Methods and Technologies of XML Data Modeling for IP Mode Intelligent Measuring & Controlling System

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Abstract. This paper presents the IP mode intelligent measuring & controlling system (IMIMCS). Based on object-oriented modeling technology of UML and XML Schema, the innovative methods and technologies of some key problems for XML data modeling in the IMIMCS were especially discussed, including refinement for systemic business by means of use-case diagram of UML, the confirmation of the content of XML data model and logic relationship of the objects of XML Schema with the aid of class diagram of UML, the mapping rules from the UML object model to XML Schema. Finally, the application of the IMIMCS based on XML for a modern greenhouse was presented. The results show that the modeling methods of the measuring & controlling data in the IMIMCS involving the multi-layer structure and many operating systems process strong reliability and flexibility, guarantee uniformity of complex XML documents and meet the requirement of data communication across platform.

1. Introduction
Since the Ethernet is popularly used in the measuring & controlling field, it is actively demanded to realize the openness of across platform and mutual communication between devices for the IMIMCS [1]. That applying the new technology of eXensible Markup Language(XML) to the networked measuring & controlling field can improve greatly the compatibility and openness for system and meet the requirement for the jointless link between the measuring & controlling network and information network. With the expansion of the IMIMCS and the variety of the components, it is important to mark out the uniform XML mode in the system. On the basis of the model of XML data universal exchange interface(XDUII) designed by the authors, this paper further discusses the XML data modeling methods and technologies for the IMIMCS.

2. IP mode intelligent measuring & controlling system
The recent researches focus on applying Ethernet as spot measuring & controlling network [2]. The IMIMCS had been accomplished successfully by the authors shown in figure 1 [3-6]. From figure 1,we can know that the whole system provides 3-layer framework. The first layer called spot measuring and controlling platform(SMCP) is primarily made up of the distributed intelligent sensor (DIS), IP intelligent measuring & controlling equipment(IIMCE), spot monitoring computer(SMC),IP fuzzy controlling equipment(IFCE), IP sensor(IS) and controlled device group(CDG). The second layer called enterprise detection platform(EDP) is primarily composed of the Ethernet exchanger or concentrator, workstation and enterprise server(ES). The third layer called remote detection
platform (RDP) is primarily composed of the remote terminals (RT) and networked server (NS). The uniform communication protocols are employed to achieve the resource sharing and synergetic work through the spot Ethernet, information network and Internet to connect all elements which are distributed at different situations. Data exchange is implemented in the IMIMCS through the XDUII [6]. The XDUII is composed of a XML forming module (XFM) and a XML interpreting module (XIM). The data which would be transmitted from sending terminals in the IMIMCS are transformed to XML format by means of the XFM. In the receiving terminals, XML data is explained by means of the XIM and transformed into the compatible data format. In the course of data flowing in the IMIMCS, as shown in figure 2, it is a greatly important estimating index for the IMIMCS performance how to package and unpackage exactly the different XML documents due to the existent of different XML documents.

3. XML data modeling

To ensure the strong reliability and accuracy when the XML document was formed and interpreted in the IMIMCS, the framework of IMIMCS should be designed through XML data modeling to unify the structure of XML documents and actions of the system. Considering the characters in the IMIMCS including various data and its complicated logic relations and so on, XML Schema is chosen as the mode depicting and validating the structure of XML documents. The different XML Schema formats must be processed simultaneously because of various components existing in the IMIMCS. Therefore, a modeling method for XML Schema is urgently required to provide a common developing platform [7].

Consequently, through analyzing systemic service models of the IMIMCS by dint of diagrammatic modeling technology of UML, the illustration of the UML object models is gained. Then XML Schema structures are obtained by means of the mapping from the UML object models to XML Schema. Finally XML documents come into being according to XML Schema formed as validating template, as shown in figure 3. The layout of the UML object models and the mapping are key parts among them.

3.1. Notional modeling for XML data

Reference to the main operating mechanism of the IMIMCS, the idea of notional modeling for XML data is illuminated below.
In response to the multi-level demanding, senior managers can define and edit the measuring & controlling strategy (MCS) and transform them into XML documents by means of strategy editing module (SEM) and kernel module (KM) and terminal monitoring module (TMM) on the EDP, as shown in figure 2. The XML documents are transferred to the IIMCE to obtain the frequency signals from the DIS on the spot. After the IIMCE deals with the signals, the parameter values are displayed on the LCD of the IIMCE. Then they are also transferred to the SMC and the IFCE. At last, the IFCE makes certain the controlling mode according to the results to bring control into effect for environmental parameters. Furthermore, remote experts and managers can know the scene conditions and exchange views each other by the Web, then can transmit the MCS to the IFCE. The core of the operating mechanism of the IMIMCS is to complete automatic measurement & control of the circumstance by dint of the MCS. The course of the MCS performance must be monitored in order to guarantee exact execution. Thereby the MCS has corresponding relationship with the relevant virtual instrument panel (VIP) in the SEM [4].

Figure 4. Demand analysis for the IMIMCS.

Figure 4 shows demand analysis for the IMIMCS by use-case diagrams of UML. From the use-case diagram, we can see that use-cases have associated with four factors in the course of the MCS performance, including the systemic engineer, the spot engineer, the spot embedded system (SES) and the spot sensor system (SSS). As the role designing the MCS, the systemic engineer edits the MCS and its corresponding information of the VIP which contains some parameters and their values in the SEM. Simultaneously the MCS is transferred to the SES and processed. According to the content of the MCS, the spot engineer can monitor the results from the SES and the SSS through the VIP. From the analysis of the use-case diagram above, the relations hips between different use-cases and actors in the course of the MCS execution are obvious. There are main three XML documents created in the whole process, including the MCS document, the VIP information document and the spot measuring data document. After the creation of the objects of XML documents, with the aid of oriented-object modeling technology and the software called Rational Rose, the structure of systemic use-case should be analyzed further to ensure the framework content contained in XML Schema, then finish the notional modeling of XML data. The Class diagram model of the MCS is shown in figure 5. The RuleEntry Class and Screen Class correspond to separately XML document objects of the MCS and the VIP information which can be found in figure 4. The Node Class corresponds to spot measuring data document objects. The DataSources Subclass and Equipments Subclass and Expressions Subclass of the RuleEntry Class represent respectively data source devices, control devices and measuring & controlling rules. A series of ComItem Class accomplish together the display function of the VIP. There is an association between the RuleEntry Class and Node Class, and it presents that the
transmitted upwards data is what the MCS needs. Another association that denotes the MCS is corresponding to the VIP, and it is realized through respective attributes called the ScreenConnected and RuleConnected.

Figure 5. UML object model for the IMIMCS.

3.2. Mapping from UML models to XML Schema
There are various Classes with complex relationship and restriction in the UML model diagram. And they have different attributes and different data types. Therefore, the mapping from the UML models to XML Schema doesn’t keep one-to-one correspondence. On the basis of the characters of the IMIMCS, many factors should be considered in order to map availably all contents of the UML object models, so the mapping rules are brought forward, as shown in Table 1 [8].

| Mapping rules            | Remark                                                                 |
|--------------------------|------------------------------------------------------------------------|
| Namespace                | The name prefix can be allocated freely to the every element of XML Schema. in all instances. |
| Element-name uniqueness  | The prefix of Class name is added to every attribute and relevancy of UML and followed by a symbol denoted as "::". The rule isn’t taken until the element name is uniqueness. |
| Element or attribute     | A element is created for every attribute and association of UML Class. |
| Diverse limitation       | The attribute values of MinOccurs and MaxOccurs allocated by all of the element statement are equal to appointed values of UML model. |
| condition                | When a SuperClass creates a UML Class, the ComplexType which contains subelements called Extension is produced. |
| Inheritance              | Every UML Class produced through using the disordered model group of <all> is regarded as a ComplexType definition. |
| Content model            | Though <all> can present disordered contents, elements should be limited by UML variety |
| Element sequence         | Every UML attribute must be created as a statement of XML attribute and styles are uniform. |
| Data style               | ID and IDREF are used for Linking internal resource and HREF attribute for linking other external resource |

According to the mapping rules, the RuleEntry Class of the UML models is considered as a example in figure 6 to illuminate simply the mapping from the UML models to XML Schema. From figure 6, it can be known that the independent XML nodes and their relationships and attributes in the
UML class diagrams are showed. The structure diagram of XML Schema can provide a legible and uniform platform for all of design personnel to ensure consistency of developed programs on XML documents. In accordance with the same mapping rules, the mapping course of other Class diagrams of UML object models is similar to the RuleEntry Class. Because of limited length in this paper, they will be presented later.

```xml
<xs:sequence>
  <xs:element name="DataSources.Name" type="xs:string"/>
  <xs:element name="DataSources.Count" type="xs:string"/>
  <xs:element name="DataSources.Item" minOccurs="0" maxOccurs="unbounded">
    <xs:complexType>
      <xs:choice>
        <xs:element ref="DataItem"/>
        <xs:element ref="Sensor"/>
      </xs:choice>
    </xs:complexType>
  </xs:element>
</xs:sequence>
</xs:complexType>
```

**Figure 6.** Mapping from the UML object models to XML Schema.

4. IMIMCS for the modern greenhouse

In order to validate the reliability and practicability of methods and technologies of XML data modeling for the IMIMCS, the IMIMCS was applied in the modern greenhouse to study on measuring & controlling data communication across platform. The experiments were carried on in the modern greenhouse for fruiter planting which holds the area of 800m² and rounded facilities for environment control, but not automatized wholly. The experimental devices include two temperature sensors, two humidity sensors, two illuminance sensors, two CO₂ sensors, two IIMCEs, a IFCE, a SMC in which the Window2000 system was installed , a ES with the WindowXp system, a RT with the Window98 system, the Ethernet lines and several connecting equipments. The controlled equipments in the modern greenhouse include the agricultural sodium lamps, skylights, shaded nets, spray devices and axial flow fans.

**Figure 7.** Surface of the MCS editing.  **Figure 8.** Result surface of the MCS running.

The visualized MCS which content is to perform the cooling controlled device group orderly when the temperature average of two places in the modern greenhouse is higher than 32°C ,was edited on the SEM of the EDP, as shown in figure 7. After compilation, it was converted into XML documents and
transferred to the kernel module, then carried out in the appointed IIMCE through the XML interpreting module. Finally, the temperature values were transmitted to the ES and displayed on the terminal monitoring module, as shown in figure 8, which were identical with those on the LCD of the IIMCE. The main segments of XML documents for the measuring & controlling data were illuminated.

```xml
<?xml version="1.0" encoding="UTF-8"?>;<!DOCTYPE DataItem SYSTEM "model.xsd">
<DataItem>;<Name>Temperature</Name>;<GID>F[1]</GID>;<IP>192.168.0.3</IP>;<Value>32.70</Value>;</DataItem><DataItem>;<Name>Temperature</Name>;<GID>F[1]</GID>;<IP>192.168.0.4</IP>;<Value>32.5</Value>;</DataItem>
```

Because the temperature average is higher than 32°C, the skylights, shaded nets and axial flow fans functioned correctly and stably according to the controlled scheme in the IFCE. By now, the MCS was accomplished successfully. The results showed that the methods and technologies of XML data modeling for the IMIMCS resolve commendably the interoperability for the various platform in a great deal. The system had run continuously for a long time and the outcome was satisfying.

5. Conclusion

The equipment integration, network integration and man-machine integration are conveniently actualized in the IMIMCS because of its strong suits, such as standardization and wide range, etc. Study on XML technologies could accelerate further the openness for the IMIMCS. The XML applied procedure involves three key technologies. The notional modeling technology of UML can express clearly the structure and relationship of XML data of the IMIMCS to realize visual development. And the mapping from the UML object models to XML Schema improves editing efficiency and quality of XML documents. The combination of XML and UML can resolve perfectly the data exchange of the IMIMCS embodying the multi-layer structure and many operation systems. This idea can be applied to other systemic development in similar fields.

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