

Now We're Cooking: Recipes for End-User Service Composition in the Digital Home

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IT Comes Home

Information technology is coming home to roost. It has been the case for some time that IT equipment such as desktops, laptops, printers, and high-speed networks have achieved ubiquity in the home. A more interesting trend is that technologies that were developed initially for general purpose computing, such as TCP/IP networking and non-specialized (e.g. x86) computing architectures capable of loading and running arbitrary software, have made substantial inroads into consumer electronics devices that have traditionally been kept entirely separate from business-focused IT.

The result is that many consumer electronics devices are becoming capable of connecting to just about anything and running just about any software. This flexibility means the potential for new applications and user experiences in the home is poised to explode. However, as long as devices are built to only support a fixed set of functions and to interact with a predefined list of other devices, the potential of the digital home will not be realized.

The industry is moving towards a world in which devices are built to be composed together in different ways. Organizations such as the UPnP Forum (<http://www.upnp.org>) and the Digital Living Network Alliance (DLNA) (<http://www.dlna.org>) are seeking to define sets of interoperating profiles to specify a range of ways that devices can interconnect. This is an important piece of the puzzle. However, interoperability alone is not enough.

In today's world, it is up to application and device developers to determine what features are available to end users in what combinations. As the numbers and types of devices increase, and as their potential combinations increase, it becomes increasingly infeasible to assume that application developers will be able to keep pace with the churn in available functionality. There will always be a gap between what functionality applications expose and the functionality that users want to access, given the devices and services available at any point in time.

What is needed is a means to allow users to compose the functionality that they need, given the components available, even in the absence of a pre-built application or device function that exposes that functionality.

End-User Service Composition

In today's world, it is sometimes possible for end-users to cobble together the functionality they want from the pieces they have available. This is generally done by leveraging the detailed technical knowledge of a friend, family member, or professional technician. Sometimes more technically savvy users can achieve their goals by piecing together bits of information gleaned from manufacturers' "knowledge bases," FAQs, and discussion boards. These users may end up being a local lead user who helps others in their immediate social network to set up and use their systems in more customized ways.

In order to look at how a wide audience could benefit from the efforts, knowledge, and skills of a smaller set of knowledgeable, skilled, or at the very least patient lead users, we looked for examples of community creation and sharing of practical technical information among participants of varying skill and background. Such communities are abundant, but perhaps none is as widespread as the community of creators and consumers of cooking recipes.

There are several aspects of recipes that suggest the features we would like to have in a system that allows end-users to compose functionality in the digital home. For example, there are often many different recipes describing different ways to prepare the same dish. A search for "apple pie" on cooks.com yields nearly 4000 results. Similarly, digital recipes could support multiple configurations to carry out the same activity, such as "watch a video" or "listen to podcasts in the car." If a particular ingredient is unavailable (or simply not preferred), many cooks are able to find a substitution. Perhaps thyme could be substituted for sage, or yellow squash for zucchini. Likewise, it would be desirable to allow an activity to proceed even if an "ideal" configuration could not be obtained. For example, a

surround-sound audio source could be rendered to a pair of headphones or even a cellphone earpiece.

Digital Recipes

A culinary recipe consists of a set of ingredients and a set of instructions about how to prepare and combine them. Sometimes they will also include instructions for obtaining hard-to-find ingredients and suggestions for substitutions in case the desired ingredient is not found. Recipes are produced and consumed by both professionals and amateurs. There is an enormous range of different recipes available for every conceivable set of preferences, available ingredients, and constraints in terms of equipment and skill.

As with recipes for food preparation, users need the ability to produce a large and varied number of compositions from a small set of ingredient components. We need a sharable representation that almost anyone can create and use. A possible example of a digital recipe is shown in Figure 1.

Ingredients	
Portable Music Player Media Role: Destination, Aggregate Input Type: audio/* Criteria: Name: Mark's iPod Model: iPod Manufacturer: Apple	RSS Feed Media Role: Source Output Type: application/rss+xml Parameters: FeedURL: http://www.curry.com/xml/rss.xml Criteria:
Storage Device Media Role: Destination, Aggregate Input Type: */* Criteria: Name: Home Media Server Model: Dimension E310 Manufacturer: Dell Location: Living Room Owner: Mark	RSS to MP3 Filter Media Role: Filter Input type: application/rss+xml Output type: audio/mpeg Criteria:
Podcast Directory Media Role: Destination, Aggregate Input Type: audio/* Criteria: Name: Podcasts InCollection: Storage Device	Latest Podcast Media Role: Source Output Type: audio/mpeg Criteria: InCollection Podcast Directory Largest DateAdded
Preparation	
Step 1: <i>Connect "RSS Feed" to "Podcast Directory," using "RSS to MP3 Filter"</i>	
Step 2: <i>When "Portable Music Player" is available, connect "Latest Podcast" to "Portable Music Player"</i>	

Figure 1: This possible example of a digital recipe shows a how a generic representation might be used to create a configuration using a user's specific devices

This "digital recipe" outlines a conventional programming procedure: variables (ingredients) are declared and instantiated at the top, with control statements (preparation) following the declarations. However, it purposely omits several programming concepts such as conditional branching, subroutines, and variables with arbitrary data types. Seminal research on end-user programming, such as Bonnie A. Nardi's *A Small Matter of Programming* [3], has shown that general-purpose programming or scripting languages are neither necessary nor desirable. Rather, a task-specific language with appropriate tool support provides an ideal environment for users to create their own applications. Nardi [3] and Mackay [2] have also demonstrated that asymmetric user communities—i.e. those comprised of both expert and non-expert members—are highly beneficial to the acceptance and growth of end-user programming and customization.

The payoffs of making digital home recipes work could be enormous. Imagine bringing home a new device, plugging it into the network, and having it automatically discover the other devices and services available in your home, and suggesting a set of recipes that are in use by *other users with similar configurations* that you might be able to put into use. Manufacturers could advertise new devices by pointing out the new recipes that you could take advantage of if you were to include these new devices into your network.

Realizing the Vision

In order to make using digital technology as easy as cooking a meal, there are a number of obstacles that must be overcome. For example—what exactly constitutes a digital recipe? What tools and support systems must be created to support finding, using, and creating new recipes? How can communities of recipe sharing be built around a set of shared device configurations?

Usable Recipes

In Figure 1, I gave an example of what a digital recipe might look like. Other recipe formats may afford increased functionality, but may do so at the expense of portability and comprehensibility. It is our belief that only extensive prototyping and testing with users will resolve the question of what expressive features can and should be included in the definition of a recipe.

The tools used to find, use, modify, design, and create recipes will be critical to this vision's success. As I will discuss shortly, I and my colleagues at PARC are developing a “remote control” application that supports all of these activities, and allows fluid transitions between each of them. While design and use are often regarded as separate activities, we believe there will be benefits to allowing them to be interleaved more closely. Opportunities for improvements are often realized in use, and these should be immediately fed back into the design process. Similarly, glitches, errors, and bugs are encountered in use that require on-the-spot troubleshooting, and thus require a blurring of the boundary of use and design.

Sharable Recipes

The true promise of digital recipes can only be realized if recipes are designed from the outset to be shared among a wide community of users. This means that recipes must be portable across different physical and virtual environments, and must deliver similar functionality even when operating with different ingredients. This is a substantial challenge, as it means that devices from different vendors and different generations must be able to fit into a shared ontology of ingredient types. Various initiatives are competing to define the profiles that will be used to describe networked devices and services, such as the aforementioned UPnP Forum and the DLNA. PARC's Obje technology [1] seeks to provide a framework of interoperable component types that is especially robust to change and evolution in terms of the underlying technology.

Community creation, support, fostering

To be sure, not every user is going to have the same level of enthusiasm, patience, or skill to bring to bear on the creation of recipes. A key to the success of the digital recipe revolution will be to leverage the efforts of the highly engaged users—the gearheads and tinkerers—to benefit the more numerous consumers of technology. The success of community-created content on the Web (e.g. wikipedia), as well as the dedicated participation of thousands of developers in open source programming efforts of all kinds, shows that some combination of appreciation, reputation, and the satisfaction of a job well done may be all of the motivation that is required to get people to contribute recipes to a wider community. Manufacturers can also benefit substantially from an open marketplace of digital recipes, in which every new recipe created by an end user has the potential to increase the utility and value of the devices that are already on the market and in people's homes. Further, the savvy manufacturer can more easily track the types of activities that people are carrying out using their products and use that information to improve future releases. As shown in Figure 2, multiple types of users can benefit from a shared collection of recipes.

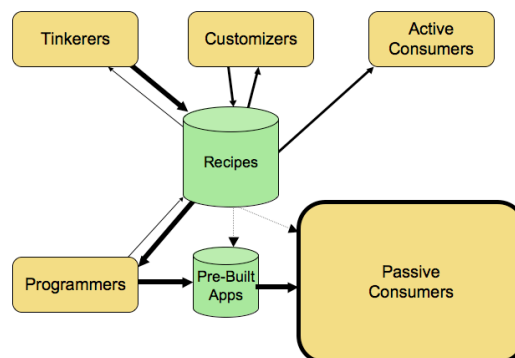


Figure 2: How various user communities might relate to a shared collection of digital recipes. The thickness of each arrow indicates the flow of contributed functionality.

An exploration: The Obje Service Composer

At PARC, we are engaging in a project to design the digital home of the future around the idea of simple, shareable compositions or “recipes” along with the frameworks to support their use and the tools to allow end users to create and manage them.

Our current efforts include the development of a universal remote control prototype that will allow users to discover, configure, and control devices in their homes as well as to locate, invoke, modify, and create digital recipes. Our prototype is based on the Obje interoperability framework [1, 4, 5] and our recipes describe ways of making data connections among Obje components such as display screens (including TVs, digital picture frames, laptop screens), streaming cameras, speakers, microphones, media libraries, storage devices, and so forth.

The goal of developing our prototype is to be able to conduct tests with users in order to explore the concept of end-user composition. At a high level, we wish to explore the feasibility and desirability of end-user composition—in other words, *can* representative users successfully select, use, modify, and create recipes, and if so, would they *want* to? At the same time, we wish to explore the area by obtaining feedback from users. We are interested to see what types of mental models users bring to the problem of service composition—does the recipe metaphor make sense? Do other possible models (e.g. “remote control,” “A/V wiring”) confuse or enhance the usability of the system?

In addition, we view this as an opportunity to evaluate certain aspects of the Obje architecture, for example the emphasis on semantically neutral device profiles [1] and the ability for to provide their own user interfaces without prior client configuration [4].

We are planning two rounds of user studies. The studies will take place in an artificial “living room” that we have set up at PARC. Each round will consist of 7-10 individual 90 minute sessions, in which participants will be asked to carry out 4-6 tasks using our prototype. Our target users are adults with above-average media consumption habits who do not have training or background in computer programming or system administration. After the tasks are complete or abandoned, we will conduct a semi-structured interview to try to understand the experience of using the prototype and to explore with the participants the potential uses, benefits, and drawbacks of our system and, more generally, of a system supporting end-user composition.

We will present users with a scenario that asks them to imagine that the “living room” in which they are sitting is the living room of their house. We will explain that their “house” is rich in media devices (screens, speakers, webcams, embedded microphones, media servers) and that all of these devices are networked together and are able to easily share media. The prototype with which we will present them is a new device that has just been introduced that will allow them to “connect and control all of the devices in your home.”

At that point, the participant is presented with a 12.1” touch-screen tablet¹ running our prototype software. This prototype allows them to browse, select, and control each of the devices in the house. It also allows them to browse, select, invoke, modify, and create “recipes” that describe how these devices are connected together. It is wirelessly connected and operated entirely by touch.

At the time of this writing, the prototype software is under active development and is under great flux, therefore I will not endeavor to describe or portray the prototype functionality or user interface at this point. By the time of the workshop, however, I anticipate that at least one if not both rounds of the user study will have been completed and I plan to report on the prototype design and any results at that time.

Related Work

Woodruff, et al. [7] used the term “recipe” to apply to an end-user created construct to support browsing and visualization of information in databases. The notion that I am proposing goes beyond Woodruff’s concept and attempts to leverage many more of the procedural aspects of recipes as well as the social aspects of recipe creation and use.

Rodden, et al. [6] explored the notion of “jigsaw puzzles” as a construct to support end-user configuration and programming in a domestic environment. This representation has several positive features, in particular it is particularly adept at demonstrating visually which components are compatible with which other components.

¹ The Sahara Touch-iT Tablet i215 from TabletKiosk, <http://www.tabletkiosk.com>

However, there are drawbacks to this representation as well. For example, it is difficult to imagine how jigsaw puzzles might be shared among various users. I argue that recipes have greater expressive power and can be used to more clearly and unambiguously express a wide variety of configurations than can the jigsaw puzzles explored by Humble, et al. However, it may be possible to combine these two concepts—for example, the jigsaw user interface could be used as a front-end for creating and viewing recipes.

There are several commercially available universal remote controls offer users considerable control over their home environments. Some, like the Logitech Harmony², even have the ability to download “activity-based” configurations from a central web service to allow users to carry out operations such as “listen to music” or “watch DVD.” The universal remote is only able to access device functions that are accessible via infrared, and is only capable of operating devices whose profiles have been entered into Logitech’s database. If nothing else, though, this product category shows that there is a demand for activity-centered device configuration.

Conclusion

As networked devices become increasingly ubiquitous, the potential benefits to users increase exponentially. However, this potential cannot be fully realized if it is left entirely up to developers and manufacturers to expose the combined functionality buried in the expanding network. The notion of the recipe holds promise as a means to capture and share the variety of compositions that are possible in the arriving world of networked components. This vision has huge potential if it can be realized, but significant challenges remain. PARC is developing a prototype of a universal remote control application that will allow users to discover, use, modify, create, and share digital home recipes, and we plan to use this prototype to explore the possibility of end-user composition with users.

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² <http://www.logitech.com/index.cfm/products/features/harmony/us/en,CRID=2078>