Making Smart Homes Personal: Fabrication and Customisation of Home Interfaces

Kashyap Todi[1] **Kris Luyten**[1] **Andrew Vande Moere**[2]

[1]Hasselt University - tUL – iMinds
Expertise Centre for Digital Media
Diepenbeek, Belgium
{kashyap.todi, kris.luyten}@uhasselt.be

[2]Research[x]Design
KU Leuven
Leuven, Belgium
andrew.vandemoere@kuleuven.be

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Abstract
In this position paper, we propose the use of personal fabrication and hyper-customisation of household physical interfaces as means to accommodate the current and future needs of inhabitants of smart homes. Allowing end-users to customise interactions to fit their needs ensures a strong personal connection between the smart home and the people who interact with it on a daily basis. Additionally, providing users the opportunity to fabricate low-cost hardware allows them to upgrade, modify, or redesign these interfaces as and when their needs evolve. We present the Design–Deploy–Dispose cycle as a model that allows end-users to design smart home interfaces according to their needs, and to revise them as these needs evolve.

Author Keywords
Personal fabrication; Hyper-customisation; Paper interfaces; Smart homes; DIY; End-user Development.

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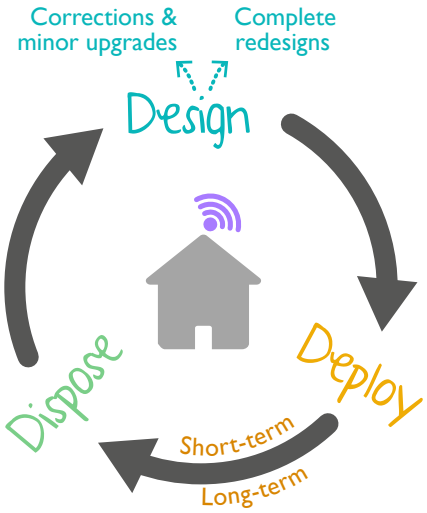

Figure 1: The Design–Deploy–Dispose cycle as a model for the personal home. Users design and deploy smart interfaces in their homes, and dispose them once their needs evolve, starting the cycle again.

Introduction

Smart homes typically consist of an assortment of sensors, controls, and other accessories, purchased by users and installed in their homes. Each of these has its own interface, and allows specific interactions, pre-defined by vendors. These devices are meant to be installed once, and serve the inhabitants for a prolonged period of time. Over the lifetime of these products, the physical interactions they support remain constant, and cannot be modified to support evolving needs. It is up to the inhabitants' to cope with the limitations and shortcomings of the product, like lack of affordance, feedforward, inappropriate feedback [3] or insensitivity to special needs. Further, installing devices by multiple vendors can lead to greater disparity in interactions supported by different devices. Current technologies rarely allow users to adapt interactions as per their needs, and this can cause frustration and deter users from using these devices to their fullest potential.

While the concept of an end-user "DIY Smart Home" is not novel, we propose a technique where users build and customise physical interfaces, in their homes, using accessible, low-cost personal fabrication techniques. By using modern fabrication techniques and providing accessible end-user development (EUD) tools, we can encourage users to actively modify and create interfaces they use on a daily basis. Since these hardware solutions are cheap and accessible to the extent that users can create interfaces in their very own homes, they enable inhabitants to modify or redesign their interfaces as and when their needs change, allowing them to adapt their homes for different life phases of the inhabitants.

We define a 'Design–Deploy–Dispose' cycle as a model for the personal home of the future. We also present some scenarios where this can be applied in different ways, and briefly outline implementation details for realising our vision of hyper-customising smart homes using EUD tools and personal fabrication.

The Design-Deploy-Dispose Cycle: A Model for the Personal Home

We propose a model for the personal home, where the occupant actively contributes to designing and customising the surrounding interfaces. This model is an adaptation of the well-known Design–Implement–Analyse (DIA) cycle, often used for iterative design of interfaces [1]. Our adaption, the Design–Deploy–Dispose (DDD) cycle, as shown in Figure 1, consists of the following phases:

1. *The Design Phase*: End-user design tools enable users to design, customise, and personalise household interfaces.

2. *The Deploy Phase*: Using accessible home fabrication techniques, users assemble the interface, and deploy them in their household.

3. *The Dispose Phase*: If and when users' needs evolve, or the end result is unsatisfactory, the low cost of hardware enables them to recycle or dispose parts, and repeat the cycle.

There are some important distinctions between the DIA and DDD cycles. First is the duration of one such cycle. While the DIA cycle is typically completed and repeated within short timespans, one DDD cycle can either be repeated within short timespans (for example, when

the end-product is unsatisfactory), or the cycle can last for a longer period of time, before the cycle is repeated (for example, when the users' needs evolve).

Secondly, the nature of the 'design' phase also differs in the two models. After initial iterations of the DIA cycle, the changes made during the 'design' phase are usually minor revisions to address the flaws discovered during the analysis. However, in the DDD cycle, the design phase can either involve minor updates or corrections, or can involve complete redesign of the interface, from scratch, to accommodate changing needs of users.

Hence, the DDD cycle is meant to serve as a flexible model to address changing needs of the inhabitants of smart homes.

Usage Scenarios

To illustrate the different ways in which the DDD cycle can be used as a general model for smart home interfaces that can evolve and accommodate changing needs, we illustrate some specific scenarios of usage.

Scenario 1: A short-term visitor with special needs. This scenario deals with a situation where the user designs and deploys an alternate interface to accommodate a visitor with special needs, a physical disability for example. Shortly before the arrival of the visitor, the owner of a house designs and deploys switches for the guest room that are easily accessible, and address the particular disability. Once the visitor departs, the owner can repurpose or dispose these special-purpose switches, and replace them with something more suitable.

In this scenario, the time-gap between 'deploy' and 'dispose' is relatively short (few days). Also, 'design' phase involves complete redesign of the interface.

Scenario 2: A home with a young child growing up. Next, consider a scenario where a parent designs the smart home interfaces to make it suitable for a young child. This interface meets the needs of the child, for example, large tangible controls placed at low heights. Additionally, to make the home childproof, the parents make some controls inaccessible to the child, to avoid accidental actions. Once the child grows older, the interfaces are replaced with something more suitable for a young adult.

In this scenario, the time-gap between the 'deploy' and 'dispose' phase is longer (few years). Additionally, the changes during the 'design' phase can be either complete redesigns, or can be minor updates and modifications to the previous interface.

Considering these disparate scenarios and the applicability of the DDD cycle, we suggest that an EUD approach, combined with low-cost personal fabrication, can help in accommodating the changing needs of users within the home environment, and can augment smart homes, making them sensitive to the different life phases of its occupants.

Realising the Personal Home: End-User Tools and Techniques

Traditionally, homes contain inflexible infrastructure, and electrical circuitry that does not allow for easy modifications. We expect this situation to change in the near future and evolve into homes where the infrastructure is open and accessible for applying

changes and making extensions. For example, in relay-based systems, or domotics, switches are connected via a hub (relays) to the circuits they control. Any device that can send an event (pulse) to the correct relay can manipulate that circuit. This makes the household electrical system flexible and open to change.

Such flexible electrical systems allows for easy integration of smart home accessories. However, typical smart home accessories are packaged with vendor-specific hardware, and software that does not allow for easy modification or customisation. Even if the software is open, and allows modifications, this requires programming skills, making the task non-trivial for non-expert inhabitants.

In our vision, inhabitants will be able to make their smart homes 'personal' by fabricating physical controls, which generate electrical pulses, and integrating them within their home environment. To realise this, appropriate EUD tools are required, together with affordable and accessible fabrication machinery. The latter is already becoming a reality, with consumer-level 3D printers, laser cutters, and even commercial printers capable of printing electronic circuits on flexible substrates [2] becoming available. Devices like Voxel8[1] enable integration of electronic circuits into 3D prints, easing the fabrication process further.

As a first step towards enabling end-user fabrication of interfaces, we have explored integrating electronics into paper, and making this accessible to people lacking expertise in electronics and programming [4]. We enable users to define simple interaction rules using a demonstration-and-recording approach that replaces programming. By automating parts of the fabrication process, and providing detailed guidance, we overcome the hurdle that lack of electronics skills presents. While our current implementation allows creation of paper-based interfaces, it can be expanded to include other materials as well, including 3D structures, which might be more suitable for interfaces intended to last for prolonged periods of time.

[1] http://www.voxel8.co

Conclusion

In this position paper, we propose that end-user development and personal fabrication can allow smart homes to address evolving needs of its inhabitants, and adapt to different life phases. We present the 'Design–Deploy–Dispose' cycle as a model for evolving home interfaces, and provide some initial insights as to how this vision of a hyper-customised smart home, with low-cost physical interfaces, can be technically realised.

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