Whole-body expansion and contraction make a robot seem more alive

Summary Text

Researchers in Japan developed MOFU (MOrphing Fluffy Unit), a mobile robot capable of whole-body expansion and contraction, and investigated how these volume-changing movements affect perceived animacy, or how lifelike the robot appears. In online video experiments, both expansion-contraction and rotational motion increased animacy ratings. Presenting two expanding and contracting robots instead of one did not produce a clear difference, while adding rotational and expansion-contraction motions to locomotion resulted in higher animacy ratings than locomotion alone. The findings suggest that whole-body volume change may serve as a design element for shaping the impressions conveyed by robot movement.

Full Text

A research group comprising Associate Professor Yoshihiro Nakata and Taisei Mogi from the Graduate School of Informatics and Engineering at The University of Electro-Communications (UEC), Japan, and Mari Saito of Sony Corporation has developed MOFU (MOrphing Fluffy Unit), a mobile robot capable of whole-body expansion and contraction. The group investigated how whole-body expansion-contraction affects perceived animacy, or the extent to which the robot is perceived as lifelike. In addition to expansion-contraction and locomotion, MOFU was designed with features including quiet operation and a soft, fluffy exterior. The study was published in PLOS ONE.

Robots are increasingly being developed for healthcare, welfare, and other settings in which they interact closely with people. In such contexts, design must consider not only what a robot can do but also how people perceive and relate to it. Perceived animacy is a basic aspect of human-robot interaction.

A robot's movements, as well as its appearance, can influence how lifelike it seems. Previous studies have examined various types of robot motion, including articulated movements involving joints and axial movements involving extension and contraction along the body axis. Living organisms, however, also show volumetric motion, in which the overall body volume changes through expansion and contraction. Such changes occur not only in physiological functions such as breathing but also in social displays, including courtship displays of peacocks and the throat pouch inflation of frigatebirds.

Devices that incorporate expansion-contraction movements have already been developed. Some mimic physiological rhythms such as breathing, while others use whole-body expansion and contraction for functional or behavioral purposes. However, the potential of whole-body volume-changing movements themselves to evoke animacy in humans has not been sufficiently explored. The research group therefore focused on whole-body expansion-contraction as a form of robotic expression and experimentally examined its effect on perceived animacy.

MOFU is a spherical mobile robot that uses a Jitterbug structure, a geometric transformation mechanism in which multiple faces move together to change the overall shape and size of the structure. A single motor-driven linear mechanism enables whole-body expansion and contraction, changing MOFU's vertical height from approximately 210 mm to 280 mm. A differential two-wheel drive enables straight locomotion and rotational motion.

The robot was also designed with quiet operation and appearance in mind. Direct-drive motors without gears and components with low sliding noise were used to reduce mechanical operating sounds. MOFU is covered with a soft, fluffy material and has an abstract spherical form rather than directly imitating a particular animal. An internal battery allows it to move without an external cable.

The Jitterbug structure naturally produces rotational motion around the vertical axis during expansion and contraction. To separate the effects of the two types of motion, the researchers used the wheel drive to cancel this rotation, creating an expansion-contraction-only motion. They also created a rotation-only motion using the wheels. In the evaluation videos, MOFU repeatedly alternated between expansion and contraction. Its rotational motion also alternated between left and right rather than continuing in one direction. Measurements with the physical robot confirmed that the designed expansion-contraction motion could be achieved as intended.

The researchers then conducted three online video experiments. Each participant watched only one 20-second video condition, following a between-subjects design, and participants were randomly assigned to conditions. After excluding incomplete or invalid responses, data from 498 participants, with a mean age of 51.69 years, were analyzed.

After watching the video, participants evaluated MOFU using the Japanese version of the Animacy subscale of the Godspeed Questionnaire Series, a widely used questionnaire for evaluating people's impressions of robots. The study used six Animacy items rated on a 5-point scale.

In Experiment 1, participants viewed one stationary MOFU under one of four conditions: no expansion-contraction or rotation; repeated rotation alternating between left and right without expansion-contraction; repeated expansion and contraction without rotation; or both repeated left-right rotation and repeated expansion-contraction. This experiment examined the individual effects of expansion-contraction and rotational motion on perceived animacy.

In Experiment 2, the researchers compared an expanding and contracting MOFU presented alone with two expanding and contracting MOFUs presented simultaneously. They also included the same four motion conditions as in Experiment 1 for the

two-robot presentation and treated comparisons among these four conditions as exploratory analyses. The two robots moved independently and did not coordinate or respond to each other.

In Experiment 3, participants viewed MOFU during locomotion. The researchers compared locomotion alone with locomotion combined with repeated rotation alternating between left and right and repeated alternating expansion and contraction.

In Experiment 1, both expansion-contraction and rotational motion increased perceived animacy ratings compared with conditions in which the corresponding motion was absent. In an additional comparison between the expansion-contraction-only and rotation-only conditions, no clear difference was found between the two.

In Experiment 2, no clear difference in perceived animacy was found between presenting one expanding and contracting MOFU and presenting two. In the exploratory comparison among the four two-robot motion conditions, the condition without either expansion-contraction or rotation received lower animacy ratings than each of the three conditions that included motion. No clear differences were found among the three motion conditions.

In Experiment 3, perceived animacy was rated higher when rotational and expansion-contraction motions were added to locomotion than when MOFU performed locomotion alone. However, the number of participants in Experiment 3 fell short of the planned sample size, so the finding should be re-examined with a sufficient number of participants. The experiment also did not separate the individual contributions of rotational and expansion-contraction motions to this difference.

Taken together, the results suggest that whole-body expansion-contraction, a movement involving changes in overall body volume, may be one form of robot movement that influences perceived animacy.

Future studies should directly compare expansion-contraction with other types of motion, such as joint-based movements or extension and contraction along the body axis. Varying the amplitude, speed, and period of expansion-contraction could also help clarify how different forms of volumetric change influence people's impressions.

Because the present study was conducted online using videos, tactile and auditory aspects of interacting with MOFU were not evaluated. Future in-person studies could assess these aspects and examine a broader range of impressions, including comfort, warmth, eeriness, and willingness to approach the robot, in addition to perceived animacy.

Such studies may provide useful guidance for using whole-body volume change to

convey impressions through robot movement. Incorporating volumetric change may also contribute to more intuitive and expressive human-robot interactions. This approach may have potential in healthcare and welfare settings, where space can be limited and quiet operation may be important.

Figure

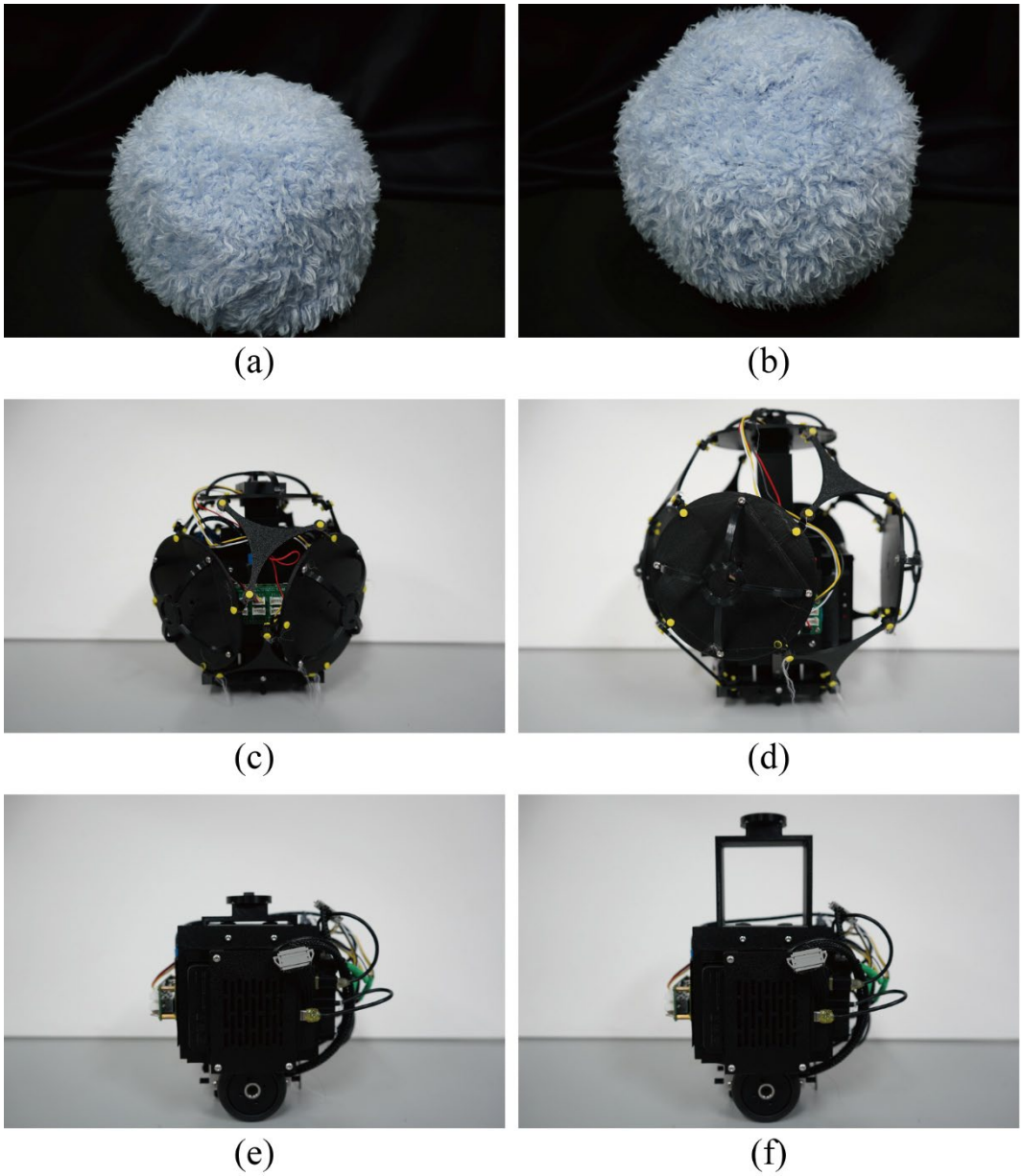

Figure 1. Appearance of MOFU: (a) with fluffy cover, contracted; (b) with fluffy cover, expanded; (c) without cover, contracted; (d) without cover, expanded; (e) without the Jitterbug structure, contracted; (f) without the Jitterbug structure, expanded.

Video 1. Overview video of MOFU
https://youtu.be/gTomSkyVIbM

Video 2. Videos used in the online experiments
https://doi.org/10.6084/m9.figshare.30437177

Title of paper

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