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# The Uncanny Valley: The Original Essay by Masahiro Mori

“The Uncanny Valley” by Masahiro Mori is an influential essay in robotics. This is the first English translation authorized by Mori.

By **Masahiro Mori**

Translated by Karl F. MacDorman and Norri Kageki

**Editor’s note:** *More than 40 years ago, Masahiro Mori, then a robotics professor at the Tokyo Institute of Technology, wrote an essay on how he envisioned people’s reactions to robots that looked and acted almost human. In particular, he hypothesized that a person’s response to a humanlike robot would abruptly shift from empathy to revulsion as it approached, but failed to attain, a lifelike appearance. This descent into eeriness is known as the uncanny valley. The essay appeared in an obscure Japanese journal called* Energy *in 1970, and in subsequent years it received almost no attention. More recently, however, the concept of the uncanny valley has rapidly attracted interest in robotics and other scientific circles as well as in popular culture. Some researchers have explored its implications for human-robot interaction and computer-graphics animation, while others have investigated its biological and social roots. Now interest in the uncanny valley should only intensify, as technology evolves and researchers build robots that look increasingly human. Though copies of Mori’s essay have circulated among researchers, a complete version hasn’t been widely available. This is the first publication of an English translation that has been authorized and reviewed by Mori. [Read an exclusive interview with him.]*


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**A Valley in One’s Sense of Affinity**

The mathematical term *monotonically increasing function* describes a relation in which the function $y = f(x)$ increases continuously with the variable $x$. For example, as effort $x$ grows, income $y$ increases, or as a car’s accelerator is pressed, the car moves faster. This kind of relation is ubiquitous and very easily understood. In fact, because such monotonically increasing functions cover most phenomena of everyday life, people may fall under the illusion that they represent all relations. Also attesting to this false impression is the fact that many people struggle through life by persistently pushing without understanding the effectiveness of pulling back. That is why people usually are puzzled when faced with some phenomenon this function cannot represent.

An example of a function that does not increase continuously is climbing a mountain—the relation between the distance ($x$) a hiker has traveled toward the summit and the hiker’s altitude ($y$)—owing to the intervening hills and valleys. I have noticed that, in climbing toward the goal of making robots appear human, our affinity for them increases until we come to a valley (Figure 1), which I call the *uncanny valley*.

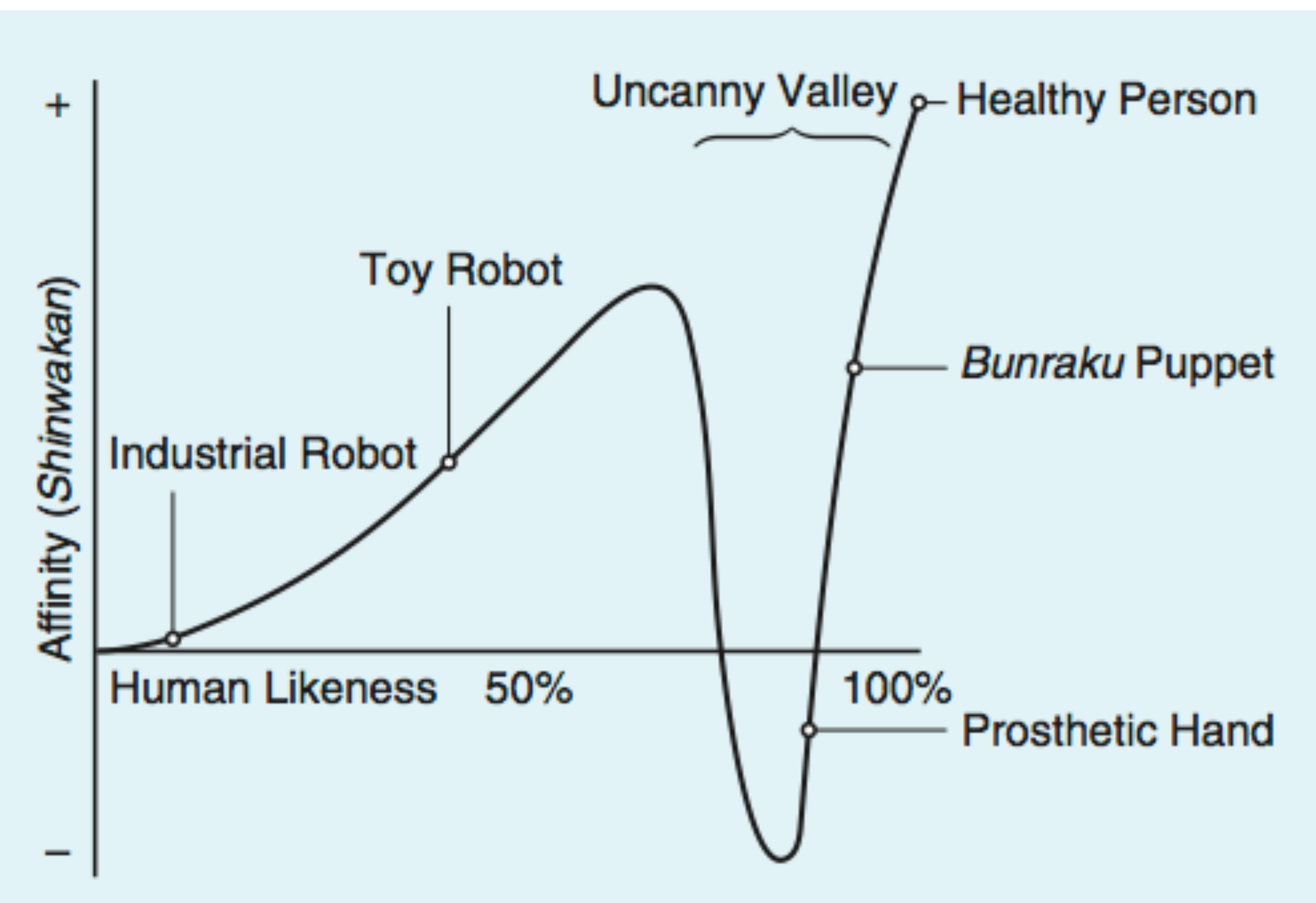


Figure 1. The graph depicts the uncanny valley, the proposed relation between the human likeness of an entity and the perceiver’s affinity for it. [*Translators’ note: Bunraku is a traditional Japanese form of musical puppet theater dating from the 17th century. The puppets range in size but are typically about a meter in height, dressed in elaborate costumes, and controlled by three puppeteers obscured only by their black robes. An example is shown on the cover of* Robotics & Automation Magazine*, above.*]

Nowadays, industrial robots are increasingly recognized as the driving force behind reductions in factory personnel. However, as is well known, these robots just extend, contract, and rotate their arms; without faces or legs, they do not look very human. Their design policy is clearly based on functionality. From this standpoint, the robots must perform functions similar to those of human factory workers, but whether they look similar does not matter. Thus, given their lack of resemblance to human beings, in general, people hardly feel any affinity for them.[1] If we plot the industrial robot on a graph of affinity versus human likeness, it lies near the origin in Figure 1.

By contrast, a toy robot's designer may focus more on the robot's appearance than its functions. Consequently, despite its being a sturdy mechanical figure, the robot will start to have a roughly human-looking external form with a face, two arms, two legs, and a torso. Children seem to feel deeply attached to these toy robots. Hence, the toy robot is shown halfway up the first hill in Figure 1.

Since creating an artificial human is itself one of the objectives of robotics, various efforts are underway to build humanlike robots.[2] For example, a robot's arm may be composed of a metal cylinder with many bolts, but by covering it with skin and adding a bit of fleshy plumpness, we can achieve a more humanlike appearance. As a result, we naturally respond to it with a heightened sense of affinity.

Many of our readers have experience interacting with persons with physical disabilities, and all must have felt sympathy for those missing a hand or leg and wearing a prosthetic limb. Recently, owing to great advances in fabrication technology, we cannot distinguish at a glance a prosthetic hand from a real one. Some models simulate wrinkles, veins, fingernails, and even fingerprints. Though similar to a real hand, the prosthetic hand's color is pinker, as if it had just come out of the bath.

One might say that the prosthetic hand has achieved a degree of resemblance to the human form, perhaps on a par with false teeth. However, when we realize the hand, which at first site looked real, is in fact artificial, we experience an eerie sensation. For example, we could be startled during a handshake by its limp boneless grip together with its texture and coldness. When this happens, we lose our sense of affinity, and the hand becomes uncanny. In mathematical terms, this can be represented by a negative value. Therefore, in this case, the appearance of the prosthetic hand is quite humanlike, but the level of affinity is negative, thus placing the hand near the bottom of the valley in Figure 1. This example illustrates the uncanny valley phenomenon.

I don't think that, on close inspection, a *bunraku* puppet appears very similar to a human being. Its realism in terms of size, skin texture, and so on, does not even reach that of a realistic prosthetic hand. But when we enjoy a puppet show in the theater, we are seated at a certain distance from the stage. The puppet's absolute size is ignored, and its total appearance, including hand and eye movements, is close to that of a human being. So, given our tendency as an audience to become absorbed in this form of art, we might feel a high level of affinity for the puppet.

From the preceding discussion, the readers should be able to understand the concept of the uncanny valley. So now let us consider in more detail the relation between the uncanny valley and movement.

### The Effect of Movement

Movement is fundamental to animals—including human beings—and thus to robots as well. Its presence changes the shape of the uncanny valley graph by amplifying the peaks and valleys, as shown in Figure 2. For point of illustration, when an industrial robot is switched off, it is just a greasy machine. But once the robot is programmed to move its gripper like a human hand, we start to feel a certain level of affinity for it. (In this case, the velocity, acceleration, and deceleration must approximate human movement.) Conversely, when a prosthetic hand that is near the bottom of the uncanny valley starts to move, our sensation of eeriness intensifies.

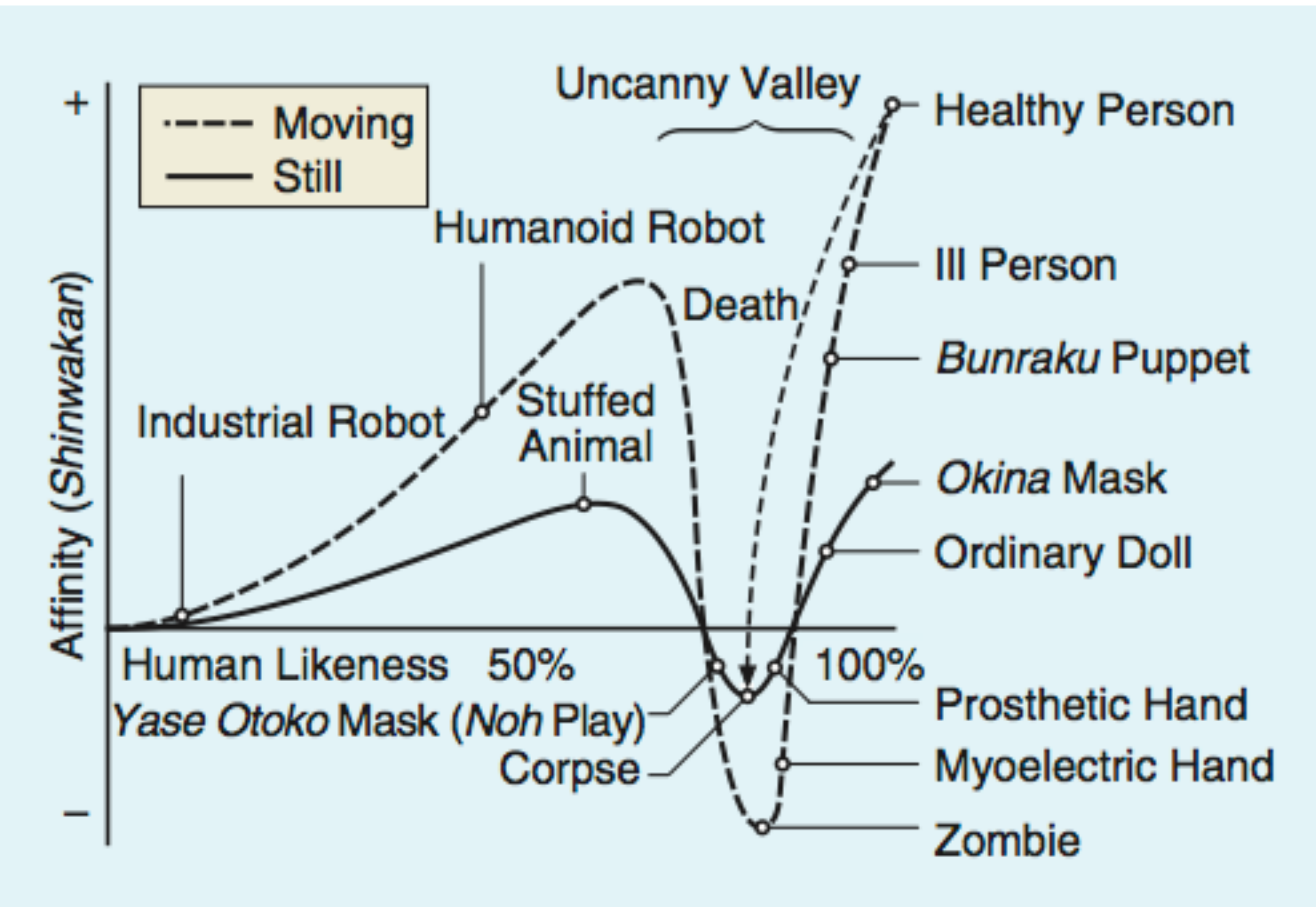


Figure 2. The presence of movement steepens the slopes of the uncanny valley. The arrow's path in the figure represents the sudden death of a healthy person. [Translators' note: *Noh* is a traditional Japanese form of musical theater dating from the 14th century in which actors commonly wear masks. The *yase otoko* mask bears the face of an emaciated man and represents a ghost from hell. The *okina* mask represents an old man.]

Some readers may know that recent technology has enabled prosthetic hands to extend and contract their fingers automatically. The best commercially available model, shown in Figure 3, was developed in Vienna. To explain how it works, even if a person's forearm is missing, the intention to move the fingers produces a faint current in the arm muscles, which can be detected by an electromyogram. When the prosthetic hand detects the current by means of electrodes on the skin's surface, it amplifies the signal to activate a small motor that moves its fingers. Because this myoelectric hand makes movements, it could make healthy people feel uneasy. If someone wearing the hand in a dark place shook a woman's hand with it, the woman would assuredly shriek!

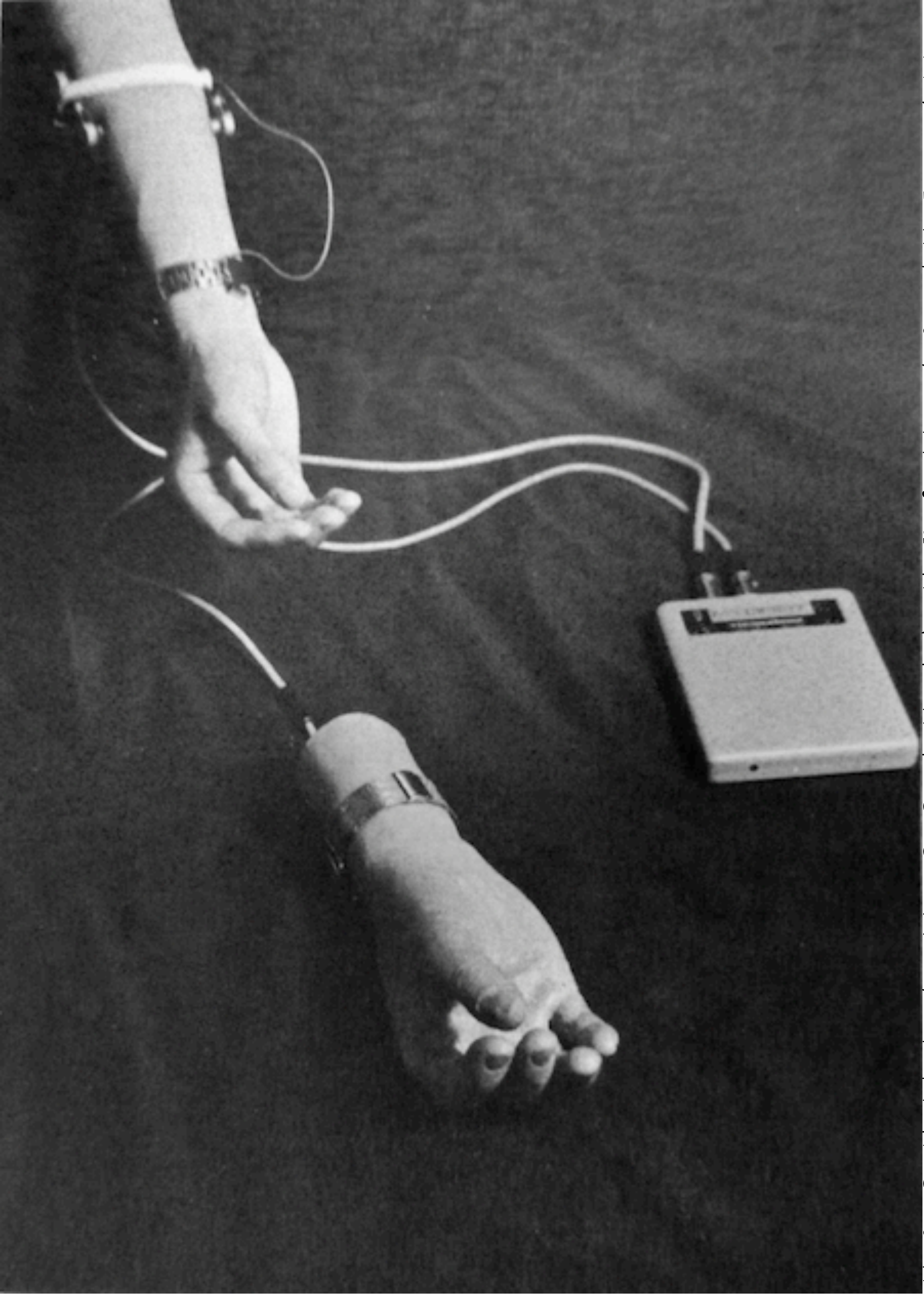

Figure 3. A human arm (top left) controls a realistic myoelectric hand, called the Vienna Hand.

Since negative effects of movement are apparent even with a prosthetic hand, a whole robot would magnify the creepiness. And that is just one robot. Imagine a craftsman being awakened suddenly in the dead of night. He searches downstairs for something among a crowd of mannequins in his workshop. If the mannequins started to move, it would be like a horror story.

Movement-related effects could be observed at the 1970 World Exposition in Osaka, Japan. Plans for the event had prompted the construction of robots with some highly sophisticated designs. For example, one robot had 29 pairs of artificial muscles in the face (the same number as a human being) to make it smile in a humanlike fashion. According to the designer, a smile is a dynamic sequence of facial deformations, and the speed of the deformations is crucial. When the speed is cut in half in an attempt to make the robot bring up a smile more slowly, instead of looking happy, its expression turns creepy. This shows how, because of a variation in movement, something that has come to appear very close to human—like a robot, puppet, or prosthetic hand—could easily tumble down into the uncanny valley.

**Escape by Design**

We hope to design and build robots and prosthetic hands that will not fall into the uncanny valley. Thus, because of the risk inherent in trying to increase their degree of human likeness to scale the second peak, I recommend that designers instead take the first peak as their goal, which results in a moderate degree of human likeness and a considerable sense of affinity. In fact, I predict it is possible to create a safe level of affinity by deliberately pursuing a nonhuman design. I ask designers to ponder this. To illustrate the principle, consider eyeglasses. Eyeglasses do not resemble real eyeballs, but one could say that their design has created a charming pair of new eyes. So we should follow the same principle in designing prosthetic hands. In doing so, instead of pitiful looking realistic hands, stylish ones would likely become fashionable.

As another example, consider this model of a human hand created by a woodcarver who sculpts statues of Buddhas (Figure 4). The fingers bend freely at the joints. The hand lacks fingerprints, and it retains the natural color of the wood, but its roundness and beautiful curves do not elicit any eerie sensation. Perhaps this wooden hand could also serve as a reference for design.

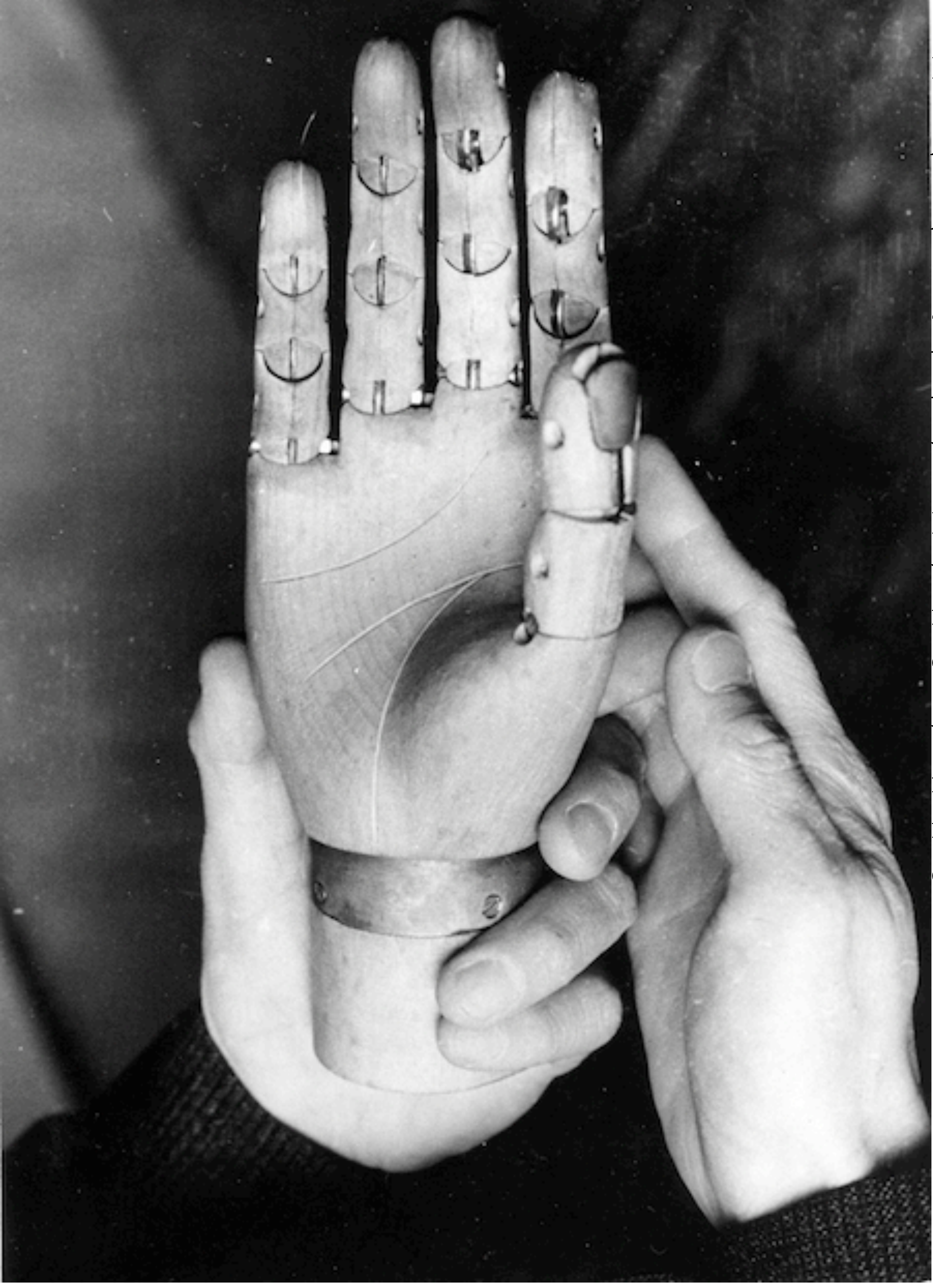

Figure 4. A model of a hand created by a woodcarver of Buddha statues.

**An Explanation of the Uncanny**

As healthy persons, we are represented at the crest of the second peak in Figure 2 (moving). Then when we die, we are, of course, unable to move; the body goes cold, and the face becomes pale. Therefore, our death can be regarded as a movement from the second peak (moving) to the bottom of the uncanny valley (still), as indicated by the arrow's path in Figure 2. We might be glad this arrow leads down into the still valley of the corpse and not the valley animated by the living dead!

I think this descent explains the secret lying deep beneath the uncanny valley. Why were we equipped with this eerie sensation? Is it essential for human beings? I have not yet considered these questions deeply, but I have no doubt it is an integral part of our instinct for self-preservation.[3]

We should begin to build an accurate map of the uncanny valley, so that through robotics research we can come to understand what makes us human. This map is also necessary to enable us to create—using nonhuman designs—devices to which people can relate comfortably.

[1] However, industrial robots are considerably closer in appearance to humans than machinery in general, especially in their arms. [back to text↑]

[2] Others believe that the true appeal of robots is their potential to exceed and augment humans. [back to text↑]

[3] The sense of eeriness is probably a form of instinct that protects us from proximal, rather than distal, sources of danger. Proximal sources of danger are corpses, members of different species, and other entities we can closely approach. Distal sources of danger include windstorms and floods. [back to text↑]

*Images used with permission from M. Mori, "The Uncanny Valley,"* Energy*, vol. 7, no. 4, pp. 33–35, 1970 (in Japanese).*

**About the translators:**

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