PC Dinners, Mr. Java and Counter Intelligence: Prototyping Smart Appliances for the Kitchen

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Abstract: We look at the effect of capillary networks and introduction of universal digital IDs on previously unconnected objects. We have developed three prototype intelligent appliances: a microwave, a coffee machine and a kitchen counter, and look at technical and human interface considerations that arise from connected devices.

1. Introduction

We have developed a series of Internet-connected kitchen appliances which allow the user to interact with the machine in an augmented but simple manner. We chose to concentrate our research on the kitchen, which has become the social and communication center of the home. A popular topic for research has been the living room of the future, which is an essentially passive environment. In the living room, you sit in front of your television surrounded by your stereo system and absorb. In the kitchen, objects and information flow in and out, and are created and absorbed by the users.

We have created three devices, each of which addresses a different aspect of interaction and connectivity. The PC Dinners project explores a barcode-based microwave that modifies cooking times and personality, depending on the food being cooked. Mr. Java is a coffee machine that recognises users and gives them the coffee and the information that they want. Finally, Counter Intelligence is a sketch of a smart kitchen counter that helps users prepare a recipe.

2. Trends & Concepts

We see these trends shaping the way that we interact and deal with products on an everyday basis. Each one of the projects presented is attempts to explore ramifications and user considerations in a real-world scenario.

2.1. Mass Customization

This century has seen a great deal of work in the fields of mass production, statistical sampling and demographics. With an increasing awareness of questions of privacy, and an increasing reluctance to provide personal information, mass customization provides an incentive or advantage for the customer or user –- a change from the general tendency of corporate demographic gathering benefiting the company rather than the customer.

2.2. Adaptive Behavior

We expect to see appliances modifying their own behaviour based on their usage, perhaps around times of high use. For example, if a fridge knows it is opened frequently between eight and eight thirty in the morning, then it might decide not to attempt to cool during that time as the energy would be wasted, and wait until eight thirty to turn on the compressor. It is a simple step from this point to add communication such that, for example, a vending machine can inform its owner of the optimal time of day for restocking.

This type of self awareness does have some current use in maintenance applications, such as office copiers. However, such information is generally used by the company for maintainance, rather than actively modifying the machine's behavior.

2.3. Task-appropriate internet

We feel that successful integration of the internet into an appliance doesn't come from simply dropping a desktop computer into an object. The optimal way to connect one's oven to the internet is not necessarily to install a touch screen into the door. Instead, the object should be to prioritize the information flow into the oven itself: recipes and cooking times are important, whereas the ability to check your email is significantly less so.

2.4. Shared input & output devices

As the kitchen itself becomes treated more as a system than as a collection of individual objects, the ability to share input and output devices amoung intelligent appliances becomes key. Developing an oven with voice recognition is difficult and expensive, but developing an oven that can be controlled by the kitchen, and the kitchen's voice recognition system, is a useful goal. It is thus fundamental to any standards effort that interoperability of controls and input be functional considerations across the board.

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Current appliances are dumb. Their interfaces are burdensome, require learning and rarely mean that the appliance works as well as it could. An intelligent and aware appliance will know what to do and when. If a washing machine knows what clothes are in it, it's no longer necessary to tell the machine anything; putting the clothes in and closing the door should be sufficient. At the time of writing, Merloni Electrodomesticci and Electrolux have announced network-connected appliances; we expect other appliances manufacturers to follow.

2.6. Current networking paradigms cannot scale

Thirty years ago, the kind of networking that we all currently have on our desks was developed. We are currently seeing moves by various entities to move the same thing on the same scale into the home, to wire fridges and dishwashers. However, we feel that the outer limits of the next wave is not wired fridges and dishwashers; it's digitally communicating Barbies, coffee cups and paintbrushes. These 'capillary networks', connected intermittently with low bandwidth, low cost and primarily wireless networking are the future.

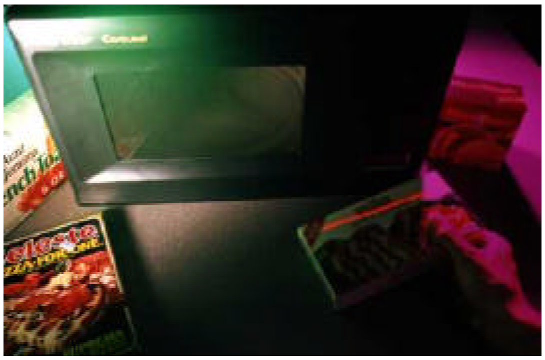
The current system for connecting a device to a network simply doesn't scale when tens or hundreds of objects in a room or house are connected. New, dynamic, scaleable and actively reconfiguring networking paradigms, along the lines of Hyphos[1] and others, are necessary for such networks. Self organization of such networks is a fundamental part of this vision, as current network configuration techniques cannot scale. We recognize there are many technical issues related to this change in networking that we do not feel qualified to comment upon, but feel that the situation itself is clear.

2.7. Ubiquitous Unique IDs

We predict – even assume, in many of our scenarios – that all products sold will have a digital ID. The barcode can be seen as a proof of concept, but, although the cost of printing is negligible, there is a cost in physical real estate, and most importantly a cost in convenience, in that the barcode can only be read when it can be seen. Another proof of concept is the Mobil Speedpass system, which has been extremely popular, and actually added revenue as users search out Mobile gas stations in return for convenience.

Most importantly, these digital Ids will be unique. Currently, UPC barcodes lack serial numbers: on the simplest home-use level, one can of peas looks like another can of peas, making it for your kitchen to know how many you have in stock. The added cost of implementing a serial number in addition to an identification number is a negligible additional cost. However, the cumulative advantages to consumer, retailer, manufacturer and recycler are huge.

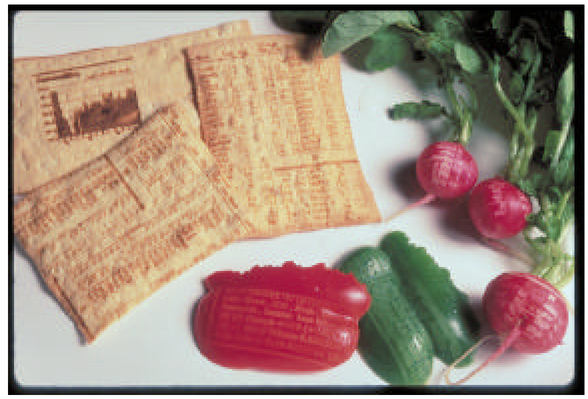
3. PC Dinners



PC Dinners is a microwave with a barcode scanner that reads the UPC code on pre-packaged food and cooks it for the appropriate length of time. In addition, it 'acquires' the personality of the food. For example, when heating frozen Danishes, the 'Danish Chef' voice advises the user to put the Danish in the microwave, and warns it may be hot when the cooking is finished. PC Dinners was developed during Fall 1996, and while it is now far from visionary technology, it laid the groundwork for much of the Kitchen Sync vision.

3.1. UPC Meets URL

It is clear that automatic identification of food is a key issue in a technologically augmented kitchen, and we have considered a number of ways of addressing this problem. One of our more unlikely suggestions, using lasers to print barcodes on food, was independently implemented in the spring of 1999 by David Small[2], using an industrial laser cutter to print diagrams, instructions and barcodes on foods. Such proposals aside, however, a large class of foods (prepackaged, ready-to-eat items in particular) already had UPC symbols as part of the packaging and these could be used for identification purposes.



A key realization was that an identification tag, be it barcode or RFID tag, need not be merely an identity, but can be a URL-like pointer to an infinite amount of information. A resource that currently doesn't exist for public access is a universal UPC to URL database. The concept that a product has an electronic identity in addition to its physical structure is something the corporate world is only now realising, and is some years from implementing. Such types of publicly accessible databases do exist for some information, such as track information on CDs[3], but the exception is the rule.

In a more sensible and sense-able kitchen, we see these digital identities will be able to react with smarter appliances in the environment. Like the Nutcracker or Pinocchio, packages, bottles, utensils, and food will tell their stories. A combination of ingredients could be more like a cast of characters, coaching you through a recipe.

3.2. Barcodes

Our decision to use barcodes was motivated by several factors. The immediacy of their availability and low cost was a primary element in this decision. Some of our later work, particularly the Counter Intelligence project, has revolved around a scenario dependent on packaging which incorporated RFID tags as a replacement or augmentation for barcodes. We expect RFID or similar tags to supplant barcodes in the near future, but such development is conditional on both technical improvements in reliable collision-detection algorithms and volume production leading to inexpensive tags.

It also became quickly apparent that a viable solution for product identification would require a serial number field to distinguish different iterations of the same product. The current format of UPC codes doesn't provide for a serial number, and thus our implementation didn't include this as a possibility. A logical step is an expansion of the existing UPC code to include a reasonably sized serial number for such use. Defining such standards is currently being undertaken by the Distributed Intelligent Systems Center at MIT in conjunction with the Uniform Code Council, the World Wide Web Consortium and the International Standards Organization.[4]

3.3. Implementation

PC Dinners is based on a conventional off-the-shelf microwave, augmented with a bar code reader, a PIC-based IRX board within the microwave for control purposes, and a computer with custom-written software.

During the course of cooking the product, the computer plays a pre-selected sound file. For the demonstration, a piece of music was chosen in keeping with the 'personality' of the food, but there is an obvious possibility for advertising in a commercial context. When cooking is complete the computer, using the appropriate personality, thanks the user, advises removal of the product from the microwave and warns them that it may be hot.

The use of different personalities for different foods is a deliberately trivial application of a nonetheless useful concept. The idea that appliances should react differently with different objects has a number of uses: a washing machine that warns you when you put a red sock in with your white shirts, for example.

3.4. Expansion possibilities

PC Dinners functioned only on a very limited number of products, and each product required custom-recorded instructions. However, each instruction was stored remotely and a pointer to it was stored as a URL with a predefined format using the UPC code. For example, a product with UPC code 12345.67890 would have the introduction sound file recorded by the appropriate personality at http://pcdinners.media.mit.edu/12345.67890/introduction.wav.

It would therefore have been possible to introduce a new product, with its associated new barcode, and PC Dinners would know the appropriate URL to look at for associated information. Essentially, PC Dinners could download information about how to cook a particular product directly from the web.

3.5. Modifications

Steve Gray, a graduate student, continued to develop PC Dinners, renamed as Microchef, incorporating a weight sensor and a touch screen for more extensive control and more elaborate user interface, allowing the user to modify preset times, cook different quantities of an item, and cook different weights of an item. This addressed many of the limitations of the original PC Dinners design while maintaining the fundamental relationship between the tagged or barcoded package and associated information.

3.6. Analysis

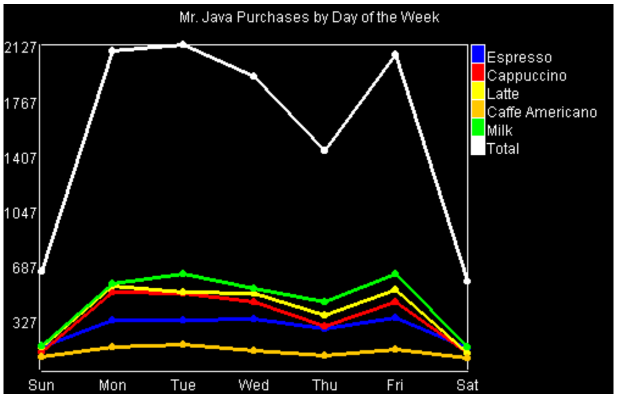
We feel that PC Dinners remains a curiosity and a thought experiment, rather than a potential product, due to its inability to heat unbarcoded foods, and the only demo-appropriate changes in personality, which would become insufferable on day-to-day use. However, we feel the underlying concept is sound, and note that at the January 2000 Consumer Electronics Show in Las Vegas, Samsung released a barcode-enabled microwave oven developed in conjunction with Kit Yam at Rutgers.

4. Mr. Java

4.1. Introduction

Mr. Java is a smart coffee machine. When you put your mug under the spout, the machine recognises it and greets you, makes you the coffee that you want and plays your choice of news or information. For example, when Kaye, a British expatriate, puts his cup under the spout, the machine's LCD screen lights up with 'Hi Jofish', it makes a double tall latte, and plays the latest news from London over the speakers. There is a delay between displaying the greeting and starting to make the coffee to enable users to pick a different selection from their usual while maintaining their standard preference.

Furthermore, the software updates the database with information about the time and type of coffee selected. This also occurs when the machine is used in the normal manner with an untagged cup. Mr. Java generates graphs of usage displayed on a nearby monitor.



It is interesting to note that it appears that Mr. Java serves more coffee on Tuesday than any other day of the week, and that Thursday is the least popular. It is possible that this data actually means that Mr. Java was least likely to be functioning (and thus gathering data) on a Thursday, but this is as mystifying.

Mr. Java was initially created in the fall of 1997, exhibited at Comdex that year at EDS's booth, and ran intermittently for approximately two years at the Media Lab.

4.2. Technical Details

Mr. Java is a prototype intelligent appliance: a high-end Acorto cappuccino machine augmented with a networked computer and a RFID tag sensors.

The Acorto 2000s automatic coffee machine has a serial port built in to the motherboard for use by service engineers for diagnostic and update use. We used this port for software control.

The serial port connects through an RJ-11 jack to a controlling computer. The computer itself is a low-end machine running Windows 95 and, appropriately enough, Java. The only other modification to the coffee machine is the addition of a waterproofed RFID tag reader, with a single cable providing power and communication also routed through the ceiling to the computer. Mugs for use with Mr. Java were modified by attaching RFID tags to their bases with hot glue.

Once registered with the system, a manual process, users were able to modify their preferences through their password-protected web page. When presented with a tag that was not in the system, the user was instructed through the small LCD screen on the coffee machine to select a drink. When the user pressed a button that drink was stored as their default. To change the personal greeting displayed on the LCD screen, to change their audio feed preferences, or to permanently change their coffee choice it was necessary to manually log on to the website with their username and password assigned when the cup was first set up.

4.3. Identification

It was apparent after the creation of PC Dinners, that the next step was the personalization of the experience to the user. To grossly generalize, current user interfaces are rarely designed with the intent of providing each individual with an individualized experience. We feel that as identification technology becomes more widespread, this will be a common trend – it's already common for ATMs to greet you in your 'home' language, for example.

It was not initially clear what system would be appropriate for recognising the user in this context. We do not predict that our choice is necessarily valid for any other application, but we wanted a robust technology that could be easily implemented in a natural manner: swiping a card, for example, we felt would make the user interface harder rather than easier to use. We considered a variety of technologies for this task.

4.3.1. IR Badges

An earlier project by our group had involved the use of IR-emitting name tags that continuously broadcast an IR signature unique to each tag. However, the problems inherent in continuously wearing a nametag (absent from the Lab's culture, unlike some other institutions), the need for battery replacement, and, above, all the lack of context, made us decide against IR recognition. By lack of context, we mean the absence of a verb associated with the noun of identity. An IR-badge recognition system doesn't distinguish between the action of standing in front of the coffee machine and the action of standing in front the coffee machine and wanting a coffee.

4.3.2. Biometric ID

We considered a variety of biometric means of identification, including fingerprint identification and face recognition. Both are technologically entirely capable of performing the task we needed. However, we felt there would be considerable social opposition to such personally intrusive technology.

4.3.3. Barcodes

Barcodes printed or stuck on the cup were considered as a possibility. However, the vicinity of the spout of a coffee machine involves a considerable amount of debris, primarily drops of foaming milk and espresso, and a barcode, not to mention the reader, could quickly become obscured and unreadable.

4.3.4. Touch memory

We also briefly considered touch memory technologies. This remains a possibility for an alternate paradigm where the user carries identification, such as on a keyring, much as the Mobil Speedpass system uses RFID. However, we felt this would impact the elegance of the interface and make it less likely to be used. Installation of the touch memory device on the cup seemed difficult in view of the comparatively bulky packaging.

4.3.5. RFID

RFID had several advantages for us. Due to the creation of the Access mousepads (an RFID-enabled connection to the Internet), there were both expertise and materials already available in the lab. The tags in question were about an inch in diameter and the thickness of a penny, which meant they could be unobtrusively attached to the bottom of the cups. Having a system that would supplement rather than replace the current paper-cup-and-press-the-button interface was necessary. The tags' robustness was adequate for the high temperatures, liquids, and relatively caustic conditions, although several attempts at waterproofing were necessary before the same could be said about the reader. The tagged cups were found to be dishwasher safe, although they were not suitable for microwaving.

We felt that identifying the cup rather than the user allowed for a relatively robust identification, and had other advantages, such as the ability for someone else to get you your coffee.

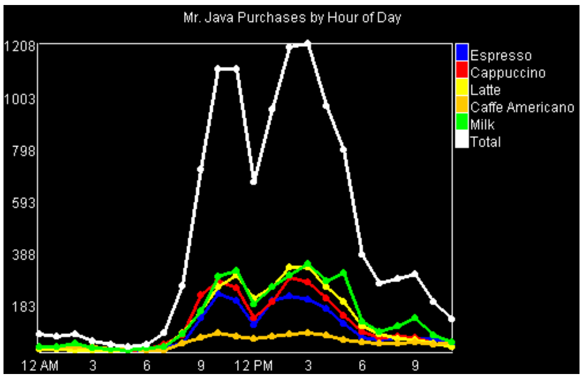
Furthermore, the tag reader could be placed directly under the spout, solving the problem of context: the only context in which the user would place their tag there would be when they wanted a coffee. Read range through the aluminium grate under the spout was approximately three inches, so the changes of an accidental read were slim.

4.4. Data tracking

The decision was made from an early stage not to track individual usage data. The nature of the RFID system we used made it impossible to have a truly privacy-conscious system. Some users expressed a desire for an untraceable system, with coffee and news preferences stored locally on the cup. We recognize this issue, but had settled on tags with a hardwired ID that was automatically read by the tag reader.

However, we did make it possible for users to track their personal coffee consumption, by making it possible for users to specify a custom URL for their sound preference. At present, this is just a response to curiosity on the behalf of the user. However, as such technology becomes more ubiquitous, there are tangible health and nutritional benefits of being able to keep track of a patient's inputs, of which this is one small part.

Aggregate data, however, was tracked, and graphs of the result were displayed as a screen saver on the computer as well as being web-accessible. Although this ability is comparatively common in high-end devices, we were surprised to learn how rare this is in beverage or vending machines. We think this ability of a machine to track its own usage appears to be a fundamental part of future appliance design.



4.5. Applications & Analysis

There are some comparatively simple real-world applications for Mr. Java's technology. There is potential for rapid transactions with Speedpass-like tags, held on the owner's keyring. Alternatively, the user could purchase a "fifty-cup" coffee cup, a travel mug with fifty prepaid cups of coffee. However, we feel the primary application for this retail technology is outside of the realm of coffee, and should been seen as an exercise in user interaction and customization.

We found that the cup interface was successful, and feel it raises an interesting question of having multiple very application-specific means of identification, rather than a universal digital identity system, which has much more serious privacy concerns.

5. Counter Intelligence

5.1. Kitchens & Counters

Over the latter half of the twentieth century, the kitchen has moved from the back of the house to the center of the home. At the center of the kitchen itself is the kitchen counter, where food is cleaned, prepared, and frequently eaten. Counter Intelligence is a sketch of a prototype intelligent counter.

It is a flat surface with a digital scale flush with the surface on the side nearest the cook. RFID tag readers are taped to the underside of the surface, and a touchscreen with built in speakers sits on one corner. Hidden beneath the counter is a computer with a twelve-serial port interface card.

Users select a recipe from a list displayed on the touchscreen. The screen displayed an ingredient list, and as tagged jars of ingredients were placed on the counter, the item would be checked off.

5.2. Counter Intelligence I

Ingredients assembled, the next screen would instruct the user to pour in three cups of chocolate chips. At this time, the chocolate chips would be in a tagged jar on top of an RFID tag reader, which was continuously sending the tag ID back to the computer. When the RFID reader no longer transmitted a tag ID, the computer assumed the jar had been lifted by the cook and would display the current weight and volume of chocolate chips, reading the scale through the serial port, and updating as chips were poured into the bowl.

The system would then look for the same to happen with the next ingredient. The screen would then instruct the cook to place the bowl in the microwave and it would microwave the ingredients for thirty seconds.

5.3. Counter Intelligence I

Counter Intelligence refers to two sequential design. Our initial version, with software produced by Niko Matsakis and Andy Wheeler, ran under Win95 and used the touchscreen for all input and output.

An RFID tag reader was placed under the surface of the scale, with an initial plan to read tags on mixing bowls. This turned out to be not practical as we found that microwaved tags frequently explode loudly in a flash of orange light and emit a surprisingly large amount of smoke. We thus note for the record that current RFID technology does not microwave elegantly.

5.4. Counter Intelligence II

Our second version of Counter Intelligence added voice output, and a re-write of the entire software infrastructure to run under Linux. On-screen choices were confirmed with pre-recorded voice output, and as the user poured items such as flour, the voice would advise "One cup…two cups… a little bit more…Stop!"

We informally studied potential users' reactions to the voice output as opposed to a purely screen-based output, and saw some very mixed responses. Many felt that voice output had a great deal of potential to be useful, and liked the concept of having their kitchen talk to them. By contrast, some hated the idea, and did not want their kitchen talking to them under any circumstances. We feel there is more potential for voice interaction in the home than in the conventional office environment.

Everything in the system was made a Hive device. Hive[5] is a Java extension allowing for interaction and connectivity of multiple objects easily across a network. Previous efforts as part of the 'Things That Think' project had relied upon one-off methods to combine sensors and computers with embedded computation. Hive provides a logical and extensible method of doing so. This process is more fully described in Matthew Gray's S.M. thesis.[6]

5.5. CI: analysis

It is important to observe that we do not consider Counter Intelligence to be a model for future kitchen interaction, but rather a sketch incorporating technologies that could be useful. The difficulties in determining a logical data structure for recipes rapidly became apparent, and we devoted considerable effort to this question. It was also apparent to us from the beginning that a touchscreen is not the ideal input device for a kitchen, but it did provide a simple method for input without using the keyboard or mouse of conventional computing systems. We feel that a context-aware voice recognition system is a key interface for such interaction-intensive systems in the future.

The Counter Intelligence system had some interesting problems. A touchscreen is not a perfect interface for a kitchen, where one's hands are frequently covered with flour or butter, although it may well have a role to play: keyboards and mice are even less appropriate. Voice output becomes more reasonable when a better infrastructure is in place to determine context: if the phone rings in the middle of baking, the last thing you want is a voice repeating "Just a bit more… Just a bit more…" The tagging technology we were using allowed only one tag in a field, with circular fields 3" in diameter, necessitating careful placing of ingredients on market spots. Ingredients had to be manually tagged; however, we feel that RFID tagging will undoubtedly be as common as barcodes are today.

Acknowledgments

The above research would not have been possible with significant contributions from many individuals. In particular, the researchers would like to thank Kyle Anderson, Chris Connor and Acorto Inc. for the coffee machine and support, Jim Young, Marc D'Arcy and EDS, Robert Poor, Kristin Hall for creative and administrative support, and multiple undergraduate researchers including Anthony Johnson, Sandy Choi, and Rhett Creighton, and the Personal Information Architecture Group, particularly Adam Smith and Wendy Ju. Funding came initially from the Things That Think Consortium at the MIT Media Lab, and the project later developed into and was funded by the Counter Intelligence Special Interest Group.

References

[1] Poor, Robert. Hyphos: A Self-Organizing, Wireless Network. Master's Thesis, MIT Media Lab. June 1997.

[2] Small, David. Covered in Newsweek, 5 July 1999.

[3] http://www.cddb.com

[4] Distributed Intelligent Systems Center, Massachusetts Institute of Technology. http://disc.mit.edu

[5] Nelson Minar, Matthew Gray, Oliver Roup, Raffi Krikorian, and Pattie Maes. Hive: Distributed Agents for Networking Things. Proceedings of ASA/MA'99, the First International Symposium on Agent Systems and Applications and Third International Symposium on Mobile Agents. August 1999.

[6] Gray, Matthew. Infrastructure for an Intelligent Kitchen. Master's Thesis, SM, MIT Media Lab. May 1999.

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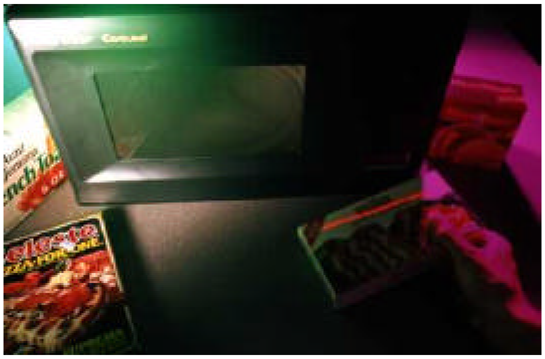

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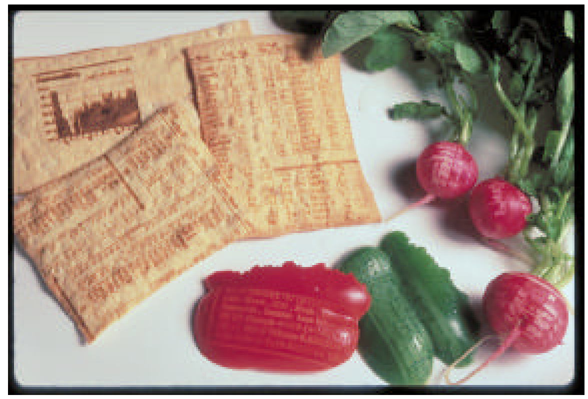
3.1. UPC Meets URL

It is clear that automatic identification of food is a key issue in a technologically augmented kitchen, and we have considered a number of ways of addressing this problem. One of our more unlikely suggestions, using lasers to print barcodes on food, was independently implemented in the spring of 1999 by David Small[2], using an industrial laser cutter to print diagrams, instructions and barcodes on foods. Such proposals aside, however, a large class of foods (prepackaged, ready-to-eat items in particular) already had UPC symbols as part of the packaging and these could be used for identification purposes.



A key realization was that an identification tag, be it barcode or RFID tag, need not be merely an identity, but can be a URL-like pointer to an infinite amount of information. A resource that currently doesn't exist for public access is a universal UPC to URL database. The concept that a product has an electronic identity in addition to its physical structure is something the corporate world is only now realising, and is some years from implementing. Such types of publicly accessible databases do exist for some information, such as track information on CDs[3], but the exception is the rule.

In a more sensible and sense-able kitchen, we see these digital identities will be able to react with smarter appliances in the environment. Like the Nutcracker or Pinocchio, packages, bottles, utensils, and food will tell their stories. A combination of ingredients could be more like a cast of characters, coaching you through a recipe.

3.2. Barcodes

Our decision to use barcodes was motivated by several factors. The immediacy of their availability and low cost was a primary element in this decision. Some of our later work, particularly the Counter Intelligence project, has revolved around a scenario dependent on packaging which incorporated RFID tags as a replacement or augmentation for barcodes. We expect RFID or similar tags to supplant barcodes in the near future, but such development is conditional on both technical improvements in reliable collision-detection algorithms and volume production leading to inexpensive tags.

It also became quickly apparent that a viable solution for product identification would require a serial number field to distinguish different iterations of the same product. The current format of UPC codes doesn't provide for a serial number, and thus our implementation didn't include this as a possibility. A logical step is an expansion of the existing UPC code to include a reasonably sized serial number for such use. Defining such standards is currently being undertaken by the Distributed Intelligent Systems Center at MIT in conjunction with the Uniform Code Council, the World Wide Web Consortium and the International Standards Organization.[4]

3.3. Implementation

PC Dinners is based on a conventional off-the-shelf microwave, augmented with a bar code reader, a PIC-based IRX board within the microwave for control purposes, and a computer with custom-written software.

During the course of cooking the product, the computer plays a pre-selected sound file. For the demonstration, a piece of music was chosen in keeping with the 'personality' of the food, but there is an obvious possibility for advertising in a commercial context. When cooking is complete the computer, using the appropriate personality, thanks the user, advises removal of the product from the microwave and warns them that it may be hot.

The use of different personalities for different foods is a deliberately trivial application of a nonetheless useful concept. The idea that appliances should react differently with different objects has a number of uses: a washing machine that warns you when you put a red sock in with your white shirts, for example.

3.4. Expansion possibilities

PC Dinners functioned only on a very limited number of products, and each product required custom-recorded instructions. However, each instruction was stored remotely and a pointer to it was stored as a URL with a predefined format using the UPC code. For example, a product with UPC code 12345.67890 would have the introduction sound file recorded by the appropriate personality at http://pcdinners.media.mit.edu/12345.67890/introduction.wav.

It would therefore have been possible to introduce a new product, with its associated new barcode, and PC Dinners would know the appropriate URL to look at for associated information. Essentially, PC Dinners could download information about how to cook a particular product directly from the web.

3.5. Modifications

Steve Gray, a graduate student, continued to develop PC Dinners, renamed as Microchef, incorporating a weight sensor and a touch screen for more extensive control and more elaborate user interface, allowing the user to modify preset times, cook different quantities of an item, and cook different weights of an item. This addressed many of the limitations of the original PC Dinners design while maintaining the fundamental relationship between the tagged or barcoded package and associated information.

3.6. Analysis

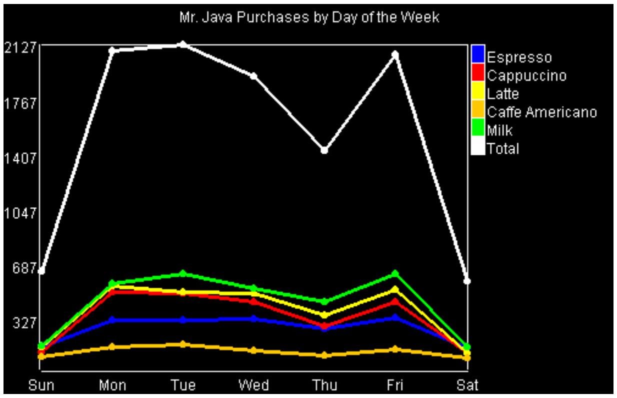
We feel that PC Dinners remains a curiosity and a thought experiment, rather than a potential product, due to its inability to heat unbarcoded foods, and the only demo-appropriate changes in personality, which would become insufferable on day-to-day use. However, we feel the underlying concept is sound, and note that at the January 2000 Consumer Electronics Show in Las Vegas, Samsung released a barcode-enabled microwave oven developed in conjunction with Kit Yam at Rutgers.

4. Mr. Java

4.1. Introduction

Mr. Java is a smart coffee machine. When you put your mug under the spout, the machine recognises it and greets you, makes you the coffee that you want and plays your choice of news or information. For example, when Kaye, a British expatriate, puts his cup under the spout, the machine's LCD screen lights up with 'Hi Jofish', it makes a double tall latte, and plays the latest news from London over the speakers. There is a delay between displaying the greeting and starting to make the coffee to enable users to pick a different selection from their usual while maintaining their standard preference.

Furthermore, the software updates the database with information about the time and type of coffee selected. This also occurs when the machine is used in the normal manner with an untagged cup. Mr. Java generates graphs of usage displayed on a nearby monitor.



It is interesting to note that it appears that Mr. Java serves more coffee on Tuesday than any other day of the week, and that Thursday is the least popular. It is possible that this data actually means that Mr. Java was least likely to be functioning (and thus gathering data) on a Thursday, but this is as mystifying.

Mr. Java was initially created in the fall of 1997, exhibited at Comdex that year at EDS's booth, and ran intermittently for approximately two years at the Media Lab.

4.2. Technical Details

Mr. Java is a prototype intelligent appliance: a high-end Acorto cappuccino machine augmented with a networked computer and a RFID tag sensors.

The Acorto 2000s automatic coffee machine has a serial port built in to the motherboard for use by service engineers for diagnostic and update use. We used this port for software control.

The serial port connects through an RJ-11 jack to a controlling computer. The computer itself is a low-end machine running Windows 95 and, appropriately enough, Java. The only other modification to the coffee machine is the addition of a waterproofed RFID tag reader, with a single cable providing power and communication also routed through the ceiling to the computer. Mugs for use with Mr. Java were modified by attaching RFID tags to their bases with hot glue.

Once registered with the system, a manual process, users were able to modify their preferences through their password-protected web page. When presented with a tag that was not in the system, the user was instructed through the small LCD screen on the coffee machine to select a drink. When the user pressed a button that drink was stored as their default. To change the personal greeting displayed on the LCD screen, to change their audio feed preferences, or to permanently change their coffee choice it was necessary to manually log on to the website with their username and password assigned when the cup was first set up.

4.3. Identification

It was apparent after the creation of PC Dinners, that the next step was the personalization of the experience to the user. To grossly generalize, current user interfaces are rarely designed with the intent of providing each individual with an individualized experience. We feel that as identification technology becomes more widespread, this will be a common trend – it's already common for ATMs to greet you in your 'home' language, for example.

It was not initially clear what system would be appropriate for recognising the user in this context. We do not predict that our choice is necessarily valid for any other application, but we wanted a robust technology that could be easily implemented in a natural manner: swiping a card, for example, we felt would make the user interface harder rather than easier to use. We considered a variety of technologies for this task.

4.3.1. IR Badges

An earlier project by our group had involved the use of IR-emitting name tags that continuously broadcast an IR signature unique to each tag. However, the problems inherent in continuously wearing a nametag (absent from the Lab's culture, unlike some other institutions), the need for battery replacement, and, above, all the lack of context, made us decide against IR recognition. By lack of context, we mean the absence of a verb associated with the noun of identity. An IR-badge recognition system doesn't distinguish between the action of standing in front of the coffee machine and the action of standing in front the coffee machine and wanting a coffee.

4.3.2. Biometric ID

We considered a variety of biometric means of identification, including fingerprint identification and face recognition. Both are technologically entirely capable of performing the task we needed. However, we felt there would be considerable social opposition to such personally intrusive technology.

4.3.3. Barcodes

Barcodes printed or stuck on the cup were considered as a possibility. However, the vicinity of the spout of a coffee machine involves a considerable amount of debris, primarily drops of foaming milk and espresso, and a barcode, not to mention the reader, could quickly become obscured and unreadable.

4.3.4. Touch memory

We also briefly considered touch memory technologies. This remains a possibility for an alternate paradigm where the user carries identification, such as on a keyring, much as the Mobil Speedpass system uses RFID. However, we felt this would impact the elegance of the interface and make it less likely to be used. Installation of the touch memory device on the cup seemed difficult in view of the comparatively bulky packaging.

4.3.5. RFID

RFID had several advantages for us. Due to the creation of the Access mousepads (an RFID-enabled connection to the Internet), there were both expertise and materials already available in the lab. The tags in question were about an inch in diameter and the thickness of a penny, which meant they could be unobtrusively attached to the bottom of the cups. Having a system that would supplement rather than replace the current paper-cup-and-press-the-button interface was necessary. The tags' robustness was adequate for the high temperatures, liquids, and relatively caustic conditions, although several attempts at waterproofing were necessary before the same could be said about the reader. The tagged cups were found to be dishwasher safe, although they were not suitable for microwaving.

We felt that identifying the cup rather than the user allowed for a relatively robust identification, and had other advantages, such as the ability for someone else to get you your coffee.

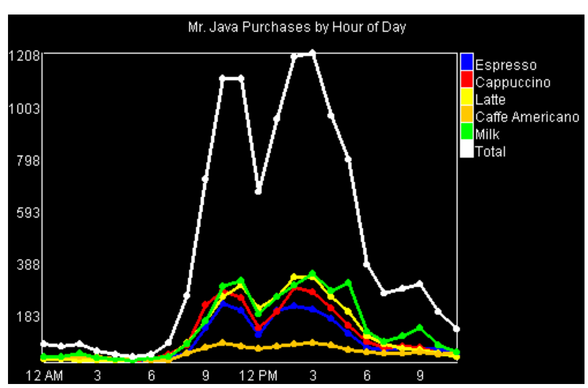
Furthermore, the tag reader could be placed directly under the spout, solving the problem of context: the only context in which the user would place their tag there would be when they wanted a coffee. Read range through the aluminium grate under the spout was approximately three inches, so the changes of an accidental read were slim.

4.4. Data tracking

The decision was made from an early stage not to track individual usage data. The nature of the RFID system we used made it impossible to have a truly privacy-conscious system. Some users expressed a desire for an untraceable system, with coffee and news preferences stored locally on the cup. We recognize this issue, but had settled on tags with a hardwired ID that was automatically read by the tag reader.

However, we did make it possible for users to track their personal coffee consumption, by making it possible for users to specify a custom URL for their sound preference. At present, this is just a response to curiosity on the behalf of the user. However, as such technology becomes more ubiquitous, there are tangible health and nutritional benefits of being able to keep track of a patient's inputs, of which this is one small part.

Aggregate data, however, was tracked, and graphs of the result were displayed as a screen saver on the computer as well as being web-accessible. Although this ability is comparatively common in high-end devices, we were surprised to learn how rare this is in beverage or vending machines. We think this ability of a machine to track its own usage appears to be a fundamental part of future appliance design.



4.5. Applications & Analysis

There are some comparatively simple real-world applications for Mr. Java's technology. There is potential for rapid transactions with Speedpass-like tags, held on the owner's keyring. Alternatively, the user could purchase a "fifty-cup" coffee cup, a travel mug with fifty prepaid cups of coffee. However, we feel the primary application for this retail technology is outside of the realm of coffee, and should been seen as an exercise in user interaction and customization.

We found that the cup interface was successful, and feel it raises an interesting question of having multiple very application-specific means of identification, rather than a universal digital identity system, which has much more serious privacy concerns.

5. Counter Intelligence

5.1. Kitchens & Counters

Over the latter half of the twentieth century, the kitchen has moved from the back of the house to the center of the home. At the center of the kitchen itself is the kitchen counter, where food is cleaned, prepared, and frequently eaten. Counter Intelligence is a sketch of a prototype intelligent counter.

5.2. Counter Intelligence I

It is a flat surface with a digital scale flush with the surface on the side nearest the cook. RFID tag readers are taped to the underside of the surface, and a touchscreen with built in speakers sits on one corner. Hidden beneath the counter is a computer with a twelve-serial port interface card.

Users select a recipe from a list displayed on the touchscreen. The screen displayed an ingredient list, and as tagged jars of ingredients were placed on the counter, the item would be checked off.

Ingredients assembled, the next screen would instruct the user to pour in three cups of chocolate chips. At this time, the chocolate chips would be in a tagged jar on top of an RFID tag reader, which was continuously sending the tag ID back to the computer. When the RFID reader no longer transmitted a tag ID, the computer assumed the jar had been lifted by the cook and would display the current weight and volume of chocolate chips, reading the scale through the serial port, and updating as chips were poured into the bowl.

The system would then look for the same to happen with the next ingredient. The screen would then instruct the cook to place the bowl in the microwave and it would microwave the ingredients for thirty seconds.

5.3. Counter Intelligence I

Counter Intelligence refers to two sequential design. Our initial version, with software produced by Niko Matsakis and Andy Wheeler, ran under Win95 and used the touchscreen for all input and output.

An RFID tag reader was placed under the surface of the scale, with an initial plan to read tags on mixing bowls. This turned out to be not practical as we found that microwaved tags frequently explode loudly in a flash of orange light and emit a surprisingly large amount of smoke. We thus note for the record that current RFID technology does not microwave elegantly.

5.4. Counter Intelligence II

Our second version of Counter Intelligence added voice output, and a re-write of the entire software infrastructure to run under Linux. On-screen choices were confirmed with pre-recorded voice output, and as the user poured items such as flour, the voice would advise “One cup…two cups… a little bit more…Stop!”

We informally studied potential users’ reactions to the voice output as opposed to a purely screen-based output, and saw some very mixed responses. Many felt that voice output had a great deal of potential to be useful, and liked the concept of having their kitchen talk to them. By contrast, some hated the idea, and did not want their kitchen talking to them under any circumstances. We feel there is more potential for voice interaction in the home than in the conventional office environment.

Everything in the system was made a Hive device. Hive[5] is a Java extension allowing for interaction and connectivity of multiple objects easily across a network. Previous efforts as part of the ‘Things That Think’ project had relied upon one-off methods to combine sensors and computers with embedded computation. Hive provides a logical and extensible method of doing so. This process is more fully described in Matthew Gray’s S.M. thesis.[6]

5.5. CI: analysis

It is important to observe that we do not consider Counter Intelligence to be a model for future kitchen interaction, but rather a sketch incorporating technologies that could be useful. The difficulties in determining a logical data structure for recipes rapidly became apparent, and we devoted considerable effort to this question. It was also apparent to us from the beginning that a touchscreen is not the ideal input device for a kitchen, but it did provide a simple method for input without using the keyboard or mouse of conventional computing systems. We feel that a context-aware voice recognition system is a key interface for such interaction-intensive systems in the future.

The Counter Intelligence system had some interesting problems. A touchscreen is not a perfect interface for a kitchen, where one's hands are frequently covered with flour or butter, although it may well have a role to play: keyboards and mice are even less appropriate. Voice output becomes more reasonable when a better infrastructure is in place to determine context: if the phone rings in the middle of baking, the last thing you want is a voice repeating "Just a bit more… Just a bit more…" The tagging technology we were using allowed only one tag in a field, with circular fields 3" in diameter, necessitating careful placing of ingredients on market spots. Ingredients had to be manually tagged; however, we feel that RFID tagging will undoubtedly be as common as barcodes are today.

Acknowledgments

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References

[1] Poor, Robert. Hyphos: A Self-Organizing, Wireless Network. Master's Thesis, MIT Media Lab. June 1997.

[2] Small, David. Covered in Newsweek, 5 July 1999.

[3] http://www.cddb.com

[4] Distributed Intelligent Systems Center, Massachusetts Institute of Technology. http://disc.mit.edu

[5] Nelson Minar, Matthew Gray, Oliver Roup, Raffi Krikorian, and Pattie Maes. Hive: Distributed Agents for Networking Things. Proceedings of ASA/MA'99, the First International Symposium on Agent Systems and Applications and Third International Symposium on Mobile Agents. August 1999.

[6] Gray, Matthew. Infrastructure for an Intelligent Kitchen. Master's Thesis, SM, MIT Media Lab. May 1999.