MULTISENSORY FUSION FOR UNDERWATER ROBOT LOCALIZATION AND EXPLORATION

BY

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1. Description of the Research Work

Pakistan has 1000 km long coast from sir creek to Jiwani in the middle of Indian Ocean which indicates that the littoral state carries out 95% of its trade through the sea and 40% of its industry is situated near the coast (Jalil, 2018). In march 2015 Pakistan successfully achieved 50000 square kilometers of seabed territory with which, other than 200 nautical Miles (NM) of Exclusive Economic Zone(EEZ), Pakistan gained the rights to explore from the area of additional 150 NM of Continental Shelf(sajjad, 2015). World is aware that trade balance of future is in favour of china and 60% of population lives in Asia. China Pakistan Economic Corridor (CPEC) is game changer for economy of Pakistan and is going to be the future trade center due to its geological position(Abid & Ashfaq, 2015). With these benefits there are also some challenges specially for Pakistan Navy because of huge seabed monitoring and protection. This situation encourages the researcher to explore for underwater resources and establish smart defensive systems across the seabed boundaries.

Underwater localization and exploration is very important research question due to unstructured and dynamic nature of water. For localization mainly redundant estimated sensors and fixed position sensors are used. The accuracy of main sensor(s) is assured using external sensor. There is high possibility of errors both in main sensor and external sensor because of unmodeled noise(Chame, Dos Santos, & da Costa Botelho, 2018). Multiple sensors are combined together for best possible results and anticipation techniques are used to eliminate abrupt noise of external acoustic sensor. In case if vision systems are used as external sensor there is a possibility low rate and we have to consider only main sensor(s) for location estimation(Karras, 2007). For optimal estimates of location the measured values are corrected by predicted value. For prediction and correction Kalman filter usually reduces Gaussian type of noise (Potyagaylo, Constantinou, Georgiades, & Loizou, 2015) because modeling of linear systems is possible in Kalman filters. In underwater environment Kalman filter performs poorly because they diverge from actual estimate if the noise is not modeled. Some parametric algorithms produce global estimates from multiple hypothesis, which can handle unmodeled noise, but they are computationally expensive. We need an algorithm which can deal unmodeled noise as well as it should be computationally efficient. It has been seen for last few years that neural networks are very optimum and efficient for approximation and classification of non linear systems. PC/BC-DIM algorithm can perform optimal cue integration with a non-flat prior and its response is optimal even when the input distributions are noisy(Spratling, 2016). Similarly some other neural network like feed-forward neural networks and recurrent neural network are very good in dealing with non linear system's estimations. So there is need to implement such algorithms, for accurate localization and exploration, which perform optimally even in the presence of unstructured noise by learning the behaviour of system.

2. Need and Significance of the Research

Significance of the research work can be explained with the help of problem statement and objectives, which are given below

2.1: Problem Statement

Available techniques for multisensory fusion under unstructured environment are either inefficient to deal unmodeled noise of sea or have expensive computational cost so there is need to propose neural network based algorithm which can efficiently fuse data of sensors and accurately eliminate unstructured noise.

2.2: Objectives

Objective of the research work are as follows

1. To develop an efficient algorithm for multisensory fusion under unmodeled environment
2. To Implement proposed technique for localization and Exploration of Autonomous underwater vehicle(AUV)

3. Review of Literature

There are mostly two types of vehicles used underwater. First is Remotely operated vehicle (ROV) which is connected through wire and has the basic working of seabed inspection, maintenance and repair operations(Grøtli, Tjønnås, Azpiazu, Transeth, & Ludvigsen, 2016). Second is Autonomous underwater vehicle (AUV) which is self driving vehicle with no directly connected wire and is used for sea navigation. AUV has multiple applications like underwater surveys, inspection of resources and bathymetry data collection. Actual or best possible location is essential to ensure the accuracy of collected data(Paull, Saeedi, Seto, & Li, 2014). A number of techniques are proposed to estimate the motion of vessel which can be categorized as either acoustic based technique or visual(Corke et al., 2007). For underwater tracking generally three types of methods are used which are instrument-assisted method, active and passive mode based method and tracking optimization method. For tracking accuracy and stability optimization methods in which prediction is being made have been considered for further improvements(Paull et al., 2014).

Underwater localization is achieved using some redundant estimates and fixed position sensors. IMU, DVL, magnetic Compass, SIMU, Gyroscope and accelerometer are some inertial sensors which provide current change with respect to last state. Vision or acoustic system can be used to assure the accuracy for redundant estimates as external sensor. Vision systems (like camera or laser vision system) usually have higher accuracy but low rate. Although these are independent of any wireless signal (like acoustic) but still it has the limitation of some reference for estimation of correct position(Karras, 2007). Acoustic systems like ultra short baseline(USBL) are commonly used for underwater tracking, exploration and localization but a signal can affect by serious noise by travelling in underwater environment. For above surface localization different geo referred techniques are used like Global positioning system (GPS) but RF signals cannot be received directly by the AUV under the water, hence we have to rely on acoustic positioning systems like ultrashort baseline sensors (Khan, Taher, & Hover, 2010). Choosing a convenient and optimal fusion technique which would have low computation cost and which would be able to eliminate underwater noise to provide accurate results is in open research question(Chame et al., 2018). Adaptable fusion of sensors is possible using conventional Kalman filters. In (Drolet, Michaud, & Côté, 2000) It is shown that Kalman Filter can handle number of redundant sensors and have capability to fuse data of these sensor. But Kalman filters performs poorly under presence of unstructured noise because noise is not modeled. Particle filter are good which can perform finely under unmodeled noise but they have expensive computational cost. For optimum and efficient computation there is need of a choosing a convenient fusion policy which can perform accurately even in presence of unstructured noise.

It has been seen for last few years that neural networks are very optimum and efficient for approximation and classification. PC/BC-DIM can also perform optimal cue integration even when the input distributions are noisy(Spratling, 2016). So there is need to implement such PC/BC-DIM type neural algorithm to describe accurate location of acoustic source and underwater exploration which can perform multi-sensory fusion optimally even in the presence of unstructured noise.

4. Methodology of Research

For successful completion of research work it is required to deeply analyse available techniques of multisensory fusion. Mathematical modeling and algorithm of currently available techniques have to be practiced in Octave or Python. The proposed method is based on artificial neural network so its deep concepts and applications should be understand. After proposing a optimal solution finally all previous techniques (like Kalman filter, Particle filter) will be compared with proposed technique.

5. Implications of Research

This project is directly beneficial for Pakistan seabed territory. It would be used for localization, exploration and target tracking. Other benefits are described below

1. To explore underwater resources using proposed technique
2. Scientific Exploration
3. Underwater surveys
4. Localization of living and non living objects
5. Unmanned defensive robot of sea boundary
6. Discovery of new species and resources
7. Sea food diversity
8. Detection of unusual activity(spy)

6. Comprehensive Tentative Budget Required for Conducting Research

Financial aspects are buying registered software for simulation work. For review of literature some papers are needed which has to be purchased. If the system is performed on hardware after successful simulations then cost of buying AUV module(with motors), acoustic positioning and inertial sensors (like usbl, gyroscope, accelerometer, digital compass,) and controller like raspberry pi to burn proposed algorithm.

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APPENDIX-01

Turnitin Originality Report

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