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Underwater Navigation and Communications

Sonar Sensing for Underwater Navigation

Introduction

SONAR (Sound Navigation and Ranging) technology is used in applications for industrial, medical and military purposes [8]. When compared with sensors such as LIDARs (Light Detection and Ranging) and cameras, sonar sensors are much more effective since they are not as adversely affected by absorption and scattering underwater as these other terrestrial sensors [1]. Inertial sensors which are effective in detecting underwater terrain like Doppler Velocity Loggers (DVLs) and Fiber Optic Gyroscopes are very expensive when compared to sonar sensors [1]. This paper reviews the current applications and the state of sonar technology in underwater navigation and other fields.

Common Applications of SONAR

Industrial

Processes such as accurately monitoring the fill level of tanks carrying milk or chemicals, detecting boom height on agricultural machines, or monitoring material flow are just a few examples of sonar sensing being used for industrial applications [4]. The 30GM-IO ultrasonic sensor made by Pepperl+Fuchs that consists of different models with sensing ranges from 500mm to 6000mm can carry out applications such as the ones listed above [7]. This sensor has dimensions of 30mm by 90mm [7]. Ultrasonic sensors are also used in park-assist of a car and blind spot sensing. The prices of these devices depend on the volume of the devices bought by companies and competition in the market.

Medical

Ultrasonic sensors are used in the medical world for abdominal, vascular, mammary/thyroid gland, etc. diagnoses. A device such as the 128ch 4.5MHz Mechanical Scanning 3D probe is used to produce images of the abdomen by acquiring 3D data obtained from the echoes of the ultrasonic waves [3]. This particular probe has a radius of curvature of 40mm [3]. A tool like this one can be used to monitor fetal growth and the health of pregnant women. Devices such as these are used to monitor other human organs as well. Companies such as the Nihon Dempa Kogyo co. Ltd. manufacture these devices. Just like the industrial sensors, these devices can only be priced after contacting the manufacturing companies.

Military

Military applications of sonar sensors are mainly underwater. One of such applications is the use of Autonomous Underwater Vehicles (AUVs) equipped with sonar and other navigation sensors to neutralize mines. Initially a high-quality AUV with inertial navigation system (INS) such as a DVL and acoustic beacons acquires accurate side-sonar scan data (more on this later). An a priori map is generated by the human operators. Then a second low-cost AUV equipped with a sonar sensor is deployed in the same field of interest. This new AUV will try to generate a new map from its sonar data while localizing itself. This process is known as SLAM – Simultaneous Localization and Mapping. Then the AUV will locate the mines and either self-detonate or place an explosive charge. Since the second AUV is expendable, it is cost efficient to use sonar sensors integrated with SLAM algorithms on it.

Technology

Sonar Sensor Technology used in Underwater Navigation

Sonar sensors have been used in deep sea AUV navigation with images and SLAM. The most common sonar sensors are side-scan sonar and multi beam sonar. Side-scan sonar technique is used to image the seafloor by sending out a sonar pulse and recording the echo intensity over time [2]. Usually the AUV sends out two narrow beams, one on each side. The ensonification process consists of factors such as the scattering properties, the actual sound speed distribution, the sonar beam form, etc. Some of the assumptions made are that the seafloor is a lambertian surface which means the scattering process dissipates energy equally in all directions, and also that the seafloor is flat. Such assumptions simplify the calculations to an extent. The multi beam sonar technique is when there is a fan of single sonar beams with a transducer corresponding to each beam [2]. This process is similar to a LIDAR system: the time of the echo is recorded. The data interpretation is simpler than the data from side-scan sonar since the multi beam sonar would readily produce a 3D image while the data has to be interpreted in the case of side-scan sonar to do that. This particular aspect makes the multi beam sonar more suitable to work with SLAM algorithms. The only drawback is that the multi beam sonar devices are expensive. These technologies are available for civilian consumption with prices ranging from \$500.00 to \$2000.00 [5][6].

Conclusion

Sonar sensors are low-cost moderately efficient sensors. They can be incorporated with other sensors such as LIDAR, INS, etc. using sensor fusion techniques such as the Extended Kalman Filters to navigate autonomous underwater vehicles efficiently.

References

- [1] M. F. Fallon, J. Folkesson, H. McClelland, and J. J. Leonard, "Relocating underwater features autonomously using sonar-based SLAM," *IEEE Journal of Oceanic Engineering*, vol. 38, no. 3, pp. 500–513, Jul. 2013.
- [2] P. Woock and C. Frey, "Deep-sea AUV navigation using side-scan sonar images and SLAM," Sydney: OCEANS 2010 IEEE-Sydney, 2010, pp. 1–8.
- [3] "Ultrasonic probe (transducer) / NDK," 2016. [Online]. Available: <http://www.ndk.com/en/products/search/ultrasonic/index.html>. Accessed: Oct. 24, 2016.
- [4] Pepperl+Fuchs, "Ultrasonic models," 2012. [Online]. Available: <http://www.pepperl-fuchs.com/global/en/18759.htm>. Accessed: Oct. 24, 2016.
- [5] L. Notices, C. Inc, 1 Cabela, and S. N. 69160, "Humminbird® ONIX 8 SI combo: Cabela's," www.cabelas.com, 2016. [Online]. Available: http://www.cabelas.com/product/HUMMINBIRD-ONIX-SI-COMBO/1745257.uts?productVariantId=3753249&WT.tsrc=PPC&WT.mc_id=GoogleProductAds&WT.z_mc_id1=03807604&rid=20&gclid=Cj0KEQjw4rbABRD_gfPA2-uQqroBEiQA58MNdJtONdOt3MHTQD21eHEtiK5G4f_LJ_Y07Gja0IJp-mcaAmz88P8HAQ&gclsrc=aw.ds. Accessed: Oct. 24, 2016.
- [6] "Simrad StructureScan 3D Sidescan imaging," 2016. [Online]. Available: http://www.starmarinedepot.com/simrad-structurescan-3d-sidescan-imaging-module-and-transducer.html?gclid=Cj0KEQjw4rbABRD_gfPA2-uQqroBEiQA58MNdBnyh3awWsglSsJqcEa20-WI0z9RmXuXWQQTy5B1FWEaAp6g8P8HAQ. Accessed: Oct. 24, 2016.
- [7] "Product overview ultrasonic sensors the pulse of automation," 2015. [Online]. Available: http://files.pepperl-fuchs.com/selector_files/navi/productInfo/doct/tdoct0614k_eng.pdf. Accessed: Oct. 24, 2016.
- [8] N. Oceanic and A. Administration, "What is sonar?," 2013. [Online]. Available: <http://oceanservice.noaa.gov/facts/sonar.html>. Accessed: Oct. 24, 2016.