論 文 内 容 の 要 旨

博士論文題目

Studies on Signal Processing for Local Ocean Wave Monitoring System
(海洋波の局所監視システムのための信号処理に関する研究)

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(論文内容の要旨)

Ocean Wave Monitoring is an essential activity that provides valuable data for travel statuses of maritime transportations, for modeling offshore infrastructures and for producing wave forecasts. This thesis studies a low cost local wave monitoring system that is reliable and robust, hence can be an alternative to sophisticated wave monitoring systems. The system consists of wave sensors that are relatively cheap and ubiquitous, such as MEMS-enabled devices. These devices are advantageous because they can be connected to a network that are smartly expanded to monitor the area of interest.

This study aims to explore on processing techniques that enables the local wave monitoring system to (1) detect severe wave conditions; (2) process data from its multiple sensors; and (3) properly classify wave conditions. Since the system considered for this purpose is an alternative system, there is one major challenge encountered. The wave sensors in the system have certain limitations in processing power, memory and battery power of the devices, and hence the data collected are short length time series data. Typically in conventional methods, they require longer time series data for generating significant wave height and period hence, these methods cannot be utilized in the alternative system. Due to this, the processing techniques should be able to address this issue. Also, if this issue is properly addressed, the alternative system will have an advantage to the conventional systems in the sense that it can acquire and process short time series data quickly hence immediate publication of wave information is possible.

For the detection of severe wave conditions, two signal processing techniques are explored. First technique is the threshold technique that processes instantaneous data gathered by the sensors. This technique enables the sensors to judge the condition

of its area and preprocess the data before sending relevant information to the central receiver of the network. This aims to compress the data that is relayed to the network. This seems a straightforward and stringent approach because the threshold levels are fixed. It is important to note that wave conditions in different areas can vary depending on the bathymetry of the location even if they are experiencing the same conditions. The threshold level set in one location might not be enough for the other location. In view of this, the second technique is explored. The second technique uses higher order statistics to evaluate data segments gathered by sensors. The sensors are allowed to gather data first on the specific location on a relatively calm day to have a base data and then, the statistical parameters are generated. These values are location specific and are the bases of comparison for each of the wave segment gathered by the sensors. Higher differences from the base data indicate that the wave conditions are more severe.

For the processing of the multiple sensors in the monitoring system, this study explored Independent Component Analysis (ICA). This technique is utilized in separating source signals from multiple sensors in a network or in an area. This is useful in getting or estimating dominant patterns of source signals in a very noisy environment which are typically experienced in field experiments or in real data. In spite of its potential, this technique falls short to the aim of the study. Wave data has certain characteristics that do not meet the requirements for a good implementation of independent component analysis.

For the classification of wave conditions, this is done through employing Support Vector Machines (SVM). This technique initially uses spectral analysis technique which decomposes the wave data into frequencies. The significant wave height and wave period are then calculated from the wave spectra. These two values are the features considered for the SVM. The SVM trains the data to create a classification model for ocean wave conditions. By having the classification model, identification of wave conditions can be done immediately hence information can be readily published. All of the processing techniques used the short time series data and were able to assess the data. These techniques were able to provide information in a short period hence immediate publication of wave condition is possible.

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（論文審査結果の要旨）

本論文では海洋波の監視システムにおける種々の信号処理手法に関して研究している。東日本大震災での津波や最近の台風による被害を例に挙げるまでもなく、四方を海に囲まれた我が国にとって海洋波の監視は重要な課題と考えられる。本論文で扱う監視システムは、海洋に浮かぶブイに取り付けられた加速度センサからの信号を無線受信し、その情報をもとに海洋波を監視するというものである。海面の変動を直接、リアルタイムでモニタできる独特のシステムであるが、海洋波は気象などの様々な外的要因に影響されるだけでなく、物理的には非線形かつ分布定数モデルとなるため取り扱いが非常に難しい。

本論文ではこの目的に信号処理技法の観点から取り組んでいる。特にブイに搭載されたセンサは消費電力の制約から短時間の時系列しか断続的に発信できないため、従来のシステムで用いていた長時間時系列から得られるものと同等に近い性能を、情報処理技術によって達成することを試みている。これが可能になれば監視のリアルタイム性も大きく向上するものと期待される。

具体的には 1) 波の厳しさ判定、2) 多数のセンサからのデータ処理、3) 波の条件による分類という3つの観点から研究している。まず、1) については閾値による判定と高次統計量による判定を提案している。短時間時系列はGauss分布から逸脱するため、あえて分散でなく高次統計量を採用している。また、2) に対処するため多変量解析の分野で注目されている独立成分分析の適用を試みている。多次元信号の線形変換から元の信号を復元する手法が幾つか提案されているので、それらの適用可能性を検討している。さらに 3) については既存の海洋波モデルとサポートベクトルマシンを用いた判定法を提案し、シミュレーションによって長時間時系列のそれと比較している。

これらの結果は基礎的段階に留まり、実用化にまでは至らないものの、広く自然現象の監視に最先端の信号処理技術を適用する斬新な試みであり、一定の学術的意義があるものと評価できる。よって本論文は博士（工学）の学位論文として価値あるものと認める。