Gesture Interaction: From 2D Multi-stroke to 3D Dynamic Gestures with Contact-Based and Contactless Devices

Nuwan T. Attygalle
Université catholique de Louvain
Louvain Research Institute in Management and Organizations
Louvain-la-Neuve, Belgium
nuwan.attygalle@uclouvain.be

Joanna Galloway
Université catholique de Louvain
Louvain-la-Neuve, Belgium
joana.galloway@student.uclouvain.be

Nacera Latreche
Université catholique de Louvain
Louvain Research Institute in Management and Organizations
Louvain-la-Neuve, Belgium
nacera.latreche@uclouvain.be

Nathan Magrofuoco
Université catholique de Louvain
Louvain Research Institute in Management and Organizations
Louvain-la-Neuve, Belgium
nathan.magrofuoco@gmail.com

Paolo Roselli
Università di Roma "Tor Vergata"
Rome, Italy
roselli@mat.uniroma2.it

Alaa Eddine Anis Sahraoui
Université catholique de Louvain
Louvain Research Institute in Management and Organizations
Louvain-la-Neuve, Belgium
alaa.sahraoui@uclouvain.be

Arthur Sluÿters
Université catholique de Louvain
Louvain Research Institute in Management and Organizations
Louvain-la-Neuve, Belgium
arthur@sluyers.be

Nicolas Szelagowski
nicolas.szelagowski@uclouvain.be
Université catholique de Louvain
Louvain Research Institute in Management and Organizations
Louvain-la-Neuve, Belgium

Jean Vanderdonckt
jean.vanderdonckt@uclouvain.be
Université catholique de Louvain
Louvain Research Institute in Management and Organizations
Louvain-la-Neuve, Belgium

Guillaume Van Issum
guillaume.vanissum@student.uclouvain.be
Université catholique de Louvain
Louvain Research Institute in Management and Organizations
Louvain-la-Neuve, Belgium

Donatien Grolaux
ICHEC Brussels Business School
Brussels, Belgium
Université catholique de Louvain
Louvain Research Institute in Management and Organizations
Louvain-la-Neuve, Belgium
donatien.grolaux@{ichec,uclouvain}.be

Thanh-Diane Nguyen
thanh-diane.nguyen@ichec.be
ICHEC Brussels Business School
Brussels, Belgium
Université catholique de Louvain
Louvain Research Institute in Management and Organizations
Louvain-la-Neuve, Belgium

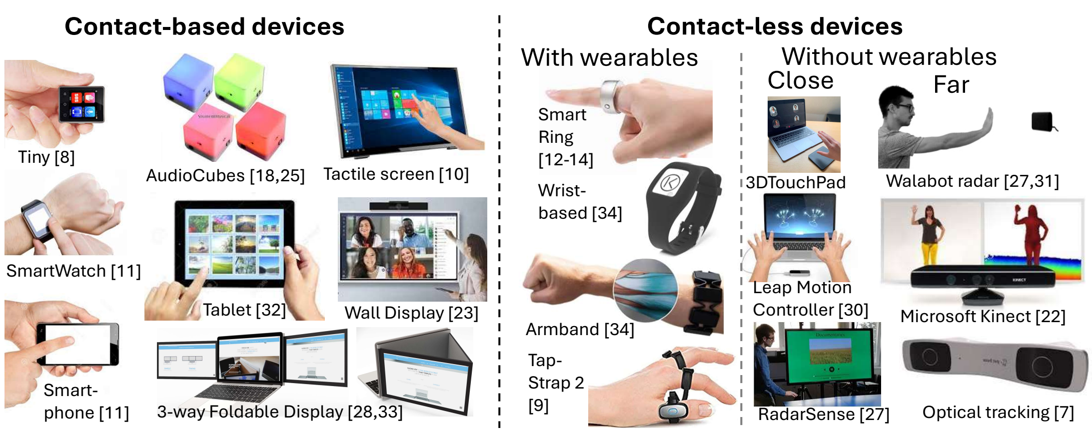

Figure 1: Overview of gesture interaction with contact-based and contact-less devices.

Abstract

Gesture-based interaction constitutes an increasingly important paradigm for interactive systems, enabling more natural and expressive forms of input. This paper presents a series of interactive demonstrations of gesture-based systems that integrates multiple recognition techniques and supports both predefined and user-defined gestures. The system enables real-time comparison between template-based and invariant gesture recognizers, thereby exposing trade-offs between robustness, flexibility, and usability. By allowing users to define and evaluate their own gestures, the demonstrations highlight the benefits of combining user-centered design with robust recognition techniques. The demonstrations range from contact-based devices, such as tactile surfaces, for 2D multi-stroke gestures to contact-less devices for 3D dynamic gestures, such as wearable devices, optical sensors, and radars.

CCS Concepts

• **Human-centered computing → Interaction techniques**; *Gestural input*; *Interaction design theory, concepts and paradigms.*

Keywords

Gesture-based interaction, gesture sets, recognizers

ACM Reference Format:

Nuwan T. Attygalle, Joanna Galloway, Nacera Latreche, Nathan Magrofuoco, Paolo Roselli, Alaa Eddine Anis Sahraoui, Arthur Sluÿters, Nicolas Szelagowski, Jean Vanderdonckt, Guillaume Van Issum, Donatien Grolaux, and Thanh-Diane Nguyen. 2026. Gesture Interaction: From 2D Multistroke to 3D Dynamic Gestures with Contact-Based and Contactless Devices. In *Companion Proceedings of the 18th ACM SIGCHI Symposium on Engineering Interactive Computing Systems (EICS Companion '26), June 30-July 03, 2026, Patras, Greece.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3807968.3816001

1 Introduction and Overview

Gesture-based interaction has gained significant attention in recent years as an alternative to traditional input modalities [34]. Its ability to provide intuitive and expressive interaction makes it particularly relevant and attractive for modern interactive applications, including mobile [40], multi-device [2, 11], and immersive systems [1]. Despite these advantages, the design and implementation of gesture-based interfaces remain challenging due to variability in gesture execution, limitations in recognition accuracy, differences in user expectations [6], and need to communicate them [15].

To address these challenges, this work presents a series of interactive demonstrations of gesture-based systems that integrate multiple gesture recognition strategies, some of them within a unified framework for engineering [30] and testing [21]. The systems are designed to support exploration and comparison of recognition techniques while emphasizing user involvement in gesture definition, such as through gesture elicitation studies [38] thanks to several metrics, including the agreement rate [35]. The objective is not only to demonstrate technical capabilities but also to provide insights into the design space of gesture-based interaction.

The demonstration consists of a fully functional prototype that allows users to interact with a graphical interface through gestures. Users can perform gestures to trigger commands such as navigation, selection, and object manipulation [31]. The system provides immediate visual feedback, enabling participants to observe how gestures are captured and recognized in real time. A key aspect is the ability to explore alternative classifiers for gesture recognition and to switch dynamically between them. This feature allows users to directly compare how each approach responds to variations in gesture input. In addition, participants can define their own gestures and evaluate how effectively the system adapts to personalized input [34].

The system is structured around a modular architecture composed of three main components: an input module, a recognition module, and an interaction module. The input module captures gesture data through touch input or simulated mid-air interaction [17]. The recognition module implements multiple algorithms, including template-based [32] and invariant approaches [20]. The interaction module maps recognized gestures to application commands and manages system feedback. Template-based recognition is employed for its simplicity and efficiency, enabling rapid matching of input gestures against stored templates [20], and potential systematic evaluation [22]. In contrast, invariant recognition techniques are designed to handle variations in scale, rotation, and articulation, thereby improving robustness in realistic usage conditions [5]. The coexistence of these approaches within a single system allows for direct comparison and evaluation. The system supports both predefined gesture sets and user-defined gestures, which are more appreciated than designer-defined gestures [24].

During the demonstrations, participants will be able to engage with the system by performing gestures to control interface elements. They are invited to experiment with different recognition techniques, observe system feedback, and assess the responsiveness and accuracy of each approach. Gesture recognition techniques can be broadly structured into two categories (Fig. 1) [19]: *contact-based devices* and *contact-less devices.* Contact-based devices involve 2D uni- or multi-stroke gesture recognizers. Since old recognizers (*e.g.,* Levensthein-based [10] or UsiGesture [4]), many progress has been achieved in developing recognizers that usually best fit a certain device or platform: tiny surfaces [8], smartwatches and smartphones [11], AudioCubes [18, 25], tablets [32], 3-way foldable displays [28, 33], tactile screens [10], and wall displays [23]. Contact-less devices can be further broken down in two subcategories: *wearable devices* (which include smart rings [12–14], wrist-based devices, armbands, Tap Strap [9]) and non-wearables (which include 3DTouchPad, Leap Motion Controller [30], radars under [27, 31] or behind multiple surfaces [29] (see [26] for a review), cameras [22] for full-body gestures [7], and optical trackers.

A significant effort has been produced towards eliciting user-defined gestures [38] for these devices in various contexts of use (see [36, 37] for a review), such as for consistency across devices [11], for sketching commands [16]. The question also concerns synthetic gestures [3] as opposed to user-defined ones [39].

EICS Companion '26, Patras, Greece

ACM ISBN 979-8-4007-2669-9/2026/06
https://doi.org/10.1145/3807968.3816001

Acknowledgments

The authors acknowledge support by the EU European Innovation Council Pathfinder-Awareness Inside Challenge "Symbiotik" project under Grant no. 101071147 and by the Fonds de la Recherche Scientifique (FNRS) under Grant n°40035986 COSMIC project.

References

[1] Roland Aigner, Daniel Wigdor, Hrvoje Benko, Michael Haller, David Lindbauer, Alexandra Ion, Shengdong Zhao, and Jeffrey Tzu Kwan Valino Koh. 2012. *Understanding Mid-Air Hand Gestures: A Study of Human Preferences in Usage of Gesture Types for HCI.* Technical Report. Microsoft.

[2] Nathalie Aquino, Jean Vanderdonckt, Nelly Condori-Fernández, Óscar Dieste, and Óscar Pastor. 2010. Usability evaluation of multi-device/platform user interfaces generated by model-driven engineering. In *Proc. of ESEM ’10.* ACM, Article 30, 10 pages. https://doi.org/10.1145/1852786.1852826

[3] Marvin Bachert and Marc Hesenius. 2024. Towards a Framework for Evaluating Synthetic Surface Gestures. In *Companion Proceedings of EICS ’24’* (Cagliari, Italy). ACM, New York, NY, USA, 22–30. https://doi.org/10.1145/3660515.3661327

[4] François Beuvens and Jean Vanderdonckt. 2012. UsiGesture: An environment for integrating pen-based interaction in user interface development. In *Proc. of RCIS 2012.* IEEE, 1–12. https://doi.org/10.1109/RCIS.2012.6240449

[5] Alexandre Calado, Paolo Roselli, Vito Errico, Nathan Magrofuoco, Jean Vanderdonckt, and Giovanni Saggio. 2022. A Geometric Model-Based Approach to Hand Gesture Recognition. *IEEE Trans. Syst. Man Cybern. Syst.* 52, 10 (2022), 6151–6161. https://doi.org/10.1109/TSMC.2021.3138589

[6] F. M. Caputo, S. Burato, F. Manganaro, S. Pini, G. Borghi, R. Vezzani, R. Cucchiara, H. Nguyen, M. T. Tran, A. Giachetti, G. Pavan, T. Voillemin, H. Wannous, J. P. Vandeborre, M. Maghoumi, E. M. Taranta II, A. Razmjoo, and J. J. LaViola Jr. 2019. Online Gesture Recognition. In *Eurographics Workshop on 3D Object Retrieval.* The Eurographics Association. https://doi.org/10.2312/3dor.20191067

[7] David Céspedes-Hernández, Juan Manuel González-Calleros, Josefina Guerrero García, and Jean Vanderdonckt. 2020. A grammar for specifying full-body gestures elicited for abstract tasks. *J. Intell. Fuzzy Syst.* 39, 2 (2020), 2433–2444. https://doi.org/10.3233/JIFS-179903

[8] Klen Čopič Pucihar, Nuwan T. Attygalle, Matjaž Kljun, Christian Sandor, and Luis A. Leiva. 2022. Solids on Soli: Millimetre-Wave Radar Sensing through Materials. *Proc. ACM Human-Computer Interaction* 6, EICS, Article 156 (jun 2022), 21 pages. https://doi.org/10.1145/3532212

[9] Guillem Cornella-Barba, Bruno Dumas, Mehdi Ousmer, Santiago Villarreal-Narvaez, Jean Vanderdonckt, Eudald Sangenis, and Adrien Chaffangeon Caillet. 2025. TapStrapGest: Elicitation and Recognition of Ring-based Multi-Finger Gestures. *Proc. ACM Hum.-Comput. Interact.* 9, 4, Article EICS001 (June 2025), 27 pages. https://doi.org/10.1145/3733047

[10] Adrien Coyette, Sascha Schimke, Jean Vanderdonckt, and Claus Vielhauer. 2007. Trainable Sketch Recognizer for Graphical User Interface Design. In *Proceedings of INTERACT ’07.* Springer, 124–135. https://doi.org/10.1007/978-3-540-74796-3_14

[11] Tilman Dingler, Rufat Rzayev, Alireza Sahami Shirazi, and Niels Henze. 2018. Designing Consistent Gestures Across Device Types: Eliciting RSVP Controls for Phone, Watch, and Glasses. In *Proceedings of CHI ’18* (Montreal, QC, Canada). ACM, New York, NY, USA, 1–12. https://doi.org/10.1145/3173574.3173993

[12] Bogdan-Florin Gheran, Jean Vanderdonckt, and Radu-Daniel Vatavu. 2018. Gestures for Smart Rings: Empirical Results, Insights, and Design Implications. In *Proceedings of DIS ’18.* ACM, 623–635. https://doi.org/10.1145/3196709.3196741

[13] Bogdan-Florin Gheran, Radu-Daniel Vatavu, and Jean Vanderdonckt. 2018. Ring x2: Designing Gestures for Smart Rings using Temporal Calculus. In *Proceedings of DIS ’18 Companion.* ACM, 117–122. https://doi.org/10.1145/3197391.3205422

[14] Bogdan-Florin Gheran, Radu-Daniel Vatavu, and Jean Vanderdonckt. 2023. New Insights into User-Defined Smart Ring Gestures with Implications for Gesture Elicitation Studies. In *Proc. of CHI EA ’23.* https://doi.org/10.1145/3544549.3585590

[15] Marc Hesenius and Volker Gruhn. 2019. GestureCards: A Hybrid Gesture Notation. *Proc. ACM Hum.-Comput. Interact.* 3, Article 22 (2019). https://doi.org/10.1145/3331164

[16] Marc Hesenius, Mak Krvavac, Valbjörn Jón Valbjörnsson, Theresia Mita Erika, and Matthias Book. 2025. How To Draw Commands? An Elicitation Study for Sketching on Spreadsheets. In *Proceedings of CHI ’25.* ACM, 848:1–848:31. https://doi.org/10.1145/3706598.3715269

[17] Panayiotis Koutsabasis and Panagiotis Vogiatzidakis. 2019. Empirical Research in Mid-Air Interaction: A Systematic Review. *Int. J. of Human–Comp. Int.* 35, 18 (2019), 1747–1768. https://doi.org/10.1080/10447318.2019.1572352

[18] Nacera Latreche, Bert Schiettecatte, Paolo Roselli, Nuwan Attygalle, and Jean Vanderdonckt. [n. d.]. User-Defined Gestures for Tangible Interaction with Cubes for Smart Home Control. In *Proc. of DIS ’26.* 30 pages. https://doi.org/10.1145/3800645.3813062

[19] 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

[20] Nathan Magrofuoco, Paolo Roselli, and Jean Vanderdonckt. 2022. μV: An Articulation, Rotation, Scaling, and Translation Invariant (ARST) Multi-stroke Gesture Recognizer. *Proc. ACM Hum. Comput. Interact.* 6, EICS (2022), 150:1–150:25. https://doi.org/10.1145/3532200

[21] Nathan Magrofuoco, Jean Vanderdonckt, and Paolo Roselli. 2025. Performance Testing of Stroke Gesture Recognizers with Gester. *Proc. ACM Hum.-Comput. Interact.* 9, 4 (June 2025), 27 pages. https://doi.org/10.1145/3734186

[22] Mehdi Ousmer, Arthur Sluÿters, Nathan Magrofuoco, Paolo Roselli, and Jean Vanderdonckt. 2022. A Systematic Procedure for Comparing Template-Based Gesture Recognizers. In *Proc. of HCI International 2022.* 160–179. https://doi.org/10.1007/978-3-031-17618-0_13

[23] Vik Parthiban, Pattie Maes, Quentin Sellier, Arthur Sluÿters, and Jean Vanderdonckt. 2022. Gestural-Vocal Coordinated Interaction on Large Displays. In *Proc. of EICS ’22.* ACM, 26–32. https://doi.org/10.1145/3531706.3536457

[24] Dmitry Pyryeskin, Mark Hancock, and Jesse Hoey. 2012. Comparing elicited gestures to designer-created gestures for selection above a multitouch surface. In *Proc. of ITS ’12.* ACM, 1–10. https://doi.org/10.1145/2396636.2396638

[25] Bert Schiettecatte and Jean Vanderdonckt. 2008. AudioCubes: a distributed cube tangible interface based on interaction range for sound design. In *Proc. of TEI ’08* (Bonn, Germany). ACM, 3–10. https://doi.org/10.1145/1347390.1347394

[26] Alexandru-Ionut Siean, Cristian Pamparau, Arthur Sluÿters, Radu-Daniel Vatavu, and Jean Vanderdonckt. 2023. Flexible gesture input with radars: systematic literature review and taxonomy of radar sensing integration in ambient intelligence environments. *J. Ambient Intell. Humaniz. Comput.* 14, 6 (2023), 7967–7981. https://doi.org/10.1007/s12652-023-04606-9

[27] Arthur Sluÿters, Sébastien Lambot, Jean Vanderdonckt, and Radu-Daniel Vatavu. 2023. RadarSense: Accurate Recognition of Mid-air Hand Gestures with Radar Sensing and Few Training Examples. *ACM Trans. Interact. Intell. Syst.* 13, 3 (2023), 16:1–16:45. https://doi.org/10.1145/3589645

[28] Arthur Sluÿters, Jean Vanderdonckt, Paolo Roselli, and Radu-Daniel Vatavu. 2025. Congruent and Hierarchical Gesture Set Design. In *Companion Publication of DIS ’25.* ACM, New York, NY, USA, 419–426. https://doi.org/10.1145/3715668.3736383

[29] Arthur Sluÿters, Sébastien Lambot, Jean Vanderdonckt, and Santiago Villarreal-Narvaez. 2024. Analysis of User-defined Radar-based Hand Gestures Sensed through Multiple Materials. *IEEE Access* 12 (2024), 1–24. https://doi.org/10.1109/ACCESS.2024.3366667

[30] Arthur Sluÿters, Mehdi Ousmer, Paolo Roselli, and Jean Vanderdonckt. 2022. QuantumLeap, a Framework for Engineering Gestural User Interfaces based on the Leap Motion Controller. *Proc. ACM Human-Computer Interaction* 6, EICS, Article 161 (jun 2022), 47 pages. https://doi.org/10.1145/3532211

[31] Arthur Sluÿters, Quentin Sellier, Jean Vanderdonckt, Vik Parthiban, and Pattie Maes. 2023. Consistent, Continuous, and Customizable Mid-Air Gesture Interaction for Browsing Multimedia Objects on Large Displays. *Int. J. of Human–Computer Interaction* 39, 12 (2023), 2492–2523. https://doi.org/10.1080/10447318.2022.2078464

[32] Jean Vanderdonckt, Paolo Roselli, and Jorge Luis Pérez-Medina. 2018. !FTL, an Articulation-Invariant Stroke Gesture Recognizer with Controllable Position, Scale, and Rotation Invariances. In *Proc. of ICMI ’18.* ACM, 125–134. https://doi.org/10.1145/3242969.3243032

[33] Jean Vanderdonckt, Radu-Daniel Vatavu, and Arthur Sluÿters. 2024. Engineering Touchscreen Input for 3-Way Displays: Taxonomy, Datasets, and Classification. In *Companion Proc. of EICS ’24.* ACM, New York, NY, USA, 57–65. https://doi.org/10.1145/3660515.3661331

[34] Radu-Daniel Vatavu. 2023. *Gesture-Based Interaction.* Springer International Publishing, Cham, 1–47. https://doi.org/10.1007/978-3-319-27648-9_20-1

[35] Radu-Daniel Vatavu and Jacob O. Wobbrock. 2015. Formalizing Agreement Analysis for Elicitation Studies: New Measures, Significance Test, and Toolkit. In *Proc. of CHI ’15.* ACM, 1325–1334. https://doi.org/10.1145/2702123.2702223

[36] Santiago Villarreal-Narvaez, Arthur Sluÿters, Jean Vanderdonckt, and Radu-Daniel Vatavu. 2024. Brave New GES World: A Systematic Literature Review of Gestures and Referents in Gesture Elicitation Studies. *Comput. Surveys* 56, 5 (2024), 128:1–128:55. https://doi.org/10.1145/3636458

[37] 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 *Proc. of DIS ’20 (DIS ’20).* 855–872. https://doi.org/10.1145/3357236.3395511

[38] Jacob O. Wobbrock, Meredith Ringel Morris, and Andrew D. Wilson. 2009. User-defined gestures for surface computing. In *Proc. of CHI ’09 (CHI ’09).* ACM, New York, NY, USA, 1083–1092. https://doi.org/10.1145/1518701.1518866

[39] Haijun Xia, Michael Glueck, Michelle Annett, Michael Wang, and Daniel Wigdor. 2022. Iteratively Designing Gesture Vocabularies: A Survey and Analysis of Best Practices in the HCI Literature. *ACM Trans. Comput. Hum. Interact.* 29, 4 (2022), 37:1–37:54. https://doi.org/10.1145/3503537

[40] Yoonsik Yang, Seungho Chae, Jinwook Shim, and Tack-Don Han. 2015. EMG Sensor-based Two-Hand Smart Watch Interaction. In *Adjunct Proc. of UIST ’15.* 73–74. https://doi.org/10.1145/2815585.2815724