DroneSuite: Affordance-Based Hiearchical Active Inference for Autonomous Drones

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Autonomous drone navigation in GNSS-denied environments is challenging because conventional systems rely on rigid spatial representations, require environment-specific training, or are too computationally intensive for edge hardware. This has significant implications for applications such as disaster response and search-and-rescue, where cost-effective autonomous navigation without a prior environmental map is essential. DroneSuite addresses this through a training-free hierarchical active inference framework, a biologically-inspired probabilistic approach that unifies perception, memory, and planning under a single mathematical objective, continuously updating beliefs and selecting actions to minimize surprise. DroneSuite embeds affordance theory, the principle that environments encode opportunities for safe action, through a latent suitability state inferred from onboard LiDAR and depth-camera observations via a learned allocentric map that builds persistent spatial memory as the drone explores. This suitability belief forms a continuous heatmap encoding where traversal is safe and feasible, directly parametrizing Expected Free Energy (EFE) planning, filtering dangerous regions before evaluation and delegating computation where it matters. A recursive EFE algorithm selects waypoints balancing epistemic drive to explore uncertain areas with pragmatic drive toward the goal, while low-level sensorimotor control executes actions on a quadcopter. DroneSuite runs on a single-core consumer CPU, ensuring low deployment costs, and was evaluated across thousands of episodes, achieving 100% task completion in AirSim and approximately 99% in MockSim, with collision rates of 2% and 7% and computation under 71 ms per step.

Awards Won: