DroneGraffiti: Autonomous Multi-UAV Spray Painting

Anastasia Uryasheva
Tsuru Robotics / Skolkovo Institute of Science and Technology
au@tsuru.su

Mikhail Kulbeda
Skolkovo Institute of Science and Technology
mikhail.kulbeda@skoltech.ru

Nikita Rodichenko
Tsuru Robotics
nsr@tsuru.su

Dzmitry Tsetserukou
Skolkovo Institute of Science and Technology
d.tsetserukou@skoltech.ru

ABSTRACT

With advances in robotics and digital arts, new ways for artwork execution emerge. One such way is mural or graffiti drawing by flying robots [Katsu 2018; TsuruRobotics 2018; Vempati et al. 2018]. This is itself a novel approach, which only recently gained traction and moved to full or partial autonomous operations. Key hurdles of drone graffiti are complicated system setup and a long painting process, associated with that only one drone is available at a time. Here we present a multi-drone graffiti dispatch system tested on up to three actual aerial robots operating simultaneously in real-time. The developed task dispatch system proved to be robust and effective. Although the proposed system and approach is best demonstrated by artistic applications, it can be transferred to commercial applications that need precise aerial vehicle operation, such as commercial painting, cleaning, and non-destructive control.

Figure 1: Autonomous Graffiti Drone by Tsuru Robotics.

CCS CONCEPTS

• **Computer systems organization → Robotics**;

KEYWORDS

dispatch system, unmanned aerial vehicle, drone, quadcopter, graffiti, spray paint, autonomous system

ACM Reference format:
Anastasia Uryasheva, Mikhail Kulbeda, Nikita Rodichenko, and Dzmitry Tsetserukou. 2019. DroneGraffiti: Autonomous Multi-UAV Spray Painting. In *Proceedings of SIGGRAPH '19 Studio, Los Angeles, CA, USA, July 28 - August 01, 2019,* 2 pages.
https://doi.org/10.1145/3306306.3328000

1 INTRODUCTION

There are several single drone-based paint deposition systems available in production and research versions [Apellix 2017; Galea et al. 2016; Vempati et al. 2018], and there is already an established mode of operation for such systems. Current systems use different power and paint sources, and the choice depends on both the environment and task at hand.

Free-fly systems are tailored towards use in challenging locations and environments like high buildings, with hard-to-reach spots [TsuruRobotics 2018]. Such systems are also more open to the art community, as they allow for use of existing off-the-shelf spray paint systems.

Tethered systems are limited by operations in the vicinity of the base unit, which provides power, paint, or both [Apellix 2017; Vempati et al. 2018]. Such systems generally do not require paint refill between flights.

Although such systems are developing rapidly, one of key limitations of such systems holds, i.e., task execution is still quite slow and requires hours or even days to complete large murals. The artist simply can't create tens of square meters mural with one drone, without spending much time and efforts.

In this work we develop a multi-drone system built upon a field-proven single-drone graffiti system, which has been extensively used both indoors and outdoors, including complicated scenarios, such as executing larger murals on tall unprepared buildings.

Previously developed single-drone system used a centralized approach, with a single dispatch server. Such architecture allowed for live system management, including drawing parameter tweaks, online image generation and tweaking, user-driven task management, and advanced fail safe modes. Server GUI also included a real-time task plan visualization, and a simulation engine for off-line testing and flight plan validation.

2 MULTI-DRONE ARCHITECTURE

Current multi-drone dispatch system is centralized, meaning that there is a single computation engine handling all of the agents and tasks. In addition to the task allocation, the system observes current agent positions and handles collision avoidance, optimal curve selection. Each flight task consists of a single drawable curve and a transition path for agent to reach the starting point of the curve. Upon completion of each task the dispatch system allocates

SIGGRAPH '19 Studio, July 28 - August 01, 2019, Los Angeles, CA, USA

ACM ISBN 978-1-4503-6316-7/19/07.
https://doi.org/10.1145/3306306.3328000

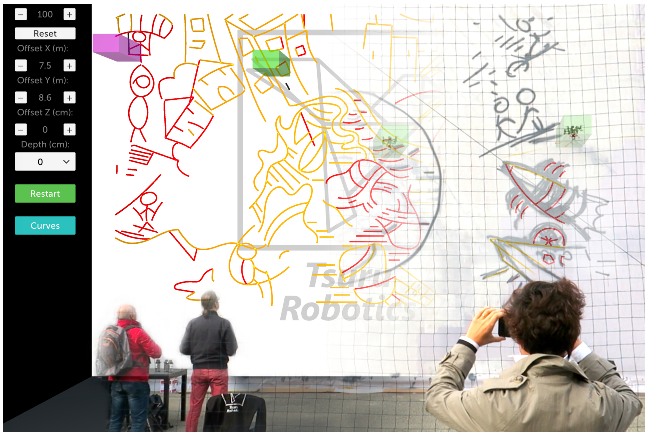

Figure 2: Photo from a live multi-drone test with superimposed dispatch software user interface. Color cubes depict agent positions in dispatch system.

a new task that can be safely executed. A dynamic intersection map is calculated after completion of a task by any of the agents. Current dispatch system is able to work with up to 255 agents, and it is possible to dynamically add and remove agents at any time. Such continuous addition or removal of agents can be used for maintenance purposes during longer installations. If there are no available tasks to execute, the agents are idling for some set amount of time until either a task becomes available, or a timeout occurs. In the latter case the drone lands to free up space for other agents.

3 TASK DISTRIBUTION AND DISPATCH

3.1 Simple greedy algorithm

Greedy algorithm was chosen as the basic algorithm for selecting the order of curves to draw by a group of drones. Although it's not the most effective method, it has a list of advantages and works well for a small number of drones and curves. After implementation and testing the greedy algorithm with more than 2 drones we encountered a set of problems, with deadlock being the most prominent.

Deadlock is a situation when most of the agents are idling indefinitely, and cannot be assigned a task as all of the remaining curves are blocked by other agents. Usually concentration of such curves occurs near the center of the canvas.

3.2 Parametric greedy algorithm

To improve task distribution and potentially to reduce deadlock situations we use a modified parametric greedy algorithm defined using potential fields for each drone position and each moment in time. The potential field is calculated for each agent and each possible curve to be drawn, and takes into account proximity to the edges of the canvas and to the canvas corners. The weight of each contributing parameter is added to the whole field, and defines the priority of tasks to be assigned to each agent at each point in time in each physical location.

Examples of parameters used to calculate the potential field are as follows:

- distance from current drone to curve start (attraction),
- distance to other agents (repulsion),
- distance to currently drawn curves (repulsion),
- distance to edges of the canvas (repulsion or attraction),
- distance from ground (repulsion).

Using these and other parameters allows for control of high-level drone behaviour and for influencing task distribution between agents.

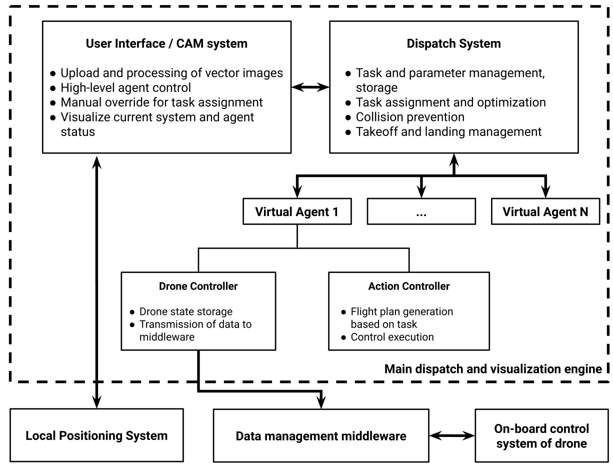

Figure 3: High-level dispatch system diagram.

4 CONCLUSION AND FUTURE WORK

Having established a framework for choreographed drone graffiti dispatch systems, we plan to continue pushing the envelope on multi-drone operations. Mural application was always considered manual labour, and we think that advances in robotics and autonomous systems can make this task cheaper and safer, while achieving similar or even better results than if done by human.

Presented technology can also be applied to different tasks or industries, where precise and scalable local navigation of robotic systems is required, such as non-destructive control and cleaning.

ACKNOWLEDGMENTS

The authors would like to thank Istituto Superiore Mario Boella (ISMB) for providing a 2D canvas positioning system and organizing the tests and Carlo Ratti Associati for creative input and artistic curatorship during this project.

REFERENCES

Apellix. 2017. Painting drone. https://www.apellix.com/. (2017).

B. Galea, E. Kia, N. Aird, and P.G. Kry. 2016. Stippling with aerial robots. *Proceedings of the Joint Symposium on Computational Aesthetics and Sketch Based Interfaces and Modeling and Non-Photorealistic Animation and Rendering* (May 2016).

Katsu. 2018. Autonomous graffiti. https://www.instagram.com/katsubot/. (2018).

TsuruRobotics. 2018. Autonomous Mural for Sprite Ukraine. https://tsuru.su/en/project/spritemural/. (2018).

A.S. Vempati, M. Kamel, N. Stilinovic, Q. Zhang, D. Reusser, I. Sa, J. Nieto, R. Siegwart, and P. Beardsley. 2018. PaintCopter: An Autonomous UAV for Spray Painting on 3D Surfaces. *IEEE Robotics and Automation Letters (RA-L) 2018* (Oct. 2018).