Clothes design using micro-UAVs

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***Abstract*— The project proposed in this paper merges art and technology to create a reality in which a swarm of small unmanned air vehicles (UAVs) can cooperatively dress a human. This swarm manipulates clothing by interpreting the movements of the human subject, where the actions of each UAV are decided independently by the collective consciousness of the swarm. To preserve the gracefulness of the manipulations, the members of the swarm must be small and unobtrusive. Despite the limitations associated with small drones that have limited carrying capacity, we have demonstrated in a set of experiments that we can successfully use a swarm of micro-UAVs to collaboratively transport a piece of fabric.**

I. INTRODUCTION

Small-scale aerial technologies are potentially an effective solution for transport tasks in industrial, commercial, and medical applications. As new use cases emerge, the carrying capacity remains the main limitation for their implementation. A fashion designer presented quite a novel use case to our team: to involve micro-UAVs in the domestic task of getting dressed. This proposal is challenging at many levels, namely: interaction, clothing design, and UAV control. The UAV control aspect is made significantly more difficult as the micro-UAVs must transport flexible pieces of clothing. In this paper, we make progress towards a solution by demonstrating the capability of a micro-UAV swarm to transport fabric. The small devices can cope with the proximity of human subject and the narrow space of a dressing room. However, a decrease in size tends to considerably decrease the carrying capacity of the UAV. We propose to base our solution on the use of multiple micro-UAVs that collaborate to accomplish the transport task, as shown in Fig. 1.

The nature of the payload in this context is itself a challenge for aerial transport. A flexible material supported from many points creates complex dynamics between the carriers [1]. A solution to this problem can be generalized to many other useful applications: supporting a net to catch other UAVs, transporting hoses to drop water over fires, and carrying slings for rescue missions on mountains have comparable dynamics with larger payload requirements. Nets, fabrics, hoses, and slings, can all be approximated with one or many deformable linear objects (DLOs).

Today, smart clothing typically incorporates tools and computers into that require the active participation of the user. On the contrary, our interactive clothes will become real interlocutors: they are more than prostheses, because they will transcend their instrumentation. This is a new perspective for the study of robot-human interaction. The UAVs, together with the clothing, create an entity capable of autonomously making decisions based solely on its environment and the movements of the human with which it is interacting. This type of robotic companion can be of great help in daily tasks, mainly for people who are not autonomous or who are losing their independence, a concern shared by many specialists [2]. The project aims at studying the subject's perceptions and interaction modalities with a surrounding decentralized fleet interacting within their sphere of intimacy.

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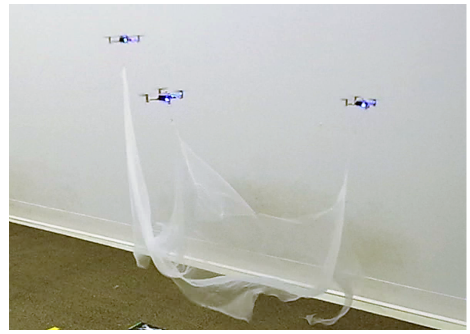

Fig. 1: Three Crazyflie micro-UAVs collaborating to transport a white fabric without requiring any central controller.

II. ARTISTIC CONCEPT

A swarm of drones carrying textile materials enable us to produce autonomous and transformable clothing. The project defines a structured methodology for inter-sectoral collaboration. This project is a platform for innovation in the areas of distributed intelligence, human-computer interaction, clothing design, and sensor networks. The solution to the problem will materialize in the development of a software system architecture and in the creation of completely original clothes. The sensitivity of the micro-UAVs, together with the transported textile materials, enable us to create animated clothing objects shaped by the human subject, and the immediate environment. Thanks to the perception of the inertial dynamics (accelerometers and gyroscopes) and sound (microphones) of the system's environment, the life-like clothing can act, or react, by manipulating its configuration in space. The intent is for the subject to gradually realize that his or her physical presence and movements modify these clothing objects, as if he or she had the power to move them by the mere fact of being there.

Ultimately, this project is meant to be shown into contemporary art galleries and toured around the world. Therefore, the system must depend on embedded sensors (optical flow, broadband communication, inertial and laser) [3].

These swarm clothes have the mission to depict the "possible universes" described by the art critic Nicolas Bourriaud [4], which are inspired by the concepts of the philosopher Edgar Morin [5]. According to Morin, there is competition between the logic of individual organisms, which aspire to autonomy, and that of the ecosystem. This relationship is also complementary: the ecosystem needs individuals, who in turn need the ecosystem. In this spirit, Bourriaud describes critical design as a social interstice whose function is to reveal "the possibilities of the life " [4]. If, formerly, art "was to prepare and announce a future world", Bourriaud says he prefers to adopt the more modest ambition of "modelling possible universes". The garment subject of this research is not *used* by the human subject, but rather it defines a "clothing environment" which incorporates them: its look, its breath, its movements, all these presence attributes activate the clothes; The result is a sort of call and reaction that creates an undulatory dialogue. This project probes these relationships. Bourriaud studies how perception evolves, how the object acts and reacts to transform itself, to become something else. The ecosystem of these possible universes modifies our relationship with reality, time, and space, using notions such as ubiquity, immediacy, and networks. From the development of the pattern up to prototyping, robotics will influence the phases of this sartorial creation project. The garment thus becomes the place where the technology and fashion creation flows meet.

III. EXPERIMENTS

A. Weight limit

From the specifications of the Crazyflie micro-UAV, each quadcopter is able to lift 42 g including its own weight (27 g), which leaves 15 g for payload and a reflective marker. We conducted our own experiments to test the specifications provided by Bitcraze, the manufacturer of the Crazyflie. Using a digital spring scale with a resolution of 1 g, we took 5 measurements of the maximum payload, and each measurement yielded 18 g. This is a promising result that suggests that just a small team of Crazyflies can bring life to an article of clothing. In fact, this was shown to be possible in our experiments.

To test a potential control algorithm, we completed the feedback loop using our motion sensing platform. Normally, each robot in the arena should have a unique configuration of reflective markers so that the sensing platform can recognize each robot. The size and limited carrying capacity of the robots did not allow for many configurations, and so we devised an unorthodox method to have a swarm of Crazyflie micro-UAVs to be seen and distinguished by the motion sensing platform. Our solution was to attach a single marker on each Crazyflie, which provides the position of the UAV in 3-D space, but not the orientation. We are able to control the attitude of the Crazyflie with its Inertial Measurement Unit. To have the robots be uniquely identifiable, we tell the software approximately where each Crazyflie is expected to start, and conduct a grid search before takeoff [6]. For the duration of the flight, we make the reasonable assumption of continuous motion of the Crazyflies. This way, the software can identify which robot is which, based on the previous frame.

B. Flight Tests

We implemented decentralized scripts in a swarm-oriented programming language, Buzz [7], for two collaborative fabric transport algorithms. We conducted 11 flight tests, each involving three Crazyflies. The first of these tests demonstrates the flight of the three Crazyflies without any payload nor any control algorithm to maintain a fixed distance between robots. Five of the flight tests demonstrate the transport of fabric using a spring-damper algorithm, and the last five demonstrate the transport of fabric using the Lennard-Jones algorithm. In each flight test, the Crazyflies were instructed to take off from slightly elevated platforms to 80 cm and maintain this altitude while travelling horizontally at constant velocity. For the tests involving the transport of fabric, one of the corners of the fabric was manually tied to each Crazyflie with fishing line before takeoff.

The experiments show that the spring-damper and Lennard-Jones algorithms do in fact allow the robots to maintain safe, stable distances with similar efficacy. In comparison to the flight test with no control algorithm, we found that the cooperation between robots was significantly enhanced when these control algorithms were employed in the flight tests. We successfully tried the same algorithms with four micro-UAVs, as shown in the attached video.

IV. FUTURE WORK

The integration of every aspect of the project (computer science, software engineering, and art) will ultimately force the design and iterative development of the interactive potential of the system. The perception of a human subjects' intentions in a system composed of simple and distributed sensors is still unexplored. It is through this type of project that the sound, ethical, and thoughtful integration of everyday automation can be generated.

This work is a first step along the way to having a safe fleet of micro-UAVs to dress a human. The decentralized approach was demonstrated to work well for such a scenario. Leveraging Buzz, other decentralized behaviours will be tested along the way for creating an autonomous flying dressing aid. In the future, we will try various shapes of clothing designed specifically to be transported with micro-UAVs. We will also work on enhancing the robustness of the algorithm and on adding infrared proximity detection to better allow the subject to interact with the system.

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