

# Joint Cognition of Remote Autonomous Robotics Agent Swarms in Collaborative Decision-Making & Remote Human-Robot Teaming

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## **Abstract**

Human-out-of-the-loop (HOOTL)/Autonomy-in-the-loop (AITL) autonomous robotics agents (ARAs) are taking their indispensable places in our societies to achieve various missions. This trend is expected to increase exponentially thanks to the advancing cyber-physical systems (CPSs) and AI techniques. A diverse range of complex tasks (e.g. Search and Rescue (SAR), and transportation of a heavy load by multiple autonomous unmanned aerial vehicles (A-UAVs)) can be assigned to ARA swarms or ARAs can randomly come across in a social environment to execute pre-determined common tasks (e.g. collision avoidance at an intersection by ground autonomous vehicles (AVs)). The establishment of "joint cognition" is imperative to accomplish operations safely and optimally. "Joint cognition" while performing a jointly assigned/determined/shared task by respecting the pre-defined rules, is to i) gain intelligence of Digital Twins (DTs) of the environment (i.e. state and situation awareness (SSA) of other agents, and environmental dynamics), previously executed actuation of all agents in the group with respect to the Region of Interest (RoI), the capabilities of these agents, and their imminent and forthcoming actuation, ii) process this gained intelligence appropriately and iii) readily determine the next actuation to contribute to the overall agent group performance while focusing and accomplishing the particular assigned individual task, paving the way for achieving the final collaborative swarm goal safely and optimally. "Joint cognition" doesn't prioritise self-interest, rather, relinquishes short-term individual rewards for cumulative larger joint rewards (e.g., not causing collisions for other AVs while avoiding collision itself) to contribute to multiple objectives (e.g., overall carbon emission of all ARA swarms) of the swarm operations. ARAs should behave in a socially responsible way and human-in-the-loop (HITL) telepresence may be required to coordinate and telemanipulate them to accomplish tasks as desired with human-robot teaming by combining human and machine intelligence. In this treatise, this talk draws a methodological framework for the establishment of "joint cognition" of remote ARA swarms to support swarm performance. The proposed framework, which aims to increase trust in the self-determined behaviours of ARAs in meeting the joint swarm goals and expectations of societal stakeholders, has demonstrated the crucial phases of both understanding the behaviours of other agents and building "joint cognition" for remote ARA swarms to make them co-work effectively and efficiently in collaborative decision-making considering social dynamics, leading to socially responsible cyber-physical social systems (CPSSs).

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