Blimpy - an artistic framework for creating a spatial augmented reality experience with helium blimps

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Abstract

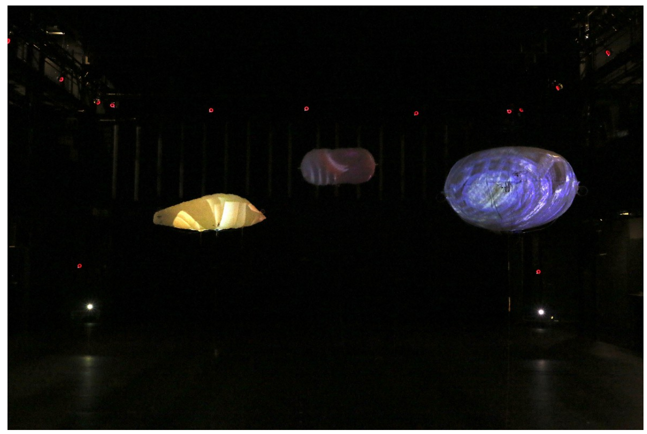
Drone technology combined with spatial augmented reality software provides novel opportunities in the creation of immersive audiovisual performances and installations. The Blimpy project leverages these opportunities by developing a spatial augmented reality experience built around helium devices, which are ideally suited for this application, to explore future research questions on the formal aesthetics and interaction between autonomous agents, people and physical spaces. This paper introduces the framework, which has evolved from the Blimpy project and provides encapsulated components dealing with the technical challenges arising in the creation of such experiences. The framework is designed to be transparent to artists and people whose sole interest lies in the creation of audiovisual performances and has been implemented at the Immersive Arts Space of the Zurich University of the Arts for verification and experimentation. The design of an interdisciplinary workshop employing the framework and Immersive Arts space will further leverage the interaction between researchers and students.

Keywords

SAR, helium balloons, 3D audiovisual mapping, drone, blimp, artistic research, autonomous agents, iot kit

Introduction

The idea of Spatial Augmented Reality (SAR) has been around for more than 20 years [1]. When compared to Augmented Reality (AR), which has become ubiquitous through smartphones over the last decade, the adoption of SAR has been limited because of its technical complexity and required resources. For the use of SAR, where graphics are projected on (potentially) moving objects, a precise and low latency motion capture system, projectors with low input-lag, and powerful graphics hardware are required to create effective real-time audiovisual immersive experiences. SAR has therefore mostly been an academic endeavor with explorations in research experiments [2]. However, continuing technological advances accompanied by cost reduction, especially the affordability of high-performance graphics cards, make SAR attainable for a larger community. At the same time, the release of powerful open source software for 3D audiovisual projection



Picture 1. The picture depicts three helium blimps in the Immersive Arts Space of the Zurich University of the Arts. The blimps are tracked with motion capture cameras (red lights surrounding the blimps) and projected onto with projectors in each corner of the space (white lights a the bottom).

mapping [3], which handles multiple render passes, transformation hierarchies and projector calibration, provides potent and accessible tools and reduces the technical overhead for the community of artists and creative technologists. In combination, this is finally opening up SAR to the field of artistic research [4][5].

Parallel to this development, a new breed of light shows have emerged based on swarms of multi-rotor vertical take-off and landing drones, commonly referred to as quadrocopters. Sophisticated proprietary hardware and software has been developed to control these drone swarms and their lights in 3D space accompanying music and/or artists performances. Several companies have specialized in this field operating on different venues, indoors and outdoors, and create shows with hundreds (and sometimes even thousands) of individual drones [6][7].

Yet in the context of SAR the potential of these drones is limited since they provide little surface area to project onto owing to their physical simplicity. While it is possible to increase the surface area by enhancing drones with additional physical entities [8], the downside is shorter flight time due to their increased payload. Instead, helium blimps have been recently adopted as an alternative to the highly dynamic drones seen in light shows [9][10][11]. Due to the lifting property of helium large physical entities ideally suited for projection mappings are conceivable, which in addition are inherently more safe and offer longer flight times when compared to drones .

The aim of this paper is to introduce Blimpy, a framework for the realization of immersive spatial augmented reality experiences with autonomous helium blimps. The framework allows artists and designers to develop their own creative language by designing the blimps' shape, behavior and the audiovisual content for the overall appearance. It is designed to be mostly transparent to those creatives that prefer to focus on aesthetic aspects, but approachable for those that wish to engage with the technical details. In addition, it functions as a teaching platform that introduces different skills and techniques required for the creation of such complex spatial augmented reality experiences with moving objects. The software and design resources of the Blimpy framework is publicly [12] available to open the framework to the community for experimentation and creation of immersive spatial augmented reality experiences.

In the following paragraphs, the core elements of the Blimpy framework are described together with the main technical challenges and related solutions.

Blimpy framework

Considering the project's requirements, the following core modules were identified that need to work together: the helium blimps, a manager, a motion capture system, the Spatial Augmented Reality software and client application(s), see Figure 1.

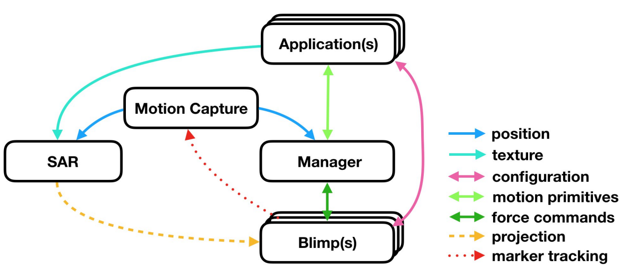
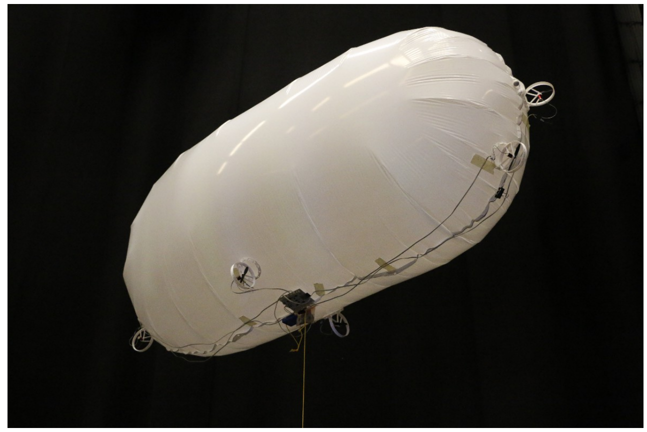


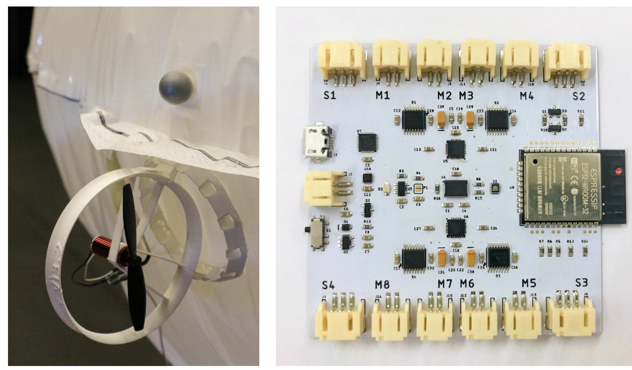
Figure 1. This diagram provides an overview of the Blimpy framework's core components and their interplay.

Helium Blimps

The helium blimps embody physical entities in different shapes, which can be choreographed to move in space and



Picture 2. The helium blimp in this picture is equipped with 6 motors to allow full actuation in its 6 degrees of freedom. The battery and control board are installed at the bottom of the blimp.



Picture 3. The picture on the left shows an actuator of the blimp. The grey ball on top is a marker for the motion capture system. The picture on the right shows the controller board, which can control up to 8 DC motors with propellers and 4 servo motors.

provide diffuse surfaces for the projections. This requires following four main components: 1) a helium balloon, 2) a controller board for receiving commands and controlling actuators, 3) actuators for propulsion, and 4) a battery for power supply. One such blimp is depicted in Picture 2.

In the spirit of creating a framework attainable for a large community, care was taken in the design of these components to allow a fast transition from envisioning a certain blimp design to the actual implementation with no prior knowledge.

The balloons are made with a 32 micron thick foil of EVOH material [13] that is weldable with professional welding machines and dense enough to keep helium inside. The foil is coated with white particles to increase the roughness of its surface for diffuse reflections ideally suited for projections. A beneficial side effect of the coating is the reduction of phantom reflections, which pose problems for the motion capture system.

A custom-designed control board employs a 32-bit, dual-core internet-of-things microcontroller with integrated WiFi and Bluetooth stack for receiving and processing commands. It is designed to handle up to 8 DC motors with the ability to reverse their spinning direction and 4 servo motors to cover a variety of propulsion solutions ranging from propellers powered by DC motors to flaps and wings actuated by servo motors.

For rapid prototyping a dedicated 3D printed enclosure is provided, which holds a specific DC motor and propeller combination and can be firmly attached to the balloon with double-sided tape at a desired location. Since the size of a blimp has an immediate influence on its ability to generate lift, care must be taken in the design process to be able to compensate the weight of all attached components; in reverse conclusion, a lower component weight allows a greater flexibility in the design process. In general, a large fraction of the total weight is attributed to the battery and hence a larger battery for longer flight time and agility of a blimp implies a larger blimp.

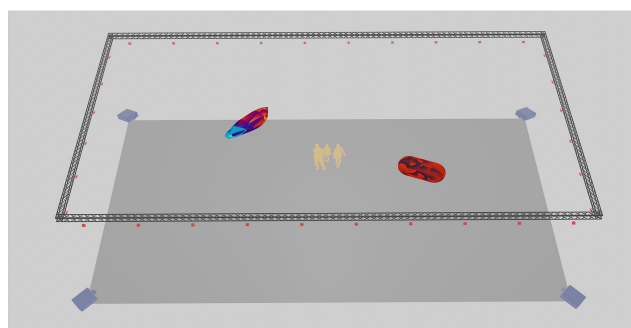
The controller board software is designed to receive desired forces and torques commands with respect to its body fixed coordinate frame. These commands are then allocated to actuator commands of the attached actuators, whose actual location and hence effect on the blimp can be configured remotely via Bluetooth.

Motion capture system
Existing commercial motion capture systems allow tracking of position and orientation of objects in a large space with high precision and low latency, both of which are required for projection mapping with dynamic objects. In general, a sub-millimeter precision and latency on the order of milliseconds is desirable to achieve good projection results. The tracking information is distributed in a computer network with standardized protocols for further processing by other components such as the SAR and manager.

Spatial Augmented Reality software
The SAR software is based on SPARCK, which is an open source 3D audiovisual mapping software. SPARCK receives tracking data for each blimp from the motion capture system and calculates dynamically the soft edge-masks for each blimp to project seamless textures onto the blimps. The texture content can either be generated by SPARCK or sent from client applications. SPARCK requires an accurate 3D model of each blimp onto which it should project. For this reason, a pipeline for scanning a blimp's shape and calibration of the projection mapping was developed to guarantee the best possible mapping result.

Manager
The manager provides an abstraction layer between the blimps and the client application(s). Each blimp is controlled to maintain a desired position and orientation by processing its current position and orientation information received from the motion capture system and sending force and torque commands to the blimp. The manager receives desired position and orientation commands for each blimp from external applications and stores them in a queue for periodic processing. At the same time, the manager can also act on higher-level commands such as flying specific predefined paths (i.e. circles), approaching certain points in space, and avoiding or following other blimps. In combination this allows a transparent interaction with a blimp, since the complexity of controlling a blimp is encapsulated within the manager and therefore hidden from the user, who only interacts with client application(s).

Application(s)
A client application sends commands such as desired position and orientation or higher-level commands for one or multiple blimps as described in the previous section to the manager obeying its application interface. At the same time, texture information of one or multiple blimps is sent to the SAR software to complete the desired choreographed projection experience. The choice on the applications' implementation details and complexity depend on the intended target user (i.e. design student, researchers, artists with no technical skills) and her or his requirements. In its most simple form, an application may avoid the manager entirely and instead directly interface with a blimp by sending force and torque commands, which could for example be a smartphone application acting as a playful remote control. In the context of SAR, by employing the manager, an application may be designed to integrate path and texture generation for a single blimp such that a swarm of blimps is controlled from distributed applications. For the generation of a choreographed audiovisual performance, one single more sophisticated application that centralizes the path and texture generation for an entire swarm is likely more practical.



Picture 4. The picture depicts the scale model of the Immersive Arts Space, with the aproximate location of the tracking cameras and the projectors in order to cover as much as possible of the available space.

Blimpy @ IA Space

The Blimpy framework has been implemented and tested at the Immersive Arts (IA) Space of the Zurich University of the Arts (ZHdK), which is a 20m x 12m x 6m space equipped with a commercial motion capture system with 40 cameras and 4 projectors. The motion capture software and manager run on a standard desktop computer, which is connected to a computer network. The SAR software runs on a separate desktop computer with a high-performance graphics card, which is connected to the projectors. A client application generates paths and texture for three blimps. A still of a such a choreography with these blimps is shown in Picture 1 and a 3D-model of the space and the positioning of the devices is shown in Picture 4.

Interdisciplinary workshop

The framework has been designed to provide a rich tool set to creative people and empower them in the process of creating audiovisual performances in the context of spatial augmented reality experiences. To test and validate this design, the framework components were developed in such a way that they can be used in experimental interdisciplinary workshops. The workshops will involve researchers and students of different Bachelor programs of ZHdK such as industrial design, visual communication, interaction design, visual art and music performance. The interdisciplinary workshops engage the students in a series of activities aiming at creating custom flying agents in combination with related behaviors and audiovisual content. The format features the following structure:

- an introduction to the framework components
- conceiving and building custom blimp shapes by cutting and welding the foil
- assembling a blimp by attaching control board, battery and actuators
- programming of the application software
- designing a complete immersive experience by conceiving movement and audiovisual content

The technology transfer enacted by the workshops, which are designed to be interactive and collaborative with the framework's developers, will help to further define future iterations on the framework and improve its documentation.

Conclusions

This paper introduces and releases a framework for spatial augmented reality experiences with helium blimps, called Blimpy, empowering creatives to focus on aesthetic aspects. At the same time, it aims at providing an innovative teaching platform where different skills and techniques are introduced to an audience with little prior knowledge and contact to the complex technology involved in spatial augmented reality experiences. The framework has been implemented and tested in experiments in the IA Space of ZHdK for verification of the concept and chosen technical solutions.

Future research will now focus on more sophisticated swarm control algorithms that enable blimps to avoid each other, different actuation methods such as flapping / wagging movements and interactive performances integrating performers and visitors into the experience.

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