White Paper: Design for Internet of Things Long-term Usability

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Engineering design is a multi-faceted optimization, balancing development time, material cost, durability, energy consumption, and a variety of other factors. A basic problem in consumer and medical products is how people will interact with them over the whole product lifetime, but this is seldom explicitly considered as a first-class design constraint. The classic interface design failure is the VCR, the vast majority of which were never properly programmed by their owners. Yet usability in the sense of some combination of ongoing interest and perceived utility is probably the most critical component for success for products in the vast embedded systems/internet of things space. In the consumer domain, the ability of a broad cross section of the public to master the interface and features, be able to attend to maintenance and software upgrades, and keep interested in the device/services determines whether it will be a niche or mass market product. The Apple ecosystem of products is a prime example of how attention to this aspect can produce a market success at a price premium compared to other products in the space. Data is collected on how the products are actually used in order to inform development of upgrades to match demands. In the health care space, it is even more important to design into the system means for assessing how the device is used, since improper use could have adverse health consequences. In this case, the patient, caregivers, and people conducting clinical trials must be explicitly educated on the proper use of the device, and the ecosystem in which the device is embedded must assess and report on the quality and frequency and interactions.

There is a strong parallel between this problem and the design of on-line learning and assessment systems, as well as computer games. In games for learning, the level of mastery for accomplishing particular tasks is related to the acquisition of concepts and skills by explicit design of game actions. A hidden Markov model is constructed, using the game actions to infer the hidden states of mastery level. The game will typically adapt to a higher level when the skill has been inferred to be mastered at a high enough level. Note that there is not a clean separation between mastery and interest in learning applications, since interest is affected by mastery: if a skill is too easy, there will be no sustained interest, but if it is too hard the application will be avoided. A gradation in difficulty that adapts to user mastery will be more compelling and effective. This inherently requires evaluation of both mastery and interest. A similar sequence of interactions with consumer and medical products can promote mastery and interest, but they must be designed and analyzed. Essentially the same mathematical analysis and control machinery can be used, producing a synergy with broad implications. Moreover, as in the games application, the product needs to be designed so that the assessment of its use would be made easier. On the education front, this would enable evaluation of mastery of use of embedded devices used in on-line labs and design projects; on the product front, it would enable development of devices that are easier to use and more compelling.

More broadly, there is a large opportunity for improving usability of products that include embedded systems. While there is a considerable literature on human computer interfaces (HCI) these relate mainly to recognizing user intent regarding the actions to be performed by the system (e.g., via speech and gesture recognition, haptic response, etc.) so that natural interactions result. There is overlap in that a common goal in HCI is for the user actions to be as intuitive as possible to ease learning, and also in that typically the system needs to be tuned to individuals. However, what is most important is how the *results of a sequence of interactions* will advance/assess interest, learning, and/or the specific goals of the product, and specifically how to adapt the system responses to meet these goals over time.

It must be noted that in each of the domains of education, health, and consumer products, expensive testing with human subjects is typically required to analyze interest and mastery. This is part of the reason for the paucity of academic engineering research on the use of assessment in product design, outside the HCI space where it is a requirement for publishing research. But with embedded systems there is large potential for reduced cost via causal analysis: costly randomized controlled trials can be replaced by observational studies if use cases are modeled by causal diagrams. The systems themselves can be designed to collect data on actual use, reducing the burden of conducting user surveys (which may then be done on a much smaller subset of users to deal with ambiguities). This demands careful design, including adding additional sensors to return information on the hypothesized confounding factors that may affect perception of product use. The collection of such information vastly simplifies inference tasks. By then inferring how products are actually used, rich information will be available for upgrades of embedded systems, much as statistics collected on use of software provide evidence-based paths for improvements. We can then embark on a virtuous cycle of continuous improvement of IoT products.