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## Article

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# Surface vector fields estimation using soft computing and remote sensing data at an open water marine renewable test site

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## Abstract

Galway Bay has one of the world's few open water marine renewable test sites and so is of national and international interest. A high frequency radar system has been deployed in Galway Bay area to monitor near real time surface currents and waves since July 2011. In this research, a soft computing approach was applied to estimate surface vector fields using the observed radar data. Results indicate that soft computing is a novel and promising method to estimate surface vector fields. It provides a potential way to obtain useful information of coastal water body for marine renewable energy development and assessment.

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**Keywords:** Marine renewable energy; Soft computing; High Frequency radar; Galway Bay; Remote sensing; Surface currents

## 1. Introduction

Understanding and estimation of surface vector fields is crucial to a number of application and operations in coastal areas, such as marine renewable energy assessment and development, which are non-polluting energy in comparison with traditional energy resources [1]. As more and more marine data can be recorded by remote sensing tools such as High Frequency radars and satellites, utilization of these data including surface currents, waves and wind has becoming a concerned topic. Data assimilation is a kind of approaches to combine observations into numerical models to improve model performance, but its computational cost is quite expensive. As Artificial Intelligence has increasingly becoming enhanced, soft computing is a promising method to use a variety of marine data to support various fields including marine engineering, atmosphere and hydrology and so on. In this research, surface vector fields were estimated using a kind of soft computing method named Random Forest and

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High Frequency radar data. Results are expected to be used for evaluating energy distribution density in space. This information is needed not only by the governing planning, but also useful for practical energy development departments.

Structure of the reminder is as follows: Section 2 give a brief introduction about research domain; Section 3 presents the High Frequency radar system, followed by Random Forest algorithm in Section 4. Results are given in Section 5 and conclusions are presented in Section 6.

## 2. Research domain

Galway Bay is a large bay at the west coast of Ireland facing the Atlantic Ocean. Galway Bay has one of the world's few open water marine renewable test sites and so is of national and international interest. A high frequency radar system has been deployed in Galway Bay area to monitor near real time surface currents and waves since July 2011. It is the first time that surface flow fields have been recorded over fine temporal and spatial scales in this area. Galway Bay is a macro-tidal bay, with a spring tidal range of approximately 5 m and a neap tidal range of approximately 2 m.

## 3. Radar system

Radar stations record radial surface currents; a single radar station determines the radial component of the surface currents relative to that station, providing current magnitudes and directions toward or away from that radar station. Surface vector fields are obtained through combining radial surface velocity components from two or more radars. The extent of alongshore surface current mapping is limited only by the number of radar systems with overlapping coverage. Spatial coverage of surface currents measured by radars can reach around 200 km, depending on transmission frequencies. Two CODAR SeaSonde radars have been deployed at Galway Bay since summer 2011 to monitor surface water information as shown in Fig. 1. The operating frequency is 25 MHz at both stations. Data from both radars are routinely transmitted to a combination center that is located in the campus of National University of Ireland, Galway. The radar system has a high spatial resolution of 300 m and maps surface flow fields every hour. Measurements of surface currents from HFR system in Galway Bay have been validated with ADCP data in detail by O'Donncha et al. [2] and Ren et al. [3]. Due to environmental conditions, spatial coverage of surface flow fields varies over time.

## 4. Random forest

The Random Forests (RF) algorithm was proposed by Breiman [4]. It is a data-driven algorithm whose development process is much easier than conventional numerical models resulting from that no physical process is considered in model [5]. The RF algorithm is an improved version of Decision Tree (DT) approach. It is an ensemble DT approach which generates a number of classifiers and aggregates their results. In standard decision trees, each parent node is split to two child nodes using the best split rules among all variables. In a RF model, each parent node is split using the best among a subset of predictors randomly chosen at that node [6]. The RF algorithm is robust to deal with both classification and regression. Classification is performed when the response is a factor; regression is carried out when the response is continuous.

The full dataset was divided into three categories: 60% training, 20% testing and 20% forecasting. During training phase, equation of soft computing approached can be expressed as:

$$\text{Velcom}(t) = f(\text{WL}(t), \text{WS}(t), \text{WD}(t), \text{Ve}(t - 1), \dots, \text{Ve}(t - i)) \quad (i \geq 1) \quad (1)$$

where,

Velcom(t) is surface velocity component at time step t;

f(.) is nonlinear function used in soft computing approaches;

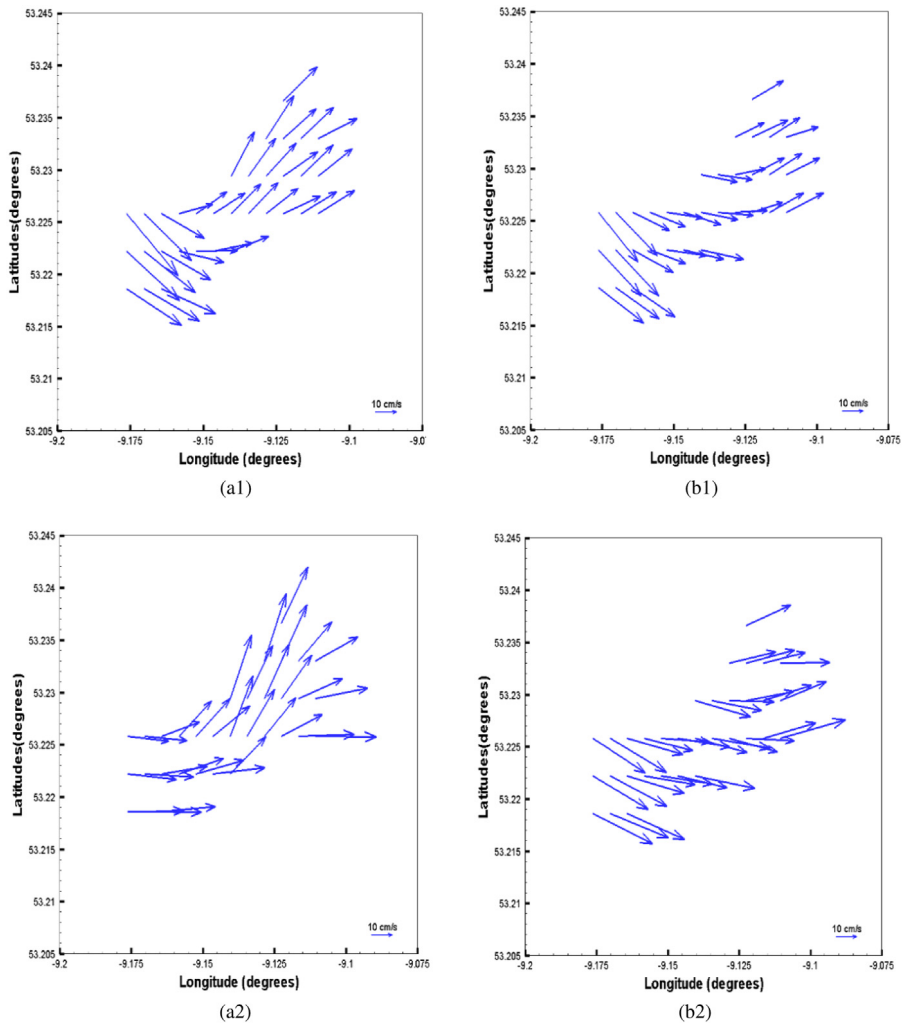
WL(t) is tidal water elevation at time step t;

WS(t) is wind speeds at time step t;

WD(t) is wind direction at time step t;

Ve(t - i) is surface velocity components at time step (t - i).

The reason for including historical current data is that the variation of surface flow fields is consistent in time and space, and the development of surface flows at the present time step is significantly related to previous states.



**Fig. 1.** Comparison of surface vector fields. (a1 and a2 are radar data; b1 and b2 are results from RF model; a1 and b1 are one-hour forward forecasting; a2 and b2 are three-hour forward forecasting)

## 5. Results

Development of soft computing models can be generally divided into three steps: training, testing and forecasting. The Authors focused on estimating surface vector fields using Random Forest and High Frequency radar data. Forecasting of surface vectors one-hour and three-hour forward is shown in Fig. 1.

Fig. 1 shows that surface vector fields generated by the development soft computing models using Random Forest approach have similar trend as the radar data. This indicates that soft computing model can capture synoptic characteristics of surface flows and provides a potential means to obtain forecasting information of surface currents. This is useful for marine renewable energy development and management.

## 6. Conclusions

In this research, soft computing models were developed using Random Forest and High Frequency radar data to estimate surface vector fields in the Galway Bay located at the west coast of Ireland. Results indicate that synoptic patterns of surface vector fields generated by the soft computing models had similar trend as radar data. This can be useful for a number of marine operations such as marine renewable energy development and management, search and rescue and oil spill treatment.

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