The framework of next generation automatic weather station in China

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Abstract

The using of AWS is comprised by sensors (analog or digital) and data collectors. Sensors and data collectors are tightly coupled in the architecture. Therefor it is hard to extend and calibrated. This paper introduce the framework of the next generation AWS named integrated surface observation system（ISOS）in China. The purpose of ISOS is trying to build an integrated device that can sense and collect data with one instrument, change the conventional tight coupled structure into small cells to make the network flexible to extend. The paper has the following contents: (1) the using architecture of the surface observing system, (2) brief introduction of the ISOS, (3) detailed information on digital sensors, (4) hardware and software of Integrated processor unit, (5) the meteorological observation data dictionary.

ISOS can produce both meteorological data and instruments status, ISOS can "recognize" its authorized component automatically, ISOS can set up a flexible network according to the application scene. In short, with all these upgrade, ISOS can become more flexible, more reliable and more intelligent.

Key words: automatic weather station, status monitoring, standardized algorithm

1. The using automatic weather station system architecture

Automatic weather station(AWS) is the main equipment for automatic surface observing. At present, the automatic weather stations used in China are mainly composed of sensors, data collector, power supply components, communication interface, peripheral components and operational management software. Since different types of sensors are used to measure various meteorological elements, the signals output of the sensors are also different, including analog signals, voltage signals, and different types of digital signals. According to the different types of sensor output, the data collector which has different interfaces is designed. Although the data collector can match with different sensors by this way, but the tight coupling between the sensors and the collector in AWS may cause two obvious problems.

1) When a new type of sensor needs to be added in the AWS, the data collector interface has to be re-designed, so it is very difficult for the AWS to extend and connect a new meteorological sensor;

2) Using this weather station architecture, when a sensor needs to be calibrated, the sensor and the data collector has to be calibrated at the same time.

In addition, some instruments are difficult to connect to the traditional data collector directly, such as: sky imager, laser ceilometer and so on. Therefore, with the continuous expansion of surface observing system, there are many problems appeared, including too many types of terminal equipment interfaces, too many software systems and too many data formats. These problems may generate low reliability, low utilization rate, poor maintainability and poor scalability in surface observing system.

2. The architecture of ISOS

Considering the situations mentioned above, the new automatic weather station architecture is designed. Since the new architecture designed to integrate all surface equipment in, it is named as "the integrated surface observation system (ISOS)". The hardware architecture of ISOS is composed of digital sensors or other instruments with digital interface and the integrated processing unit (IPU). At the same time we also develop the software architecture of ISOS, including the data acquisition and quality control software running inside digital sensors, embedded unified management software running inside the IPU. And a communication standard has been developed for data transmission between digital sensors and IPU which called "the meteorological observation data dictionary(MODD)". The architecture of ISOS is shown below.

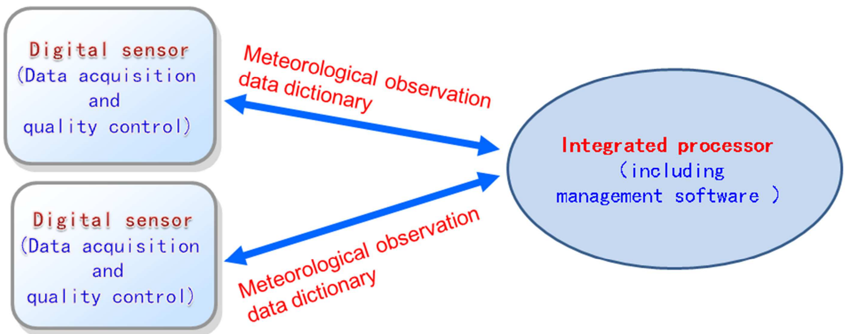

Fig 1. The architecture of ISOS

3. Digital sensors and data quality control

With the development of sensor technology and microelectronics technology, the integration of meteorological sensors and signal acquisition circuit become possible, and it will become the developing trend in the future. This kind of digital meteorological sensors can be used as independent meteorological observing instruments, and it will change the situations from the automatic weather sensors and collector tightly work to separately work physically. As a stand-alone device, digital weather sensors can not only improve the measurement accuracy and anti-interference ability of sensors, but also can improve the calibration and maintenance of the sensors.

In addition, digital sensors is designed to have the common network ports, such as serial ports, network ports, and wireless modes, including various interfaces using in Internet of things. The using of these network interfaces not only standardizes the format of the hardware interface of these digital sensors, but also are convenient for building the meteorological observation sensors network.

The digital sensors of various meteorological elements adopt the sampling algorithm specified in the CIMO guide for data acquisition. At the same time, the sampled data is processed at two levels of quality control. The first level quality control is the process of transforming sampling value into meteorological elements, and the quality control object is the sampling value of meteorological elements. The second level is to control the quality of the observed elements. The object of quality control is meteorological elements instantaneous value and minute's average value.

The first level quality control including:

1) Sampling data limit check, check whether the value of each sampling data is outside the scope of measurable value.

2) Sampling data change rate check, the current value of sampling data should be compared with the previous value to see if it is correct.
3) Calculating the instantaneous meteorological value, the proportion of effective sampling data should be more than a certain number in total sampling data.
The second level quality control include processing instantaneous weather values from the following three aspects:
1) Cannot exceed the prescribed limits;
2) The change rate of two adjacent values should be within the allowable range;
3) There should be a minimum rate of change in a measurement period (usually 60 minutes).

4 . Integrated processor unit and software

IPU is similar to the AP that provides WiFi functionality, which connects and manages multiple digital sensors over short distances. When a number of digital sensors used at the same time in a small certain area, the sensors can transmit meteorological observation data to IPU by low power communication. After IPU process the received data(such as statistics, analysis, package data), the data will be transferred out through a communication link (wired or wireless, or fiber). Standard interface is used between digital sensors and IPU, the connection mode is a loosely coupled, just as WIFI management. It is very convenient to increase new digital sensor. If the digital sensor is designed according to the standard, it can be "plug and play".
IPU contains a high performance processor, high precision clock circuit, memory, I/O interface (ZigBee interface, RS232, Ethernet interface, optical fiber interface, USB interface, SD card interface), monitoring circuit, power supply interface and indicator lights. IPU has standardized interface supporting wired and wireless, which can realize the expansion connection and management of a variety of instrument. And the standardized interface can also solves the problem of connecting new observation instrument such as sky imager, laser ceilometer cloud, visibility sensor. The block diagram is shown below.

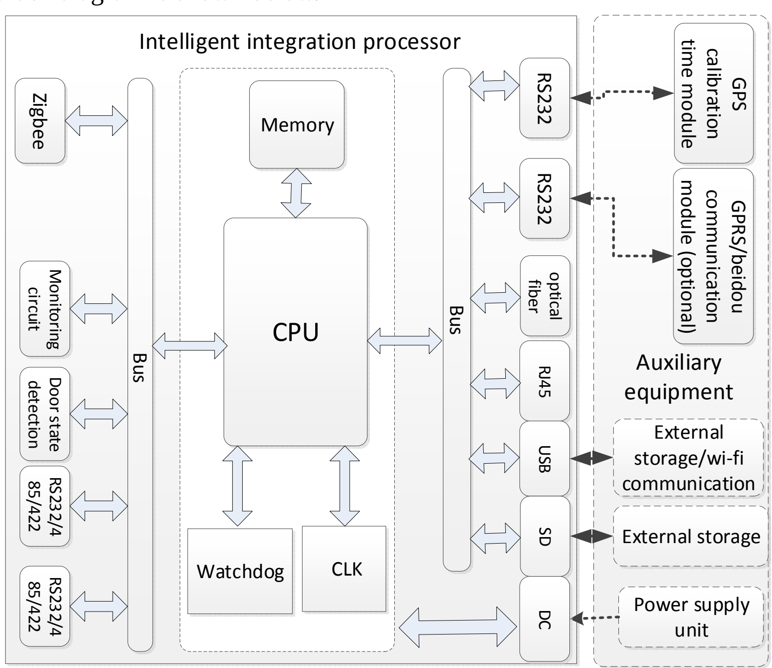

Fig2 Block diagram of IPU

Embedded software running on IPU includes four functional modules: a master control module, a data acquisition processing and monitoring module, a communication module and a software upgrade module.

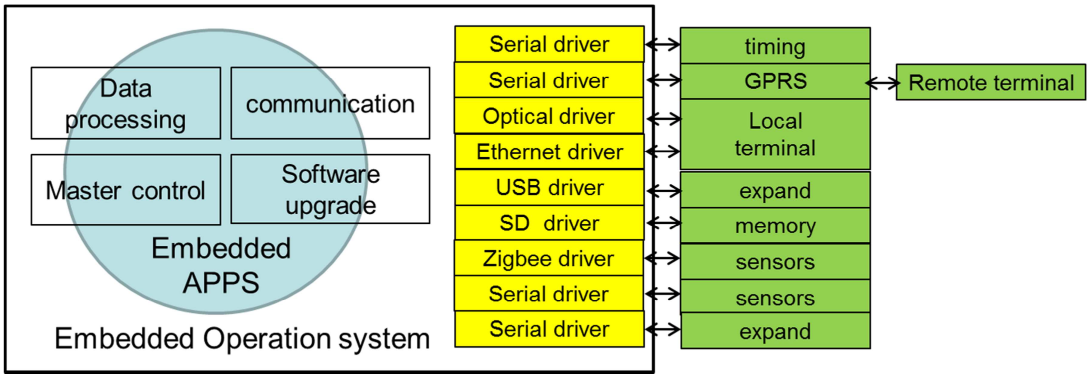

Fig 3 Integrated processor software architecture diagram

Master control module: the module mainly completes the logical control of the system, including the initialization of the system, the call of functions (processes), the response of interrupt and the management of RTC clock.

Data acquisition processing and monitoring module: the module mainly collects the meteorological information created by the digital measuring instrument, execute data calculation, comprehensive quality control, data storage and status monitoring functions.

Communication module: it mainly interacts with digital sensors and peripheral instrument, and transfers data to the service center station. The mode of interaction can be wired or wireless communication.

Upgrade module: it mainly implements the function of upgrading embedded software locally or remotely.

5. Meteorological observation data dictionary(MODD)

MODD is designed to set a complete data specification, which follows the established rules and can also extend data format flexibly. This specification regulates digital sensor format for both input and output data, in order to make sure the transformation of the meteorological observation collections is in a standard process. Not only can it manage the digital sensor more conveniently, but it also facilitates the observation data to be processed and stored later.

Written in ASCII code table, MODD uses self-defining features from Extensible Markup Language (XML), companied with self-defining, self-description and sequence extension designing methods. The "dictionary" stipulates various meteorological elements, which make it easier to understand and expand. The data dictionary unifies the input and output format of the digital sensor as well, make it easier for instrument manufacturers, software programmer, and meteorological operation technician to use in application.

MODD defines the variables of the meteorological observation elements, the encoding of the status variables, the format of the data transmission and the format of the communication commands.

Meteorological elements encoding include encoding rules and encoding form. The encoding rules include surface meteorological observations variable naming rules, surface meteorological observation variables describing rules and observation elements variable units. The classification table of the variables of observation is presented in tabular form, as shown below.

Tab 1. The classification table of the variables of observation

Code	Name of observation element	Code	Name of observation element
AA	Temperature	AK	Sunshine
AB	Ground temperature	AL	Cloud
AC	Liquid temperature	AM	Visibility
AD	Humidity	AN	Weather phenomenon
AE	Wind direction	AP	Wire icing
AF	Wind speed	AQ	Pavement condition
AG	Pressure	AR	Soil moisture
AH	Precipitation	AS	Negative oxygen ion
AI	Evaporation		
AJ	Radiation		

The instrument state variables encoding include encoding rules and encoding form, the encoding rules include naming rules and describing rules of instrument state variables, the meaning of instrument status values. Instrument factors classification encoding is presented in tabular form, the specific provision is omitted. The device status property class encoding table is shown below.

Tab 2. The device status property class encoding table

Property class name	Code
Instrument self inspection	z
Sensor status	y
Power status	x
Operating temperature condition	w
Heating element status	v
Ventilation unit status	u
Communication state	t
Window contamination status	s
Instrument working state	r
……	……

A complete data frame contains 5 parts information(start identifier, packet header, data body, check code, and end identifier). The start identifier, packet header, check code, and end identifier are all fixed length data. Data body is not fixed length data, it contains Observation data, quality control information and device status information. The data frame transmission uses ASCII character (8Bit), each segment of data frame is separated to one or more fields, each field is separated by character ",". The full data frame format is shown below.

Tab 3. The data frame format

Start identifier（BG）					
packet header					
version number	Station No.	latitude	longitude	Altitude	Service type
3-digit	5-digit	6-digit	7-digit	5-digit	2-digit
Device identifier	device ID	Observation time	Frame identifier	Observation variable number	Device status variable
4-digit	3-digit	14-digit	3-digit	3 -digit	2 -digit

Data body(Observation data)					
Name of observation element variable 1	observation element variable value 1	……	Name of observation element variable value m	observation element variable m	
Data body(quality control)					
Quality control bit	Status variable name 1	State variable value 1	……	Status variable name n	State variable value n
Data body(Device status information)					
Status variable name 1	State variable value 1	……	Status variable name n	State variable value n	
Check code（4-digit）					
End identifier（ED）					

The communication command format specifies the communication protocol between the integrated processor and the sensor. It also makes IPU to get or put various data and parameters to the digital sensor, and carries out the timing of the digital sensor. Each kind of communication command composed of commands and parameters. And the commands are composed of English letters. The parameters can be absence, or be composed of one or more components. Commas are used to separated commands and parameters, or parameters and parameters.

Provided following the principle of MODD, IPU can effectively manage added digital sensors through the dynamic allocation at once. ISOS can easily manage the dynamic changes of various digital sensors.

6. Summary

ISOS has been applied in Chinese meteorological administration. So far, we have completed functional specifications and the test of 7 conventional digital meteorological sensors (such as digital temperature sensors, digital humidity sensors and so on) and IPU. The “intelligence” of ISOS lacking in AWS is mainly embodied in the following aspects:

Ad hoc networks. All the measuring instruments that meet the requirements in the network can be automatically connected according to the rules of MODD.

Self-processing. It is able to collect, calculate, transmit, store the observation data and do quality control automatically.

Self-diagnosis. It is able automatically test data quality and operating status information of digital sensors and integrated processors, and do automatic diagnosis to see if the instrument and data is correct. It is also able to locate the faults, and facilitate real-time monitoring and maintenance.

Self-recovery. It is able to revert to the standard state automatically according to status information of the digital sensor and self-diagnostic results.

Online upgrade. The software in digital sensors and IPU can be upgraded online through a local or remote network.

Plug-and-play. According to the standardized data format and interface, plug-and-play can be realized. And an QR code can be generated to facilitate the management of device’s access to the network.

ISOS is only a preliminary exploration of surface intelligent weather observation system. It is believed that with the development of information network technology and sensor technology, intelligent meteorological observation will have greater development.