

# Galatea: Personalized Interaction with Augmented Objects

by

David Arthur Gray Gatenby

B.A. English & Drama, University of Virginia, 1993

M.S. Computer Science, New York University, 2003

Submitted to the Program of Media Arts and Sciences,  
School of Architecture and Planning,  
in partial fulfillment of the requirements for the degree of

Master of Science in Media Arts and Sciences  
at the  
Massachusetts Institute of Technology

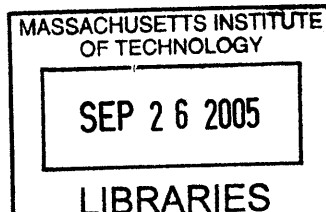
September 2005

© Massachusetts Institute of Technology, 2005. All rights reserved.

Signature of Author \_\_\_\_\_  
Program in Media Arts and Sciences  
August 5<sup>th</sup>, 2005

Certified by \_\_\_\_\_  
Pattie Maes  
Professor of Media Arts and Sciences  
Program in Media Arts and Sciences  
Thesis Supervisor

Accepted by \_\_\_\_\_  
Andrew B. Lippman  
Chairman, Departmental Committee on Graduate Studies  
Program in Media Arts and Science



ROTCH



# **Galatea: Personalized Interaction with Augmented Objects**

by

David Arthur Gray Gatenby

Submitted to the Program of Media Arts and Sciences,  
School of Architecture and Planning,  
on August 5<sup>th</sup>, 2005, in partial fulfillment of the  
requirements for the degree of  
Master of Science in Media Arts and Sciences

## **ABSTRACT**

In Galatea (gäl'ə-tē'ə), digitally augmented physical objects actively attract a person's attention to online information relevant to both the object and the person's interests. Galatea combines intelligent software agents and digitally augmented physical objects to uniquely bridge the gap between the two disciplines. In a unique twist on typical Ubiquitous Computing models that require intentional request for or asynchronous, periodic delivery of information, Galatea's smart objects proactively attract the attention of a nearby person by blinking a light when there is relevant information about the object. The object also sends the relevant information to the person's cell phone. We use books as our test case. Any augmented book can visually attract a user's attention when there is information it believes is relevant to the user. This information is personalized, i.e. unique to the person's interests, the current location, and the book, and when appropriate is delivered unobtrusively using the person's cell phone interface. A user can likewise request information from the books in the nearby vicinity by searching the books using their cell phone. A user study of and demonstration responses to Galatea show tradeoffs between the benefits of orienting information in objects and its usefulness as a collaborative tool, versus its potential as a distracting and invasive interface.

Thesis Supervisor: Pattie Maes  
Professor of Media Arts and Sciences

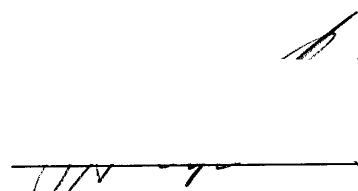


# Galatea: Personalized Interaction with Augmented Objects

by

David Arthur Gray Gatenby


Thesis Reader:



---

Ted Selker  
Associate Professor of Media Arts and Sciences  
Program in Media Arts and Sciences

Thesis Reader:



---

Henry Lieberman  
Research Scientist  
MIT Media Laboratory



# Table of Contents

<b>Acknowledgements.....</b>	<b>10</b>
<b>Chapter 1. Introduction.....</b>	<b>11</b>
1.1 Cell Phones as Context Managers.....	13
1.2 Extending Personalization Into the Real World.....	15
1.3 Galatea: a summary.....	20
1.4 Guide to the rest of this thesis .....	24
<b>Chapter 2. Background / Related Work .....</b>	<b>25</b>
2.1 Recommendation Systems .....	26
2.2 Embedded Communication Devices for Ubiquitous Computing .....	28
2.3 Physical Object Based Information Displays .....	31
2.4 Discussion .....	32
<b>Chapter 3. Galatea Usage Scenarios.....</b>	<b>33</b>
3.1 Relevant Book Scenario .....	35
3.2 Book Influence Spreading Scenario .....	37
3.3 Book Search Scenario .....	38
<b>Chapter 4. Software Design and Implementation .....</b>	<b>40</b>
4.1 Software Design.....	41
4.1.1 User Profile.....	41
4.1.1.1 User Profile Graph.....	42
4.1.1.2 Making Recommendations.....	47
4.1.1.3 User Interaction History .....	50
4.1.2 Book Profile .....	51
4.1.3 Interaction Manager.....	52
4.1.4 Search Inside Functionality .....	54
4.1.5 Software Network Protocol .....	56
<b>Chapter 5. Test Platform and User Interface.....</b>	<b>59</b>
5.1 Phone.....	59
5.1.1 Phone UI Screens.....	60
5.1.2 Application Modes .....	61
5.1.2.1 Relevant Books Mode.....	62
5.1.2.2 Related Books Mode.....	64

5.1.2.3 Search Results Mode.....	65
5.1.3 Phone Details .....	67
<b>5.2 Object Devices.....</b>	<b>67</b>
5.2.1 Description .....	67
5.2.2 Design.....	69
5.2.2.1 Price.....	69
5.2.2.2 Protocol .....	69
5.2.2.3 Size .....	71
5.2.2.4 Power.....	72
5.2.2.5 Capacitive Sensor.....	73
5.2.2.6 Device Discussion.....	74
<b>Chapter 6. User Study and Demonstration Responses</b>	<b>75</b>
<b>6.1 Personalization Assessment.....</b>	<b>75</b>
6.1.1 Setup.....	76
6.1.2 User Comments .....	77
6.1.3 Discussion .....	80
<b>6.2 Task Completion Study .....</b>	<b>81</b>
6.2.1 Setup.....	81
6.2.2 Results .....	83
6.2.2.1 Observations.....	83
6.2.2.2 User Comments.....	86
<b>Chapter 7. Future Work.....</b>	<b>88</b>
<b>Chapter 8. Conclusions .....</b>	<b>92</b>
<b>References.....</b>	<b>94</b>
<b>Appendix .....</b>	<b>98</b>
<b>Appendix A Object Device Schematic .....</b>	<b>99</b>
<b>Appendix B Bluetooth Gateway Schematic .....</b>	<b>100</b>
<b>Appendix C Study Questions.....</b>	<b>101</b>



## Table of Figures

Figure 1. Objects indicating their relevance. ....	13
Figure 2. Orb ambient display from Ambient Devices, Inc.....	32
Figure 3. Relevant book lighting up with relevant information on phone. ....	35
Figure 4. Relevant book shown on phone. ....	36
Figure 5. Book review selection screen on phone. ....	36
Figure 6. Book review page. ....	37
Figure 7. Book spreading its influence.....	38
Figure 8. Explicit Search Query. ....	39
Figure 9. Orkut profile. ....	42
Figure 10. Steps 1-3 of graph setup. ....	43
Figure 11. Steps 4-5 of graph setup. ....	44
Figure 12. Step 6 of graph setup. ....	45
Figure 13. Step 7 of graph setup. ....	46
Figure 14. Find weight of connection between user and book. ....	48
Figure 15. First, find shortest path.....	48
Figure 16. Remove previous shortest path and find next shortest path. ....	49
Figure 17. Repeat previous step. ....	49
Figure 18. Interaction manager ranks and chooses interaction opportunities. ....	53
Figure 19. GUI for Search Inside Results. ....	55
Figure 20. Data flow for related books alert. ....	57
Figure 21. Phone interface screens. ....	61
Figure 22. Phone GUI for relevant books notification.....	64
Figure 23. System components. Books, phone, gateway, interaction manager server.....	67
Figure 24. Embedded device. ....	68
Figure 25. Bluetooth Object Gateway. ....	70
Figure 26. Bluetooth piece of the gateway device. ....	71
Figure 27. RF Comparison Table. ....	73
Figure 28. Example survey page. ....	82
Figure 29. Results of user study. ....	85
Figure 30. Schematic for the object devices.....	99
Figure 31. Bluetooth gateway schematic. (Designed by James Cooley.).....	100

## Acknowledgements

Thanks to Pattie Maes and all the members of the Ambient Intelligence group at the MIT Media Lab for their feedback and support.

Thanks to my readers, Henry Lieberman and Ted Selker, for their advice along the way.

Thanks to the Media Lab for, well, being the Media Lab in all its geekysmartcool ways.

Thanks to family and friends, especially Jelly Bean and the Meatball, for your patience with d'Ape!

## Chapter 1.

### Introduction

*“There are two motives for reading a book: one, that you enjoy it; the other, that you can boast about it.”*

-- Bertrand Russell

I like books. I like reading books. I like talking about books and the things I read in them. Often when I walk into a room that has a shelf of books, whether it is a bookstore or a friend's living room or a coworker's office, I enjoy looking to see what kinds of books are there. If it is a bookstore, I look forward to exploring the many different kinds of books and considering the journeys each different book I look at might take me on. Sometimes all the books on display overwhelm me. When I go to a friend's house or stop in a coworker's office, and I have a chance to look at their bookshelves, I feel I get a little extra insight into their personality by seeing the things they put on their shelves. I often search around their collection for books they have that I might have read, or for books that might be of interest to me. Many of the connections I have made with people have been influenced by conversations about the different books we had read or liked or hated.

The joy of discovering new books initially motivated this work. Wouldn't it be nice, I thought, if books, which give me so much pleasure and subtly influence my views of the world, could have more of a life of their own? What if books that might be interesting to me could wink at me to suggest I check them out? What if a book could tell me that a friend had just read and liked it? What if a book could tell me that it was one of my favorite author's favorite books?

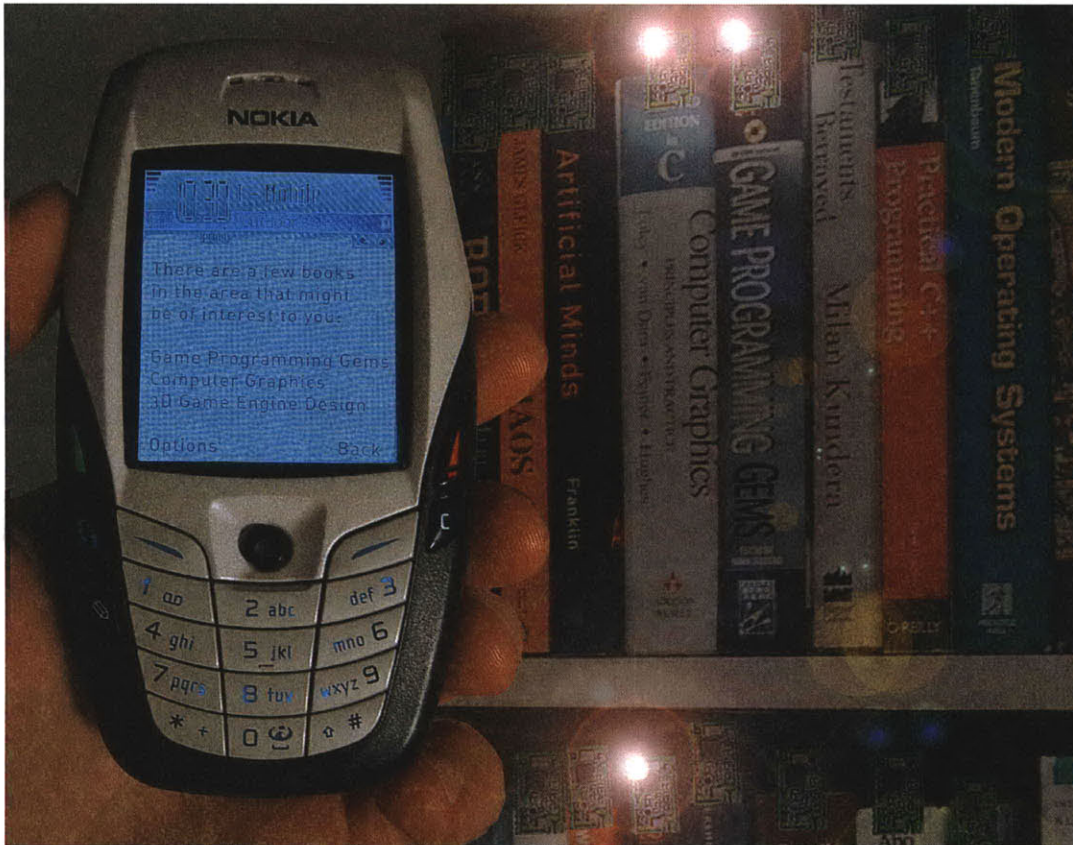
What if when I walked into a bookstore or a friend's living room the books that I might be interested in could all greet me by lighting up, and my cell phone could tell me a little more about why each one might be interesting? What if I could do a search in a bookstore and the books that matched my query would all light up?

In the following pages, we describe a system called Galatea\*, created to realize the scenarios in the preceding paragraph. We will talk about how the system integrates ideas from and is positioned amongst the ubiquitous computing, recommendation system, context-awareness, and smart-object disciplines. We will demonstrate that the Galatea system is a unique application that allows augmented physical objects to actively attract a user's attention to both the object itself and, using a cell phone interface, information about the object that is relevant to the person and the object. We will show how the information that is offered is uniquely personalized to an individual based on their interest profile, their network of friends, and their interaction history. We review what participants in our user study and assessment said about the system. We will review how we concluded from these comments that people are interested in getting recommendations from trusted friends and in knowing more about their friends' interests and that a system like ours, where physical objects are enabled with the ability to proactively facilitate these sorts of community-based interactions without a loss of privacy, is a welcome technology. We will also explore the prior work, influences, design considerations, and implications of the Galatea system.

\* Galatea - a maiden who was first a sculpture created by Pygmalion and was brought to life by Aphrodite in answer to Pygmalion's prayers.

## 1.1 Cell Phones as Context Managers

Everyone has a cell phone. Many people are starting to communicate using their phones in ways other than phone calls. They send email or other text messages from their phones. In many ways, people are no longer tied to our desktops to do our computing. Considering their size, our phones are quite powerful computers. As people become more and more accustomed to carrying our personal computers in our pockets, they will become more accustomed to using cell phones as interfaces to the physical objects and physical environment around them.



**Figure 1. Objects indicating their relevance.**

People are already used to this in countries like Japan, where buying a coke from a soda machine using your phone is commonplace and people are starting to use their NTT DoCoMo FeliCa phones as full-on credit cards[28]. Newer phones are equipped with assorted functionality like music players, cameras, and web browsers[12]. More and more they are used to push and pull almost any kind of data a user can imagine. People read spreadsheets, make stock trades, record movies. Any kind of data we can get online we are coming to expect access to on our phones.

As the data that was once locked away behind the desktop keyboard, video monitor, mouse model of computing becomes available to us as we move around our environments, people will have new ways to use the data. Instead of having to write down, print out, or remember what was learned online in order to bring that knowledge to the physical locations where the information is relevant, cell phones will provide a new means of using online information to help in direct interactions with one's environments. In many ways some of these capabilities already exist. For instance, with an Internet enabled phone, someone can do a web search on a cell phone while walking by a restaurant to get a quick review of it.

Even with these new functionalities marching ahead, there is still a fundamental divide between the physical world and the real world. For the most part, people still use a web browser to search over the entire web to do a search for a review of a product that might be sitting right in front of them. They shouldn't have to do that. Handheld devices allow people to talk to anyone anywhere in the world or search terabytes of info about almost any topic but they have little or no ability to help people learn about things that are literally right in front of them.

One of the problems with the divide between the digital and physical worlds is that computers haven't traditionally needed to be very context aware. As they were physically tied to desktops, they had no notion of different locations. Unlike

any other personal digital device, cell phones are changing that. Phones are uniquely positioned to become more than just personal communication devices. They are well suited to become personal context managers.

People carry phones around with them wherever they go. With GPS, phones can locate themselves in the world. With Internet access, they can interface with all the available online information. With Bluetooth or other near area RF technology they can talk to locally resident devices and other nearby mobile devices. The Ubiquitous Computing field takes on the challenge of enabling our environment with sensors to help make interaction with the digital and physical worlds more seamless[47]. People who have used the Galatea system have shown that they do not simply want a digital annotation overlaying the physical world, but they want a technology that will help them communicate more effectively with the people they share interests with.

In the coming chapters we will explore further some scenarios for how a cell phone can be used to help a person's immediate environment offer them relevant interaction opportunities. For now, suffice it to say that soon personal handheld devices will have the ability to understand where people are, what they are doing and have a good sense as to what opportunities there might be for them to take full advantage of their environments.

## 1.2 Extending Personalization Into the Real World

Many people spend a significant portion of their day online. They email with loved ones or coworkers sharing the activities and stories of their days and relating their opinions and thoughts about different topics. They network over the internet to find people with similar interests with whom they can share their experiences and

knowledge about those interests. People use web sites that offer them new products based on the usage patterns of others who behave similarly.

People are accustomed to using the tools that facilitate these kinds of interaction. Personalization agents, social networking, and information filters are common aids for people's online activities. While this sort of functionality already exists in the purely digital domain, people are much less likely to find these tools helping them interact with the objects in their environment.

The physical spaces people inhabit and the objects they employ and interact with are meaningful and important to the way people live. They say a lot about who a person is, who their friends are, what kind of job they have, their status, and their culture. Most physical things have some sort of symbolic meaning in relation to the people who use them, whether it is social, economic, or personal[7]. While it is possible for a person to be in a physical location and not use or refer to any of the physical objects (i.e. physical context), it is improbable. Look at the objects in the room you are currently in. There are probably objects that are very personal to you in some way, and other objects that hold less interest for you. There are also likely to be objects that if you think about them for a moment you realize have something about them that is intriguing. You might wish you understood something about the object better, or you may wish to understand how the object came to be in this location. Every thing, like every person, has a story; some more interesting than others. Often those hidden stories about objects involve people we know and could help us understand them better. Part of the motivation for this work comes from a simple curiosity about the stories that objects could tell, if they only had a voice. The Galatea system tries to begin to give objects a voice and help them open new channels of communication between people and the communities they share their interests with. The stories objects tell in the beginning may be very simple and functional, but they will be stories nonetheless.



When objects are found in a certain location, an ecology of sorts forms, and that ecology is generally representative of the location. In other words the objects in the location define the context of the location. When a person moves into a new home and moves a few boxes into the basement, the basement becomes a storage room. As time goes on, the owner might set up a workbench in one corner of the basement and put the boxes in the other corner. Now the space is divided into two different contexts, the workspace and the storage space. The context of a location typically defines the type of activity that takes place in the location and visa versa.

When a person is in a specific location, like their offices, bedrooms, workspaces, meeting rooms, or train stations, they are usually involved in activities that directly relate to the context of the space they are in. Unless they are homeless or missed the last train home, people usually don't sleep in train stations, and hence they don't often find beds there either. And while they might wish they could, they typically don't catch trains in conference rooms, and they usually cannot find train schedules there either. This seemingly obvious connection people and the spaces they inhabit throughout their days, with all the accompanying objects therein, has not been fully leveraged against the wealth of object specific information that exists in the digital domain. The chapter on related work will look at how people have tried to enable their physical environments with digital intelligence. Later chapters will explore our attempts at giving physical objects a means for managing and communicating their own digital data.

Let us return briefly to the relationship between digital information and physical objects. As mentioned above, people have many direct and indirect interactions with other people and objects in the digital world as they go about their daily routines. They send emails, check movie times, read reviews. In the physical world, people do similar things. They talk with friends and co-workers, play sports, read books and newspapers, eat, shop, etcetera. But there is a disconnect

between the digital and physical worlds. Using the traditional computing model, people often can't manage interacting with both at the same time in a seamless way.

In both of these domains, the physical and the digital, there are times when one could benefit by having access to the information only found in the other domain. For instance, if a person is planning to buy a camera, it would be nice for them to be able to both try out the camera and read reviews that other people have written online, especially if the reviews were written by someone the person knows. Generally, though, a person's computer is at home and the demo cameras are at a store, so it becomes a two or three step process. Read a few reviews at home, go to the store and look at a few cameras, go back to the office and recheck the reviews, and then perhaps make a purchase. Needless to say, this is an inefficient model.

People have begun using their cell phones to browse the web to get information relevant to their current physical world needs. People check movie times, look up restaurant addresses, and even get navigation assistance from online maps. But these activities are usually either performed for novelty or last resort reasons, not because they are the most intuitive or easiest to perform. As mobile computing matures and embedded devices become cheaper and more ever-present there will be more opportunity for our cell phones to be the logical center for managing the information flow between the rich contextual information of our physical surroundings and the dense set of reference material of the online world.

Given a dynamic model of what objects are in the current surroundings and an interest model of a person, a computer can try to predict what kinds of information might be useful to that person, and to have that information delivered to the person through the objects the information references. For instance, if someone were in an electronics store digital camera department, presumably they would be well served to have customer review information available to them on

their cell phone. They shouldn't have to search for reviews and hunt and peck through results. The software agent present on the phone should be ready with reviews for the cameras that are close to the person, preferably ordered by their ranking. If the information is available, the phone could also offer up the models of cameras that the person's close friends use. And more than that, the agent should parse those reviews and have the best cameras attract the person's attention to them.

This type of scenario suggests that merely a simple convenience is being added to a process we can already do on our internet-enabled phones. While in a limited sense this is true, in a broader sense augmenting our physical world with the world's combined digital knowledge as found online is a powerful notion, especially if the digital knowledge has been vetted through a person's social network and has been filtered by their interest profile. A layer of depth is added to our understanding of our lives by having more references to guide us through the world. A digitally augmented world would be like always having one's friends with them giving them advice right when they need it and helping them satisfy the many curiosities about their world that may come up at any time throughout each day.

Considering the size and relative scarcity of relevant information on the internet, filtering out as much of the useless noise as possible is not just a convenience, it is a necessity. Especially considering that most truly mobile devices, like phones or PDAs, have miserly GUIs with nearly unusable input mechanisms. Having a system that can make solid predictions about a person's needs and interests and guide them both to personalized information about objects and to the objects themselves would be welcome to most people.

The question is...how to make such a system work?

## 1.3 Galatea: a summary

This thesis looks at a piece of the solution to bringing the digital world and the physical world together in a more seamless way. Instead of going back and forth between the two worlds, the distinction should disappear. Mark Weiser, one of the progenitors of Ubiquitous Computing, said that the computer should become invisible to the user[46]. The digital services provided by the computer should "emphasize the metaphors of life, interaction with other people, and invisibility." The traditional desktop computer is not ready for obsolescence, yet. However, the barriers to accessing the digital information and online services relevant to a person's physical contexts could be lowered by embedding some computing into the environment.

With information being embedded into the environment comes the need for managing how a person will interact with that information. The typical Ubiquitous Computing model has a person either intentionally request information from an enabled smart object or they asynchronously receive information about the objects they are interested in. The Galatea system takes a third approach: the objects themselves can proactively attract the attention of a user to information relevant to both the object and the user.

There are any number of situations when it might be useful for objects to attract your attention to their presence or the presence of information relevant to them and you. Many of these situations are common Ubiquitous Computing scenarios. If the weather forecast is for rain later in the day, it might be of use to you to have your umbrella know about it and alert you to the information as you are walking out the door. If you forget an important notebook on your way to a meeting, it would be good for your notebook to remind you of its presence as you are leaving your office en route to the meeting. While a soldier on the way to the front lines is

taking inventory of his equipment, his equipment, knowing the type of mission, could suggest itself and its relevance. At the supermarket products that you usually purchase but that might not have made it on to your list could remind you of their presence. Another set of scenarios arises when there is new information online that you can be alerted to through the object that the information refers to. If there is a recall of some product, you could be alerted about it before you are about to use that item.

Even though the technologies in the Galatea system can be applied to other objects, this work is limited to the domain of books. Books serve not only as a close at hand reference for the information they contain, but people also attach themselves to the meaning the objects represent. Like other cherished objects, such as a well-tailored suit or the art people put on their walls, objects reflect a person's individuality, their professional skills, education, religion, and culture[7]. As such, people do not want to give up their physical books for the digital versions. In many ways the books one reads defines and refines their perception of and interaction with the world.

Complementing our physical books, an enormous reserve of book-related information exists online. There is an abundance of information search, mining, and retrieval tools to gather relevant information about and out of books. There are reviews, reader's notes, recommendations, full-text search, academic papers, and even the texts themselves. There are book clubs and social networking groups built around different book topics. But most of that information is only available online, is often difficult to find, and is quite useless to readers who might be browsing for a new book at a bookstore, waiting in a friend's office, or lingering in any space where books are found. This divide between the digital and physical worlds exists not just for books, but for many of the objects found in everyday environments.

The objective of this thesis is to make digital online information available in a more intuitive, proactive, and useful way. To do this, information is implanted in the physical objects it refers to. If the enhanced object has information that might be of use to a person in the vicinity, it will actively alert the person to the relevant information, all in a simple, agent-based, personal, and portable interface. Leveraging previous work in the areas of personal recommendation agents, context-awareness, ubiquitous computing, and electronic and wireless communication, the Galatea system creates digital prostheses for physical objects that allow them to actively and intelligently offer people access to personalized online information.

The recommendation system, context-awareness, ubiquitous computing, and smart-object communities are all active areas of research. What makes Galatea unique is both that the books actively attract the user's attention to information and that the information is specific to the book and is personalized to the user, i.e. the information is chosen based on an interest profile of the user, the recommendations of his social network, his activity history, and the profile of the book. Whereas recommendation systems are typically online and refer to the universe of objects they recommend for, Galatea focuses on allowing the objects, which are actually available in the person's physical environment, to essentially recommend themselves. In much ubiquitous computing research the focus is on generic architectures for smart environment systems to use, or the focus is on providing static information or state information about physical objects. Galatea on the other hand focuses on enabling the environment with information about books that is personalized to a particular person's interests and is aware of the person's history of interaction.

There are many types of personalization. The model of personalization used in Galatea is not simply a set of user preferences, but is based on a user's profile of interests as well as a network of influencers that drive the information

opportunities. An influencer for a particular book might be a friend who has just put a book in their favorite books section of their social network profile. Another influencer might be the release of a new book by an author the user likes. The notion of personalization in the Galatea system refers not to the specific information that a user might be interested in, but rather to the adaptive process of information selection. An interaction manager looks at the changing online information about objects and tries to predict when information about locally available physical books might interest a person present in that local environment.

There is also research that has been done where objects attempt to get a person's attention, for example, Ambient Devices' Orb[1] or Vert's Intelligent Displays[41]. However this is typically not in response to an adaptive, intelligent system modeling a user's interests, predicting useful interaction opportunities, and allowing the objects to proactively offer the information. This sort of personalization applied to the domain of proactive smart books is a unique contribution of this thesis.

This thesis presents a system of physical smart-books enabled with the ability to proactively alert a user to new information opportunities. Both books and users are modeled as software agents. Each agent has a profile that is updated dynamically when there is either new data added or removed from the profile or new interactions occur between the agents. An interaction manager monitors the user and the books that come into the user's vicinity and notifies a book agent when that book agent should signal the user that it has relevant information to offer the user.

The two sets of user studies uncovered some interesting findings. The studies show that people see a benefit to a system like ours when it can help them retrieve useful information, communicate their interests to others and get

recommendations from people they trust with similar interests. At the same time people raised concerns about interruptability and privacy.

## 1.4 Guide to the rest of this thesis

Chapter 2 surveys relevant research and commercial products that are either similar to or influenced the work presented here and discusses how the Galatea system differs from those systems. Chapter 3 walks through a few typical usage scenarios for the Galatea system. The hardware, software, and user interfaces are covered in Chapters 4 and 5 together with discussions of some of the benefits and drawbacks of the different solutions considered. Chapter 6 discusses the results of two user studies, one that reviews issues concerning smart books and the proactive delivery of personalized information, and a second that compares how people use books when searching for information given different search tools. The results of the studies show that the Galatea system offers opportunities to augment people's interactions both with physical objects and with people who are interested in those objects. Chapter 7 talks about in which directions this work could go and some of the issues that need to be dealt with when designing systems like this one. Chapter 8 offers a closing discussion of the Galatea system.



## Chapter 2.

### Background / Related Work

*“A wonderful thing about a book, in contrast to a computer screen, is that you can take it to bed with you.”*

-- Daniel J. Boorstein

This work is influenced by and builds upon a large body of inspired and groundbreaking previous work. There is certainly no shortage of systems that do online recommendations, networked embedded devices, physical object based information displays, and cell phone information interfaces. While pulling from each of these areas, our system uniquely combines these fields to allow objects to proactively provide personalized that is relevant to both the object and a person’s interests and current context. In this chapter we will look at a few of the systems that are relevant to ours and discuss some of the differences between their systems and ours.

## 2.1 Recommendation Systems

Ever since information has been catalogued in digital format there has been a need to both retrieve and filter information. Certainly this was true even before that. This quote from Vannevar Bush in 1945 shows him yearning for a better recommendation system:

This is a much larger matter than merely the extraction of data for the purposes of scientific research; it involves the entire process by which man profits by his inheritance of acquired knowledge.

The prime action of use is selection, and here we are halting indeed. There may be millions of fine thoughts, and the account of the experience on which they are based, all encased within stone walls of acceptable architectural form; but if the scholar can get at only one a week by diligent search, his syntheses are not likely to keep up with the current scene[3].

As more and more digital information was becoming available, especially online, recommendation systems arose as a solution to a person's desire to keep up with the constant stream of new information without having to wade through a sea of data irrelevant to their interests and without having to explicitly search for the information.

Many systems have been created to solve different recommendation problems. Social recommendation systems like Google's link analysis use community usage patterns to organize and rate information. Collaborative filtering systems like Firefly's ratings system automate the process of relying on friends and people with similar interests to guide us in the effort of acquiring new information[33].

Content recommenders like the Letizia agent use the content of our past interactions to suggest new content that might be of interest to us[19].

The success of many online recommendation systems, some notable ones being Firefly, Amazon, Google's link analysis, PHOAKS, GroupLens, speaks to the merit of this type of approach to information filtering[33][31][38][39].

A few projects have expanded recommender systems outside of the purely digital realm. For instance, GloBuddy 2 is a mobile language translation agent that helps people translate between different languages by using common sense reasoning to help provide contextually relevant phrases[16]. While not in a strict sense a recommendation system, (but still a system that relates information based on the associative connection strengths of a graph) GloBuddy 2 does offer contextually relevant information based on a users explicitly expressed situation. Another system that offers physically based recommendations is the Voyager project described in the next section.

It seems a natural progression would be to continue to extend the reach of recommender systems to the physical world. This thesis does not seek to create a new recommender algorithm, but rather to piggyback on existing algorithms to create a new way of interacting with augmenting physical objects.

Social networking sites are also important to this research. Social network sites make use of a graph of the relationship between different people to give members of the sites a means to meet other people. The intuition behind a social network site is that we are likely to be interested in people our friends like. Social network sites have much in common with collaborative filtering and social recommendation. In fact, websites like 43things.com and del.icio.us are leading the trend of blurring the lines between social networking sites and recommendation systems. The social networking sites Orkut and Friendster serve as a basis for our physical object recommendation system. The natural trust

hierarchies and interest profile graph that falls out of the structure of those sites served as a good data model to start from in building our system.

## 2.2 Embedded Communication Devices for Ubiquitous Computing

There has been a lot of research on giving physical objects digital counterparts in the field of Ubiquitous Computing. Wieser and Brown's paper on Calm Technology was one of the first forays into finding ways to make computing less irritating and more in tune with the world around us[43]. As computing power gets cheaper and cheaper and smaller and smaller the ability to begin to realize the goals of Ubiquitous Computing get closer and closer. There is much research that talks about plans for systems that will make our physical environments smart. In fact, there is no end of ideas that have been floated in this domain. There are decidedly fewer implementations of systems that do interesting things. A few that are interesting for various reasons follow.

One group that is a leader in creating architectures for future ubiquitous applications is the SmartIts project group. Their objective, as stated on their web site <http://www.smart-its.com>, is:

The Smart-Its project is interested in a far-reaching vision of computation embedded in the world. In this vision, mundane everyday artefacts become augmented as soft media, able to enter into dynamic digital relationships. In our project, we approach this vision with development of "Smart-Its" - small-scale embedded devices that can be attached to everyday objects to augment them

with sensing, perception, computation, and communication. We think of these "Smart-Its" as enabling technology for building and testing ubiquitous computing scenarios, and we will use them to study emerging functionality and collective context-awareness of information artifacts.

In two representative papers [32][35] we see that their research primarily focuses on building a generic and extensible infrastructure for smart objects. They seem to develop applications using their system more as descriptive demonstrations of the architecture than as interesting applications in their own right. Technologically their work is quite sound. This seems to be a trap many researchers in this domain fall into. The technology is so challenging and interesting that the application of the technology becomes secondary.

The House\_n and Oxygen groups at MIT, and the Berkeley Motes are all large-scale initiatives looking into embedding intelligence into everyday environments. House\_n looks at merging person-centered design with new technologies to create the home of the future[25]. The MIT Oxygen project aims to create configurable generic devices that will help enable our environments to "communicate naturally, using speech and gestures that describe our intent ("send this to Hari" or "print that picture on the nearest color printer"), and leave it to the computer to carry out our will[26]." The Motes project seeks to enable areas with "small, low-cost flexible wireless devices with a flexible open operating system and environment to combine sensing, communication and computations[3]." Each of those endeavors has generated great and copious research. This system does not compete with those. The object of this system is to look at an interesting application for a smart-object environment and study the affordances it can offer.

Another set of similar and influential work in the area focuses on intentional extraction of information from augmented objects. For example, Want et al.[42]

and Andreoli et al.[1] look at ways of annotating objects with information and then scanning the objects manually to leave or extract the information. There are even commercially available systems of this sort now. For instance, Delicious Library allows you to use a common web cam to scan the barcode on books, movies, music, and video games and “the item's cover appears on your digital shelves filled with tons of in-depth information downloaded from one of six different web sources from around the world.[9]” Engaging work by Ma and Paradiso on the FindIT Flashlight looks at ways to enable explicit, intentional searching in an environment for specific active objects[22]. Their active objects can survive for 10 years on a single coin battery.

Cooltown also presents a similar system whose aim is to annotate physical objects with the appropriate web based information[15]. The primary demo for this project was an art gallery and bookstore that a user with an enabled PDA could intentionally get non-personalized information about the art on the walls or books through their device. The HP Cooltown project has since moved away from the pervasive computing model to a wireless services model.

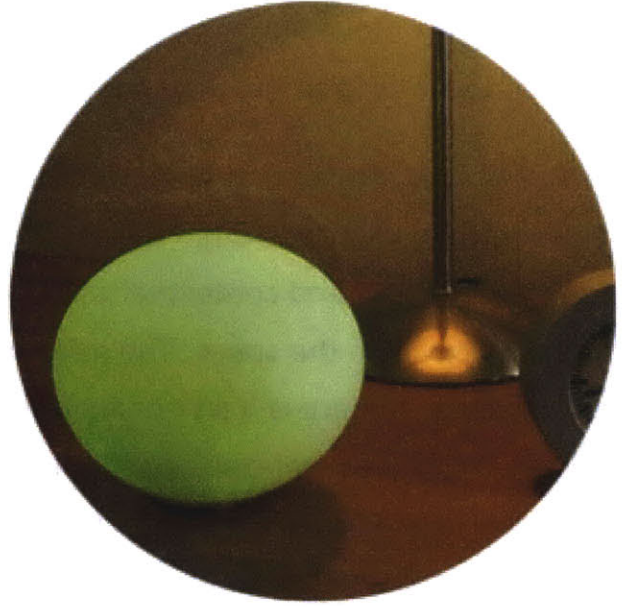
One final type of project that is commonly compared to this system is the RFID or bar code scanning shopping assistant. MyGrocer [27] and Voyager[6] are examples of this type of system. The general idea is that with an enabled shopping cart, you can put tags on the shelves or in the products of a store, typically a supermarket, and as you put items in your cart, the cart crosses off items on your shopping list and directs you to other parts of the store where you can find other items left on your list. The cart can also offer you items related to the product you scanned. A similar technology is the Smart Shelf[8]. The smart shelf puts the RFID scanning technology in the shelves of the store. The shelves then can read what products are on them and know when a user picks up a product. There is a small display on the shelf that can show the price of the objects and potentially show recommendations for other products related to the

one picked up. However, the shelves do not attract a user's attention to them, the interaction starts after the user has picked a product off the shelf.

One issue in all the work mentioned is that while the digital counterparts may communicate with or through the user's handheld device, they do not proactively offer personalized and contextualized information that is directly tied to the physical objects in the space. The information is usually passive and non-personalized. If there is a personalized component to the systems mentioned, typically there is no opportunity for the objects themselves to autonomously attract the user's attention to their presence in the space. We are trying to fill that void with the Galatea system and show that there are unique benefits if objects are able to attract our attention and if they are able to offer useful information.

## 2.3 Physical Object Based Information Displays

Another related area of research deals with attracting a person's attention to things in their environment or ambiently displaying information through objects. For example, a blinking light might indicate to you that you have voice or e-mail. Hiroshi Ishii's Tangible Media group has done significant work on "ambient media" displays[7]. Ambient Devices, Inc, sells a lighted orb that through changing colors conveys the state of some form of changing information, for instance whether particular stocks have gone up or down or whether it is sunny or rainy outside. These systems do not try to infer what might be of interest to a user but instead the user has to explicitly program them to show some information.



**Figure 2. Orb ambient display from Ambient Devices, Inc.**

## 2.4 Discussion

While there has been a lot of relevant work, especially in the ubiquitous computing area, no one has built a system with all the affordances of our system. Namely, we have not seen another system that allows books to proactively use a visual signal to attract a person's attention to both the book itself and to information about the book that has been chosen based on the book's profile, the person's interest profile, and the person's interaction history.



## Chapter 3.

# Galatea Usage Scenarios

*“A book lying idle on a shelf is wasted ammunition. Like money, books must be kept in constant circulation. Lend and borrow to the maximum -- of both books and money! But especially books, for books represent infinitely more than money. A book is not only a friend, it makes friends for you. When you have possessed a book with mind and spirit, you are enriched. But when you pass it on you are enriched threefold.”*

-- Henry Miller

In this work we bring Ubiquitous Computing and Intelligent Interface techniques together in a useful application that leverages the power of online social recommendations to enable physical objects with the means to offer relevant information to users. We also study how such a system might affect users and how it might augment their interaction with the physical world. We create an adaptive user model using long-term interests as well as short-term contextual information and an adaptive object model and constantly compare these two to decide on relevant information to present to the user.

At its core, the work we present is a physically situated information delivery and retrieval system where smart objects actively suggest or provide relevant online information opportunities. Our smart objects piggyback on top of the existing physical organization infrastructure and enhance it by advertising to a person access to related digital information centered on the person's personalized profile of interests.

These objects can get your attention and let you know when they have information that might be of interest to you. They do this by having access to your interest profile. Your interest profile stores what books you have read and which ones you liked, the products you use, your hobbies, favorite movies, tv shows, news interests, cultural tastes, and whatever else you put in it. It is also tied to your friends' interest profiles through your social network. For instance, sites like Friendster.com link you to your friends, and links your friends to their friends and so on, so that you are connected to many different people through different degrees of separation. With our system, each book in the real world that you come in contact with has its own profile composed of the digital content available for the book, including editorial and customer review text, excerpts, indices, and summaries. There is an interaction manager that cross-references each book that you come in contact against the your profile and the profiles of the your network of friends to find how strongly connected you are to the book. The interaction manager instructs the books to let you know when they might be of interest to you. For instance, if a friend has just written a review of a book that they just finished reading, the book might alert you to the review the next time you walk by it by flashing an LED at you and offering to show you the review on your cell phone.

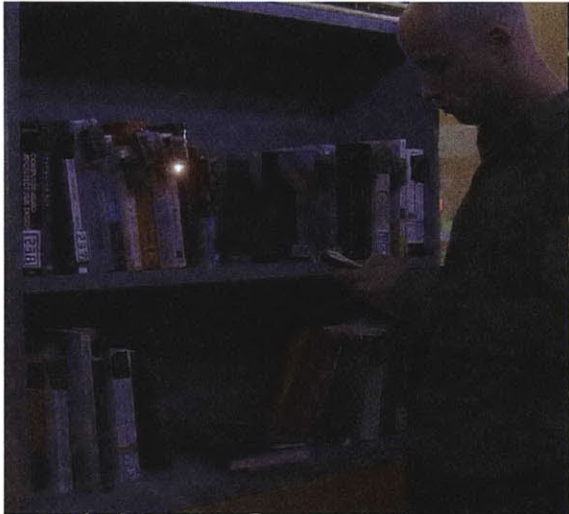
This chapter presents three usage scenarios: Relevant Books, Book Influence Spreading, and Book Search. The Relevant Books and Book Influence Spreading scenarios has been implemented using only a limited set of data using

dynamically generated data as well as hand processed data. There is more discussion of how the data was gathered in the design chapters. The Book Search scenario is a fully functioning prototype. All the scenarios use a Bluetooth gateway to manage the communication between the phone and the books.

### 3.1 Relevant Book Scenario

A user of the Galatea system walks into a small local bookstore. This user was previously registered in our system. He has an up to date interest profile that includes the books he has read, movies he has seen, product reviews he has written, hobbies, sports, cuisine, likes/dislikes, and activities. His profile also includes links to the profiles of his friends as well as links to the different user groups he is a member of. This profile was assembled by pulling profile and friend connection information from Orkut and Friendster and doing custom post-processing to add extra information based on simple heuristics such as linking books by the same author to each other and linking books together based place on Amazon’s Similar Products list.

In the bookstore, he starts out in the Fiction section. He is an avid reader of mid-twentieth century novels and has recently become enamored of the Beat movement. He doesn’t know much about the Beats, but he has, of course, read Keroac’s *On the Road*. As he walks through the fiction aisles his cell phone starts to vibrate and a book, *Naked Lunch*, on the shelf starts to flash an LED at him. He



**Figure 3. Relevant book lighting up with relevant information on phone.**

walks over to the book, and he takes out his cell phone to see what message the book has for him.

On his cell phone he sees an entry on the system's Relevant Books screen highlighted. The Relevant Books screen always lists all the books in the environment that are trying to get the users attention. In this case, the book is "Naked Lunch." He selects the entry and goes to the next screen.

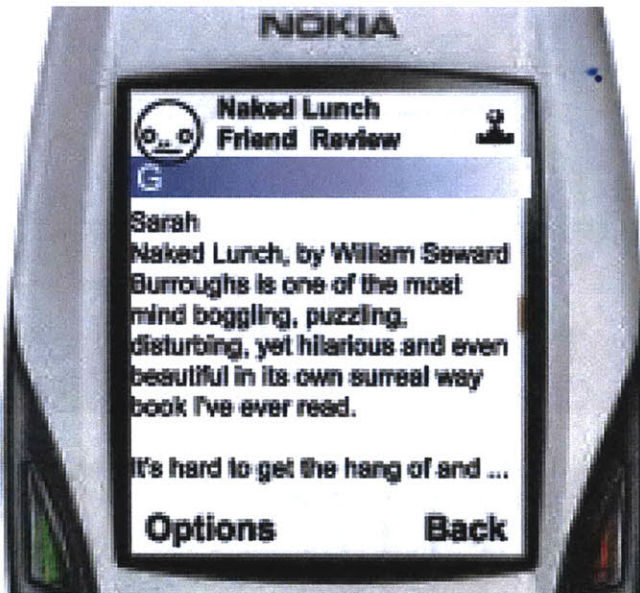


**Figure 4. Relevant book shown on phone.**



**Figure 5. Book review selection screen on phone.**

The next screen shows two sub entries. One entry shows that there are five reviews on Amazon that he might be interested in, and the other one tells him that a friend has written a review of the book. The phone offers him the opportunity to read any of the reviews. The user uses the scroll function to move to the item in the list he is interested in. He selects his friend's review.



**Figure 6. Book review page.**

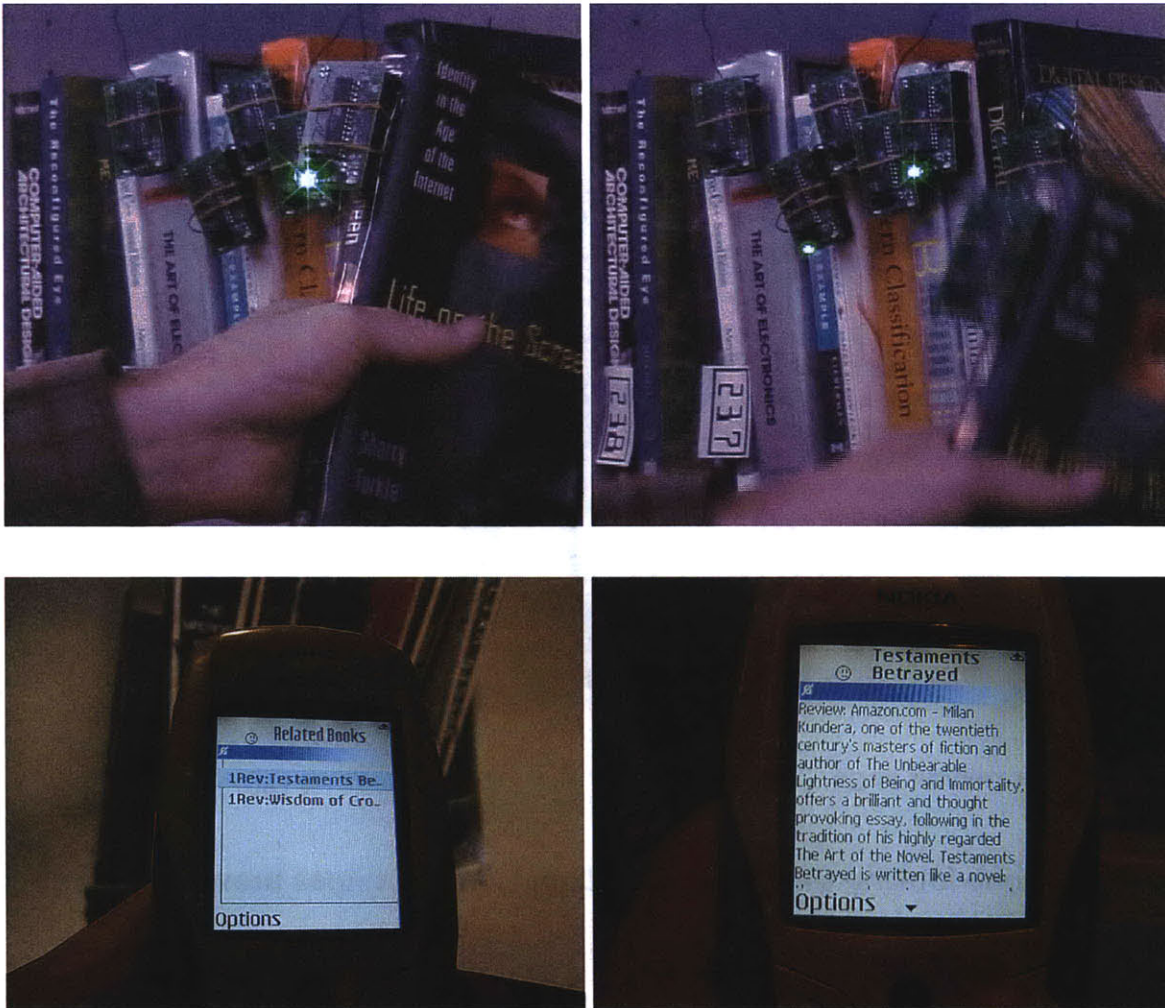
The phone switches to the review screen. The review screen shows the first part of the text of the review. Our user reads the review from his friend.

When the user is done reading the review, he picks up the book and browses through it for a few minutes.

When he is done looking through *Naked Lunch*, he continues browsing in through the store.

### 3.2 Book Influence Spreading Scenario

As our user continues browsing, he shows an interest in the book *Life on Screen*, and decides to pick it up. The book senses that it has been picked up and it sends a message to the user's phone to indicate this event. The system then tells the two most conceptually related books to the one in his hand to light up. In this case, the books are *Testaments Betrayed* and *The Wisdom of Crowds*. His cell phone also shows a list of online reviews for those books. He briefly looks at the review for *Testaments Betrayed* on his phone, then when he is done looking at *Life on Screen* he picks out *Testaments Betrayed* and looks at it.

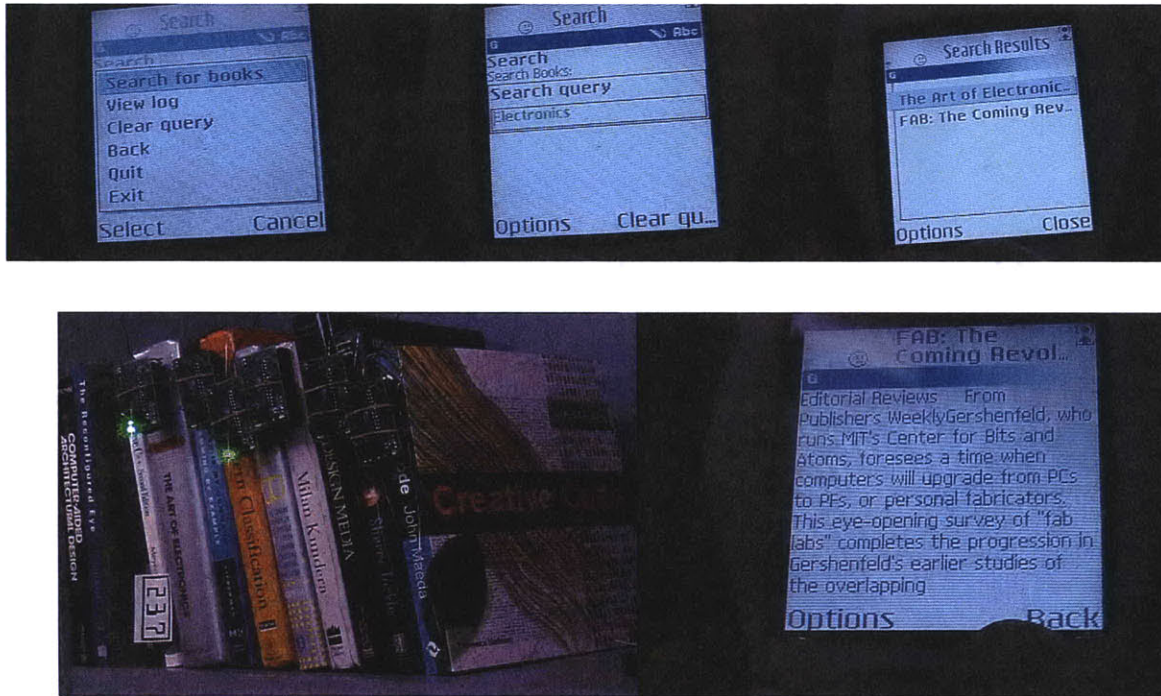


**Figure 7. Book spreading its influence.**

### 3.3 Book Search Scenario

Our user then walks over to the non-fiction area to find a book on electronics. He goes to the Engineering section and takes out his cell phone. He selects “Search for books” from the Options list. The phone switches to the search books mode and brings up the search screen. Our user types ‘Electronics’ into the query box on the search screen and clicks the search option. Simultaneously, two books on the shelves in front of him light up and two book titles are added to the search results page list box. Our user first clicks on the list item for *The Art of Electronics*,

and reviews the editorial comments on the phone's interface. Then he looks at the editorial review of *Fab*. He likes the description of *Fab* and so he picks up the book and flips through it. He decides he is going to buy it.



**Figure 8. Explicit Search Query.**

These scenarios showcase some of functionality that Galatea offers. The next two chapters discuss how the system works and some of the design issues and solutions.

## Chapter 4.

# Software Design and Implementation

*"A room without books is like a body without a soul."*

--Cicero

From a low level design point of view, the Galatea system can be broken down into two different parts: the software design and the device design. For discussion's sake these distinctions will make describing the implementation easier. In talking about the software design, the conceptual design of the system will also be covered. When talking about the hardware, the low-level implementation side of things will be covered. Also, the software behaves differently for the different test scenarios. Code was developed for three different situations. The first is the most generic and most interesting in terms of the design and so will be covered it more deeply. It concerns how the system should work if it were to be used in the real world. The other two situations were developed to showcase certain affordances the system offers in a more constrained setting such as an hour-long user study or a 20-minute demonstration. We begin with a discussion of the conceptual design and how it



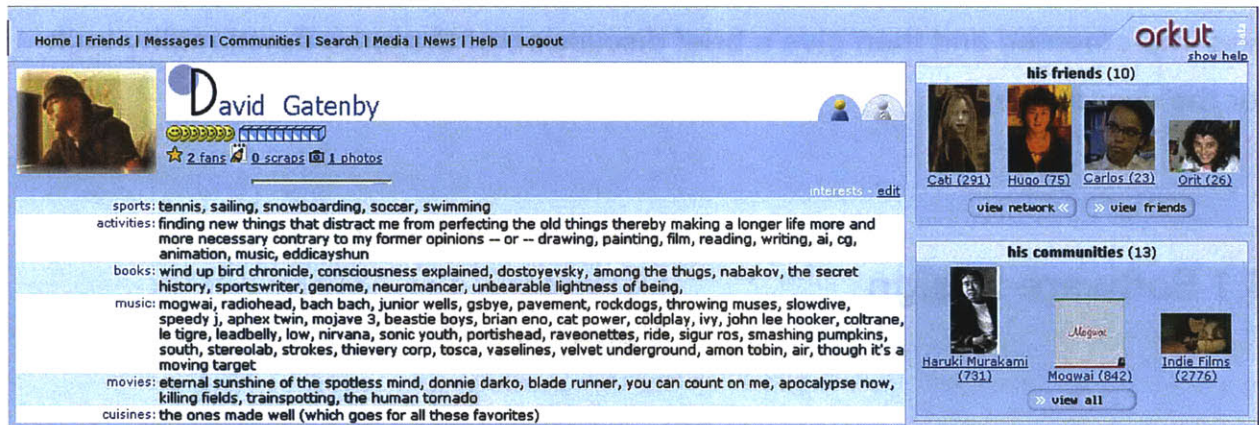
was implemented and then give a brief discussion of the extra functionality built for the user studies.

## 4.1 Software Design

The central metaphor for how the software works is that of a software agent. There are two types of agents in the system: book agents, and user agents. At the core of each agent is a profile that defines what information and interests the agent is responsible for. In addition to the agents there is a profile generator and an interaction manager. The profile generator is responsible for building and updating a profile for each book and user. The interaction manager is responsible for arbitrating interactions between the book agents and the user agents.

### ***4.1.1 User Profile***

The user profile is the base through which interactions with the objects occur. The profile contains links to the user's friends and to the user's interests. For a user profile, the system starts out with a simple profile similar to profiles you would find on a typical social networking site like Orkut or Friendster. There are sections for Hobbies, Books, Movies, Activities, Sports, Food, and Music.



**Figure 9. Orkut profile.**

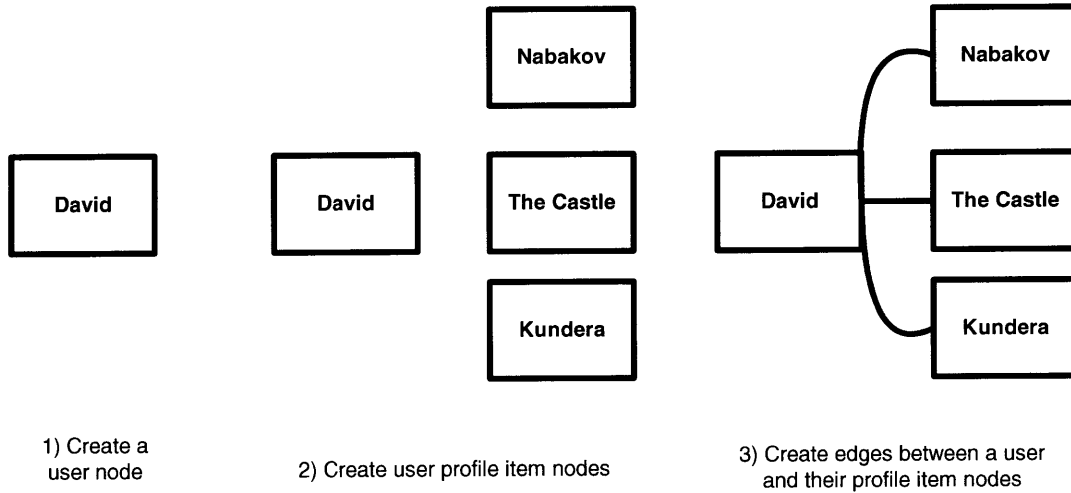
A user's profile data is held in a MySQL database, as are the edges connecting different users and data. Each interest data point (e.g. a book title, author, friends list, hobby, sport, or movie) is mapped to other data points using a connection graph. The next few sections discuss how relationships between different interests and people are created in the graph.

Information is pulled from social networking sites to populate the user profile for ten different people. To get more data to pull recommendations from, information was extracted about people up to two levels away from the ten users both in the direction of their friends network and from people in their community network. Two levels of connectedness provided data to provide ample recommendations. From this raw data a graph was constructed connecting the books and interests from people's profiles to the books and interests in other people's profiles. The following section describes this process in more detail.

#### **4.1.1.1 User Profile Graph**

To construct the connection graph, there are ten users who serve as the primary demonstration users. First a node for each user is created (Figure 10). Then nodes for each of the items in the profile of a particular user are created. An undirected

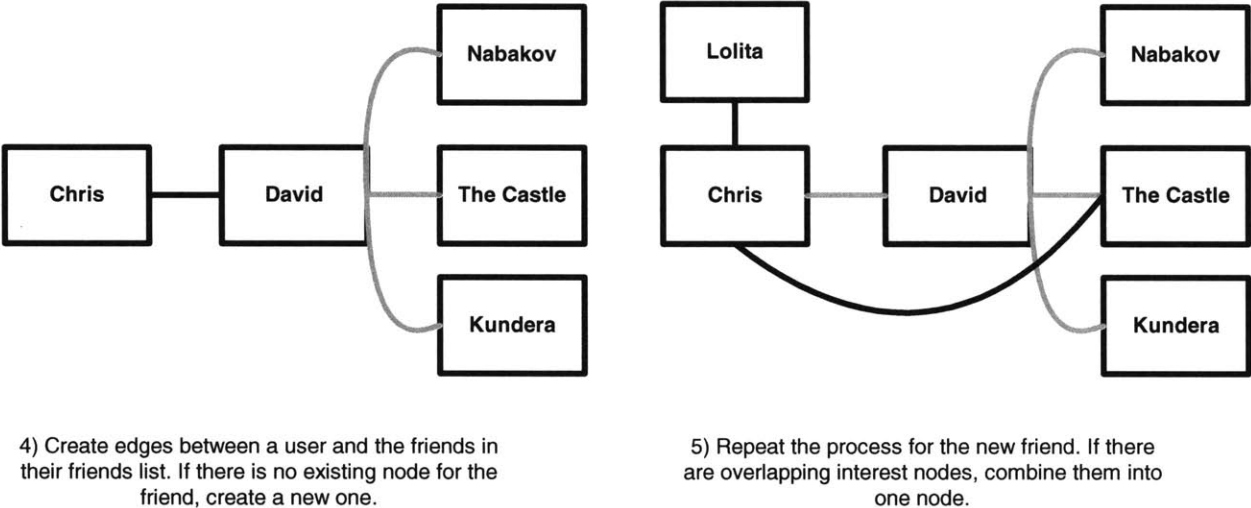
edge is created between the user node and each item node in the user's profile. So if the user David has *The Castle* as a book in his profile, there will be an edge between the node representing David and the node representing the book *The Castle*.



**Figure 10. Steps 1-3 of graph setup.**

While creating nodes for profile items, such as the node for the book *The Castle*, the node is checked to make sure it does not already exist. If the node has already been created while processing another user's profile list, a pointer to that node is used. In other words, any duplicate profile item nodes are merged into a single node. This has the effect of connecting people through their interests. For example, if Chris and David both have the book *The Castle* in their profile list, then regardless of any other connections, Chris and David are connected through the book node representing *The Castle* in their profiles (Figure 11). Similarly, a connection is also made from a user to the community nodes in that user's

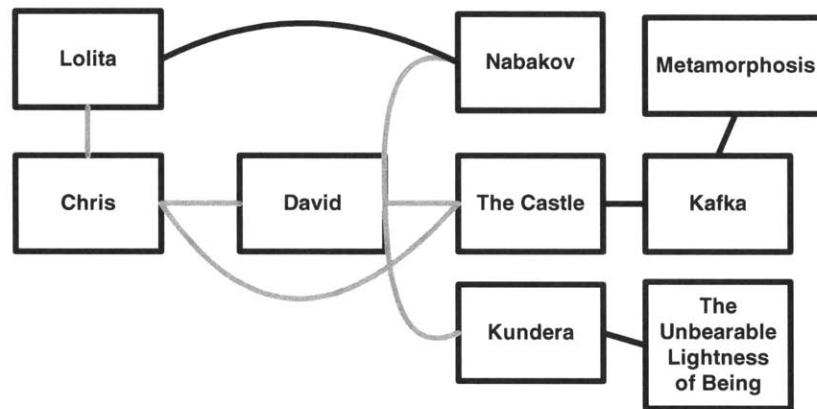
community list. A user can belong to any number of community groups. Community groups are set up to allow a user to connect with other people who share a particular interest. One example of such a group is the Murakami group, which brings users together to talk about the life and works of writer Haruki Murakami. The members of a community group are good resources for recommendations as there is already an established link between two users in the group, namely that they both are interested in the same topic. While only the community group is currently used as a means to create new edges in the recommendation graph, a future implementation might mine the community message boards for new books or topics that are being talked about and notify a user who belongs to the group of this new information.



**Figure 11. Steps 4-5 of graph setup.**

Once a user and the items in her profile have been added to the graph, the next step is to create edges between the user and the friends in the user’s friends list (Figure 11). If one of the friends in the user’s friends list does not already exist in the graph, i.e. does not already have a node associated with them, then a new one

is created. From this point on the process of creating a user node, linking it to the items in the user's profile, and linking the user to the friends in the user's friends list is repeated recursively down to two levels beneath a top-level user node.

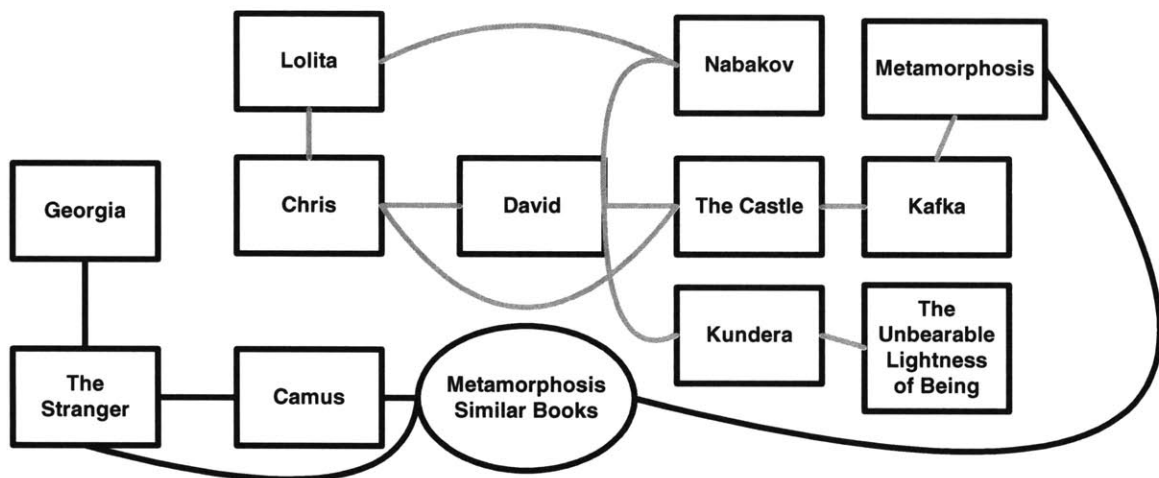


6) If possible, associate authors with titles. This can create new links between users and also increases the opportunities for recommendations.

**Figure 12. Step 6 of graph setup.**

Once all the users have been created and the links to their profile items have been added to the graph and the users have been linked to the friends in their friends lists, we proceed with two steps that are designed to increase the connectedness of the graph. In the first step to increase the connectedness of the graph, a part manual, part automatic process is run that creates extra edges by associating authors with titles (Figure 12). First the cleaning up of the title and author data is done. The titles and authors in the profile data that we pulled down from the social networking sites are cleaned manually by double-checking to make sure that the information looks valid and that the title and author names are complete and spelled correctly. Next a script is run that loops through the list of all titles that were found in the profiles processed in the previous steps, pulls the author

names for those titles from Amazon, and creates an edge in our graph between the title and its author(s). The process is repeated for all the authors that were pulled out of the profiles, only this time a new edge is created to link to any book the author has written. Part of the cleaning process is described in more detail in the book profile section. A live system would have to automate this process and do a better job disambiguating the data. Liu in [21] gives a description of a nice automated solution to this problem.



7) Add Amazon Similar Products links to increase the connectedness of the graph and improve recommendation opportunities.

**Figure 13. Step 7 of graph setup.**

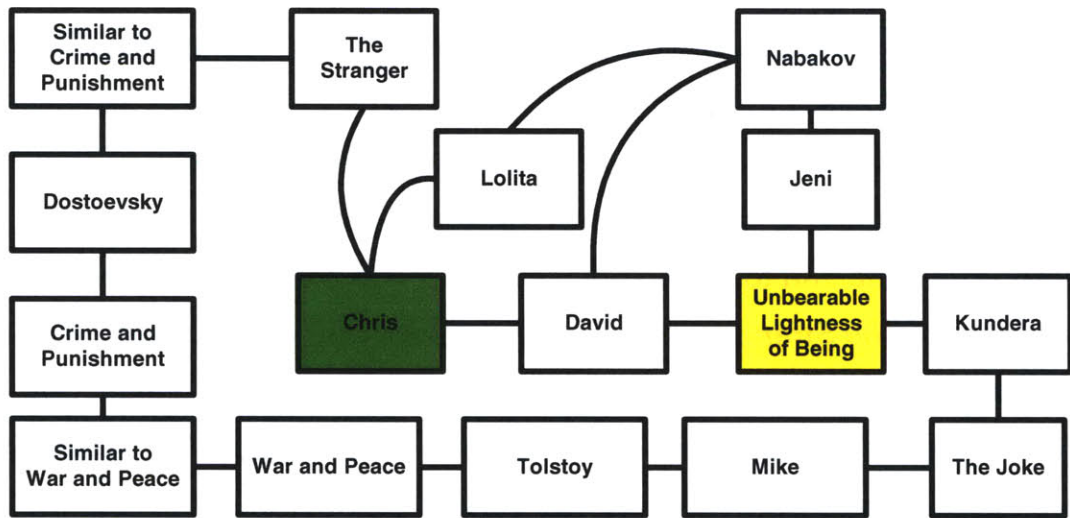
Another step taken to create a more fully connected graph with more opportunities for recommendations is to add nodes and edges that help connect books together that have some similarity. To do this really well, a more complex analysis of document similarity would need to be employed using natural language processing, or some other machine-learning algorithm. A simpler

approach was taken. These extra nodes were generated by pulling the Similar Products for a particular book from the Amazon API (Figure 13). For instance, if David has *Metamorphosis* in his profile, a new node “Metamorphosis Similar Books” would be added to the graph and create an edge from it to the *Metamorphosis* node and to the nodes for each of the books in the similar products list, e.g. *The Stranger*. Adding these nodes and edges has the effect of strengthening the links between different people and between a person and a book. For instance, if David were to enter a room with the book *The Stranger*, and he had not been previously alerted by this book, the addition of the similar products edges from the book *Metamorphosis* would make *The Stranger* a good candidate for recommendation.

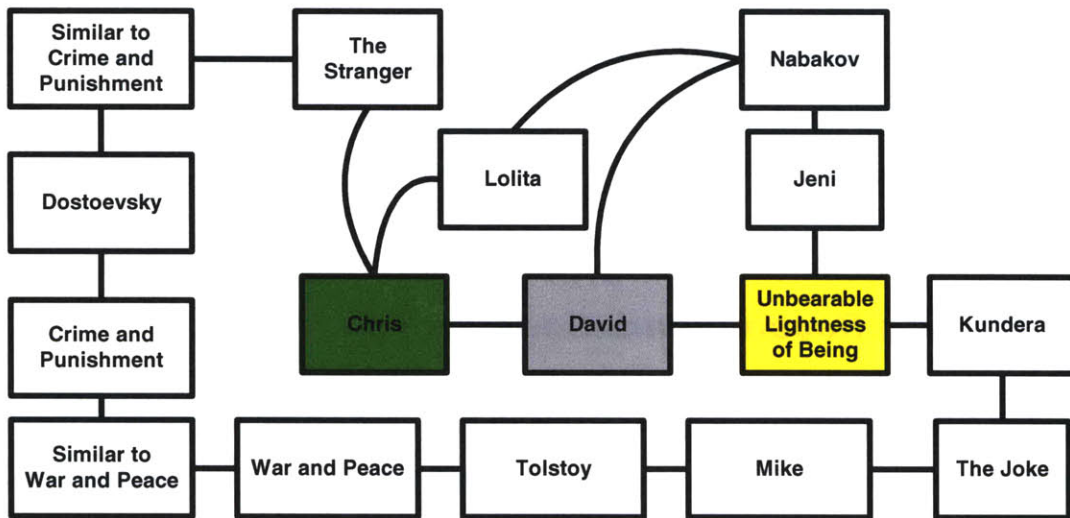
The greater the number of connections in our graph between two people the more likely each would be to have one of their books referred with the assumption being that two people who have more objects in common are more likely to be interested in the things they don't have on their list but that the other likes.

#### **4.1.1.2 Making Recommendations**

In this version of the system, a book that is in the user's immediate surroundings is suggested based on how strongly connected it is to the person to whom the book is being referred. The strength of a connection is determined by the number of paths between a book and the person and the lengths of those paths. The number and lengths of individual paths between a person and a book are found using the following algorithm.



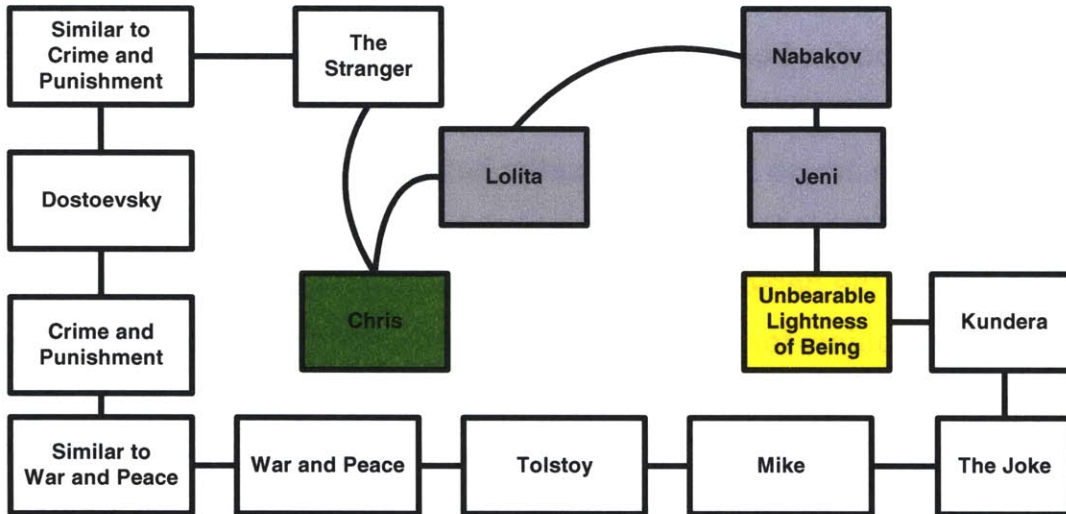
**Figure 14. Find weight of connection between user and book.**



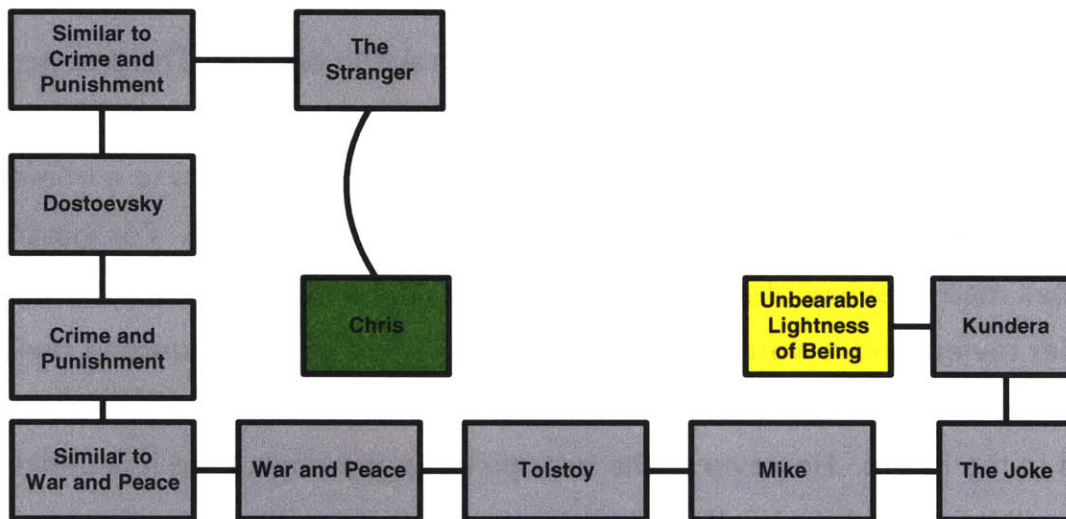
**Figure 15. First, find shortest path.**

**This one has length of one. Its score is increased because the path goes through a friend.**





**Figure 16. Remove previous shortest path and find next shortest path. This one has length of three.**



**Figure 17. Repeat previous step. Remove previous shortest path and find next shortest path until they are all gone. This last one has length of ten.**

First the shortest path between the item and the book is found using a simple breadth first search. When a shortest path has been found, the nodes and edges

of that path are removed and the length of the path is saved. If the path goes through a friend node, a bonus is added to the final score to make recommendations that go through friends more influential. This process is repeated until there are no longer any paths between the person and the book or the length of the paths is longer than the upper bound. The number and length of the paths between the person and book are combined to create a score for the book. Any bonus points for going through a friend node are also added. The book's final score determines how likely it is that the book will try to get the person's attention. The interaction manager keeps track of the scores for the different books and picks the best matches. The interaction manager also takes into account the user's interaction history. More information about how books are chosen can be found in the interaction manager section.

#### ***4.1.1.3 User Interaction History***

The user profile keeps a record of the user's interaction history. The interaction history keeps track of what objects and information the user has already seen. The interaction manager uses this information to keep repetitive alerts to a minimum. A user can have multiple interaction records for a particular book. For instance, if a user has read a review of a book, then there will be a history record for that particular review and it won't be shown again. If there are other unread reviews and the user has not yet picked up the book, the user might be alerted to the other reviews in the future. However, if the user picks up the book, then it is unlikely that he will be alerted again about the reviews for that book, unless there is a new review available from a trusted friend.

### **4.1.2 Book Profile**

In the previous section, the user profile and user profile graph were discussed. The user profile graph contains information about the relationship between books and users. The book nodes in the graph are simply pointers to each book's profile. The book profile itself is the container for all the information that has been pulled about the book. A book's profile is generated from available digital resources such as reviews, table of contents, excerpts, textual or critical analysis, summaries, category hierarchies, and citations. For the current implementation web crawlers were built in Python and Java to pull information from Amazon, the Amazon API, and Bn.com. These crawlers are run as a batch process that reads from a text file the titles and authors of books that need to be entered into the system.

These crawlers go through the list of books created during the user profile graph generation described in the previous section. For each book, the first step is to call the Amazon API with the book and author information. Amazon Web Services (AWS) provides a programmatic interface to the Amazon product database. Call to the Amazon Web Services system look as follows:

[http://webservices.amazon.com/onca/xml?Service=AWSECommerceService&SubscriptionId=\[SUB\\_ID\]&Operation=ItemSearch&SearchIndex=Books&Title=Notes%20From%20Underground&Author=Fyodor%20Dostoevsky&ResponseGroup=Large](http://webservices.amazon.com/onca/xml?Service=AWSECommerceService&SubscriptionId=[SUB_ID]&Operation=ItemSearch&SearchIndex=Books&Title=Notes%20From%20Underground&Author=Fyodor%20Dostoevsky&ResponseGroup=Large)

The AWS returns an XML file containing the ISBN, title, author, first five customer reviews, ratings, pricing information, similar product lists, a link to a detail page for the book, summary, publication date, number of pages, and other sundry information. This XML file is processed using our custom-built python SAX parser. The parser pulls out the customer reviews, ratings, summary, and similar products list for each book and the python script writes the data to the Galatea system's MySQL database. In addition to this information, the script also pulls

down and stores editorial reviews by crawling and processing the book detail page link. This information is not returned by the AWS, so the system has gather the data itself. The script also checks to see if the Amazon “Search Inside” functionality is available for this book. If it is the URL for the search is saved in the database. The “Search Inside” functionality is described in a later section.

The database is designed so that new types of content about books can easily be added to the database. For instance, if a profile management site like Orkut added the ability to post reviews of the books a user had in her profile, the Galatea system could simply insert that data with the new content type into the database and the system would immediately be ready to offer that type of content to the user if it were relevant.

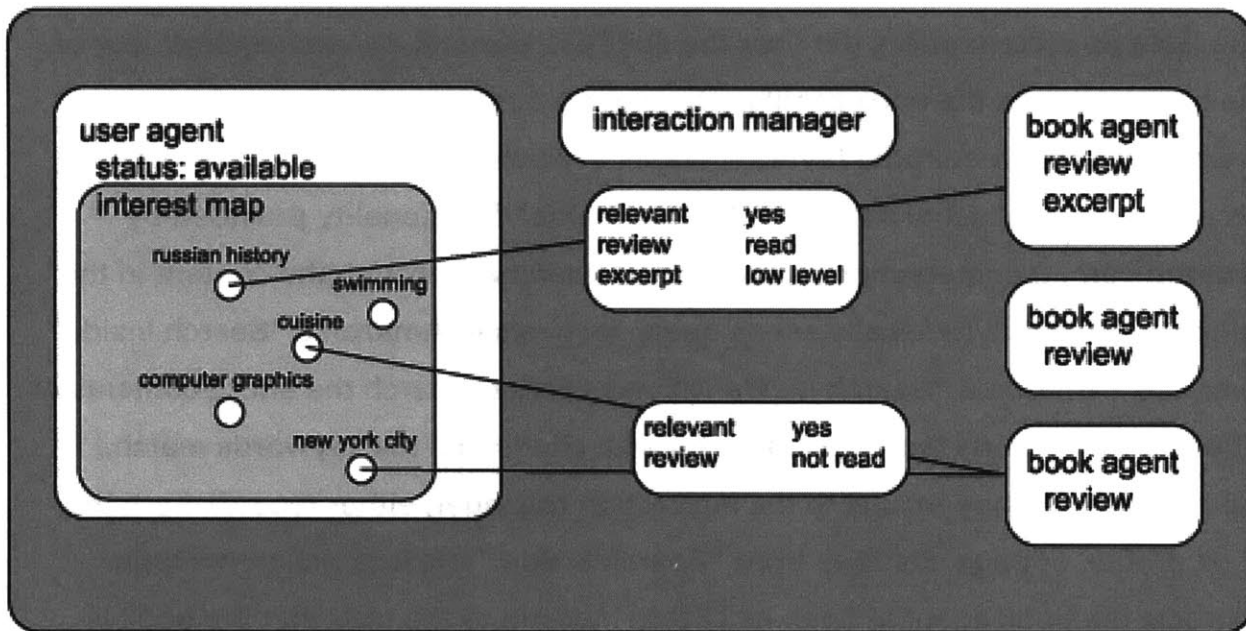
Each piece of content, for example the customer reviews, editorial reviews, and summaries, that are stored about a book has a unique id in the MySQL database. The user agent uses these ids to track the user’s interaction history. For instance, when a book has alerted a user to an editorial review and the user has read the review, the id of the review is put into the interaction history for the user. Later, when the user comes across the book again, the interaction manager will see that the user has already read the review and the interaction manager will allow the book to alert the user about the review again.

### ***4.1.3 Interaction Manager***

The interaction manager coordinates the communication between the user agents and the different book agents (Figure 20). It decides what books are appropriate for interaction in the current user context. When the user agent resident on the cell phone perceives that there are books in the nearby environment, it sends the book ids back to the central server. At this point the book agents are activated and

each one registers its relevance score with the interaction manager. The interaction manager then determines which books best suit the current user.

To do this the interaction manager queries the database and collects the profile results for each of the books. With the book profile records, the interaction manager checks against the user profile interaction history to check whether the user has previously consumed any of the records. If the book agent still has active records, then the interaction manager checks the connection graph for books that have a high enough connection score to the user. The interaction manager then sorts the books by their score and sends them back to the phone. At this point the user agent on the phone will alert the user to the existence of the books in the environment. At the same time the book agents will send out signals to the book objects with instructions for them to flash their lights at the user.



**Figure 18. Interaction manager ranks and chooses interaction opportunities.**

An example of this process follows. The interaction manager might decide to alert the user to a book when the user agent and the book agent both advertise in

their profiles an interest in or content related to New York City and cuisine. The interaction manager also makes sure that the content is relevant to the user by checking that the user and the book are strongly connected. Before alerting the user of the presence of a book with relevant content, the interaction manager checks to make sure the user has not recently interacted with the book. If all these checks pass, then the interaction manager directs the user agent to alert the user about the book and directs the book agent to flash at the user.

The interaction manager is also responsible for listening for when a book agent announces that the user has touched the book. In that case, the interaction manager does a search for other books in the environment that have similar content and alerts those books to light up in response.

#### ***4.1.4 Search Inside Functionality***

The Galatea system offers the user the ability to execute a search against any of the information in the book profile. Depending on the book, this can include searching through editorial reviews, reader reviews, tables of contents, or excerpts. For books that have the “Search Inside” functionality provided by Amazon.com, the interaction manager both searches through the content in the book profile and dynamically sends query requests to Amazon’s “Search Inside” interface. (Amazon’s “Search Inside” allows users to search the entire contents of a book and it returns the page numbers with citations if the keywords match.) If the book returns any results to the interaction manager, either records from the book profile, or page citations from “Search Inside,” the interaction manager instructs the book agent to flash its LED to indicate to the user that the book is relevant to the user’s query. The interaction manager also instructs the user agent to send the relevant information to the phone interface.



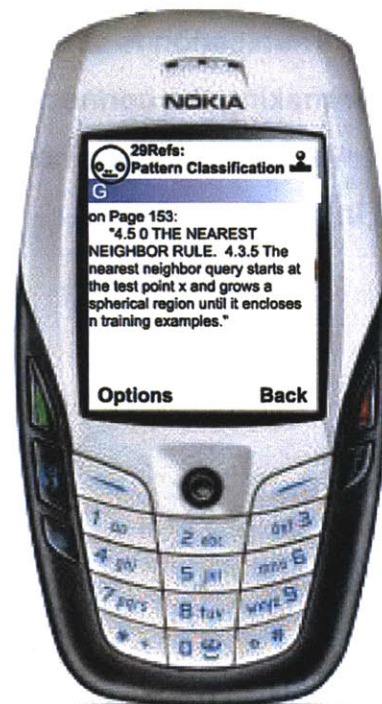
1



2



3



4

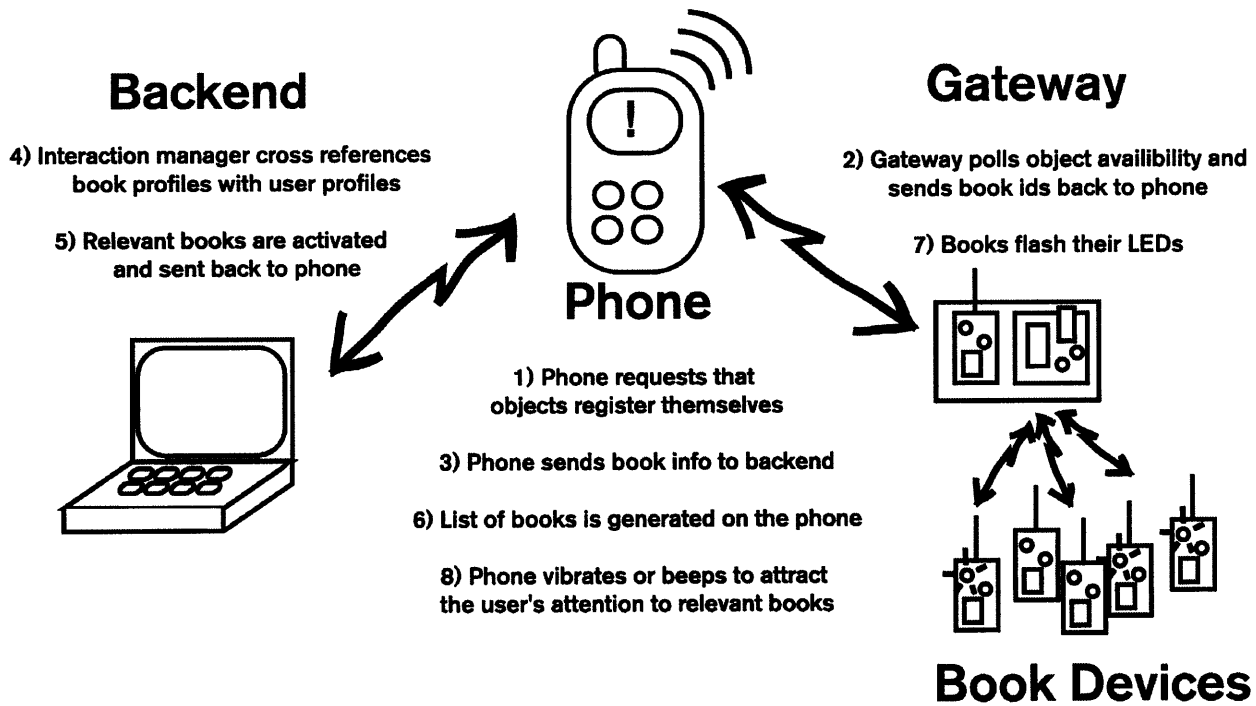
Figure 19. GUI for Search Inside Results.

When the user explicitly runs a query searching for information from the books in his environment, the interaction manager does not reject interaction opportunities, regardless of whether the content that matches the query has been viewed before. For instance, the user might explicitly request to be shown books about a certain topic or books with new reviews. When the user does this kind of an explicit search of the surrounding area using the query interface on the phone the interaction manager does not edit out results based on the user's interaction history or the influence of the user profile graph. Instead the user's history and interest profile now only affect the ordering of the books on the phone interface but not which books are shown.

#### ***4.1.5 Software Network Protocol***

The system uses a simple communication protocol. For all but the embedded devices the communication is over wireless serial data lines. The phone is responsible for making the connection to the backend server and to the Bluetooth gateway. An overview of the communication paths for the related books mode can be found in the figure below.





**Figure 20. Data flow for related books alert.**

The protocol for messages is as follows. The device with a message to send sends first the length of the message, then one of a set of commands, and then the data part of the message. For instance when the backend server is returning data about a book, the message would be:

005780637|On Intelligence|2|on Page 80| "... attribute a door can have and specific entries for your particular door. When you approach the door, the computer would query the entire database, looking at width, color, size, knob position, weight, sound, and so on. While this may sound superficially ..." |on Page 189|: "... after the fact by memory erasure. The more difficult question about consciousness concerns qualia. Qualia is often phrased in Zen-like queries , such as "Why is red red and green green? Does red look the same to me as it does to ..."

The length of the message is 578 bytes. The command is 06. Then follows the data, which for command 06 has the format: the book id (37), the book title, the number of pages in this book that matched the query (2), and the list of page numbers with corresponding excerpts that matched the query.

## Chapter 5.

# Test Platform and User Interface

*"This is not a novel to be tossed aside lightly. It should be thrown with great force."*

-- Dorothy Parker

This chapter reviews the Galatea system's user interface. Section 5.1 looks at the phone interface, the different modes that the system can be in, and how/when the modes are used. Section 5.2 discusses at the embedded book devices and reviews how we made some of our design decisions.

## 5.1 Phone

The phone is the go-between for the digital and real worlds. It is important for the phone interface to be simple and unobtrusive. The requirements for the phone GUI are quite simple. There are four different types of screens: books list, book information list, content view, and search page.

### **5.1.1 Phone UI Screens**

The books list screen displays a list of names of nearby books that are currently relevant to the user. Next to the name of the book in the list is the number of content records that are available to the user. As the book list is populated with a new book, that book simultaneously begins flashing at the user. On the books list screen, the user can select one of the books and they will be taken to the next screen, which is the book information screen.

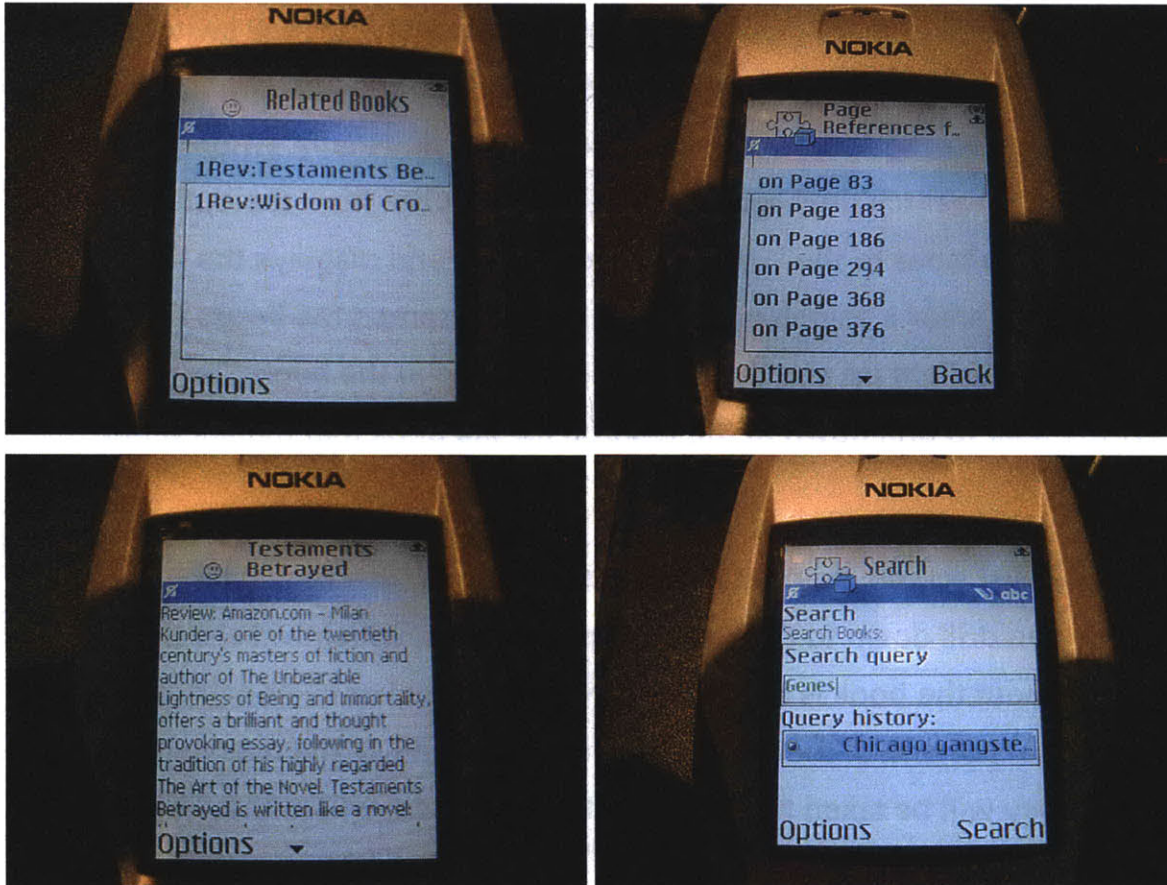
The book information screen shows the different kinds of content that are available about the currently selected book. For instance, there might be an editorial review and a summary of the book available for the user to look at. If the user selects one of the content items from the list, they will be taken to the content view screen.

The content view screen shows the user the contents of the record that was referred to on the previous screen. If the user selected a Publisher's Weekly review from the book information screen, then the content screen would show the text of that review. The content screen is always the last screen a user can drill down to.

From any of these three screens, the book list, book information list, and the content view, the user can open the options menu and select the "Flash Light" command. This command makes the currently selected book device flash its LED, giving the user a specific visual cue as to where the book is spatially in their environment.

The fourth screen available is the search page. The user can enter the search screen at any time by selecting "Search Books" from the options menu available on all screens. This page give the user a text input box to enter a query string. The user enters the query string using the numeric input pad on the Nokia 6600.

When the user has finished entering the query, they can activate the query by clicking on the "Search" button, which is the right quick button on the 6600. On the search screen the user can also select a previous query to rerun from a history list of the previous twenty queries.



**Figure 21. Phone interface screens.**

**Book list, book information list, content message, search screen.**

### **5.1.2 Application Modes**

There are three modes that the Galatea application can be in: "relevant books" mode, "related books" mode, and "search results" mode.

Each mode is used as follows. When a user is not actually touching books or using the search functionality, the system is in the “relevant books” mode and as the user moves into a new space, the books that are relevant to him or her will show up on the phone’s books screen and the book devices will flash their LEDs. When the user picks up a certain book, this event will be sent back through the phone to the interaction manager, and the interaction manager will switch to the “related books” mode and the books in the area that are related to that book will show up in the books list and the book devices will flash. Finally, when the user wants to perform a search they can select “Search Books” from the options menu. The application switches to the “search books” mode and displays the search screen. Once they enter a search query on the search screen the books that match the query keywords light up and the titles will show up in the books list with the option for the user to drill down to the records for the book that matched the query.

From the books list screen, no matter the mode, the user can request a book to flash, or they can drill down to the book information list, which will show the user what content about the book is available, such as editorial or customer reviews. To see the content of one of the items in the information list, the user can select the item and they will be taken to the content view screen, where they can read the review or other content.

### ***5.1.2.1 Relevant Books Mode***

The “relevant books” mode is the default mode. In this mode the phone will actively poll the environment looking for new objects. It does this by running a Bluetooth device and service discovery. If there is a bluetooth gateway within range, the phone will register the gateway and request that the gateway scan for the currently active books within the range of the DP1203 module of the gateway.

If the gateway finds active books in the area, it will send the ids of those books back to the phone. The phone relays these ids back to the interaction manager.

The interaction manager takes the list of book ids and begins the process of creating book agents for them. For each book id, the interaction manager will check to see if there is already an active book agent managing this books profile. If there is an active book agent for this book then the book is already being handled and the interaction manager ignores the new request. If there is not an active book agent for the book, the interaction manager creates one. When a new book agent is created, all of the content records for this book are pulled from the database that have not been marked in the user's interaction history as previously consumed. If there are no records for this book, or the user has previously consumed all the records, then the construction of the book agent is halted, otherwise, the book agent is ready for the interaction manager to check its relevance to the user.

With the list of newly created book agents, the interaction manager calculates the connection strength of each book to the user as described in Section 4.1.1.2 . When the interaction manager is finished ranking the books, it registers the top ranked book agents with the user agent. The user agent then sends a command to the phone to display the list of the top ranked books. The phone responds by alerting the user, either with a beep or vibration, to the fact that there are books in the environment trying to get her attention. The phone also switches to the book list screen and displays the list of relevant books.



**Figure 22. Phone GUI for relevant books notification.**

At the same time as the user agent sends the phone the list of books, each top ranking book agent sends a “Flash Light” command along with the agent’s book id to the phone. The phone receives this command and passes it through to the gateway. The gateway looks at the id of the book and forwards the “Flash Light” command on to the specific book device, which then flashes its LED.

From the list of relevant books the user can drill down to get a list of what information there is about the book. Usually this consists of editorial and reader reviews, query results, “search inside” results, or other book matter. From this list of options the user can go to a content screen to view the text of the particular book profile record.

### **5.1.2.2 Related Books Mode**

The “related books” mode shows what other books in the local environment have similar content to the active book, effectively showing the local spread of the current book’s content. The motivation for this mode is that when interacting with



a certain book, it is likely that a person will be most interested in other books with similar subject matter. This mode explicitly cues the user to the availability and similarity of these other books.

The Galatea application automatically switches to the “related books” mode when a user picks up a book. A sensor on the edge of the book recognizes when a person is touching the book (more on the sensor in Section 5.2.2.5 .) When a book is touched, the sensor triggers the book device to send its book id along with an event that indicates that the book was touched to the Bluetooth gateway. The gateway passes the event and book id on to the phone, which relays it back to the interaction manager. The interaction manager keeps a record of all the books that are currently in the user’s vicinity. When the interaction manager receives the touched book event it immediately queries the profile graph to find out which if any of the nearby books have strong connections to the touched book. The books with strong connections are considered to be related books.

In similar fashion to how the “relevant books” mode works, the interaction manager registers the related book agents with the user agent. The user agent sends a command to the phone to enter the “related books” mode. When the phone receives this command, it opens the book list screen, sets the headline to “Related Books,” and populates the book list with the relevant books the interaction manager chose.

The book agents also send out “Flash Light” commands to their book object proxies. The user can navigate from the book list the same way they did in the “relevant books” mode.

### **5.1.2.3 Search Results Mode**

The “search results” mode allows the user to execute a dynamic query against all the books that are within range. Whenever the user wants to enter the “search

results” mode, she can choose the “Search Books” option from the options list using the left quick button. This will bring up the search screen. When the user selects the “search mode” and the search screen opens, the other modes are turned off. The user can enter a search query into the search text box and hit the “Search” button. This will trigger the phone to send the search query to the interaction manager.

The interaction manager will take the search query and do two things. First it will run a query against the book profiles of the currently active book agents (active books are the books that are currently in range of any Bluetooth gateway that the user is connected to.) This query searches the records of each book profile. These records are typically editorial and customer book reviews, and summaries. The query keywords are matched against the book profile records using MySQL’s full-text search functionality. Any records that match are returned to the interaction manager. The second thing the interaction manager does with the user’s query is to look at the active book profiles and see if any of the books are enabled with Amazon’s “Search Inside” functionality. If they are then the interaction manager sends the query string to the “Search Inside” engine and collects the results.

The interaction manager lastly combines the results from the two searches and registers the books agents that had results with the user agent, which similar to the other two modes sends a command to the phone to populate the book list screen. The book agents with results also send out “Flash Light” commands to their book object proxies. The user is then free to navigate through the book information screens as usual.

### **5.1.3 Phone Details**

We are using the Nokia 6600 cell phone and Java MIDP. Originally the phone code was written in Symbian C++, but we switched to Java. The phone uses the Bluetooth Serial Port Protocol to talk to both the server and the Bluetooth gateway device that talks to the objects.



**Figure 23. System components. Books, phone, gateway, interaction manager server.**

## 5.2 Object Devices

### **5.2.1 Description**

The object devices are built using Xemics DP1203 RF transceivers, ATMega 88 microcontrollers, capacitive sensors, LEDs, and various RC components. In a previous prototype, each object had a Bluetooth chip and spoke directly to the phone. For performance and cost reasons, we switched to the Xemics transceivers. In order for the phone to speak to the book devices we use a gateway device that handles the communication between the phone and the books. The gateway contains a Xemics DP1203 and a Bluetooth module. The phone receives and parses the commands from the interaction manager and relays the message on to the gateway. The gateway then broadcasts the message out to the book devices. If a device hears its name, it will run the requested command, which typically is to flash its LED. The devices can also send commands back to the gateway based on its sensor data.

The devices contain a capacitive sensor that allows the devices to know when the book they are attached to has been picked up. This enables the functionality in the system where other books in the environment that have similar content to the currently touched book to also light up and provide information to the user.

If the capacitive sensor on one of the books detects that the user has touched the book, the device will send a message back through the Bluetooth gateway to the phone, which relays the message back to the interaction manager. As with all the interactions, the interaction manager searches local book agents for books that are related in content to the touched book and sends commands to light up those books.

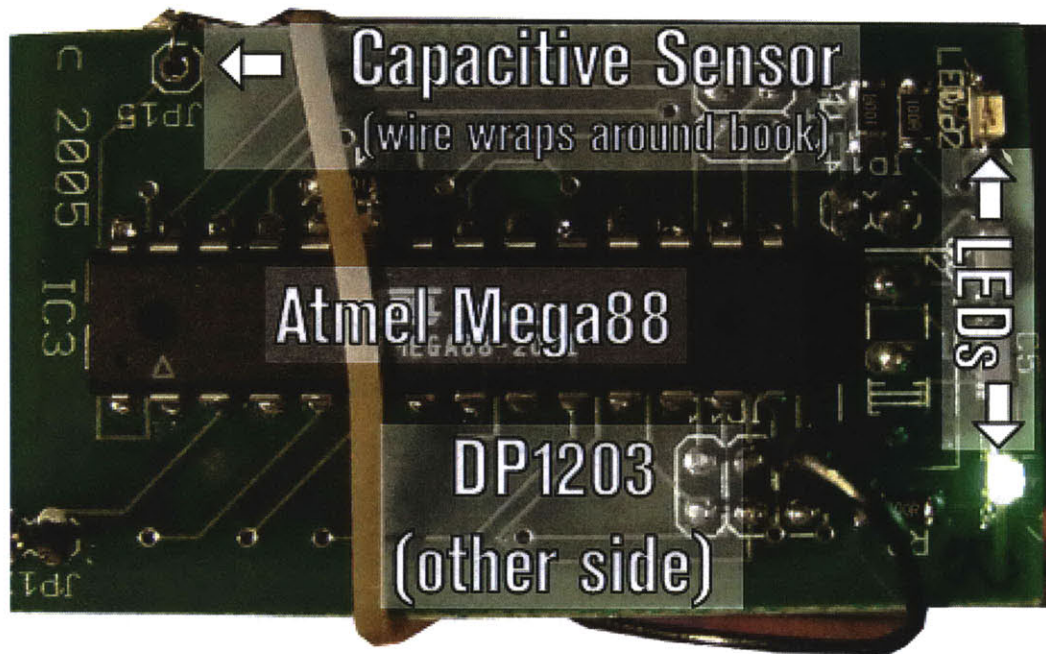


Figure 24. Embedded device.

## **5.2.2 Design**

The most difficult decisions in the process of designing the system had to do with the embedded devices. There were a number of factors to consider: Price, protocol, size, and power. These mostly had to do with the RF solution we were trying to choose, as microcontrollers are very cheap and relatively interchangeable. What follows is a discussion of some of these issues and some of our solutions. We will also briefly discuss what sensor we used and some alternatives we considered.

### **5.2.2.1 Price**

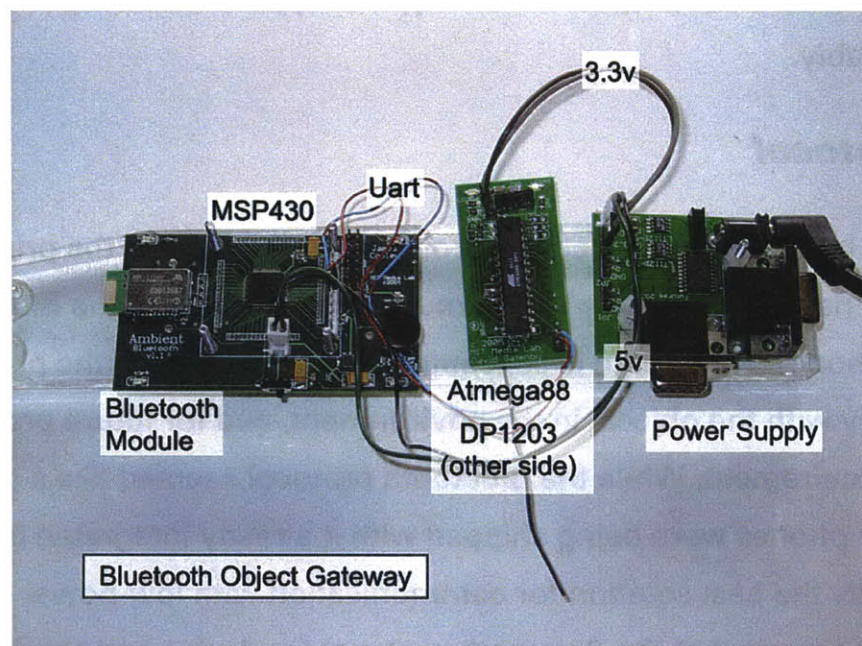
The earliest prototype design of the system used Bluetooth modules made by BlueRadios. These modules were quite expensive for the functionality they offered. Most modules on the market with a Bluetooth stack built in tend to be pricey, so we decided to forgo the Bluetooth protocol for a cheaper RF solution. If Bluetooth becomes more popular for this type of application, the prices should drop considerably.

### **5.2.2.2 Protocol**

Unfortunately in leaving the Bluetooth protocol behind we lost the prime benefit that it offered, namely the ability to communicate directly with the Bluetooth enabled cell phone. The design is conceptually much cleaner if the phone can interact directly with the objects in the environment, and for future projects that should be a requirement. While the Bluetooth protocol seemed like a good choice because many phones were being shipped with it already integrated into them, it is not inherently the best solution for communication with low-power embedded objects. One reason is that the Bluetooth protocol for device and service discovery is very slow, which potentially delays notification of relevant objects. Another reason for this is that the protocol has a lot of overhead that makes devices using

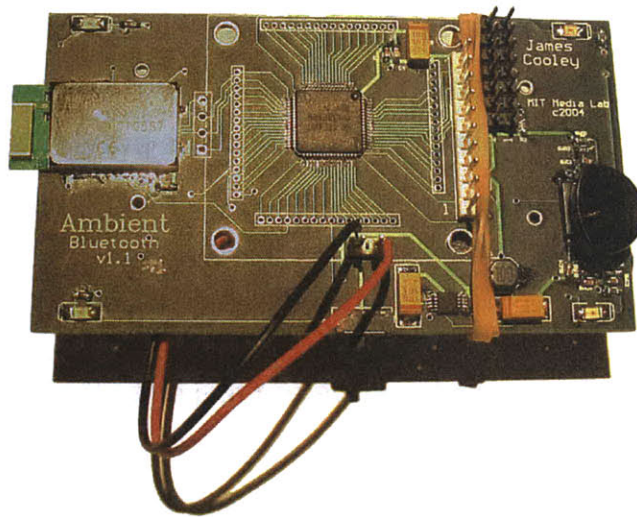
it more power hungry than necessary for a low throughput application like ours. As the Zigbee protocol becomes more mature, it might turn out to be a good replacement in an application like this one, but there are very few implementations using Zigbee [49]. Another solution is to build an add-on device for cell phones with optional peripherals or extra ports. For instance, a phone with a serial port could interface with an external device like the DP1203 device that we built for our gateway. This would require the user to purchase extra hardware for their phone, but would do away with the need to put a gateway in every environment where smart objects could be used. This way anywhere a smart object was a user could communicate with it.

If more interesting research and product development is done in this area of embedded devices talking to cell phones we might see more market pressure to have a good protocol built into phones. Either that or perhaps phones will become more modular and consumers will be able to easily upgrade their phones to be compliant with object aware systems.



**Figure 25. Bluetooth Object Gateway.**

In the mean time, without Bluetooth in each book device, a gateway was built that speaks Bluetooth to the phone and a microprocessor translates the command into the protocol that the DP1203 modules understand. This means that any smart device enabled book has to be within range of a gateway device to be able to interact with a person using the system. While this is a limitation that has to be dealt with before a system like this could be universally usable, it doesn't restrict the system from being used in smaller environments like a shop or a home.



**Figure 26. Bluetooth piece of the gateway device.**

### **5.2.2.3 Size**

In order to embed devices into objects like books, the device needs to be as small as possible and as thin as possible. Ideally the devices would have the same form factor as, say, an RFID tag. Of course, current technology prohibits having an active tag at that size, but there are a number of two-way active RF devices that are quite small. We considered using the MITes designed by House-n at the Media Lab, but we couldn't be assured when we would get the parts nor if we could get

support for the platform should we need it [37]. The size of these devices was quite desirable. After moving on from the MITes, we started looking at building our own solution. We considered a few different models that were very small. We built prototypes with the Chipcon 2420 and the Nordic RF24E1. While these devices would have allowed us to create smaller devices, these solutions posed a potential problem of being difficult and time consuming to put together manually and since we wanted to build about forty devices we started looking elsewhere. We finally settled on the Xemics DP1203, which is a larger, but still only 30x18mm, drop-in module. In making the decision to go with the larger DP1203, we decided that size was not paramount to our investigating what happens when proactive devices are embedded into objects. The devices still needed to fit on the spine of a book, but they would not be hidden in the spine. From this point we decided to use the Atmega88 microcontroller. The Atmel chips provide a nice set of functionality in a good package.

#### **5.2.2.4 Power**

Power is another area of concern for a system like this. If systems like these are going to be developed then there needs to be an ultra low power means for objects to communicate with users. Our objects in low power mode can last for a few days, although in this mode there is some latency in the gateway connecting to the devices since they cycle off the power for short periods. If systems like these are to be widely used, power is one of the most important design factors, and the smart objects will have to last on the order of years without needing their batteries recharged. Some solutions are mentioned briefly in the future work chapter.



<b>Product</b>	<b>Size</b>	<b>Price</b>	<b>Protocol</b>	<b>Interface/Command</b>
<b>Blueradios</b>	<b>1.25"x.8"</b>	<b>\$100</b>	<b>BluetoothSPP</b>	<b>Serial/AT Command Subset</b>
<b>DP1203</b>	<b>30.5mmx8.5mm</b>	<b>\$17</b>	<b>User defined</b>	<b>SPI-like/Serial Control</b>
<b>CC2420 w/ Zigbee Stack</b>	<b>7mmx7mm</b>	<b>\$17 + \$5000 dev kit</b>	<b>Zigbee</b>	<b>TBD</b>
<b>Radiotronix</b>	<b>1"x1"</b>	<b>\$33</b>	<b>User defined</b>	<b>Serial</b>

**Figure 27. RF Comparison Table.**

### **5.2.2.5 Capacitive Sensor**

The embedded device needed a way to sense when a user picked up the book. Initially we tested using an accelerometer to detect when the book moved. We also began testing using some basic machine learning to try to understand different use patterns for how the book was being used. This testing was not adding any perceived benefit to the proposed application, so we decided not to use it. We moved to a capacitive sensor, because the power requirements and cost were significantly less than the accelerometer.

The capacitive sensor uses what is known as "loading mode" sensing. Loading mode senses how much current is drawn away from the transmitter plate[36]. In this system, the transmitter plate is a copper wire that is attached to the circuit and wrapped around the binding of the book. Another wire is attached to ground and wrapped around the other side of the binding. A square pulse signal is sent through the transmitter plate and read on one of the Atmega88's ADC pins. When a user picks up the book, their skin, which is conductive, draws off some of the current to ground. This affects the rise time of the square pulse. The microcontroller looks at the change in the rise time of the square wave at the ADC

pin. Once the rise time crosses a threshold value, the book object transmits the touched event back to the interaction manager through the phone. There is further discussion of the sensor solution in the future work chapter.

### ***5.2.2.6 Device Discussion***

While we spent a good deal of time trying to solve many of the interesting hardware problems facing research in the area of ubiquitous, embedded smart devices, we wanted the focus of the system to be less concerned with these technical details. There are many other researchers working on solving these lower-level problems of price, protocol, size, and power issues. We, on the other hand, have been more interested and more concerned with building a feasible user application that we could explore what kind of benefits and problems there might be with such a system.

## Chapter 6.

# User Study and Demonstration Responses

*"Outside of a dog, a man's best friend is a book. Inside of a dog, it's too dark to read."*

-- Groucho Marx

Demonstration and response sessions and a user study were run to test the interest in and usability of the system. The demonstration and response sessions looked at the feasibility of the personalization portion of the system. They were used to get people's reactions to using a system like this. The user study was set up to help understand how people search for information in books both with and without the aid of the Internet, and what effects our system has on how their search.

## 6.1 Personalization Assessment

### **6.1.1 Setup**

People gave a positive response to the system in the demonstration and response sessions that were run. The sessions were purely qualitative analyses. Physical objects were shown attempting to attract the participant's attention based on certain elements of the user interest profile. Over the course of two months the system has been demoed approximately two dozen times to people including Media Lab students and faculty, lay people, as well as a number of sponsors from companies related to the telecom and wireless cell phone industries such as Motorola, France Telecom, Nokia, and British Telecom.

The demonstration showcased three different pieces of the system's functionality. These were object attraction, object search, and related recommendations.

For object attraction, the phone is set up to simulate one of six different predefined users each with a clean user interaction history. When the application is started on the phone, one of the six users is picked. The application then begins polling the environment for a gateway. Once a gateway is within range, the interaction manager on the phone requests that all available objects identify themselves. As the books register themselves, the interaction manager sends the user agent the relevant book records, the phone agent alerts the user with a beep, and the books alert the user to their location by flashing their LEDs. The participant can then look at the list of books on the phone and review any of the records they are interested in. They can also explicitly request a particular book to flash its LED for easy spatial localization.

For object search, the user can enter a query into the search interface and the list of books that match the keywords are returned. The user can again find what records for each book matched the query. There is a more detailed discussion of the search interface in the next section on the task completion study.

For related recommendations, the user simply picks up a book and the books with related content show in a list on the phone and the book devices flash their LEDs.

### **6.1.2 User Comments**

During these demonstrations, there were many different responses to the system. People generally fell into one of two categories of responders. Either they had a lot of ideas about what ways the system would help them keep in touch with their friends and make their lives easier, or they came up with a lot of worst-case scenarios where the system would introduce privacy and usability concerns.

Some of the responses from the ideas group follow. A common response was that people said it could help them find their keys or that it would help them when they were shopping. They said the products that were on their shopping list could flash at them as they walked through the store. Some who mentioned this also mentioned that there has been work done with RFIDs that offer the same functionality. Under further examination of the projects people referred to, it was found that while the RFID implementations of similar systems do have an understanding of the environmental context and can offer information about objects intentionally picked up, they generally don't have any way for an object itself to attract a user's attention, nor do they typically have dynamic, personalized interest models proactively offering new information about physical objects.

In discussing the nature of the social recommendations that the system provides, a few people mentioned that having a system like this might give them more reason to update their social network profiles and review more of the books they had read. They commented that they don't currently make these updates because there is no incentive for doing so. While many people professed using online reviews, they confessed to not registering their own because there was no

perceived benefit. They suggested that they could see more merit in updating their online profiles and writing reviews with the tangible benefits the system offers. They related that if they had access to a system like this, with its ties to real world scenarios like being in a store shopping for birthday presents, they could see the benefit of the system having up to date information. That is, they could see the benefit both in getting useful information about their friends when they needed it, but also in providing friends with information about their own interests. One person mentioned, "It might be nice (to use the system), because it might mean getting things I want, because if [friends] can see what I like, they might get me something I want, and not something they think they would like that I might like, too." Another participant mentioned that when she was browsing in a bookstore she would like to know which books her friends had read recently and liked. She said that while she could currently go online with her phone, it was too much of a hassle, but having the information actively offered would make it easier and more useful.

About as many people responded positively to the demonstrations as responded with hesitation. The worst-case scenario respondents had a lot of questions. They questioned whether they would be overwhelmed with too many interruptions from the system. That they got enough emails and phone calls already and would more messages from random objects do anything but distract them from their already busy schedules. Many people also responded that it reminded them of the *Minority Report* scene where the advertisements vie for Tom Cruise's attention. They said that they would hate a system that could be prone to such spam-like abuses. At the same time, many who were hesitant, citing questions about privacy, also showed interest when they considered new possibilities for getting and leaving information from and for friends. One participant commented that this system could be used to create a digital public message board. The digital public message board takes its idea from traditional message boards. Traditional message boards are often found in public areas and have usually consist of Xerox

copies of flyers announcing special events, movies, property for sale, music lessons, classes, etcetera. The digital message board takes what is usually a visually chaotic mess of overlapping, outdated information and tries to overlay it with certain amount of personalization. The flyers on the message board would be embedded with smart devices and people walking by the message board would be attracted by messages that were relevant to their interests. They could also leave comments about the messages, or leave new messages themselves.

People also made quite a few suggestions about what they would like to see in the system. Some said they would like to leave messages for their friends in books, or put virtual post it notes in the books that they could access later when they were at their home computer. Yet another comment was that it would be nice to use the books as a way to meet new people by connecting to people who were also looking at the same types of books in different locations. Another said that it would be cool to ask real-time questions on the phone while in a bookstore about a particular book or type of book and get an answer either from someone who worked at the store or from other shoppers. These comments showed the many different directions that this sort of system could take if a bookstore or library were outfitted with a system like this.

From the reactions to the demonstrations, it appears safe to conclude that people are particularly attracted to the community-related functionality such a system can provide: getting recommendations from trusted friends, having friends know what you like, communicating with others through common activities like reading the same books, either synchronously or asynchronously.

### **6.1.3 Discussion**

Subjects in the sessions often remarked about similarities they saw in the system to other system's in the Ubiquitous Computing domain. When questioned further about this similarity, subjects often could not point to specific work that had the same functionality. This seems to point out that the idea is conceptually intuitive, that a physical object is an obvious place where information about that object should be delivered, and if there is information about the object that might be useful to a person, the object should have a means to inform the person.

There is another issue that the users' comments bore out. It concerns messing around with systems that already work well. Physical objects have a meaning and functionality that is distinctly separate from the digital information that refers to them. Typically, information about objects is not stored in the objects themselves. As physical objects begin to be embedded in the environment meta functionality like review data, searchability, and personal annotation, it is necessary to be sure that the interfaces for getting and leaving this information is as intuitive as the traditional use of the objects themselves is, or there is the risk of ruining the interfaces, i.e. the physical objects, we currently trust. With this work we have tried to discover what are the obvious features that one would expect to see in a book enabled with digital information, and we have also tried to gauge how useful those features are. People said they want to be able to trust the system not be interrupted with spurious information at inopportune times. However, if they felt they could easily control the system and understand why and from where they were getting the information, they could see the benefits of using it.



## 6.2 Task Completion Study

A second, more objective user study looked at how useful the system was for users trying to answer specific questions. This study was an attempt to see how people currently do searches in a group of books when faced with some information need.

### **6.2.1 Setup**

The study was setup as follows. Fifteen people participated in the study. Each participant was asked to answer three sets of five questions. They were given fifteen minutes to answer the first set of five questions. Then they were given fifteen minutes to answer the second set of five questions. Then they were given fifteen minutes to answer the third set of five questions. For each set of questions they were given a different set of tools to help answer the questions.

The three tool sets were:

1. A shelf of books.
2. A shelf of books and a cell phone with full Internet connectivity.
3. A shelf of books with embedded devices attached to the spines and a cell phone running a version of our system.

The respondents were given a survey form to fill out their answers to each of the questions asked. The survey also had space for users to give us feedback about how they went about their search.

Galatea Survey New Survey

0 You are using: Just the books

Question: 0

Where is the research being done on implanting electrodes into monkey brains and training them to control a robot arm?

Did you already know the answer to the question?

Yes  
 No

Which book(s) did you look in?

Which book(s) did you find the answer in?

What would have made it easier?

Do you feel you got the question right?

Yes  
 No

Why/Why not?

Other Comments

You can't go back  
so if you are sure you are ready...  
Go to next question==>

**Figure 28. Example survey page.**

The questions a user had to answer were picked at random from a pool of thirty questions (see the Appendix for the pool of questions.) There were three different types of question. One type of question was primarily conceptual. An example of this type of question is, "Why are short sellers looked upon with suspicion?" Another type of question was primarily factual. An example of this type of question is, "What is phobophobia?" The final type was topical. For instance, "List some books about the mind." With each of the questions, the scope of the

questions was limited so that they could be answered in a couple of minutes by using just the shelf of books. All the information needed to answer any of the questions could be found somewhere in the forty books. Some of the questions were more open to interpretation than others.

At the end of the survey, the users were given the opportunity to give their input about the different tool sets, the issues they had in trying to answer the questions given the different tools, and the survey in general.

## **6.2.2 Results**

This study looked at how people go about searching for information in a complex physical space. Three different approaches to searching for information contained in a shelf of books were compared.

### **6.2.2.1 Observations**

Tool set 1 was just a shelf of books. Participants had to search for the answers to each question by using the books as their sole means of reference. Each participant took a different approach to finding the information. One participant looked for the answer to the questions by looking only at the authors' names and flipping through a couple of pages of one or two books at random. After this cursory examination the participant decided they could not answer the question and went on to the next question. The participant was unable to answer any questions in this set. Another participant took a more structured and successful approach. She looked at all the titles to see which might be related the most to the question. Then they looked in the index for references to the subject of the question. This participant answered two of the questions correctly before running out of time. This approach was probably the most common across the 15

participants. A third participant looked at the table of contents of the books for pointers to information about the questions. Most of the participants started out unsure of how to approach the books, but each of them eventually fell into a unique a pattern of search. On average, participants answered two questions in the allotted 15 minutes with 73 percent accuracy.

Tool set 2 was the same shelf of books with a web browser enabled cell phone. Participants could search for the answers by looking in the books and using an Internet-enabled Nokia 6600 phone. Almost every participant used the Internet phone to search for the answers to their queries. The exception to this was when the question was topical, like "Find books about wireless privacy issues." In most cases users used the web browser on the phone exclusively and only rarely went to the books. More comments about this are in the section on user comments. On average, participants answered between three and four questions with 61 percent accuracy. The lower accuracy seems to have to do with the ambiguity in some of the questions, and therefore participants were unsure of how to pick between different answers they found online.

Tool set 3 was the shelf of books enabled with our embedded devices and a cell phone with our system running. Using the third tool set participants could search for the answers using our system's search interface on the phone and by looking in the books. In this case, on just under half of the questions the participants first used the phone interface to do a search, and then used the page number they got from the results to finalize their answer to the question. On the slight majority of the questions, however, participants used only the information returned on the phone interface to answer the questions without referencing the books at all. Participants using this tool set showed a better balance between using the phone interface and using the books than did participants while using the second tool set. On average, participants answered four questions with 69 percent accuracy.

	Answers				Average per person
	Total	Correct	Wrong	% Right	
<b>Tool set 1</b>	33	24	9	73%	2.2
<b>Tool set 2</b>	52	32	20	62%	3.5
<b>Tool set 3</b>	63	44	19	70%	4.2

**Figure 29. Results of user study.**

It is important to note that the stability of percentage accuracy measures for this study are in question. Without a considerably larger set of participants and a more constrained set of questions, it would be hard to make any hard claims about whether any one of the tool sets was better than another. The accuracy measure in this section is left as a guide to the results.

With all three tool sets, results were thrown out when people already knew the answer to the questions. Participants were given full credit for answers that were partially right and questions were thrown out where a participant read the question and decided not to answer it. One question that was consistently thrown out was, "What does Andre Breton think about the novel?" Questions like this one proved to need more time than a person was willing to take to find the answer given the fifteen-minute time limit.

Participants seemed to take the most time when answering using the books alone. This appeared to be because they had to pick up each book and flip through many pages of the index or table of contents before finding an area of the book where they wanted to try to find the answer. Even though they took more time to find the answers by looking in the books, their accuracy was quite good.

### **6.2.2.2 User Comments**

When using our system or using the Internet phone it was found that people were able to answer the questions more easily than answering questions using the books alone. An interesting observation was that when using our system as opposed to the Internet phone, people commented that they were usually more confident in the answers because they had found them in a book as opposed to on a random website. This was not as true when the people found an answer on a website they knew and trusted. Another interesting result was that when people used the web browser on the phone, they often did not use the books at all as a reference. Participants speculated that this is likely due to the fact that their Internet searches were not tied in any way to the books themselves, except by accidental query results having references to one of the books.

One participant noted that they would find our system useful when looking for specific information in a specialized section of books. For example, he said it would be useful “to find the books in the painting section that had specific tutorials on the acrylic simulation of the egg tempura method of oil painting.”

The results did suggest a bias in the experiment that favors the Galatea system versus the web browser on the phone. When doing an Internet search on Google or a book search on Amazon, results are returned from the entire spectrum of data that the engines search over. Galatea, on the other hand, only searches for information in the books that are used in the experiment. All of the questions developed for the experiment have answers within the contents of the books used in the experiment. In general, people answered the questions more quickly using our system. There were many instances where participants would rapidly find a correct answer in the Google results. In fact, Google’s mechanism for expanding or adjusting a query sometimes allowed for people to get better results more

quickly than they did using our system. These biasing factors make a more empirical analysis of how well the participants did answering the questions in the allotted time less meaningful.

The bias notwithstanding, the experiment did provide interesting insights into how people perform everyday information retrieval tasks and showed how a system like ours might be of practical use to people, how it might offer people a way to use online information in novel ways, and how making a connection between physical objects and online information can add benefit to a person's use of both mediums. For instance, it showed that people like the convenience of the fast querying that online searching allows, but that for browsing and extraction of more significant information, most participants indicated that there is no replacement for the physical books. As such, they were attracted to the being able to use our system to do a search for information using their phone and be directed to the actual books in the room where they could find more information about their search question. Three participants commented that this was especially true for non text-only books like design books, art books, cooking books, manuals, etcetera, where the layout and images were equally if not more important than the text the books contained. Participants liked the integration of online search with direct reference to the local physical books that our system offered.

These evaluations suggest that there is perceived value added by making online information available through the physical objects it refers to as long as issues of privacy and interruption are properly accounted for.

## Chapter 7.

### Future Work

*“Choose an author as you choose a friend.”*

-- Sir Christopher Wren

One of the things that many users commented on was interruptability and attention. To make a system like this acceptable to a wide audience, the system must not irritate users with too many objects flashing at them. The useful alerts the objects provide in one context could be considered interruptions in another. The system needs to know when the information it wants to provide is useful. This is a hard problem for a system like this. The user agent has to model not only the interest profile and interaction history of the user, but also has to predict the social context of the user. While the current system models the physical context of the user by ranking the different objects in the environment by how well connected they are to the user's interest profile, the system does not currently try to model the social context. The system does not know when the user is engaged in a conversation with someone or in a meeting where they do not want to be disturbed. With the coming of age of ubiquitous computing projects, developing robust context models of a user's activity and interruptability is an important



research goal. [17] and [14] provide some insight and solutions to these issues. These types of problems need to be addressed in a future version. In the short term, we would like to incorporate more context awareness into the system by both allowing people to set up different interruption levels and to plug in to a person's scheduling software to give the system a better understanding of what activities the user is engaged in.

We have also been working on extending the system to automatically pull additional profile information from a user's personal web site, web browsing activity and history, email, blogs, and offline documents, as well as the interests of friends or people with similar behavior patterns, in the vein of Amazon's "people who read this also liked" suggestions. This additional information is mined using text mining, template matching, and common sense expansion tools [5] [20] [48].

One piece of functionality that people suggested and that is partly built into the system but that has not been tested is a messaging interface that lets someone leave a message in a book either for anyone in their primary friends group, or for a specific friend. This message gets added to the book profile content list with a high priority for the user(s) that it was left for.

Another area that would be interesting to explore is giving users the ability to see what objects their close circle of friends was currently near. Similar to Natalia Marmasse's work, WatchMe, this would give people a non-interruptive way to get an idea what their friends were currently doing, i.e. through the indirect channel of the contextual clues given by the objects they are currently near[23].

From the user study, one participant suggested that it would be nice to be able to ask questions of people through the objects they were near. For instance, if someone was in the cooking section of a bookstore, they might ask a question about bouillabaisse recipes through the phone interface and the question would

make books on cooking light up for users who were currently near cooking books. On their phone the question would show up and they could choose whether or not to answer the question. The implication here is that if people are near certain kinds of books, then it is likely that they might have knowledge about the kind of information in the books and so are more likely to answer a question about that kind of content. Another suggestion that perhaps the objects could work together to help guide a person to areas, say of a bookstore, that might be more interesting to them than where they are now. Objects might flash in synchrony like a landing strip pointing the way to a specific object down the way.

There are many challenges for the embedded object piece of the Galatea system. The most obvious one is making embedded devices that have enough power to communicate with other devices as well as be able to support some type of sensors and actuators without needing to be recharged frequently, if ever. We have been looking at smaller, more power efficient technologies like Zigbee for the embedded devices. Researchers at UC Berkeley are also building super tiny, very low power Motes that might be a viable solution in the relatively near future[43].

There is also interesting work being done in other groups looking at harvesting power from the environment to power small devices[24][29]. This sort of solution would be ideal because the devices could be self-sustaining and a person would never have to replace the batteries. Although ambient power supplies in typical home or office environments are very low, perhaps wall socket devices could be developed that would send focused charging power to devices in a room while the room was empty.

There is another pressing hardware issue with the current implementation. In future revisions of the system we need to find a way to link a book that is picked up to the person picking up the book. Currently the book senses that it was picked up and sends a signal out to any user agent in the area. There is no

discrimination between a user that is touching the book and a user that is not. Both will receive the book-touched event. We have come up with two solutions for this problem. Another ongoing project in the Ambient Intelligence group is ReachMedia, whose interface includes a wristband with an embedded RFID reader[11]. This reader is placed so that it reads an RFID placed in a book. This functionality would solve the problem of the link between the user and the book, but would require that we add the wristband technology to our system. The ReachMedia system is complementary to ours in many ways and we have discussed integrating the two systems together.

Another solution would be to use an intrabody bus to send the id of the book from the book through the user's body. Using the body as a wireless network has been shown to be plausible[30]. In fact, Microsoft even has a patent on the idea[40]. This solution would require the extra technology to interface with the skin of the user and receive the id of the book when the user touched the capacitive sensor on the spine of the book. This added technological requirement makes this solution less likely in the near term, but could be a solution if intrabody personal area networks ever become popular. The ReachMedia solution is a more reasonable short-term solution.

Even though there is not an ideal solution to the smart object device problem, there is definitely a need for more work to be done on designing and testing interesting applications for smart environments. Our user studies show that people are concerned about usability and privacy issues with regard to smart object systems. There should be more research being done on finding the right application that addresses these concerns and provides a useful product.

## Chapter 8.

# Conclusions

*“The things I want to know are in books; my best friend is the man who'll get me a book I ain't read.”*

-- Abraham Lincoln

It is important for researchers of smart objects not to focus only on the architecture and infrastructure. It should be asked not only “how will it work,” but also “what will it do for us?” When smart environments become easy to outfit hopefully researchers will begin to focus more on building interesting applications for those environments.

The Galatea system described in this thesis is meant to be such an application. This work has sprung from a love of books and an interest in how people communicate information and a belief that the objects in our lives are important symbols of who we are. Starting with an intuitive idea, that physical objects and the digital information about them should be merged together, the Galatea system lets people take advantage of both their physical world, by being alerted

to personalized digital information about objects in their vicinity and take advantage of the digital world, by dynamically situating digital information into the physical contexts where it might be most relevant.

Galatea allows the personalized information and services that are so common on the Internet to be managed and proffered to people by the relevant augmented physical objects in the real world. Galatea allows proactive, information-enhanced physical objects to assist people by alerting them to relevant information opportunities. A user study and assessment of the system suggest that there are tangible benefits to enabling physical objects with the ability to attract a person's attention to pertinent online information. People have suggested that they are most interested in the how Galatea might enable them to keep in touch with, learn more about and share experiences with their friends, families, and communities that share their interests. They have also expressed concern about privacy and interruptability.

Most of the objects one interacts with in the physical world have counterparts in the digital world. There are reviews, excerpts, comparisons, indices, specs, lyrics, recipes and on and on. While this information is often relevant as people interact with the world, most of the information is either inaccessible or people are unaware of the information that is available. As physical environments get smarter, people should take advantage of all that digital information by embedding it into the environment. But the designers of such systems should take care to make the information useful, and make it useful immediately, when it is needed, which often is right now, and not later when at home with some free time to browse for it. Information should work for us and it should enrich our interaction with the world. The Galatea system was meant to be a step in that direction.

## References

- [1] Ambient Devices' Orb, <http://www.ambientdevices.com/>.
- [2] Andreoli, Castellani, Grasso, Meunier, Muehlenbrock, O'Neill, Ragnet, Roulland, Snowdon, "Augmenting Offices with Ubiquitous Sensing," in *Proceedings of SOC 2003*, Grenoble, France, 2003.
- [3] Berkeley WEBS, Wireless Embedded Sensors project, <http://today.cs.berkeley.edu/> .
- [4] Bush, Vannevar, "As We May Think," *Atlantic Monthly*, July, 1945.
- [5] Chakrabarti, Soumen, *Mining The Web*.Morgan Kaufmann, San Francisco, CA, c2003.
- [6] Chan, Wesley, "Project Voyager.: Building an Internet Presence for People, Places, and Things," Master's Thesis, MIT Media Lab, May 2001.
- [7] Csikzentmihalyi, Mihalyi, *The Meaning of Things: Domestic Signals and the Self*, 1981.
- [8] Decker, Christian, Kubach, Uwe, and Beigl, Michael, "Revealing the Retail Black Box by Interaction Sensing," IWSAWC 2003, Providence, Rhode Island, *Proceedings of the ICDCS 2003*, 2003.
- [9] Delicious Library, [www.delicious-monster.com](http://www.delicious-monster.com).
- [10] Donelson, William, "Spatial Management of Information," *Proceedings of the 5th annual conference on Computer graphics and interactive techniques*, 1979.
- [11] Feldman, Assaf, Tapia, Emmanuel Munguia, Sadi, Sajid, Maes, Pattie, Schmandt, Chris, "ReachMedia: On the Move Interaction with Everyday Objects," *ISWC*, 2005.
- [12] Handspring Treo 650,  
<http://handspring.com/products/smartphones/treo650/index.jhtml;jsessionid=11XX3SU35AJ40CQFGJDSF EYKAUZEMIVO> , 2005.

- [13] Ishii, Hiroshi, and Ullmer, Brygg, "Tangible Bits: Towards Seamless Interfaces Between People, Bits and Atoms," Published in the *Proceedings of CHI'97*.
- [14] Kern, Nicky, and Schiele, Bernt, "Context-Aware Notification for Wearable Computing," ISWC, 2003.
- [15] Kindberg, T., Barton, J., Morgan, J., Becker, G., Caswell, D., Debaty, P., Gopal, G., Frid, M., Krishnan, V., Morris, H., Schettino, J., Serra, B., and Spasojevic, M. "People, places, things: Web presence for the real world." *Mobile Networks and Applications 7*, (2002).
- [16] Lieberman, Henry, Faaborg, Alexander, Espinosa, José, Stocky, Tom, "Common Sense on the Go: Giving Mobile Applications an Understanding of Everyday Life," *BT Technology Journal*, Kluwer, (2004).
- [17] Lieberman, Henry, and Selker, Ted "Out of context: Computer systems that adapt to, and learn from, context," *IBM Systems Journal* 39, Nos. 3& 4, 617632, 2000.
- [18] Lieberman, Henry, and Selker, Ted "Agents for the User Interface," in *Handbook of Agent Technology*, Jeffrey Bradshaw, ed., MIT Press, 2003.
- [19] Lieberman, Henry, "Autonomous Interface Agents," *ACM Conference on Human-Computer Interface [CHI-97]*, Atlanta, March 1997.
- [20] Liu, Hugo, Lieberman, Henry, and Selker, Ted, "Goose: A Goal Oriented Search Engine with Commonsense," *Conference on Adaptive Hypermedia and Adaptive Web Systems*, Malaga, Spain, May 2002.
- [21] Liu, Hugo, and Maes, Pattie (2005) InterestMap: Harvesting Social Network Profiles for Recommendations. *Proceedings of the Beyond Personalization 2005 Workshop*, to appear. ACM Press 2005. San Diego, January 9, 2005.
- [22] Ma, Hongshen, and Paradiso, Joseph, "The FindIT Flashlight: Responsive Tagging Based on Optically Triggered Microprocessor Wakeup," *UbiComp Proceedings*, 2002.
- [23] Marmasse, Natalia, Schmandt, Chris, Spectre, David, "WatchMe: communication awareness between members of a closely-knit community," *Proceedings of UbiComp 2004: Ubiquitous Computing*, September 2004.
- [24] Martinez Araiza, Jorge Ulises, "Wireless Transmission of Power for Sensors in Context Aware Spaces," Master's Thesis, May 2002.
- [25] MIT House\_n, [http://architecture.mit.edu/house\\_n/](http://architecture.mit.edu/house_n/) .
- [26] MIT Oxygen Project, <http://oxygen.lcs.mit.edu/> .
- [27] MyGrocer, <http://www.eltrun.gr/mygrocer/> .
- [28] NTT DoCoMo, "NTT DoCoMo to Launch Revolutionary Mobile Wallet Service Useable with New i-mode Smart-Card Handsets"  
[http://www.nttdocomo.com/presscenter/pressreleases/press/pressrelease.html?param\[no\]=457](http://www.nttdocomo.com/presscenter/pressreleases/press/pressrelease.html?param[no]=457) , 2004.
- [29] Paradiso, Joe, Starner, Thad, "Energy Scavenging for Mobile and Wireless Electronics," *Pervasive Computing*, January-March 2005.

- [30] Post, E. Rhemi, Reynolds, Matt, Grey, Matthew, Paradiso, Joe, Gershenfeld, Neil, "Intrabody Buses for Data and Power," *IEEE*, 1997.
- [31] Resnick, Paul, "GroupLens: An Open Architecture for Collaborative Filtering of Netnews," Internal Research Report, MIT Center for Coordination Science, March 1994.
- [32] *Recommender Systems*. Special section in Communications of the ACM, Vol. 40, No. 3; Edited by Paul Resnick, March 1997.
- [33] Shardanand, Upendra, Maes, Pattie, "Social Information Filtering: Algorithms for Automating "Word of Mouth"," *Proceedings of {ACM} {CHI}'95 Conference on Human Factors in Computing Systems*, 1995.
- [34] Siegemund, Fank , and Florkemeier, Christian, "Interaction in Pervasive Computing Settings using Bluetooth-Enabled Active Tags and Passive RFID Technology together with Mobile Phones," ETH Zurich, Switzerland.
- [35] Siegemund, Frank, and Krauer, Tobias, "Integrating Handhelds into Environments of Cooperating Smart Everyday Objects," *Proceedings 2nd European Symposium on Ambient Intelligence (EUSAI 2004)*, pp. 160-171, Eindhoven, The Netherlands, November 2004.
- [36] Smith, Joshua, White, Tom, Dodge, Christopher, Allport, David, Paradiso, Joseph, Gershenfeld, Neil, "Electric Field Sensing for Graphical Interfaces," *Special Issue on Input Devices, IEEE Computer Graphics and Applications*, May 1998.
- [37] Tapia, Emmanuel M., Marmasse, Natalia, Intille, Stephen, and Larson, Kent, "MITes: Wireless portable sensors for studying behavior," in *Proceedings of Extended Abstracts Ubicomp 2004: Ubiquitous Computing*, 2004.
- [38] Terveen, L., Hill, W., Amento, B., McDonald, D., Creter, J., "PHOAKS: A System for Sharing Recommendations," *Communications of the ACM*, March 1997.
- [39] Terveen, Loreen, and Hill, Will, "Beyond Recommender Systems: Helping People Help Each Other," in *HCI in the New Millenium*, Jack Carroll ed., Addison Wesley, 2001.
- [40] US Patent 6,754,472, "Method and apparatus for transmitting power and data using the human body," Microsoft.
- [41] Vert Intelligent Displays, <http://www.vert.net/> .
- [42] Want, Roy, Fishkin, Kenneth, Gujar, Anuj, and Harrison, Beverly, "Bridging Physical and Virtual Worlds with Electronic Tags," *Proceedings of CHI'99*, ACM Press, April 1999.
- [43] Warneke, Brett, Last, Matt, Liebowitz, Brian, Pister, Kristopher, "Smart Dust: Communicating with Cubic-Millimeter Computer," *IEEE*, January 2001.
- [44] Weiser, Mark & Brown, John Seely, "Coming Age of Calm Technology," Xerox PARC  
<http://www.ubiq.com/hypertext/weiser/acmfuture2endnote.htm>
- [45] Weiser, Mark, "Ubiquitous Computing." <http://www.ubiq.com/hypertext/weiser/UbiHome.html>



- [46] Weiser, Mark, "Does Ubiquitous Computing Need Interface Agents? No." Talk given at Mit Media Lab Symposium on User Interface Agents, October 1992.
- [47] Weiser, Mark, "Building Invisible Interfaces," slides from keynote talk at *User Interface, Systems, and Technologies (UIST)* conference, November, 1994.
- [48] Whitman, Brian, and Lawrence, Steve, "Inferring Descriptions and Similarity for Music from Community Metadata," In "Voices of Nature," *Proceedings of the 2002 International Computer Music Conference*. 591-598. Göteborg, Sweden, September 2002.
- [49] Zigbee resources online can be found at: <http://zigbee.org/en/resources/> .

## Appendix

# Appendix A Object Device Schematic

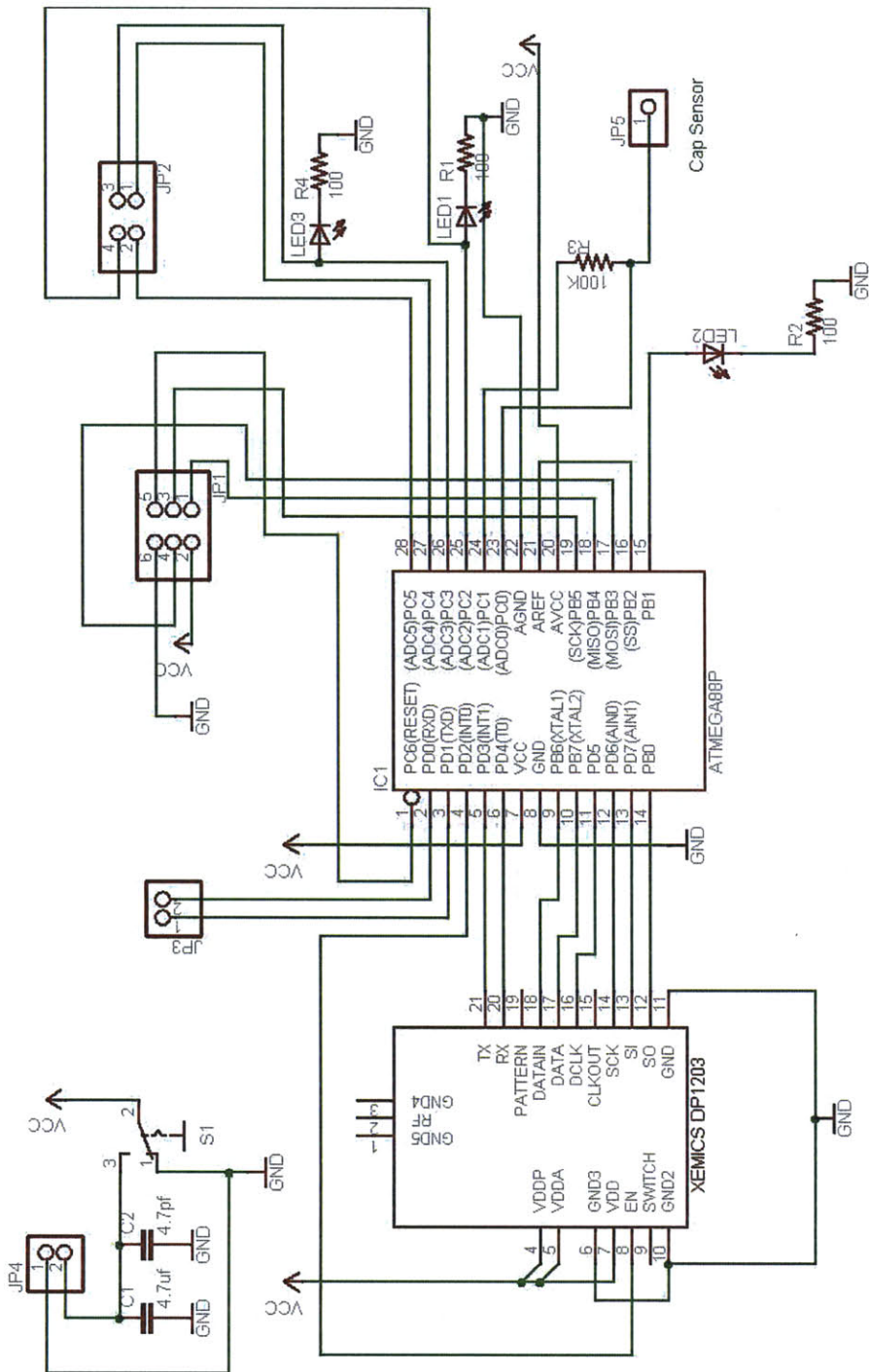
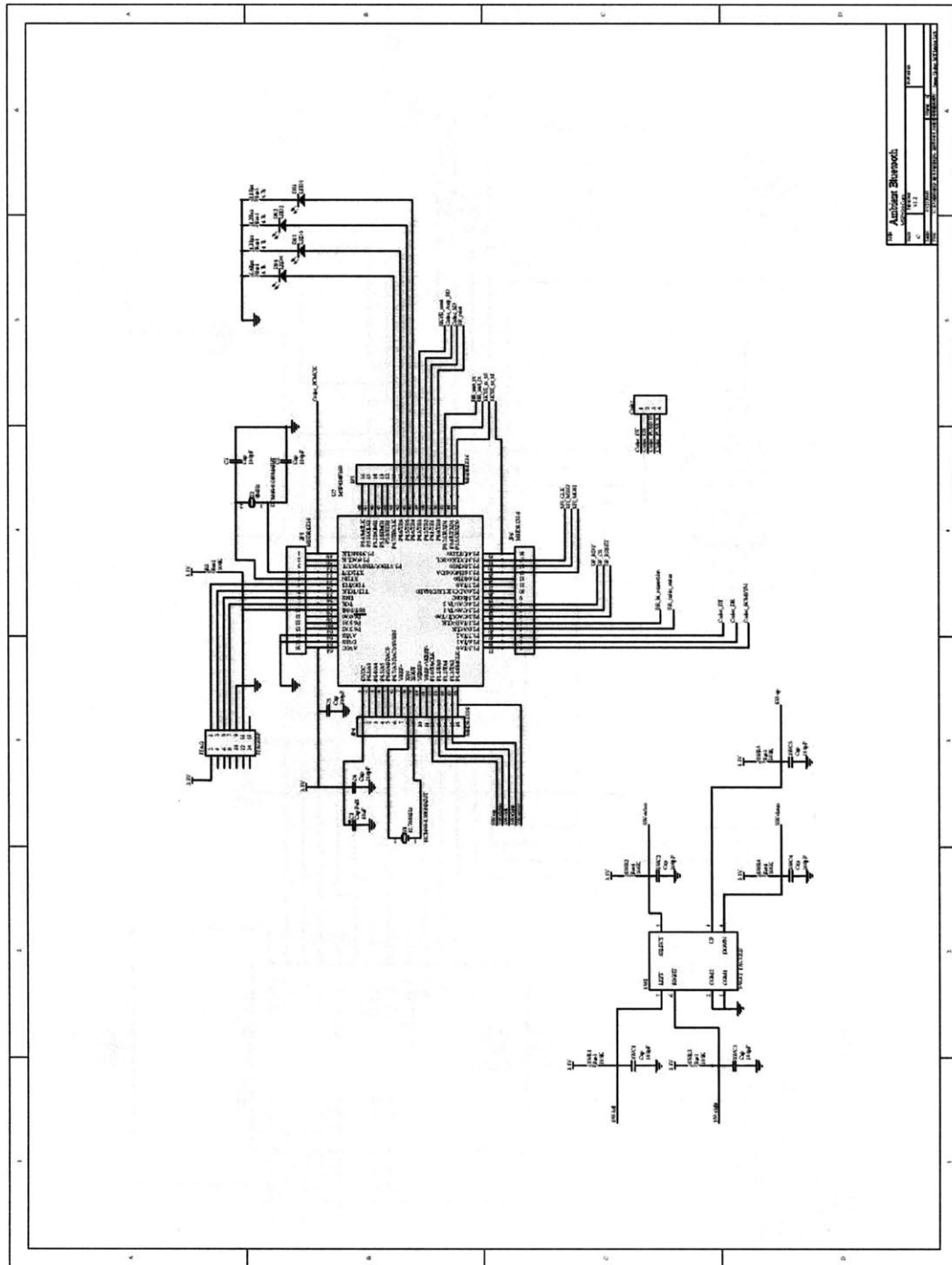


Figure 30. Schematic for the object devices.

# Appendix B Bluetooth Gateway Schematic



**Figure 31. Bluetooth gateway schematic. (Designed by James Cooley.)**

## Appendix C Study Questions.

1. Who is the editor of the luddite publication "Plain Magazine?"
2. What do Chicago gangsters have to do with genes?
3. What is Generation Txt and what government's president did they help topple?
4. What is dualism, in terms of philosophy of mind?
5. What is Chinese icebreaker?
6. What does Sense/Net sell?
7. What ailment does severing the corpus callosum cure?
8. Who coined the term informavore?
9. What is phobophobia?
10. Monkey Problem: A monkey and a rock are attached to opposite ends of a rope that is hung over a pulley. The monkey and the rock are of equal weight and balance one another. The monkey begins to climb the rope. What happens to the rock?
11. Why are quaternions better than euler angles?
12. What is BRDF?
13. What does a translation matrix look like?
14. Who invented the mouse?
15. To what prejudice does the term "centralized mind-set" refer?

16. What is the triboelectric effect?
17. Comment on Roger Penrose, mathematics, AI, and Godel's theorem.
18. Examples of prominent academics who believe we will be able to download our consciousness.
19. Who gave the talk "Why Immortality is a Dead Idea"?
20. What do extropians believe in?
21. Where is the research being done on implanting electrodes into monkey brains and training them to control a robot arm?
22. What is the Blind Watchmaker?
23. Who wrote the essay "The Cathedral and the Bazaar"?
24. What is a Herbertian Mentat?
25. What is Bayes rule?
26. How does Andre Breton feel about the novel?
27. What is the ultimatum game?
28. Why are short sellers looked upon with suspicion?
29. List some books about the mind?
30. List some books about wireless security?