Designing Interaction for Trustworthy Swarms

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Platform: DOTS[1]

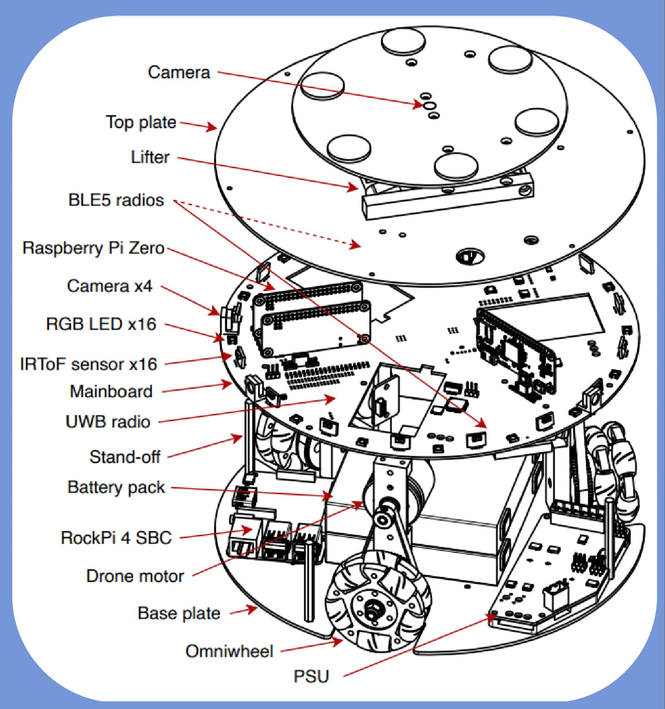
Our open access industrial swarm testbed, DOTS, sits at the centre of our research into swarm trustworthiness. This hardware platform allows us to consider, design, and test potential swarm use cases that closely parallel real-world swarm implementation in industrial settings.

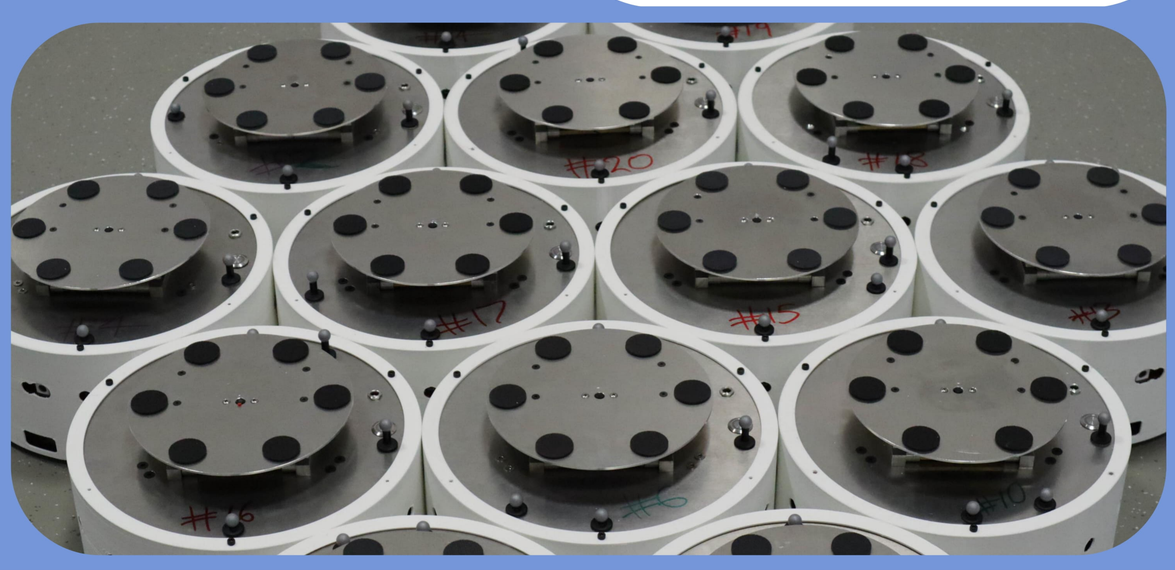
Test Arena Capabilities:

- Private 5G
- Motion capture
- Multiple cameras
- Openly accessible via an online portal.
- Platform-agnostic development pipeline.

DOTS Agent Capabilities:

Specification	Value
Diameter	250 mm
Height (Lifter Lowered)	145 mm
Height (Lifter Raised)	197 mm
Weight	3 kg
Lifter max Load	2 kg
Max velocity	2 ms^{-1}
Max acceleration	4 ms^{-2}
Wheel torque	0.35 Nm
Battery capacity	100 Wh
Endurance: All cameras enabled, moderate vision processing & movement	6 hours
Endurance: No cameras, minimal processing & movement	14 hours

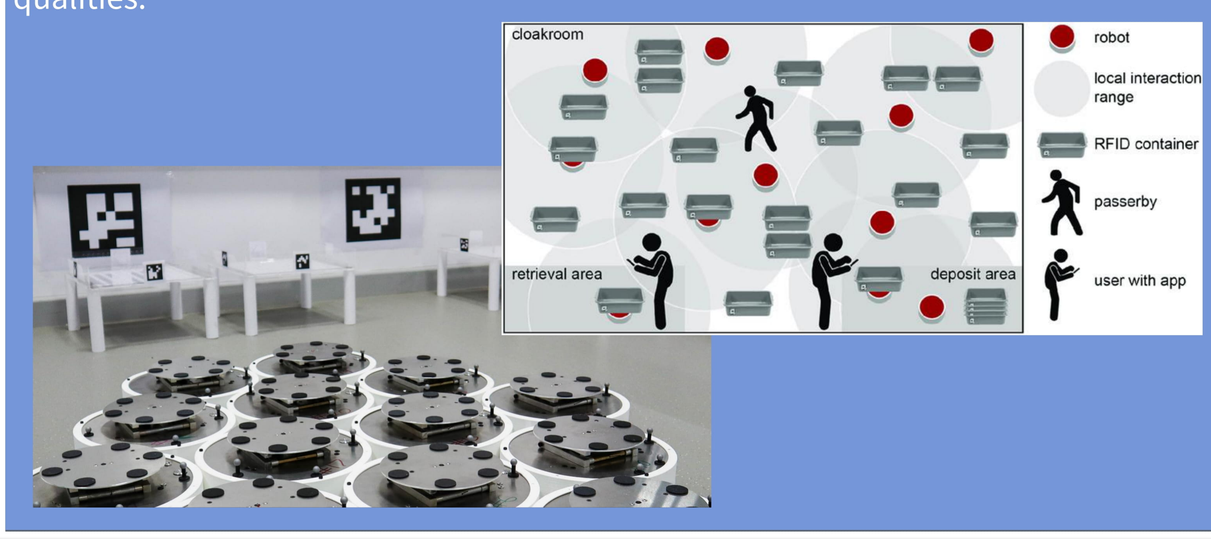




Swarm Interaction and Trust

Swarms of robots present many future opportunities in logistics, surveillance and exploration. Their robust and autonomous nature suits them well to out-of-the-box use by SME's (highlighted in our cloakroom use-case [2]). However, for swarms to be trusted and brought into common use, there is demand for monitoring of swarm activity, as well as some level of control over the swarm.

Our recent work looks to identify methods which provide operators with the control and information they need, while simultaneously preserving beneficial swarm qualities.



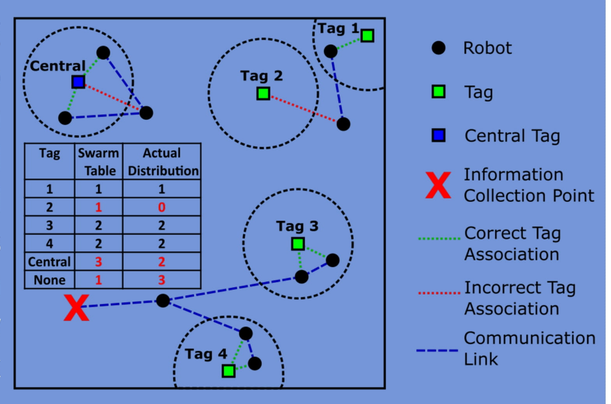
Challenges in Interaction

- **Cognitive overload** of the operator.
- Communication needs to remain **distributed.**

Interrupting a swarm with a new command can be detrimental. This is called **"neglect benevolence"**[5].

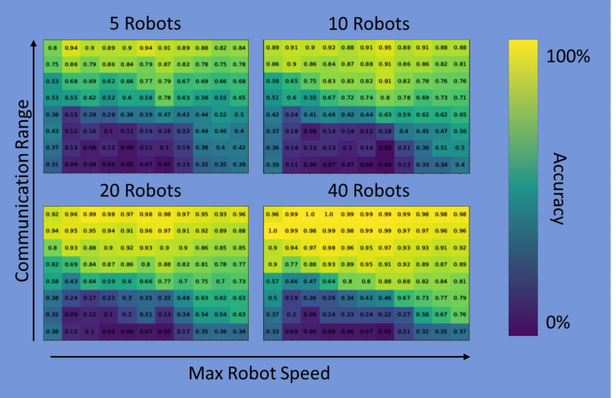
Information Extraction[3]

To address information extraction for SME use cases, we conducted experiments to identify the accuracy of information collected by the swarm, if it was collected and transported physically and transferred only by local interaction. This method diverges from traditional swarm information collection, which tends to rely on expensive infrastructure or complex agent networks.



We found:

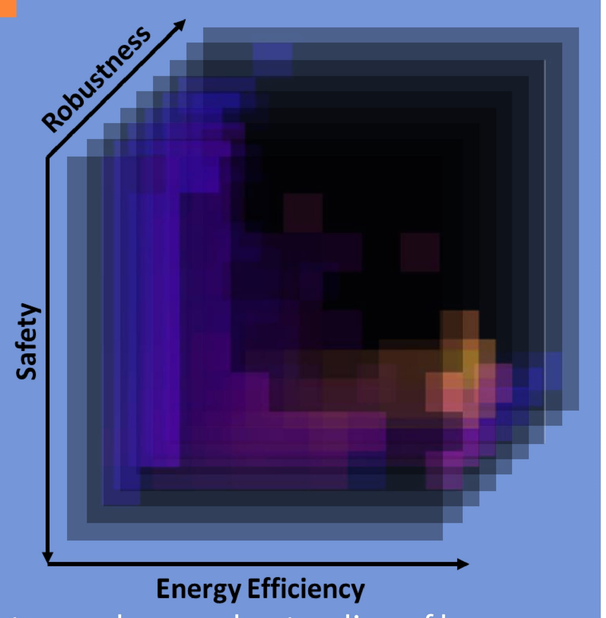
1. Added **swarm mobility** can compensate for **limited communication.**
2. Our **self-monitoring** swarm system scales well **from 5 to 40 agents**.
3. In particular scenarios with huge swarms or vast amounts of individual data, performance may suffer due to **memory constraints.**
4. Self-monitoring may be a viable means of creating a swarm that will encourage adoption from SME's.

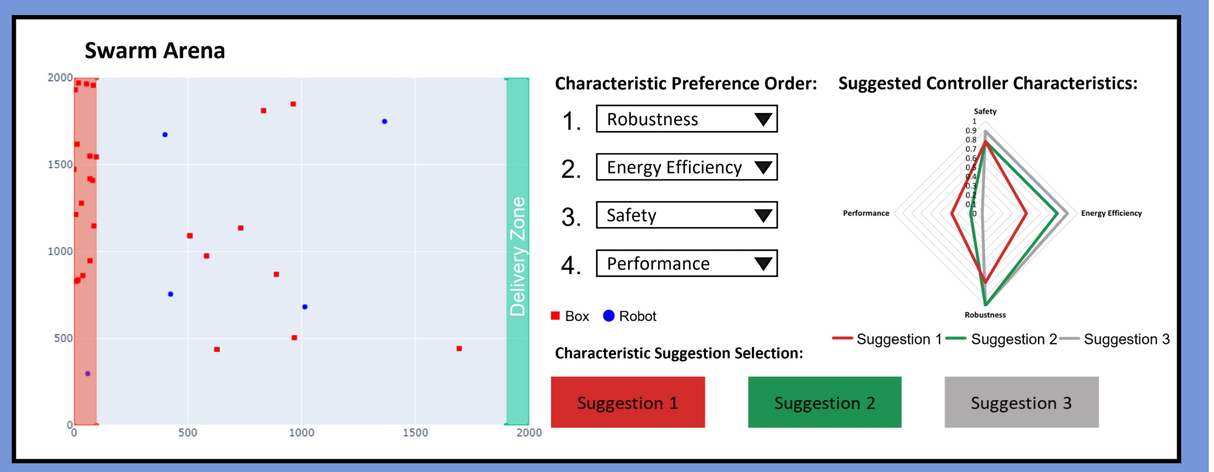


Swarm Operator Control[4]

To address the issue of control over multiple agents, we have designed a system that allow users to select preference for particular characteristics.

Using a method of search space illuminations, Map-Elites, we generate a multi-dimensional array of characteristics which relate to specific swarm parameters. We can then suggest parameter sets that provide the performance and characteristics closest to the user's specification. Thus, we create a system in which an operator can influence swarms towards preferential **behaviour**, without direct control over agents or a deep understanding of how parameters effect the behaviour. The image below illustrates how this interface might be implemented as we attempt to test this system via human studies.





References

[1] Jones, Simon, et al. "DOTS: An Open Testbed for Industrial Swarm Robotic Solutions." arXiv preprint arXiv:2203.13809 (2022).

[2] Jones, S., Milner, E., Sooriyabandara, M. and Hauert, S., 2020. Distributed situational awareness in robot swarms. Advanced Intelligent Systems, 2(11), p.2000110.

[3] Wilson, J., Hauert, S. Information transport in communication limited swarms. Artif Life Robotics (2022).

[4] Wilson, J., Hauert, S. Search Space Illumination of Robot Swarm Parameters For Trustworthiness (In Press).

[5] P. Walker, S. Nunnally, M. Lewis, A. Kolling, N. Chakraborty and K. Sycara, "Neglect benevolence in human control of swarms in the presence of latency," 2012 IEEE International Conference on Systems, Man, and Cybernetics (SMC), 2012, pp. 3009-3014

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