Concept Paper

Degrade to Upgrade: Harnessing Programmed Degradation for Sustainable, Evolving Interactive Devices

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Degrade to Upgrade: Harnessing Programmed Degradation for Sustainable, Evolving Interactive Devices

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Abstract: Interactive device design traditionally prioritizes delaying or preventing degradation during the functional phase, as it is generally perceived as a disadvantage. However, the concept of intentionally designing controlled material breakdown can unlock new properties and functions that enhance both the system and its environment. This approach, termed *"Degrade to Upgrade"*, challenges the conventional view of degradation as merely an end-of-life process. Instead, it encourages Human-Computer Interaction (HCI) researchers and designers to see it as an active phase, one that can be leveraged for innovative device design.

Keywords: sustainability; degradation; unmaking

1. The Vision

Sustainable design has gained increasing prominence in HCI, influencing material exploration, interface design, and device fabrication. Various strategies have emerged to address resource-related challenges, with the degradability of materials at their end-of-life stage being a promising approach to sustainable waste management. While material degradation is typically viewed as detrimental to system operation and only desirable once a system reaches end-of-life [4], there are instances where breakage serves a valuable function. For instance, electrical fuses protect sensitive circuits by breaking during overloads [2], and in nature, the seed capsules of the squirting cucumber burst to release seeds [3]. Such principles have inspired novel design strategies within HCI. For example, "Degrade to Function" explores the development of eco-friendly, self-contained morphing devices that rely on environmentally-triggered degradation to operate [6]. Similarly, "Functional Destruction" proposes that material destruction can be strategically employed in transient electronics to achieve specific objectives [1]. Song et al. introduced a new vocabulary of unmaking operations within standard 3D modeling tools [7], while Vasquez et al. investigated how intentionally dissolving biofoam yarns could enhance the design of fashion wearables [5].

Building on these precedents and with the goal of advancing this emerging design strategy, I introduce the concept of *"Degrade to Upgrade"* (*DtU*, Figure 1), where degradation processes lead to the acquisition of new properties and functions, potentially improving or enhancing a system. This concept invites HCI researchers and designers to view degradation not merely as an end-of-life stage but as an active phase that can be leveraged for innovative device design.

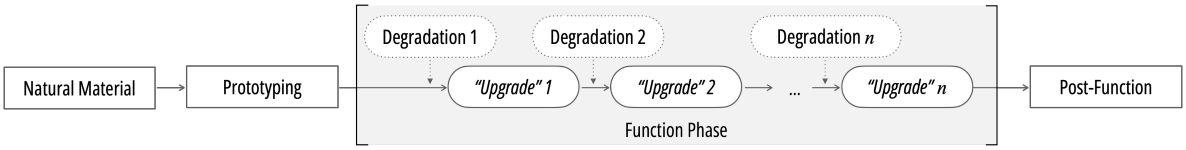

Figure 1. The Degrade to Upgrade concept overview. "Upgrade" refers to functions or interactions executed in response to programmed degradation, potentially improving or enhancing a system.

Although interest in degradable materials and devices within HCI is clearly growing, *DtU* reveals significant work still needed in rethinking degradation processes, expanding material libraries, and developing prototyping strategies, among other challenges. This vision aims to encourage the HCI community to collaboratively explore and define the research possibilities that *DtU* presents. The

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ultimate goal is to establish *DtU* as a viable strategy for designing sustainable, evolving interactive devices that function through programmed degradation.

Looking ahead, *DtU* has the potential to reshape the future of interactive systems by enabling devices to dynamically adapt and evolve through degradation, offering new possibilities in fields like environmental sustainability, adaptive technology, and post-consumer systems. This shift could lead to a new class of interactive devices that not only extend their usefulness by transforming in response to environmental factors but also contribute positively to their surroundings. In a future where technology is designed to coexist harmoniously with nature, *DtU* could serve as a guiding principle for creating systems that improve as they degrade, reducing waste while enhancing functionality. Such innovations hold the promise of transforming how we think about product life cycles and resource utilization, driving a new wave of sustainable, adaptive technology solutions.

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