Innovations in swarm behaviors improve military force protection, firepower, precision effects, and ISR capabilities in urban operations

The United States military successfully launched what it's calling "one of the world's largest micro-drone swarms" in October. The Department of Defense, the Strategic Capabilities Office, partnering with Naval Air Systems Command, successfully demonstration consisted of 103 Perdix drones launched from three F/A-18 Super Hornets. The micro-drones demonstrated advanced swarm behaviors such as collective decision-making, adaptive formation flying, and self-healing.

"Due to the complex nature of combat, Perdix are not pre-programmed synchronized individuals, they are a collective organism, sharing one distributed brain for decision-making and adapting to each other like swarms in nature," said SCO Director William Roper. "Because every Perdix communicates and collaborates with every other Perdix, the swarm has no leader and can gracefully adapt to drones entering or exiting the team."

Earlier state controlled China Electronics Technology Group Corporation (CETC) created record by demonstrating swarm of 67 drones flying together, at the 11th China International Aviation and Aerospace Exhibition. The drones can fly in group to destroy targets. They can also been assigned with different missions if needed. Besides, the swarming drone system also has better survivability since the whole system will not been significantly affected by the loss of a small amount of drones.

Recent successful demonstrations that Swarm challenges are being overcome by advances in computer science, artificial intelligence, cognitive and behavioral sciences, machine training and learning, and communication technologies. Collaborative autonomy is an extension of autonomy that enables a team of unmanned systems to coordinate their activities to achieve common goals without human oversight. Autonomously coordinated unmanned systems may be capable of faster, more synchronized fire and maneuver than would be possible with remotely controlled assets. This trend will lead to a shift toward strategic decision making for a team of vehicles and away from direct control of any single vehicle.

On October 12, 2017 DARPA announced plans to to solicit ideas for a drone swarm system that could assist U.S. troops. The aim is to overcome the challenges of Urban canyons—with their high vertical structures, tight spaces, and limited lines of sight and dramatically increase the effectiveness of small-unit combat forces operating in urban environments, DARPA has launched its new OFFensive Swarm-Enabled Tactics (OFFSET) program.

The program, known as OFFSET, (OFFensive Swarm-Enabled Tactics), was launched in December 2016 with the goal of getting small-forces infantry to use “swarms of 250 robots or more to accomplish diverse missions in complex urban environments.”

Pentagon successfully tests world’s largest micro-drone swarm

“I congratulate the Strategic Capabilities Office for this successful demonstration,” said Secretary of Defense Ash Carter, who created SCO in 2012. “This is the kind of cuttingedge innovation that will keep us a step ahead of our adversaries. This demonstration will advance our development of autonomous systems.”

The demonstration is one of the first examples of the Pentagon using teams of small, inexpensive, autonomous systems to perform missions once achieved only by large, expensive ones. Roper stressed the department’s conception of the future battle network is one where humans will always be in the loop. Machines and the autonomous systems being developed by the DoD, such as the micro-drones, will empower humans to make better decisions faster.

As SCO works with the military Services to transition Perdix into existing programs of record, it is also partnering with the Defense Industrial Unit-Experimental, or DIUx, to find companies capable of accurately replicating Perdix using the MIT Lincoln Laboratory design. Its goal is to produce Perdix at scale in batches of up to 1,000.

Challenges for Swarm robotics

Many of applications like improved disaster response and unique vehicles for transportation are still stuck in the lab or still in concept phase. The main factors holding back swarming robotics are the stigma of widespread robots, the lack of reliable communications, readily available distributed algorithms, and the cost of individual robots. However, these are quickly changing and the concerns can be mitigated by designing safeguards into these complex systems, writes Jason Ernst, PhD Candidate, CS, is the CTO of Redtree Robotics. The sensors, cameras, motors and other parts that make the robot work are all expensive, however the scale of mobile phones have made some of the key sensors like accelerometer, gyroscope, GPS have become insanely cheap.

The robots need to exchange positions, direction of motion, pitch, yaw, roll, and they may need to also keep track of information about the task they are solving, there is a lack of coordinated algorithms readily available writes Jason.

In turn, holding back the development of coordinated algorithms is the lack of reliable, robust communications between robots. For swarm to become a reality, robots must communicate with each other directly, in addition to communicating to the Internet. This means local meshes must be setup between robots. The communications stack must be smart enough to determine if it should use local meshes or external Internet communications to reach other robots or the Internet.

In addition, since the information being exchanged between robots may affect critical systems and prevent crashes and other dangerous behavior, the communications should use either redundant technology (several Wi-Fi cards, or a variety of communication tech – satellite, Bluetooth, UHF/VHF, 4G/LTE, etc.

The last, and perhaps most troublesome, is the fear people have of the robot revolution, Many people in manufacturing are afraid of losing their jobs, and people are becoming downright afraid to even imagine a future with robots as core enabling technology.

The drones for military missions face additional challenges

Originally designed by Massachusetts Institute of Technology engineering students, the Perdix drone was modified for military use by the scientists and engineers of MIT Lincoln Laboratory starting in 2013. Drawing inspiration from the commercial smartphone industry, Perdix software and hardware has been continually updated in successive design generations. Now in its sixth generation, October’s test confirmed the reliability of the current all-commercial-component design under potential deployment conditions—speeds of Mach 0.6, temperatures of minus 10 degrees Celsius, and large shocks—encountered during ejection from fighter flare dispensers.

“The key is a modular UAV that can easily accept different payloads depending on which missions are desired and can be produced cheaply enough that they are one-way.” Adaptability is important because different payloads are required for different types of mission: the drones may be equipped with video cameras or other sensors, jammers to interfere with enemy radar or they might carry explosive warheads for kamikaze-style attacks. In defensive mode, a swarm can form a protective cordon against fleets of fast boats like those used by Iran’s Revolutionary Guard. The swarm might carry out high-risk reconnaissance missions, collecting imagery or other data from targets too well-defended for a Predator drone or a manned aircraft to approach, explains Lee Mastroianni, project manager of LOCUST.

Managing the swarm requires a new approach to control: instead of remotely piloting a single drone, the operator manages the swarm. He describes how the operator’s interface will handle “aggregation” and “disaggregation”, his terms for drones joining or leaving the swarm. A single drone might detach to get a closer look at a target, and return or carry out an attack.

Battery life is a big issue for small drones. But a swarm can have a “hive”, a base station where individual drones return for recharging while the rest continue their mission. To the operator, unaware of charging going on in the background, the swarm’s endurance is unlimited. This approach is relatively easy for fixed bases; Stephen Crampton, CEO of Swarm Systems says a mobile hive for soldiers on patrol is more challenging.

Mastroianni says the biggest challenges for the swarm are not technical, but more based on perception: safety policies treat unmanned aircraft as if they are manned, meaning that they are highly regulated. “Establishing trust in autonomous UAV systems is not only the biggest challenge, but a major objective,” Mastroianni says. Swarms at sea are a start, but the real impact will be when they engage in land warfare. Stephen Crampton, CEO of Swarm Systems, says the cluttered environment where drones have to avoid trees, buildings and power lines is far more difficult than open water. Autonomous sense-and-avoid for small drones is still in its early stages, but as processors get more powerful, it is becoming more reliable. Crampton says that other advances such as deep learning and neural networks also offer potential solutions and the technology is advancing rapidly.

DARPA OFFSET program is Seeking ideas for Drone Swarms to Assist Troops

Urban canyons—with their high vertical structures, tight spaces, and limited lines of sight—constrain military communications, mobility, and tactics in the best of times. These challenges become even more daunting when U.S. forces are in areas they do not control—where they can’t rely on supply chains, infrastructure, and previous knowledge of local conditions and potential threats.

Unmanned air vehicles (UAVs) and unmanned ground vehicles (UGVs) have long proven beneficial in such difficult urban environs, performing missions such as aerial reconnaissance and building clearance. But their value to ground troops could be vastly amplified if troops could control scores or even hundreds—“swarms”—of these robotic units at the same time. The prime bottleneck to achieving this goal is not the robotic vehicles themselves, which are becoming increasingly capable and affordable. Rather, U.S. military forces currently lack the technologies to manage and interact with such swarms and the means to quickly develop and share swarm tactics suitable for application in diverse, evolving urban situations.

To help overcome these challenges and dramatically increase the effectiveness of small-unit combat forces operating in urban environments, DARPA has launched its new OFFensive Swarm-Enabled Tactics (OFFSET) program. OFFSET seeks to develop and demonstrate 100+ operationally relevant swarm tactics that could be used by groups of unmanned air and/or ground systems numbering more than 100 robots. These swarm tactics for large teams of unmanned assets would help improve force protection, firepower, precision effects, and intelligence, surveillance, and reconnaissance (ISR) capabilities. OFFSET plans to offer frequent opportunities for engagement with anticipated end users in the U.S. Army and U.S. Marine Corps and would share successfully tested swarm tactics with them on a rolling basis.

“With the technologies and tactics to be developed under OFFSET, we anticipate achieving a deeper understanding of how large numbers of increasingly autonomous air and ground robots can be leveraged to benefit urban warfighters,” said Timothy Chung, DARPA program manager. “We aim to provide the tools to quickly generate swarm tactics, evaluate those swarm tactics for effectiveness, and integrate the best swarm tactics into field operations. If we’re successful, this work could also bring entirely new scalable, dynamic capabilities to the battlefield, such as distributed perception, robust and resilient communications, dispersed computing and analytics, and adaptive collective behaviors.”

To accomplish these goals, OFFSET seeks to develop an active swarm tactics development ecosystem and supporting open systems architecture, including:

- An advanced human-swarm interface to enable users to monitor and direct potentially hundreds of unmanned platforms simultaneously in real time. The program intends to leverage rapidly emerging immersive and intuitive interactive technologies (augmented and virtual reality, voice-, gesture-, and touch-based) to create a novel command interface with immersive situational awareness and decision presentation capabilities. The interface would also incorporate a swarm interaction grammar, similar in concept to playbooks coaches in soccer, basketball, and other games prepare with pre-made plays combined with "freestyle" design tools that allow dynamic action and reaction based on real-time conditions in the field.

- A real-time, networked virtual environment that would support a physics-based, swarm tactics game. In the game, players would use the interface to rapidly explore, evolve, and evaluate swarm tactics to see which would potentially work best on various unmanned platforms in the real world. Users could submit swarm tactics and track their performance from test rounds on a leaderboard, as well as dynamically interact with other users.

- A community-driven swarm tactics exchange. This curated, limited access program portal would house apps to help participants design swarm tactics and combine collective behaviors, as well as swarm algorithms. It would provide these key ingredients to an extensible architecture for end-user-generated swarm tactics and help create a lasting community to innovate and cultivate the most effective tactics, with the potential to integrate third-party tactics and playtesters in the future.

- OFFSET aims to demonstrate its technologies through frequent live experiments with various unmanned air and ground platforms. Every six months, operational vignettes of progressively increasing complexity would challenge both the swarm architecture and the developed swarm tactics across numerous technological and

> operational test variables, such as swarm size, proportion of air and ground platforms, and mission duration. Users would employ the swarm interface to test the best of the virtual tactics in the real world, and interactively supply their unmanned platforms with near-real-time tactics updates using automated deployment technologies.

“We’re interested in developing practical swarm systems in an agile way, so future operators will have the tools they need to outsmart and outperform urban adversaries,” Chung said.

A team of autonomous quadcopters can now work together without crashing.

One of the challenge for implementing large swarm of drones is avoiding crashes. Even gentle touching or getting in the airflow of another quadcopter lead them to crash. But now, researchers at Georgia Institute of Technology have found a way to fix this by implementing a “barrier certificate” around each quadcopter. It works like a forcefield that rejects any other quadcopter that gets too close. As soon as one quadcopter flies within range, it reroutes to move away and continues peacefully on its way.

While this combats the collision problem, researchers also had to solve the air flow problem. They gave each quadcopter a two feet tall “top hat” to make sure they can’t undercut another quadcopter and mess with its air flow.

“Safety bubbles” and “top hats” together now allow groups of quadcopters to swarm without the aid of human operators. So now instead of worrying about just one rogue quadcopter, we can worry about entire teams of them.

Textron’s Synturian family of multi-vehicle control and collaboration technologies

The Synturian family of products includes two main product lines: Synturian Control and Synturian Remote. Synturian Control is a multi-platform, multi-vehicle, multi-domain control system that enhances collaboration and dissemination of information. Synturian Remote includes mobile, network-strengthened tools that enhance situational awareness through timely information and collaboration.

The Textron systems can control multiple aircraft, ground and maritime and vessels or vehicles at a onetime including Army Shadow, Hunter and Gray Eagle Unmanned Aerial System (UAS). The Textron systems is compliant with NATO standardization agreement (STANAG) 4586 and configurable with the S-788, S-280 and Conex shelters as well as shipboard environments.

The Textron control station features are command and control, payload control and weapons control capabilities. Scalable, modular and intuitive, the Synturian system delivers situational understanding to the point of action. Built around a service-oriented architecture for rapid capability integration, users can access new capabilities with plugand-play simplicity through the universal interface. This gives users the same experience across controlled assets, with a map-centric view that brings mission information forward while platform status is automated in the background.

Synturian Remote has successfully demonstrated its remote terminal capabilities with Shadow, Aerosonde, and Textron Aviation’s special missions platforms.

The iCommand suite is a battlespace management system that links people, platforms and payloads in a real-time and highly intuitive, integrated experience. iCommand is a Integrated

Command Suite which delivers superior command and control technology. ICommand harnesses real time data fusion to provide synchronized C2 across manned and unmanned systems, unparalleled operational pictures for decision makers and provide touch screen speed for contingency planning, decision making and asset management. The iCommand suite links people, platforms and payloads in real time.

The RemoteView Pro is comprehensive imagery analysis capabilities which can quickly find, interpret and annotate items of interest. The RemoteView Pro includes toolsets for imager and multi-image analysis, centric graphical user interface (GUI) and customizable streamlined navigation and workflow-aligned toolbars and profiles. The Unmanned Aerial Vehicle (UAV), Ground and Maritime collects imagery and information, the RemoteView software allows tactical teams to interpret and analyze the information collected.

References and resources also include

- https://www.defense.gov/News/News-Releases/News-Release-View/Article/1044811/department-of-defense-announces-successful-micro-drone-demonstration
- http://www.dronestakedown.com/home/control-station-analysis
- http://www.popularmechanics.com/military/research/a24494/chinese-drones-swarms/
- http://www.roboticstrends.com/article/4_challenges_holding_back_swarm_robotics
- http://www.wired.co.uk/article/drone-swarms-change-warfare
- https://www.darpa.mil/news-events/2016-12-07