A Combined Acoustic and Optical Instrument for Fisheries Studies

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I. Introduction

A combined acoustic and optical system (AOS) has been developed and deployed from commercial fishing trawlers in Australian and New Zealand waters to advance the quality and efficiency of acoustic-based biomass estimates used for fishery stock assessment [1]. The AOS platform combines scientific echo-sounder technologies with video and paired digital stills cameras in a self contained autonomous platform with an operating depth in excess of 1000 meters.

The instrument has been designed for attachment to the headline of trawl nets which are deployed from commercial fishing trawlers (Fig. 1a). Deployment of the system from trawl nets overcomes a number of problems associated with shipboard systems which are particularly evident in deepwater fisheries studies where range dependant errors due to beam spreading, platform motion, estimation of seawater absorption and acoustic near bottom dead zone can be significant [2]. The novel approach of deploying the instrument via the trawl net integrates with the existing infrastructure of a single commercial vessel, greatly reducing the cost and complexity of acoustic biomass surveys. Previously two survey vessels were required, one for acoustics to deploy a deep towed body system via a dedicated optic fiber winch and a catcher vessel to obtain biological samples.

The AOS (Fig. 1b) is sufficiently robust to withstand the environmental challenges of cold, depth, vibration and impact to which the platform is exposed in normal trawling operations.

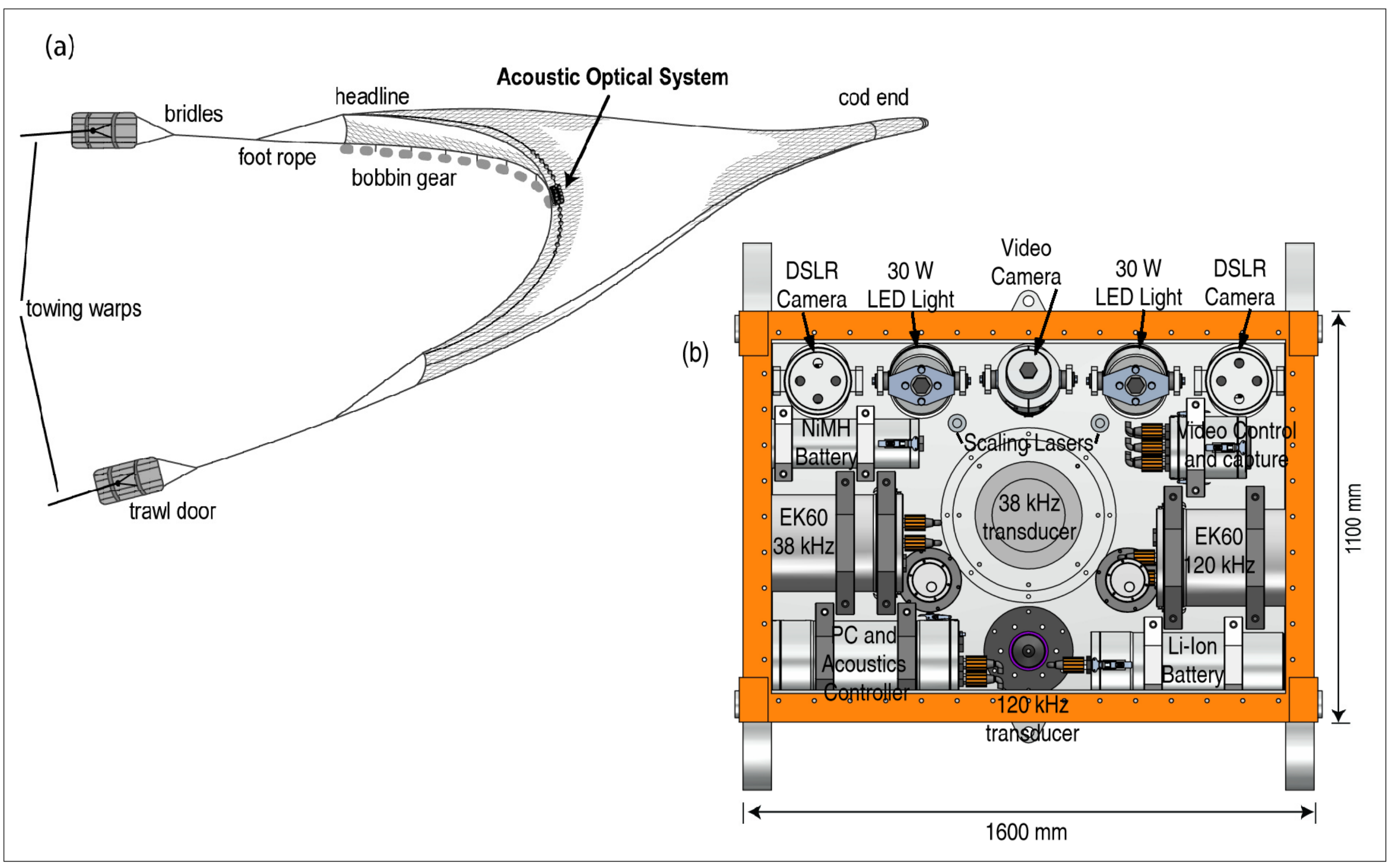

Figure 1 (a) Typical deepwater trawl configuration. AOS platform shown attached to headline (b) AOS system diagram

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Video and paired digital stills cameras on the AOS platform capture images of fish which can be directly related to the acoustic data, for the first time allowing key research questions to be answered. Of particular importance is the determination of the in-situ acoustic reflectivity value (target strength) for different species of fish. Further, images of fish allow direct identification of species, whereas previously this could only be inferred from the absolute amplitude of the acoustic signature and its relative difference across a range of frequencies [3]. The digital stills subsystem on the AOS has two digital SLR cameras mounted in housings and a strobe unit. A custom synchronizing circuit accepts trigger signals from the acoustics system to capture paired images of candidate fish targets. Paired images of individual fish are post processed using stereo photogrammetric analysis software to determine metrics of length, direction and inclination. These metrics can then be matched to the concurrent acoustic target strength measures.

II. SYSTEM DESCRIPTION

A. Platform Design

The AOS system comprises an aluminium sled deployment frame with protective top cover and timber runners (Fig. 2).

A rigid flat instrument plate is bolted into the base of the frame (Fig. 3). Pressure cases containing electronics, cameras, batteries, strobes, lights and control computer are fixed to this plate along with acoustic transducers. The plate provides a rigid structure to ensure the alignment of transducers and cameras is maintained. The system has a weight in air of 483 kg and in water weight of 325 kg.

An independent aluminium mount frame shown in Fig. 4 is secured to the headline of the net. The AOS system is bolted into this mount for deployment. The system is easily removed for maintenance or calibration while at sea. In normal operation however the entire system remains attached to the trawl net between deployments.

Figure 2. AOS System showing sled frame and hinged protective cover (yellow). Independent aluminium mount frame is shown bolted to the top of the protective cover.

Figure 3. AOS underside showing Instrument Plate. Orange Simrad acoustic transducers are visible.

Performance of the system from an acoustics perspective requires that the platform be stable and level during a survey. Floats attached to the system provide buoyancy making the system approximately neutrally buoyant in water (Fig. 5). The flat instrument plate in the base of the system also acts to provide extra stability resulting from water flow over its face. Adjustment of floats during the first few tows of a survey particularly when using different trawl gear is required to trim the platform. In practice the AOS system benefits greatly from the size and dynamic stability of the trawl net.

A number of pressure cases house the various electronics modules, lights and cameras that constitute the system. All pressure cases are constructed from aluminium (6061T6) and are hard anodized.

Figure 4. Mount frame secured to the headline of the trawl.

Figure 5. AOS attached to the trawl headline during deployment. Floats are attached to create a neutrally buoyant package when in the water.

B. System Overview

The AOS platform comprises three key subsystems which are integrated together to provide the instruments unique functionality. These are the acoustics system, video camera system and paired digital stills camera system.

1. Acoustics System

The acoustic system consists to two Simrad EK60 scientific echo-sounders coupled to Simrad split beam transducers. The two sounders operate at 38 kHz and 120 kHz. The echo-sounders operate throughout a deployment collecting data as the trawl net is towed above fish aggregations or through aggregations in bottom trawling operations.

The EK60 echo-sounders produced by Simrad are supplied in a box enclosure suitable for installation on board a ship. In order to improve the space efficiency of these sounders for subsea deployment, the backplane configuration was re-engineered at CSIRO with assistance from Simrad who provided the backplane circuit detail. The revised cross backplane allowed installation of the sounders into more compact cylindrical housings (Fig. 6).

A separate acoustics electronics module houses a compact industrial PC, low power supervisory microprocessor circuit and power switching circuit. This module performs the function of acquiring data from the echo-sounders and controlling data flow to other subsystems. Power and Ethernet signals are routed from the acoustics module to both echo-sounders.

The low power supervisory circuit within the acoustics module is configured by the system operator to power the system on and off at preset depths. This feature saves battery power during the lengthy periods when the trawl gear is being deployed and recovered to the ship's deck. In addition this prevents potential PC hard disk damage during rugged treatment on deck as the gear is manoeuvred up and down the stern ramp. The circuit also provides a status window to the operator which can be viewed on deck to verify the system is correctly configured prior to deployment (Fig. 7). Using a magnet the operator can also power the system on and off when on deck independent of the internal depth sensor. This is required to allow Ethernet communication with the acoustics computer to download data at the end of each deployment.

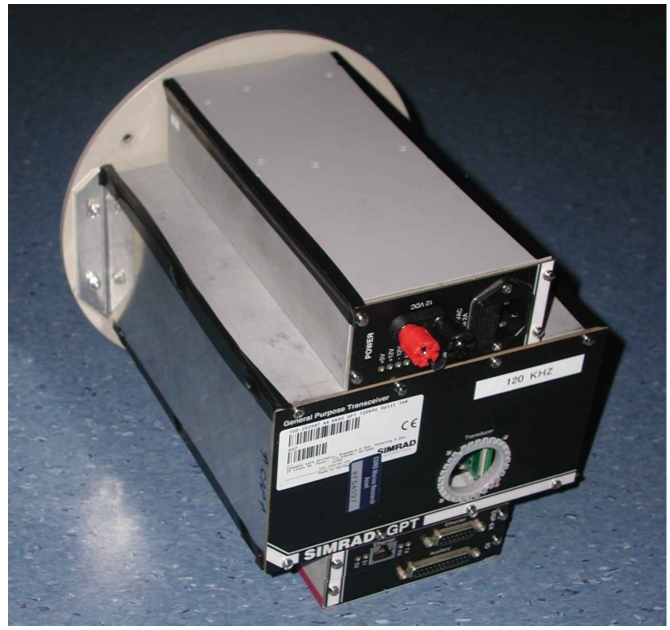

Figure 6. Simrad EK60 echo-sounder repackaged for space efficient installation in underwater housing.

The Simrad ER60 data acquisition program running on the PC is used to acquire data from the echo-sounders. In normal operation this software would be controlled by a ship board operator using mouse clicks to configure and activate the system. Underwater this function is performed by a custom software application ('ER60-Autostart') which communicates with the remote control server within the Simrad ER60 application. XML commands are sent to configure and start operation of the echo-sounders.

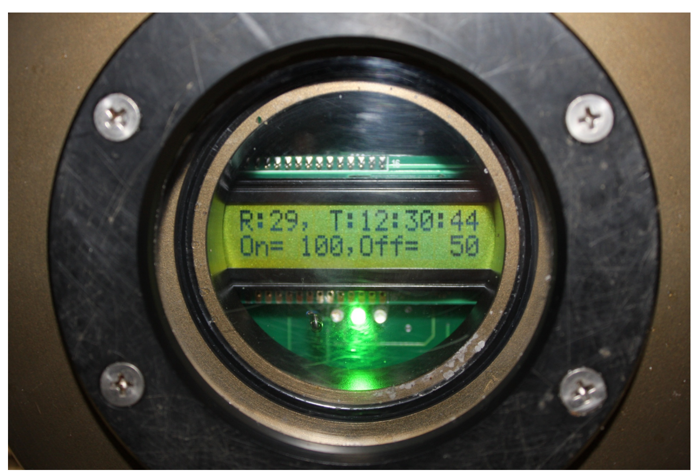

Figure 7. Acoustics module status display. Trigger depths for system activation are shown: power on below 100 metres, power off above 50 metres.

A key feature of the AOS system is the ability to integrate imagery with the acoustics. This is important when combining acoustic data used to determine in-situ target strength of individual fish with optics data used to determine fish species, their length, tilt angle and behaviour. This is achieved in two ways. Firstly the independent video camera system has video overlay text inserted. This is generated by an application on the acoustics PC which provides time and depth to the video. In this way the captured video can be related directly to the acoustics to associate fish species and behaviour with acoustic signature. Secondly the digital still camera subsystem is configured to capture stereo paired images of individual fish targets which are detected by the acoustics. The 'ER60-Autostart' application which initially starts the echo-sounders subsequently requests a subscription to target detection information from the sounder using XML commands. It does this by specifying a detection range (typically 3 to 8 metres) and target strength threshold (typically between -55 to -65 dB). Reported target detections transmitted from the Simrad software are further filtered by the ER60-Autostart application to reject targets outside a detected angle threshold. When a valid target is detected a serial command is sent to the paired digital stills subsystem to capture a rapid sequence of paired images. The digital stills subsystem signals back to 'ER60-Autostart' as each photo is taken allowing a time stamp record of each image to be recorded which is synchronized to the PC clock. In this way image pairs can be linked back to the acoustic system allowing development of relationships between fish size, their inclination and target strength.

The acoustics module is also fitted with a Microstrain 3DM-GX1 orientation sensor which provides pitch/roll measurements for the platform at 10 Hz rate throughout a deployment. This information is integrated directly into the acoustics dataset via an ER60 auxiliary motion input channel.

2. Video Camera System

The video camera subsystem on the AOS platform uses a high sensitivity PAL colour camera, Hitachi HV-D30P. Lighting is provided by two custom built LED lighting modules each containing six 5 watt Luxeon LEDs for a total of 60W on the platform. A low power supervisory microprocessor circuit equivalent to that in the acoustics subsystem allows for depth activation of the camera system to conserve battery power and recording capacity.

Composite video data is recorded to compact flash memory modules using an Outrider CF module manufactured by Fast Forward Video. This module allows scalable motion jpeg compression of video and typically provides greater than two hours of video recording with two 16 GByte cards at low compression ratio. The Outrider CF module accepts a serial input for overlay of text on the recorded video. This text contains a time stamp derived from the acoustic acquisition PC and platform depth. Fig. 8 shows a frame grab from the video system.

Included with the video system are a pair of parallel scaling lasers which project marker dots onto the seabed 400 mm apart. During bottom trawling when the platform is close to the seafloor these dots can be seen in the recorded video and are used to determine approximate sizes of biota.

Figure 8. Video frame grab from the AOS system showing Orange Roughy on the seabed at 846 meters. Trawl bobbins are visible in the lower left of the frame. Sizing laser dots are also visible on the seafloor ~400 mm apart.

3. Paired Digital Stills Camera System

The paired digital stills camera subsystem comprises two camera housings and two strobe housings. Each camera housing contains a Canon 500D digital SLR with EF35mm F2.0 lens. Each strobe housing contains a Canon 580EXII strobe. The digital camera subsystem has been carefully designed to ensure mounting and alignment of the camera housings is strictly maintained. The instrument plate and paired digital camera assembly can be removed as a complete module from the platform without disturbance of the camera housings. This allows in water calibration to be undertaken in a large tank or pool using a reference frame which is photographed at different orientations [4]. Custom software is then applied to the images to characterize the system and produce a calibration model [5]. This enables sizing of fish captured in the frame of both cameras during a survey using image analysis software [5].

A custom camera control and strobe synchronization circuit is fitted into the master camera housing of the subsystem. The control circuit initiates capture of a sequence of paired photos driving the cameras at maximum frame rate when a detected acoustic target meets the range and target strength criteria. The circuit also handles synchronizing of strobe firing by monitoring the hot-shoe PC sync signal from each camera.

Fig. 9 shows a captured stereo image pair from the digital stills subsystem. Note the offset positions of the single Grenadier closest to cameras. This corresponds to the displacement between the two cameras of approximately 1.2 meters.

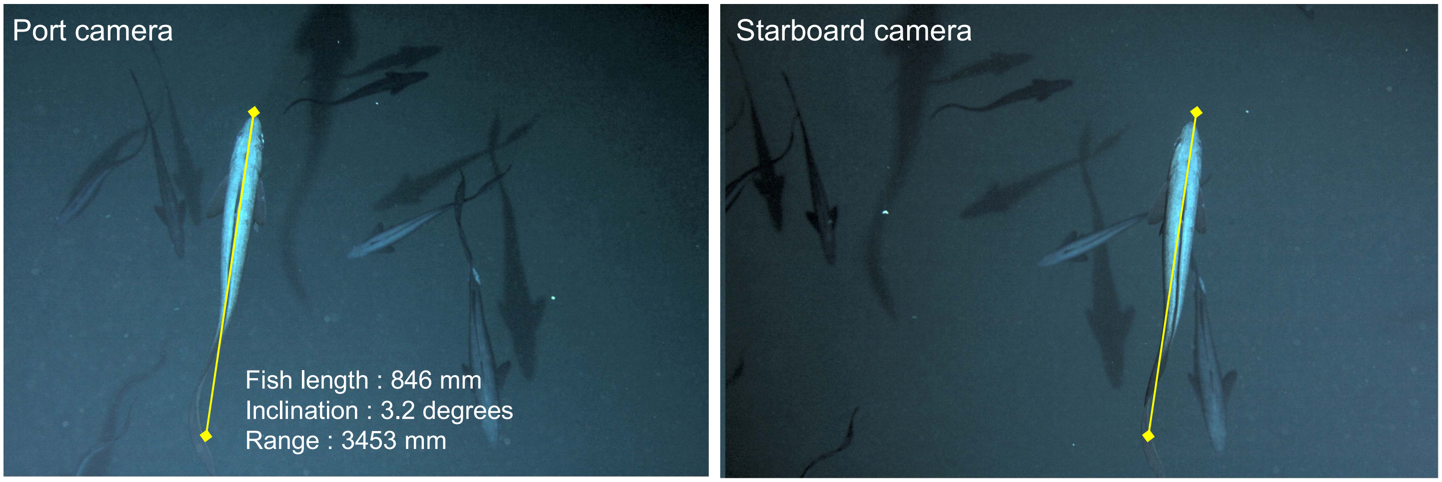

Figure 9. Blue Grenadier captured as a stereo image pair by the AOS digital stills subsystem showing example stereo photogrammetric derived metrics for one fish

4. System power

The system is powered by two separate rechargeable battery modules each in their own independent pressure housing. The acoustics system has a 50 AHr Li-Ion pack which provides sufficient energy to operate the acoustics system continuously for approximately 24 hours. The video camera system and LED lights are powered by an 18 AHr, Ni-Mh battery pack which provides approximately 2.5 hours of continuous operation. Spare battery packs and housings allow rapid swap out of batteries between deployments.

III. Conclusions

The AOS system was developed through the merging of acoustic and optical technologies to further the quality of fisheries stock assessment. The system has been deployed from several ships (40 m to 75 m in length) over the past three years providing improved accuracy of acoustic target strength measures for commercial fish species and delivering biomass estimates of fish stocks. It has proven to be robust withstanding the harsh environment of pressure and temperature to depths of 1000 meters.

The platform must also cope with exposure to significant impacts and vibration during deployment and recovery as the trawl net moves up and down the stern ramp of commercial trawlers.

The system continues to be incrementally improved to gain better performance and to streamline post survey data analysis. These improvements come as a direct result of new measurement challenges identified through working with data sets collected by the instrument.

Acknowledgment

We would like to acknowledge the contribution of colleagues who assisted in the manufacture and operation of the system. David Kube and the CSIRO Engineering Technical Services team who constructed the system. Matthew Horsham who designed the AOS platform. Jeff Cordell who assisted in the implementation of the system and who has participated in numerous surveys using the system. Simrad for provision of circuits for the EK60 echo-sounder allowing development of re-engineered backplane.

References

[1] Ryan, T. E., Kloser, R. J., and Macaulay, G. J. (2009). Measurement and visual verification of fish target strength using an acoustic-optical system attached to a trawlnet. – *ICES Journal of Marine Science*, 66: 1238–1244.

[2] Kloser, R.J., (1996). Improved precision of acoustic surveys of benthopelagic fish by means of a deep-towed transducer. *ICES Journal of Marine Science* 53:405-413.

[3] Kloser, R.J. and Horne, J. (2003). Characterising uncertainty in target strength measurements of a deepwater fish: orange roughy (Hoplostethus atlanticus). *ICES Journal of Marine Science* 60(3): 516-523.

[4] Shortis, M.R., and Harvey, E.S. (1998) Design and calibration of an underwater stereo-video system for the monitoring of marine fauna populations. *International Archives of Photogrammetry and Remote Sensing*, 32, 792-9

[5] Seager, J.W. (2008) SEAGIS CAL and Photomeasures stereo photogrametric calibration and analysis software. SEAGIS Pty Ltd, www.seagis.com.au