitement associated with emerging technologies.

The FashNYC app is geared toward those interested primarily in high-end fashion designers. It helps its users make smarter shopping choices while connecting with the current fashion scene. FashNYC brings awareness to the fashion industry, connects with seasonal events, creates an exciting new shopping experience, and establishes a presence in today's heightened mobile application culture. Through the app, consumers have access to online videos showcasing each brand's current collections. They can watch interviews with designers and access garment information including sizes, colors, materials, prices, and availability. What is particularly interesting about this proposal is its narrow, yet integrated, approach to providing services. It identifies a specific target group of potential users and attempts to deliver a comprehensive solution reminiscent of the traditional one-stop shopping approach.

The app was developed for the Layar AR browser using PHP programming with MySQL database. The student team focused not only on creation of individual assets and associated Web pages (fig.4) but also on the overall packaging, user experience (UX) (fig.5), and final layout for the navigational map (fig.6). The idea of branding, characteristic of the fashion and design industry, was central when developing the user interface (UI). Since the seamless connectivity to various social networks and fashion-based websites was key here, the app UI became a critical part of the overall effort.

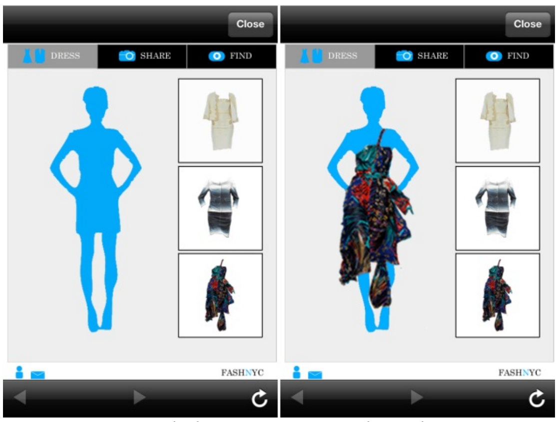

Figure 4. *Virtual changing room with FashNYC*

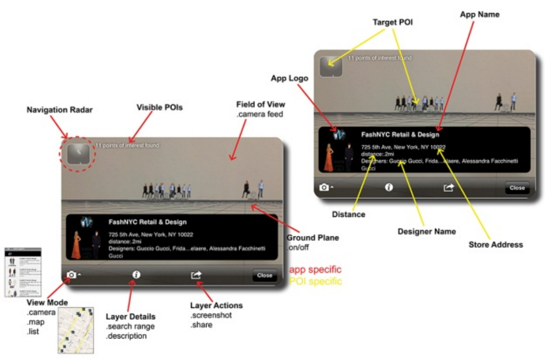

Figure 5. *Mobile interface for FashNYC*

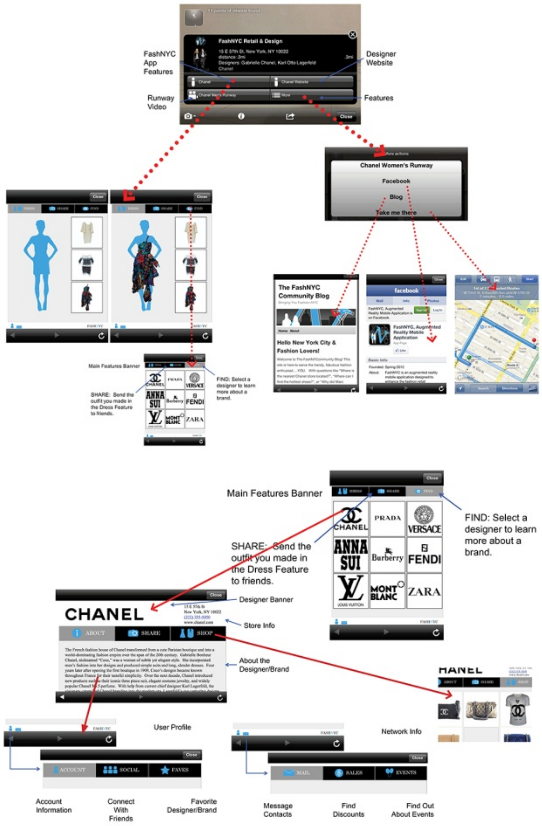

Figure 6. *App navigation map*

While the student team developed a fully functional prototype,[3] they also proposed the next level of functionality that went beyond the scope of the class and their technical competencies. This was an important part of the overall design strategy, where each team developed the initial project concept and later expanded it into a more formalized business proposal with outlined future development stages. This became an important learning experience about technology development and idea implementation. The ability to project a series of intermediate goals with each phase forming a defined and comprehensive package that achieves particular functionalities helped students to divide work based on their expertise. At the same time, it helped in setting realistic and easily achievable goals even within a relatively short course timeline. One of the proposed features that could be implemented with Layar's interactive graphics was garment (image) recognition. Another was developing a screening tool that would provide shopping alternatives. The proposed app functionality was expressed in the following statement.

> *Let's say you're looking for a new blue suit. You see one you like in the window of Versace. To be quite frank, you can't afford it, but you really like the color and the style. You can take a picture of the suit and have the application search for it. As the application searches for it, you take the time to watch a video of the Fall/Winter 2013 runway show where the suit was first featured. You notice you like the way it looks when on the runway, but the blue one that was shown looks even better. Once the suit has been found in the search, you can try to find similar garments in nearby stores. You're in luck! That application located a*

similar blue tight-fitting suit in Zara across the street for half the price! Bam! Success. (Philip Caleja, Nicholas Haby, and Daniel Schittone)

While this particular functionality was never implemented, it provided a stimulating basis for discussion on the ways it could be realized in the future. Two approaches were identified: (1) as a searching application/agent to find alternatives based on the combination of text and image recognitions, and (2) as a method of capitalizing on user purchasing/searching patterns similar to Amazon's "Customers Who Bought This Item Also Bought," which suggests additional purchases to customers.

As with any new app or a product relying on social interconnectivity and input, the key issue is to develop a critical mass of active users who would propagate its virtual life. This is a major challenge facing many new media products including an AR community like the one proposed by students. The strategy to address this impediment and help with the future commercialization of the app was to tie it to a particular event that is highly localized with a defined time frame. The student team proposed to connect it to the Fashion's Night Out (FNO) event or the New York Fashion Week. While this was not implemented yet, it provides a feasible strategy for launching an AR app product that is highly contextualized with its theme, location, and timing. This is also an approach used by other mobile AR games such as Comfort of Strangers[4] that rely on a critical mass of participants for their success. More recently, an augmented reality massively multiplayer online role playing game (MMORPG) Ingress[5] used a similar approach of staged events/happenings to develop momentum and mobilize its players.

Highline Tour[6] is a navigational and informational mobile AR app geared toward visitors to the High Line, an urban park in New York City (fig.7). It provides users with historical and current information as well as plans for future developments. Its location-aware functionality allows for sorting and positioning data in relationship to the urban context. It shows year-around activities with imagery of various plants and foliage reflecting seasonal changes occurring in the park. In many aspects the app functions as a time capsule that combines multiple layers of information into a single geo-location. These multiple layers can be individually accessed and combined to provide a selected perspective into the High Line project. Users of the app can look at a particular section of a project and freely navigate through historic photographs and future proposed designs (fig.8). To some extent this media overlay provides a third alternative to "renovate and loose the charm of the past" versus "keep the past untouched and do not adapt to new uses or current needs." The AR component, at least virtually, preserves to a certain extent the original conditions and memories of the past.

The Highline app utilizes a Layar AR browser that is available for most mobile platforms. After initial time spent on understanding Layar SDK environment, students focused on gathering geo-location data for individual points of interest (POIs) (fig.9) and setting up online databases. Since this particular section of the course was made up almost exclusively of architecture and design students, teaching faculty had to provide initial help with basic PHP programming and MySQL database setup.

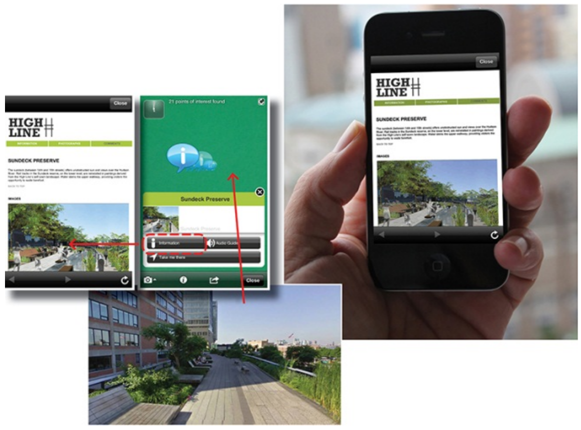

Figure 7. *Highline navigational AR app*

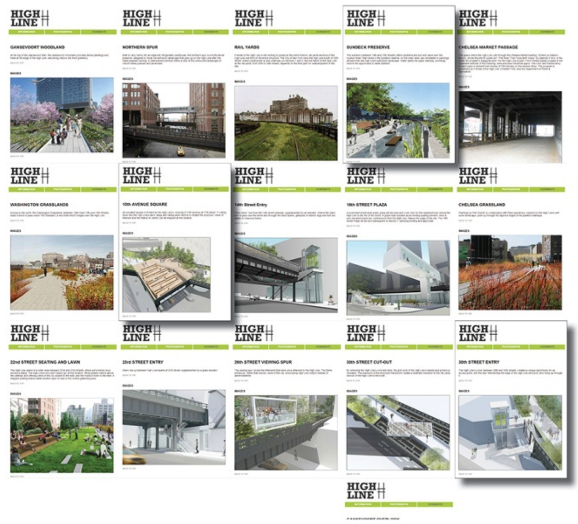

Figure 8. The d*iversity of assets developed by students*

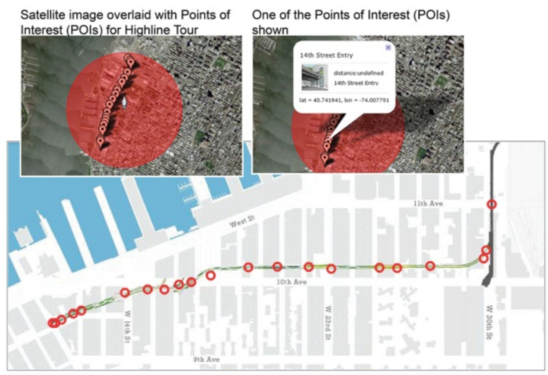

Figure 9. *Points of Interest (POIs) for Highline app*

As part of the development process, students participated in hands-on workshops organized by faculty and on some occasions received a skeletal prototype of an app. This helped to stage the progress of the project in such a way that at any level of its development, students had a fully functional prototype ready for testing with various numbers of features and assets. The focus of the student design team was on gathering relevant information, imagery, and outside references. The second stage involved population of the database, interface design, and development of Web page links with additional information. Since many of the assets were Web pages related to the app content, students had to consider designs that were both desktop and mobile browser friendly. This quickly became a challenge on its own, considering the diversity of mobile devices (phones and tablets), their screen resolutions, and horizontal/vertical layouts. Once all the assets were in place, the design team focused on overall packaging, user experience, and interface design.

While the AR app development process required a broad set of skills, from basic programming to graphic design, this diversity made students more engaged in the project and provided opportunities for the development of specific expertise with a relatively low learning curve.

5. Contextualized Learning

The design process can be seen as developing multiple competing spatial scenarios and testing them against logistical constraints. The Sustainable Growth Economy game follows the same framework and uses AR marker-based mobile technology to provide an immediate visual feedback and greater participant engagement to players. The game was developed as an educational aid for middle school students to understand the consequences of various economic growth choices and the fine balancing required to maintain economic growth. The game mechanics parallel a simplified version of the SimCity model, with a focus on increasing the visual feedback loop as an important part of the game play. The goal of the game is to grow a civilization that is self-sustaining. This requires addressing the following three competing objectives: (1) reaching a certain level of population, (2) maintaining a habitable environment, and (3) sustaining enough energy to keep the civilization going. Each of these objectives directly compromises the remaining two, which requires a fine balancing act. The game play relies on the use of physical cards (markers/image targets; see fig. 10), which facilitate virtual community growth. Players use these cards to add and remove assets or to modify their properties. The outcomes of the game play are registered on mobile devices (fig. 11), which provide an opportunity for open—what-you-see-is-what-you-get (WYSIWYG)—or individualized game maps. Since most of the assets are virtualized (visible only on the screen), they can be easily customizable and tailored based on the player preferences and the experience level. While this game focuses on the sustainable growth economy, its dynamics and mechanics could be adopted to serve as town master planning or building programming tools, helping designers to engage clients and the broader public. In this case, the game fulfills the role of the design facilitator, and to some extent design simulator, with an immediate and visually explicit feedback.

Figure 10. *AR markers used as game cards.*

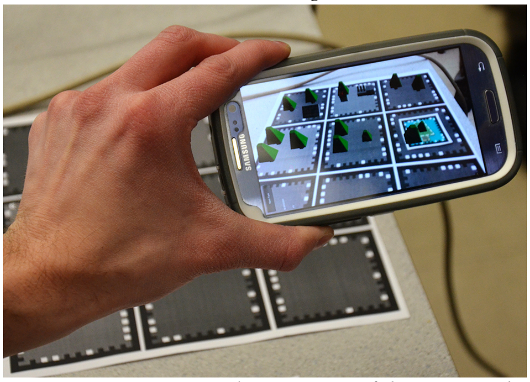

Figure 11. *An early prototype of the game with assets visible on the mobile screen*

6. Augmented Interiors

The goal of the project was to enhance communication between interior designers and their clients, and to empower consumers to experience the impact a particular design or set of furniture may have on their home (fig.12). Traditional home decorating is done by imagining what a space would look like with the new furniture or other design features without having a true sense of scale or color gamut. Most commonly, customers would measure the space in a house and see if a new piece of furniture would fit within. Let's consider another scenario.

> *You're looking through a furniture catalog and find a piece that you like. But how would it fit into your living room? Now you can find out without leaving your couch, or wherever you are. Take the marker attached in the catalog, place it on the desired location, download the AR app, and look through the display of your mobile device camera. The piece of furniture you're considering is there for you to see in the context of your own living room.*

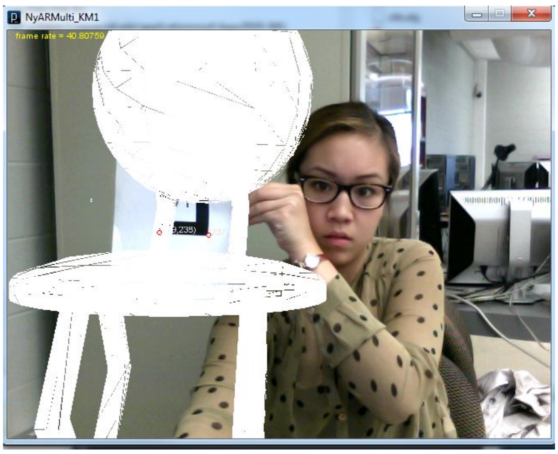

Figure 12. A *student working with a marker-based AR application*

The marker-based AR application associates each marker with a piece of furniture, material color, or design features. The combination of markers allows for a high number of variations of possible designs. This app would allow ordinary people to take design into their own hands and see exactly how a new furnishing would look like in the context of their home before they buy it. The approach does not require a digital rendering of the entire room. Instead, it overlays a product in real time over the camera image of the existing space. The applicability of AR in this project is appropriate; it achieves its desired effect with very few resources, could be easily commercialized, and has the potential of reaching a broad consumer population. The limiting factor of this particular project was its development environment—Processing with ARToolkit. While Processing is an excellent designer prototyping tool, the AR extension had a series of limitations in the number and resolution of fiduciary markers. This limitation can presently be significantly overcome with applications such as the Vuforia extension to Unity3D.

7. The Maze Game

This marker-based AR game involves navigation of a virtual ball through a virtual maze by physically moving around and tilting the AR marker (fig.10). Movements and adjustments of the marker in the physical world are registered in the virtual space and interpreted with physics-based interaction (gravity and collisions).

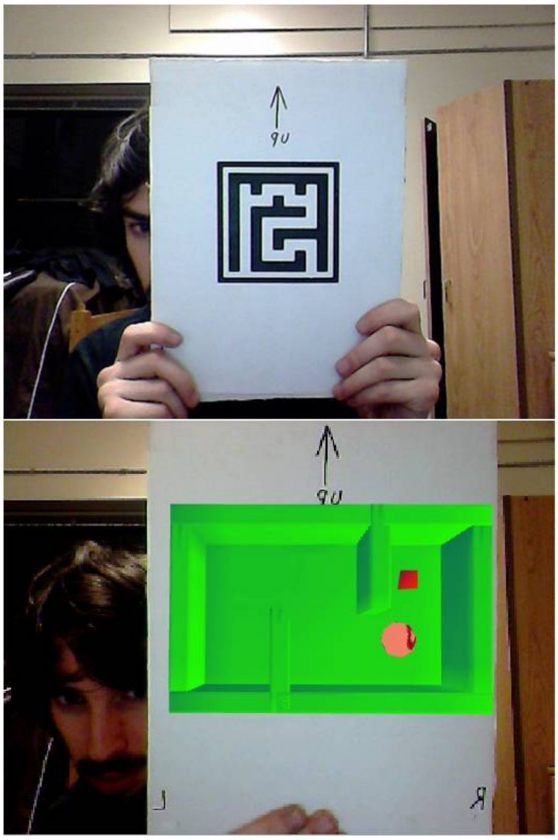

Figure 9. A *student interacting with the Maze Game*

While this is a relatively straightforward design, it involved a wide range of problems to be resolved and thus multiple software toolkits. Four main toolkits that contribute to this game's functionality. FLARtoolkit (Flash/ActionScript port of ARToolkit) deals with camera and marker detection. Papervision3D (open-source real-time 3D engine for Flash) deals with the construction and placement of maze walls. JiglibFlash (open-source ActionScript 3D physics engine) provides the collision detection between the ball, the floor, and the maze walls as well as gravity to propel ball movement. Finally, FlashDevelop (open-source code editor for ActionScript 3) compiles all the layers of code and runs the game application. The maze walls are built and placed based on X, Y, and Z coordinates, and then the gravity is directed inward from the Z axis. The floor is the plane with collision detection, preventing the virtual ball from falling down.

Another variation of this game, proposed but not realized, could utilize a mobile device instead of a computer. It would use a stationary marker with the device functioning as a display and a virtual maze. In this case, the device's accelerometer, compass, and tilt sensors would provide the rotation and slop information. This is one of the earlier projects developed for the course before the Vuforia and Unity3D platforms were introduced. Presently, the latter would be the platform of choice from the physics engine, easiness of development environment, and mobile output perspectives. Additionally, the Unity3D game engine would provide a more effective and streamlined environment for graphic user interface (GUI) development, particularly in tracking game scores and enhancing user interactions.

8. Broader Discussion

AR technology is entering a new stage where it is no longer the domain of technology-oriented individuals with heavy involvement of computer programming and other software tools. Products such as Vuforia, Qualcomm's plugin for the Unity3D Game Engine, delivers a highly functional tool that can be easily integrated into academic teaching and professional practice. The choice of a game engine like Unity3D, used to develop Sustainable Economy game, further makes the commercialization of AR technology easier and more imminent. The ability to integrate physics and other modules already existing in game engines simplifies the development process and reduces the need for technology savviness from the creative team. This does not mean that the development is completely effortless as far as coding is considered—scripting is always required for effective game engine implementations—but it significantly eases the learning curve, leading to democratization of digital creative tools. This transition from technology heavily involving tools to designer-oriented technology directly facilitates the content and the user becoming the primary drivers for the future of AR. This also suggests that the climate is ready for design schools and practices to embrace AR technology as a new creative and information visualization medium.

A number of the AR applications discussed here exemplify an idea of "learning anytime, anywhere," which builds on Weiser's proposition for the role of computation in the 21st century [Wes1991]. This new role synergizes key characteristics of AR environments that include location awareness of data sets, always-connected networks, and the ability to superimpose images of the physical world with interactive digital graphics. It allows for passive as well as active interaction with information and virtual content. Users are able not only to visually experience static information but also to interact with data in more dynamic and speculative ways by posing "what if…" questions. These speculative investigations create an environment of increased user engagement with the benefits of experiential learning.

Through the AR projects and courses discussed above, students are becoming aware of new modes of visual and data-based thinking. Concepts such as location- and context-awareness form an important framework for dealing with the over-supply of information and navigating the current, almost ubiquitous data jungle.

While teaching AR-based courses, lectures and discussion are usually heavily involved with the mechanics of AR technology, which often overwhelm students this initial technology shock quickly evaporates, with projects' focus shifting toward design, user experience, and content. Projects connect with other disciplines and uses that respond to a broad range of social and cultural needs. Students perceive AR technology, even more than other modes of computer graphics, as highly transparent, without a strong technological footprint. Thus, this technology naturally transitions them to explore diverse content-based topics. There was very little "technology for the sake of technology" attitude among students, who naturally gravitated toward the multitude of ways to connect AR technology with design, cultural, or social needs.

The course discussed above attracted a diverse group of students. While all of them were interested in the AR technology, they all saw different opportunities emerging from its use. For architecture students it allowed for an interactive visualization of buildings and built environments with context-aware capabilities. Similarly, industrial design majors perceived AR technology as an effective way to communicate product design, its assembly, and product branding. A number of information technology (IT) students developed gaming applications, while communication students saw opportunities in various aspects of interactive print and gamification-based motivational activities. Ultimately the AR technology became a lateral platform for collaboration that manifested itself in a diverse range of applications, with each of them well integrated into and benefiting individual design and communications disciplines.

9. Conclusions

AR-based applications increasingly occupy an important place in branding/marketing, tourism, education, and many other parts of life. AR has brought the virtual and the physical world closer and made them highly interconnected and interdependent through location-awareness, enhanced data overlays, and user-focused content. It also finds its applications in a diverse range of disciplines. This is evident in the types of applications coming to the mobile market and in the technology development associated with Google Glass, Microsoft's HoloLens, and even products like Google Cardboard. All these indicate broad and rapidly developing interests that are also reflected in academic curricula and general public attitudes.

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Student Project Credits

FashNYC: *Philip Caleja, Nicholas Haby, and Daniel Schittone*

Highline Tour: *Mike Litus, Pawel Zawistowski, and Travis Flick*

Augmented Interiors: *Samantha Goldman and Kirstianne Marcado*

The Maze Game: *David Einstein*

The Sustainable Growth Economy: *Louis Saporito and James Wolff*

Endnotes

[1] www.110stories.com/
[2] the-tuts.org
[3] www.layar.com/layers/pdnar1/
[4] comeoutandplay.org/2008_comfortofstrangers.php
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[6] www.layar.com/layers/highlinefinal/