Beyond Radar Waves: The First Workshop on Radar-Based Human-Computer Interaction

Klen Čopič Pucihar
University of Primorska, FAMNIT, Koper, Slovenia
Faculty of Information Studies, Novo Mesto, Slovenia
Stellenbosch University, Dep. of Information Science
Stellenbosch, South Africa
klen.pucihar@famnit.upr.si

Francesca Meneghello
Department of Information Engineering
University of Padova
Padova, Italy
francesca.meneghello.1@unipd.it

Dariush Salam
Nokia Bell Labs
Espoo, Finland
dariush.salami@nokia-bell-labs.com

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

Radu-Daniel Vatavu
MintViz Lab, MANSiD Research Center
Ştefan cel Mare University of Suceava
Suceava, Romania
radu.vatavu@usm.ro

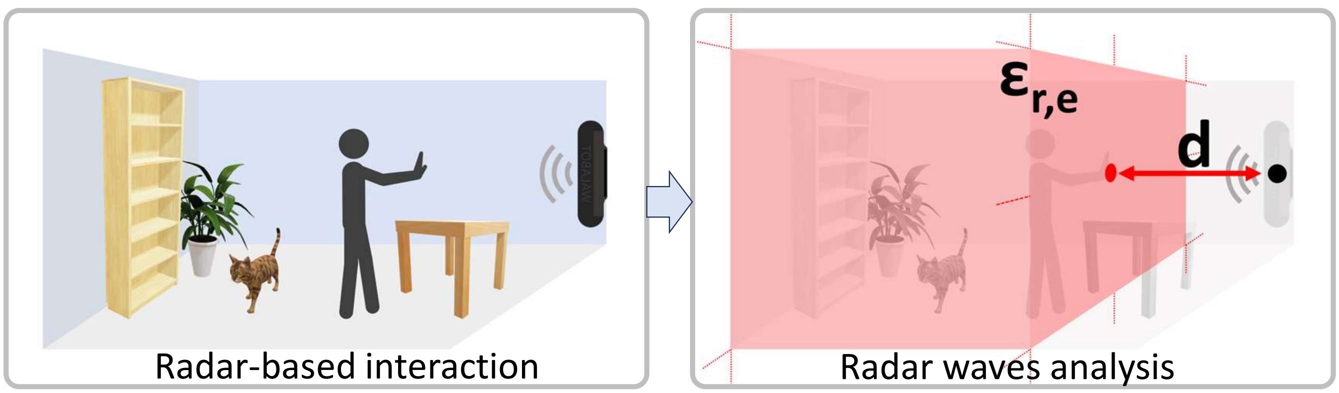

Figure 1: Visual illustration of radar-based interaction in the context of radar signal acquisition and analysis.

ABSTRACT

This workshop targets topics in the emerging area of radar-based interaction while focusing on scientific explorations centred on Engineering Interactive Computer Systems as part of Human-Computer Interaction. Radar technology, traditionally employed for surveillance and object detection applications, has been recently adopted by Human-Computer Interaction researchers and practitioners for creating novel user experiences in relation to computer systems, including gesture-based interaction, material recognition, and enabling interactions performed through fabrics, surfaces, and objects. In this context, the participants in this workshop will explore fundamental, practical, and experimental challenges posed by radar-based human-computer interaction in various application domains, such as gaming, virtual and augmented reality, healthcare, emergency response systems, and smart environments.

CCS CONCEPTS

• **Human-centered computing** → **Gestural input**; **Graphical user interfaces**; *Interactive systems and tools*; • **Computing methodologies** → *Model development and analysis*; • **Software and its engineering** → Runtime environments; • **Hardware** → Radio frequency and wireless interconnect.

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KEYWORDS

Radar-based sensing, radar-based interaction, body gesture recognition, engineering radar-based user interfaces, radar datasets

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1 BACKGROUND

Radar-based interaction [67] (RBI) represents the fusion between radar technology and human-computer interaction [27], addressing a novel approach for interacting with computer systems, while also creating new engineering challenges to the development life cycle [47]. Radars, historically employed in various fields, such as aviation and target localization [51], ground imaging [14], and traffic safety [22], have recently found new applications in human-computer interaction. In this area, radars provide the means for users to interact with computer systems without the need for making physical contact or having a line of sight to those systems [5]. The key advantages of RBI lie in the versatility and adaptability of the underlying technology to accommodate both diverse and adverse contexts of use [44, 45]. Unlike other sensing technologies, such as those employed in computer vision-based systems, that are influenced by lighting conditions, visual occlusion, and characteristics of the environments where interaction sensing takes place, RBI can successfully operate in a wide range of lighting conditions, is not impacted by occlusion [49], and can detect interactions even through surfaces [46], which makes it suitable for both indoor [5, 52, 71] and outdoor [13] contexts of use [23, 33].

Unlike conventional input methods that rely on keyboards, mice, and touchscreens, RBI operates by detecting and interpreting the reflected radio waves emitted by the human body [15], such as for hand gesture movement detection [2, 62]. By leveraging radars' capacity to precisely acquire position, motion, and even physiological parameters of the human body from a distance, new opportunities emerge for interactions with computer systems using various input modalities. Among these, gesture input has gained significant interest in the scientific literature [4, 20, 38, 45]. For example, prior work [6, 29, 36, 40, 53] has examined numerous advantages of radar-based gesture detection and recognition, including aspects of resilience of the underlying technology to environmental factors, such as light and weather conditions, low power consumption, compact form factor, and detecting gestures through objects [6, 26, 49, 53].

In this context, this workshop addresses fundamental principles, technological advancements, and applications of RBI. Moreover, it sets to explore how radar sensing can be harnessed for user input detection, user and object tracking, and user intent inference for the goal of effective and efficient interaction with computer systems. This workshop focuses on, while not being limited by, the following specific topics relevant to radar-based human-computer interaction:

- *Case studies and datasets for RBI* for evaluating, comparing, and benchmarking interactive systems [3, 7, 11].
- *Fundamentals of radar technology applied to HCI*, including models [25], methods[72], and techniques [16] to capture radar waves and extract key data from radar signals for high-level, meaningful information for RBI.
- *Signal processing for RBI,* including techniques for filtering, curating, analyzing, and synthesizing radar signals [71] for the purpose of human-computer interaction.
- *Radars availability for RBI,* addressing aspects of radar sensors, either custom-made [20] or commercially available [5, 50], that can be readily used by HCI researchers and practitioners. There are many radar-based tracking systems concerned by RBI, such as EtherPose, CW-Radar [68], Magic Carpet [37] and the Gesture-Sensing Radars Project, GestureVLAD [10], Ingenious [47], Forte [12], Pantomime [36], RadarCat [65], RadarHand [18], RadarNet [19], RadarSense [48], Soli [28] and applications [19, 53, 61], RaITIn [17], UWB [3], and ViSar [42], among others. In this direction, we are interested in ways in which radar sensing technology can be made more available.
- *Artificial Intelligence, Machine Learning, and Deep Learning for RBI applications,* entailing processing algorithms [6, 9, 26, 53] for handling high-level data and interpreting it towards meaningful feature extraction for application in human-computer interaction.
- *Applications of RBI,* representing common application domains where radars have been traditionally applied [15, 62], but also new opportunities for employing radar-based technology to new interactive computer systems.
- *Engineering considerations to facilitate design and development of RBI,* including software architectures and artifacts [47, 48] for facilitating the development life cycle of radar-based applications, user interfaces, and interactions. Specifically, radar-based sensing devices fit well into smart environments characterized by heterogeneous input/output devices, for which dedicated software architectures have been proposed in the HCI community [43].
- *The user experience of RBI.* Given that interactions enabled by radar-based sensing, *e.g.,* interactions through objects and surfaces, may feel substantially different than traditional ones, understanding the user experience of RBI is important. Specifically, end-user elicitation studies [31, 49, 55, 56, 63] conducted with radar sensing technology enable new discoveries about micro [6, 54] and macro [36] gesture interactions.
- *RBI in challenging situations and environments,* including applications of RBI to multi-user and multi-device scenarios, *e.g.,* interacting with a smartphone while in the pocket or through a leather bag [9, 26, 49, 53], or interactions through walls [32, 57, 70] and involving multiple users [34].

2 WORKSHOP ORGANIZATION

The target audience of this workshop consists of researchers and practitioners interested in RBI with a focus on engineering interactions and user interfaces.

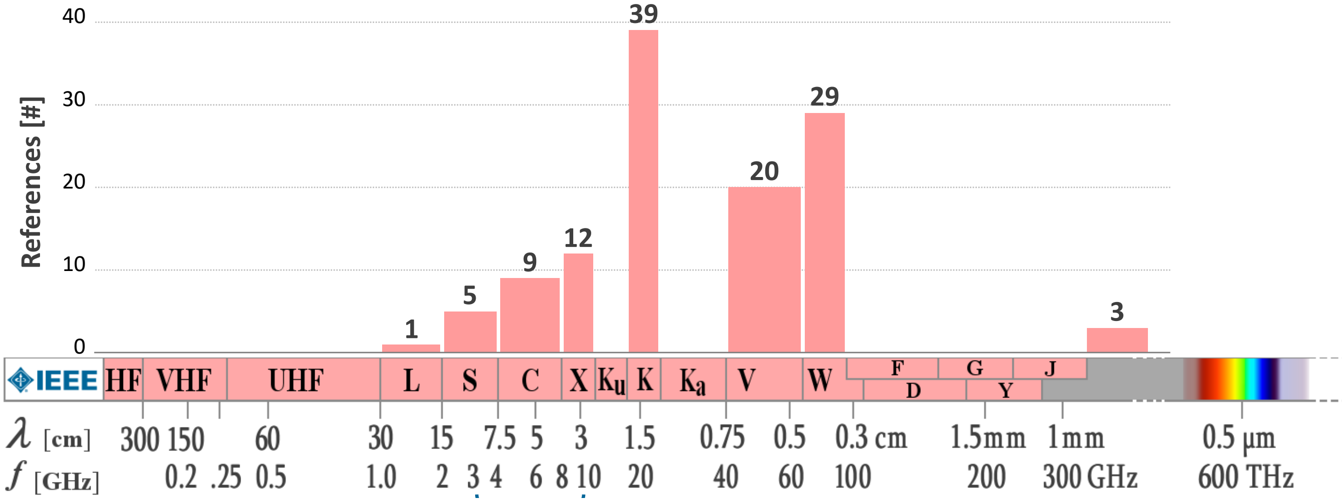

Figure 2: Number of radar-based systems, according to their frequency band [35], distributed along the electromagnetic spectrum, from an analysis involving 118 radars [48]. Note: bottom illustration of wave types and frequency ranges used with kind permission from Christian Wolff [64].

2.1 Before the Workshop

Authors will be invited to submit papers formatted according to the Springer HCI Series format,[1] which will undergo a double-blind review by at least two members of the PC. The workshop website, available at the address https://radarwaves.upr.si, will also be used as a first step to the creation of a RBI community of interest and/or community of practice. Authors are strongly encouraged to consider submitting work related to evaluation, comparison and benchmarking of existing and novel radar-based interactive systems (where possible, including the datasets). This will form the core of joint journal publication. Authors are also encouraged to provide detailed descriptions in their papers of the following aspects relevant for RBI technology, utility for HCI, replicability and comparability:

- Details system description in terms of radar type [48].
- Radar bandwidth (see Figure 2) and range (*e.g.,* short-range [13], mid-range [21], or long-range).
- Sensor type, *i.e.,* custom *vs.* commercially available [5].
- Usage context *i.e.,* stationary *vs.* mobile [26, 58], end users [8] and human body parts involved in the interaction, *e.g.,* fingers, wrist, hands [39, 40], forearm [30], arm [2, 29].
- Main goals of the proposed systems, *e.g.,* object classification [16], material identification [1, 65] and classification [24], rough interfaces [23], aphasia detection [41], ambient intelligence [44, 45], multimedia [50], etc.
- Interaction types, *e.g.,* tangible [17, 66], graspable [6, 54], mid-air [27, 47, 69], air-writing [59], and so forth.
- Environment characteristics, *e.g.,* indoor [5, 52] or outdoor, and the setup, *e.g.,* below a surface [8, 46], under a work surface [9], through the wall or other surfaces [32, 53, 57, 60, 70].
- Implemented algorithms and techniques [6, 10, 12, 47].
- Dataset availability, *e.g.,* UWB-gestures [3].

2.2 The Day of the Workshop

The workshop agenda consists of the following activities:

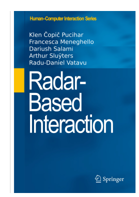

Figure 3: Tentative cover of the RBI book proposal.

- Individual presentations of the accepted papers. Authors of accepted papers will be invited to deliver a short presentation of their work, optionally with an accompanying demo. The demos will be featured in a summary video representing an overview of the workshop. This activity addresses the *description dimension* of the workshop.
- Engaging in discussions based on the description of the accepted papers and related work. In particular, each presented paper will be positioned with respect to specific radar-based technology characteristics, such as sensing frequency, algorithms, datasets, etc. A complementary point of discussion will focus on RBI datasets to further examine their scope, capabilities, and availability in the scientific community. When relevant, datasets will be collected and posted on a common permanent repository, such as http://www.kaggle.com. This activity, addressing the *comparative dimension* of the workshop, will form the basis for a potential common paper presenting the results of the workshop.
- Open questions and future work. Attendees will be engaged in an overall discussion of the breakthroughs induced by RBI and the limitations of the underlying technology in various contexts of use for interacting with computer systems.

[1] https://www.springer.com/series/6033

This activity represents the *generative dimension* of the workshop.

2.3 After the Workshop

The results of the the workshop, structured according to the three dimensions (descriptive, comparative, and generative) will constitute the basis for a common paper and a potential submission to a journal. Furthermore, a book proposal to Springer HCI series is envisaged depending on the accepted papers. Other workshop results, such as videos and presentations, will be made available through the workshop website.

2.4 Tentative Dates

- Paper submission deadline: May 10th, 2024
- Decision notification: May 31st, 2024
- Deadline for registration to the workshop: June 7th, 2024
- Final program of the workshop: June 15th, 2024
- Workshop (full-day): June 25th, 2024
- Chapter proposal for an RBI book: June 30th, 2024. Authors should provide a provisional title, the list of authors, and the abstract. This information will be used to submit a book proposal to the Springer HCI series.
- Submission of the book proposal by the workshop organizers to the Springer HCI series: July 7th, 2024.
- Decision notification: August 1st, 2024
- Post-workshop chapter submission: August 23rd, 2024
- Book enters production: September 2024

3 ORGANIZERS

Klen Čopič Pucihar is an Assistant Professor at the Faculty of Mathematics, Natural Sciences and Information Technologies, University of Primorska, Slovenia and a Research Fellow in the Department of Information Science of Stellenbosch University, South Africa. He co-directs the HICUP Lab, an HCI laboratory fixated on making the digital world fit for humans. His research focus on ways of creating interactive systems that would best understand and react to users' needs and expectations through research in (i) manipulation of light and matter to generate meaningful and believable AR and MR experiences that go beyond photorealism; (ii) human perception and cognition to create benchmarks for best humanly perceivable systems; and (iii) exploration of a multitude of sensing modalities (e.g., radar sensing, eye gaze tracking, facial expression analysis, etc.) and computational thinking–abstraction, automation, and analysis–to design, explain and enable interactive systems. He has co-organised several successful workshops, such as The 1st International Workshop on Cross-Reality (XR) Interaction at ACM ISS 2020, The 2nd Multimodal Virtual and Augmented Reality workshop at IEEE ISMAR 2018 and the IEEE AIVR Workshop on Immersive Analytics (ImAna) at IEEE AIVR 2020. For the past 3 to 7 years, he has been acting as PC member for the IEEE ISMAR, ACM UMAP, and ACM IUI conferences.

Francesca Meneghello is an Assistant Professor in telecommunications at the Department of Information Engineering, University of Padova. Her work specifically focuses on the integration of wireless communications, computing and sensing, with her main research objective being to contribute to the definition and development of next-generation data-driven wireless networks. In her research, Dr. Meneghello combines mathematical modelling and analysis of the radio propagation systems with algorithm implementation and performance evaluation through commercial Wi-Fi devices and custom-tailored testbeds. In 2023, she was awarded a Fulbright-Schuman visiting scholar fellowship and was a visiting researcher at Northeastern University (USA).

Dariush Salami received his BSc and MSc degrees from Shahid Beheshti University and Amirkabir University of Technology in Software Engineering in 2016 and 2019, respectively. He is a former Marie Skłodowska Curie fellow in ITN-WindMill project and a PhD researcher at the department of communications and networking at Aalto University. He is now a radio research scientist in Nokia Bell Labs focused on Artificial Intelligence and Machine Learning for wireless communications and sensing.

Arthur Sluÿters received his MSc degree in Computer Science and Engineering in September 2020 from Ecole Polytechnique de Louvain (EPL), Université catholique de Louvain (UCLouvain). He is a former Ph.D. researcher in computer science at Louvain Research Institute in Management and Organizations (LouRIM), UCLouvain. His main research interests include gesture interaction, radar-based gesture recognition, and software engineering. He is currently dedicated to building software tools aimed at fostering the development of gesture-based interfaces. Arthur Sluÿters is funded by the "Fonds de la Recherche Scientifique - FNRS" under Grants n°40001931 and n°40011629.

Radu-Daniel Vatavu is a Professor of Computer Science at the Ştefan cel Mare University of Suceava, where he conducts research in Human-Computer Interaction (HCI), Ambient Intelligence (AmI), Augmented and Mixed Reality (AR/MR), and Entertainment Computing. He directs the Machine Intelligence and Information Visualization Lab (MintViz), an interdisciplinary research laboratory within the MANSiD Research Center. His topics of interest include gesture technology for effective interaction with computing systems, from large public displays to personal mobile and wearable devices, accessible computing, and user interface design for young children or people with visual or motor impairments. He was Full Papers Co-Chair for ACM EICS 2019, Full Papers Co-Chair for ACM TVX 2019, and Area Chair for ICEC 2018 and RCIS 2019.

The Program Committee members are represented by experienced researchers with expertize in the area of RBI including, in alphabetical order: Nuwan Attygalle, University of Primorska, Slovenia, Batagelj Boštjan, University of Ljubljana, Slovenia, Matjaž Kljun, University of Primorska, Slovenia, Sébastien Lambot, Université catholique de Louvain, Belgium, Luis A. Leiva, University of Luxembourg, Luxembourg, Aaron Quigley, CSIRO, Australia, Jacopo Pegoraro, University of Padova, Italy, Stefano Savazzi, CNR – Italian, National Research Council, Italy, ,Alexandru-Ionut Siean, Stefan cel Mare University of Suceava, Romania, Stephan Sigg, Aalto University, Finland.

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