Multivariate Gaussian 함수를 이용한 센서 네트워크의 수화 인식에의 적용

Application of Sensor Network Using Multivariate Gaussian Function to Hand Gesture Recognition

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Abstract : Sensor networks are the results of convergence of very important technologies such as wireless communication and micro electromechanical systems. In recent years, sensor networks found a wide applicability in various fields such as health, environment and habitat monitoring, military, etc. A very important step for these many applications is pattern classification and recognition of data collected by sensors installed or deployed in different ways. But, pattern classification and recognition are sometimes difficult to perform. Systematic approach to pattern classification based on modern learning techniques like Multivariate Gaussian mixture models, can greatly simplify the process of developing and implementing real-time classification models. This paper proposes a new recognition system which is hierarchically composed of many sensor nodes having the capability of simple processing and wireless communication. The proposed system is able to perform classification of sensed data using the Multivariate Gaussian function. In order to verify the usefulness of the proposed system, it was applied to hand gesture recognition system.

Keywords : Multivariate Gaussian function, sensor networks, pattern classification

I. Introduction

Recent technological improvements have made possible the development of small, inexpensive, low-power, distributed devices, which are capable of local processing and wireless communication. Such nodes are called sensor nodes. Each sensor node is capable of only a limited amount of processing. But when coordinated with the information from a large number of other nodes, they have the ability to measure a given physical environment in details. Thus, a sensor network can be described as a collection of sensor nodes which coordinate to perform some specific action. Sensor networks have a variety of applications such as environmental monitoring, condition based maintenance, habitat monitoring and smart spaces etc.[2].

The justification for using sensors in many applications ranges from use in intelligence augmentation to automating tasks depending on particular features of the situation. Regardless of whether these applications would be sought after by a large community, the trend shows that sensors are gradually becoming mobile and wireless devices.

Finding the optimal way to interconnect many sensors in a network is still an unresolved issue in ongoing research. Approaches of collecting and managing sensor data in a network are classified into two classes, based on how and where the data is fused. The one is a tree-like hierarchy to assemble high-dimensional vectors at the root, so they can be fed into a classification algorithm that assigns a description to each input. The latter alternative processes the sensor data locally and then communicates further data to propagate throughout the entire network.

Recently, inspired by perception in biological systems, distribution of a massive amount of simple sensors is gaining more support in recognition applications.

The goal of this paper is to propose a new recognition system which is hierarchically composed of many sensor nodes having the capability of simple processing and wireless communication. This idea takes encouragement from perception in biological organisms, where massively parallel neural pathways maintain a robust flow of sensed impulses to the brain[3].

The structure of this work is as follows: Section 2 outlines the feature of sensor node in a sensor network; in section 3, detailed description on recognition system based on sensor node with multivariate Gaussian function is presented; in section 4 and 5, application of the proposed scheme to hand gesture recognition and experimental results are given.

II. Sensor node in sensor network

1. Hardware platform

Many hardware platforms are currently available for

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designing of sensor nodes. The sensor node is a small device called mote which have been designed and developed by the Computer Science Division from University of California, Berkeley. The sensor nodes are capable of limited computation due to limited memory and network bandwidth. Still, they offer a flexible platform to aid the research, running the TinyOS operating system that provides the software building blocks necessary to capture and transmit data. TinyOS was designed specifically for use in sensor networks. Combined with a family of wireless sensor nodes, TinyOS is currently used as a research platform by many institutions. It provides high parallelism and efficiency through the programming interface. In this work, sensor nodes based on ATMega128L-

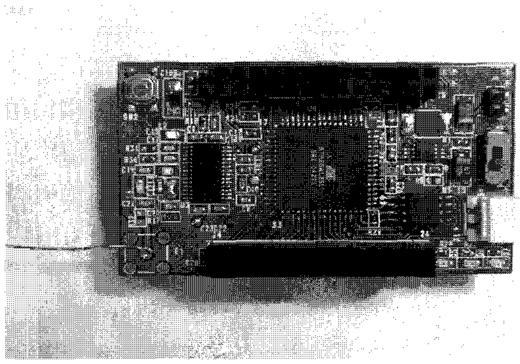

Fig. 1. Sensor node based on ATMega128L microprocessor.

```
typedef struct TOS_Msg
    {
    uint16_t addr;
    uint8_t type;
    uint8_t group;
    uint8_t length
    int8_t data[TOSH_DATA_LENGTH]
    uint16_t crc;
    uint16_t strength;
    uint8_t ack
    uint16_t time
    } TOS_Msg
```

Fig. 2. Structure of TOS message.

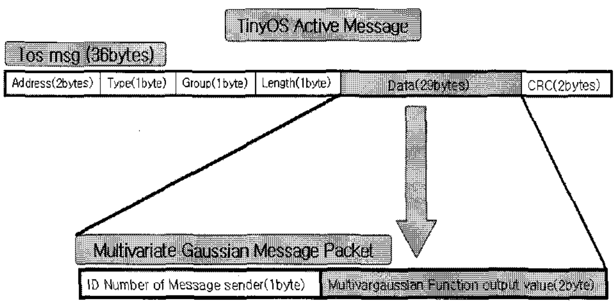

Fig. 3. Structure of TinyOS Active Message packet.

microprocessor were developed for our experiment as in fig. 1. The developed sensor node supports 40Kbit communication on its radio.

2. Communication mechanism

The communication mechanism is based on Active Message (AM) that is the top-level TinyOS packet abstraction. AM is an asynchronous communication mechanism that exposes the hardware flexibility. The main idea is simple: each message contains the address of a user-level handler as header. The role of the handler is to get the message out of the network and enter the computation running on the processing node[4].

In TinyOS, the original AM packet is TOS_Msg and all the other message types are encapsulated in it. The structure of the TOS_Msg is as follows:

The addr field specifies the destination address (a mote ID or the broadcast address), the group field specifies a channel for motes in a network, the type field specifies which handler to be called at the AM level when the packet is received and the length field specifies the length of the data portion of the TOS_Msg. Packets have a maximum payload of 29 bytes. The data field consists of an array of 29 bytes. The last 2 bytes are assigned to CRC field. Data are transmitted from motes to sink as a TOS_Msg packet of maximum 36 bytes[5]. The structure of AM packet on which the communication mechanism stands is shown in fig. 3.

III. Recognition system based on sensor node with Multivariate Gaussian Function

In this work, a new recognition system hierarchically structured with sensor nodes is proposed. The proposed system is shown in fig. 4.

The proposed system has the centrally-processed sensor platform. Every sensor node tries to stream pre-processed data to a central location called "sink node" wirelessly. Every sensor node calculates Multivariate Gaussian output for current sensed data and sends it to the sink node. In sink node, recognition algorithm is performed by using received Multivariate Gaussian outputs from each sensor node. Generally,

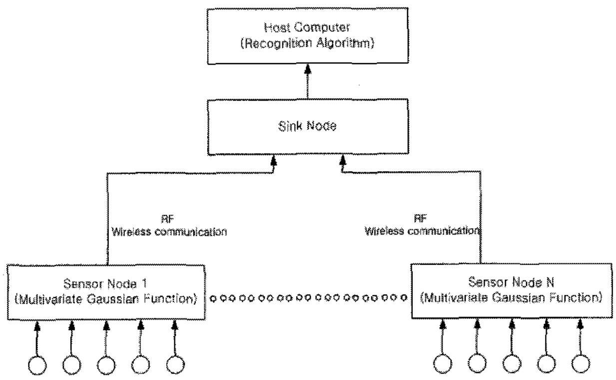

Fig. 4. Structure of the proposed system.

sink node is connected to host computer. Therefore, in this work, recognition algorithm based on neural network is used. The details on Multivariate Gaussian and neural classifier are given into the next subsection.

1. Multivariate Gaussian model

Multivariate Gaussian Models have relatively simple analytical properties. In this model, the distribution of features for each context is modeled by a single n x n dimensional Gaussian, which is specified by an n dimensional mean μ and n x n covariance matrix (Σ). The feature vector x is multivariate Gaussian if, for mean μ and covariance matrix Σ, the feature vector is distributed according to the formula:

$$P(x/\mu,\Sigma)=\frac{1}{(2\pi)^{\frac{d}{2}}.|\Sigma|^{\frac{1}{2}}}.e^{-\frac{1}{2}(x-\mu)^T.\Sigma^{-1}.(x-\mu)} \quad (1)$$

where, d is dimensionality of the feature vector x.

In order to classify a feature vector we have to calculate the posterior probability or density function $p_n=p(x/u_n,\Sigma_n)$ for each class n and choose the class with the largest p_n.The model parameters u_n and Σ_n, are estimated separately for each class n as follows:

$$u_n=\frac{1}{j_n}\cdot\sum_{\forall x\in X_n}x \quad (2)$$

$$\Sigma_n=\frac{1}{j_n}\cdot\sum_{\forall x\in X_n}(x-u_n)\cdot(x-u_n)^T \quad (3)$$

where, μ represents the mean and Σ is the covariance matrix.

Using multivariate Gaussian for each data, we can find the most likely classification for the data set. This multivariate Gaussian is transmitted to sink node wirelessly. In sink node, further process for recognition is carried out.

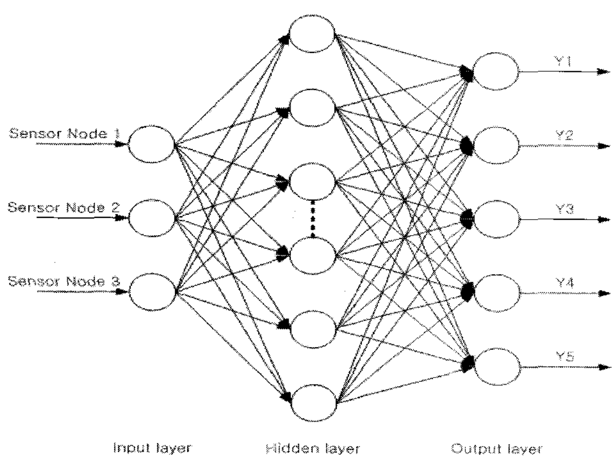

Fig. 5. Structure of neural classifier.

2. Neural classifier installed on sink node

A neural network is an information processing paradigm inspired by the way the biological nervous system (human brain) processes information. The neural networks composed of a large number of highly interconnected processing elements (neurons) are configured for specific applications such as pattern recognition or data classification, through the learning process. Learning involves adjustments to the synaptic connection (weights) that exist between neurons. For classification of sensed data we used a simple neural network with three layers: input layer, hidden layer and the output layer. The number of neurons in each layer is as follows: 3 neurons in input layer, 30 neurons in hidden layer and 5 neurons in output layer. Simulations were performed using feed-forward neural network function newff (epoch: 1000, error rate: 0.0001) within Matlab Simulink. The structure of neural classifier installed on the sink node is shown in fig. 5.

IV. Application of proposed scheme to Hand Gesture Recognition

To verify the performance and feasibility of the proposed system, the proposed scheme is applied to hand gesture recognition[6]. The goal of the system is to recognize the hand gesture and the hardware platform is shown in fig.6. There are three sensor nodes and one sink node. Several sensors are connected to each sensor node.

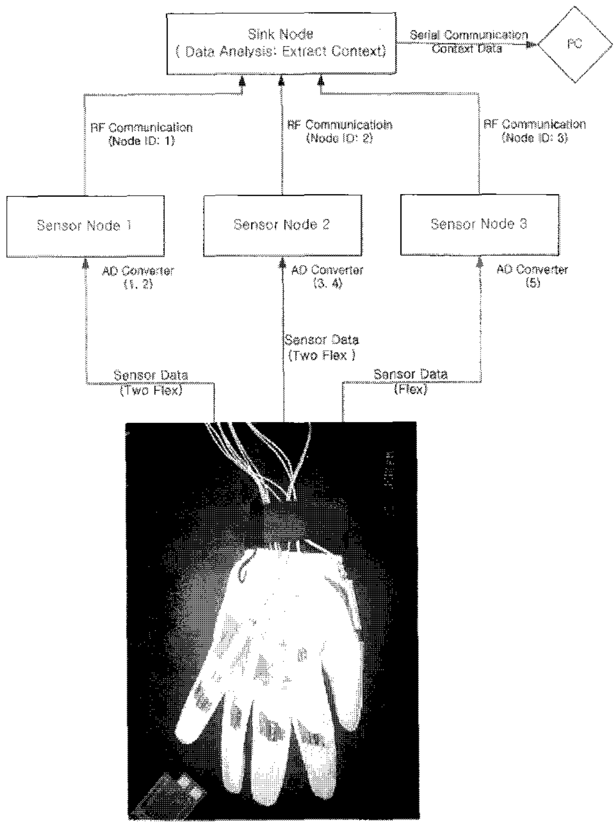

Fig. 6. Hand gesture recognition system.

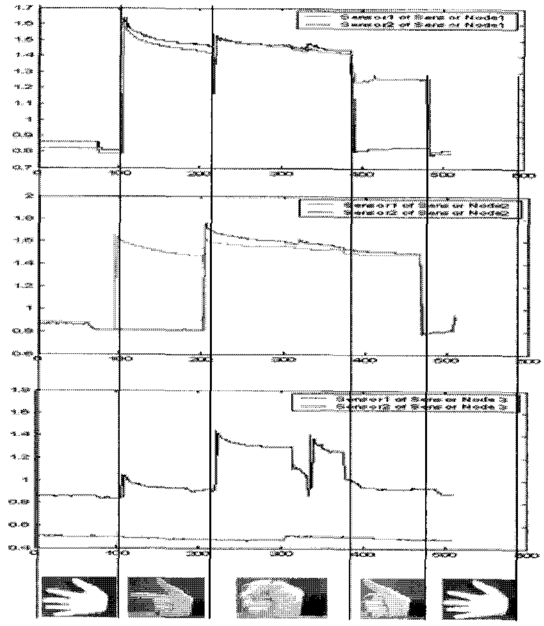

Fig. 7. Raw data collected by flex sensors.

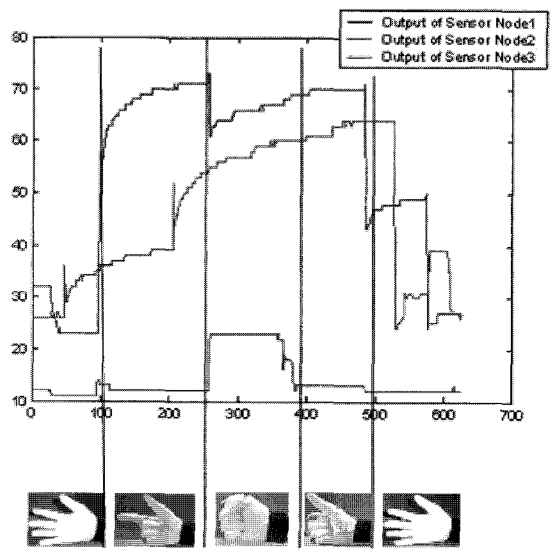

Fig. 8. Output of Multivariate gaussian function for each sensor node.

In this system, five sensors are mounted on the surface of the glove. Five sensors are mounted on the top of each finger to measure the bending degree of finger. For this, flex sensors are used. The flex sensor changes resistance when bent. An inflexed sensor has a resistance of about 10,000 ohms and as it is bent, the resistance increases up to 30 Kohm at 90 degrees.

For the purpose of verifying the feasibility of the proposed scheme, two sensors are connected to one sensor node on purpose. Therefore, three sensor nodes are used in this experiment.

As mentioned earlier, in each sensor nodes, corresponding data are collected periodically, and temporal features are extracted by using Multivariate Gaussian function. Corresponding Multivariate Gaussian output is transmitted to a sink node by using a communication mechanism based on active messages which was described before. After the sink node receives each Multivariate Gaussian from every sensor nodes, the recognition algorithm is executed to recognize the current status of hand. As recognition algorithm, one of the various recognition schemes such as: Hidden Markov Model (HMM), neural networks, temporal models for gesture recognition, Principal Component Analysis (PCA), Bayesian networks, etc, can be used. In our application, for gesture recognition we used a feedforward neural network with three layers.

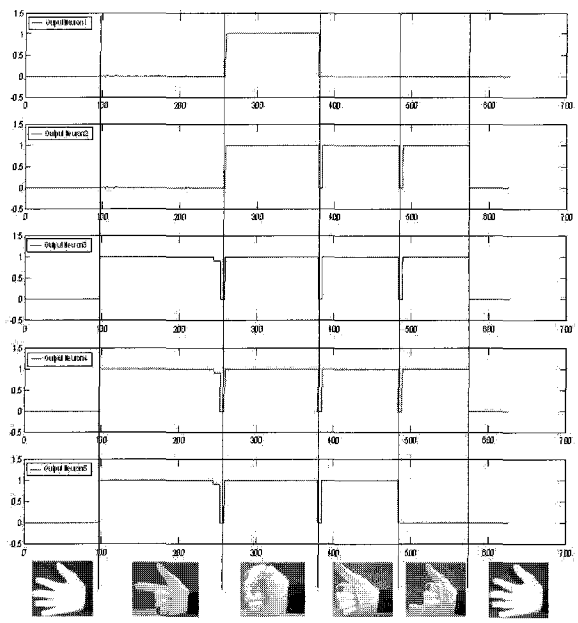

Fig. 9. Recognition result of neural classifier.

An operator wearing the sensory glove performed different motions: bending the fingers successively or a combination between various motions. The raw data collected by flex sensors corresponding to certain motions are shown in fig.7. The output of multivariate Gaussian function for each sensor node is shown in fig. 8.

Multivariate Gaussian outputs for each sensor node are transmitted to sink node wirelessly. Recognition algorithm based on neural network for recognition of hand gesture should be installed on host PC and it should be trained with appropriate data pattern before its usage. Recognition result of neural classifier is shown in fig. 9.

As one can see from the result of experiment, the proposed scheme shows a good recognition.

V. Conclusion

By utilizing the characteristics of sensor node in the field of sensor networks and basic neural network scheme, we have presented a new recognition system which uses Multivariate Gaussian function to extract the simple feature value corresponding to the current situation. To verify the feasibility of the proposed scheme, it was applied to hand gesture recognition problem.

The experimental result shows that the performance of the system can be satisfactory. Furthermore, the very promising results obtained allows us to consider that even if sensor network have not yet reached maturity, they will undoubtedly provide an important future technique for dealing with wearable computing etc.

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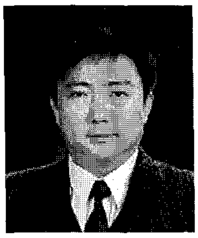

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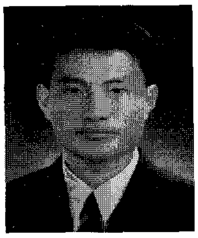

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