A Light Carbon Crane as an Alternative Approach for Vertical Structures and Facade Surveying

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***Abstract*— Aerial surveying is, since more than 100 years, a huge field of research and application in the domain of architecture, archeology and, besides, cultural heritage. Increasing operational capabilities of recent UAV platforms, initially concieved for both civilian and military purposes, are today capable of autonomous flight and self decision making attitudes but must deal with complex regulatory options, resulting on limited operational possibilities, especially in dense urban areas. In France, the drone activity is subject to strict administrative constraints and flying today with high definition heavy-load cameras for SfM[1] applications is becoming more and more restrictive. Existing alternatives are captive or remote controlled buoyant aircraft (blimps, balloons...) which are extremely subject to meteorological hazards, especially with turbulent and gusty atmosphere conditions, often incompatible with accurate spatial data gathering needs. Our laboratory developed an original solution to make possible, in a specific surveying context, the vertical deployment of a HD digital camera. This approach should be able to provide, on the basis of almost 10 years or SfM experience, an accurate 3D surveying of existing murals or vertical artifacts, that could guide, when needed, the involved research partners through a restoration and a safeguard process.**

***Index Terms*— Structure from Motion, surveying techniques, aerial photography, still picture aerial crane.**

I. Introduction

Reasoning and interacting with highly detailed 3D models concerns today many disciplinary fields: Architecture, urban planning, product design but also historical and cultural heritage. Realistic 3D models are part of stunning video games, enlightening theoretical demonstrations, interactive visits of remote or lost artifacts and even state-of-the-art immersive experiences. Traditional primitive or Constructive Solid Geometry is often at the very core of the modeling process but the increasing power of SfM technologies requires since a few years specific techniques to gather existing spatial data.

Collecting exploitable photographic material to build accurate 3D models with existing SfM tools is, needless to say, crucial. Small artifacts can be easily surveyed with terrestrial campaigns but as soon as the subject gets bigger, landscapes, buildings or archeological sites, terrestrial surveying is unable to ensure a sufficient spatial coverage. Photogrammetry exploits manned aerial vectors almost since the birth of aeronautics and the most recent photografic capture protocols involve automated aircraft to fullfill its specific needs. In any case, the subject must be seen in almost every inch of its detail and to do so, we need to position high precision cameras with a high degree of freedom around it.

In this domain there are no miracle solutions and every aerial vector has its own advantages and drawbacks, depending on the technology involved: Unmanned Aerial Vehicles provide today a safer operability for often a cheaper flying budget, depending not only on the smaller average size of the aircraft but also because of the light training programs needed for involved crew members. Most of them are electric-powered solutions and are so even able to perform accurate in-door flights. Nevertheless, even present light-weight HD cameras must deal with weight and gravity and existing solutions to carry safely and stably such devices in every potential point of view is still a challenge today.

II. Related works

Early surveying techniques employed by our research team for SfM purposes involved paragliders, helium balloons and blimps, RC helicopters and more recently electric multi-rotor drones (fig. 1). Several surveying campaigns took place since 2002 and permitted to establish a robust acquisition workflow that brought to life highly detailed 3D models of famous sites and landmarks: the Ventimiglia roman theatre, Pompei, Carcassonne and the Pierrefonds Castle among others [1][4].

To fulfill specific SfM requirements, the flight path must be as accurate as possible in order to provide a constant overlapping ratio between consecutive or adjacent pictures, a controlled distance to the subject and above all a regular flight path, as flawless as possible to ensure a dense and sufficiently redundant spatial data coverage [2].

Facade surveying, besides the difficulty and the danger to fly as close as possible to vertical structures, is often subject to fuzzy and turbulent aerological conditions. Buoyancy flight, even if safer, could be subject to severe turbulent conditions in

[1] Structure from Motion, an automated photogrammetry process for building 3D digital models from 2D image sequences

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proximity of the facade and the precise positioning of the aircraft rapidly decreases with the vertical distance to the operator. This often leads to inaccurate camera positioning with subsequent very poor computation results.

Fig. 1. alternate aerial vectors used by the MAP since 2002

Flying a multirotor drone in such conditions might be even more tricky, considering aerological hazards besides the partial masking of the GPS satellite constellation in proximity to the vertical structure, that will weaken, or even dis-engage, the flight control assistance which partial or total loss will force the operator to perform (when possible) an inconvenient manual in-flight recovery, pretty hazardous if performed in dense or crowded urban areas. Finally, existing cinema cranes (the "Jib" series or the world renowned Louma) are interesting solutions when lifting and maneuvering heavy TV broadcast or cinema cameras. Their weight is however prohibitive (up to 460kgs) for the experimental conditions that we put to the test.

III. Main approach

The renewal of the Necker Children Hospital in Paris plans to keep in place a 30 years old fire escape structure that should be preserved as it supports a unique Keith Haring mural which presents, due to its nearly 30 years of outdoor permanence, some very critical surface conditions. An accurate structural health monitoring is necessary to ensure its survival and a precise preliminary study is engaged to analyze, classify and plan the whole restoration process. To ensure the best technical strategy, a detailed 3D mapping of the mural is needed and will become the support of specific spatial annotations which will provide useful assets to accompany the recovery project. [3]

Because of the impossibility to fly a drone or a balloon in the specific context of a Children hospital (aerology, dense crowded area, rescue vehicles in immediate proximity, noise pollution...) we planned to develop a custom system, taking in account the local architectural and spatial constraints, providing a light-weight easy-to-mount transportable mini-crane, able to deploy from a roof-top a overhang structure – up to 4m to the façade with a 100m of twin-wire winch action (fig.2) - for remotely operating a universal camera support.

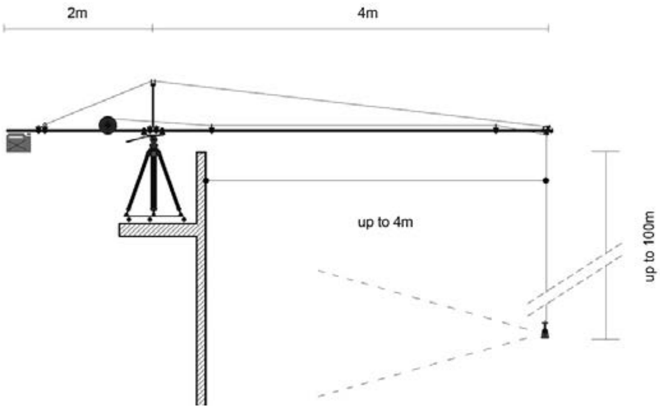

Fig. 2. operational dimensions

The result is a very light carbon frame with an adjustable water tank counterweight and a fishing rod type winding mechanism that can be unfolded and deployed within only a few minutes. Present system needs at least two operators to be deployed, one to control the crane on the roof-top (fig. 3) and the camera remote-control operator which remains on the ground to monitor at a distance the surveying process.

Fig. 3. Installing the crane on the roof-top

In reality, when operating the carbon crane from a reduced flat roof, the presence of two operators is highly recommended, and it is mandatory to secure the crane structure to a steady support. The crane is also equipped with a dolly camera mount which provides a smooth translation action over the roof surface when possible. Assembling the whole device takes up to five minutes and as soon as mounted, the empty camera support is attached to the twin-pulley balance and dropped overboard; when touching the ground, the camera operator is in charge to place the camera and to switch on all the electronic on-board devices.

Fig. 4. The central mechanism, partly made of carbon rods and printed and/or laser-cutted frames

Fig. 5. A close view of the suspended remote-controlled camera mount (tilt and yaw action).

IV. Technical aspects

The rugged "rods and wires" structure is weather-effective even in poor atmospheric conditions: unlike drones and buoyant flight, the camera remains stable and reasonably under control even in turbulent and gusting wings. The crane is made of three 30 millimeters section carbon tubes, 2 meters long each, jointed end-to-end, holding another carbon transverse bar of 1meter that keeps in balance the twin-wire pulley mechanism (fig. 5). Just above the resting mount, the support for the main vertical strut keeping the upper tie-rod deployment in tension.

The lower part of the resting mount system is nested within a steady heavy camera commercial tripod. The counterweight is made of a gasoline plastic tank, filled up with water that can be cranked along the rear section of the horizontal carbon bar to keep the system balanced, depending on the payload weight. Most of the assembly parts of our device are custom designed and printed with a commercial 3D printer (fig. 4), (fig. 5).

The assembly pieces that need a high degree of resistance are made of three overlapping laser cutted 12mm plywood boards, strongly assembled to the tripod mounting plate with 6 robust throughbolts (fig. 4).

Fig. 6. Vertical deployment of the camera support.

The ground control station permits to control the frame through a video high frequency signal, to remotely operate the camera support (yaw and tilt) and by the way to take a picture when needed. For the first experimental campaign we used a Nikon D7000 camera with a 12-24mm zoom lens which provided, at +- 3m of distance from the mural and a fixed 24mm focal, an average theoretical resolution of 0.6mm/pixel.

Taking account of the dimensions of the first surveyed artifact, a 27 meters high tower with a cross section of 6.5 x 3 m, we planned to perform 12 vertical paths, at an average distance of 3 meters from the mural. Considering the sensor dimension and the field of view of the mounted optics, the surveyed theoretical dimension for each picture is roughly 3m x 2m. To ensure the ideal overlapping ratio, pictures are taken every 50cm vertically and, considering the round shape of the support, every roughly 30° in circonference. As a result, we can calculate a 75-80% of vertical and 50-60% of horizontal overlapping, even more than needed for an accurate spatial data redundancy. (fig. 6).

Fig. 7. Camera matching and first trial sift pointcloud.

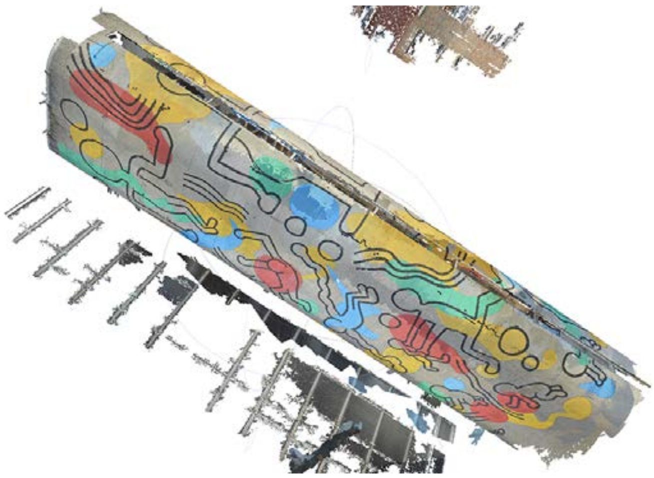

Fig. 8. First dense matching results

V. Perspectives

UAV platforms are certainly becoming an affordable solution for surveying and monitoring urban and architectural artifacts. They are today a low-cost alternative to manned flight and can be combined to terrestrial surveying to produce high 3D definition digital models. Despite existing techniques, even unmanned flight suffers so far from a lack of operability in poor weather conditions or in dense crowded areas. We planned to design and develop a light and affordable solution to bring an effective operability in certain critic environments, dangerous or hazardous to be flown with present free-flight or captive solutions: a roof-top overhanging carbon crane with a rugged mechanism able to deploy a universal camera support close to a facade or a vertical structure.

Future upgrades will aim to reduce the overall weight and storage dimensions to enhance spatial surveying capabilities. Further refinements should also introduce a light-weight gyroscopic turret with a reinforced yaw stabilization system to allow a motorized single wire suspension, though reducing even more the weight, the dimensions and widening up the operational capabilities (single operator with a wearable steady mount). We plan also to develop a heavy lift system designed to specifically inspect engineering structures (bridges, decks, viaducts...) but also to perform dense picture capture of specific works of art, unreachable with other aerial vectors (heavy statues, vertical artifacts, mosaics...)

The development of such a rugged vector will certainly ensure, in a close future, the possibility to explore and survey presently unreachable spots to traditional manned or unmanned vehicles, providing, in hazardous conditions, safer and more accurate operations able to meet and to maybe overwhelm the upcoming challenges in the domain of Structure From Motion protocols.

Aknowledgements

All pictures showing Keith Haring artwork are © Keith Haring Foundation.

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