Project Title: Automated Image Processing for Fisheries Applications (Year 2)

Principal Investigators: Kresimir Williams[1], Jenq-Neng Hwang[2], Chris Rooper[1], Craig Rose[1]

Affiliations: 1- Alaska Fisheries Science Center
2- University of Washington

Project Duration: 2 years

Amount Requested (Year 2): $87,500

Abstract: Automated image processing has the potential to remove one of the primary impediments on the use of image–based sampling in fisheries research, which is the large amount of time necessary to manually extract meaningful data from images. The requested funding will support ongoing research into overcoming several major challenges in the automated processing of image data from aquatic environments. Research efforts will continue current work on object detection from moving uncontrolled backgrounds, such as fish targets on rocky seafloor as seen from lowered cameras, species classification from images, and we will initiate a new research topic of automated fish behavior analysis based on target tracking. These tasks will be undertaken in a modular fashion, and will be based on a variety of different image data (SD video, HD video, still images) making the resulting software generally applicable. Resulting software will expand on previous work of automated target detection, tracking and fish measurement to provide critical information for fisheries research.

Introduction

Optical instruments are rapidly becoming a standard methodology for use in fishery resource surveys and related research efforts. Projects using cameras accumulate high volumes of image data, which require substantial time to analyze. Automated image processing is a rapidly developing field in many areas of science and industry (McLeod et al., 2010), and the challenges faced in marine image-based sampling are common to many other endeavors using images for quantitative work. The recent ASTWG sponsored image processing workshop (IPW) highlighted the need within all six NMFS Science Centers for development of automated analysis systems to identify, count, and measure fishes and other organisms, as well as to facilitate habitat classification (Williams et al. 2012). With appropriate effort, automatic image processing systems can meet these challenges and improve resource use and efficiency within NOAA. This proposal addresses automation objectives identified at the IPW, building on previous collaborative success of NOAA scientists and computer vision researchers that began in 2009.

Statement of Work

The image processing topics proposed for software development reflect general needs throughout NOAA that were identified at the IPW. These needs will likely become critical over the next decade in order to extract useful data from the increasing number of projects using underwater imaging for scientific purposes. For this reason, research into new automation techniques and adaptation of existing automation approaches from the computer vision research community to fisheries applications is an important and necessary step. This proposal seeks to continue successful collaborations with computer vision software engineers, leveraging the high level of expertise and familiarity with state-of-the-art software techniques to benefit NOAA scientists using image-based sampling to assess and study marine environments. Earlier ASTWG-funded collaboration in FY2010 with Dr. Jenq-Neng Hwang at the University of Washington, Information Processing Lab (UW IPL) resulted in the delivery of automated segmentation, fish measurement, and tracking algorithms (Fig 1. Chuang et al., 2011) for CamTrawl (a trawl mounted quantitative imaging system; Williams et al., 2010). The first year of the proposed work was funded in FY2012 and is currently supporting software development with IPL though September 2013. The focus of the first year iss the development of algorithms for automated species classification for CamTrawl and other image data, and detection of fish targets in images with complex, uncontrolled backgrounds such as ROV's, drop cameras, and benthic sleds. This proposal seeks funding for the second year of this project to 1) complete development on these topics and 2) introduce a third research objective of automated analysis of fish behavior based on tracking objects in image data.

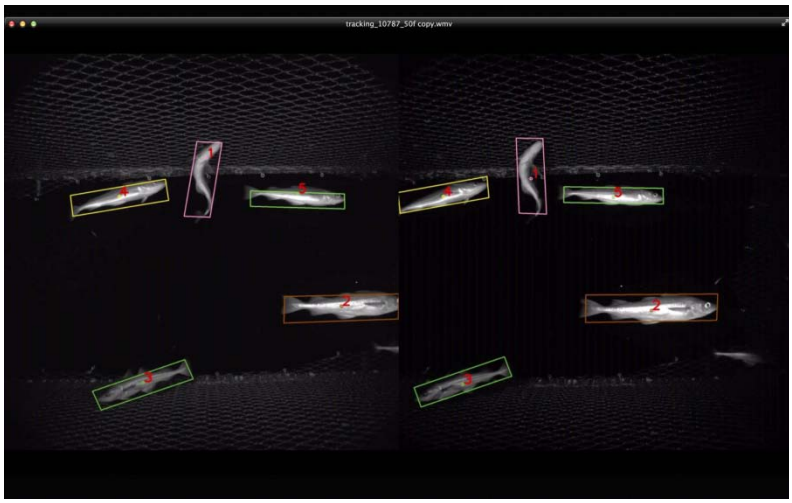

Figure 1. Example of automated image analysis of Camtrawl data. Automated segmentation, tracking, and stereo correspondence allows counts and measurements to be extracted from image data. Software was developed by UW Information Processing Lab

1. *Continued work on species classification*

Automated fish species classification from underwater images represents a technically challenging endeavor with high potential returns to current image-based sampling programs throughout NOAA. Funding for year 1 of this project is supporting rapid development of a novel approach using supervised classification with a hierarchical framework. Automated species classification performance is often characterized by varying precision in results due to variability in image quality, fish orientation relative to cameras, and similar appearance among species (Wilder et al., 2012). A hierarchical analysis framework where the analysts specify the species groupings in higher levels of hierarchy can provide most robust classification from images, while avoiding forced assignments of species level classifications with high levels of uncertainty. An illustration of this principle from CamTrawl Images is shown in figure 2, based on a single feature extracted from fish objects consisting of a curvature scale space (CSS) shape descriptor (Abbasi et al., 1999). Continued work will involve extracting many more features from the

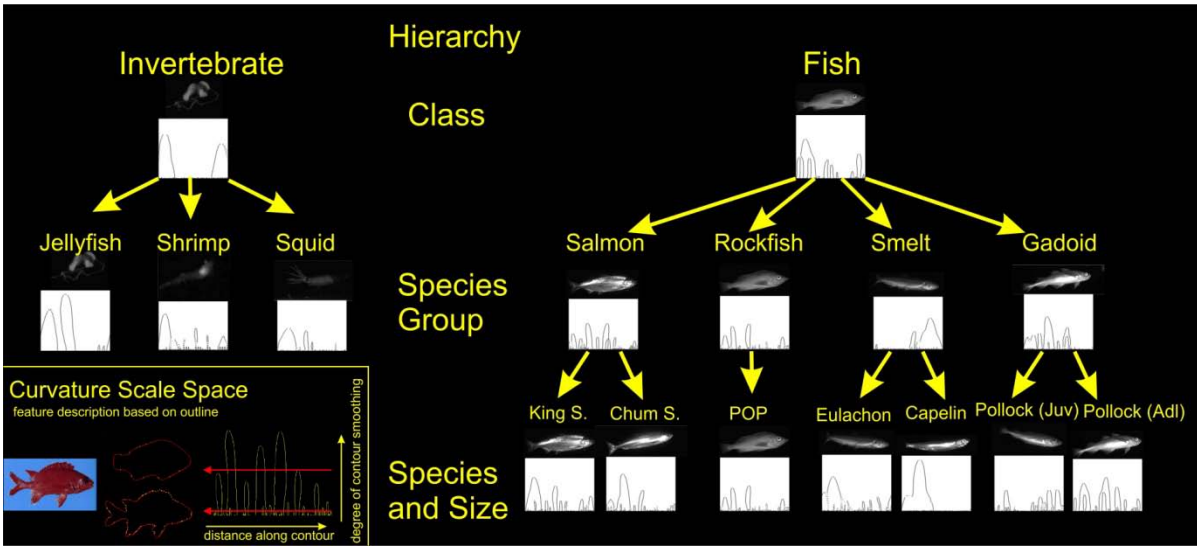

Figure 2 – Example of classification scheme using Curvature Scale Space (CSS). The derivation of CSS is explained in lower left inset. Hierarchical approach shows CSS graphs for each class at three different levels of classification hierarchy.

targets such as target size (available for stereo-image analysis), grayscale histogram, and texture. Another benefit of collaboration between computer vision scientists and biologists is identification of potential object features that may be specifically useful in separating fish species and are not part of the general approach to object classification. For example, fish eyes (location, appearance, and size) are a distinctive and potentially exploitable feature for classification, as well as other morphometric characters such as fin shapes and body dimension ratios. These types of metrics will be evaluated for their potential in discriminating between fish species. The next step in automated classification is the selection of an appropriate classifier. Several classifiers will be evaluated, including random tree (Breiman, 2001) and support vector machine algorithms (Cortes and Vapnik, 1995). For species classification work, several different data sets will be used to assess broader applicability of classification to the various types of image data within NOAA. For example, segmentation of fish targets from a conveyor belt was recently completed at IPL in a related project and will be used as a secondary data set for

automated classification (Fig 3). Fish targets identified from drop stereo-camera will also be included in classification efforts. Given the differences in the appearance of fish between these data sets, it is likely that different sets of features and/or classifier choices may be found to perform best for each set. Final software for classification will therefore incorporate several options for processing, allowing successful segmentation of targets from a variety of image types and camera platforms .

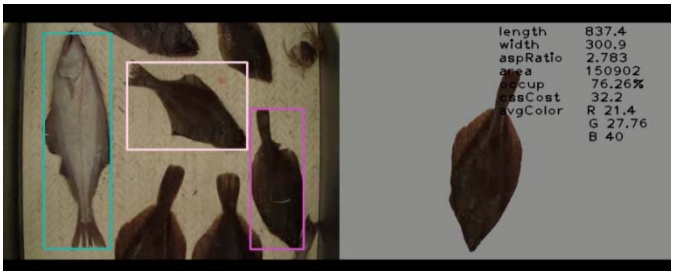

Figure 3. Automated segmentation of fish on a conveyor belt developed by UW Information Processing Lab

2. *Segmenting fish from uncontrolled backgrounds*

A second topic for ongoing software development from the first year of the project is the detection of fish from images where background is highly patterned, such as rocky and coral reefs. This problem was identified as key challenge in automated processing of underwater images at the IPW. Several approaches detailed in the first phase of the proposal will be evaluated as part of the first year effort. In brief, the technical approach for this work will evaluate both temporal (intra-frame) and spatial (inter-frame) techniques for detecting objects of interest in video sequences. First approach is best suited for moving targets (Aach et al., 1993), and can be applied in cases where the camera platform and the fish targets are moving against a complex background such as rocky habitat. The spatial approach uses pattern recognition to locate fish in individual images and has been successfully applied by other projects within NOAA (i.e. Matai et al., 2010). Key challenges for this approach are dependencies on specific fish morphotypes and fish orientations relative to the camera. We propose to train pattern based detection algorithms using groupings based on similar body plans, such as percoid, gadoid, and flatfish types, rather than species level classes. This approach will evaluate the flexibility of pattern based approaches when applied to several species of similar appearance, for example, gadoids and smelts, as a precursor step to species level analysis performed by the classification work described previously. By training algorithms with species groups rather than actual species level classes, more flexibility in this approach may be achieved allowing wider applications to different image-based sampling projects.

3. *Automated classification of fish behavior based on tracking*

Automated analysis of target behavior has been applied in the security monitoring field, where automated detection of potential security threats is highly desired. We propose to adapt these approaches to fisheries data in a framework of statistical analyses using classifier algorithms to identify behavioral responses with associated likelihood of outcomes or events. Cameras are an important tool for observing fish behavior *in situ*, and have been used to study important aspects of fisheries science such as gear performance and bycatch reduction (e.g. Glass & Wardle 1989, Piasente et al., 2004). Sampling gear performance is especially critical for fish abundance

surveys, where avoidance of or escapement from survey gears such as trawls can produce biased estimates of abundance (Williams et al., *in prep*). Understanding the role of fish behavior in gear performance often requires observing large numbers of individuals, which in turn requires substantial analysis effort. In some instances, results from these kinds of analyses are required on a timely basis, further increasing processing challenges. With recent developments in live image transmission during trawling (Crowley, 2011), real-time analysis of fish behavior using automated approaches such as those proposed here could play a critical role in supporting adaptive trawling strategies to reduce survey bias and monitor performance of bycatch reduction devices.

There are several specific applications for this work at AFSC. One example is the Optical-trawl samplers (OTS; e.g. CamTrawl), where fish passing by cameras may exhibit several types of reactions that are pertinent to the interpretation of the image data during fisheries survey operations. Specifically, image data can reveal size-dependent escapement of fish from the trawl (Fig. 4A), which results in biased size composition estimates from images/and or trawl catch. In addition, it is important to identify fish that remain in front of the camera for prolonged periods of time, as they may be difficult to appropriately associate with specific trawling depths or acoustically observed aggregations due to the increased residence time in the trawl. Automated analysis of these individual movement patterns based on tracking increases the value of OTS data and reduces analysis efforts. Fish reactions show how fish behavior is influenced by gear design, which is important in gear choice and design for surveys where they are used as scientific sampling tools, and in industrial applications where fish behavior is exploited to reduce bycatch and increase efficiency of capture of desired catch. Studies on motion trajectories of fish in trawls (e.g. Kim et al., 2008) often have limited sample sizes due to the effort required to manually analyze the data. By automating this process, the number of observations can be increased allowing more accurate assessment of the conditions under which fish are most likely to exhibit behaviors of interest, such as escapement. Motion trajectories could also be used to inform simulation models of fish movement in response to capture (Kim & Wardle, 2005)

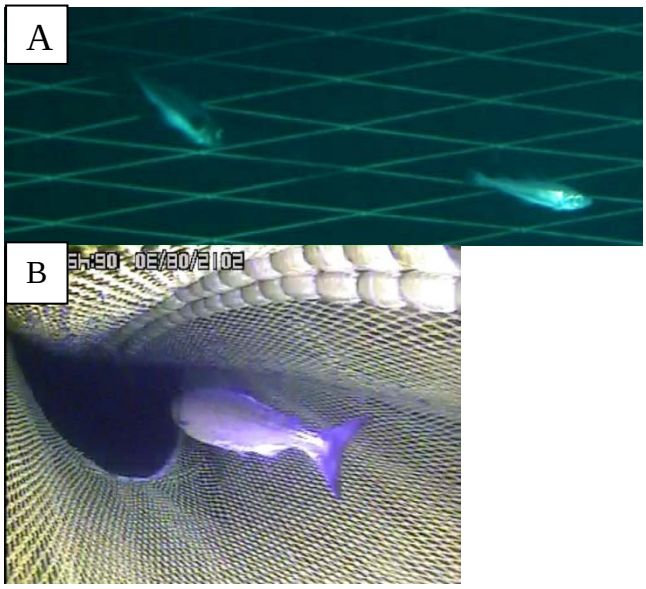

Figure 4. A: Juvenile pollock escaping the midwater survey trawl during an acoustic survey. B: Salmon exiting commercial pollock trawl using escapement openings

A second situation where automated behavior analysis can provide critical data is in monitoring performance bycatch exclusion devices in commercial trawls. Recent work in developing salmon excluders in the walleye pollock fishery relies on image data to monitor the performance of the gear as well as estimate quantities of salmon escaping capture by the trawl. Salmon excluder designs exploit differences in pollock and salmon swimming behavior to reduce salmon take (Fig. 4B). As bycatch reduction designs evolve to increase their effectiveness, their performance must be evaluated, which requires substantial effort to observe how individual fish respond to trawl modifications.

Automated analysis of images to detect, identify and measure fish targets, and track individuals across sequential image frames all constitute the base information needed from images to be able to automate analysis of behavior. For this reason, this topic is introduced as a final piece in the series of automation components already developed or actively being worked on at this time.

For fish behavior analyses, some additional information needs to be extracted from images after segmentation. We describe four methods that can be applied to this work, consisting of space-time information, frequency transform, local descriptors, and body modeling. Many of these methods were developed for analysis of human behavior, but the principles are applicable to the motion of any object. The space-time volume (STV; Blank et al., 2005, Ke et al., 2007) is constructed by concatenating the consecutive silhouettes of fish objects along the time axis. The extracted 3D XYT volume (along x-y spatial coordinates and time) can capture the continuity of fish action. STV is generally limited on non-periodic activities. In cases where some cyclical activity is of interest, the frequency domain information can also be exploited; for example, the discrete Fourier transform (DFT; Kumari & Mitra, 2011) can be used to represent information about recurring fish movements. STV and DFT are global approaches that consider the whole image, and are limited by viewpoint changes and occlusion of fish by other fishes or objects during their movement though the image space. To assist with these cases, methods that do not depend on complete segmentation will also be considered. Local descriptors, such as SIFT (Lowe, 1999; Lowe, 2004) and histogram of oriented gradient (HOG; Dalal & Triggs, 2005), capture the characteristics of an image patch, i.e. a small subcomponent of the fish body such as the head or tail. This approach is more robust to background clutter, appearance and occlusions, and can be robust to varying fish orientation and range from the cameras. Local descriptors can however be limited, as they do not fully capture the whole fish body actions. To address this we propose to include 2D and 3D fish body modeling methods, which can aid in understanding body movements in occluded/obscured views (Kunz & Hemelrijk, 2003; Ke et al., 2010; Ke et al., 2011). Applying these latter approaches also increases the precision of tracking and segmentation results by overcoming limitations of basic tracking in high densities of fish in the image.

Fish behavior classification algorithms can be used used to recognize various fish activities based on the represented features. One such algorithm that will be explored in the proposed work is dynamic time warping (Veeraraghavan et al., 2005; Sempena et al., 2011), a

method for measuring similarity between two sequences that vary in time or speed, is one of the most common temporal classification algorithms due to its simplicity. In cases where a large variety of different fish responses is expected, DTW may not be appropriate due to its reduced performance with a large number of classes with many variations. For these cases, probability-based methods using generative models (dynamic classifiers) such as hidden Markov (Brand et al., 1997) and dynamic Bayesian network (Luo et al., 2003) are proposed.

Resulting algorithms would find immediate application for CamTrawl system and salmon excluder work, although the algorithms could be applied to any situation where targets can be segmented identified and tracked with reasonable success. In addition to these cases, developments may be well suited to other optical monitoring applications, such as fish approaches to traps or pots and reactions to artificial lighting from ROV's and AUV's (Stoner et al., 2008). The project authors would welcome additional image sets from within NOAA to be investigated for automated behavior analysis, under the discretion of ASTWG representatives from each NOAA fisheries science center.

The recent automated image processing workshop sponsored by the ASTWG demonstrated the need for automation for a growing number of image-based sampling programs within NOAA, as well as possibilities for great advances in this area by building on established knowledge in other fields. Automating image processing tasks through software developments will benefit multiple image-based sampling programs currently undertaken at the AFSC, and other similar projects throughout NOAA. By supplying the software development team with a range of image data, the resulting solutions will be flexible and generally applicable for a broader group of marine researchers using images to survey or observe marine environments. An emphasis will be placed on making the proposed software products usable to researchers without a programming background by including a graphical user interface. With the growing need for developing non-lethal survey methods and expanding survey capability to encompass more components of the ecosystem, development of efficient methods of processing image data is of critical importance to present and future stock assessment and resource management efforts. Research efforts such as these represent an investment into technological solutions for NOAA operations, ensuring that resource assessments are utilizing the latest science in data collection and analysis.

Relevance to the ASTGW directives and NOAA NMFS stock assessments

The software products resulting from the funding of this proposal are relevant to several ASTWG objectives. Automated tracking measurement and species classification of image data from Optical –Trawl devices enables these systems to become practical tools for acoustic and trawl surveys by reducing or removing processing time associated with extracting data from images. In turn, OTS devices have to potential to significantly reduce uncertainty in acoustic surveys by providing high spatial resolution needed for classification of acoustically observed aggregations, making this project relevant for ASTWG objective #1 to identify and rank measurement and sampling uncertainties, and define gaps in existing LMR assessments.

Similarly, automated behavior analysis will aid in recognizing situations where image and or catch data may be compromised by high rates of escaping fish. The automation of fish detection in complex backgrounds will similarly increase the usability and timeliness of camera platforms currently side to assess untrawlable habitats, such as the AFSC drop stereo-camera. This will lead to better understanding of the relationship between fish densities in trawlable and untrawlable habitats, which is considered to be a major source of uncertainty in bottom trawl surveys. Objectives outlined in this proposal also directly address the second ASTWG objective, to develop and refine advanced sampling technologies, specifically research theme 2, by providing methodology for enumeration, and species identification based on optical advanced sampling devices. The proposal also addresses theme 3, as image-based sampling systems are often used to enumerate animals in untrawlable areas that are also often not accessible to acoustic sampling due to the near-bottom acoustic dead zone. By increasing the usability of these assessment methods, automated image processing techniques directly contribute to improved data for resource management and ecosystem studies.

Expected results and probability of success – Year 2:

Past ASTWG funded AFSC collaborations with computer vision experts at UW IPL have resulted in software products that are incorporated into current survey data analysis tools as standard operating protocol. Previous software development was accompanied by continual monthly meetings between AFSC and UW to ensure projects are kept on track, to share results, and provide opportunities to exchange ideas relevant to the work. We anticipate this pattern to continue in future work, with the delivery of software packages as they are completed and the dissemination of novel techniques in the form of publications in both fisheries and computer vision literature. Since these efforts will make use of previously collected test data sets from CamTrawl collections, video and stereo-video drop camera surveys of rockfishes and corals, and video material collected inside trawls as part of fish behavior studies, software development can proceed at a rapid pace and is insulated from any required field work at this point.

Project Schedule and Milestones

Time period	Activity
September - December 2012	Finalizing software development on species classification (topic 1)
January 2013	Delivery of software module for species classification
January – March 2013	Continuing development of routines for target detection from uncontrolled backgrounds (topic 2) and testing on validated sets supplied by AFSC
April 2013	Delivery of software module target detection from uncontrolled backgrounds

May-August 2013	Initiate automated fish behavior analysis (topic 3) using CamTrawl and salmon excluder video
September 2013	Final software package delivery and manuscript preparation.

References

Aach, T., Kaup, A., Mester, R. 1993. Statistical model-based change detection in moving video. Signal Processing, Vol. 31, No. 2, pp. 165-180.

Bookstein, F.L. 1991. Morphometric Tools for Landmark Data: Geometry and Biology. Cambridge University Press, New York, 435 pp

Chuang, M.C., Hwang, J.N., Williams, K., Towler, R. 2011, Automatic Fish Segmentation via Double Local Thresholding for Trawl-Based Underwater Camera Systems. Int'l Conference on Image Processing (ICIP 2011), Brussels Belgium, Sept. 2011.

Chuang, M.C., Hwang, J.N., Williams, K., Towler, R. in prep. Multiple fish tracking for underwater stereo camera systems, submitted to Int'l Conference on Acoustics, Speech and Signal Processing (ICASSP 2012), Kyoto Japan, March. 2012.

Diehl, N. 1991. Object-oriented motion estimation and segmentation in image sequences. Signal processing : Image Comm., vol. 3, pp.23-56.

Gu, C., and Lee, M.C. 1998. Semantic Segmentation and Tracking of Semantic Video objects. IEEE Trans. Circuits Syst. Video Technology, vol. 8, pp.572-584.

Kim, C., and Hwang, J-N. 2000. Video Object Extraction for Object-Oriented Applications. Journal of VLSI Signal Processing, Dec. 2000.

Kim, C., and Hwang, J-N. 2002. Fast and Automatic Video Object Segmentation and Tracking for Content-Based Applications. IEEE Transactions on Circuits and Systems for Video Technology (CSVT). 12(2):122-129.

Kim, Y., Wardle, C.S., An, Y. 2008. Herding and escaping responses of juvenile roundfish to square mesh window in a trawl cod end, Fisheries Science 74(1):1-7

Larsen, R., Olafsdottir, H., and Ersboll, B. K. 2009. Shape and Texture Based Classification of Fish Species. Proceedings of the 16th Scandinavian Conference on Image Analysis, pp. 745-749.

Lee, D.J., Redd, S., Schoenberger, R., Xu, X., and Zhan, P. 2003. An automated fish species classification and migration monitoring system. Industrial Electronics Society, The 29th Annual Conference of the IEEE (IECON '03), vol.2, no., pp. 1080- 1085 Vol.2, 2-6.

Lee, D.J., Shiozawa, D., Xu, X., Zhan, P., Schoenberger, R.B. 2004. Contour matching for a fish recognition and migration-monitoring system. in Proc. SPIE, Two- and Three-Dimensional Vision Systems for Inspection, Control, and Metrology II, Philadelphia, PA, USA, 2004.

Matai, J., Kastner, R., Cutter, G.R., Demer, D.A. 2012. Automated Techniques for Detection and Recognition of Fishers Using Computer Vision Algorithms. *In* Report of the National Marine Fisheries Service Automated Image Processing Workshop. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-F/SPO-121, 48 p.

MacLeod, N., Benfield, M., & Culverhouse, P.2010. Time to Automate Identification. Nature 467 : 155-156.

Mech, R., and Wollborn, M. 1998. A noise robust method for 2D shape estimation of moving objects in video sequences considering a moving camera. Signal Processing, Vol. 66, No. 2, pp. 203-217.

Meier, T., and Ngan, K.N. 1998. Automatic Segmentation of Moving Objects for Video Object Plane Generation. IEEE Transactions on Circuits and Systems for Video Technology, Vol.8, No.5, pp 525-538.

Neri, A. et al. 1998. Automatic Moving Object and background Separation. Signal Processing, vol.66, pp 219-232.

Rooper, C. N., Hoff, G. R., De Robertis, A. 2010. Assessing habitat utilization and rockfish (Sebastes spp.) biomass on an isolated rocky ridge using acoustics and stereo image analysis. Can. J Fish. Aquat. Sci. 67:1658-1670.

Storbeck, F., and Daan, B. 2001. Fish species recognition using computer vision and a neural network. Fisheries Research, 51(1):11-15.

Strachan, N. J. C. 1993. Recognition of fish species by colour and shape. Image and Vision Computing, ACM Journal of, Vol. 11, No. 1.

Strachan, N. J. C., and Nesvadba, P. 1990. Fish Species Recognition by Shape Analysis of Images. Pattern Recognition, ACM Journal of, Vol . 23, No. 5, pp. 539-544.

Wilder, J., Chetan Tondea, C., Sundar, G., Huang, N., Barinov, L., Baxi, J., Bibby, J., Rapport, A., Pavoni, E., Tsang, S., Garcia, E., Mateo, F., Lubansky, T.M., Russell. G.J. 2012. An automatic identification and monitoring system. Applications of Digital Image Processing XXXV, edited by Andrew G. Tescher, Proc. of SPIE Vol. 8499

Williams, K., Towler, R., Wilson, C.D. 2010 Cam-trawl: a combination trawl and stereo-camera system. Sea Technology, December issue: 45-50. (http://www.sea-technology.com/features/2010/1210/cam-trawl.php)

Williams, K., Rooper, C., Harms, J. (editors). 2012. Report of the National Marine Fisheries Service Automated Image Processing Workshop. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-F/SPO-121, 48 p.

Williams, K., Wilson, C.D., Horne, J.K. In review. Walleye pollock (*Theragra chalcogramma*) behavior in midwater trawls. Submitted to Fisheries Research.

Williams, K., Punt, A.E., Wilson, C.D., and Horne, J.K. in prep. Effect of trawl selectivity on the acoustic survey time series and assessment of Gulf of Alaska walleye pollock (*Theragra chacogramma*).

Zhang, D., and Lu, G. 2001. Segmentation of moving objects in image sequence: A review. Circuits, Systems, and Signal Processing, Birkhäuser Boston, Vol. 20, No. 2, pp. 143-183.

Budget (Year 1):

Item	Cost	Total
Contract for software development	87,500	87,500

Budget Justification:

The funding amount reflects current cost estimates to support an individual software engineer or doctoral graduate student for one year. Analyses will use existing data sources, and funds will not be required for collaborating NOAA researchers.

CV's for PI's are attached below.

Kresimir Williams

7600 Sand Point Way
Seattle, WA 98115
206-526-4133
kresimir.williams@noaa.gov

Education:

M.S. Auburn University, 2002, Fisheries And Aquaculture
B.S. Samford University, 1995, Biology

Positions:

Fishery Biologist, NMFS, NOAA, AFSC, Midwater Assessment and Conservation Engineering, 2003-present
Fisheries Observer, Alaskan Observes, Inc. 1997-2000

Research Interests:

Influence of fish behavior on survey design and uncertainty, advanced sampling technology and underwater instruments fish observation and enumeration, fisheries management, population modeling

Computer Skills:

Proficient programming skills in Matlab, Python, VB, R statistical software. Database design, image processing, 3-D visualization

Awards:

Bronze medal, NOAA, 2007 – for development of open design high precision fish measurement device
H.S. Swingle Award for Outstanding Master's Student, Auburn University, 4/02
Presidential Fellowship, Auburn University, 9/00 – 5/02
Russel – Barber Award for Excellence in Marine Studies, Samford University, 6/93

Publications:

Williams, K.; Punt, A.E.; Wilson, C.D.; Horne, J.K. 2011. Length-selective retention of walleye pollock, Theragra chalcogramma, by midwater trawls. ICES J Mar. Sci. 68:119-129.

Williams, K., Rooper, C. N., Towler, R. 2010. Use of stereo camera systems for assessment of rockfish abundance in untrawlable areas and for recording pollock behavior during midwater trawls. Fish Bull 108(3): 352-362.

De Robertis, A; Williams, K. 2008. Weight-length relationships in fisheries studies: The standard allometric model should be applied with caution. *TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY* 137 (3): 707-719.

Handegard, NO; Williams, K. 2008. Automated tracking of fish in trawls using the DIDSON (Dual frequency IDentification SONar). *ICES JOURNAL OF MARINE SCIENCE* 65 (4): 636-644.

Williams, K. 2007. Evaluation of the Macroscopic Staging Method for Determining Maturity of Female Walleye Pollock *Theragra chalcogramma* in Shelikof Strait, Alaska. *ALASKA FISHERY RESEARCH BULLETIN* 12 (2): 252-263.

Williams, K; Papanikos, N; Phelps, RP; Shardo, JD. 2004. Development, growth, and yolk utilization of hatchery-reared red snapper *Lutjanus campechanus* larvae. *MARINE ECOLOGY-PROGRESS SERIES* 275: 231-239.

Jenq-Neng Hwang
Department of Electrical Engineering
206-685-1603 (office), hwang@uw.edu
www.ee.washington.edu/faculty/hwang/

Educational Record University of Southern California, 9/85-12/88, Ph.D. EE
National Taiwan University, 9/81-6/83, M.S. EE.
National Taiwan University, 9/77-6/81, B.S. EE.

Appointments **University of Washington**
- Associate Chair for Research, 9/11 -- present
- Associate Chair for Research & Development, 9/03 – 10/05.
- Full Professor, 9/99 – present.
- Associate Professor, 9/94 – 8/99.
- Assistant Professor, 8/89 -- 8/94.
- Research Associate (Princeton University), 1/89 – 6/89

Honors and Awards IEEE Signal Processing Society **Annual Best Paper Award**, 1995.
IEEE Fellow, 2001.
Annual Faculty Service Award, UW, Dept. of EE, 2006.

Research Interests Multimedia Signal Processing, Multimedia Networking, Pattern Recognition, Image/Vision Analysis

Current professional society membership and service

1. ***Editor***, - ETRI Journal, Information, Telecommunications & Electronics, 2009--present.
2. ***Associate Editor***, - IEEE Trans. on Image Processing, 2008--present.
3. ***Editorial Board Member***, -- IEEE Signal Processing Magazine, 2009 - Present.
4. ***Editorial Board Member***, -- International Journal of Digital Multimedia Broadcasting, Hindawi, 2007 - Present.

Organization activities of international conferences and forums

1. **Conference Tutorial Chair**, - IEEE Midwest Symposium on Circuits and Systems, Seattle, WA, August 2010
2. **Conference Technical Program Co-Chair**, - IEEE Int'l Symposium on Circuits and Systems, Taipei, May 2009.
3. **Conference Special Session Co-Chair**, - IEEE Int'l Symposium on Circuits and Systems, Seattle, May 2008.

Publications

Related Referred Archival Journals

1. Y. H. Tseng, J. N. Hwang, and Florence Sheehan, "Three-Dimensional Object Representation and Invariant Recognition Using Continuous Distance Transform Neural Networks," IEEE Trans. on Neural Networks, special issue on Pattern Recognition, 8(1):141-147, January 1997.

2. Changick Kim and Jenq-Neng Hwang, "Fast and Automatic Video Object Segmentation and Tracking for Content-Based Applications," IEEE Transactions on Circuits and Systems for Video Technology (CSVT). 12(2):122-129, Feb. 2002.
3. Changick Kim and Jenq-Neng Hwang, "Object-Based Video Abstraction for Video Surveillance Applications," IEEE Transactions on Circuits and Systems for Video Technology (CSVT). Vol. 12, No. 12, pp. 1128-1138, December. 2002.
4. Ying Luo, Tzong-Der Wu, Jenq-Neng Hwang, “Object-based Analysis and Interpretation of Human Motion in Sports Video Sequences by Dynamic Bayesian Networks,” Computer Vision and Image Understanding, Vol. 92, Issues 2-3, pp. 192-216, special issue on Video Retrieval and Summarization, November 2003.
5. Hsu-Yung Cheng, Jenq-Neng Hwang, “Adaptive particle sampling and adaptive appearance for multiple video object tracking,” Signal Processing, Elsevier, 89(9):1844-1849, Sept. 2009.
6. Timothy Shih, Nick Tang, Josephy Tsai, Jenq-Neng Hwang, “Video Motion Interpolation for Special Effect Applications,” IEEE Trans. on SMC, 2011.
7. Hsu-Yung Cheng and Jenq-Neng Hwang, “ Integrated Video Object Tracking with Applications in Trajectory-Based Event Detection,” accepted by Journal of Visual Communication and Image Representation, 2011.

Fully Referred Conference Proceedings

1. Chun-Te Chu, Jenq-Neng Hwang, Ho-Youl Jung, Hung-I Pai, Kung-Ming Lan
“ Robust Video Object Tracking based on Multiple Kernels with Projected Gradients,” The IEEE Int'l Conf. on ASSP (ICASSP 2011), Prague, Czech Republic, May 22-27, 2011.
2. Shian-Ru Ke, Jenq-Neng Hwang, Kung-Ming Lan and Sheng-Zheng Wang
“ View-Invariant 3D Human Body Pose Reconstruction using a Monocular Video Camera ,” ACM/IEEE Int'l Conf. on Distributed Smart Cameras (ICDSC 2011), Ghent Belgium, August 22-25, 2011.
3. Chun-Te Chu, Jenq-Neng Hwang, Shen-Zheng Wang and Yi-Yuan Chen
“ Human Tracking by Adaptive Kalman Filtering and Multiple Kernels Tracking with Projected Gradients,” ACM/IEEE Int'l Conf. on Distributed Smart Cameras (ICDSC 2011), Ghent Belgium, August 22-25, 2011.
4. Chun-Te Chu, Jenq-Neng Hwang, Kung-Ming Lan and Shen-Zheng Wang
“ Tracking Across Multiple Cameras with Overlapping Views Based on Brightness and Tangent Transfer Functions ,” ACM/IEEE Int'l Conf. on Distributed Smart Cameras (ICDSC 2011), Ghent Belgium, August 22-25, 2011.
5. Meng-Che Chuang, Jenq-Neng Hwang, Kresimir Williams, Richard Towler
“ Automatic Fish Segmentation via Double Local Thresholding for Trawl-Based Underwater Camera Systems,” The IEEE Int'l Conf. on Image Processing (ICIP 2011), Brussel Belgium, Sept 11-14, 2011.

Christopher N. Rooper
Work: NMFS, Alaska Fisheries Science Center
7600 Sand Point Way NE, Seattle WA 98115
(206) 526-4689
Chris.Rooper@noaa.gov

Education

Ph.D. University of Washington, Aquatic and Fishery Sciences, 2002
M.S. University of Alaska, Fairbanks, Fisheries and Aquatic Sciences, 1996
B.S. Oregon State University, Biology, 1991

Employment

2002-present Research Fishery Biologist- Alaska Fisheries Science Center, RACE Division, Seattle Washington, USA.
1999-2002 Research Assistant- School of Aquatic and Fisheries Sciences, University of Washington, Seattle Washington USA
1999-2000 Teaching Assistant- School of Aquatic and Fisheries Sciences, University of Washington, Seattle Washington USA
1997-1998 Biological Science Technician- U.S. Forest Service, Juneau Forestry Sciences Laboratory, Juneau, Alaska, USA.
1997 Fishery Biologist- U.S. Geological Service, Columbia River Research Lab, Cook Washington, USA.
1996-1997 Biological Science Technician- U.S. Forest Service, Juneau Forestry Sciences Laboratory, Juneau, Alaska, USA
1994-1996 Research Assistant- Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks, Alaska, USA.
1992-1994 Experimental Biology Aide- Oregon Department of Fish and Wildlife, Clackamas, LaGrande and Astoria, Oregon, USA

Five most relevant publications

Rooper, C.N., G. R. Hoff & A. De Robertis. 2010. Assessing habitat utilization and rockfish (Sebastes sp.) biomass in an isolated rocky ridge using acoustics and stereo image analysis. Can. J. Fish. Aquat. Sci. 67:1658-1670.

Williams, K., C.N. Rooper, & R. Towler. 2010. Use of stereo camera systems for assessment of rockfish abundance in untrawlable areas and for recording pollock behavior during midwater trawls. Fish Bull 108:352-362

Rooper, C. N. 2008. Underwater video sleds: Versatile and cost effective tools for habitat mapping, p. 99-107. In J. R. Reynolds and H. G. Greene (editors), Marine Habitat Mapping

Technology for Alaska. Alaska Sea Grant College Program Report No. AK-SG-08-03, University of Alaska, Fairbanks.

Rooper, C.N. & M. Zimmermann. 2007. A bottom-up methodology for integrating underwater video and acoustic mapping for seafloor substrate classification. Continental Shelf Research 27:947-957.

Rooper, C.N., J.L. Boldt & M. Zimmermann. 2007. An assessment of juvenile Pacific Ocean perch (Sebastes alutus) habitat use in a deepwater nursery. Estuarine, Coastal, and Shelf Sciences 75:371-380.

Five other publications

Rooper, C.N., M.E. Wilkins, C. Rose & C. Coon. 2011. Modeling the impacts of bottom trawling and the subsequent recovery rates of sponges and corals in the Aleutian Islands, Alaska. Cont. Shelf Res. 31:1827-1834

Rooper, C.N. & M.H. Martin, 2009. Predicting presence and abundance of demersal fish: a model application to shortspine thornyhead (Sebastolobus alascanus). Mar Ecol Prog Ser 379:253-266

Boldt, J. L. & C. N. Rooper. 2009. An examination of links between feeding conditions and energetic content of juvenile Pacific ocean perch in the Aleutian Islands. Fishery Bulletin 107:278-285.

Rooper, C.N. 2008. An ecological analysis of rockfish (Sebastes spp.) assemblages in the north Pacific along broad-scale environmental gradients. Fishery Bulletin 181:1-11.

Rooper, C. N., D. R. Gunderson, & D. A. Armstrong. 2006. Evidence for resource partitioning and competition in nursery estuaries by juvenile flatfish in Oregon and Washington. Fish Bull 104:616-622

Memberships and Awards

Member: American Society of Limnology and Oceanography, 2000
American Fisheries Society, North Pacific International Chapter, 1998
Best Student Paper, Pacific Estuarine Research Society Annual Meeting, 2000
Pearl Jam 10 Club, 2009
Greater Seattle Hockey League, All-Star Division 6-7, 2003-2004
Cobb Fellowship, University of Washington, 1998
Graduation with High Honors, Oregon State University, 1991

Dr. Craig S. Rose
RACE Division, Alaska Fisheries Science Center
7600 Sand Point Way NE
Seattle WA 98115
Phone (206) 526-4128, Fax (206) 526-6723 craig.rose@noaa.gov

Education

Bachelor of Science in Fisheries - 1979
Humboldt State University, Arcata, California

Master of Science in Fisheries - 1982
University of Washington, Seattle, Washington

Doctor of Philosophy in Fisheries - 1993
University of Washington, Seattle, Washington

Experience

Research Fisheries Biologist, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, NMFS, 1977 - present

Fishing Gear Research Leader, Conservation Engineering - 1987 - present
Assessment Survey Biologist, Gulf of Alaska Groundfish - 1977 – 1986

Selected Publications

Rose, C. S., A. W. Stoner, J. E. Munk, J. R. Gauvin, C. F. Hammond. 2010a. Quantification of unobserved mortality rates of snow, Tanner and red king crabs (Chionoecetes opilio, C. bairdi and Paralithodes camtschaticus) after encounters with trawls on the seafloor. NPRB Project 711 Final Report. http://doc.nprb.org/web/07_prjs/711_final%20report.pdf

Rose C.S., J. R. Gauvin, & C. F. Hammond. 2010b. Effective herding of flatfish by cables with minimal seafloor contact. Fish. Bull. 102(2): 136–144.

Stoner, A.W., C.S. Rose, J.E.Munk, C.F. Hammond, & M.W. Davis 2008. An assessment of discard mortality for two Alaskan crab species, Tanner crab (Chionoecetes bairdi) and snow crab (Chionoecetes opilio), based on reflex impairment. Fishery Bulletin 106: 337-347.

Kaiser, M.J., N. Graham, C.S.Rose & P.H. Weibe. 2007. Ecosystem-sensitive approaches to fishing: reconciling fisheries with conservation through improvements in fishing technology. ICES J. Mar. Sci. 64: 1610-1611.

Rose, C.S., A.W. Stoner & K. Matteson 2005. Use of high-frequency imaging sonar to observe fish behaviour near baited fishing gears. Fisheries Research 76: 291-304.

Rose, C.S. and Jorgensen, E.M. (2005) Spatial and temporal distributions of trawling intensity off Alaska: Effects of spatial scale on perceptions of the distribution and magnitude of fishing effects. Pages 679-690 in P.W. Barnes and J.P. Thomas editors. Benthic Habitats and the Effects of Fishing. American Fisheries Society, Symposium 41, Bethesda, Maryland.

Abookire, A.A. & C.S. Rose. 2005. Modifications to a plumb staff beam trawl for sampling uneven, complex habitats. Fisheries Research 71: 247-254.

Karp, W.A., C.S.Rose, J.R. Gauvin, S.K. Gaichas, M.V. Dorn and G.D. Stauffer. 2001. Government-Industry cooperative fisheries research in the North Pacific under the MCFCMA. Mar. Fish. Rev. 63(1) 40-46.

Rose, C.S.and Gauvin J. 2000. Effectiveness of a rigid grate for excluding halibut from groundfish trawl catches. Mar. Fish. Rev. 62(2) 61-66.

Rose, C.S., Carr, A., Ferro, D., Fonteyne, R., & MacMullen, P. 2000. Using gear technology to understand and reduce unintended effects of fishing on the seabed and associated communities: background and potential directions. Report of the Fish Beh. & Fish. Tech. Wk. Grp., Int. Coun. Expl. Seas 24 pp.

Olla, B.L., M.W. Davis and C.S. Rose 2000. Differences in orientation and swimming of walleye pollock Theragra chalcogramma in a trawl net under dark and light conditions: concordance between field and laboratory observations. Fisheries Research 44: 261-266.

Rose, C.S. 1999. Injury rates of red king crab, Paralithodes camtschaticus, passing under bottom trawl footropes. Mar. Fish. Rev. 61(2) 72-76.

CURRICULUM VITAE

JAMES WILDER ORR
Resource Assessment and Conservation Engineering Division
Alaska Fisheries Science Center
National Marine Fisheries Service/NOAA
7600 Sand Point Way NE
Seattle, WA 98115-0070

EDUCATION:

High School Diploma, Virgil I. Grissom High School, Huntsville, Alabama, 1976.
B. S., Biology, Wheaton College, Wheaton, Illinois, 1980.
M. S., Fisheries Management, Auburn University, Auburn, Alabama, 1987.
Ph. D., Fisheries, University of Washington, Seattle, Washington, 1995.

POSITIONS:

Research Associate, School of Fisheries, University of Washington, Seattle, Washington: UW Fish Collection Manager, 1987-1988, and Species Identification Instructor to National Marine Fisheries Service Foreign and Domestic Groundfisheries and High Seas Driftnet Observer Programs, 1988-1992.

Teaching Associate, Ichthyology, School of Fisheries, University of Washington, Seattle, Washington, Spring 1989, Winter 1990, Winter 1992.

Associate Scientific Editor to Dr. L. J. Jones, *Fishery Bulletin* and *NOAA Technical Reports NMFS*, National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, Washington, 1992.

Associate Scientific Editor to Dr. R. W. Hardy, *Fishery Bulletin* and *NOAA Technical Reports NMFS*, National Marine Fisheries Service, Alaska Fisheries Science Center and Northwest Fisheries Science Center, Seattle, Washington, 1992-1993.

Research Fisheries Biologist, Alaska Fisheries Science Center, Resource Assessment and Conservation Engineering Division, National Marine Fisheries Service, Seattle, Washington, 1995-present.

Affiliate Assistant Professor, College of Ocean and Fishery Sciences, University of Washington, 1999-present.

Affiliate Curator, The Burke Museum of Natural History and Culture, 2009-present.

RECENT PUBLICATIONS:

Pietsch, T. W., and J. W. Orr. 2007. Phylogenetic relationships of deep-sea anglerfishes (Teleostei: Lophiiformes) based on morphology. *Copeia* 2007(1):1-34.

Stevenson, D. E., J. W. Orr, G. R. Hoff, and J. D. McEachran. 2008. Emerging patterns of species richness, diversity, density, and distribution in the skates (Rajidae) of Alaska. *Fishery Bulletin* 106(1):24-39.

Orr, J. W., and S. Hawkins. 2008. Species of the rougheye rockfish complex: resurrection of *Sebastes melanostictus* (Matsubara, 1934) and a redescription of *Sebastes aleutianus* (Jordan and Evermann, 1898) (Teleostei: Scorpaeniformes). *Fishery Bulletin* 106(2):111-134.

Lannoo, M. J., J. T. Eastman, and J. W. Orr. 2009. Nervous and sensory systems in sub-Arctic and Antarctic snailfishes of the genus *Paraliparis* (Teleostei: Scorpaeniformes: Liparidae). *Copeia* 2009(4):733-740.

Miya, M., T. W. Pietsch, J. W. Orr, T. P. Satoh, H.-C. Ho, R. Arnold, A. M. Shedlock, M. Shimazaki, M. Yabe, and M. Nishida. 2010. Evolutionary history of anglerfishes (Teleostei: Lophiiformes): a mitogenomic perspective. *BMC Evolutionary Biology* 10:58.

Baldwin, Z. H., and J. W. Orr. 2010. A new species of the snailfish genus *Paraliparis* (Scorpaeniformes: Liparidae) from the eastern Bering Sea. *Copeia* 2010(4):640-643.

Kai, Y., J. W. Orr, K. Sakai, and T. Nakabo. 2011. Genetic and morphological evidence for cryptic diversity in the *Careproctus rastrinus* species complex (Teleostei: Liparidae) of the North Pacific. *Ichthyological Research,* 12 pp [Available at doi 10.1007/s10228-010-0202-2].

Orr, J. W., D. E. Stevenson, G. R. Hoff, I. Spies, and J. D. McEachran. 2011. *Bathyraja panthera*, a new species of skate (Rajidae: Arhynchobatinae) from the western Aleutian Islands and a revision of the subgenus *Arctoraja* Ishiyama. *NOAA Professional Papers NMFS* 11.

Wilson, A. W., and J. W. Orr. 2011. The evolutionary origins of syngnathid fishes. *Journal of Fish Biology, Special Issue,* 78:1603-1623.

Laman, E. A., and J. W. Orr. In press. First record of an aurora rockfish, *Sebastes aurora*, from Alaskan waters. *Northwestern Naturalist* 92(3), 10 ms pp.

Orr, J. W. In press. Pleuronectiformes, flatfishes, soles, and hogchokers, 80 ms pp. *In*: North American Freshwater Fishes: Evolution, Ecology, and Behavior. B. Burr and M. Warren (eds.), Johns Hopkins University Press.

Stevenson, D. E., and J. W. Orr. In review. A new species of lumpsucker (Cyclopteridae: *Eumicrotremus*) from the San Juan Islands. *Copeia*, 22 ms pp.

Orr, J. W. In review. Two new species of *Careproctus* (Scorpaeniformes: Liparidae) from the eastern North Pacific. *Copeia*, 20 ms pp.