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Sensor Grid Middleware Architecture for Food Quality Control Units

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ABSTRACT

Food processing is a large sector which also includes industries that use agricultural products to produce edible products. This paper examines the role that Sensor grids can play in providing these industries with an automated software solution that will help to improve the quality of the products in the various production lines. The sensors transmit vital parameters through gateway to the grid where supervisor receives messages if there is any deviation in the quality. A grid gateway is available which act as a middleware for pivoting the request and scheduling. This system can act as a mediator between the production line in remote areas and supervisors in another area.

Keywords: Sensor, food, Quality control

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INTRODUCTION

Food processing is a large sector that covers activities such as agriculture, horticulture, plantation, animal husbandry and fisheries. It also includes other industries that use agriculture inputs for manufacturing of edible products. Quality is an important aspect considered in these industries. The term quality involves taste, aroma, hygienic etc. In earlier days it was monitored manually and later technology was introduced for this. The sensors served as a boon to this industry as it served as electronic tongue and nose. Sensor networks enabled to transmit the sensed parameters. But they have certain barriers which can be complemented by using the sensor grid computing technology .The objective of this research was to apply on-line continuous sensors in food processing manufacture, in order to achieve higher quality, increased yields and reduced losses. This paper is focused on technologies for monitoring parameters related to the quality of the product.

FOOD PROCESSING SCENARIO IN INDIA

The food processing industry is one of the largest industries in India-it is ranked fifth in terms of production, consumption, export and expected growth. The food industry is on a high as Indians continue to have a feast. Fuelled by what can be termed as a perfect ingredient for any industry -large disposable incomes - the food sector has been witnessing a marked change in consumption patterns, especially in terms of food. The Confederation of Indian Industry (CII) has estimated that the foods processing sectors has the potential of attracting US$ 33 billion of investment in 10 years and generate employment of 9 million person-days. The Ministry of Food Processing, Government of India indicates the following segments within the Food Processing industry: Dairy, fruits & vegetable processing ; Grain processing ; Meat & poultry processing ; Fisheries; Consumer foods including packaged foods, beverages and packaged drinking water.

Value addition of food products is expected to increase from the current 8 per cent to 35 per cent by the end of 2025. Fruit & vegetable processing, which is currently around 2 per cent of total production will increase to 25 per cent by 2025. The Processed Foods with respect to Specific Sectors are, Dairy, Fruits and Vegetables, Grains, Meat and Poultry, Fish Processing, consumer Foods .The food processing industry have certain initiative policies such as Food Safety and Standard Act, 2006, Foreign Direct Investment, Vision strategy and action plan, Eleventh Five Year Plan (2007-2012) Initiatives .Certain infrastructure are developed for improving the food processing sector. They are Packaging Centers, Integrated Cold Chain Facility, Value Added Centre (VAC), Irradiation Facilities, and Modernized Abattoir. Indian food processing industry has seen significant growth and changes over the past few years, driven by changing trends in markets, consumer segments and regulations. These trends, such as changing demographics, growing population and rapid urbanization are expected to continue in the future and, therefore, will shape the demand for value added products and thus for food processing industry in India. The major challenges faced by food processing industries are Lack of awareness about the industrial needs and gap between the technology and the prevailing industries.

The industries that lead the food processing sector are Dabur India Ltd, Godrej Industries ltd, Godrej Industries Ltd, MTR Foods Ltd etc .These industries have their processing units at more than one location .Quality control of the products becomes a tedious process because of the distributed nature of the units stretched all over the country. Quality is the major force that runs these industries. Therefore a stringent measure is needed for the distributed quality control.

ROLE OF SENSORS IN FOOD PROCESSING

Many products require constant monitoring throughout their supply chain. This is not only for compliance purposes but also to ensure that the basic quality assurance requirements to retailers are met. For example, the chill chain requires that chilled products are stored at a constant temperature throughout the delivery and storage of the product. Typically each product batch is examined by the retailer on arrival and is rejected if it does not meet the required temperature. Up to now, the only solution to this problem for many smaller companies was to take periodic manual temperature readings.

Woodworth [5] outlines how the Food industry is generally receptive to the use of information systems. Traditionally the principal use of Information Technology by Food Processing companies has been in Enterprise Resource Planning (ERP) Software. However, in recent times companies have started using mobile devices such as PDAs and wireless technology such as 802.11 to provide solutions in areas as diverse as traceability and logistics. Indeed, the incidents outlined in the previous section have led to increasing interest in Product Life Cycle Management Software which, in conjunction with RFID (Radio Frequency Identification Technology), is being mooted as a solution for addressing food safety [6].

As pointed out in Friend[7], ERP software is designed for managing operations within the enterprise only. However, given a typical food processor‘s dependencies on external suppliers and the external environment this is no longer adequate for food industry. Indeed, many of the key tasks in food production are still carried out manually. For example, growers still manually measure temperature and food scientists often have to manually carry out tests to detect ingredient composition and check for the presence of contaminants. Mobile technology is one factor in providing an automated software solution for the food industry but the solutions offered today only cater for the tagging and labeling of products. Granted, these are key components of a good traceability system and are vital for the post-auditing of food contaminations but they don‘t prevent the actual problem. It is in addressing that the sensors can provide a vital role.

With the advent of Sensor Networks it is now possible to devise a solution whereby the producer is notified virtually instantaneously if the temperature failed outside acceptable parameters. A wireless sensor network is a system comprised of radio frequency (RF) transceivers, sensors, microcontrollers and power sources. Wireless sensor networks with self-organizing, self-configuring, self-diagnosing and self-healing capabilities have been developed to solve problems or to enable applications that traditional technologies could not address.

Once available, these technologies would allow us to find many new applications that could not have unconsidered possible before. Wireless sensor technology is still at its early development stage. Applications of wireless sensors in agriculture and food industry are growing Wentworth (2003) conducted a study aimed at inexpensive, disposable RFID biosensor tags used on food products for history checking and contamination and inventory control. The biosensor was based on an acoustic wave platform and used antigen-antibody reaction to detect bacteria. Chandler (2003) discussed the potential of RFID tags for smart packaging, automatic checkout, smart appliances, smart recycling and marketing/promotional opportunities. He believed that this type of technology could improve security, productivity, inventory control, traceability and result incapital and operational savings.

Najjar et al. (1997) developed a handheld PC for quality inspectors of a food-processing plant. The system allowed inspectors to select a form, complete the form and send the data to the plant manager's computer through a 16-bit, full duplex audio and 2 Mb/s wireless data communication. The system also allowed mobile workers to use their voices rather than their hands, to enter data from anywhere in the plant. In recent years, wireless sensors have been adopted in food processing to monitor and control the quality attributes of food products. For example, a temperature sensor can be inserted into a food can to record the evolution of temperature, and transmit the temperature data wirelessly to a central controller.

Marra and Romano (2003) developed a mathematical model to study the effects of different methods of inserting wireless temperature sensors into conductive canned food for monitoring thermal sterilization.

A wireless, passive resonant sensor was developed by Ong et al. (2001) to monitor the bacterial concentration in food products. The sensor was built on a thin film with an LC resonant circuit and was placed on a biological medium. The resonant signals related to the bacterial concentration in the medium were detected remotely by a loop antenna. The sensor showed great potential for food quality monitoring.

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SENSOR NETWORKS DRAWBACK FOR THE FOOD INDUSTRY

There are a number of factors that act as serious barriers to entry for the use of Sensor Networks in the Food Industry:

Reliability

A recent deployment of Sensor Networks in two redwood trees in Sonoma, California found that 65% of the nodes never returned data [18]. The former statistic would be unacceptable in any commercially deployed food monitoring network and it would be very difficult to make a business case for a network where a significant proportion of the nodes never work.

Ease of Use

Food processing organizations tend to be technology agnostic. Microsoft based technology prevails as it is easy to use and install. For the non-technical user Sensor motes are intimidating to deploy and use. Indeed, implementing a Sensor Network lies outside the range of the average Food Industry Information Systems Professional.

Data gathering and Data Interpretation

While Sensor Networks undoubtedly can play a significant role in improving the availability of update data on a physical environment there is currently no standard way for gathering and interpreting the data. The Food Industry relies heavily on standard reporting tools such as Crystal Reports and Brio and would be loathe using non-standard Java-based reporting GUIs.

Organizing Networks and Clustering

There is at present no mechanism by which end users can organize their sensors for reporting purposes. Granted, group IDs are available but there can be limited – for example, two sensor groups might be monitoring the same area and would be effectively the same sensor group from a reporting perspective. What is required is a means by which users can organize their groups into clusters that make sense to them.

Other than these major problems we have issues like

1. Standardization is not yet completed. A big sign, Path ahead is still under construction, is in most people‘s minds.
2. Early adopters are still smoothing out the bumps and many potential adopters are waiting on the sidelines for proofs of successful and safe adoptions.
3. The massive data generated by wireless sensors have the potential to overwhelm while providing limited values unless the structure and process are in place to take advantage of all their potential.
4. Existing IT infrastructure, predominately wired communication structures, was simply not designed for pervasive inputs and require significant overhaul.
5. Compatibility with legacy systems is not addressed so that many existing systems prevent adoption of wireless products. Complete adoption may require abolishment of existing,

wired infrastructure and changes to status quo. Once implemented; the flexibility of infrastructure may be restricted.
6. Security issues need to be resolved; the WLAN security crisis may serve as an example.
7. Complexity and high cost for coverage in large plants prevent fast adoption.
8. Power supply is always a great concern for wireless systems.
9. The reliability of wireless system remains unproven and it is considered too risky for process control.
10. Lack of experienced staff for troubleshooting.

SENSOR GID – SOLUTION FOR BETTER USAGE OF SENSOR NETWORKS

Grid computing is an established standards-based approach to solve large-scale problems through coordinated sharing of distributed and heterogeneous resources in dynamic virtual organizations. [1] Has received increasing attention from the research community. Sensor grids extend the grid computing paradigm to the sharing of sensor resources in sensor networks. A sensor grid integrates sensor networks with the computational and storage resources in the conventional grid fabric. The vast amount of data collected by the sensors can be stored, processed and analyzed by the computational and data storage resources of the grid. Sensor resources can be efficiently shared by different users and applications through the resource sharing and coordination capabilities of the grid

It is an enabling technology for building large-scale infrastructures, integrating heterogeneous sensor, data and computational resources deployed over a wide rea, to undertake complicated surveillance tasks .The sensor grid enables the collection, processing, sharing, and visualization, archiving and searching of large amounts of sensor data. There are several rationales for a sensor grid. First, the vast amount of data collected by the sensors can be processed, analyzed, and stored using the computational and data storage resources of the grid. Second, the sensors can be efficiently shared by different users and applications under flexible usage scenarios. Each user can access a subset of the sensors during a particular time period to run a specific application, and to collect the desired type of sensor data. Third, as sensor devices with embedded processors become more computationally powerful, it is more efficient to offload specialized tasks such as image and signal on the sensor devices. Finally, a sensor grid provides seamless access to a wide variety of resources in a pervasive manner. Advanced techniques in artificial intelligence, data fusion, data mining, and distributed database processing can be applied to make sense of the sensor data and generate new knowledge of the environment. The results can in turn be used to optimize the operation of the sensors, or influence the operation of actuators to change the environment. Thus, sensor grids are well suited for applications such as quality control in food processing.

PROPOSED ARCHITECTURE

The proposed system limelight's a grid gateway which act as a middleware to provide scalability, reliability, availability .Sensor nodes reside with the production unit which senses the vital parameters such as temperature, aroma, existence of micro organisms etc. The parameters are transmitted to the grid. Through a gate way they reach the grid. The middleware accommodates decision support system which handles queries up to some level. When the parameters go beyond normal level it informs the person concerned. The detailed architecture for the proposed system is given below in the figure 1

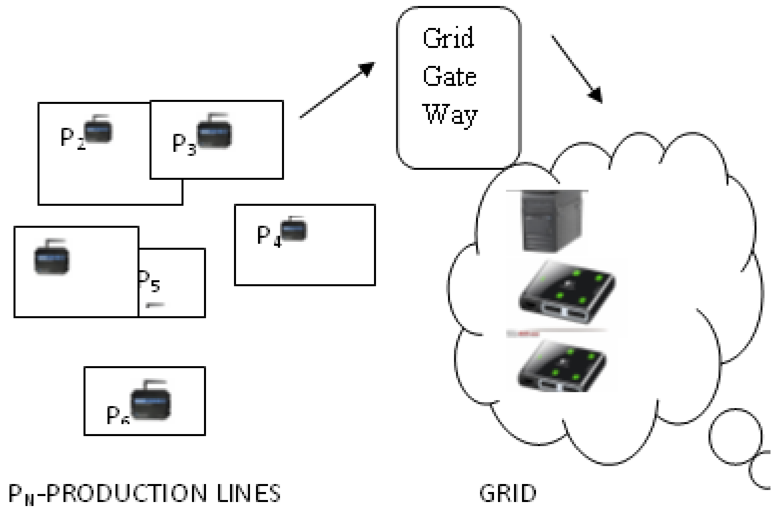

Figure 1. Architecture of sensor grid.

The architecture consists of the following components such as sensor nodes, gateway, grid middleware, and grid of specialist. A brief description about the functionalities of these components is given below.

Table 1.1 Datastructure

Notation	Description
Cd	Defect identity
CI	Sensor identity
Cs	Supervisor identity
Ksl	Supervisor sensor keypair

Sensor nodes

Sensor nodes reside in the production line. They are used for sensing the vital parameter values such as temperature, temperature, aroma, existence of micro organisms etc.

Gateway acts as a middle ware between sensors and distributedsupervisors, it provides three functions:

1. Decision support system
2. Identifying supervisors and diverting request.
3. Load balancing.

Decision Support System

It frequently receives vital signs as parameters from the sensors. Then it compares the vital parameters with the normal value. If the parameter value exceeds the normal value, it sends the information to the distributed supervisors.

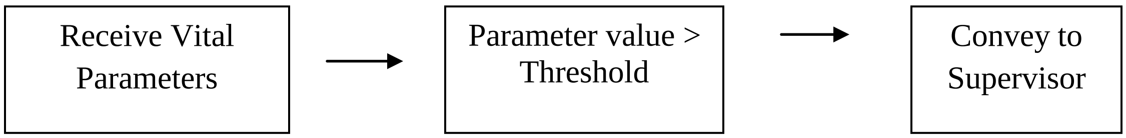

Figure 2 Decision system support

Identifying Supervisors and Diverting Request

The area key pair received is compared with the corresponding supervisor key pair in the distributed grid. If the area key pair matches with the supervisor key pair then the data is transferred to the corresponding supervisor.

The data structures used in this architecture are given in table 1.1 and format of code is given in table 1.2. The mostly prevailing defects are classified and are given a unique three digit code for identification. Each sensor is given with an area code .The supervisor is also given with the unique code whose first three digits also specify the area . An important data structure used here is the key pair which consists of area and supervisor code which aids in identifying specialist for corresponding patient.

Table 1.2Pattern of unique identity

Area identity	Sensor identity	Supervisor identity
111	111456	111564
222	222345	222987
333	333567	333531

The Supervisor – area code pair is first checked for the availability. If the pair is available, then it sends the vital parameter to the corresponding supervisor. The supervisor then takes decision according to the defect. When the supervisor is busy or not available, then the sensor data is diverted to the alternate available supervisor.

Algorithm

↓

Match the identity in transmitted data with pair (Ci , Cs)

↓

If combination (Cp,Cs) available

↓

Then SEND the parameter to corresponding supervisor

↓

If supervisor is available

↓

Receives appropriate action to be taken

↓

Else

↓

Search for alternate supervisor

Load Balancing

The decision support system filters the request according the value of vital parameters. If the values are above the normal level then it is directed to the supervisor in the grid. Hence the load to the grid is reduced to certain level.

The supervisor serves the request of the area that he is intended to only .this is identified by the supervisor -area key pair. Thus each supervisor node‘s load is balanced. Sometimes the supervisor may receive request from the new area if key pair is not available or if the corresponding supervisor t of an area is not available. This may increase the load of a specialist node .In future a threshold number of request may be assigned to each node and if it exceeds the request may be diverted with node with lesser load.

CONCLUSION

This paper proposes a middleware architecture that senses the parameters from the sensors in the production line of food processing technology. The supervisor could take action on based on the received parameters. This middleware architecture complements the sensors by lessening the burden of sensors created due to less power, storage and computing capacity. The computation, storage and decision making are done on the grid.

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