Skeu the Evolution: Skeuomorphs, Style, and the Material of Tangible Interactions

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ABSTRACT
We examine skeuomorphs - holdovers from previous functional material requirements - as they pertain to the design of tangible interactions. We offer several definitions of skeuomorphs from different disciplines, seeking to distinguish among different types and uses to explore skeuomorphs' potential value for designing tangible user interfaces. Through critical analysis of several skeuomorphic designs, both GUI and TUI, we show that skeuomorphs are far from being limited to mere sensual metaphors; some types of *interaction* can be characterized as skeuomorphic. Finally, we offer three specific ways that skeuomorphic evolution can be present in design, with diverse implications for materiality, user experience, and style.

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Tangible Interactions, Materiality, Medium Specificity, Skeuomorphs

ACM Classification Keywords
H.5.2 Information interfaces and presentation (e.g., HCI): User Interfaces – *theory and methods*.

General Terms
Design, Human Factors, Theory

INTRODUCTION
While the term "skeuomorph" has taken on many meanings, its standard definition is "an ornament or design on an object copied from a form of the object when made from another material or by other techniques" [20]. This definition implies that when a new material introduces new properties, previously functional elements become stylistic ones. Because they are now seen as unnecessary, skeuomorphs have come under fire. For example, [3] writes, "A skeuomorph is an element of design or structure that serves little or no purpose in an artifact fashioned from new material but was essential to the object made from the original material." Examples of skeuomorphs in everyday design include the fluting in stone columns that imitate the marks left by tools on wooden columns, braiding on the handles of plastic pales imitating rope chord [2], and Apple's "Notes" application that imitates the appearance of a legal pad.

Skeuomorphs have become recently vilified in popular press. "Ultimately, it encourages designers to become less critical and less inventive, which is detrimental to evolving new and improved solutions" [11], resulting in "silly, faux-real UIs" [11] that are "baffling and annoying" [21]. Interestingly, the term seems to have become synonymous with Apple's interface designs - becoming a more sophisticated-sounding means of superficially arguing the superiority of one OS over the other. This has resulted in less of a critical engagement with the concepts of skeuomorphs.

Our central claim is that the understanding of skeuomorphs common in interaction design is too narrow. Stated more precisely, the dominant notion of skeuomorph in interaction design is that it is a reference to an earlier medium used as a metaphor, and its only value is the extent to which it enhances usability in a virtual context. But interaction designs including tangible user interfaces (TUIs) have design goals other than usability, including innovation in the use of digital materials and aesthetic user experiences. We argue that a richer formulation of skeuomorphs sheds light on a range of issues - including materiality, experience, and hybridity - that are fundamental to TUIs.

Our formulation is that skeuomorphs are signs of a change in the materiality of a type of artifact, and that this change has implications for the experience of using an artifact, partly independent of its functionality. Skeuomorphs can illuminate the evolutionary process by which technology develops, and that this illumination can be *expressive* as well as functional at the material level. We prefer this formulation because it accounts for both the experiential aspects of interacting with new materials as well as the functional aspects. It also helps to reveal the important historical connections between artifacts that develop as new materials are introduced. Our analysis reveals that interaction itself - not merely visual cues - can be skeuomorphic, and we identify three different types of skeuomorphic evolution. In a domain such as TUIs, where materials are strongly foregrounded on every level—innovation, user experience, functionality, aesthetics, communicativeness, usability—we

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believe that a strong theoretical understanding of skeuomorphs contributes to the core vocabulary of the field.

BACKGROUND

Combining physical and digital materials, the design of tangible interactions can be very complex. New, composite materials [18, 22] create new properties for designers to employ, which may introduce a great number of functional affordances than are perceived [13]. These materials may also make previous design elements no longer functionally necessary or even desirable. However, as formal [15, 4] aspects of a design, skeuomorphs also have connections to the materiality of an artifact, meaning they can play an important role as an expressive [10] element of an artifact's style [9]. An exploration of the "material simulation" [15] of skeuomorphs may be beneficial to designing for materiality. We suggest that there is room for both negative and positive views of skeuomorphs in tangible interactions. A review of the few occurrences of the concept in an HCI / computational context will help to illuminate this debate.

Wiberg [23] mentions skeuomorphs in his study on materials. He proposes what will here be referred to as the *deliberate-choice* formulation of skeuomorphs. He writes, "In some designs, an object might look as if it is made of a certain material when in fact it is not (e.g., a wooden table might not be made out of solid wood, but might in fact only demonstrate a ''wooden character,'' while the table surface might, in fact, be made out of plastic)" [23]. This suggests that a designer has made a deliberate choice that the table should look like wood. Moving into the realm of interaction design "a skeuomorph borrows its material look from a real-life everyday object (like a physical book or a physical calendar) which is then re-represented digitally" [23]. When moving from the physically constrained forms of paper and binding agents, traces of these elements still appear in similar digital applications in the forms of pixels representing binding thread, pages, and even the functionality of turning a page. Wiberg problematizes skeuomorphs, however, pointing out that they can be not "authentic" in their appearance. "Is the appearance equal to 'the real thing,' that is, what you see is what you get, or is it built around a certain metaphor" [23]?

The deliberate-choice formulation of skeuomorph is quite common in digital interfaces. Typically, these skeuomorphs behave similarly to affordances and metaphors, that is, by taking visual cues from the familiar as a means to explain the strange. But visual skeuomorphs can also impede the usability of a new artifact in the same ways that overly specific metaphors have been shown to do[5]. As we have shown, this use of skeuomorphs has been criticized in both popular and academic writings.

But there is another formulation of skeuomorphs that presents them in a very different light. Information scientist Nicholas Gessler [8] evokes skeuomorphs to explore evolutionary computing. Evolutionary computing uses the processes and systems employed by biological evolution (e.g. selection, fitness, and mutation) as a way to solve complex optimization problems. Gessler's argument is that the ties to the specifics of *biological* evolution can be skeuomorphic – inadvertently carried over from the physical materials of biology and hindering what is possible in digital material. "Failing a comprehensive theory explaining why these systems should operate in silicon in the same way as they do in carbon, we have a mixed metaphor, a scrambled skeuomorphic system par excellence" [8]. This uncritical carrying-over of carbon-based biological elements into the silicon-based elements of computing suggests that skeuomorphs can be inadvertent, artifacts of evolution rather than deliberate choice; we refer to this as the *evolutionary* formulation. Just as biological organs may stick around after their biological usefulness (e.g., the Erector Pili, which raise hair but still appear as "goosebumps" even in cases of diminished hairiness), elements of a design may be carried over from previous artifacts.

Philosopher and literary critic Dan O' Hara further describes the difference between Gessler's definition and the one more commonly employed in the popular press. "What's being called 'skeuomorphic' is not at all skeuomorphic… They're kitsch visual metaphors, but they're not the unintentional side-effects of technological evolution" [O'Hara in 1]. The evolutionary formulation leaves little room for design intention with regards to skeuomorphs. In other words, Gessler and O'Hara use skeuomorphs to describe a very different phenomenon than what we see in the HCI and design literatures.

The evolutionary formulation allows historians and archaeologists to place an artifact in a specific context in relation to other artifacts. Just as biologists can use an extraneous organ or bodily form to show how animals are related to each other, skeuomorphic forms can place a particular artifact in a lineage of other artifacts. Lack of intention partially contributes to this evolution. Architect and design theorist Christopher Alexander [paraphrased in 3] clarifies this by dividing the design into "unselfconscious" and "self-conscious processes." An unselfconscious process is driven by an attempt at exact replication while a self-conscious process is driven by theory and a desire for innovation. In O'Hara's definition, skeuomorphs are a result of an unself-conscious process.

Rather than leaving the deliberate-choice and evolutionary formulations at odds, we propose a third formulation that builds on their commonalties. Our formulation is that skeuomorphs are evolutionary, but their use may not be entirely unselfconscious. We will refer to this as the *self-conscious evolutionary* formulation of skeuomorphs. In both the deliberate-choice and evolutionary formulations, skeuomorphs are seen as indicators of an evolutionary process. In a discipline like archaeology, this can reveal connections between artifacts where other records of technological advances are unavailable. In a contemporary context such as

the design of tangible interactions, this extends more historical and tradition-oriented views of material [e.g. 19, 6, 12] and further illuminates the materiality of designs. Skeuomorphs highlight meanings, experiences, and expressions associated with materials. They relate form and function in an artifact in a way that brackets off causal need: the materials do not require that a specific form be employed, but that form is still used. This means the use of specific forms is predominantly for expressive purposes. In terms of style, this can help to make explicit the expressive capabilities of materials, which we argue should be understood as equal to, not subordinate to, functionality and usability. For tangible interactions, skeuomorphs provide a way of looking at the relationship between materials and materiality.

APPROACH

To explore the roles and meanings of skeuomorphs in TUI, we use interaction criticism [2]. This hermeneutic approach involves the interpretation of the observer characterized by careful close reading of a text (or work), performed in conjunction with an informed understanding of related texts, the contexts (including social, material, and technical) of their creation, and any publicly available records about the intentions of their authors (in this case: designers) and their reception in public [2]. Given that skeuomorphs are stylistic elements, the specific form of this hermeneutic approach will be guided by an understanding of style. As [9] describe, a stylistic analysis involves both a historical and a critical perspective – looking at how an artifact's formal qualities fit into the temporal continuum of formal qualities in other, related artifacts. This temporal element of stylistic analysis is particularly suitable to skeuomorphs given that they are, themselves, references to previous artifacts. The nature of the artifacts in question requires that their skeuomorphs be examined in terms of material and formal qualities, but also in terms of their interactive context.

These specific skeuomorphic artifacts were chosen as a means of balancing breadth and depth for this investigation. Given the large number of digital skeuomorphs, three examples were chosen because they are typical and widely known. As a common provider of digital skeuomorphs, one of these is taken from Apple (Notes), and the other two are tomorrow.do and Poly Ana. These examples will be used to build a critical understanding of relationships between design decisions and resulting experiences that can reasonably be attributed to specific uses of skeuomorphs.

In addition to these GUI-based skeuomorphs, we consider two examples of skeuomorphic design in TUI. We have chosen only two examples to allow space for a more in-depth analysis of the greater complexity provided by the combination of digital and physical materials. The first of these is the iTypewriter, an addition to an iPad that turns it into a typewriter, and the second is metaDESK, a physical manifestation of a Graphical User Interface (GUI).

CRITICAL ANALYSIS OF DIGITAL SKEUOMORPHS

For digital skeuomorphs, we examine three examples. These examples are not intended to represent all skeuomorphs, but rather to illustrate and support the exploration of different facets of skeuomorphic design.

Poly-Ana

A virtual synthesizer for the production of electronic music, Poly-Ana's interface is comprised of a number of dials, switches, and a full keyboard (fig. 1 left). These elements are laid out on the screen in a manner similar to how they would be laid out on a physical synthesizer – grouped on a basis of the kinds of signal manipulation they cause. The different UI elements all have visual appearances that correspond to their analog counterparts. Consistent shading, reflective metal, and glossy keyboard keys all create a photo-realistic image of a synthesizer. The customizable background even looks like the surface of an analog synthesizer, with examples of alternate backgrounds all displaying reference to physical materials.

Its strict adherence to the visuals of physical materials emphasizes the physical as opposed to the digital. We read these skeuomorphs as more than a usability-enhancing metaphor. Because of their strong emphasis, the design implicitly argues that in some ways the physical is superior to the digital. At one level, more common to metaphor, this superiority of the physical would refer to the intuitive nature of the affordances of that material. However, the level of detail presented in the various controls of Poly-Ana far exceeds the requirements for this purpose. This level of fidelity to analog synthesizers presents a different kind of response to the nature of the digital.

In a domain like music production, where aesthetics and the creative, nuanced use of material are important, expressive details take on a heightened importance. The specific nuances of the sounds created by analog synthesizers are held in high regard for having qualities that are not found in the digital. The visual skeuomorphs in Poly-Ana's interface are an extension of this. As a tool for creativity, an important part of the interface is how it *engages* the user as a creative artist. The use of highly detailed visual representation of physical materials makes a statement about something lacking in traditional GUI representations, which historically have been deliberately minimal and inorganic. From an overly simplified view of skeuomorphs, Poly-Ana's design is a gimmicky and cheap means of making an interface look cool. From an evolutionary standpoint, these are aspects of an expressive instrument intended to inspire its users, in part by embodying a concern for quality in material craftsmanship. In this framing, the skeuomorphic design elements in Poly-Ana are a subtle means of helping musicians to produce good music.

Apple Notes

Notes began as a device application and then became a desktop/laptop application with similar styling. Here we

will focus on the desktop/laptop version. The bulk of the interface appears similar to a legal pad. This is set on a representation of a desk blotter that wraps around a sidebar containing a list of the different notes available and other UI controls. In terms of skeuomorphic elements, the part of the interface where the user actually writes is the standard legal pad yellow, complete with gray rules for the text. By default, the text in this area is Noteworthy, a script font that emulates handwriting. The pad has a leather-textured binding with a large number of remnants of torn yellow pages above the writing space. The "desk blotter" backdrop has a black leather texture, complete with stitches, running around the periphery.

With the addition of the elements of a desk blotter, this design harkens back to the desktop metaphor of early GUI design. Just like the calendar, though, these elements do not seem to add much to the explanation of how this design functions. Instead, they point more to the qualities and values built into these items as well as the assumed user. A desktop blotter is an item that is commonly used to protect a desk, and a leather blotter denotes a certain level of taste and sophistication. Collectively, these elements point to a luxurious, valuable item. This expression of luxury also comes with the belief that the user will be able to not only recognize these symbols of value, but also will be able to transfer them to the experience of using Notes.

However, this raises some questions. Notes is a free application that comes bundled with the OS; its functionality is extremely limited and for any serious writing or document production, its user will need to upgrade to a real word processor. The paper-world activity that it translates into computing was also originally cheap and simple, for examples, notes made on napkins, scraps of paper, and even body parts. Whereas Poly-Ana uses elements of a previous style to link old and new, enhancing a sense of fit for a highly specialized creativity tool whose medium has evolved, Notes couples strong connotations of luxury with a free and simplistic tool. Poly-Ana stylistically asserts that it is equivalent—functionally and expressively—to a very expensive piece of technical equipment. Notes asserts that it is a luxurious free single-function application, something akin to a diamond-studded scrap of dinner napkin.

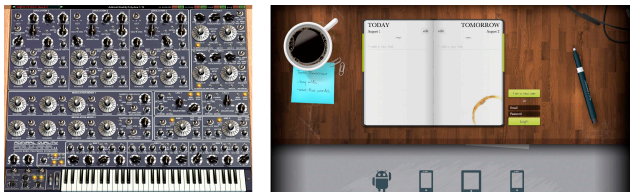

Figure 1 left: Poly-Ana from http://www.admiralquality.com/ right: tomorrow.do screencapture

tomorrow.do

While Notes tries to imply a certain quality, in terms of the cost and durability of the objects being represented, skeuomorphs need not always focus on things being nice and neat. The website tomorrow.do (a task manager available in app form for mobile and tablet as well), offers a two-day task list in the form of two pages in a book.

This website does have some of the elements seen before (e.g. wooden desk and a leather bound book) but there is also a coffee stain on one of the pages of the book. Stretching the browser window results in the appearance of the offending coffee cup, a post-it note, uncapped pen, scuff marks, and some wiring (fig. 1 right). Taken in combination, these elements combine to create a slightly messy, disorganized desk.

This defines the user differently than previous examples. While the organized desk spaces of the Apple apps place the user in the role of someone whom is on top of things, this presents the user as someone who may be treading water - exactly the kind of person who needs a task manager. In one sense, this could be seen as the app not working – if the person using it still had a messy desk, then the task list has not accomplished its function of offloading organization. In a different sense, it serves as a reminder of why the app is necessary. At any rate, this design uses skeuomorphs to express the visual language of the interface to the phenomenology of its use in a witty and empathic way.

CRITICAL ANALYSIS OF TANGIBLE SKEUOMORPHS

To explore how skeuomorphs return to the physical in tangible interactions, we analyze two skeuomorphic tangible interactions. We describe both similarly to the previous digital/virtual skeuomorphs, but with added emphasis on how the physical materials used add a further dynamic to the nature of the skeuomorphs.

iTypewriter

The iTypewriter is an addition to an iPad that adds aspects of a typewriter to the experience of using an iPad (fig. 2 left). The iTypewriter is the creation of industrial designer Austin Yang. This device meets Fishkin's basic definition of a "tangible interface": "a user uses their hands to manipulate some physical object(s) via physical gestures; a computer system detects this, alters its state, and gives feedback accordingly" [7]. In terms of interactivity, iTypewriter is hardly novel as a tangible interaction – the setup seems to be a closer relative to early digital word processors than to the kind of designs that come out of the Tangible Media Lab. However, its reference to early digital word processors is the very reason that it is pertinent to this discussion.

The iTypewriter has a matte body that creates a frame surrounding the mostly open area in which the keys are placed. The iPad itself sits within the opposite side of the machine, facing the user, in a position similar to that of paper in a traditional typewriter. It is only slightly larger in width than the iPad, making the whole apparatus smaller than a full sized typewriter. The keys themselves are slightly smaller than the size of the keys on the iPad's digital keyboard and are laid out in three tiers, corresponding in layout to the

letters on the iPad's screen keyboard (as opposed to the QWERTY layout used on computer and traditional typewriters). Each key connects to an arm in the body of the machine. Pressing the keys causes an arm to rise on the side of the typewriter towards the iPad. These arms are tipped with capacitive material. That capacitive material strikes the screen of the iPad, hitting the key on the virtual keyboard that corresponds to the one pressed on the iTypewriter's keyboard. This produces both an audible clank and the tangible feedback similar to a traditional typewriter.

Since skeuomorphs result from a change of material making certain forms unnecessary, it becomes important to consider what materials have changed in the iTypewriter. Unlike a traditional typewriter, the iTypewriter uses the iPad as both paper and ink. While the overall form of the typewriter is not that different from a traditional typewriter, and the traditional typewriter's action - tapping a key that activates a striking arm, producing a letter. However, the form and materials that accomplish this have changed with respect to the replacement of paper with an iPad. Capacitive tips are needed to make the arms activate the iPad's screen. Slightly subtler, a traditional typewriter operates by striking in the same spot and moving the paper. This makes for a different kind of form than that of the iPad or that of a traditional typewriter. This supports Bassalla's [3] observation that sometimes emulating a previous form in new materials can cause an increase in the difficulty of construction.

The iTypewriter gives two main reasons for the creation of this device: "users… can use this familiar typewriter and type in a familiar way" [24], anachronistically referring to "typists" as "users." Similar to digital skeuomorphs, this shows a merging of stylistic form and function. The idea of familiarity also brings this skeuomorph into the realm of metaphor – the typewriter serving as a metaphor iPad operation. The process of typing, as opposed to tapping on a pad, also gives important feedback on the process, making it functional as well. While the style of a traditional typewriter values the interaction of an older time, tangible aspects of the interface cause style, form, and function to become even more entwined than in digital skeuomorphs.

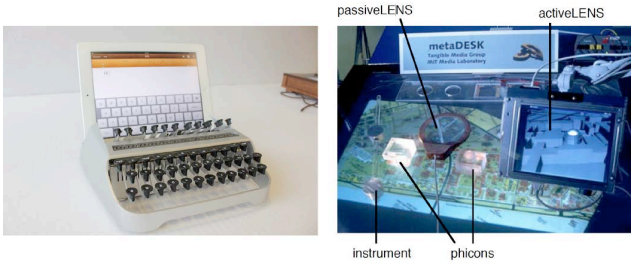

Figure 2 left: iTypewriter from [24], right: metaDESK from [14]

metaDESK

Whereas the iTypewriter takes the physical form of a typewriter and applies it to the more digitally-based interaction of an iPad, metaDESK takes the opposite approach of bringing the elements of digital interaction into the realm of the physical (fig. 2 right). An early Tangible User Interface (TUI) from Ishii and Ullmer, the metaDESK employs the metaphors of computing as a means of tangible interaction. The metaDESK consists of a nearly horizontal back projected graphical surface; the "activeLENS," an arm-mounted LCD screen; the "passiveLENS," a passive optically transparent "lens" actively mediated by the desk; "phicons," physical icons; and instruments which are used on the surface of the desk [14]. Although the interface style of metaDESK could be applied to a number of different interactions, the one that is associated with it is Tangible Geospace. This interaction uses a transparent model of the Great Dome and the MIT Media Lab as phicons. When these elements are placed onto the graphical surface, a map of MIT's campus appears, with its orientation and scale corresponding to the positions and orientations of the phicons. The activeLENS and passiveLENS both allow for different views of the information displayed on the map. The activeLENS displays a 3D version of the map while the passiveLENS shows additional aspects of the map. Taken collectively, the metaDESK is a very literal translation from GUI to TUI.

Previously described skeuomorphs had explicitly, and in great detail, applied the formal elements of physical materials to digital material. In moving back to the world of the physical, metaDESK takes the formal elements of a GUI and builds them into physical objects. Icons become phicons, windows become lenses, and handles, the drag-able parts of a GUI, become phandles [14]. These elements themselves are based upon metaphors to help guide users in controlling a computer. As a metaphor, these elements have been reduced to their functional elements, removing the specific attributes of physical materials. Bringing the interaction back into the physical world, metaDESK uses forms that also minimally emphasize function. They are icons, windows, and handles mapped directly into three dimensions.

The use of forms that are taken directly from digital material has implications for the interactions that are possible with metaDESK. Although these representations of digital elements have all the properties of physical materials, their function within the design is reduced to the operations of a GUI. In a sense, interaction itself with metaDESK is skeuomorphic as well. That interaction is intended to be the same as interacting with GUI, but taking "advantage of natural physical affordances" [14]. However, the affordances of physical forms are not as limited as the forms of a GUI [13]. Nonetheless, the interaction with metaDESK is constrained to the same type of interaction found in GUIs. This is not to say that metaDESKis flawed; it merely shows how this TUI carries over its interaction along with the formal elements of its components.

The physical skeuomorphs of digital materials that we see in metaDESK seem to be the opposite of the digital skeuomorphs of physical material seen in Notes and other applications. The use of GUI forms in metaDESK seem to favor expressions and behaviors that are specific to the digital realm. In other words, whereas applications such as PolyAna or Notes seem to suggest that the expressive capabilities of digital material are impoverished compared to those of physical material, metaDESK proposes that the functional forms of materials are less useful to digital interaction. However, in a complex twist, the forms taken from GUIs are themselves skeuomorphic metaphors of physical objects (windows, icons, handles, etc) once used to make computer interactions more accessible. One interpretation of this could be that the metaphor of physical material is preferable to actual material in tangible interactions. Alternately, the functional forms used in GUIs are its expressive forms as well. The stylistic elements of digital material are its functional elements. In either situation, the style of metaDESK is provocatively entangled in its function.

DISCUSSION

As a record of the ways that technological artifacts evolve, skeuomorphs present a number of implications for understanding how these artifacts relate to each other in terms of function and style - implications that can be leveraged to inform design.

Skeuomorphic Interaction

While in the context of digital applications skeuomorphs often seek to represent non-digital materials, the skeuomorphs in tangible interactions play a different role. Rather than just visually replicating the properties of a material, the skeuomorphs in the two tangible interactions described here do not just visually take on previous forms, but they also tangibly construct those forms and employ them as part of an interactive whole. This suggests that the interaction itself is skeuomorphic - that is, interactive behaviors are hybridized behaviors bridging the carbon and silicon realms in a far more literal way than Gessler describes, as summarized earlier. Interaction itself becomes another stylistic element for the designer to employ.

In the case of the iTypewriter, a visual representation of a typewriter could have been used, (there are a number of computer accessories that emulate the appearance of a typewriter) but instead the application faithfully reproduces the function and interaction of a typewriter around the new material composite of the iPad. The metaDESK takes the interactions of a GUI and maps them into 3-dimensional space using physical materials. While these materials take forms that resemble their computational counterparts, the most striking skeuomorph is the interaction, not a graphical design choice.

This means that interaction itself is intimately tied to style in such a way as to sometimes make them difficult to distinguish. In the case of the iTypewriter, its functioning as a typewriter is supported by materials that are necessary, but the form of typewriter is not necessary to type on an iPad. These necessary materials support the style of typewriter's functioning, and in turn affect the functioning of the iPad. The metaDESK's operation has a style similar to desktop environment, and this constrains activities, for example by making rotations of both phicons unviable [14]. What makes these interactions skeuomorphic is the level of specificity with which they capture the experiences they are emulating in new materials. Interacting with the metaDESK is very similar to interacting with a GUI, just with physical material; interacting with the iTypewriter is very similar to interacting with a typewriter, but with an iPad replacing the paper. This means that style, in tangible interactions, should not be considered independent of the function of that interaction; that is, style is not just a "skin" on top of Platonically unchanging functional substrate. It also means that style has important ramifications for the functioning of a tangible interaction. This makes it difficult to write off an aspect of a design as "merely" aesthetic or stylistic, as they have real implications for the use of the artifact, both in terms of interactive behaviors and in terms of the felt experience.

This blurring the lines between style and function should not conflate the two ideas however. There are important distinctions between style and function that are illustrated by skeuomorphs. Of particular importance are the ways that these two ideas evolve. In an tangible interaction context, where style and function intermingle, it becomes especially important to also understand how these different evolutionary tracks affect each other as they are evolving.

Skeuomorphs as Stylistic and Functional Evolution

The analysis of digital and tangible interactions that employ skeuomorphs has shown that the evolutionary course of skeuomorphs is not always the same. Here we will describe three types of evolutionary developments – style-borrowing, style-mediating, and function-giving. While not inclusive of all skeuomorphs, these three types of evolution emerge from our critical analyses and can be differentiated by how style relates to function.

Fundamental to the process of designing tangible interactions is the use of new materials in the context of computing. This may also include new materials that are composites of digital and physical materials that can be treated as a single material [18, 22]. These new materials have new properties that allow them to do things that previously were not possible. As with more traditional materials, these new possibilities make certain forms unnecessary. The occurrence of these forms in new materials becomes skeuomorphic and stylistic. Within this definition of skeuomorph is one movement of the evolution of style and function – the shift from function to style.

Style-Borrowing Evolution.

In the examples featuring digital skeuomorphs, we saw how skeuomorphs brought aesthetic qualities and their attendant

connotations that were missing from the digital material into it, for better or worse. By carrying over concepts such as beauty, luxury, and individuality from physical material, there is an implicit argument that these stylistic conventions had not been sufficiently developed in the digital material; otherwise, skeuomorphs introducing them wouldn't be necessary. Such skeuomorphs imply that digital material is either not well suited for such forms of expression or it is incapable of expressing such things. However, what a material is perceived to be good at expressing is subject to change over time, and recognizing that absence can catalyze change. The appearance and recognition of a skeuomorph, then, becomes as much about functional efficiency as it does about a perceived lacking of expressive capabilities in a given material.

This move from function to style is what we will refer to as a *style-borrowing evolution,* pulling formal qualities directly from the properties of an earlier design material into a new one. The formal elements that are carried over from a previous material are rooted in the physical properties of that material. The leather blotter of Notes connotes elements of the materiality of actual leather blotters – durability, resilience, luxuriousness, or, more broadly, professional success, being organized and on top of things, and so forth. The use of the skeuomorph, then, is a reference to these actual properties, attempting to transfer these properties to the newer material. Thus, the use of skeuomorphs that employ style-borrowing evolution in an artifact may point to a lack of medium-specific forms of expression established in that artifact's material. This kind of evolution attempts to maintain the connections between materiality and function in spite of a change in material.

Style-Mediating Evolution.
In the example of the metaDESK, a different kind of evolution is shown, what we will call *style-mediating evolution*. While the windows, icons, and handles are important functional elements of interacting with computers in a virtual desktop environment, these elements do not have that same function when brought into the tangible world. However, these elements are themselves metaphors – a reduced version of yet another material. While this is a functional element, it also shows certain stylistic decisions in terms of what is kept in the metaphor and what gets left out. The skeuomorphs in metaDESK not only constitute a style built off of a previously functional element, but they also constitute a style that is built off of another style, hence the term *style-mediating evolution.* As with the previous type of evolution, the implicit argument is that there is something lacking in the capabilities of the physical materials that control computers and that by emulating the stylized function of computers, better results can be achieved. However, this becomes physical material emulating physical material mediated by digital material.

As changes occur in the expressive capabilities of digital material, so too would they need to change in the physical material representing it. This can be seen in the later work that came out of MIT's Tangible Media Lab (e.g., Illuminating Clay [17] and Amphorm [16]) where new styles of interaction are introduced along with respect to changes in how the functioning of the digital material changes in terms of both style and function. Robles and Wiberg's example of IceHotel X [18] also exemplifies this kind of mediated evolution after further development of the stylistic use of digital material – showing representations of meaningful physical phenomena, mediated by technology, in digital material.

Function-Giving Evolution. Finally, there is an evolution from style to function. This type of evolution is antagonistic to the very idea of skeuomorphs, which are predicated on the concept of functional obsolescence, but it can result from the use of a skeuomorph. The iTypewriter introduces the style of interaction that comes from a traditional typewriter. The introduction of this style to the use of an iPad has certain implications for the device's functionality. The haptic feedback that the keys give in this kind of interaction is an example of such a functional element. While adding a typewriter to an iPad is not the only means to arrive at such feedback, it is a consequence of the introduction of that style.

This final evolution is a *function-giving evolution* and its consequences can be both positive and negative. While the typewriter shows how a functional benefit can come from the introduction of a new style, it is more frequent for skeuomorphs to be noticed when the opposite occurs – when a stylistic element introduces problems which need to be resolved in order for the artifact to be usable. In interaction design, we see complaints that skeuomorphism "hinders an 'efficient interaction' and optimum usability" [11]. This sub-optimal usability means that the users are required to exert extra effort when interacting with the artifact. However, if users have a real choice (i.e., an alternative in the market) but continue to use it anyway, we can reasonably infer that there is an investment in that style. Not every interaction with a computer can be reduced to task completion, and this final evolutionary effect shows how expressive and aesthetic aspects of the experience of interaction can contribute to the value of a design beyond its functional efficiency.

With these evolutionary aspects of how skeuomorphs emerge in tangible interactions, we return to the concept of skeuomorphs as inauthentic. Examining skeuomorphs as an aspect of the evolution of technology has shifted understanding away from this aspect of skeuomorphs, but it still remains as an important critique of their use. Using a leather blotter as a background begs the question of whether any note taking application can truly be "luxurious," and whether that sense of luxury is actually honest to the application or not. Such questions require a level of analysis that extends beyond the purpose and space of this paper. Rather than advocating for or against the use of skeuomorphs, these three descriptions of the evolution of technology suggest

that skeuomorphic design is a powerful indicator of important aspects of the evolving relationships between style and function. These relations may lead to the formal representation of non-existent material properties, but their appearance also can tell designers a great deal about the nature of the development of style and function.

CONCLUSION

To explore the concept of skeuomorphs in tangible interactions, we developed a richer definition of skeuomorphs than had been previously existed in an HCI context. Taken from a more archaeological perspective, this definition added the evolutionary relationships between artifacts to the previous understanding. Applying this definition of skeuomorphs to the analysis of tangible interactions, we have explored how style and function relate through three types of evolution: style-borrowing, style-mediating, and function-giving. These types of evolution shed light on the materials, forms, materiality, and experiences of tangible interactions relate in terms of medium-specificity and style.

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REFERENCES

1. Baraniuk, C. (2012) How we started calling visual metaphors "skeuomorphs" and why the debate over Apple's interface design is a mess. Available online http://tinyurl.com/dxodr2e. Accessed 07/19/2013.
2. Bardzell, J. (2011). Interaction Criticism: An Introduction to the Practice. *Interacting With Computers 20*: 604-621
3. Basalla, G. (Ed.). (1988). The evolution of technology. Cambridge University Press.
4. Bergström, J., Clark, B., Frigo, A., Mazé, R., Redström, J., & Vallgårda, A. (2010). Becoming materials: material forms and forms of practice. *Digital Creativity*, 21(3): 155-172.
5. Blackwell, A. F. (2006). The reification of metaphor as a design tool. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 13(4): 490-530.
6. Fernaeus, Y., Jonsson, M., & Tholander, J. (2012). Revisiting the jacquard loom: threads of history and current patterns in HCI. In *Proc. SIGCHI'12*, ACM, pp. 1593-1602.
7. Fishkin, K. A. (2004) Taxonomy for and Analysis of Tangible Interfaces. *Personal and Ubiquitous Computing* 8(5): 347-358.
8. Gessler, N. (1998, January). Skeuomorphs and cultural algorithms. In *Evolutionary Programming VII,* Springer pp. 229-238.
9. Gross, S., Bardzell, J., & Bardzell, S. (2013). Touch style: creativity in tangible experience design. In *Proc. C&C'13,* ACM, pp. 281-290.
10. Hallnäs, L., & Redström, J. (2002). From use to presence: on the expressions and aesthetics of everyday computational things. *ToCHI*, 9(2): 106-124.
11. Hobbs, T. Can we please move past Apple's silly, faux-real UIs? Co.Design Available online at http://tinyurl.com/7bu8f69, Accessed 03/25/2013.
12. Horn, M. (2013). The role of cultural forms in tangible interaction design. In Proc. TEI'13, ACM, pp. 117-124.
13. Hornecker, E. and Buur, J. (2006) Getting a grip on tangible interaction: a framework on physical space and social interaction. In *Proc. CHI'06* ACM, pp. 437-446.
14. Ishii H, Ullmer B (1997) Tangible bits: towards seamless integration interfaces between people, atoms, and bits. *Proc CHI'97*, pp 234-241.
15. Jung,H. and Stolterman, E. (2012) Digital form and materiality: propositions for a new approach to interaction design research. In *Proc. NordiCHI'12*, ACM, pp. 645-654.
16. Lakatos, D. (2012) Amphorm. MIT Media Lab Tangible Media Group. Available online http://tinyurl.com/kvbcbns. Accessed 07/29/2013.
17. Piper B, Ratti C, Ishii H (2002) Illuminating clay: a 3-d tangible interface for landscape analysis, *Proc CHI'02*, ACM pp. 355-362
18. Robles E, Wiberg M (2010) Texturing the "material turn" in interaction design. In *Proc TEI'10*, ACM pp 137-144.
19. Rosner, D. K., & Taylor, A. S. (2011, May). Antiquarian answers: book restoration as a resource for design. In Proc. of the SIGCHI'11, ACM, pp. 2665-2668.
20. Skeuomorph. Dictionary.com Available online http://dictionary.reference.com/browse/skeuomorph. Accessed 07/29/2013.
21. Thompson, Clive (2012) Clive Thompson on Analog Designs in the Digital Age. Wired Magazine. Available online at www.wired.com/magazine/2012/01/st_thompson_analog/. Accessed 03/25/2013.
22. Vallgårda A, Sokoler T (2010) A material strategy: exploring material properties in computers. *Int J Des* 4(3):1–14
23. Wiberg, M. (2013). Methodology for materiality: interaction design research through a material lens. *Personal and Ubiquitous Computing,* online, 1-12.
24. Yang, A. (2012) iTypewriter Available online http://tinyurl.com/d5ncbav. Accessed 07/29/2013.