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## Special issue on nonverbal cues for human–robot cooperative intelligence

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PREFACE



## Special issue on nonverbal cues for human–robot cooperative intelligence

As robots increasingly move from structured industrial settings into homes, workplaces, healthcare environments, and public spaces, human–robot interaction is evolving beyond task execution toward cooperative intelligence. Recent advances in artificial intelligence have accelerated the transition from systems optimized for isolated tasks toward embodied or physical AI – intelligent systems capable of perceiving, reasoning, and acting in the physical world. Unlike purely digital intelligence, physical AI operates in dynamic environments shared with humans, where successful interaction depends not only on autonomous capabilities but also on social understanding and adaptation. Achieving such capabilities requires moving beyond explicit communication toward richer interaction mechanisms based on implicit behavioral signals.

In this context, cooperative intelligence has increasingly emerged as a paradigm in which humans and physical AI systems coexist, co-adapt, and collaborate toward shared goals. Such cooperation requires more than physical coordination; it also depends on trust, contextual awareness, and shared understanding. In human interactions, this understanding is often conveyed through subtle nonverbal signals, including gaze, gestures, body posture, movement patterns, and other behavioral cues that shape attention, reveal intentions, and regulate social behavior. As AI systems become increasingly integrated into human environments, the ability to perceive, interpret, and respond appropriately to these implicit signals becomes fundamental for effective cooperation.

The Nonverbal Cues for Human–Robot Cooperative Intelligence (NOC) workshop series was established to address these challenges through interdisciplinary collaboration and has evolved into an emerging research community focused on how nonverbal communication and social intelligence can support future ecosystems where humans and physical AI coexist and collaborate. Across activities in 2024 and 2025, and with continuing workshops and related events in 2026, discussions have emphasized multimodal perception, internal-state

understanding, social interaction modeling, and intelligent behavior generation. These discussions further reveal a shift from perception and recognition of observable cues toward higher-level reasoning involving anticipation, contextual understanding, and adaptive social behavior. This progression may be viewed as a transition from cue perception, to intention understanding, to social reasoning, and ultimately toward embodied cooperative intelligence supporting future human–AI hybrid societies.

The collection of papers in this special issue, consisting of both new submissions and extended contributions originating from the NOC workshop series, reflects different stages of this progression. FocusViT: Dynamic Patch Focus for Transformer-based Gaze Estimation by Sochirca et al. addresses visual attention understanding through improved gaze estimation mechanisms supporting collaborative interaction. Implicit Behavioral Cues for Enhancing Trust and Comfort in Robot Social Navigation by Lian et al. explores how subtle behavioral signals influence trust and comfort during human–robot navigation. Anticipating Daily Human Actions: Comparing Pipelines for Long-Term Skeleton-Based Prediction in Real-World Scenarios by Wen et al. investigates predictive understanding of future human behavior for proactive interaction. Finally, Zero-shot Group Social Interaction Dynamics Modeling using Large Visual Language Model and Task Decomposition Prompting by Nguyen et al. demonstrates emerging capabilities enabled by generative AI and foundation models for understanding complex social interactions.

Collectively, these contributions reflect broader developments driven by advances in generative AI, including large language models, multimodal foundation models, and visual-language-action models, together with the emergence of physical AI. Discussions within the NOC community suggest that meaningful cooperation extends beyond isolated cue recognition toward integrated understanding of behavioral and contextual information, with increasing emphasis on anticipation,

internal-state reasoning, and human-centered considerations such as trust and transparency. Looking ahead, emerging directions increasingly emphasize unified multimodal representations together with systems capable of continuous adaptation and evolution through interaction. Progress toward scalable intelligence is also likely to benefit from knowledge transfer across domains and embodiments, as well as generative approaches that support richer social understanding.

We express our sincere gratitude to all authors who contributed to this special issue, to the reviewers for their thoughtful evaluations and valuable feedback, and to the editorial team of Advanced Robotics for their continuous support. We also acknowledge the organizers, speakers, and participants of the NOC workshop series whose efforts continue to shape this growing research community. We hope this special issue contributes to advancing the long-term vision of cooperative intelligence in which humans and physical AI coexist and evolve within future hybrid societies.

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