Calibration Stability of an Underwater Stereo-Video System: Implications for Measurement Accuracy and Precision

PAPER

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ABSTRACT

Assessment of population structure is often used to detect and analyze the impact on marine fauna of environmental factors or commercial fishing. A primary tool in the characterization of population structure is the distribution of the lengths of a large sample of individual specimens of a particular species. Rather than use visual estimates by SCUBA divers, an underwater stereo-video system has been developed to improve the accuracy of the measurement of lengths of highly indicative species such as reef fish. In common with any system used for accurate measurements, calibration of the camera system is of paramount importance to realize the maximum possible accuracy from the system. Further, the determination of the relative orientation of the two cameras is vital to the correct estimation of fish lengths. Also at issue is the stability of the calibrations and relative orientation of the cameras during deployments to capture video sequences of marine life, as any variations will inevitably lead to systematic errors and therefore inaccuracies in the measured lengths. This paper describes a series of experiments concerning the determination and testing of camera calibration, relative orientation and stability of the underwater stereo-video system. The strategy for the integrated determination of calibration and orientation is described. Variations in calibration and orientation parameters are quantified in terms of magnitude and significance. Finally, the detected variations are analyzed for the propagated effects on object space accuracy.

INTRODUCTION

Traditional biological sampling techniques in the marine environment have involved the use of nets, bottles, grabs and cores to obtain samples. More recently visual estimation and photographic recordings have become used, particularly in reef ecology. Marine scientists rely almost exclusively on manual taxonomic classification and enumeration of these samples, techniques which are highly sensitive to human error, subjectivity and sampling bias. The flow on effects resulting from error in classification, enumeration and morphometric measurement must affect confidence in results which compare spatial and temporal data.

Accurate information about fish or invertebrate abundance and distribution is required for fisheries and natural resource management, and to further a basic understanding of the population dynamics and ecological interactions that occur within rocky reef, deep sea and pelagic marine environments. Of possibly greater value than estimates of relative abundance is a knowledge of the size frequency distribution or biomass of a population. For example, the size structure of a fish population, when linked with an even rudimentary knowledge of the biology of the species, can provide insights into recruitment to the adult population, fishing intensity and rates of recovery from fishing (McCormick and Choat, 1987). Harvey and Shortis (1996) describe an underwater stereo-video system, which can be used to overcome the problem of subjectivity and inter-observer variability and bias in visual length or biomass estimates of marine organisms, particularly of reef fish (Harvey et al., 1998a, b, c, d).

STEREO-VIDEO SYSTEM CALIBRATION

Camera Calibration Techniques

In order to be used for accurate, quantitative measurement, any photographic system must be geometrically calibrated. With few exceptions, cameras do not provide a perfect central projection and calibration is necessary in order to model the small departures from an ideal perspective image (Figure 1). Lens distortions (Ziemann and El-Hakim, 1986) are an example of such departure which is always present in the lenses commonly used with video cameras. The calibration of video cameras also typically requires an affinity correction to allow for timing errors in the horizontal scan lines of the video images. Further, if the cameras are able to focus, some of the fundamental characteristics of the cameras, such as the principal point position (the intersection of the optical axis with the focal plane) and the principal distance (separation between the perspective center of the lens and the focal plane) are variable and must be determined for the specific focus setting.

Calibration of an underwater photographic system must incorporate the effects of refraction at the various air-glass and glass-water interfaces which are present when the camera is mounted in a housing for use underwater (inset Figure 1). A number of different approaches to the calibration problem have been