Only Robots on the Inside

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I recently had the chance to see an automated machine shop where robots were being used to precisely manufacture many copies of a single part. Similar machines, designed to perform a precise, accurate, and repeatable task, currently make up a large portion of the robotics market.

It is fascinating to see what happens when robots leave the factory for everyday environments such as the home. A robot like the iRobot Roomba vacuum cleaner, which is primarily a utility device, enters into an entirely new dynamic once put into a home setting. People have been found to name and talk to their Roombas [1]. While robots are by no means the first devices to be anthropomorphized in the home, they are more recent additions to other common items such as televisions, computers, and home appliances [2].

Increasingly, robots are being designed with anthropomorphic qualities as part of their function. Robots such as Kismet [3] have been designed to explore the ways in which emotional states can be detected and displayed to enable social communication. Other robot platforms have been created with more specific social applications: Paro [4], a robotic seal, is designed to be a therapeutic companion for elderly patients, and Keepon [5] is designed to study social development by interacting with children. Similar robots could have numerous applications in health care, education, elder care, and communication, to name a few. In many of these emerging applications, anthropomorphic qualities are not just beneficial but essential to the robot's purpose.

Designing for Anthropomorphism

Creating anthropomorphic characters is not new to the field of animation. Many of the animation techniques used today were pioneered decades ago. The early techniques used by Disney studios are articulated in *The Illusion of Life* [6], widely considered a classic text in the animation field. Pixar Animation Studios has applied many of these classic 2-D animation principles to 3-D animations. John Lasseter has argued that the principles have a similar meaning regardless of the medium of animation [7].

A natural question to ask is how can these animation principles be used to give robots "the illusion of life"? An important and critical difference exists between non-physical and robotic animation mediums. Robotic systems are constantly battling the laws of physics and the cost of materials needed to achieve a given design requirement. Many animated characters would be extremely expensive or even impossible to synthesize in robot form. As budget and design constraints are introduced, an important question arises: In what ways could robots that are designed at the most basic level best enable the illusion of life? As socially expressive robots enter into consumer markets, it becomes important to find ways in which robots can maintain their ability to have rich interactions at an accessible production price. My research interests have been directed toward this goal of finding ways of creating highly expressive and engaging robots, while maintaining a simple and cost-effective mechanical design.

Tofu and Miso

Through a collection of robots including Tofu (top) and Miso (bottom), I have been exploring this space of highly expressive yet inexpensive robotic characters, each of which cost under $500 to produce in small quantities. I am most interested in how people perceive and interact with the robot characters, which are controlled through a game-controller-based puppeteering interface. Evaluation of the character's anthropomorphic qualities has been done informally and anecdotally. A great deal of insightful feedback has come from casually interacting with many people (easily numbering in hundreds), from a wide age range. Some of these informal evaluations have been more focused, such as a storytelling exercise done with a group of kindergartners who collaboratively generated a story while a robotic character was used to act out the story in real time

[1] Forlizzi, J. "How Robotic Products Become Social Products: An Ethnographic Study of Cleaning in the Home." In *HRI '07.* Arlington, Virginia: ACM Press, 2007.

[2] Reeves, B., Nass, C. *The Media Equation.* Stanford, CA: Cambridge University Press, 1996.

[3] Breazeal, C. *Designing Sociable Robots.* Cambridge, MA: The MIT Press, 2004.

[4] Wada, K., Shibata, T. "Living With Seal Robots—Its Sociopsychological and Physiological Influences on the Elderly at a Care House." *IEEE Transactions on Robotics* 23, 5 (2007): 972–980

[5] Kozima, H., Yano, H., "A Robot That Learns to Communicate with Human Caregivers." *Proceedings of the International Workshop on Epigenetic Robotics* (2001).

[6] Thomas, F., Johnston, O. *Disney Animation: The Illusion of Life.* Abbeville Press, 1981.

[7] Lasseter, J. "Principles of Traditional Animation Applied to 3-D Computer Animation." *SIGGRAPH '87 Conference Proceedings* (1987): 35–44.

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with other plush characters. I am currently in the process of designing similar robots to be used in a more formal evaluation of how storytelling can be used to enable learning within a constructionist framework [8].

As with any design, Tofu and Miso have been generated through an iterative process that incorporates many design inspirations. Classic animation references such as *The Illusion of Life* have been highly influential, as well as meeting with animators and storyboard artists from Pixar, who utilize a much broader set of tools to bring characters to life. In addition, the work of Donald Norman has influenced many design decisions that affect the automatic prewired layer of human perception, or the visceral level [9]. Drawing from these various design influences, I have collected a small set of design concepts that have proven useful in the creation of Tofu and Miso. They are by no means a panacea, but hopefully a start-

[8] Papert, S. "Situating Constructionism." In *Constructionism: Research Reports and Essays, 1985-1990,* eds. Harel, I. and Papert, S., 1–11. Norwood, NJ: Ablex, 1991.

[9] Norman, D.A. *Emotional Design: Why We Love (or Hate) Everyday Things.* New York: Basic Books, 2004.

ing point in finding low-cost methods of making expressive robot characters.

Deliver on expectations. The form of a robotic character greatly determines the affordances [10] it provides, influencing the perceived function of the character. A form similar to a cheetah would imply the ability to bolt across the room, where an amorphous blob of fluff sets an expectation that is much easier to deliver on. The affordances of a character can also envelop its believable functionality. For this reason, a simple character such as Tofu uses only simple emotive sounds to communicate instead of, say, eloquent French, which, coming from a robot with this appearance, simply wouldn't be believable.

Squash and stretch. Out of the fundamental animation principles described in *The Illusion of Life*, the authors regard "Squash and Stretch" as the most important principle. The effect is achieved by creating forms that preserve their volume when deformed. This emulates the behavior of a bouncing ball that widens when compressed, as well as the numerous organic systems that conserve their volume throughout movement. Tofu and Miso are made of compressible foam surrounded by strips of material that bow when compressed to achieve this effect.

[10] Norman, D.A. *The Design of Everyday Things.* Doubleday, 1988

Secondary action. Animators use the secondary action technique to illustrate cause-and-effect relationships found in natural systems. An example is the motion of a horse's tail in response to the horse's body motion. Similarly, low-mass aesthetic elements, such as the inexpensive feathers used on Tofu and Miso, provide a mechanism to amplify the effects of secondary action in response to the robot's motion.

Eyes. Among robots designed for social interaction, the presence of eyes is a common and powerful anthropomorphic design element. The use of eyes with actuated pupils enables the robot to convincingly convey areas of interest. Commonly, eyes of this nature are actuated quietly to appear more lifelike, usually at the cost of using expensive, high-performance motors. Tofu and Miso make use of low-cost OLED displays to achieve a similar effect by emulating the silent and dynamic eye motions often found in nature.

The illusion of thinking. A large component of creating lifelike robotic characters is creating an illusion that the character has the ability to think. The ability to convey emotions is in vain if no one appears to be behind the wheel. The illusion of thinking is largely created by the behavior of the robot in the context of its surroundings, but it can also be influenced by emulating subtle cues found in nature. These include looking up when contemplating, as well as actions perceived as thinking, such as dogs cocking their heads. Small timely expressions like blinking can also be used to suggest the presence of a cognitive process.

Engagement. Building on the illusion of thinking, a powerful way of creating lifelike robotic characters is to provide simple ways for the characters to present body language. By expressing engagement, a robotic character demonstrates not only awareness of its surroundings, but also a fascination with the world it lives in. This powerful mental state can be conveyed simply by leaning forward while maintaining a fixed gaze on an object of interest. Similarly, leaning back with a fixed gaze can convey a sense of uncertainty or surprise.

As robots leave the factory and enter into our daily lives, a new metric will define the success of these platforms. The adoption of robots in this new space will not just be determined by functional utility, but also by an ability to connect relationally. Well-animated characters and the stories they tell have a long history of capturing the hearts and imaginations of people regardless of age or culture. I believe that well-designed, expressive, and engaging robots will have a positive impact in many environments where their presence is welcomed. To create these robots, the relational design elements cannot be an afterthought, but must be carefully integrated at every step.

ABOUT THE AUTHOR Ryan Wistort is a graduate student in the Personal Robots Group at the MIT Media Lab, where he builds and studies robots as a human interface. Before his studies at MIT, he worked with Intel Research developing robots for elderly care applications, and NASA designing robotic systems for planetary exploration. His research interests include finding cost-effective ways of enabling rich social interactions with robots. He is most interested in using these technologies to develop new education applications capable of reaching large audiences. Currently, Wistort is exploring how such technologies could be used to enable robot-based creative mediums and content creation models for children. More information about his work can be found at www.RyBOTS.com.

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