SOM Based Multi-agent Hydro Meteorological Data Collection System

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Abstract. The paper presents the possibilities of development the hydro meteo-ro-logical data collection system (HMDCS) involving advanced technologies such as multi agent based interaction and data collection between several monitoring system's nodes (i.e. buoys) based on self-organizing maps (SOM). The require-ments for such system development are rather complex and are attached to allow-ing the real-time monitoring, control, and prediction of the negative consequences of contamination of surface water recourses and making their evaluation by effec-tiveness in monitoring of Baltic Sea surface water. The experiment is based on the design an inexpensive, but reliable Baltic Sea autonomous monitoring network (buoys), which would be able, continuously monitor and collect temperature, waviness, and other required data. Moreover, it makes ability to monitor all the data from the costal-based station with limited transition speed by setting different tasks for agent based buoy system according to the SOM.

Keywords: wireless networking system, hydro meteorological sensors, multi agent systems, embedded systems.

1 Introduction

There is a variety of tools to monitor and evaluate the Baltic Sea hydro meteorological data, but most of received information has low spatial coverage and low level of detail in time [2]. Sea wave height, water temperature, underwater noise data is used for many practical applications usually obtained from three sources: buoy measurements, model calculations, and ship observations. Compared to other data acquisition methods, the buoy measurement is the most reliable and readily data source available continuously for years [13]. Basically the network of buoys involves mapping of

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temperature, wave height and underwater noise at a buoy location using the date retrieved at other buoys locations [10]. However, many hydro meteorological data measurements from sea buoys can be lost due to malfunctioning, maintenance, connection problems or dubious data recorded by the buoy. In order to ensure greater reliability of data collection it is necessary to develop the distributed information system, predicting complex situations and supporting the decision-making processes. Information provided from such system is important for decision makers and are needed to ensure the provision of information for decision-making institutions [3], [4], [7]. An important feature of such a buoys network is the ability to monitor, collect and evaluate wide spatial coverage and real time hydro meteorological data of the Baltic Sea [4]. Hydro meteorological information system is faced with great data flows, but the data often is excess, depending on the observed region of the water. Therefore, the current traditional methods are no longer sufficient to ensure the rapid collection of data and valuable information extraction

The purpose of this study is to show possibilities of development the hydro meteorological data collection system (HMDCS) involving advanced technologies such as multi agent based interaction and data collection between several monitoring system's nodes (i.e. buoys) based on self-organizing maps (SOM). The experiment is based on the design an inexpensive, but reliable Baltic Sea autonomous monitoring network (buoys), which would be able, continuously monitor and collect temperature, waviness, and other required data. Moreover, it makes ability to monitor all the data from the costal-based station with limited transition speed by setting different tasks for agent based buoy system according to the SOM.

2 Sea Hydro Meteorological Data Monitoring

Nowadays, there are numerous and varied designs for autonomous systems used for meteorological and oceanographic monitoring with different integration degrees. The buoy network system used in Canary Islands is one of them [1]. It has a control center that manages the transmission communications, and provides data in a useful form to diverse socioeconomic important sectors which make an exhaustive use of the littoral in the, and need data from the buoys to well manage the coastal environment. These buoys monitor water temperature, salinity, dissolved oxygen, hydrocarbons, and other characteristics, which allow to measure equipped other sensors such as fluorometer, turbidimeter and also each buoy is able to communicate via GSM modem. Following a programmed sampling rate (every hour), the ECU send to the central receiver unit a SMS message, which includes a sensor data set, GPS position and battery level. However, deeper analysis of the data has showed that such a sampling rate is not sufficient which means that data transmit protocol has to be re-viewed.

In order to provide greater hydro-meteorological data monitoring reliability and faster data retrieval there are proposed variety of sensory systems networks [8], [9], and [12]. There are proposed communication technologies that enable communication between sensor nodes [12], the systems for communication between maritime platforms like vessels, commercial ships or buoys [9], real-time monitoring of the underwater environment where an acoustic mesh network is located between the underwater senor networks and central monitoring system [8]. The proposed models can solve various problems, but require more flexible solutions for complex data transfer problems. This problem can be solved by developing active autonomous sensor multi-agent based system, which according to the situation is able to combine the data processing methods.

3 Hydro Meteorological Data Sensory System

3.1 Temperature Data Collection

During the investigation stage of the HMDCS development, several types of temperature sensors were compared. The comparison possibilities are made analyzing their parameters according to the technical specification presented in datasheets.

After comparative analysis of temperature sensors, we have selected digital sensor DS18B20. This digital temperature sensor can measurement temperatures within range from -55°C to +125°C by 12-bit precision, with accuracy – 0.50°C [11]. However, after additional calculations, it is possible to reduce the temperature measurement error of up to 0.10°C. The most attractive is the fact, that these sensors have already been calibrated at the factory and their accuracy error is ±0.5°C in the range from -10°C to +85°C and ±2°C error over the operating range (55°C to +125°C). Sensor supply voltage is in the range of +3 to +5.5 V. In standby mode, current consumption is close to zero (less than 1 μA), while the temperature conversion will be used during the current is about 1 mA. The measurement process lasts no more than 0.7 sec. The DS18B20 communicates over a 1-Wire® bus that by definition requires only one data line (and ground) for communication with a central microprocessor. In addition, the DS18B20 can derive power directly from the data line ("parasite power"), eliminating the need for an external power supply. Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. Thus, it is simple to use one microprocessor to control many DS18B20s distributed over a large area. This part has already become the corner stone of many data logging and temperature control projects.

3.2 Waviness Measurements

At present, the sea and the oceans waviness measurements uses variety of methods, depending on the geographic region, measuring accuracy, and common tasks [5]. The main and most commonly used are:

- Ultrasound based sensors:
  - Pros: suitable for measuring waves with a height of over 5 meters
  - Cons: significant measurement errors
- Rheostat-type structures:
  - Pros: allows you to get a fairly accurate data
  - Cons: because of its design features cannot be long-lasting

- Satellite image analysis:
  - Cons: due to big error can used only for ocean waviness measurement,
- GPS system :
  - Cons: not suitable for measuring waves with a height of 0.5-2.0 meters range,
- Accelerometer and gyroscope design:
  - Pros: small measurement errors, easy implementation.

For our experiment couple of accelerometer and gyroscope was used. Based on the experience of other scientists [2], accelerometer data were processed by removing the component of gravity, according to the formulas (1) – (13).

$$\begin{bmatrix} X_E \\ Y_E \\ Z_E \end{bmatrix} = \begin{bmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{bmatrix} \begin{bmatrix} X_s \\ Y_s \\ Z_s \end{bmatrix} \tag{1}$$

Here X_S, Y_S, Z_S represent the accelerations measured in the sensor frame, X_E, Y_E, Z_E are the accelerations rotated into the earth coordinate frame; and the direction cosines for the above transformation are in terms of the Euler attitude angles.

The coefficients a, b, and c are calculated by following formulas:

$$a_1 = cos\theta cos\psi \tag{2}$$

$$b_1 = sin\varphi sin\theta cos\psi - cos\varphi sin\psi \tag{3}$$

$$c_1 = sin\varphi sin\theta cos\psi + cos\varphi sin\psi \tag{4}$$

$$a_2 = cos\theta sin\psi \tag{5}$$

$$b_2 = sin\varphi sin\theta cos\psi + cos\varphi sin\psi \tag{6}$$

$$c_2 = sin\varphi sin\theta cos\psi - cos\varphi sin\psi \tag{7}$$

$$a_3 = -sin\theta \tag{8}$$

$$b_3 = sin\varphi cos\theta \tag{9}$$

$$c_3 = cos\varphi cos\theta \tag{10}$$

Here θ, ψ and φ are data from gyroscope. After the accelerations have been rotated into the earth frame, the earth-referenced accelerations of the buoy are given by

$$A_x = -gX_E \tag{11}$$

$$\mathrm{A_y} = -gY_E \tag{12}$$

$$A_Z = g(1 - Z_e) \tag{13}$$

Where Ax, Ay, and Az are no gravitational accelerations along the earth oriented x, y, and z axes.

3.3 Data Transmissions

Comparison of most popular data transmission protocols such as: Bluetooth, UWB, ZigBee, Wi-Fi and other where done [4]. We have decided that the best transmission protocol, for such type task (low cost, low power, mesh network support) ZigBee was preferable. So, this mash type network protocol has been used for developing of the HMDCS buoys network. ZigBee is an open standard for short range wireless networks based on the Physical Layer and the Media Access Control from IEEE 802.15.4, focusing on minimizing the overall power consumption and at the same time maximizing network reliability [14].

ZigBee protocol offers three kinds of devices to form PAN (personal area network):

1. End-devices, which periodically collect data and transmit them.
2. Routers. They collect data from end-devices and forward them to the destination (like another router or to the final coordinator).
3. Coordinator. One of the routers in a PAN is usually configured as coordinator. Its main function are parameterization and management of the PAN and the collection of the networks data.

In our case, we have used so-called “Full function Devices” which collects data and works as router and Coordinator that manages PAN network and sends collected data via GSM to costal station (Fig. 1). Following ZigBee network configuration were used for data transmitting to the costal station.

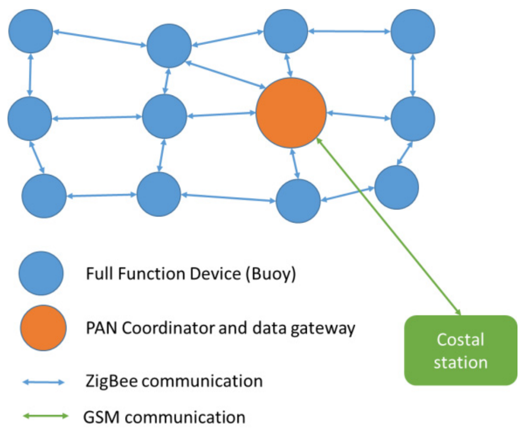

Fig. 1. Mash network

4 Agent Action Distribution Using SOM

The proposed multi-agent sensory system is based on the goal of the task distribution for agents according to the action similarities. This can be implemented applying selforganising map neural networks (SOM). SOM defines a two-dimensional nonlinear manifold as a regular array of discrete points. In this way, the application of an un-supervised learning allows multidimensional vector represent in two-dimensional output space. SOM output layer neurons retain topological structure according to internal data structure. The typical SOM neural network architecture is shown in Fig. 2. The input nodes represent parameter vector, which according to the similarity is projected in the two-dimensional output space - competitive layer. The input layer represents the parameters of agents target selection, and the competitive layer represents the autonomous agents based sensory system.

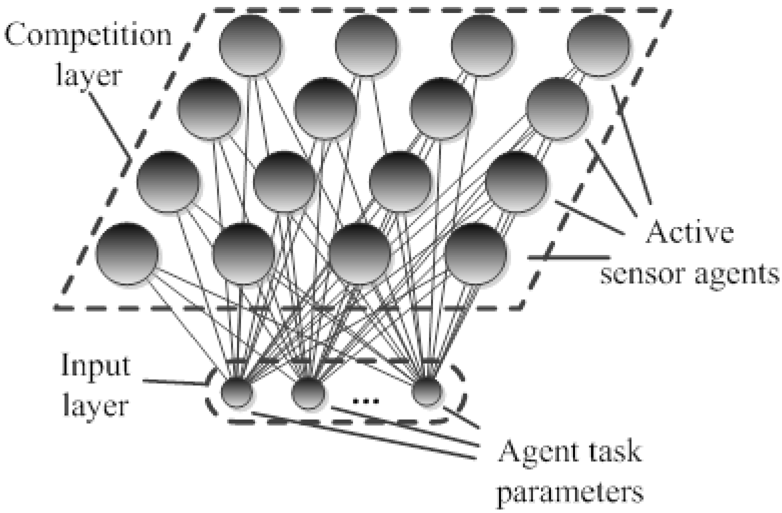

Fig. 2. SOM for autonomous agents based sensory system

In order to get the topological structure of the SOM the training process should be applied. Each unit in the competition layer array is associated with a parametric reference vector weight of dimension n. Each input vector is compared with the reference vector weight wj of each unit. The best match, with the smallest Euclidean distance is defined as response, and the input is mapped onto this location. Initially, all reference vector weights are assigned to small random values and they are updated as [6]:

$$\Delta w_j = \alpha_n(t) h_j(g,t)(x_i - w_j(t)) \tag{14}$$

where α(t) is the learning rate at time t and hj(g, t) is the neighborhood function from winner unit neuron g to neuron j at time t. In general, neighborhood function decreases monotonically as a function of the distance from neuron g to neuron n. This decreasing property is a necessary condition for convergence [6].

SOM competition layer nodes correspond to individual agents as active sensory nodes, which are able to process data at a different level (filtering, sampling, transfer and other). From these characteristics depends the capacity of wireless network, data capture excess in central database, and so on. Assuming that each agent as an active buoy sensor node performs different actions, the central unit can distribute tasks for the agents in accordance with their capabilities and required information. In this case, we use three parameters, which determine the actions performed by agents - the significance of the measurement data, hydro-meteorological characteristics of interest and the number of sampling rate. Under these settings, agents distribute the action according to the common goal. For example if we need the raw data – the task will be forwarded to agents that have a high data transfer bandwidth but do not have the filtering capabilities.

5 Multi-agent System Model for Hydro Meteorological Sensory System

For proper buoys operation multi-agent type system was designed. Agent software was developed using multi agent framework and works internally in the buoy. The Fig. 3 shows one buoy agent example. Buoy agent has main goal: measure data and different tasks are given by posting newMeasurmentGoal message from coordinator (SOM network). Buoy agent can read new data using capability Measure (Fig. 4). After sensors has read the data the messages onReadWTemper (for water temperature), oReadOTemper (for weather temperature) and onReadWaveHg (for wave height) occurs.

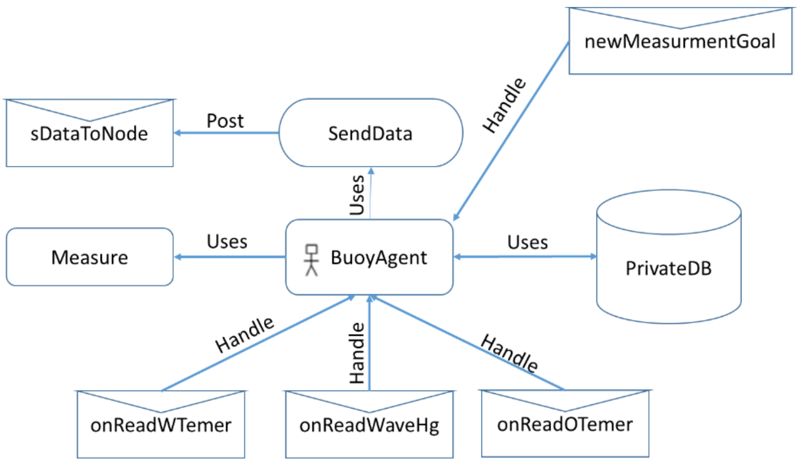

Fig. 3. Buoy Agent schematic

Buoy agent stores data in local DB and if it is necessary, it is able to post it to the other agents via ZigBee network using the plan SendData.

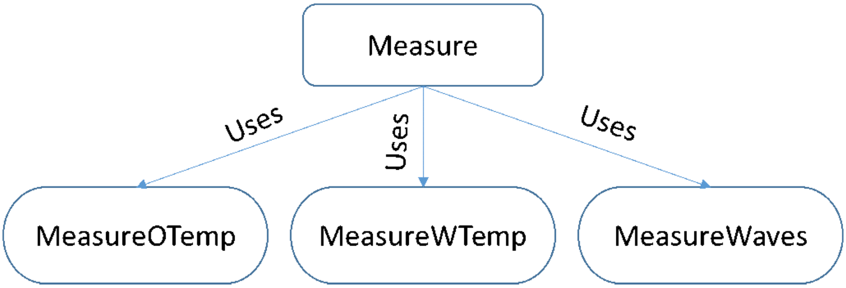

Fig. 4. Measure data capability

6 Results and Discussion

For sea waves height five different measurement methods were analyzed: using ultrasonic sensor, rheostat type sensor, accelerometer and gyroscope sensors, satellite photos and GPS data [5]. For data transmission from buoys to main station where analyzed different transmission methods and protocols, but most focused on mash type wireless networks and agent based communication methods [11],[15].

For testing purposes experimental buoy sensory system was developed. The core component of the prototype is Arduino Mega platform with ATmega2560 microcontroller which operating at 16 MHz clock frequency, (Fig. 5 - 1). The experimental buoy system is powered by solar power supply, which also recharges Ni-Mh batteries, which allow buoy sensory system operate at the night (Fig. 5 - 3, 9, 10). Buoy status are shown on LCD display (Fig. 5 – 2). XBee Pro modules (Fig. 5- 4) implement communication via ZigBee protocol, which have 10mW transmission power and according to the specifications, expected distance is about 1-1.5 km in the outdoor. Temperature measurements (underwater and weather) are implemented using DS18B20 sensors array connected in to the 1-wire network (Fig. 5 - 5). Data loging to MMC (Fig. 5 – 7). The wave height is measured using MPU6050 (Fig. 5 – 6) accelerometer/gyroscope and calculated by provided method.

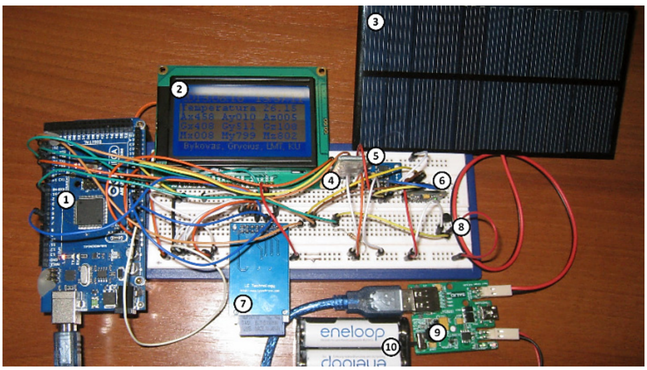

Fig. 5. Buoy electronic system prototype

The constructed prototype was placed in hermetic housing and tested in offshore Baltic Sea. The construction design and electronics solutions looks much promising: one buoy electronics cost only about 100 EUR, experimentally tested point to point network with 10mW Xbee modules in open sea have transmit distance for at least 900 m (it is enough for building buoy mash type network).

According to the Baltic Sea Monitoring Data Base [16] it was established hydro meteorological data collection mash type network, which allows the performance evaluation of each sensor node. This evaluation allows costal central station to distribute the agent performance according to the amount of required data. The Fig. 6 shows the distribution of sensory nodes priorities using SOM neural network.

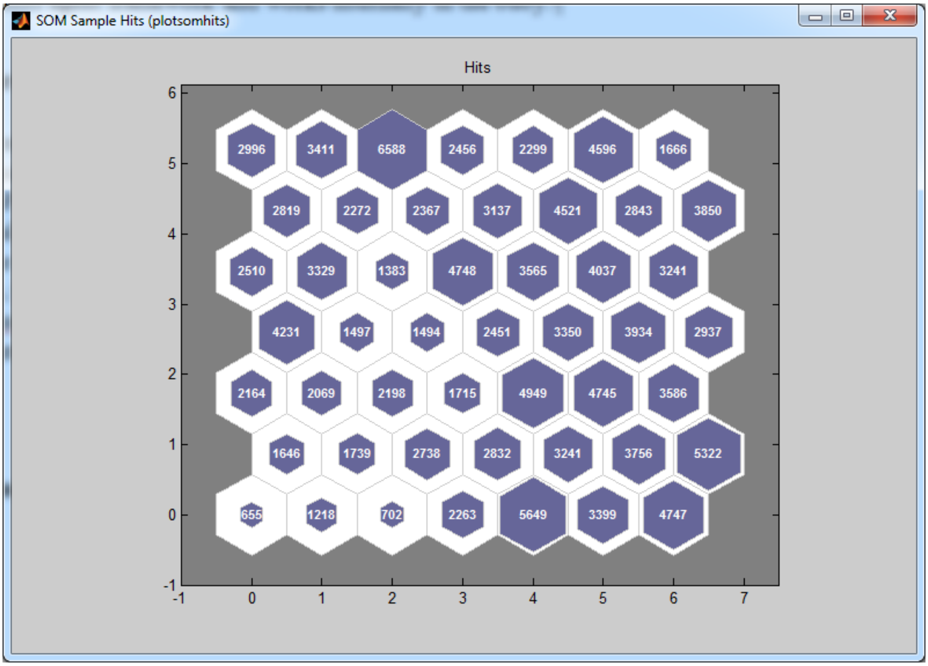

Fig. 6. The distributed sensory nodes priorities using SOM neural network

Each sensor node priority defines the importance of the measurements and the amount of data transmitted – i.e. sensor node with higher priority requires agent transmit larger amounts of data, which should allow more accurate assessment of the interested sea region.

7 Conclusions

This paper presents the possibilities of development the hydro meteorological data collection system (HMDCS) involving advanced technologies such as multi agent based interaction and data collection between several monitoring system's nodes (i.e. buoys) based on self-organizing maps (SOM). The construction design and electronics solutions of HMDCS looks much promising because of inexpensive, but reliable Baltic Sea autonomous monitoring network (buoys), which would be able, continuously monitor and collect temperature, waviness, and other required data. The multi-agent type system was designed enabling to monitor the data from the costal-based station with limited transition speed by setting different tasks for agent based buoy system according to the SOM.

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