Designed to be Hacked: Benefits of user-side remanufacture in consumer electronics

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ABSTRACT
In this paper I defend the position that consumer electronics should be designed with a mind toward enabling users to re-arrange, fix, or otherwise hack their parts into new devices at the end of the product's life. Among other benefits, I argue that working toward this end would enable more fruitful innovation in electronic consumer products.

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H5.m. Design.

INTRODUCTION
Consumption driven market growth has provided both increases in product diversity and performance, and decreases in cost. In order to facilitate more rapid turnover of products by consumers, a planned obsolescence model has been widely adopted. This model favors highly optimized, monolithic assemblies of components, and emphasizes selling points like styling and nominal external features such as color, finish, and form factor [1]. Simultaneously, in the pursuit of lower costs, issues of repair, upgrading, or design for disassembly are generally disregarded. Unfortunately, when products cannot be upgraded, high rates of turnover due to changes in fashion or changes in functional requirements (such a playing high-bandwidth media) cause many ostensibly functional products to be discarded as waste. Additionally, these product failures are often due to only a small percentage of components within the product.

I assert that current trends toward design for disassembly and reduced component toxicity do not address the underlying problem of waste production. Additionally, these trends act to limit innovation in the market. Designing to facilitate user-side remanufacture (USR – what some would term "hardware hacking") has the potential to reduce electronic waste, increase innovation, particularly in long-tail market sectors, and confer competitive market advantages.

CURRENT PRACTICES
Current efforts to mitigate electronic waste currently fall into two categories. Design for disassembly is a principle which originated in low-complexity products like furniture [2] and has only recently made its way into the electronics community recently (i.e. Apple's unibody laptops)[3]. Design for disassembly addresses a need to separate assemblies composed of melt-able (or otherwise recyclable) materials. By designing components which are more easily separated into pure waste streams, the resulting second-generation material is cleaner and of higher value to a recycler.

Reduction of component toxicity addresses the individual materials in electronic assemblies. This reduction is driven by regulations imposed by government or standards adopted by manufacturers, based on pressure from constituents, or consumers. Examples include elimination of lead in solder (as the RoHS standard advocates) or PVC in plastic components (as Apple has pledged to do).

ARGUMENTS AGAINST DESIGN FOR USR
While neither of these efforts run in opposition to USR, there are multiple operational assumptions in the consumer electronics industry which counter indicate design for USR.

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First, closed hardware platforms are seen as a competitive advantage. In the past, this was generally true, since innovations primarily occurred at the hardware level, and hardware innovations were costly to develop. Companies which had faster CPU designs (such as Intel's pentium architecture) or novel sensor/processor packages (such as Logitech's web cameras) commanded a premium over their competitors, or enjoyed a virtual monopoly in the market. Additionally, if a design was released, it could be used to create competing products.

Second, open, flexible platforms for hardware are seen as both inefficient from a manufacturing and final cost perspective. Certainly, given two systems of comparable functionality, the system with hardware more open to modification will generally have a higher initial cost. Physical features like modular plugs, programmable features like FPGA chips or flexible ram-based processors, and even circuit boards designed using generic components and accessible pinouts for power, etc all increase cost verses a highly integrated, simplified design. This cost savings is amplified when the final design is manufactured in bulk. This cost differential can be seen in projects like the OLPC, MOCO phone, and Chumby internet device – initial cost is almost always lower when mass production is combined with streamlined, closed design.

USR ADDRESSES FAILINGS OF CURRENT PRACTICE

While design for disassembly is effective in reducing waste from large-scale objects such as chairs [2] and cars [4], its value has yet to be proven for smaller, higher complexity assemblies like consumer electronics, for three reasons. First, elements of these assemblies are composed largely of non-heterogeneous materials, such as electronic components, batteries, and thin-film coated glass. Generally, these components cannot be re-used because of the high cost of testing and re-certification, and because their multi-material composition makes reclamation by melting impossible. Second, the average consumer electronic device may have an order of magnitude more components than a chair or desk. Even well-designed objects require large amounts of labor to separate and grade components in order to create re-usable components, or even clean bulk material waste streams. Since the cost of reclamation is seldom factored into the initial device cost, this labor must be carried out as cheaply as possible. This is the reason that, despite laws specifically prohibiting the practice, electronic waste is shipped from the United States and European Union to China and Northern Africa for "recycling"[5]. Often, lack of funds for regulation in these countries leads to unsafe practices like burning PVC insulation from copper wires, or cooking solder from circuit boards over open flames [5]. Lastly, reclamation of materials works because the materials themselves constitute the primary cost in creating the object – for example, the plastic in a plastic chair, or the steel of a car door. In contrast, the primary cost of electronics is energy – energy used to create the complex materials that make them up, and arranging those materials in very complex ways such as batteries, displays, or integrated circuits. Reclaiming the silicon, metals, and trace elements from electronic components discards significant amounts of sunk cost embodied in often still functional parts. Products designed to be re-manufactured or repaired locally would push the labor cost of remanufacture to the consumer, either in the form of DIY labor, or local "hacktory" type shops. Additionally, since this remanufacture can use relatively skilled labor, functional parts (and the cost embodied in them) can be saved, building an incentive for longer-lived components in the future.

Efforts to reduce toxicity are generally ineffective for similar reasons. First, though toxicity may be reduced, it cannot realistically be eliminated in the near term. The reality is that crucial conductors (such as copper), dopants (arsenic or selenium), polymers, and flame retardants all exhibit toxic properties when disposed of incorrectly. For reasons already discussed, current construction practices make correct disposal unlikely. So, while toxicity reduction may delay the accumulation of dangerous levels of material in waste streams or bio-concentrators (as mercury does in tuna), it does not address the underlying problem. Products designed for USR, though not necessarily lower in toxicity, would be disassembled and coded for recycling locally, in countries with stronger regulations, so disposal or reclamation would be carried out more safely.

ADDITIONAL BENEFITS OF USR

While it is true that competitive advantage was formerly gained through hardware innovations heavy R&D, the modern ease of reverse engineering, combined with the App model for product innovation has shifted the focus to open systems of innovation. Apple's success with the iPhone has largely been driven by user-developed apps which leverage the then-unique sensor package within the device. However, as more participants (android, palm, windows mobile) begin opening their app-space, innovation will again shift to hardware, as it did when Nintendo developed the Wii. The question is, how many, and which sensors will a consumer be willing or able to pay for in a device? Rather than spend the effort to design for the "average" user's desires, a more open, plastic hardware design could allow users to "mod" their own optimal sensor package – perhaps publishing the results to a wiki to encourage adoption by other users. The benefit of a somewhat open design specification is that a healthy community of user/designers can iterate and select for new design specifications much faster than any institutional R&D group; the advantage lost in price is made up for in feature generation. Apple's app store created new functionality – from mass-market to long tail – faster than the company could make new catchy commercials to hype it.

The issue of cost can also be addressed by designing for USR through modular product design. Modular designs, though larger and more expensive than monolithic assemblies, benefit from ecologies of manufacture that increase volume of production and competition, and drive down price [6]. This is the primary reason for significant price differentials between desktop and laptop computers. Modular designs also give consumers the option to fix or upgrade a broken or outmoded component (for example a battery or onboard memory) without having incentive to switch manufacturer entirely. An iPhone customer might use a worn battery as an excuse to switch out of an inadequate service contract, despite the significant value remaining in the phone's still functional parts.

Finally, products positioned as an open platform are more amenable to user-driven support. For example, Nokia's new N900 device running the Maemo build of Linux had over 22,000 users already developing and debugging applications before the hardware had even shipped [7]. Other products like the Makerbot robotic 3d fabrication platform are supported almost completely by users through communities maintained by the manufacturer.

CONCLUSION

Any sustainable manufacturing method for creation of consumer electronics must address concerns of functional obsolescence, loss of value in still-functional components, material reclamation, and waste disposal. Designing for USR can provide compelling options for product breakdown, testing, reassembly or re-purposing, and disposal of waste. Modular USR-directed products would make it much simpler for product designers to innovate on a small scale, without investing in expensive tooling. Best of all, these design directives can be implemented using existing technologies and manufacturing methods. In order to seize this opportunity, hardware designers, manufacturing theorists, and product manufacturers will need to collaborate on developing new methods for creating modular products and new standards for allowing those modules to share functionality. Partnerships will also need to be formed between industry and the maker community, to better understand and communicate the needs of each. A truly rich ecology of USR-focused products will not be easy to transition to, but it offers value compelling enough that I believe it worth pursuing.

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