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Mobile Electronic Nose Architecture for Beef Quality Detection Based on Internet of Things Technology

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Abstract

Food Is The Most Basic Human Needs. One Of Popular Type Of Food Is Beef. Beef Is A Source Of Protein That Can Broke Easily If It Is Treated Improperly. The Poor Quality Beef Leads To The Poisonous Food And Health Problem If It Is Consumed. General Way To Detect Beef Quality Is Using The Sense Of Smell However That Way Cannot Be Relied On. It Is Because Human's Sense Of Smell Is Easily Tired And Subjective Property. Therefore, In This Research Beef Quality Detection Instrument Using Mobile Electronic Nose (Molen) Is Proposed. Molen Concept Is The Development Of Conventional E-Nose. It Applies Sensing As A Service (S2aas) Paradigm Which Tries To Increase Conventional E-Nose Ability Thorough Mobile Technology Adoption And Wireless Sensor Network (Wsn) As The Main Key In The Internet Of Things (Iot) Technology. The Utilization Of Mobile Technology And Wsn As An E-Nose Sensor Gas Will Offer Scalability And Flexibility. Molen Architecture Has Been Defined In This Paper. It Consists Of Four Layers Such As: Sensing Layer, Network Layer, Cloud Layer And Application Layer. Each Of The Layers Has Their Own Specific Functions And Challenges.

Keywords : Mobile electronic nose (MoLen), Sensing as a service (S2aaS), Wireless Sensor Network (WSN), Internet of Things (IoT) .

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Introduction

Based on the Centers for Disease Control and Prevention, in 2013, a total of 19,056 infections, 4,200 hospitalizations, and 80 deaths were reported in USA(Prevention, 2014). Moreover, Indonesia's food poisoning phenomenon in 2014 increases up to 3845 cases(POM, 2014). Food poisoning usually starts with nausea, seizure,suddenly stomach ache and flatulence especially at the bottom. It is followed by vomiting, diarrhea, and weakness. The symptoms will appear in two up to four hours after eat the food which is contaminated by bacteria. For some cases, it is often end with the death of the poisonous food patients. Based on those facts, the researchers try to build the methods to detect quality of food.

Beef is one of the main dishes which often consumed by human. One of its characteristic is easily staling if it is kept in the room temperature for specific times.It is because beef is the best media for the microbe growth. Stalling beef caused by microbe decreased the quality of the meat. The amount of microbe contamination determines the meat quality and shelf life.Besides, the beef quality based on the food safety requirement and the consumer health has to be considered. The meat is needed to be preservedsuch that stale can be avoided. It is because the longer meat is kept, the lower quality of the meat. The deadline of meat shelf life is eleven months if it is kept in the refrigerator.After the meat shelf life, the meat cannot be sold or consumed. However, in the development countries meat quality still has low people attention. For example, it can be seen by the low quality beef circulated in several places in Indonesia. There are "daging sapi gelonggongan" which first made the cow to drink excessive water. It aims to increase the weight of the meat so that it will add profit to the seller. On the other hand, it will be affected to meat quality because meat become easier to rotten. However, the circulation of low-quality beef is very harmful to the consumer.

General ways to ensure meat quality are checking the structure (texture, softness, flavor, juiciness, and color), detecting the amount of microorganism and gas or Volatile Organic Compound (VOC) which is come from those microorganism. Human's sense of smell is used to ensure meat condition. However, using the human sense of smell as a tool to check the condition of the meat has a weakness because it is subjective and easily tired or fed up so that less scrupulous measurement results. Therefore, it needs a better instrument in measuring the quality of beef. Based on those needed, this study proposes the development of quality measurement instrument based on beef Volatile Organic Compound (VOC). This instrument is also called electronic nose (e-nose) which is built with gas sensors. This research attempts to define the architecture of the mobile electronic nose (MoLen) technology which is using theWireless Sensor Network (WSN) and integratingto the cloud computing services. The proposed architecture emphasizes the flexibility of the use of e-nose instruments compared with the conventional e-nose.

Electonic Nose Concept

The electronic nose term is becoming known in the 1980s which refers to the instrument consisting of the heterogeneous electrochemical gas sensors collection. It serves as the input parameters on a pattern recognition system(J.W. Gardner, 1999; Dodd, 1982). The mechanism of e-nose adopts the human sense of smell works. It is based on chemistry interaction between compounds that emit odors and olfactory receptors in the nasal cavity. The sensing result is sent to the brain through the nervous system.Then, it is processed and identified what smell is wafted by the nose. According to Gardner and Bartlett, e-nose is defined as a collection of chemical gas sensors which has the capability of detecting and measuringthe volatile compounds in a sample which is combined with the data processing system of computerized multivariate statistics(Bartlett, 1994).

Past And Related Research

Several researches related to the detection of food quality are using Metal Oxide Semiconductor Sensors, data analysis using Principal Component Analysis (PCA) and Support Vector Machines (SVM). Experiments using beef and mutton were stored at four degrees Celsius for 15 days. The result accuracy is 98.81% beef and 96.43% mutton(N.E. Barbri, 2008). Another study is using a gas sensors field combined with the Artificial Neural Network (ANN). Testing samples are stored at ten and four degrees Celsius. The result accuracy is 82.99%(Ghasemi-Varnamkhasti, 2009). Balasubramanian et al. research is using Metal oxide sensor and ANN which the accuracy of result was about 92% (S. Balasubramanian, 2009). Moreover in 2010, Musatov et al. studied about distinguishing the meat among suppliers using Linear Discriminate Analysis (LDA) and metal oxide sensor (MOS) microarray. It uses sample which is stored at four and twenty five degrees Celsius(V.Yu. Musatov, 2010).

In 2011, Anthoula et al. used Fourier transform infrared spectroscopy to differentiate meat variants (fresh, somewhat fresh, rotten). It used ANN as classification methods and the accuracies are 91.7% for fresh meat, 94.1% for rotten meat, and 81.2% for somewhat fresh meat(Anthoula A. Argyri, 2011). In the same year, Efstathios et al. used partial least squares (PLS) which the result of accuracy is from 63.1% up to 94.7% comparing with ANN which the result of accuracy is from 98.2% up to 100% (Efstathios Z. Panagou, 2011). Three years later, Vassilis et al. used neuro fuzzy identification model which the accuracy of the result was about 95.94%(Vassilis S. Kodogiannis, 2014).

There are the other researches related to the data processing algorithm which can be used to MoLen. One of them is comparing Artificial Neural Network (ANN) and Support Vector Machine (SVM) to predict ground water level (GWL). The experiment result shows that overall SVM performance is better than ANN(Heesung Yoon, 2011). Muniz. et al were comparing Probabilistic Neural Network (PNN), SVM and Logistic Regression (LR) to evaluate the sub thalamic stimulation effect on the Parkinson disease. The experiment result shows that PNN performance is better than SVM and LR(Muniz, 2010). In 2010, Kara et al. built a prediction system of stock price movement using ANN and SVM which used Istanbul-Turkey stock exchange case studies. The average result shows that ANN model (75.74%) is significantly better than SVM model (71.52%)(Yakup Kara, 2011).

Based on overall researches which has been done, gas sensor type which is mostly used is MOS gas sensor array. However, there is no one which is using wireless MOS gas sensor. Therefore, sample data result must be transferred manually to the personal computer to be processed(Aleixandre, 2008). MOS gas sensor which has wireless interface will have ability as well as WSN. The wireless gas MOS sensor combined with mobile technology will greatly enable the development of e-nose as Sensing as a service (S2aaS)(Xiang Sheng, 2013). This is the motivation for vendors to produce wireless WSN MOS gas sensors. Many types of gas sensors WSN that are currently being used to detect common gases and air pollutants such as CO, CO_2, NO_2, H_2, and others (Yang, 2009; Kuncoro, 2012). But there is no WSN specifically created to detect VOC.

In addition, up until now most studies related to the e-nose only use accuracy parameter in the beef detection. There is no research which considersdata speed in the processing time whereas time becomes the important parameter when MoLen is considered as a service (S2aaS).

Mobile Electronic Nose For Beef Quality Detection

Based on the studies which have been done earlier, the type of sensor used is MOS gas sensors (N.E. Barbri, 2008; S. Balasubramanian, 2009; V.Yu. Musatov, 2010). Data from the sensors are transferred to the Personal Computer in semi-manual for further analysis. The proposed system is based on Internet of Things (IoT) technology and Cloud Computing which use gas sensors equipped with wireless interface communication. This system enables the sample data delivery to a high computation system on the cloud computing in a real time. Then, it is processed and the results obtained with a relative short time.

A. System architecture

Figure 1 shows the architecture of MoLen. It consists of four layers such as: sensing layer, network layer, cloud layer, and application layer. Each layer has a specific function but linked one to another.

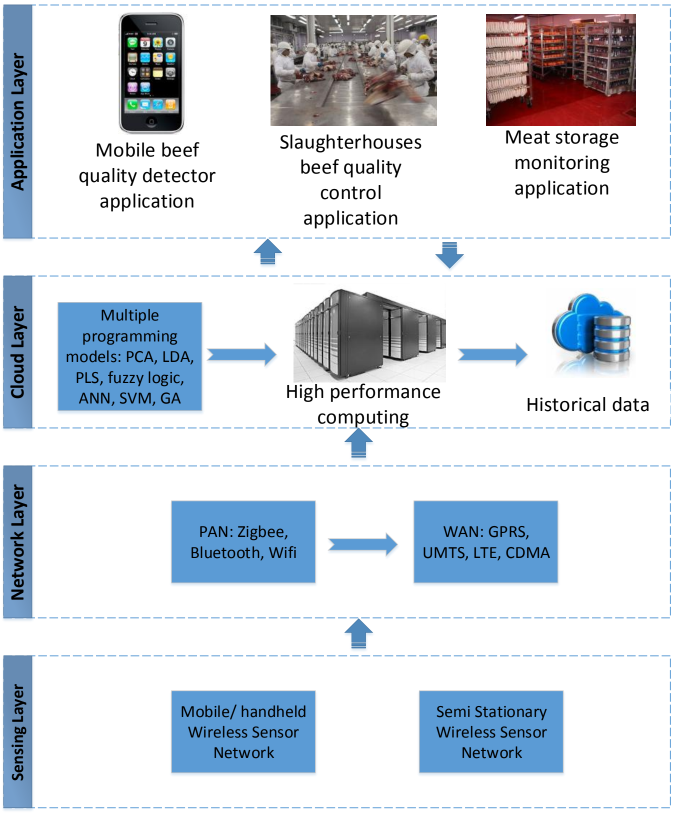

Figure 1. Mobile e-nose (MoLen) system architecture

1. Sensing Layer

Sensing layer is a layer that interacts directly with the beef samples to be tested or monitored. This layer consists of a collection of gas sensors to detect VOC. One of sensor type which can be used is metal oxide semiconductor (MOS) gas sensor that generally is used for e-nose. MOS gas sensors can be further developed by adding a wireless communication module. Therefore they have characteristics as well as WSN which can communicate between nodes (Jennifer Yick, 2008). E-nose sensors used must have a high portability while having its basic functions. It aims to be an E-nose instrument which can be used starting from household level, small industries, medium industries, up to large scale industries. Gas sensor instrument for e-nose is formed as handheld devices for personal or household usage. As for meat storage space monitoring system, it can be formed as semi-stationary devices. Some sensor nodes can be installed easily on meat storage space to determine the quality of the meat which is placed near to the node.Another challenge is about sensor array selections. The classification accuracy is depend on sensor array selection. In many cases, the sensor array produces an imprecise, incomplete, redundant, and inconsistent dataset and thus the classification accuracy degrades due to these unsuitable sensor arrays (Anil Kumar Bag, 2011; P. Saha, 2012).

2. Network Layer

VOC sample data obtained from gas sensors which come from the sensing layer is sent in real time through a Personal Area Network (PAN) such as Zigbee, Bluetooth, and Wi-Fi. Sample data obtained can be directly sent to the Cloud Layer or collected first prior to a central node and then transmitted simultaneously. In the handheld e-nose, first collected sample data through a smartphone or tablet via Bluetooth or wifi then it is sent to the Cloud Layer via WAN. In the other hand in the semi stationarye-nose, sample data isgenerated relatively more numerous and complex. In addition, the wide area monitoring and the number of nodes are some challenges. Data communication using Zigbee and wifi is the best options in this case. Each node can be connected to each other forming the mesh network of E-nose. Sample data is collected from all nodes to the primary node then it is sent to the Cloud Layer for further processing

3. Cloud Layer

The sample data sent by a single node or network node are multivariate. Processing the sample data has their own challenge and issue. The output should be processed quickly with the high accuracy. Speed in getting the meat quality measurements is very important. It is because the user interacts with the system using a mobile device which is designed to obtain information quickly and easily.

The other Issues and challenges is how to provide computing to produce decisions of the beef quality efficiently. Although cloud computing technology has the shared resource pooling characteristics which provides dynamic resource, the sample data processing must be done efficiently considering to the large users(Qi Zhang, 2010). This will be more severe if a user has more than one node. It causes that the sample data processing will become increasingly severe. There are many options of data processing techniques such as:Principal Component Analysis (PCA), Linear Discriminate Analysis (LDA), Partial Least Squares (PLS), Functional Discriminate Analysis (FDA), Cluster Analysis (CA), fuzzy logic, Artificial Neural Network (ANN), Probabilistic Neural Network (PNN), etc(Amy Loutfi, 2015). Choices the processing algorithms type is very important because most computational load is in the Cloud Layer.

When sensor amount grown, it can be make another problem to search the sensor and related data. Specific technique must be used to prepare this condition (Charith Perera A. Z., 2014; Charith Perera A. Z., 2013).A semantic searching method that proposed in the architecture of Workflow Management System (WFMS) method can be used to searching technique for sensor and related data(Riyanarto Sarno, 2015).In this layer, the middleware architecture must be well defined based on both of functional and non-functional requirements. The middleware architecture can be adopted from RFID Middleware that has already been developed before(Wijaya, 2014).

4. Application Layer

Application layer is a direct user interface to the MoLen sensors service. Sample data of the gas sensor will be collected prior to the application of MoLenthen it is sent to the cloud layer to be further processed. Beef quality detection results will be sent back to the user throughapplications such as mobile applications for personal scale users, small and medium industries, as well as for large industrial scale. The application runs on mobile devices such as smart phones and tablet PC. The application can be used by every household to detect the quality of the beef which will be consumed. Applications can also be used by slaughterhouses to perform quality control of beefs which have been cut and stored. Small scale of beef seller up to large supermarkets will also be able to use this application to monitor the quality of the beef before it is sold to the consumers. Moreover, health department can also use the mobile application of E-nose to inspect the quality of beef in the market.

B. Componen Builder

E-nose Wireless Sensor

Characteristics of an ideal sensor which is used for the E-nose instrument must fulfill the following criteria (P.N. Bartlett, 1993): 1) high sensitivity to the chemical compounds (able to detect compounds at concentrations of less than 10^{-12} g / mL), 2) low sensitivity to the temperature and humidity, 3) capable of detecting the presence of different compounds in a sample, 4) high stability, 5) high reliability and reproducibility, 6) rapid reaction and recovery time, 7) strong and durable, 8) easily calibration, 9) easily resulting data processing, and 10) small dimensions.

Recently, there is MOS portable gas sensor which has the low price, high performance, and ability to detect multipletargets(Lei Zhang, 2014). However, the sample data obtained from the portable gas sensor still must be manually transferred to the PC for further processing.MOS portable gas sensor needs to be further developed so that it fulfills the characteristics of WSN which has advantages in terms of scalability and real time. MOS gas sensor must have the wireless interface which is used to communicate between nodes and send the sample data to the cloud layer. Communication scheme of MoLencan be seen in Figure 2.

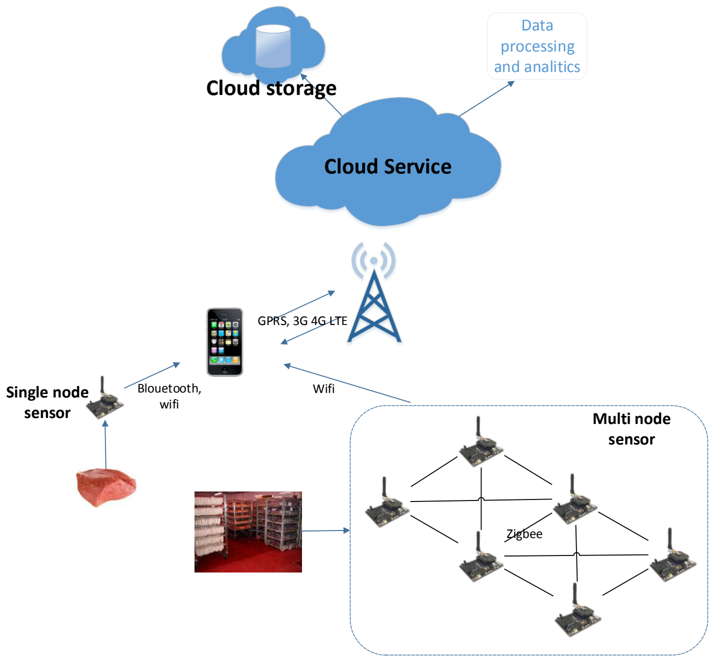

Figure 2. Mobile e-nose (MoLen)communication scheme

The e-nose instrument variant is divided into two type. They are single node and multi-node sensor. Single node is suitable for personal or household needs whereas multi-node sensor is suitable for slaughterhouses and meat storage space in supermarkets. Sample data obtained through a single sensor node can be directly sent to the smart phone or tablet PC. Bluetooth or wifi can be used as data communication. As for the data communication in the multi-node sensor, Zigbee or Wifi can be used for scalability reasons. Gas parameters can be seen by users then sent again to the cloud service for further processing. The results of the sample data processing are sent to the user's smart phone or tablet PC in order that the user can get information about the beef sample quality. In addition, users can also see the history of sample data which has been tested.

Cloud Computing Infrastructure

Speed in getting the meat quality measurements is very important. It is because the user interacts with the system using a mobile device which is designed to obtain information quickly and easily. High performance computing needs to provide this quick and accurate result. From this challenges and requirements, the cloud computing infrastructure is suitable option to provide high computation service for MoLen. Cloud computing services such as: Microsoft Azure, Rackspace Public Cloud, Amazon Web Services (AWS) can be used to provide Infrastructure as a service (IaaS). Some example IoT application that use Cloud Computing technology are traffic management system(Xi Yu, 2012), smart city(G. Suciu, 2013), vehicle management system (Zhao, 2011), and manufacturing system (Fei Tao, 2014).

Conclusion

In this paper, we introduce MoLen architectureto measure the beef quality. The MoLenconcept is application of the Sensing as a service (S2aaS) paradigm which odor sensing technology offered as a service. This concept attempts to offer an E-nose technology combined with the advantages possessed by the concept of the Internet of Things and Cloud Computing. There are some advantages offered by those concepts such as: 1) The users can be easily detecting thebeef quality using mobile devices, 2) The sample data collection and measurement results is available in the real time without having to move the sample data to a PC manually for further processing, 3) The advantages of using cloud computing technology in terms of flexibility in resource allocation to process the beef quality sample data, 4) Scalability and flexibility by using WSN as an instrument of E-nose. However, there are main challenges which are identified as follows: 1) Up until now, there has been no research or product on WSN which is specific to e-nose, 2) The sample data processing algorithm which produces quickly and accurately the measurement data in the real time. Hopefully, theMoLencan be used by household or personal scale up to large industries to detect the beef quality which will be consumed in the easy way and low cost.

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