Impressions of Size-Changing in a Companion Robot

Martin Cooney and Stefan M. Karlsson
Intelligent Systems Lab, Halmstad University, Box 823, 301 18 Halmstad, Sweden

Keywords: Adaptive Interfaces, Physiology-driven Robotics, Human-Robot Interaction, Size-Changing.

Abstract: Physiological data such as head movements can be used to intuitively control a companion robot to perform useful tasks. We believe that some tasks such as reaching for high objects or getting out of a person's way could be accomplished via size changes, but such motions should not seem threatening or bothersome. To gain insight into how size changes are perceived, the Think Aloud Method was used to gather typical impressions of a new robotic prototype which can expand in height or width based on a user's head movements. The results indicate promise for such systems, also highlighting some potential pitfalls.

1 INTRODUCTION

The current paper reports on the first phase of our work in designing a novel physiological computing system involving a companion robot which can adapt its size. Size-changing functionality in a robot will allow useful behaviour such as stretching to reach for objects or attract attention, as well as shrinking to be carried, get out of the way in urgent situations, or operate in narrow spaces. This concept is shown in Figure 1.

One challenge is that size strongly influences our impressions: we can feel reverence toward high mountains, trepidation toward a large predator, affection toward a small infant, and disregard for a mote of dust. When a robot changes size based on a user's commands, it should be perceived as fun and helpful and not as dangerous or bothersome.

Thus the goal of the current study was to obtain knowledge of how a robot's size-changing will be perceived by people. The investigated scenario involved a humanoid prototype as a familiar interface—simplified to avoid eliciting unreal expectations—and basic size changes in height and width, which could be perceived differently. To eavesdrop on user impressions, the Think Aloud Method (Lewis and Rieman, 1993) was used. The acquired knowledge—a list of size changes and typical associated impressions—will be extended in the next step of our work, in which we will focus on specific size-changing tasks, thereby informing a next generation of size-adaptive robot systems.

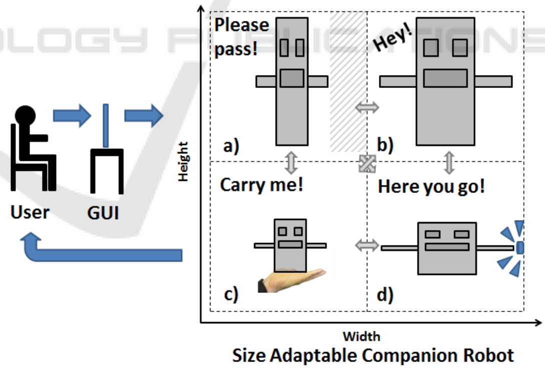

Figure 1: The basic concept for our system: a user's physiological signals are transformed via a Graphic User Interface (GUI) into commands for a robot to change size—e.g., becoming (a) thin to let someone pass, (b) large to attract attention, (c) small to be more easily held, or (d) wide in order to access a far object—which should be perceived by the user as pleasant and unthreatening.

2 RELATED WORK

This work touches on three areas—physiology-driven robotic interfaces, size-changing artifacts and perception of size-changing cues.

2.1 Physiological Interfaces

Fairclough et al. described various forms of physiological computing—mouse and keyboard, body tracking, muscle or gaze, and Brain Computer Interfaces (BCI) (2011)—which have also been used

Cooney M. and M. Karlsson S..
Impressions of Size-Changing in a Companion Robot.
DOI: 10.5220/0005328801180123
In *Proceedings of the 2nd International Conference on Physiological Computing Systems* (PhyCS-2015), pages 118-123
ISBN: 978-989-758-085-7

to control robotic devices. For example, a BCI interface was used to control a wheelchair and devices in an intelligent environment (Kanemura et al., 2013). Fiber optic sensors detecting finger motions were used to control two extra fingers (Wu and Asada, 2014). And, a head tracker was used to control the humanoid robot PR2 to allow a tetraplegic person to scratch himself and wipe his face (Cousins and Evans, 2014). We selected the latter kind of approach, which is easy to use and inclusive as arms are not required.

For head pose estimation, promising work is being conducted using active appearance models (AAM) (Cootes et al., 1992), but challenges with lighting and lack of temporal consistency can lead to jitter in estimates. An approach intended for controlling a cursor, “eViacam”, estimates overall head position in video using the Viola Jones detector (eviacam.sourceforge.net). The approach we propose is faster and smoother, utilizing less computational resources and optical flow to track a face in between detected frames.

2.2 Size-Changing Artifacts

The need for adaptive companion robots has been voiced (Dautenhahn, 2004). Already, simple size changes such as becoming longer or taller can be enacted by some factory and tele-operated robots; more complex changes can also be achieved using multiple modules (Alonso-Mora et al., 2012; Revzen et al., 2011), objects (Brodbeck and Iida, 2012), and approaches such as “jamming” (Steltz et al., 2009) or programmable matter/4d printing (An et al., 2014). Outside of robotics, size-changing mechanisms involving (1) elastic/absorbent materials, (2) telescopic cylinders, (3) scissor linkages, (4) folding, and (5) rack and pinions, have been used to build artifacts such as (1) balloons; (2) construction vehicles; (3) furniture, elevators, architectural displays and toys (e.g., Hoberman’s combinable Expandagon blocks); (4) maps, satellites (Miura, 1985) and medicinal devices (You and Kuribayashi, 2003); as well as (5) locomotive devices. Unknown was how to build a robot which can expand in height or width.

2.3 Perception of Size Changes

Some pioneering studies showed that tall robots can appear more conscientious and human-like and less neurotic (Walters et al., 2009), and more dominant (Rae and Mutlu, 2013) than short robots. Also, in comparing simulations of shape changes in a cell phone, growing larger evoked a strongest emotional response in terms of both pleasure and arousal, as well as a highest sense of animacy, and seemed highly desirable (Pedersen et al., 2014). These results suggested the usefulness of investigating how size changes are perceived in a robot.

Human and animal cues offered some additional insight. Height-wise expansion can seem dominant with an erect posture (Carney et al., 2005), draw attention as in hand-raising, or indicate curiosity if conducted to see over an obstacle. Height-wise contraction expressed through a downcast face can indicate shame or dejection (Darwin, 1872), or focused tension, like a crouched runner ready to spring forward. Width-wise expansion can indicate dominance when an expansive open posture with extended limbs is adopted (Carney et al., 2005), or happiness from a full belly, through satisfying an important need (Maslow, 1943). Width-wise contraction can indicate tension via a closed posture (Burgoon, 1991), or suffering through a metaphor of malnourishment or dehydration. Becoming small can express fear as cowering (Darwin, 1872), and possibly cuteness because small size is a characteristic of children (Lorenz, 1971). Thus, many predictions could be made, which required investigation to determine if they would apply to the case of a robot.

Thus, the contribution of the current work is acquiring some first knowledge of how people perceive a robot’s size changes using a new humanoid prototype capable of itself expanding and contracting in both or either height and width.

3 SUICA: A SIZE-CHANGING HUMANOID PROTOTYPE

Design of our new prototype, Suica, involved (1) a proof-of-concept physiological computing interface and (2) an embodiment with a cover and size-changing mechanism.

3.1 Control Interface

Our requirements for an interface included that it would be robust, simple, fast, and provide a natural mode of interaction without the use of arms. Also we restricted ourselves to the scenario of a single user controlling one robot with a computer.

The designed interface uses a standard low-end web camera to acquire video data at 30 frames per second. An elliptic region containing a frontal face was detected at 1Hz (one frame per every 30 processed) using the Viola-Jones detection algorithm provided with Matlab/Computer Vision Toolbox (www.mathworks.se). Optical flow was calculated similar to the Lucas-Kanade approach (Lucas and Kanade, 1981), yielding a dense flow by regularization (Karlsson and Bigun, 2012). Optical flow was used for two purposes. First, to implement a smooth tracking of the face region in frames for which the Viola Jones algorithm was not invoked. Second, optical flow with support from inside the tracked face region was used to control the computer's mouse cursor. To achieve smooth, natural motions of the cursor, a concept of momentum was also implemented in which optical flow affects a particle of small mass (the cursor) with a force in a surrounding of high friction.

The system was implemented entirely in Matlab, and worked well on a resolution as low as 200 by 200 pixels. At that resolution, the application took up roughly 14% of the CPU load, without skipping any frames, whereas the well-written C-implementation of "eViacam" took up roughly 25% (as measured on a Lenovo ThinkPad X1 Carbon laptop, with an Intel Core i5 microprocessor, 1.80 GHz, and 4GB RAM).

Also VoxCommando (voxcommando.com) was used to quickly associate a speech command with a mouse click event. Using this system and a GUI we built, a user can turn their head in any direction (e.g., left, right, up, or down) and say "right click" to issue commands for a robot to change size.

3.2 Embodiment

When changing size, a robot should be covered to protect nearby persons from potential injury. Our requirements for a cover were: robustness, ease of changing and retaining sizes (low energy and "multistability"), light weight, and compactness. (Water-proofing was not felt to be a priority for the current study.) Also we focused on the scenario of a (1) flat, (2) rectangular area which can be scaled (3) along its principal axes. (1) Curvature was not considered for simplicity. Also, because we wished to consider the simplest case of a plane for our initial investigation, we did not require our prototype to stand but decided it could be laid on the floor in front of a user. (2) Although triangles are also important because they can be used to build all other shapes, a rectangle was chosen due to relevance in engineering for modeling objects (box modeling), as well as in psychology because many fabricated objects are rectangular, and a single rectangle better approximates the frontal humanoid form in two dimensions. (3) Shear transformations were not considered because shape is not preserved.

To create a cover, a simple solution involving an elastic material such as latex could have problems such as tearing, deterioration, force required to maintain an expanded state, slack in the contracted state, and allergies in some interacting persons. Therefore, we instead designed and implemented a folding pattern as shown in Figure 2, composed of squares connected by V-shaped strips (contracted: 27.5cm, expanded: 77.5cm). This plane can be made arbitrarily flat and holes too small for a person's fingers to pass through by reducing the length of the sides of the squares and connecting strips, or covering with a top layer.

In addition to a cover, a size-changing frame was constructed using four rack and pinion style linear actuators, as can be seen in Figure 3. Bluetooth and a camera were included to issue motor commands and capture video. Typical features of a humanoid companion robot such as simplified face with a neutral expression and moving hands were also added to provide a feeling of human-likeness and familiarity. Although Suica is only a prototype with various limitations, unlike previous artifacts it can expand and contract in height, width, or both, while presenting a safe, complete appearance.

4 IMPRESSIONS OF A SIZE-CHANGING ROBOT

To gain insight into how changes in height and width are perceived in a robot, a study was conducted with Suica using the Think Aloud Method (Lewis and Rieman, 1993). This method was useful because we did not know how people would perceive size changes.

4.1 Participants

Eight participants (age: M = 33.5 years, SD = 9.6, 2 female, 6 male) working at a university lab in Sweden participated for approximately 30 minutes each and were not remunerated.

4.2 Procedure

Each participant sat in front of Suica in a small room and the door was closed, leaving them alone with the experimenter, as in Figure 4. A simple handout introduced our robot and stated that they could freely speak any thoughts that came to mind. When ready, participants imagined interacting and watched the prototype change size, describing aloud what they saw. Suica was controlled by the experimenter to reduce participants' workload and ensure the same stimuli were witnessed by all. Afterwards, short interviews were conducted and transcribed protocols coded by the experimenter.

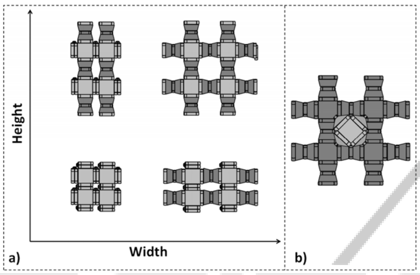

Figure 2: Size-changing cover: (a) a main layer which enables changes in height and width, and (b) an optional top layer (shown lightly shaded over the dark main layer).

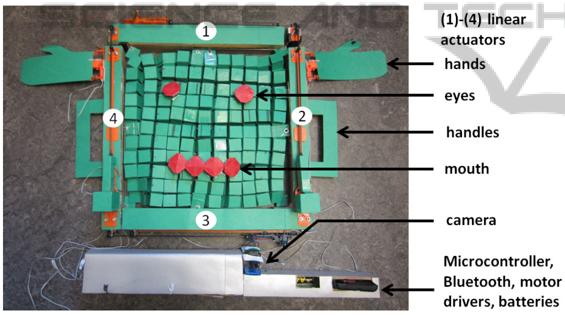

Figure 3: Actual photo of our humanoid prototype, Suica, indicating component locations.

4.3 Conditions

Seven size changes were shown in random order:

S1 Tall: the robot became tall from a small state (a transition from state "c" to "a" in Figure 4)

S2 Short: the robot became small from a tall state (Figure 4 "a" to "c")

S3 Wide: the robot became wide from a small state (Figure 4 "c" to "d")

S4 Thin: the robot became small from a wide state (Figure 4 "d" to "c")

S5 Large: the robot became tall and wide from a small state (Figure 4 "c" to "b")

S6 Small: the robot became short and thin from a large state (Figure 4 "b" to "c")

S7 Repeated: the robot expanded and contracted three times (Figure 4 "c" to "b").

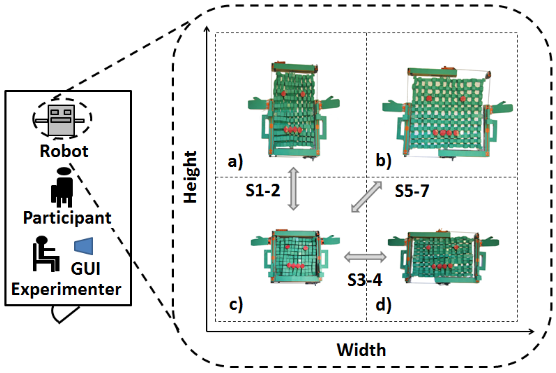

Figure 4: Experiment layout and depiction of the seven size changes which participants observed (S1-7) using actual photos of our prototype, Suica, changing between four states: (a) tall, (b) large, (c) small, and (d) wide.

4.4 Predictions

We had some expectations of how size changes would be perceived based on the literature in Section 2.3 and our own ideas (the term "intimidating" was used in place of "dominant" to try to avoid specialized words which participants might not use).

P1 Tall: Height-wise expansions would appear intimidating, show a desire for attention, or indicate curiosity.

P2 Short: Height-wise contractions would indicate shame or focused tension.

P3 Wide: Width-wise expansions would appear intimidating or show contentment.

P4 Thin: Width-wise contractions would show tension or suffering.

P5 Large: Becoming large in both height and width would appear intimidating.

P6 Small: Becoming small in both height and width would appear cute or indicate fear.

P7 Repeated: Repeated changes would be perceived as playful.

4.5 Results

Typical impressions common to more than one participant, shown in Table 1, were analyzed in regard to (1) positivity, (2) consistency, (3) and agreement with our predictions. (1) A Chi-squared test did not reveal a difference in the prevalence of positive, neutral, and negative impressions: $\chi^2(2, N = 54) = 0.8$, $p = .7$, indicating promise for communicating various cues. (2) Some consistency was also observed: expansions were reported as showing incredulousness similar to eyebrows rising or eyes opening wide, and contractions were

Table 1: Typical impressions of size changes (bold font and italics show predicted and related impressions; solid and dotted lines show positive and negative impressions).

Size Change (Prediction)	Impressions (No. of participants)
S1 Tall (P1)	incredulous (3), *angry (2)*
S2 Short (P2)	**sad (3)**, *fearful (2)*, *attentive (2)*, angry (2), responding (2)
S3 Wide (P3)	smiling (3), **happy (2)**, incredulous (2)
S4 Thin (P4)	*attentive (3)*, *fearful (2)*, attractive (2)
S5 Large (P5)	**intimidating (4)**, unnatural (2)
S6 Small (P6)	**cute (4)**, **fearful (2)**, *attentive (2)*, face more visible (2)
S7 Repeated (P7)	*ebullient (3)*, wanting to show something (3), disagreeing (2)

perceived as cute, fearful, or attentive. (3) Predictions were partially supported in only 4/7 cases, with only 28% and 57% of impressions directly predicted or related to predictions. The reason is the high complexity of human signalling (many related cues exist with similar expression), and interpretation required to associate robot size changes with biological motions. We feel that the number of unanticipated impressions confirmed that it had been useful to attempt to gain insight into the kinds of impressions which result from observing size changes.

Some impressions were not directly predicted but related to our predictions. For P1, the robot was described as angry rather than intimidating, which could have been because anger displays intimidate (Clark, Pataki and Carver, 1996). For S2 and S4, impressions of fearfulness related to P6, for becoming smaller. For P2, P4 and P6, although one participant was reminded of the focused tension of a player in a Judo match, attentiveness was attributed in place of tension; these two constructs have been grouped as "activation" (Tonn, 1984). For P4, fear was perceived in place of suffering, which relate as fear exerts unpleasant physical effects. For P7 repeated changes were described not as playful but as happy and excited, like jumping for joy or a dog wagging its tail; these concepts relate, as "cheerful" and "joyous" have been listed as synonyms for playfulness (www.thesaurus.com/browse/playful).

Some results were unanticipated. For P1, only one participant reported feeling that Suica desired attention by becoming taller because we had asked participants to watch the robot, and curiosity was not perceived as there was no obstacle to see over. For P2, impressions of shame were not reported, possibly because shame is conveyed by gaze directed toward the ground (whereas Suica's eyes always looked forward). For P3, the widening robot seemed to be smiling, laughing, finding humor in something, and otherwise happy; however this was due to a Cheshire Cat-like widening of the robot's mouth and not to the robot seeming like it had a full belly as we had predicted.

5 DISCUSSION AND CONCLUSIONS

Results of the current study were encouraging. The main contribution of the study was to identify a rich range of positive and negative impressions which people associate with size changes in a robot. Positive impressions included that our robot appeared cute and attentive when contracting, and happy when widening or repeatedly expanding and contracting. Negative impressions included that the robot seemed intimidating when expanding, angry when thin, and fearful when contracting. This suggests that to present a fun impression when being controlled, a robot could seek to show mostly positive signals, and accompany negative signals with positive ones: e.g., a robot could smile while expanding to accomplish a task then contract again. Additionally, we built a physiological computing interface based on head motion which could be used by elderly or disabled persons and requires less computational resources than previous work. We also reported on the construction of a new prototype companion robot, Suica, which can expand in height or width (a video is available online, e.g., at the first author's homepage: martin-cooney.com).

These results are limited by the prototype used and exploratory data acquisition design, including the participants (a small number of researchers at a university in Sweden). Our next step will be to conduct a more solid experiment with a robot capable of performing practical tasks such as reaching for objects and getting out of the way. This will indicate if perceptions differ based on a robot's task: e.g., will becoming large intimidate even if it is known that a robot is reaching for a high object? Physiological measurements such as skin conductance and saliva hormone tests will provide objective evidence of unpleasant impressions. We also aim to design a new GUI in which a user can control online the area and symmetry of a robot by bringing their face closer or further away, and tilting their head. Furthermore, impressions will be investigated of changes in speed and depth (e.g., swiftness could indicate arousal and a thick or paper-thin embodiment could indicate solid resolve or indecision), as well as shear and local size changes (e.g., skew could indicate discord, a large head could seem intelligent or cute, and large eyes or ears could express interest). Sensors and mechanisms to improve symmetry, prevent some drooping due to gravity and compensate for friction will improve accurate transmission of cues.

ACKNOWLEDGEMENTS

We'd like to thank all those who helped! We received funding from the Center for Applied Intelligent Systems Research (CAISR) program, Swedish Knowledge Foundation.

REFERENCES

Alonso-Mora, J., et al., 2012. Object and Animation Display with Multiple Aerial Vehicles. In *Proc. IROS*, 1078-1083. DOI: 10.1109/IROS.2012.6385551.

An, B., et al., 2014. An End-to-End Approach to Making Self-Folded 3D Surface Shapes by Uniform Heating. In *Proc. ICRA*, 1466-1473. DOI: 10.1109/ICRA.2014.6907045.

Brodbeck, L., Iida, F., 2012. Enhanced Robotic Body Extension with Modular Units. In *Proc. IROS*, 1428-1433. DOI: 10.1109/IROS.2012.6385516.

Burgoon, J. K., 1991. Relational Message Interpretations of Touch, Conversational Distance, and Posture. *Journal of Nonverbal Behavior* 15 (4), 233-259. DOI: 10.1007/BF00986924.

Carney, D.R., Hall, J.A., Smith LeBeau, L., 2005. Beliefs about the nonverbal expression of social power. *Journal of Nonverbal Behavior* 29 (2), 105–123. DOI: 10.1007/s10919-005-2743-z.

Clark, M. S., Pataki, S. P., Carver, V. H., 1996. Some thoughts and findings on self-presentation of emotions in relationships. *Knowledge structures in close relationships: A social psychological approach*, 247-274.

Cootes, T. F., Taylor, C. J., Cooper, D. H., Graham, J., 1992. Training models of shape from sets of examples. In *Proceedings of BMVC'92*, 266-275.

Cousins, S., Evans, H., 2014. ROS Expands the World for Quadriplegics. *IEEE Robotics & Automation Magazine* 21 (2), 14-17.

Darwin, C. R., 1872. *The expression of the emotions in man and animals*. London: John Murray. 1st edition. Retrieved Nov. 4, 2014 from http://darwin-online.org.uk/content/frameset?itemID=F1142&viewtype=text&pageseq=1.

Dautenhahn, K., 2004. Robots We Like to Live With? – A Developmental Perspective on a Personalized, Life-Long Robot Companion. In *Proc. RO-MAN*, 17-22. DOI: 10.1109/ROMAN.2004.1374720.

Fairclough, S., Gilleade, K., Nacke, L.E., Mandryk, R.L., 2011. Brain and Body Interfaces: Designing for Meaningful Interaction. In *Proceedings of CHI EA*, 65-68. DOI: 10.1145/1979742.1979591.

Kanemura, A., et al., 2013. A Waypoint-Based Framework in Brain-Controlled Smart Home Environments: Brain Interfaces, Domotics, and Robotics Integration. In *Proc. IROS*, 865-870. DOI: 10.1109/IROS.2013.6696452.

Karlsson, S. M., Bigun, J., 2012. Lip-motion events analysis and lip segmentation using optical flow. In *Proc. CVPRW 2012*, 138-145. DOI: 10.1109/CVPRW.2012.6239228.

Lewis, C., Rieman, J., 1993. Task-Centered User Interface Design: A Practical Introduction. Technical Document.

Lorenz, K. 1971. *Studies in Animal and Human Behavior.* Harvard Univ. Press, Cambridge, MA.

Lucas, B. D., Kanade, T., 1981. An Iterative Image Registration Technique with an Application to Stereo Vision. In *Proc. IJCAI '81*, 674-679.

Maslow, A. H., 1943. A theory of human motivation. *Psychological Review* 50 (4), 370–96. DOI: 10.1037/h0054346.

Miura, K., 1985. Method of Packaging and Deployment of Large Membranes in Space. *Inst. of Space and Astronaut. Science report* 618, 1-9.

Pedersen, E. W., Subramanian, S., Hornbæk, K., 2014. Is my phone alive?: a large-scale study of shape change in handheld devices using videos. In *Proc. CHI*, 2579-2588. DOI: 10.1145/2556288.2557018.

Rae, I., Takayama, L. Mutlu, B, 2013. The influence of height in robot-mediated communication. In *Proc. HRI*, 1-8. DOI: 10.1109/HRI.2013.6483495.

Revzen, S., Bhoite, M., Macasieb, A., Yim, M., 2011. Structure synthesis on-the-fly in a modular robot. In *Proc. IROS*, 4797-4802. DOI: 10.1109/IROS.2011.6094575.

Steltz, E., et al., 2009. JSEL: Jamming Skin Enabled Locomotion. In *Proc. IROS*, 5672-5677. DOI: 10.1109/IROS.2009.5354790.

Tonn, B. E., 1984. A sociopsychological contribution to the theory of individual time-allocation. *Environment and Planning A* 16 (2), 201-223.

Walters, M. L., Koay, K. L., Syrdal, D. S., Dautenhahn, K., Boekhorst, R., 2009. Preferences and Perceptions of Robot Appearance and Embodiment in Human-Robot Interaction Trials. In *Proc. New Frontiers in Human-Robot Interaction: Symposium at AISB09*, 136-143.

Wu, F. Y., Asada, H. H., 2014. Bio-artificial synergies for grasp posture control of supernumerary robotic fingers. In *Proc. Robotics: Science and Systems*.

You, Z., Kuribayashi, K., 2003. A Novel Origami Stent. In *Proc. Summer Bioengineer Conf.*