6 Choosing Materials for Personal Robot Design

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Choosing materials for human-made objects has been at the center of a millennia-long tradition of artifact design and production. As humanity accelerated through a sequence of found and manufactured materials, designers increasingly had to carefully choose the appropriate material for the task at hand. Should a container be made of fired clay or woven reed fibers? Will a table be made of heavy oak wood, or a thin marble plate supported by wrought iron legs? Is aluminum required for this garden shed, or is PVC sufficient? A glance around the reader's desk will likely reveal a collection of human-made objects which incorporate a vast diversity of material choices echoing humanity's trajectory through its history, from wood, stone, and bamboo fibers, through metals, fabrics, paper, and ceramics, to synthesized plastics and engineered composites.

The design of personal robots stands in stark contrast to this rich tradition, with most robot designers making seemingly automatic choices, informed by convenience, functionality, and pragmatism. The result is a near consensus on plastics and metals as the materials used, and a concerning similarity in the design of robots that interact with humans. This lack of creativity could be excused in an industrial setting, where engineering considerations dominate, but should be questioned when it comes to the design of robotic devices that would make their way into our living, leisure, and educational spaces. There are, of course, good arguments to be made for pragmatic choices of convenient materials, including price, availability, ease of manufacturing, machinability, and strength. That said, the choice of materials offers designers modes of interaction and expression which are beyond mere functionality and should be incorporated into personal robot design.

I will suggest four ways in which materials matter for human–object interaction and which can be used to better inform the design of personal robots: visual aesthetics, tactile interaction, auditory expression, and a relationship to time and place.

6.1 VISUAL AESTHETICS

Most apparently, materials communicate to humans in visually aesthetic ways, which are in turn informed by cultural references. Physically, different materials capture and reflect light in unique ways, displaying specific colors and textures. Deep-shaded

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wooden furniture, rough textured or glazed clay pots, and colorful stained-glass lampshades affect the observer from a distance, before direct interaction even starts. The emitted colors can be categorized as warm or cool, and the textures as inviting or unpleasant.

Beyond their physicality, materials can also visually radiate cultural histories and traditions. Any choice of material recalls thousands of years of craft skills, honed and reimagined by generations of designers and artisans. When one observes a manufactured object, one can see how generations of woodworkers, potters, metalsmiths, glass blowers, and weavers have embedded their ideas into the object. These ideas carry meaning: the difference between placing a rough-sawn wooden farm table in the center of a dining area and choosing a chromed steel and laminated diner-style table embeds a narrative, either of tradition and rural life or of modernity and convenience.

Even if ignored by the designer, the choice of usually white plastic and metal for personal robot design also carries visual aesthetic and cultural connotations (see: Dunstan & Hoffman, 2023). A designer might only think of functionality when choosing materials for a personal robot, but they might inadvertently tell a story of futurism and consumer convenience, while leaving a wide space of design potential unexplored.

6.2 TACTILE INTERACTION

Coming closer to the manufactured object, humans interact with artifacts by touching them. When touched, materials interact with the user's skin in rich ways that designers have long taken advantage of. Materials have unique textures and a characteristic resistance to deformation, which are quickly experienced by anyone who handles them. Running a hand over a glass lampshade shares very little with the experience of touching a fabric one. A vegetable peeler made purely of stainless steel performs differently in a cook's hand than one with engineered plastic handles.

In addition to texture, a material's thermal conductivity causes it to feel colder or warmer to the touch, as can be experienced by touching either metal or fleece, both at room temperature. While this property of materials is sometimes exploited by robot designers, for example by adding fur to robots that are expected to be held (e.g., Paro, the robotic baby seal; Wada & Shibata, 2007), most personal and social robots are cold to the touch.

What would it feel like to touch a wooden robot versus one made of marble? Would a robot covered in fleece be preferred in the winter, and a cool glass one serve better in the summer? The tactile expressivity of a robot's exterior offers a wide canvas for design exploration (see: Hu & Hoffman, 2023), one that is yet to be fully discovered.

6.3 AUDITORY EXPRESSION

Touching an object, picking it up, tapping it, stroking it, dropping it, placing it down—all of these interactions produce characteristic sounds that depend on a combination of material choice and shape, in interaction with the surface onto which the

object may have been released. Setting down a thin vessel of glass makes a sound that reflects its fragility, running one's fingers through leaves of paper generates a rustle, and metal spoons resonate in idiosyncratic ways when they are dragged across a cast-iron pan or a glazed dinner plate.

While sound has been explored as a nonverbal modality in human–robot interaction (e.g., Moore et al., 2017; Pelikan & Jung, 2023; Wolfe et al., 2024), these works dealt mostly with computationally produced sounds or peripheral sounds, such as those emitted by electric motors and gear transmissions. The auditory expression of the materials chosen to construct the machine is rarely considered when designing a robot.

We can imagine a robot with a shell made of paper that makes crumpling, folding, and unfolding sounds as it moves. Or one made of pieces of fired clay that rub against each other, generating the scratching noises of erosion. Even when a mobile personal robot hits an obstacle, the material from which it is made can be designed to create a certain sound, be it a soft rubber thump, or an alarming shattering of glass.

6.4 TIME AND PLACE

Finally, material choice relates to the designed object beyond the immediate interaction with users. Each design material has a longitudinal temporal relationship to the world, which projects in both directions, into its history and its future. Looking to the past, materials are chosen for their location of origin, be it to support local production or remind one of a specific time or place in the world, from which a material originated. Many enjoy furniture made from reclaimed wood planks that still carry painted shipping stamps from bygone centuries. A set of coasters crocheted from yarn brought on a boat by an immigrant grandparent might remind one of their ancestry. Looking into the future, people may choose objects made from certain materials for their longevity, as well as for their environmental impact, preferring degradable materials to those who will pollute oceans for centuries.

Personal robot design rarely taps into its potential to connect to distant times and places. Robots come from nowhere, designed by no one, made from materials that don't have a spatiotemporal identity, whether in the past or in the future. To use the famous term coined by Benjamin (1936), they don't have a unique "presence in time and space." When they are done operating, they will disappear into a landfill, forgotten, with some notable exceptions like the mindful rituals surrounding the zoomorphic AIBO robot in Japan (Knox & Watanabe, 2018).

When choosing materials for a personal robot, designers should consider their origins and fate. If long-term interaction is a goal, one can think longer-term than just the period of the robot's usage.

The four interactive considerations in material choice listed above come together to produce a holistic affective relationship between humans and their artifacts, a relationship completely missed by designers of social and personal robots, even as they proclaim to design robots that are intended for long-term, personal, and emotional interaction. It should therefore not be surprising if users are more attached to their hand-made clay tea mug than to their personal robotic assistant.

How can the field of personal robot design address this blind spot in material choice? One way is to formalize material choice in the education process of designers in the human–robot interaction field. Product designers and architects are meticulously trained in material selection from not just a pragmatic, but also a cultural and affective perspective. When they begin to practice, they carry this training and sensitivity into their trade. Designers of social robots should take similar care in the materials they offer their users.

6.5 DESIGNING ROBOTS WITH AN INTENTIONAL MATERIAL CHOICE: BLOSSOM

I would like to offer *Blossom*, in Figure 6.1, as a case study of intentional material choice in a robot's design (Suguitan & Hoffman, 2019). Blossom was designed in my research laboratory as a speculative project reacting to the common tropes in personal robot design, especially that of a streamlined white plastic appliance. One design principle of the Blossom project was the use of traditional craft materials, most prominently wool and wood.

The choice of craft materials was made with several objectives in mind. First, aesthetically, I wanted to position a personal robot in the material context of domestic objects. A cold consumer electronics device feels out of place on a hand-made wooden coffee table. Second, Blossom was made compliant and out of a soft crocheted fabric to encourage tactile interaction, including holding, petting, pushing, and squeezing the robot. Third, the choice of craft was to encourage amateur manufacturing and social interaction. I envisioned a grandparent and grandchild, neither of which might have access to a metal shop or a 3D printer, working together to build a Blossom robot (see the interior and components in Figure 6.2 and 6.3). Finally, the natural materials chosen for Blossom would eventually decay, contributing both to a reduction in waste-related pollution, and lending a temporary aspect to the ownership of the robot (for a discussion on the value of transience in social robot design, see: Hoffman, 2020).

Blossom was adopted by other researchers as a low-cost hand-made social robot (e.g., Swaminathan et al., 2021; O'Connell et al., 2024). Its adoption was perhaps due to the robot's accessibility to production or because of the joy of crafting one's own robot. Still, Blossom is merely a single speculative suggestion that can expand the scope of material imagination in personal robot design.

To productively move forward as a field toward intentional material choice, we should encourage collaborations between robotics engineers and traditionally trained product designers. The latter would bring a more nuanced, aesthetic, and culturally grounded approach to material choice in robot design. Robot designers themselves would also benefit from both a more elaborate product design education with a focus on material choice, which may result in a more intentional process when choosing materials for their next project.



FIGURE 6.1 The Blossom robot displaying a hand-crocheted wool cover and handcrafted wooden ears. These materials were intended to aesthetically fit in domestic environments, be warm to the touch, and evoke a sense of a unique time and place.

Photo courtesy of Cornell University.

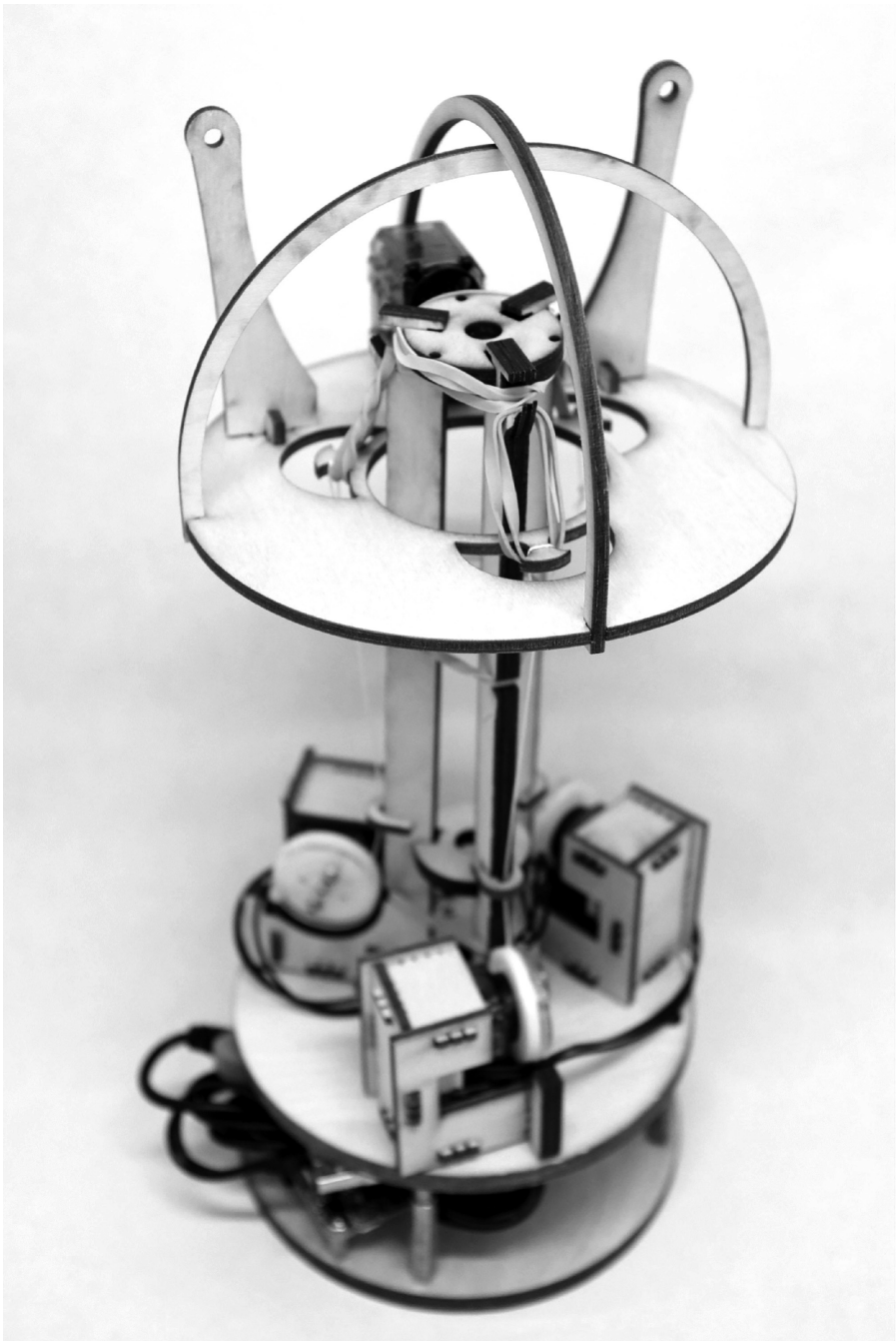


FIGURE 6.2 Blossom's interior is also made mostly of wood, an ecologically friendly, degradable material, that suggests temporality and accessibility.

Photo courtesy of Cornell University.

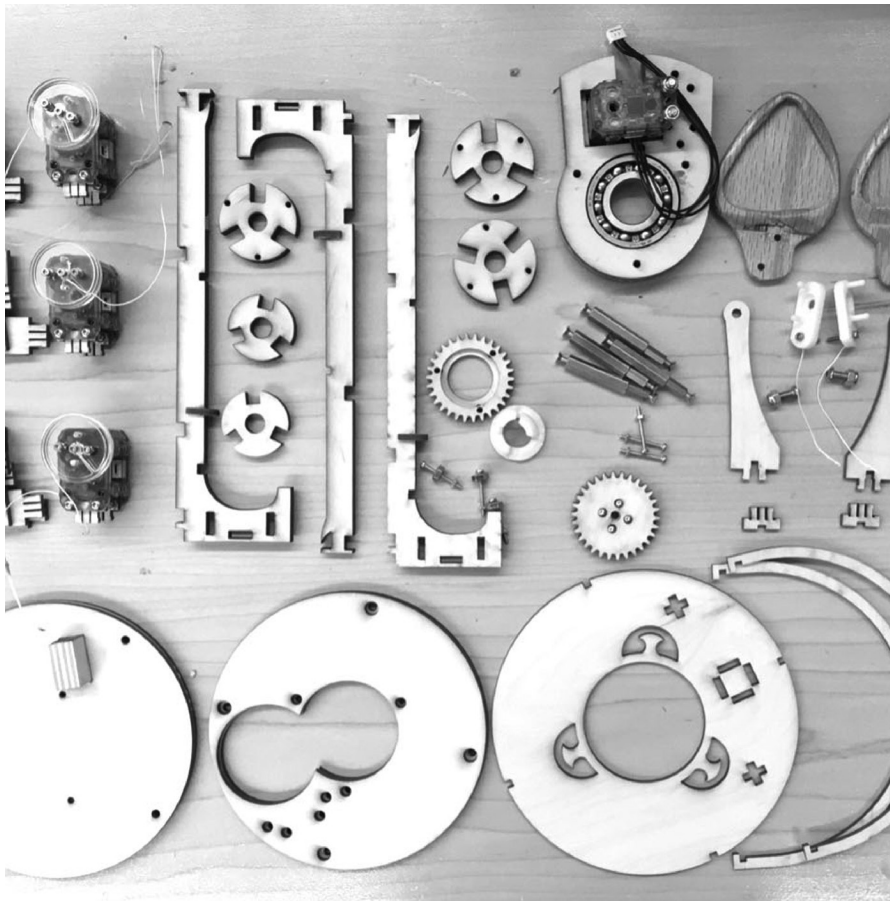


FIGURE 6.3 The wooden mechanical parts Blossom is made of are cost-effective, degradable, and easy to assemble, enabling amateurs to participate in robot construction.

Photo courtesy of Cornell University.

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