Int J Adv Manuf Technol (2003) 21:866–873
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The International Journal of Advanced Manufacturing Technology

Intelligent Data Acquisition Technology Based on Agents

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Nowadays, information is the most important factor for any manufacturing enterprise. Information helps a manufacturer to make decisions about management, production, operation, maintenance, and repair. Information technology is a key for enterprises who are realising integrated manufacturing all over the world. Data acquisition is the backbone of information technology. Data acquisition technology is the product of the fusion and interaction of many technologies. It is necessary to develop new data acquisition technology and methods by using the recently produced research results. It is also important for realising manufacturing automation, promoting product quality, and enhancing the competitive ability of an enterprise. In this paper, we first analyse three common kinds of data acquisition mode and their features used in manufacturing systems. Then, based on the background of manufacturing automation, agents and distributed artificial intelligent technology, which form a new data acquisition model framework suitable for an advanced manufacturing system, is proposed, and some details about this new model are discussed. Two examples of this model used in manufacturing systems are then given to show the availability and correctness of this model framework. We conclude with current research results in this area and give an outline of future work.

Keywords: Advanced manufacturing; Agent; Artificial intelligent; CIMS; Data acquisition

1. Introduction

Competition in manufacturing technology is a feature of the world economic competitive environment in the 21st century. Advanced manufacturing technology is now a key scientific and technological challenge. As the trend of globalisation continues, more companies must adopt advanced manufacturing technologies to maintain their competitive edge [1,2]. One concept that has received much attention is computer integrated manufacturing (CIM). Since 1973, when Dr Joseph Harrington first proposed the concept, much progress has been made in bringing knowledge and manpower together with the help of computers. Computer integrated manufacturing systems (CIMS) are being developed rapidly and are widely acknowledged to be an advanced approach in realising modern enterprise management. Through effective use of modern management, computers, information, automation, manufacturing systems, system engineering, and Internet/Intranet technology, the traditional factors – man, techniques, equipment and management – of production, can be better integrated to produce low-cost high-quality optimal operations that are easier to maintain and more responsive to market demands [1,3].

In CIMS, integration requires a tight coupling of the manufacturing system into the enterprise management information systems (EMIS) for design, operation, maintenance, and management. Integration achieves centralised analysis and processing of information at every stage, such as supply, manufacture, distribution and maintenance. The target of integration is to achieve deployment, reconfiguration, and sharing of global manufacturing resources and information. The basis of integration is the data acquisition process. Information technology, especially data acquisition technology, is the kernel for realising CIM.

A CIM system is typically made up of two subsystems – a functional subsystem and a support subsystem. The functional subsystem consists of product design and manufacturing, resource management, manufacturing automation, and quality assurance. The support subsystem consists of a computer, a network, and a database.

Manufacturing automation plays a pivotal rule in CIMS. The term “manufacturing automation” refers to:

Automation of information detection, test and supervision of production processes.

Automation of management of equipment and material.

Automation of equipment fault diagnosis and maintenance.

In manufacturing automation, data acquisition technology is the backbone in all phases of manufacturing, i.e. information

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Received 25 April 2002
Accepted 25 April 2002

detection, testing, supervision, equipment fault diagnosis, and management. Indeed, it may be said that data acquisition technology is the foundation of manufacturing and CIMS.

In this paper, we discuss the data acquisition mode used in a manufacturing system, and a new kind of data acquisition model framework suitable for advanced manufacturing system is proposed. The more common modes of data acquisition are described in the next section. Then, in Section 3, we propose a new kind of data acquisition model, i.e. agent-based data acquisition technology, that is well suited for advanced manufacturing systems. In Section 4, we discuss the agent realisation issue. The availability and correctness of the model is shown by a chemical process example and by a metallurgical equipment example in Section 5. Finally, a summary of the current work in this area will be provided, followed by an outline of how our own work may continue.

2. Manufacturing System Data Acquisition Mode

Modern manufacturing systems are characterised by a high degree of automation, complex process conditions, and diverse process objects. In order to ensure safety, efficiency, and quality products, as well as environmental protection and minimum pollution, a plant operator relies on sensors and data acquisition systems installed in the manufacturing systems for input about the conditions of equipment, processes, techniques, product quality, and their environmental impact. By using these sensors and data acquisition systems, raw data about the manufacturing process are obtained [4]. There are, in general, three modes of data acquisition.

2.1 Concentrated Acquisition Mode

Figure 1 gives an overview of this mode. The concentrated acquisition mode is used in simple and small-scale systems. All sensors in the manufacturing system connect directly to the acquisition system. An industry-grade PC (IPC) accomplishes the data acquisition and process tasks. The characteristics of this acquisition system include:

The structure of this data acquisition system is simple.

The system is relatively easy to set up and implement.

The use and maintenance of the system is convenient.

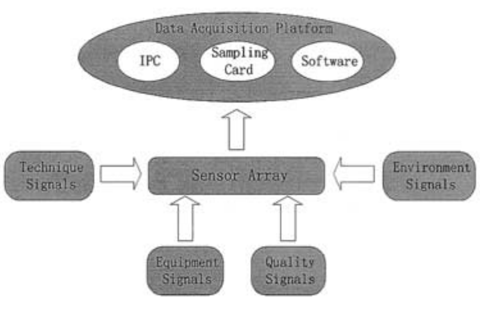

Fig. 1. Concentrated acquisition mode.

2.2 Distributed Acquisition and Concentrated Control Mode

Figure 2 is an overview of the distributed acquisition and concentrated control mode. This mode is recommended for manufacturing systems of moderate scale and complexity. Ideal manufacturing systems have a few facilities situated within short distances of each other. In this mode, signals are grouped according to their origin. Nearby signals are placed in the same group. A separate acquisition workstation samples signals from each group. Several acquisition workstations accomplish the whole sampling task. One data acquisition server manages the sampling workstations. In terms of networks, the data acquisition system forms a sampling LAN (local area network) dedicated to the distributed acquisition and concentrated control mode. This mode is the main mode of data acquisition.

In practice, a switch from concentrated to distributed acquisition usually means that:

System structure is more complex than before.

Cost is higher than before.

The use and maintenance of the system is not necessarily more complex than before.

The system now has a network function.

Data can be transmitted remotely.

Unmanned operations become possible.

2.3 Distributed/Concentrated Acquisition and Concentrated Control Mode

This mode is shown in Fig. 3. It is often used in large-scale and complex manufacturing systems. This mode is a combination of the distributed acquisition and the concentrated acquisition modes introduced before. In complex large-scale systems, such as chemical or metallurgy factories etc., there are many large-scale continuous product lines and complex equipment or facilities in use. Concentrated acquisition or distributed acquisition and concentrated control are not all suitable for these scenarios. Thus, a distributed/concentrated acquisition and concentrated control mode should be used.

In this mode, separate sampling workstations are used to collect the condition parameters of each machine unit in the line; and the data acquired by sampling workstations are transmitted to the data acquisition server. Because the technical

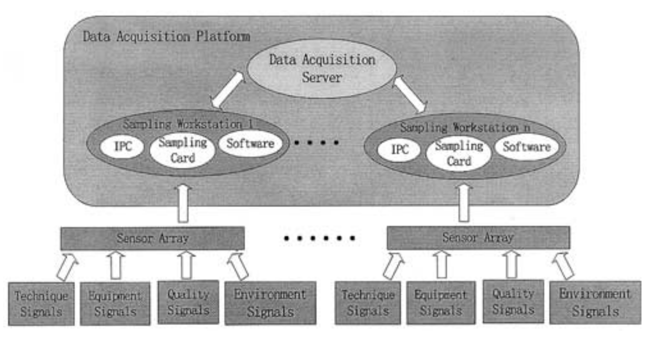

Fig. 2. Distributed acquisition and concentrated control mode.

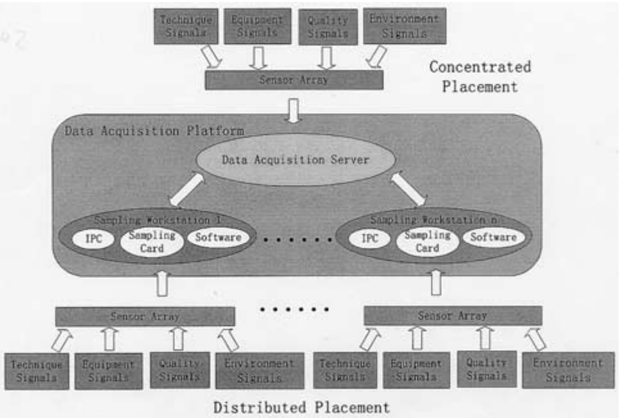

Fig. 3. Distributed and concentrated acquisition and concentrated control.

parameters of processes such as temperature, humidity, displacement, force, and pressure, are dispersed in the line, the data acquisition server directly acquires these parameters. The data acquisition server manages the whole data acquisition system, it also communicates with the upper information system. In terms of networks, the data acquisition system is also a data sampling LAN dedicated to distributed/concentrated acquisition and concentrated control mode.

It has the features that the distributed mode and concentrated mode also have, i.e.:

System structure is most complex.

Cost is higher.

The use and maintenance of data acquisition system is not necessarily more complex than before.

The system now has network function.

Data can be transmitted remotely.

Unmanned operations become possible.

3. Manufacturing System Data Acquisition Technology Based on Agent

3.1 Agent and Distributed Intelligence

Agent technology has been a focus of artificial intelligence study in recent years[5–7]; it deals with almost all key problems. The development of agent technology provides us not only with new computing methods and paradigms, but also with a good solution for the implementing of CIMS. For example, using the methods and ideas of agent research, we can construct a DAS (data acquisition system) based on agent technology and benefit from intelligent data acquisition technology [8–18].

Agent research is part of the study of DAI (distributed artificial intelligence). Relative to concentrated control, DAI, i.e. DPS (distributed problem solution) is derived from DCS (distributed control system) research.

The design of early control systems can be thought of as a kind of local optimisation, which performs the function of the concentration of data acquisition and control, to form concentrated control. With an increase in the scale, complexity of structure, and scope of function, the number of factors that can influence system performance suddenly multiplies. The need for control based on an overall optimal strategy is vital. That means that the optimal function should be constructed based on the overall target. This function relates not only to capacity and quality technique indices, but also to energy, cost, pollution, and social indices. It is a synthesis of the requirements of the techniques, the economy, and the environment. With this function, an overall tradeoff automation mode can be achieved.

In order to solve the overall optimisation problem of large engineering systems, decomposing and collaborating are introduced. By decomposing a large system into several small subsystems and controlling each subsystem to obtain optimum results locally, a relative overall optimal target can be achieved for a large system.

Collaboration means compromise. Taking into account the interaction and/or coupling of each subsystem, local optimal solutions must satisfy the premises for overall optimal goal. Collaboration seeks an answer to the tradeoff local optimal policy for achieving overall optimisation. Collaboration plays an important role in distributed system control and computing. Without this concept, it is impossible to achieve overall relative optimisation.

Following the development of computer and Internet/Intranet technology in recent years, DAI now appears to rely more on a combination of distributed computing and artificial intelligence. Now, DAI is regarded as a key technology in data acquisition, supervising and controlling and in fault diagnosis [4,7,17,19,20].

The main features of a DAI-based system are:

Open and flexible structure.

High interaction.

An heterogeneous system can interchange information in a quickly changeable environment.

Cooperation between heterogeneous systems.

We have devoted several years to studying DAI and DAI-based systems for data acquisition, supervision and control, and fault diagnosis. Many results have been obtained. We now introduce our results on data acquisition technology for manufacturing systems.

3.2 Agent-Based Data Acquisition Technology for Manufacturing Systems

In general, the goal of setting up a DAS is to obtain information about a manufacturing process using different kinds of sensors. The analysis and processing of the information acquired by the DAS allows it to judge whether the manufacturing system is working normally or not, and report any prevailing trends in the system performance. During fault diagnosis, a DAS can also provide the operator with the recommended response policy.

The manufacturing process information is complex and transient. The need for information is continuous. Taking into account acquisition requirements and the real-time condition of the manufacturing process, a DAS must be capable of decomposing and distributing the acquired tasks to different sampling workstations and steering every workstation to cooperate with each other to achieve the acquired tasks based on the acquiring policy. That means the DAS must possess the abilities of distributed computing and collaborating. Since intelligent agents have these capabilities, we can use DAI technology to construct an agent-based intelligent data acquisition system (AIDAS).

The basic principles of agent-based data acquisition technology are:

1. Agent senses environment information.
2. After analysis and reasoning, the agent deduces a global assessment and decides on a response strategy to the outside environment.
3. In a multi-agent system (MAS), collaborating, negotiation, and competition among agents must take place before an agent system can decide on matters of availability and reliability and choose how to respond to the environment.
4. Repeat step 1 to 3 until the agent achieves appointed tasks.

3.3 Framework of AIDAS Model

The methods and results of agent research can be used to improve traditional acquisition methods and systems. Figure 4 shows a model of AIDAS for manufacturing systems.

3.3.1 Model Structure Analysis

Structurally, the model consists of three main parts: a data acquisition platform, a sampling workstation, and a sensor array. We now discuss the role of these three parts in turn.

1. *Data acquisition platform.* A data acquisition platform is the basis of building DAS. It is the working environment of DAS. It provides supporting tools for DAS. In addition, it is where agents reside.

   The data acquisition platform consists of computers (sampling workstations and data acquisition server), operation system software (UNIX or Windows NT), network communication protocol (TCP/IP), support software (developed management software such as the Management Agent, Database, web Explorer, Outlook, etc.) and hardware (hub, network card, sampling card, audio/video card and equipment, monitor, and printer, etc.)

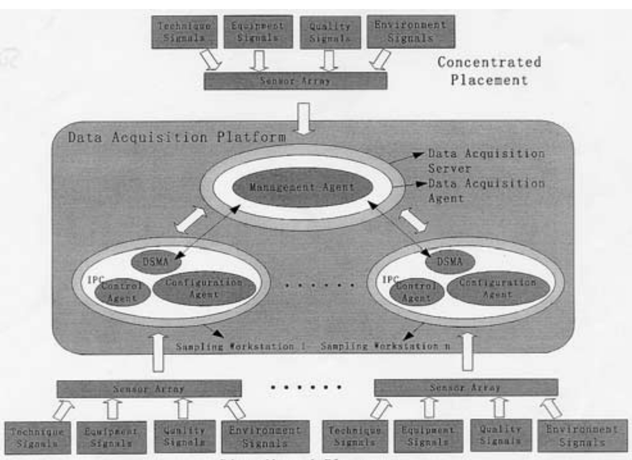

Fig. 4. Model framework of AIDAS for manufacturing systems.

2. *Sampling workstation.* Several sampling workstations construct a distributed data acquisition subsystem. The roles of a sampling workstation are to accomplish data sampling, to transfer data and to configure sensor arrays.

   Each sampling workstation is equipped with an IPC, network card, sampling card, operation system software (Windows), network communication protocol (TCP/IP), support software (Database, web Explorer, Outlook etc.), the DATA Sampling Mobile Agent, the Controlling Agent and the Configuring Agent.
3. *Sensor array.* A sensor array is made up of different kinds of sensors such as current/voltage, force/torque, power, temperature/humidity, pressure, motion, displacement and vibration sensors.

   A sensor array is used to detect a group of manufacturing process signals (variables) such as technical, equipment, facility, quality, and environmental signals. These signals are transmitted to a sampling workstation and are sampled by the data sampling mobile agent (DSMA).

3.3.2 Model Function Analysis

Functionally, the data acquisition platform is hierarchical. It has three layers. From inside to out, they are Data Acquisition Management Layer (DAML), Data Sampling Layer (DSL) and Basic Supporting Environment Layer (BSEL). The functions of these three layers are introduced below.

1. *Data Acquisition Management Layer.* The DAML is the kernel layer, which is constructed by the Management Agent (MA). Its functions are:

Providing for communication, interaction and collaboration between DAS and the outside environment.

Receive tasks and commands from the outside environment.

Transmit results and data to the outside environment.

Analyse and decompose tasks received from the outside environment into subtasks, and rearrange subtasks in the system.

Configure hardware of data acquisition platform.

Accomplish DAS self-detection, self-diagnosis, and self-maintenance.

Directly manage concentrated data acquisition subsystems.

2. *Data sampling layer.* The DSL accomplishes data sampling tasks. It is constructed by the DSMA. The functions of this layer are to:

Receive tasks and commands form the DAML.

Create the DSMA of this layer.

Dispatch the DSMA to correspond with sampling workstation to accomplish data sampling tasks.

Receive data from sampling workstation and passing it to the DAML.

Configure sensors.

3. *Basic supporting layer.* The BSEL is the hardware and software basis of the whole data acquisition system. It provides the conditions required by the other layers and the agents living space and environment.

Except for the above three layers, the sampling workstation and the complementary sensor array form an independent data acquisition subsystem. The subsystem's data sampling and management are the Control Agent's responsibility. In addition, the Control Agent makes interaction and communication with the upper-layer's server possible.

The Configuration Agent of the data acquisition subsystem is responsible for the subsystem's hardware configuration. Configuration information is transmitted to the Management Agent in the data sampling server by the Control Agent. The Management Agent of the DAML appends the configuration information of every sampling workstation to a system configuration information table and forms system configuration information.

The DSMA of the DSL brings sampling subtasks and moves to the sampling workstation, and also controls the start and/or stop of sampling and fetches sampling data back to the upper-layer server.

3.3.3 Principle

The working principle of the AIDAS is described as follows:

1. When starting, the DAML accomplishes system initialisation and hardware configuration, then waits for tasks and commands from the outside environment.
2. After the DAML receives tasks from the outside environment, it decomposes these tasks into subtasks and deploys subtasks to different functional layers.
3. After the data sampling layer receives sampling subtasks, it creates the DSMA.
4. The DSMA brings sampling subtasks to the correspondingly data sampling workstation.
5. After the DSMA arrives at the sampling workstation, it configures sensors according to sampling subtasks and starts collecting sensor data.
6. After sampling subtasks is accomplished, the DSMA stops collecting and bring sampling data back to the sampling layer.
7. When the sampling layer receives the data fetched by the DSMA, it transmits the data to the DAML.
8. The DAML analyses and processes the data from the sampling layer, and returns the analysing and processing results to the outside environment.

By repeating these steps, the AIDAS can achieve continuous data acquisition, analysis, process and transmission.

4. Agent Realisation

4.1 Agent Structure

The intelligence agent is the main component of the AIDAS model. There are four types of agent in the model: Management Agent, Data Sampling Mobile Agent, Control Agent, and Configuration Agent. Functionally, they can be divided into two categories: Static Agents and Mobile Agents.

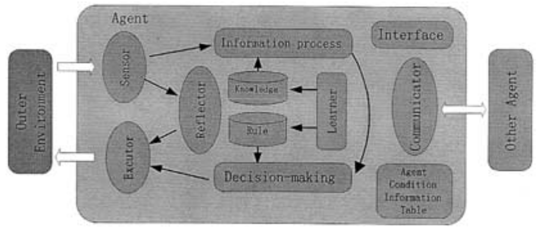

Fig. 5. Agent structure model.

The Management Agent, the Control Agent and the Configuration Agent are Static Agents. They reside in a fix location.

The DSMA is a Mobile Agent, it can move between a data acquisition server and a sampling workstation.

In our work, we adopt the agent model in Fig. 5.

The Java language can be used as a programming language for agent realisation. Java is developed by SUN as a new generation object-oriented programming language. It characterised by:

Independent of working platforms.

Distributed.

Multi-threaded.

Secure.

Reliable.

It is very suitable for the agent development. JATlite can be used as agent building toolkit.

4.2 Communication

Communication and interaction between agents are the basis of collaboration. There are two communication modes: blackboard mode and message/dialogue mode.

1. *Blackboard mode.* A common working area is provided in the multi agent system. Agents can exchange information, data, and knowledge with each other in this common working area. This common working area is the so-called blackboard. When an agent writes a message on the blackboard, other agents can use this message by authorisation. In a blackboard system, communication realisation between agents is not direct but is indirect via the blackboard.

   Figure 6 is the Blackboard communication model.
2. *Message/dialogue mode.* Message/dialogue communication is another mode. It can achieve complex cooperation strategy. In the communication process based on

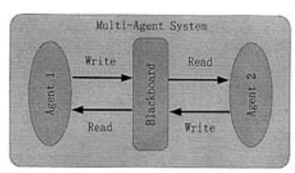

Fig. 6. Blackboard communication.

message/dialogue, a transmitter (agent 1) transmits a piece of a message to a receiver (agent 2), message exchange between agent 1 and agent 2 is direct, there are no buffers and no delays.

Figure 7 is the message/dialogue communication model.

3. *Communication language.* A communication language is the basis for highly efficient information exchange. Many communication languages can be used as agent communication languages. For example, Knowledge Manipulation Language (KQML), Software Communication Language (SACL) and Agent Communication Language (ACL) are all suitable for agent communication.

5. Example

5.1 Chemical Process Monitoring, Control and Diagnosis

In general, chemical production is continuous. The monitoring, control and diagnosis system of chemical production is a process monitoring/control/diagnosis system type. The system introduced here is used in a chemical factory. The factory produces kinds of chemical products. The producing process is: raw material preparing →premix →mix →product. The main technical requirements are:

Unmanned operations.

Monitoring and control remotely.

Temperature and humidity of workshop kept at a certain level.

Temperature and pressure in mixing crucible must be controlled at a certain level.

The clockwise or anti-clockwise rotational speed of a kneading blade is adjustable.

Automatic feed of raw material in the kneading procedure.

The main production equipments are a kneading machine, coarse material feed machine, and a fine material feed machine. The related driving systems are an electrical motor driving system, hydraulic transmission system, a pneumatic transmission system, and a warm water system. All of the equipment, processes, and technical parameters should be controlled and monitored by the designed monitoring, control and diagnosis system, and any fault and/or failure should be detected by the system.

According to the monitoring, control, and diagnostic requirement and referring to the model framework proposed before, we designed a prototype of a monitoring, control and diagnosis system for the whole factory as shown in Fig. 8 and a detailed design project for the kneading workshop as shown in Fig. 9.

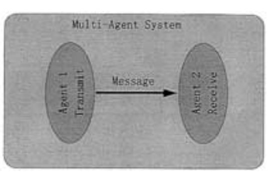

Fig. 7. Message/dialogue communication.

The system is characterised by:

A PLC (programmable logic controller) deploying a monitoring module, an audio/video module and a safety protecting module to realise monitoring and control of all equipment and processes.

Dual-CPU PLC module and dual-cable wiring between PLC module and remote I/O module to form a master–slave redundant control mode.

Applying a network to realise remote monitoring, control, and diagnosis.

Communication between PLC and upper IPC/HMI (human machine interface) is realised by Modbus Plus protocol.

The system structure (software and hardware) is configured in a distributed mode, a single module failure would not affect the whole system function.

The system can implement self-recovery after a fault.

Data backup is automatic and periodic.

The monitoring and control system was installed two years ago. Two years' experience shows the system is reliable, stable and highly efficiency. This proves the model is correct and it is available.

5.2 Metallurgic Equipment Monitoring and Diagnosis

The turret of a slab continuous casting machine in a steelworks has the features of low rotational speed and heavy load. It also works continuously. The monitoring and diagnosis system of the turret is a condition monitoring system type. The rules of the turret monitoring and diagnosis system are:

Condition variables such as vibration, displacement, temperature, torque, and current measurement.

Prevailing trend of bearing and gearbox prediction.

Bearing and gearbox fault and/or failure monitoring and diagnosis.

Because there is a great deal of data to be collected and processed, we designed the system framework for data acquiring based on the AIDAS introduced in Section 3.3. In order to realise the function of prediction and diagnosis in realtime via the Internet remotely, the hardware configuration and software design are Internet compatible.

The system model is shown in Fig. 10.

Figure 11 is the software structure. The software consists of five functional modules, i.e. the system configuration module, the condition monitoring module, the analysis/diagnosis module, the database management module, and the public information module. Each module has its own submodule. In this system, we develop three kinds of agent: Sampling agent, Analysis/Diagnosis Agent and System Management Agent. The sampling Agent accomplishes data collection and transfer. Analysis/Diagnosis Agent accomplishes prevailing trend prediction and fault and/or failure diagnosis. The system Management Agent realises system configuration, communication and collaboration between different agents. Figure 12 shows the relationship of the different function module of the system.

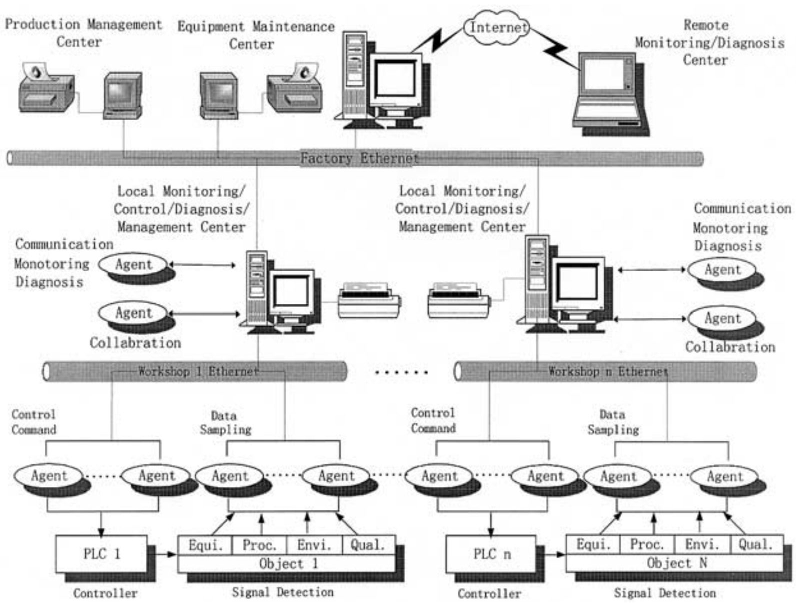

Fig. 8. Example of monitoring/control/diagnosis system.

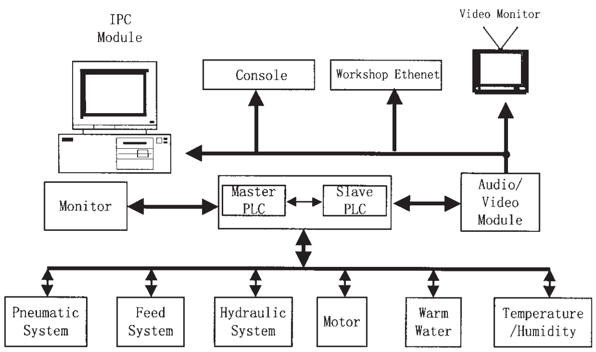

Fig. 9. Kneading workshop system project.

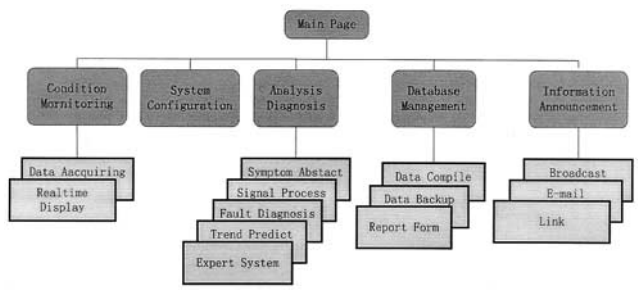

Fig. 11. Software structure.

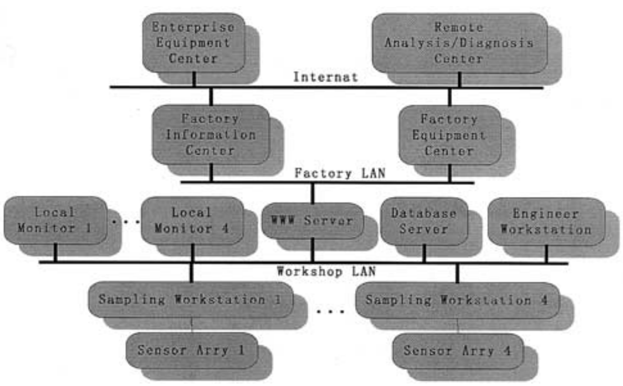

Fig. 10. Turret monitoring system model.

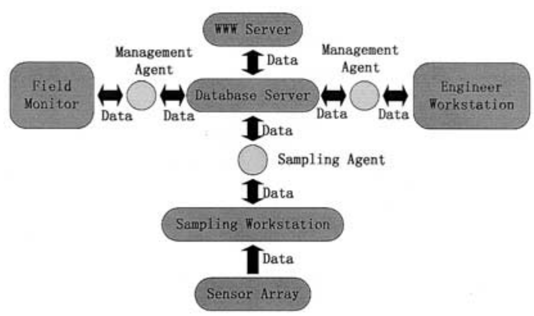

Fig. 12. System function framework.

6. Conclusions

Continued progress of distributed artificial intelligence technology has greatly accelerated the development of data acquisition technology. It is important to study new methods and the technology of data acquisition for manufacturing enterprises interested in implementing manufacturing automation, and promoting product quality and enhancing competition capability.

There are three kinds of data acquisition mode now used in manufacturing systems. Each of these three modes has its own characteristics and application scenarios.

Based on analysing the characteristics of these three modes, we proposed a new model framework of the AIDAS. Its structure, function and working principle are discussed in detail.

By this stage, we have accomplished a pilot study about agent-based data acquisition technology, including theoretical analysis, modelling, and prototype system design. Our future work will focus on

Perfecting the model.

Developing technology for implementing the model.

Structuring and implementing the technology of agents in the AIDAS.

Improving communication and collaboration between agents in the AIDAS.

Improving reliability and availability of AIDAS.

Acknowledgement

Support for this work was provided in part by the National Natural Science Foundation of China under grant no. 59990470-I. The authors thank the anonymous reviewers for providing valuable feedback on the original manuscript.

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