# Automatic Underwater Multiple Objects Detection and Tracking Using Sonar Imaging

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# Bibliography


[1] S. M. Smith and S. E. Dunn, "The Ocean Voyager II: an AUV designed for coastal oceanography," in *Autonomous Underwater Vehicle Technology, 1994. AUV '94.*, Cambridge, MA, USA, 1994, pp. 139-147.

[2] C. Weber, "Maritime Terrorist Threat: Focus Report," New York State Office of Homeland Security, New York, 2006.

[3] P. E. An, A. J. Healey, S. M. Smith, and S. E. Dunn, "New Experimental Results on GPS/INS Navigation for Ocean Voyager II AUV," in *Autonomous Underwater Vehicle Technology, 1996*, Monterey, CA, USA, 1996.

[4] J. J. Leonard, A. A. Bennett, C. M. Smith, and H. J. S. Feder, "Autonomous Underwater Vehicle Navigation," Technical Report 1998.

[5] J. A. Catipovic, "Performance Limitations in Underwater Acoustic Telemetry," *Oceanic Engineering, IEEE,* vol. 15, pp. 205-216, 1990.

[6] L. Lucido, J. Opderbecke, V. Rigaud, R. Deriche, and Z. Zhang, "A Terrain Referenced Underwater Positioning using Sonar Bathymetric profiles and Multiscale Analysis," *OCEANS'96. MTS/IEEE. 'Prospects for the 21st Century'. Conference Proceedings,* vol. 1, 1996.

[7] M. Sistiaga, J. Opderbecke, and M.-J. Aldon, "Depth Image Matching for Underwater Vehicle Navigation," in *10th International Conference on Image Analysis and Processing (ICIAP'99)*, 1999, p. 624.

[8] H. Durrant-Whyte and T. Bailey, "Simultaneous localisation and mapping (slam): Part I the essential algorithms," *Robotics and Automation Magazine*, vol. 13, pp. 99-110, 2006.

[9] M. Montemerlo, S. Thrun, D. Koller, and B. Wegbreit, "FastSLAM 2.0: An improved particle filtering algorithm for simultaneous localization and mapping that provably converges," 2003.

[10] M. J. Chantler, D. M. Lane, D. Dai, and N. Williams, "Detection and tracking of returns in sector-scan sonar imagesequences," IEE Proceedings-Radar, Sonar and Navigation, vol. 143, 1996.

[11] S. Reed, Y. Petillot, J. Bell, "Unsupervised Mine Detection and Analysis in Side-scan Sonar: A comparison of Markov Random Fields and Statistical Snakes, " ProcCAD/CAC 2001, Halifax, 2001

[12] J. M. Bell, E. Dura, S. Reed, Y. R. Petillot, D. M. Lane, and E. Riccartton, "Extraction and classification of objects from sidescan sonar," 2002.

[13] Creuze, V. and B. Jouvencel "Avoidance of underwater cliffs for autonomous underwater vehicles." Intelligent Robots and System, 2002. IEEE/RSJ International Conference on 1.

[14] C. Barat and M. J. Rendas, "Benthic boundary tracking using a profiler sonar," presented at Intelligent Robots and Systems, 2003. , 2003.

[15] L. Hellequin, J. M. Boucher, and X. Lurton, "Processing of high-frequency multibeam echo sounder data for seafloor characterization," IEEE Journal of Oceanic Engineering, vol. 28, pp. 78-89, 2003.

[16] D. Ribas, P. Ridao, J. Neira, and J. D. Tardos, "Line Extraction from Mechanically Scanned Imaging Sonar," *LECTURE NOTES IN COMPUTER SCIENCE,* vol. 4477, p. 322, 2007.

[17] L. Henriksen, "Real-time underwater object detection based on an electrically scanned high-resolution sonar," *Autonomous Underwater Vehicle Technology, 1994. AUV'94., Proceedings of the 1994 Symposium on,* pp. 99-104, 1994.

[18] I. Quidu, A. Hetet, Y. Dupas, and S. Lefevre, "AUV (Redermor) Obstacle Detection and Avoidance Experimental Evaluation," *OCEANS 2007-Europe,* pp. 1-6, 2007.

[19] S. Daniel, F. Le Leannec, C. Roux, B. Soliman, and E. P. Maillard, "Side-scan sonar image matching," *IEEE Journal of Oceanic Engineering*, vol. 23, pp. 245-259, 1998.

[20] S. Williams, G. Dissanayake, and H. Durrant-Whyte, "Towards terrain-aided navigation for underwater robotics," *Advanced Robotics*, vol. 15, pp. 533-549, 2001.

[21] P. Newman, "On the structure and solution of the simultaneous localisation and map building problem," *Unpublished Ph. D. thesis, Australian Centre for Field Robotics, University of Sydney, Australia*, 2000.

[22] D. R. Romagos, "Underwater SLAM for Structured Environments Using an Imaging Sonar," in *Department of Computer Engineering*. Girona, Spain: the University of Girona 2008.

[23] D. Clark, B. N. Vo, and J. Bell, "GM-PHD filter multi-target tracking in sonar images," presented at Signal Processing, Sensor Fusion, and Target Recognition XV. Proceedings of the SPIE, 2006.

[24] Y. Petillot, I. T. Ruiz, and D. M. Lane, "Underwater vehicle obstacle avoidance and path planning using a multi-beam forward looking sonar," *IEEE Journal of Oceanic Engineering*, vol. 26, 2001.

[25] A. B. Baggeroer, W. A. Kuperman, and P. N. Mikhalevsky, "An overview of matched field methods in ocean acoustics," *IEEE Journal of Oceanic Engineering*, vol. 18, pp. 401-424, 1993.

[26] G. Ginolhac and G. Jourdain, "Detection in presence of reverberation," presented at OCEANS 2000 MTS/IEEE Conference and Exhibition, Providence, RI, USA, 2000.

[27] G. Ginolhac and G. Jourdain," Principal component inverse" algorithm for detection in thepresence of reverberation," *IEEE Journal of Oceanic Engineering*, vol. 27, pp. 310-321, 2002.

[28] D. C. Schleher, *MTI and pulsed Doppler radar*: Artech House Boston, 1991.

[29] K. M. Kim, C. Lee, and D. H. Youn, "Adaptive processing technique for enhanced CFAR detectingperformance in active sonar systems," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 36, pp. 693-700, 2000.

[30] J. Ren and J. S. Bird, "Detecting Small Slow-moving Sonar Targets Using Bottom Reverberation Coherence," *OCEANS 2006*, pp. 1-6, 2006.

[31] A. D. Waite, *Sonar for Practising Engineers*: Wiley Chichester, 2002.

[32] Tritech International Limited, "Tritech Super SeaKing DST Sonar Datasheet," 2008

[33] J. U. Robert, "Principles of Underwater Sound," *New York: McGraw-Hill Book Company,* 1983.

[34] M. Sezgin and B. Sankur, "Survey over Image Thresholding Techniques and Quantitative Performance Evaluation," *Journal of Electronic Imaging,* vol. 13, p. 146, 2004.

[35] D. A. Forsyth and J. Ponce, *Computer Vision: A Modern Approach*: Prentice Hall Professional Technical Reference, 2002.

[36] N. Otsu, "A Threshold Selection Method from Gray-level Histograms," *IEEE Transactions on Systems, Man, and Cybernetics,* vol. 9, pp. 62-66, 1979.

[37] J. Serra. Image Analysis and Mathematical Morphology. Academic Press, 1982.

[38] R. M. Haralick, "Mathematical Morphology and Computer Vision," in *Twenty-Second Asilomar Conference on Signals, Systems and Computers* 1988, pp. 468-479.

[39] R. C. Gonzalez and R. E. Woods, *Digital image processing*: Prentice Hall, 2007.

[40] J. Canny, "A Computational Approach to Edge Detection," *IEEE Transactions on Pattern Analysis and Machine Intelligence,* vol. 8, pp. 679-698, 1986.

[41] Y. Bar-Shalom, "Tracking and data association," *Academic Press Professional, Inc. San Diego, CA, USA*, 1987.

[42] R. L. LaFara, *Computer Methods for Science and Engineering*. Rochelle Park, N.J: Hayden Book Co., 1973.

[43] M. Pilu, A. W. Fitzgibbon, and R. B. Fisher, "Ellipse-specific direct least-square fitting," 1996.

[44] F. L. Bookstein, "Fitting Conic Sections to Scattered Data," *Computer Graphics and Image Processing,* vol. 9, pp. 56-71, 1979.

[45] W. Gander, G. H. Golub, and R. Strebel, "Least-squares Fitting of Circles and Ellipses," *BIT Numerical Mathematics,* vol. 34, pp. 558-578, 1994.

[46] G. Taguchi and Y. Yokoyama, *Taguchi Methods: Design of Experiments*: ASI Press, 1993.

[47] T. Aridgides, M. F. Fernandez, and G. J. Dobeck, "Side-scan sonar imagery fusion for sea mine detection and classification in very shallow water," 2001.

[48] L. Linnett, S. J. Clarke, C. S. J. Reid, and A. D. Tress, "Monitoring of the seabed using sidescan sonar and fractal processing," *PROCEEDINGS-INSTITUTE OF ACOUSTICS*, vol. 15, pp. 49-49, 1993.

[49] L. M. Linnett, D. R. Carmichael, S. J. Clarke, and A. D. Tress, "Texture analysis of sidescan sonar data," 1993.

[50] B. R. Calder, L. M. Linnett, and D. R. Carmichael, "Spatial stochastic models for seabed object detection," 1997.

[51] S. Reed, Y. Petillot, and J. Bell, "An automatic approach to the detection and extraction of mine features in sidescan sonar," *IEEE Journal of Oceanic Engineering*, vol. 28, pp. 90-105, 2003.

[52] I. Jagielska, C. Matthews, and T. Whitfort, "An investigation into the application of neural networks, fuzzy logic, genetic algorithms, and rough sets to automated knowledge acquisition for classification problems," *Neurocomputing*, vol. 24, pp. 37-54, 1999.

[53] L. A. Zadeh, "Fuzzy sets," *Information and Control,* vol. 8, pp. 338-353, 1965.

[54] O. Cordon, F. Herrera, F. Gomide, F. Hoffmann, and L. Magdalena, "Ten years of genetic fuzzy systems: current framework and newtrends," 2001.

[55] L. A. Zadeh, "Soft computing and fuzzy logic," *IEEE software*, vol. 11, pp. 48-56, 1994.

[56] J. S. R. Jang, "ANFIS: Adaptive-network-based fuzzy inference system," *IEEE Transactions on Systems, Man and Cybernetics*, vol. 23, pp. 665-685, 1993.

[57] H. J. Zimmermann, *Fuzzy Set Theory-and Its Applications (3rd ed.)*. Norwell, MA, USA: Kluwer Academic Publishers, 1996.

[58] W. Pedrycz, "Why triangular membership functions" *Fuzzy Sets and Systems*, vol. 64, pp. 21-30, 1994.

[59] L. A. Zadeh, “Outline of a new approach to the analysis of complex systems and decision processes,” *IEEE Trans. Syst., Man, Cybern.,* vol.3, pp. 28-44, Jan. 1973.

[60] K. Asai, "Fuzzy Systems for Information Processing," Amsterdam IOS Press, 1995.

## Appendix A

### Super SeaKing Technical Specifications

**Super SeaKing DST Sonar Head**

| | |
|---|---|
| Operating frequency (low) | 300 kHz |
| Operating frequency (high) | 670 kHz |
| Beamwidth, vertical | 20°[300 kHz] |
| Beamwidth, vertical | 40°[670 kHz] |
| Beamwidth, horizontal | 3.0°[300 kHz] |
| Beamwidth, horizontal | 1.5°[670 kHz] |
| Maximum range | 300 m [300 kHz] |
| Maximum range | 100 m [670 kHz] |
| Minimum range | 0.5 m |
| Source level | 210 dB re 1uPA@ 1 m |
| Pulse length | 400 µsec [300 kHz] |
| Pulse length | 200 µsec [670 kHz] |
| Power requirements | 18 to 36 VDC @ 15VA |
| Communication protocols | Arcnet, RS232 |
| Data communication rate | RS232 115.2 kbaud |

**Control and Display Features**

| | |
|---|---|
| Range selection | 2 to 300 m |
| Gain and contrast | Rotatory controls |
| Scanned sector | Fully variable in 360° |
| Resolution selection | 0.45°,0.9°,1.8°,3.6° |

## Appendix B

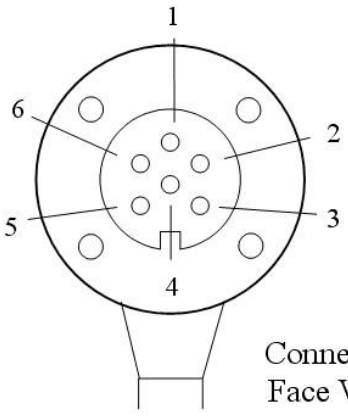
### Super SeaKing DST Sonar Computer Connection

**Power Supply**

The Power requirements for Super SeaKing DST sonar is 18 V~30 V DC (Abs. Max. 36v DC) @ 9 Watts max. If the supplies are less than 18 V (DC), the sonar head may not work correctly. Also, never try to make sonar work down a long cable by increasing the power supply above 36 V (DC). 24V DC is suggested.

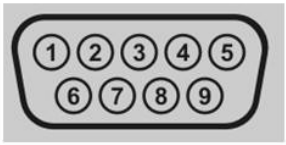
**Sonar Head Interconnect Cabling**

The communication between the Super SeaKing sonar and computer is linked via a 9-PIN, D-type RS232 port. The SeaKing heads use a Tritech 6 way U/W Connector cable. The wiring code is shown in Figure **B.2-1**. The 9 PIN, D-Sub RS232 female connector wiring code is shown in Figure **B.** B.2-2.




| | | |
|---|---|---|
| 1 | ***RS232 Tx*** | Yellow |
| 2 | ***RS232 Rx*** | Blue |
| 3 | **+24 v DC** | Red |
| 4 | **0 v DC** | Black |
| 5 | ***RS232 Ground*** | Green |
| 6 | **HEAD CHASSIS** | Screen |

Fig. B.**2-1**: Tritech 6-Way Underwater Connector and wiring configuration.




| | |
|---|---|
| Pin 1 | Received Line Signal Detector(Data Carrier Detect) |
| Pin 2 | Received Data |
| Pin 3 | Transmit Data |
| Pin 4 | Data Terminal Ready |
| Pin 5 | Signal Ground |
| Pin 6 | Data Set Ready |
| Pin 7 | Request To Send |
| Pin 8 | Clear To Send |
| Pin 9 | Ring Indicator |

Fig. B.2-2: The 9 PIN, D-Sub RS232 female connector assignments.

The wiring for RS232 Sonar head via a Tritech Connector to a 9 Pin D-Type (for a common port) is as follows:

RS232 Tx (Yellow) ======== PIN 2 (9 Pin D-TYPE)

RS232 Rx (Blue) ======== PIN 3 (9 Pin D-TYPE)

RS232 GND (Green) ======== PIN 5 (9 Pin D-TYPE)

24V Positive (Red) ======== The Positive rail on your battery or power supply

0V (Black) ======== The Negative rail on your battery or power supply

* The RS232 Ground on the sonar heads in not the same and the 0v Power supply.

**Software Configuration**

1. Changing the Computer COM baud rate to 115,200. Go to the Hardware → Device Manager → Port; double click the number of the COM port which has been chosen for the communication. Change the Port Setting → Bit per second to 115200. Then
2. Choosing the port for communication. Start the SeaNet Pro software; click the Utilities → Com Setup. Set the COM Port number used to communicate.
3. Enabling the 'Aif' data transfer function. Tick 'enable' for 'Aif' device (see Figure B.2-3 ).

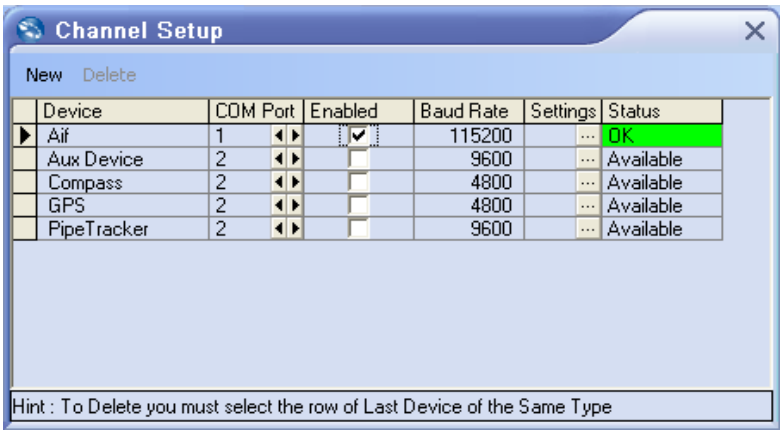



Fig. B.2-3: Software configuration for the communication.

The PC COM port settings are adjusted by means of the SeaNet Setup Program.