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Identification of a putative man-made object from an underwater crash site using CAD model superimposition

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ABSTRACT

In order to identify an object in video, a comparison with an exemplar object is typically needed. In this paper, we discuss the methodology used to identify an object detected in underwater video that was recorded during an investigation into Amelia Earhart's purported crash site. A computer aided design (CAD) model of the suspected aircraft component was created based on measurements made from orthogonally rectified images of a reference aircraft, and validated against historical photographs of the subject aircraft prior to the crash. The CAD model was then superimposed on the underwater video, and specific features on the object were geometrically compared between the CAD model and the video. This geometrical comparison was used to assess the goodness of fit between the purported object and the object identified in the underwater video.

1. Introduction

Finding and identifying pieces of manmade wreckage in underwater environments can be challenging. Many types of information must be taken into consideration when identifying objects, such as texture, pattern, and color differences. The size and dimensions of objects are also critical and, unless the object is retrieved, must be derived from scaling information plus relative and absolute position. There are many different methods to survey and document artifacts with a wide range of ease and accuracy [1]. Cost and availability are major determining factors when choosing the best way to carry out a survey. Depending on the depth and location, methods can range from side scan sonar to having a diver on site to perform running distance based measurements [2,3]. Affordable precise digital cameras are widening the relevancy of photogrammetry in many disciplines. Image based analysis can significantly cut down the man hours needed to identify objects compared to traditional hands-on approaches [4]. Many image based reconstruction methods, based on photogrammetry and geometric principles are available. Stereo cameras can be very effective but require precise calibration and complexity that is too costly for many applications [5]. Approaches for monocular cameras include structure from motion (SfM) [6], projection of structured light [7], and depth from defocus [8]. These methods often require high quality recording and very structured illumination. [9]. Underwater photogrammetry provides an efficient and nondestructive mechanism for sampling environments with limited accessibility. In the absence of enough information to create a dense reconstruction of an object, geometric comparisons can be sufficient to identify objects.

In this retrospective analysis, we were provided with video footage from which we were tasked with identifying any pieces of wreckage and verifying their connection to a wrecked aircraft. The video was taken with a monocular camera on a remote controlled underwater vehicle (ROV). The site was located on a Pacific atoll at 200–300 m depth and so, because of its remoteness, there was no opportunity to return at a later date to take better or closer video of objects identified after filming. As a result, a different, off-site approach for identification of objects in the video was needed. Man-made objects would likely be coated with biologically derived accretions, possibly also with sediment, so analyzing their size and shape and matching them with known objects is a key first step toward identification. This paper focuses on a method to use features on a man-made object to compare it to both historical

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photographs as well as an exemplar specimen for identification. Photos of the exemplar specimen were adjusted into an orthographic view. The features were then quantitatively compared to the object of interest and also to historical photos of the aircraft taken prior to the crash.

In our previous publication on the same subject matter, we detailed our methodology for superimposing CAD models of landing gear on underwater video [10]. In that case study, a man-made rope was visible adjacent to two pieces of purported landing gear. The two CAD model overlays allowed for independent measurements of the diameter of the reference rope, which showed that the rope statistically had the same diameter and that the rope had an appropriate diameter for aircraft tie-down rope. This indicated that both of the objects seen in the video were of the correct scale and general shape of the landing gear on the wrecked aircraft. However, a goodness of fit of the overlays could not be made due to the geometry of the components. In the present analysis, the repeated rivet patterns provide a unique opportunity to allow a goodness of fit calculation to be performed on a new object located at the same site.

1.1. Background

In this case study, we describe using the superimposition of CAD models using underwater video as source data to assess the geometry of objects purported to be from the July 2, 1937 crash site of Amelia Earhart's lost airplane, a Lockheed Electra Model 10E, construction number 1055, off of the island of Nikumaroro in the western Pacific Ocean. This airplane has an overall length of approximately 11.8 m, a wingspan of 16.8 m, and a height of 3.1 m (Fig. 1). The outer skin of the aircraft was attached using rivets, and a section of rivets along the window slide rail appeared to match the objects seen in the underwater video.

We received the video for analysis retrospectively and we were tasked with extracting as much information as possible from the video footage itself. During an internal review of the video, two objects were identified which resembled a series of rivets. Rivet patterns covering the aircraft were reviewed and the closest resemblance was the rivets located at the window slide rail. Due to the remoteness of the crash site and difficulty involved in safely retrieving the objects, the objective of this study was to assess the geometry of the purported airplane component to determine whether additional investigation of these objects, such as retrieval, is merited.

2. Methodology

Using the provided video, we identified two potentially man-made objects, shown in Fig. 2. The top object contains a series of repeating, staggered features on a rectangular or cylindrical base. A second object, perpendicular to the first, contains two long, parallel edges. The left side of the second object contains a series of repeating, staggered features, similar to those on the first object. These objects were investigated further because they presented features that bore a resemblance to a rivet pattern seen on the aircraft in Fig. 3, and they were located in the suspected crash site.

Fig. 1. Amelia Earhart's Lockheed Electra Model 10E aircraft. Scanned from *Lockheed Aircraft since 1913*, by René Francillon. Photo credit USAF.

Fig. 2. An object was identified in the suspected underwater crash site.

We first found historical photos of the aircraft from which the potential piece of wreckage is believed to have originated. Historical photographs of the aircraft were reviewed to identify possible matches to the rivet pattern seen in the purported wreckage. The most visually similar parallel features and rivet patterns were located at the window slide rail (red, Figs. 3 and 4) and below the hatch (blue, Fig. 3).

An aircraft of the same make and model as the one at the potential crash site was used for measurement of the identified rivet pattern, using photographs supplied by the owner of the aircraft. The window slide rail of the intact aircraft contained parallel features, and rivets (Fig. 4) that were similar to those seen in the wreckage image (Fig. 2) and the historical aircraft (Fig. 2).

A yard stick was placed in the field of view of each photograph of the intact aircraft (Fig. 5). In order to take more accurate measurements from the photograph of the window slide rail, an orthographic transformation of the angled photograph was performed using MATLAB in order to view the window from a perpendicular view (Fig. 6). Orthographic projections preserve both distances and angles, and there is no distortion of shape for two-dimensional transformations [11]. The yard stick, having a known length, width, and shape was used as a reference to perform the transformation, with the assumption that the outer face of the

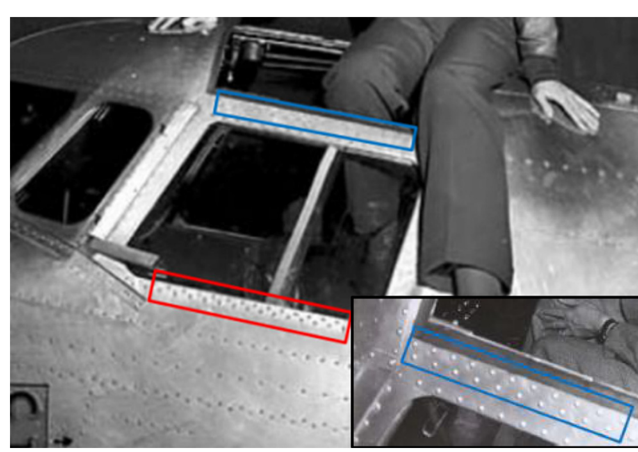

Fig. 3. A photograph illustrating a similar pattern of rivets on the aircraft was taken prior to the crash. (For interpretation of the references to color in the text, the reader is referred to the web version of this article.)