Informing Future Gesture Elicitation Studies for Interactive Applications that Use Radar Sensing

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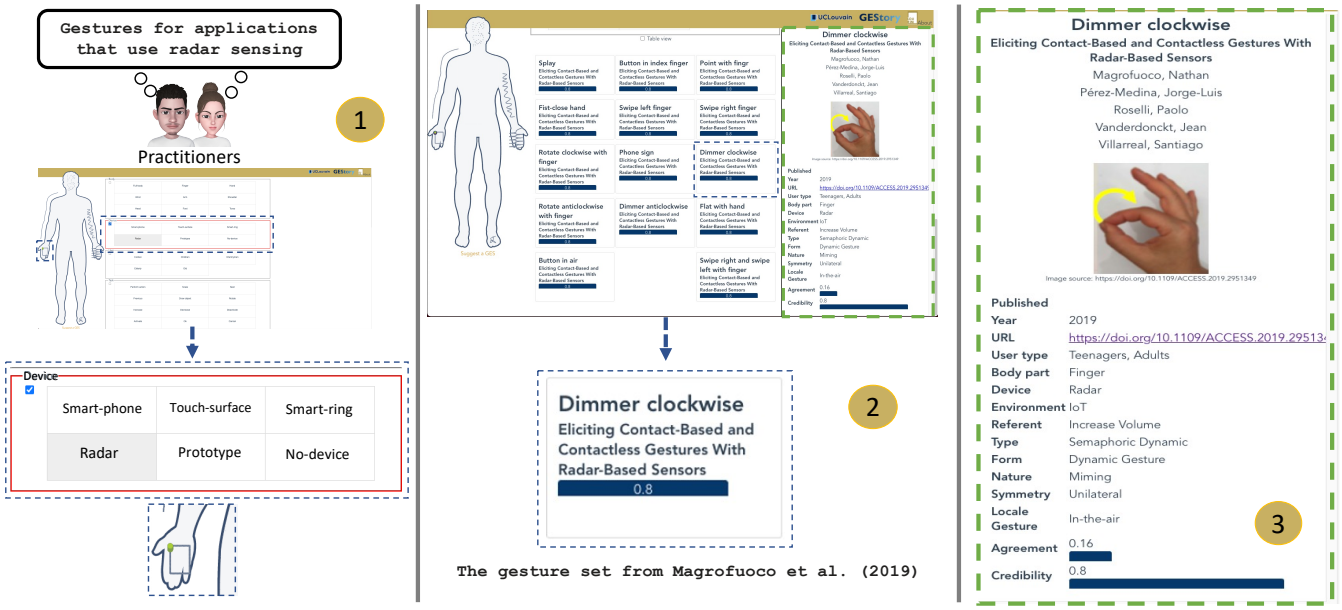


Figure 1: A query conducted in GEStory to identify gestures for applications that use radar sensing.

ABSTRACT

We show how two recently introduced visual tools, RepliGES and GEStory, can be used conjointly to inform possible replications of Gesture Elicitation Studies (GES) with a case study centered on gestures that can be sensed with radars. Starting from a GES identified in GEStory, we employ the dimensions of the RepliGES space to enumerate eight possible ways to replicate that study towards gaining new insights into end user's preferences for gesture-based interaction for applications that use radar sensors.

CCS CONCEPTS

• **Human-centered computing** → **Gestural input**; *User interface design*; *Participatory design.*

KEYWORDS

Gesture elicitation studies, reproducibility, radars

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1 INTRODUCTION

Gesture elicitation studies (GES) [13, 14] represent a fruitful method to uncover end users' preferences for interactive gesture commands, and have been applied for a variety of gesture types, devices, and applications [11]. While some application domains have been studied more closely, others are still to be examined. Among the latter, we note the paucity of GES involving gestures sensed with radars, despite the many applications of such sensors [6, 11] and the recent interest for their use for new applications in HCI [16]. In this paper, we show how RepliGES and GEStory [4], two recently introduced visual tools for GES, can be used conjointly to inform new designs of GES about radar gestures.

2 RADAR GESTURES

Radars are convenient for gesture sensing since they work effectively in a variety of conditions, including low light, darkness, adverse weather, and occlusion [2, 7, 16]. Figure 2 shows two examples of mid-air gestures that can be sensed with a radar. Prior work has introduced and evaluated various gesture recognition techniques for interactions enabled by radars, mostly based on deep learning approaches. For example, Soli [5] is a millimeter-wave radar sensor with sub-millimetre gesture tracking accuracy; RadarCat [15] is a radar-based system that recognizes materials and objects; Wang et al. [12] used high-frequency short-range radars for recognizing fine finger gestures using an end-to-end trained combination of Convolutional and Recurrent Neural Networks; and Sluÿters et al. [8] introduced a processing pipeline for hand gesture recognition that combined full-wave electromagnetic modelling and inversion with pattern matching. We refer to Ahmed et al. [1] for a review of hand gesture recognition with radars in HCI.

3 USING GESTORY AND REPLIGES

In a first stage, we used GEStory [4] to identify end-user gesture elicitation studies conducted to understand users' preferences for gesture commands and corresponding mental models of gesture-based interaction for applications involving radar sensing. We performed a query in the electronic database of GEStory (a total number of 216 records) using the "Device" filter option (Figure 1-1), which resulted in just one study [6] consisting of fourteen gesture types (Figure 1-2). Magrofuoco et al. [6] conducted their GES for radar gestures in the context of controlling IoT devices that involved 25 participants and a confirmatory study with 20 participants. The authors analyzed micro-gestures performed with the hands and fingers, and compiled a consensus set of 19 gestures[1] using the agreement rate measure [10]. Figure 1-3 displays information about one of the gestures from that study.

In a second stage, we used RepliGES [4] to identify possible types of replication, extension, and continuation of Magrofuoco et al.'s [6] GES about radar gestures, as follows:

(1) *Repeatability.* The objective is to reanalyze the data using the same method to confirm the results from [6].
(2) *Reproducibility.* The collected data is analyzed with a new method, such as the dissimilarity-consensus technique [9].

[1] GEStory lists 14 gestures for the study of Magrofuoco et al. [6] instead of 19, because one of the gestures was assigned to multiple referents.

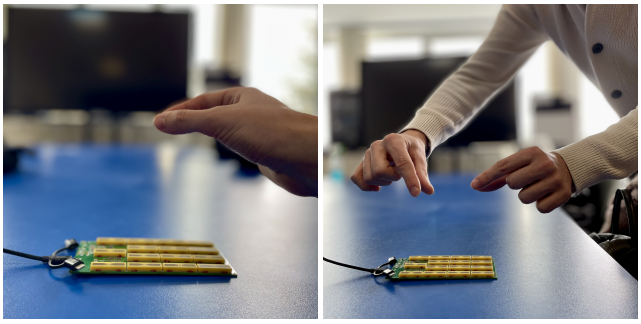


Figure 2: Examples of two gestures, a single-handed and a bimanual pinch performed in mid-air, that can be sensed with a radar. In these photographs, the Walabot radar is visibly shown for exemplification purposes, but the radar could be hidden away, e.g., placed under the table.

(3) *Replicability.* Using the same participants to collect new data is difficult, if not impossible. However, a confirmatory study, such as that from [6], can be conducted more easily.
(4) *Extensibility.* A new method for gesture elicitation and/or analysis is used with new participants. For example, the Walabot radar (Figure 2) is presented to the participants, but the elicitation implements a Wizard of Oz study [3].
(5) *Generalizability.* The same methodology of the original GES is applied to elicit and analyze gestures suggested by a different category of end users than employed in the original study [6], such as old people, children, people with motor impairments, etc., to understand whether the results, e.g., the consensus gesture set, are consistent between user groups.
(6) *Extensibility and generalizability.* This replication may combine the Wizard of Oz study (see variant no. 4) and a new category of end users (variant no. 5).
(7) *Repurposability (same population).* The gestures elicited in the original study are repurposed to serve as a dataset for evaluating the accuracy rate of gesture recognizers.
(8) *Repurposability (new population).* The gestures elicited in the original study are used for insights to inform the design of new GES addressing the needs a new population, e.g., different users that might articulate the same gestures differently and for which a new sensor or a better performing sensor (e.g., a radar with a higher resolution) might be needed.

4 CONCLUSION

We showed in this paper how GEStory and RepliGES [4] can be used conjointly to arrive at various possibles replications of a GES [6] for applications that use radar sensing. Future work will focus on conducting such replications to complete the existing knowledge from the community regarding end users' preferences for gestures that can be sensed with radars.

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REFERENCES

[1] Shahzad Ahmed, Karam Dad Kallu, Sarfaraz Ahmed, and Sung Ho Cho. 2021. Hand Gestures Recognition Using Radar Sensors for Human-Computer-Interaction: A Review. *Remote Sensing* 13 (2021), 24 pages. https://doi.org/10.3390/rs13030527

[2] Daniel Avrahami, Mitesh Patel, Yusuke Yamaura, and Sven Kratz. 2018. Below the Surface: Unobtrusive Activity Recognition for Work Surfaces Using RF-Radar Sensing. In *Proceedings of the 23rd International Conference on Intelligent User Interfaces (IUI '18)*. Association for Computing Machinery, New York, NY, USA, 439–451. https://doi.org/10.1145/3172944.3172962

[3] Phil Cohen, Colin Swindells, Sharon Oviatt, and Alex Arthur. 2008. A High-Performance Dual-Wizard Infrastructure for Designing Speech, Pen, and Multimodal Interfaces. In *Proceedings of the 10th International Conference on Multimodal Interfaces* (Chania, Crete, Greece) *(ICMI '08)*. Association for Computing Machinery, New York, NY, USA, 137–140. https://doi.org/10.1145/1452392.1452419

[4] Bogdan-Florin Gheran, Santiago Villarreal-Narvaez, Radu-Daniel Vatavu, and Jean Vanderdonckt. 2022. RepliGES and GEStory: Visual Tools for Systematizing and Consolidating Knowledge on User-Defined Gestures. In *Proceedings of the 2022 International Conference on Advanced Visual Interfaces (AVI 2022), June 6–10, 2022, Frascati, Rome, Italy (AVI '22)*. ACM, New York, NY, USA, 9 pages. https://doi.org/10.1145/3531073.3531112

[5] Jaime Lien, Nicholas Gillian, M. Emre Karagozler, Patrick Amihood, Carsten Schwesig, Erik Olson, Hakim Raja, and Ivan Poupyrev. 2016. Soli: Ubiquitous Gesture Sensing with Millimeter Wave Radar. *ACM Trans. Graph.* 35, 4, Article 142 (jul 2016), 19 pages. https://doi.org/10.1145/2897824.2925953

[6] Nathan Magrofuoco, Jorge Luis Pérez-Medina, Paolo Roselli, Jean Vanderdonckt, and Santiago Villarreal. 2019. Eliciting Contact-Based and Contactless Gestures With Radar-Based Sensors. *IEEE Access* 7 (2019), 176982–176997. https://doi.org/10.1109/ACCESS.2019.2951349

[7] Sameera Palipana, Dariush Salami, Luis A. Leiva, and Stephan Sigg. 2021. Pantomime: Mid-Air Gesture Recognition with Sparse Millimeter-Wave Radar Point Clouds. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 5, 1, Article 27 (mar 2021), 27 pages. https://doi.org/10.1145/3448110

[8] Arthur Sluÿters, Sébastien Lambot, and Jean Vanderdonckt. 2022. Hand Gesture Recognition for an Off-the-Shelf Radar by Electromagnetic Modeling and Inversion. In *Proceedings of the 27th International Conference on Intelligent User Interfaces (IUI '22)*. ACM, New York, NY, USA, 506–522. https://doi.org/10.1145/3490099.3511107

[9] Radu-Daniel Vatavu. 2019. The Dissimilarity-Consensus Approach to Agreement Analysis in Gesture Elicitation Studies. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3290605.3300454

[10] Radu-Daniel Vatavu and Jacob O. Wobbrock. 2015. Formalizing Agreement Analysis for Elicitation Studies: New Measures, Significance Test, and Toolkit. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. Association for Computing Machinery, New York, NY, USA, 1325–1334. https://doi.org/10.1145/2702123.2702223

[11] Santiago Villarreal-Narvaez, Jean Vanderdonckt, Radu-Daniel Vatavu, and Jacob O. Wobbrock. 2020. A Systematic Review of Gesture Elicitation Studies: What Can We Learn from 216 Studies?. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*. Association for Computing Machinery, New York, NY, USA, 855–872. https://doi.org/10.1145/3357236.3395511

[12] Saiwen Wang, Jie Song, Jaime Lien, Ivan Poupyrev, and Otmar Hilliges. 2016. Interacting with Soli: Exploring Fine-Grained Dynamic Gesture Recognition in the Radio-Frequency Spectrum. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (Tokyo, Japan) *(UIST '16)*. Association for Computing Machinery, New York, NY, USA, 851–860. https://doi.org/10.1145/2984511.2984565

[13] Jacob O. Wobbrock, Htet Htet Aung, Brandon Rothrock, and Brad A. Myers. 2005. Maximizing the Guessability of Symbolic Input. In *Proceedings of CHI '05 Extended Abstracts on Human Factors in Computing Systems* (Portland, OR, USA) *(CHI EA '05)*. Association for Computing Machinery, New York, NY, USA, 1869–1872. https://doi.org/10.1145/1056808.1057043

[14] Jacob O. Wobbrock, Meredith Ringel Morris, and Andrew D. Wilson. 2009. User-Defined Gestures for Surface Computing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '09)*. Association for Computing Machinery, New York, NY, USA, 1083–1092. https://doi.org/10.1145/1518701.1518866

[15] Hui-Shyong Yeo, Gergely Flamich, Patrick Schrempf, David Harris-Birtill, and Aaron Quigley. 2016. RadarCat: Radar Categorization for Input & Interaction. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (Tokyo, Japan) *(UIST '16)*. Association for Computing Machinery, New York, NY, USA, 833–841. https://doi.org/10.1145/2984511.2984515

[16] Hui-Shyong Yeo and Aaron Quigley. 2017. Radar Sensing in Human-Computer Interaction. *Interactions* 25, 1 (dec 2017), 70–73. https://doi.org/10.1145/3159651