Computer Vision for Wave Flume Experiments

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INTRODUCTION

During the past several decades, a number of attempts have been made to contain oil slicks (or any surface contaminants) in the open sea by means of a floating barrier. Many of those attempts were not very successful especially in the presence of waves and currents. The relative capabilities of these booms have not been properly quantified for lack of standard analysis or testing procedure (Hudon, 1992). In this regard, more analysis and experimental programs to identify important boom effectiveness parameters are needed.

To achieve the desirable performance of floating booms in the open sea, it is necessary to investigate the static and dynamic responses of individual boom sections under the action of waves; this kind of test is usually carried out in a wave flume, where open sea conditions can be reproduced at a scale.

Traditional methods use capacitance or conductivity gauges (Hughes, 1993) to measure the waves. One of these gauges only provides the measurement at one point; further, it isn't able to detect the interphase between two or more fluids, such as water and a hydrocarbon. An additional drawback of conventional wave gauges is their cost.

Other experiments such as velocity measurements, sand concentration measurements, bed level measurements, breakwater's behaviour, etc… and the set of traditional methods or instruments used in those experiments which goes from EMF, ADV for velocity measurements to pressure sensors, capacity wires, acoustic sensors, echo soundings for measuring wave height and sand concentration, are common used in wave flume experiments. All instruments have an associate error (Van Rijn, Grasmeijer & Ruessink, 2000), and an associate cost (most of them are too expensive for a lot of laboratories that can not afford pay those amount of money), certain limitations and some of them need a large term of calibration.

This paper presents another possibility for wave flume experiments, computer vision, which used a cheap and affordable technology (common video cameras and pc's), it is calibrated automatically (once we have developed the calibration task), is a non-intrusive technology and its potential uses could takes up all kind experiments developed in wave flumes. Are artificial vision's programmers who can give computer vision systems all possibilities inside the visual field of a video camera. Most experiments conducted in wave flumes and new ones can be carried out programming computer vision systems. In fact, in this paper, a new kind of wave flume experiment is presented, a kind of experiment that without artificial vision technology it couldn't be done.

BACKGROUND

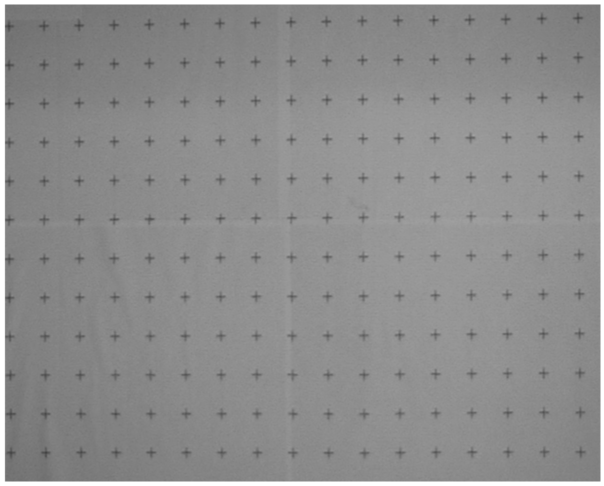
Wave flume experiments are highly sensitive to whatever perturbation; therefore, the use of non-invasive measurement methodologies is mandatory if meaningful measures are desired. In fact, theoretical and experimental efforts whose results have been proposed in the literature have been mainly conducted focusing on the equilibrium conditions of the system (Niederoda and Dalton, 1982), (Kawata and Tsuchiya, 1988).

In contrast with most traditional methods used in wave flume experiments computer vision systems are non-invasive ones since the camera is situated outside the tank and in addition provide better accuracy than most traditional instruments.

The present work is part of a European Commission research project, "Advanced tools to protect the Galician and Northern Portuguese coast against oil spills at sea", in which a number of measurements in a wave flume must be conducted, such as the instantaneous position of the water surface or the motions (Milgran, 1971) of a floating containment boom to achieve these objectives, a non-intrusive method is necessary (due to the presence of objects inside the tank) and the method has to be able to differentiate between at least two different fluids, with the oil slick in view.

Others works using image analysis to measure surface wave profile, have been developed over the past ten years (e.g., Erikson and Hanson, 2005; García, Herranz, Negro, Varela & Flores, 2003; Javidi and Psaltis, 1999; Bonmarin, Rochefort & Bourguel, 1989; Zhang, 1996), but they were developed neither with a real-time approach nor as non-intrusive methods. In some of these techniques it is necessary to colour the water with a fluorescent dye (Erikson and Hanson, 2005), which is not convenient in most cases, and especially when two fluids must be used (Flores, Andreatta, Llona & Saavedra, 1998).

Figure 1. Template to image rectification. Crosses are equidistant with a 4cm separation.



A FRAMEWORK FOR MEASURING WAVES LEVEL IN A WAVE FLUME WITH ARTIFICIAL VISION TECHNIQUES

Following is presented an artificial vision system (Ibáñez, Rabuñal, Castro, Dorado, Iglesias & Pazos, 2007) which obtains the free surface position in all points of the image, from which the wave heights can be computed. For this aim we have to record a wave tank (see laboratory set-up in section 2) while it is generating waves and currents (a scale work frame), and after that we have to use the frames which make up the image to obtain the crest of the water (using computer vision techniques described in section 3) and translate the distances in the image to real distances (taking into account image rectification, see section 1).

Image Rectification

Lens distortion is an optical error in the lens that causes differences in magnification of the object at different points on the image; straight lines in the real world may appear curved on the image plane (Tsai, 1987). Since each lens element is radially symmetric, and the elements are typically placed with high precision on the same optical axis, this distortion is almost always radially symmetric and is referred to as radial lens distortion (Ojanen, 1999). There are two kinds of lens distortion: barrel distortion and pincushion distortion. Most lenses exhibit both properties at different scales.

To avoid lens distortion error and to provide a tool for transforming image distances (number of pixels) to real distances (mm) it is necessary to follow a rectification procedure.

Most image rectification procedures involve a two step process (Ojanen, 1991). (Holland, Holman & Sallenger, 1991): calibration of intrinsic camera parameters, and correction for a camera's extrinsic parameters (i.e., the location and rotation in space).

However, in our case we are only interested in transforming pixel measurements into real distances (mm). Transforming points from a real world surface to a non-coplanar image plane would imply an operator which, when applied to all frames, would considerably slow down the total process, which is not appropriate for our real-time approach.

So a .NET routine was developed to create a map with the corresponding factor (between pixel and real distances) for each group of pixels (four nearest control points on the target). Inputs to the model are a photographed image of the target sheet (see fig.1), and target dimensions (spacing between control points in the x- and y-directions).

Laboratory Set-Up and Procedure

The experiment was conduced in a 17.29-m long wave flume at the Centre of Technological Innovation in

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