Inquiry: The University of Arkansas Undergraduate Research Journal

Volume 11 Article 4

Fall 2010

Smart Objects in a Virtual World

Akihiro Eguchi
University of Arkansas, Fayetteville

SMART OBJECTS IN A VIRTUAL WORLD [1, 2]

By Akihiro Eguchi
Department of Computer Science and Computer Engineering

Faculty Mentor: Craig Thompson
Department of Computer Science and Computer Engineering

Abstract

The coming Internet of Things will usher in a smart semantic world where many more physical objects will be networked so that they can communicate with each other and with humans. This paper identifies protocols that smart objects will need to follow and the ways in which today's virtual worlds can be used to better design and understand these protocols for tomorrow's smart world.

Problem

Pervasive computing is a megatrend. Computing has migrated from mainframes to desktops, from laptops to cell phones. Embedded computing is increasingly integrated into objects such as cars and washing machines. An "Internet of Things," where every individual object has a unique identity provided by technologies such as RFID, is approaching. There is talk of smart worlds full of smart objects. But – what makes a smart object smart?

Objective

The objective of our project [1] is to gain an understanding of how to design "smart objects." Our long-term aim is to help to create a collection of interoperability standards that provides a migration path to convert incrementally a world of ordinary objects into a smart world containing smart objects, one smart object and one protocol at a time.

Related Work

Since 1990, the World Wide Web has been accessed to construct web pages and use URLs to link information. Since 2001, the research community has been actively identifying ways to make the World Wide Web into a "semantic web" [2] so that machines can access knowledge sources and use business rules to locate and reason about web-based information. Smart home and smart car technology [3] methods and standards have been developed to control refrigerators, doors, and other parts of our environment. Radio Frequency Identification (RFID) technology provides a useful, low-cost way to manage identity and communicate with any object. Smart phones are beginning to be used as remote controllers, as a search of Google Patents shows (http://www.google.com/patents?as_q=smart+phone+as+remote+control+device). Recent papers have begun to generalize this work to explore frameworks for smart objects [4][5][6] that identify some of the attributes that make an object smart. Our work differs in that we believe a smart object is more or less smart depending on the standard protocols it supports, and these protocols can change over time. Our work also differs in that we use 3D virtual-world technology to construct and demonstrate the protocols in an understandable manner.

Thesis #1 – A smart object is made smart by the protocols it obeys.

Today's ordinary objects (e.g., a chair, a lamp, a can of corn, or a pet) have interfaces. For example, a lamp has a physical interface consisting of size, shape, flexibility, weight, and composition; a visual appearance interface with aesthetic properties including color, brightness, and texture; a functional interface with an application program interface (API) that humans use to turn the lamp on or off; a power interface for connection to the electric grid; an implicit identity so people can tell two lamps apart even if they look the same; an implicit ownership (*I saw a new car at the dealership. I just bought the car, so now it's mine and used.*); and a compositional interface typically used for repairs. Objects may also have a corresponding repair manual (a model kept at home in a drawer of user manuals), associated images that appear in retail catalogs or in photographs, a location where the owner keeps the spare bulb, and a history and / or schedule of use. This list is not complete.

What additional interfaces would transform an ordinary object into a smart object?

- Explicit identity – Explicit identify could be implemented using RFID tags or other means. Identity provides a way to address each object uniquely. Legal ownership and an object's ontological type are additional interfaces related to aspects of identity.[3] Nearly everyone can afford hundreds of RFID tags (at $.07 each) to explicitly identify all the objects they own, though it is not yet cost effective to do so with inexpensive items such as those purchased at grocery stores. Local identities can be used within an enclave so that only members know the mapping to global identities; thus, the RFID tags in one's home are not meaningful if read from outside.

- APIs supported – A smart object may support one or multiple APIs, and these different APIs may be available for different purposes and to different personnel. The owner may be able to use

[1] Accepted as a position paper at the *X10 Workshop on Extensible Virtual Worlds*, venue: Second Life, March 29-30, 2010, http://vw.ddns.uark.edu/X10. Accepted and presented at *Conference on Applied Research in Information Technology*, sponsored by Acxiom Laboratory for Applied Research, Conway, AR, April 9, 2010.

[2] See YouTube video available on the web at http://vw.ddns.uark.edu/index.php?page=media (see *Healthcare Remote Control and Smart Objects* demo)

the object, but a qualified repair person might be required to repair it.

- Security – Not just anyone should be able to command, control, and communicate with one's possessions. Access control could be used to specify any user's digital rights along with encryption to communicate securely over less-secure channels. Many objects will communicate only with their owners or with a repair person.

- Object-to-object communication – A networked object is one with which humans or other objects can communicate. The network can be wired or wireless, local area or wide area. It may use 802.11* or RFID and may communicate through several messaging languages such as SNMP or WSDL. [4]

- Human-to-object communication – A person needs a way to command, control, and communicate with smart objects. Assuming a person has a way to designate a device and upload information about that device (e.g., its ownership or API), then a GUI or menu-based interface can be used to control or query the device, possibly from a remote location. [5]

- Micropayments – There may be a cost for accessing, communicating with, or using an object which one does not own. Some objects may have longer life spans and better sustainability properties than others.

- Plugins – A basic device might be extendible with plugin behaviors. The functions of a simple thermostat can be extended with a scheduler plugin to designate times of the day and days of the week and / or with a history-logging plugin to remember all past settings, which is useful for calculating energy usage.

- Driver Update – As with other kinds of software, a device driver update service is needed.

The above protocol list is incomplete, and additional useful protocols are mentioned below. Each item needs refinement, and one could argue about any or many of the characterizations. For instance, implicit identity is sufficient for many purposes, such as "Buy me one of those lamps."

Does an object have to support all interfaces to be smart? Is there a core set? Not necessarily. A degenerate smart object might contain no additional interfaces as long as it is possible to add interfaces from the list. The binding time for adding smart object protocols could be during the design or assembly, or it could be dynamic. For example, protocols could be added as needed during use. As interfaces are added (or removed), the object becomes increasingly (or decreasingly) smart.

Are all the smarts located inside the object? No, but some might be. The following is a simple algorithm for making a smart world. Add an item-level RFID to many or all objects, which can be done inexpensively for all objects in the home. Add an RFID reader to a smart phone, just as GPS was recently added to cell phones and RF plugins are now being added to control televisions and stereos. Since the smart RFID-enabled phone can now read the tags of any object and since the phone is already connected to the Internet, all information about the object can be downloaded from the web cloud. Chairs with RFID tags will immediately become smart. Of course, to achieve full value, future devices will need to be manufactured with network controls so that people can remotely control their behaviors. This is not to say that smart objects will contain no processing. Rather, the knowledge and processing that makes a smart object smart might be contained within the object, the controller, the user, and/or various information sources on the Internet, and different smart objects may distribute this information differently. For instance, the Internet might be only intermittently available, and smart objects might need to cache some of the log history to upload later.

A significant challenge to the widespread adoption of smart objects involves reducing complexity while increasing functionality. Today, managing 5 to 10 network objects is challenging and requires humans to run virus scans, set up firewalls, change permissions, run defragmenters, and download security updates. Many users (e.g., the elderly) are challenged by this complexity and just want unintelligent, simple, reliable, and low-maintenance objects. Smart complex objects will compete against unintelligent objects on criteria such as cost, reliability, functionality, and ease of use. In a world where every user controls hundreds to millions of smart objects, having hundreds or millions of separate remote controls (one per object) does not scale, so truly universal remotes (e.g., smarter smart phones) will be needed. These Star Trek-type communicators are called soft controllers [7] because they import different object interfaces from the objects and network. Furthermore, different users may see the object differently, so one user may have a simple controller while another has a more sophisticated controller. With a more sophisticated controller, for example, the typical problem of hitting the input button on a TV remote and not understanding how to reset it is solved.

Thesis #2 – Virtual Worlds are good places to develop Smart Object Protocols.

In the future, when people go to the store, buy a smart object, and bring it home, a 3D model of the object will be installed into the virtual model of their smart home (another protocol). Changes people make in the real world may affect the model and vice versa, resulting in a bidirectional mirror world [8].

In the meantime, before the real world converts to smart-object protocols, it is necessary to understand how such a world will function. What will it be like to manage and maintain thousands of smart objects, especially when many people have trouble maintaining tens of complex semi-literate objects such as laptops, stereos, and televisions despite having a drawer full of user manuals? Certainly, people do not want to have to remember to set manual permissions on the TV channel by channel when a houseguest visits, but each family member might want an individual

[3] Just because an object has identity does not mean that everyone has access to all aspects of identity. For example, we do not tell each other our names or Social Security numbers except when there is a reason.

[4] An additional interface for this list of protocols is Business Rules and Policy Management. For example, medical personnel will need a way to control collections of objects so that a smart IV drip can synchronize with a smart blood pressure machine, as discussed later.

[5] People do not want simply to talk to one individual object at a time. Sometimes, they want to talk to collections of objects (e.g., "Turn off the lights and the heater in the bedroom when I leave for work.").

list of favorite channels. The world needs to become simpler, not more complex. Therefore, uniform and simple ways to manage a smart world are needed. Virtual worlds provide a way to manage and manipulate smart objects, and simulating the objects in a virtual world helps people imagine how new devices can change the world. In addition, since development and testing in a virtual world may eventually be less expensive than it is in the real world, this approach to prototyping and testing could provide advantages over real-world prototyping and testing. In all likelihood, smart-object interface protocols will be platform-agnostic, operating in either the real or the virtual world.

Thesis #3 – Standards will be needed soon.

Based on our description of smart objects, some objects are already smart, and more are becoming smarter every day. A migration path is in place that is already causing more object types to be made smarter, application by application. For example, smart home entertainment, security systems, and washing machines are typically not interoperable. To get the most value, interoperability standards will be needed to enable plug-and-play so that all objects obey a suite of smart-object protocols, possibly with many implementations. Understanding more about such a suite and early testing of the suite can accelerate progress toward a universally smart world. As noted above, virtual worlds provide a way to design and test these protocols.

Prototype

To experiment with some smart object protocols, we developed a collection of smart healthcare objects in the virtual world Second Life. We toured the University of Arkansas School of Nursing's training facilities with the original intent of determining how to overlay training scenarios on virtual world architectures (still an interest), but our research focus became how to build smart objects for training. Screenshots are provided to give the idea of what we developed, and videos demonstrating the functions of these objects are available on the web [Smart Objects and Remote Control in a Healthcare Setting (http://www.youtube.com/watch?v=YlsE3AVnO4Q); Using Second Life for Healthcare Training (http://www.youtube.com/watch?v=MqaeE1bp2Qo)].

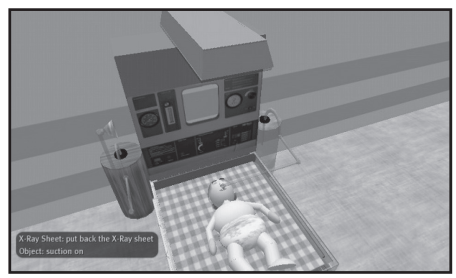
<u>Smart Objects</u>

As can be seen, our selected smart objects were:

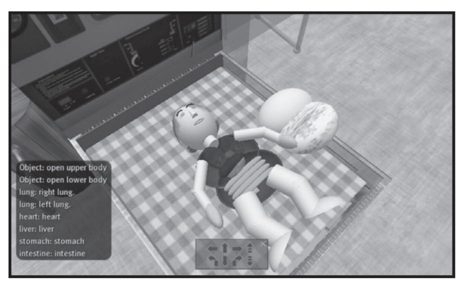
- A hospital bed with several functions for the patient's comfort, including a bed angle adjustment function, a fan switch, and a pullout table.
- A wall-mounted air conditioner / heater that can be turned on or off or adjusted from cool to warm, as visually displayed with blue and red particle effects.
- A human-scale dummy for nurses' training. We developed an infant dummy that can be opened to show the internal organs. The name of each organ is displayed when activated.
- An infant warmer with mechanical arms to give the infant oxygen and to measure suction. The machine can display an X-ray from a nearby portable X-ray machine, and it also has a drawer and a pullout table.
- A portable X-ray machine with a screen on

HILL-ROM Stabilet Infant Warmer

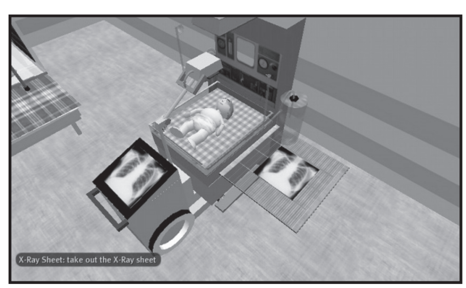
Infant dummy in infant warmer



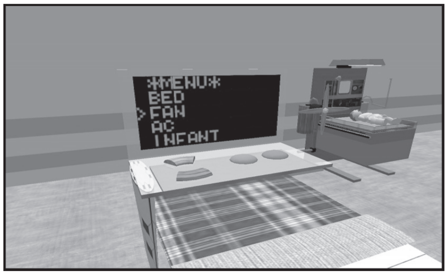
Baby warmer machine with multiple functions



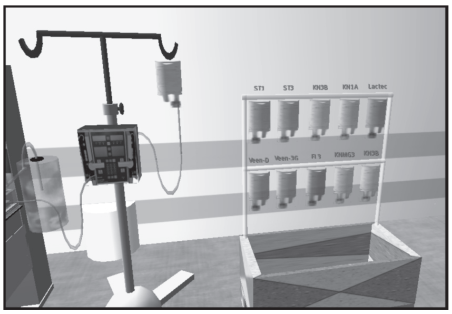
Dummy with several training functions for nurses



Portable X-ray machine



In-world soft controller prototype to control smart devices



IV drip machiine with a bottle changing function

which a digital picture of the X-ray is displayed. When the machine is clicked, it moves its arm upward and approaches the object. Then, the red particle is shown as the X-ray picture is printed on the X-ray sheet in the infant warmer and is displayed on the digital screen. When the machine is clicked again, it returns to its original place and turns off the digital screen.

- An IV drip stand. See the training discussion below.
- A search robot that roams around the virtual healthcare clinic to search for and catalog other smart objects. The robot has a remote control and can leave the user's sight to discover new smart objects as it traverses the clinic independently. A handheld GPS control device with scheduling capabilities can store the current location of the user as he or she enters the checkpoints that the robot will follow. The user can create fixed paths which the robot will traverse by itself. An RFID tag, an identification tag which responds to an RFID light source, responds by giving its identification information. The robot's position can be approximated based on its response to the RFID light emitter.

Soft controller

In addition to the scripted smart objects described above, we developed a protocol for all of our smart objects so that they can be controlled in a uniform manner. All of our smart objects in Second Life use listen event handlers (using Linden Scripting Language) executed when the llListen function receives a chat message that satisfies a condition in an assigned channel. As a result, all devices accept commands from external sources, either avatars or other smart objects.

A controlling device shows the menu of functions for each smart object on the soft controller screen. Avatar users can choose from the menu and control the devices. Since we use the same format of input for each smart object, there can be more than one controller. The controller has text-based instructions on its screen using imported Roman letters.[6] The names of smart objects in the range are displayed on the screen, and the user is asked to choose one. Then the functions of the chosen device are displayed on the screen, and the avatar can choose from the list and send the command to the device.

Instead of a real-world frequency band such as infrared, in Second Life, various channels are used to communicate between devices and avatars or among devices. All smart objects are in one sense connected to each other because all the devices can be controlled by one controller. Although each device has different uses and different commands and works independently, a common input format will result in a universally formatted API.

Training

We developed two training scenarios:

- The infant dummy has a function that trains nurses in monitoring the saturation of peripheral oxygen (SpO2) or the blood-oxygen supply. When a trainer avatar types "/5 start SpO2," the infant starts with 100% SpO2, but the level decreases. The infant dummy's face becomes paler as it loses SpO2, and if the SpO2 drops below 75%, the infant dummy dies. When the SpO2 drops below 95%, a monitor shows the message "problem zone." When the level goes below 85%, the message "danger zone" is displayed. When the nurse avatar administers oxygen, the infant dummy gradually stabilizes as the SpO2 returns to 100%.
- Different IV medicine bottles are used for another nurse training simulation that allows nurses to gain virtual practice in setting the proper infusion bottles. Training is begun by touching the console on the IV drip stand. A prompt instructs the nurse to set a certain bottle. If the procedure is completed successfully, a new bottle is prompted. This process continues until training is complete, after which an overall score is produced.

Actual nursing dummies are expensive and are available only at nursing schools and similar facilities. We originally conjectured that using virtual worlds to simulate nursing dummies and associated procedures could accelerate training for nurses anywhere in the world at any time and at no cost. We still believe our conjecture is valid but to a more limited extent. The virtual world can familiarize nurses-in-training with devices, their operation, and procedures and thus can be used for training. However, certain actions such as learning the physical action of administering a shot or the fine motor skills needed to open a latch still require hands-on experience.

Potential Impact

An interesting exercise is to consider an object and ask, *If this object could talk, what would I want to ask or tell it?* The object might know about its manufacture history, its similarities to and differences from other types of devices, its maintenance requirements and history, its location and environment, and other information. Simulating devices in a virtual world can provide a new means of understanding how devices operate and how they are repaired, leading to a potentially more interactive approach to the traditional training manual or training video. Usually, to create a real-world test model requires significant funds; however, a virtual-world simulation is often much less expensive and can be made available anywhere in the world for little or no cost. Although there will be some differences between a virtual object and a real-world object, simulations have a useful purpose.

A problem with many Second Life scripted projects is that avatars other than the developer do not know whether the object is scripted or how to operate it. Even if a device has many functions, it is useless if the user cannot learn how to control it. Therefore, not only the communication between devices but also the communication between the device and the user is important.

Establishing a standard interoperability infrastructure for smart objects makes it possible to mass produce interoperable smart objects, real and virtual, that are available to users anywhere in the world, thus accelerating the move toward a smart world. Creating a unified, extensible standard protocol for controlling smart objects solves this problem and makes it possible to control all such devices from a controller device. The controller can upload the controls from any device, even devices it has never encountered before. Separating the interface of a device from the implementation benefits end users and developers for the same reason that pull-down menus benefitted end users in the 1980s by giving a common look and feel to a wide variety of applications. Developers benefit because separating the interface from the device can reduce the cost of designing physical interfaces where there are no standards. The end user benefits because a uniform thermostat controller can be used with any thermostat without the user's needing to learn the custom interface of each new thermostat. In other words, it is easier to control unfamiliar devices because the interface style is familiar.

With a uniform interface for smart objects, it is easier to build higher-level interaction protocols for controlling assemblies of objects. Many of the business rules (another protocol) for such assemblies are application-specific, but the ability to see physical objects as exporting their interfaces in an object-oriented programming style bodes well for providing higher-level mechanisms for composing them together.

Just as the World Wide Web uses URLs to link information, a virtual-world URL that includes a region and an x/y/z location can be used to teleport to a location in a virtual world. Similarly, RFID tags and smart phones can be used to locate objects in the real world. Real and virtual objects have unique identities. We can associate additional information with these identities in web- or cloud-based data sources and associate information and rules with these objects. In this way, we can view our work as extending the "semantic web" directly toward a "semantic world" where more information about any physical object and the ability to control the object (subject to access control permissions) may be available to humans via their soft controller smart phones.

Future Work

Areas for future work include the following:

- Determining and removing limitations of Second Life as a simulation platform. [9]
- Determining standards for representing 3D objects – SL prims do not mesh well with CityGML/Collada and AutoCAD standards. Some applications may benefit from more or less modeling accuracy. Should we compose a proverbial elephant with a modeling notion of a top prim?
- Improving identity management so that an object retains its identity even if it is stored and retrieved.
- Improving access control so that it is easier to manage shared objects. In Second Life, many students build interesting objects and then graduate from the program without removing all protections; as a result, others in the group cannot build on the work.
- Determining how to represent interfaces in a general manner, e.g., using SNMP, WSDL, or other standard approaches.
- Gaining experience in combining the smart-object protocols and implementing them in a variety of ways, including using smart phones as platforms.
- Extending smart phones with RFID readers and smart objects with network actuators.
- Arranging the hundreds of thousands of real-world smart objects into 'lower ontologies" to make it easier to develop protocols using categories and inheritance. [10]
- Identifying additional smart-object protocols, e.g., touch, taste, and smell.

References

[1] "Modeling Healthcare Logistics in a Virtual World," Project website, http://vw.ddns.uark.edu. Also see
• C. Thompson, "Everything is Alive," IEEE Internet Computing, January-February 2004. http://csce.uark.edu/~cwt/DOCS/2004-01--PAPER--IEEE-Internet-Computing--Everything-is-Alive.pdf
• C. Thompson and F. Hagstrom, "Modeling Healthcare in a Virtual World," IEEE Internet Computing, September-October 2008, http://csce.uark.edu/~cwt/DOCS/2008-10--Modeling-Healthcare-Logistics-in-a-Virtual-World--final.pdf
[2] T. Berners-Lee, J. Hendler, and O. Lassila, "The Semantic Web," Scientific American, May 17, 2001. http://www.sciam.com/article.cfm?id=the-semantic-web&print=true
[3] Home Automation, Wikipedia, http://en.wikipedia.org/wiki/Home_automation
[4] Charlton, Stefan. Ubiquitous Computing: Smart Devices, Environments and Interactions. New Jersey: John Wiley, 2009. Print.

[3] An internationalization service would be straightforward so that different avatars could control the same devices using their native languages. Support for text would be a very useful addition to SL.

[5] C. Floerkemeier et al., "Smart Objects as Building Blocks for the Internet of Things," IEEE Internet Computing Jan.-Feb. 2010. Print.
[6] Pieter Jorissen, Maarten Wijnants, and Wim Lamotte. "Dynamic Interactions in Physically Realistic Collaborative Virtual Environments." IEEE Trans. Vis. Comput. Graph. 11.6 (2005): 649-660. Print.
[7] C. Thompson, "Smart Devices and Soft Controllers," IEEE Internet Computing, January-February 2005, http://csce.uark.edu/~cwt/DOCS/2005-01--PAPER--IEEE-Internet-Computing--Smart-Devices-and-Soft-Controllers.pdf
[8] P. Martin, J. Haury, S. Yennisetty, D. Crist, and S. Mandava, "Mirror Worlds," Position Paper, X10 Workshop on Extensible Virtual Worlds, venue: Second Life, March 29 – April 2, 2010.
[9] Keith Perkins, "Virtual Worlds as Simulation Platform," Position Paper, X10 Workshop on Extensible Virtual Worlds, venue: Second Life, March 29 – April 2, 2010.
[10] T. Censullo, "Ontologies for the Virtual World," Position Paper, X10 Workshop on Extensible Virtual Worlds, venue: Second Life, March 29 – April 2, 2010.
[11] A. Eguchi, D. Freeman II, and L. Revollo, "Smart Devices in a Virtual World," Term Project Report, Artificial Intelligence, CSCE Department, University of Arkansas, Fayetteville, AR, Fall 2009, http://www.csce.uark.edu/~cwt/COURSES/2009-08--CSCE-4613--AI/TERM-PROJECTS/FINAL-REPORT--Smart%20devices--Eguchi-Freeman-Revollo.doc

Mentor Comments

Professor Craig Thompson provides insight into the virtual world research domains and their potential value to us in the future. Akihiro's paper was the recipient of an Undergraduate Research Award, but two other papers in this journal issue – by Kumar and by Starling – also take on the challenge of current and future applications of artificial intelligence.

For the past three years, my research has involved how to use 3D virtual worlds like Second Life to explore what the real world will be like when every physical object is a network object, with its own identity, behaviors, and the ability to communicate with humans and other objects. While this may seem far-fetched, it is happening rapidly as cheap RFID tags reach consumers with smart phones that can connect to Internet information repositories. Very soon, people will use smart phones as remote controls for not just TVs and stereos but many other interactive objects. They will be able to point at a real-world object to get more information similar to the way we follow web links today. In Fall 2009, I taught Artificial Intelligence where term projects focused on how to build such a smart world. All of my students were seniors or graduate students – except one sophomore, Akihiro Eguchi. For his term project, Akihiro decided to model healthcare equipment, in particular nurse mannequins and associated medical equipment to demonstrate the idea of how to model smart objects using virtual world technology. Akihiro visited Dr. Nan Smith-Blair, associate professor and interim director of the University of Arkansas' Eleanor Mann School of Nursing. She provided a tour of their nursing facilities and demonstrated nursing mannequins and associated equipment. Akihiro took pictures and notes. All was quiet for about a month, and then it came time for project demos. Akihiro's was absolutely excellent. Not only did he model the mannequin and equipment, he also demonstrated a full scenario of how to use a model of a smart remote control device to query a smart object for its programming interface. The interface is copied from a virtual object to the virtual remote device. Then the remote can be used by a human to control the object. Akihiro even built a robot that wanders through our virtual hospital to discover smart objects that humans can then communicate with. Akihiro's work clearly demonstrated several important aspects of how virtual worlds can model future ubiquitous computing. See Healthcare Remote Control and Smart Objects YouTube video – available on the web at http://vw.ddns.uark.edu/index.php?page=media (). In Spring 2010, Akihro, still a sophomore, took my graduate course Modeling Healthcare Logistics in a Virtual World. He continued to refine his work adding training scenarios and also retail supply chain scenarios. He wrote a paper based on his work "Smart Objects in a Virtual World" for the X10 Workshop on Extensible Virtual Worlds (http://vw.ddns.uark.edu/X10, March 29-30, 2010). This international workshop, organized by myself and members of the IBM Academy of Technology, attracted world leading developers and academics in the emerging virtual world field. The 2-day event was held entirely in Second Life. Akihiro attended the event and, as a scribe for several sessions, took careful notes. This summer, Akihiro is taking advantage of an UA Honors College travel grant to present our paper "Towards a Semantic World: Smart Objects in a Virtual World" in the Web Virtual Reality and Three-Dimensional Worlds Workshop (IADIS WEB3DW2010) in Freiburg, Germany, 26-31 July 2010. Also, during the summer 2010, Akihiro applied for a UA Undergraduate Research Grant and is working with CSCE PhD candidate Josh Eno to help analyze data from Josh's virtual world search engine to see if we can rapidly classify virtual world objects into an ontology classification and can query to find, say, all Second Life parcels that are focused on healthcare, supply chains, RFID, or other affinity groupings. Akihiro's work and our team's crosses over from virtual worlds to real world pervasive computing and is in the vanguard of technologies to build a smarter world.