The Implementation of Aeronautical Information Exchange Model in SWIM

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Abstract. System Wide Information Management (SWIM), as an advanced civil aeronautical information management method, aims to solve the problems of global civil aeronautical information systems such as difficulty in obtaining common data in a timely manner and high information exchange costs. SWIM was first proposed by Europe and the United States and was recognized and valued by the International Civil Aviation Organization. It is to ensure the correct information transmission at the correct time. In order for the consistent information in the "virtual information pool" to be efficiently, accurately and securely transmitted, the information and data in the SWIM environment need to be defined in detail and standardized, so the two sides of data interaction can maintain the consistency in syntax and semantics. The Aeronautical Information Exchange Model (AIXM) is a core standard model for data transmission and format conversion, which mainly involves information in the aeronautical intelligence field. It covers multiple thematic elements such as airspace, airports and air routes, and provides a standardized description for data conversion and transmission in this field. The article analyzes the model composition of AIXM in the SWIM information exchange model, the modeling process, and the key technologies involved in model establishment, and preliminary design and implementation of AIXM.

Keywords: SWIM · Information exchange model · AIXM

1 Introduction

The continuous development of the civil aeronautical industry has optimized the civil aeronautical information network to a certain extent, but the current global civil aeronautical information system is still unable to communicate flexibly and conveniently. When data is exchanged between different or a large number of civil aeronautical systems, many complicated problems such as data interface independence will arise. The phenomenon of "information islands" [1] will become a great obstacle to information sharing between systems. SWIM, as the basis of flight coordinated operation control, is a standard and flexible civil aeronautical information sharing strategy. It can not only make the standardized interaction of information a reality, but also ensure that the information is used securely and efficiently, and thus play a role in promoting the realization of a new generation of air traffic management operational concept and mode.

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The SWIM global interoperability framework has a clear division of labor for the functions of each layer. The information exchange model layer [2] can set standards for the content and format of the information to be exchanged between service providers and consumers. The information exchange model layer includes the three main standards: AIXM, FIXM, WXXM and other information exchange standards. They are models formed after categorizing and modeling different aeronautical business data and representing them in a unified manner. It is the basis and core of data conversion from multi-source heterogeneous to unified format.

AIXM is a data exchange specification, which is led by Europe and the United States and vigorously promoted, mainly involving relevant data in the aeronautical information domain. Unified Modeling Language (UML) modeling standards and XML Schema specifications are used in the process of model building.

In this paper, the concept and components of AIXM are introduced in detail by analyzing the deficiencies of existing aeronautical information systems in data interaction. At the same time, the main technologies involved in AIXM are analyzed. Finally, the model building method of AIXM is given.

2 Aeronautical Information Exchange Model

2.1 AIXM Overview

AIXM is an important member of the SWIM data model family. It is an exchange model designed for aeronautical data. It describes the entities, attributes and relationships between aeronautical elements such as airports, runways, and airspace, and performs modeling. The goal of AIXM is to ensure that the complete and accurate aeronautical data contained in the Aeronautical Information Services (AIS) can have a uniform format on a global scale, while enabling digital interaction and management in the SWIM system.

AIS will gradually transition to Aeronautical Information Management (AIM), and gradually realize the dynamic management of AIS. While AIXM improves the AIS system, it can also promote the information circulation of the AIS systems of various countries. Finally, it provides good and reliable data support for the entire flight process, aircraft operation monitoring and flow management.

2.2 AIXM Composition

The AIXM model mainly consists of two parts [3]. One part is the Aeronautical Information Concept Model (AICM), which can describe various concepts involved in the aeronautical information field in the form of a collection of Feature, Attribute and Association. The other part is the aeronautical data exchange model AIXM XML Schema. It is derived from AICM and uses XML Schema to encode aeronautical data in a certain format, thereby realizing electronic data transfer between computer systems [4], also known as AIXM's XML architecture.

Unlike FIXM, AIXM data sources have greater requirements for time and geospatial description. Therefore, the AIXM model needs to be based on certain geospatial description specifications and meet the time description requirements. In the latest version of the AIXM5 modeling standard officially released by the SWIM working group, AIXM needs to comply with the ISO19100 series of spatial information standards.

2.3 Time Slice Model

AIXM must have a detailed time model to meet the time-critical requirements of the aerospace system. Through out the life cycle of aeronautical elements, their attributes may change. Therefore, AIXM specifically sets a time model mechanism when modeling, that is, a time slice model. The time slice model encapsulates the time-varying attributes of dynamically changing elements.

AIXM uses a time model when describing characteristic events and states. The GML standard mentions that an event is an action that occurs instantaneously or within a period of time, and its essence is that one or more functional attributes have changed. The state is a set of feature attributes that are valid for a period of time, which can be captured by instances through the function of time stamps.

It can be seen intuitively in Fig. 1 that the vertical lines represent events, and the part of the feature attribute set between events is the state. Among them, P1, P2, … P5 are the element attribute values along the time axis, and the reference time slice is the value of all time-varying element attributes defined by the effective time of the time slice; for example, TS2 in Fig. 1 contains P1, P2, P4 and the value of P5. Temporary time slices are only those that contain temporarily changed attribute values. Regarding the UML model, because the temporary incremental time slice needs to be distinguished from the baseline time slice, an additional attribute called "interpretation" is required in the AIXM FeatureTimeSlice class.

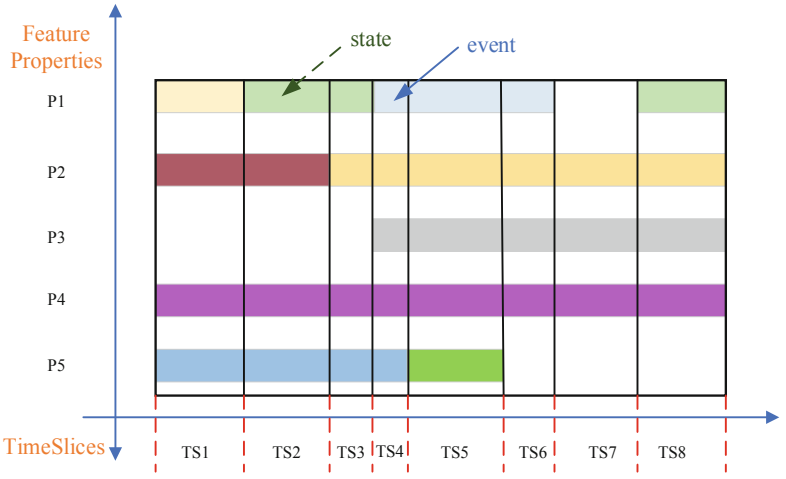

Fig. 1. Time slice model.

Encapsulating the time change attributes of the AIXM dynamic change elements as "AIXM TimeSlice" can better describe the characteristic attributes of the state and the event during this period. Each "status" time slice contains the time change attribute value of the event between two consecutive changes and has a specified validity period and a constant which reflects the information of each attribute.

3 Method of Establishing AIXM

3.1 AIXM Modeling Process

The data modeling process is the basis for the establishment of the SWIM data model and a prerequisite to ensure the success of data conversion. The model of AIXM can be categorized and structured from an object-oriented perspective. Therefore, the entire AIXM model needs to be established in the order of conceptual model, logical model and physical model. The modeling sequence is shown in Fig. 2.

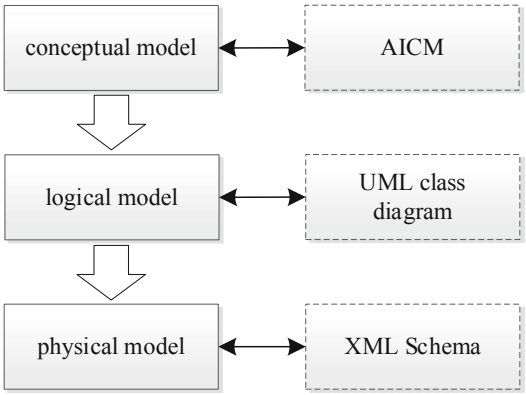

Fig. 2. Level of model building.

AICM extracts and categorizes the required data from the level of aeronautical business requirements, thereby forming the concept of entities. It is used to describe the specific meaning of the aeronautical information domain and is a model of an organization or an industry's interest area. AICM is not only a conceptual model, but also a logical basis for database design. The logical model can consider the association between entities on the basis of the conceptual model. It can be used to describe the structure of the aeronautical information domain and use UML class diagrams to describe it. The AIXM physical exchange model further forms a structured data description on the basis of the logical model, which is used to provide a physical method of storing data. Using XML Schema for data description, the characteristics, attributes and business rules in AICM can be mapped to XML to realize the conceptual model.

XML Schema is a concept in the Extensible Markup Language XML, which can describe the structure of XML language documents [5] and defines the elements that can appear in an XML instance and its type specifications. The current physical model that AIXM can support is AIXM XML Schema, that is, XML Schema is used to represent AIXM.

On the basis of meeting the basic rules of AIXM modeling, the basic structure can be defined for extension and other operations, and the brakes can be adapted to the needs of various aviation. Establishing various aviation data models can better integrate with international standards.

3.2 AIXM UML Class Diagram Example (Airport/Heliport Class Diagram)

As a standardized modeling language, UML is a modeling tool for object-oriented design. Among them, the Class Diagram provides a graphical representation for modeling objects and their relationships [6], representing a class of objects with the same attributes and the relationships between classes, and the Package diagram divide the related classes into a package to organize the related relationships of the class diagram more structured.

The definition of aeronautical elements in AICM is based on ICAO Annex 15 concerning aeronautical information necessary to support international navigation. Each aeronautical element describes a realistic aeronautical information entity. Take the airport/heliport element as an example to illustrate how a specific AIXM element is modeled in AICM. Its class diagram is shown in Fig. 3.

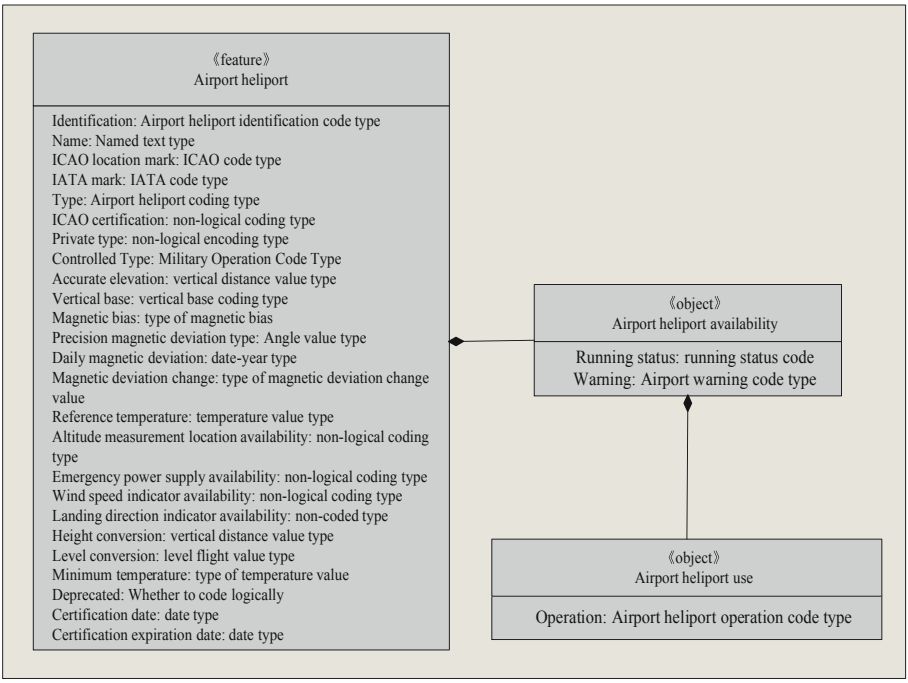

Fig. 3. UML class diagram of airport heliport elements.

It can be seen from Fig. 3 that the airport heliport (AirportHeliport) element has the stereotype <<feature>> and several attributes and the types of these attributes, and the element has the availability of the airport heliport with the stereotype <<object>> (AirportHeliportAvailability) object. In AICM, object is used to describe the abstraction of a thing entity and is often used to represent the attributes of an entity. In this example, the availability object of an airport heliport is an associated combination object of the elements of an airport heliport (AirportHeliport). Its life cycle and elements are closely related, and elements and objects cannot exist separately.

According to the AICM model's description of the data set, the following mapping method is used to derive the AIXM XML Schema physical model. First, according to ICAO's AICM and AIXM XML Schema mapping specification, the UML class name is directly mapped to the XML Schema.

Then according to the time slice model of AIXM, the corresponding rule model is created in the process of element mapping. For each AIXM element in AICM, create XML schema elements in the order of the arrows in Fig. 4.

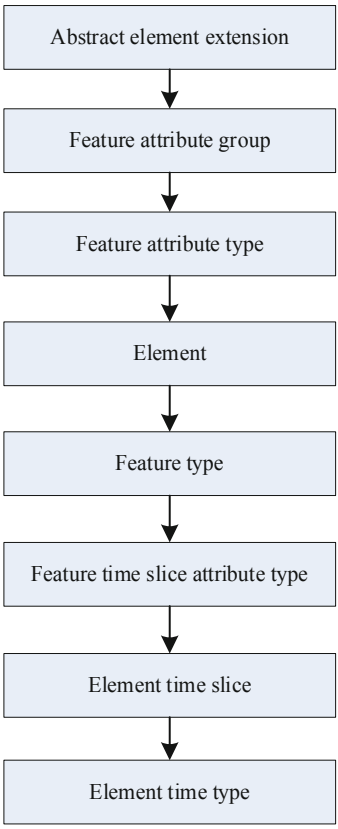

Fig. 4. Sequence diagram of element mapping.

Because of the time requirements of elements, the creation of elements is based on and precedes the feature time slice (FeatureTimeSlice). For AIXM objects, since the object cannot exist independently of the element, the TimeSlice object entity will not be created. The airport heliport element can create XML Schema elements according to the above mapping sequence.

The UML class diagram of the basic time slice model is shown in Fig. 5. There are several possible TimeSlice types for the complete AIXM Feature Time Slice model. AIXM TimeSlice cannot be deleted or modified, and its model is based on the "append only" principle.

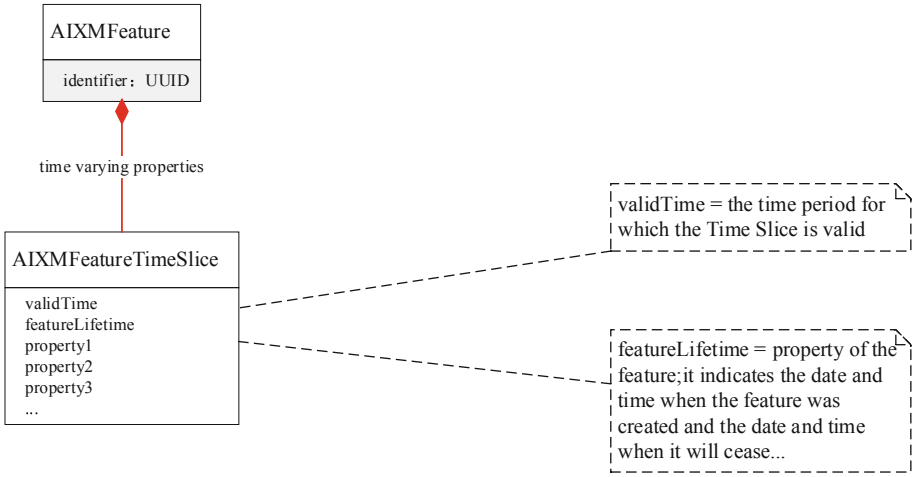

Fig. 5. The UML class diagram of the basic time slice model.

4 Modeling Process Realization

4.1 Process of Model Building Method

The establishment of the AIXM data model is a process of mapping from the logical model representation of UML to the physical model representation of XML Schema. Therefore, in the establishment and implementation of the AIXM standard, the following methods are used, as shown in Fig. 6.

It can be clearly seen that Fig. 6 shows the establishment process of the AIXM standard, which uses the mapping algorithm.

First, according to the class diagram document of the UML model of AIXM, that is, the description of the data set by the AICM model, the mapping algorithm is used to map the UML class diagram document to the AIXM XML Schema model.

Then, according to the time slice model of AIXM, the corresponding rules are created in the process of mapping the elements. For example, the airport heliport (Airport/Heliport) element can generate the corresponding XSD file according to the above mapping sequence, where the airport heliport type (AirportHeliportType) is a complex type mapped by the airport heliport element (AirportHeliport).

Finally, use the JAXB Referennce Implementation (JAXB RI) tool to generate the Java class with the corresponding data structure from the obtained XSD document conforming to the XML Schema specification. Java class is used as the basic data structure in the development of data conversion module to realize the data conversion function.

After obtaining the XSD document conforming to the XML Schema specification, the XML can be instantiated according to the aeronautical data of the actual system. Figure 7 describes this process.

Marshal is a process of converting java objects into xml objects, and unmarshal is its reverse process. Fill the real data in the infrastructure layer into the JAVA class, which can be instantiated by this method.

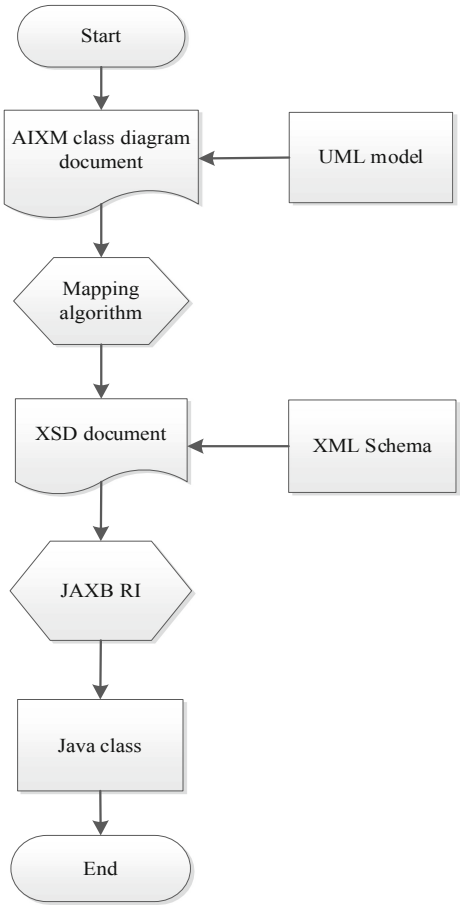

Fig. 6. AIXM standard establishment process.

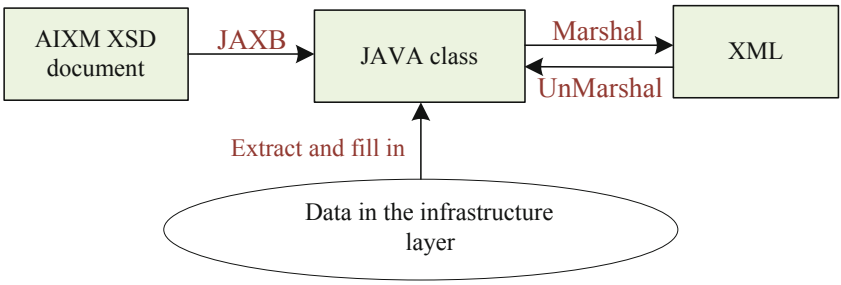

Fig. 7. Instantiation process.

Table 1. Regular expression for NOTAM message.

NOTAM components	A data item	Example	Regular expression
Header	Cable grade	GG	(GG|DD)
	Unit code for receiving electricity	ZBB BYNYX	[A-Z]{8}
	Date and time of	01	([012][1-9]|3[01])
	issue		
	The issuance of time	1539	([01]*|2[0-3])([0-5]*)
	Transmitting unit	ZBTJIOXX	[A-Z]{8}
Telegram serial number and code	Series and serial number/year	A0623/91	[ACD](.{4})/(.{2})
	The cable type	NOTAMN	NOTAM[NCR]
	To replace or cancel a sailing notice number	Null	[ACD](.{4})/(.{2})
Restricted line	FIR	EGXX	[A-Z]{4}
	Q code	QRDCA	Q([A-Z]{2})([A-Z]{2})
	Types of flight	IV	(I?V?|K)
	The flight to	NBO	(N?B?O|M|K)
	scope	W	(A?E|A?W|K|A)
	The lower limit	000	\d{3}
	online	400	\d{3}
	Coordinates the radius	5510N00520W050	([0-8]\d[0-5]\d[NS])([0-2]\d{2}|3[0-5]\d)[0-5]\d[EW]
	Location of situation	EGTT EGPX	([A-Z]{4}){1,7}
Effective time	Starting time	9104030730	(\d{2})(0[1−9]|1[0−2])(0[1−9]|[12]\d|3[01])([01]\d|2[0−3])([0−5]\d)
	End time	9104030730	(\d{2})(0[1−9]|1[0−2])(0[1−9]|[12]\d|3[01])([01]\d|2[0−3])([0−5]\d)(EST)?|PERM
	Effective period	APR 03 07 12 21 24 AND 28 0730 TO 1500	\D.*\s
Plain language		DANGER AREA DXX IS ACTIVE	\E.*\s
Upper and lower limits	Lower limit	GND	SFC|GND|\d{6}M\s(AGL|AMSL)|FL\d{3}
	Upper limit	12200AMSL	UNL|\d{6}(AGL|AMSL)|FL\d{3}

4.2 Source Data Processing

The Notice To Airmen (NOTAM) message is an important business message in the integrated aeronautical information series delivered by AIS in the current aeronautical information business. It is a typical carrier of dynamic aeronautical information. NOTAM and the static data Aeronautical Information Publication (AIP) jointly serve the information business in the aeronautical domain. The specifications provided by AIXM support dynamic air navigation information including NOTAM. While ensuring the consistency and accuracy of aeronautical information required by pilots and airlines, AIXM's digital interaction provides the best choice for the efficient transmission of aeronautical service data, and it supports future ATC systems.

NOTAM is a notice to pilots distributed by means of a communications network and notifying aviation of facilities, services, procedures, or dangerous beginnings or changes, and states. According to the NOTAM dispatch procedure [7], The NOTAM message is mainly composed of header, telegraph number, qualified line, and the body part of a-G item.

The parse of NOTAM message using regular expression is shown in Table 1.

Table 1 lists the data items and corresponding regular expressions of the NOTAM message. Therefore, any regular expression can be matched and the corresponding data item can be extracted as the aeronautical information data source.

4.3 Model Test Results

The test uses the black box test method, which refers to testing whether the module can correctly accept input and get the correct output. Select the NOTAMN in the NOTAM message as the test case for the AIXM input data subset. The message test case and test results are as follows and the test case is shown in Table 2.

Table 2. NOTAM test case.

A0046/13 NOTAMN
Q) ZABB/QFALC/IV/NBO/A
/000/999/5353N02802E005
A) ZABB B) 1309012100 C) 1309020200
E) AERODROME CLOSED

Based on the corresponding airport AIP data, the XML data about airport elements obtained from the above test cases are shown in Table 3.

In Table 3, the information data item about airport closure in NOTAM message was superimposed on the aviation information compilation of Beijing Airport, and XML was instantiated with AirportHeliport as the main element.

Table 3. NOTAM test case results.

```
<aixm:AirportHeliport xmlns:gco="http://www.isotc211.org/2005/gco" xmlns:aixm=
"http://www.aixm.aero/schema/5.1" xmlns:gmd="http://www.isotc211.org/2005/gmd"
xmlns:gts="http://www.isotc211.org/2005/gts" xmlns:gsr="
http://www.isotc211.org/2005/gsr" xmlns:gss="http://www.isotc211.org/2005/gss"
xmlns:message="http://www.aixm.aero/schema/5.1/message" xmlns:event="
http://www.aixm.aero/schema/5.1/event" xmlns:gml="http://www.opengis.net/gml/3.2"
xmlns:ns10="http://www.w3.org/1999/xlink">
  <gml:boundedBy xmlns:xsi=" http://www.w3.org/2001/XMLSchema-instance "
xsi:nil="true"/>
  <aixm:timeSlice>
    <aixm:AirportHeliportTimeSlice>
      <aixm:designator >ZABB</aixm:designator>
      <aixm:name >Beijing International Airport</aixm:name>
      <aixm:locationIndicatorICAO >ZABB</aixm:locationIndicatorICAO>
      <aixm:designatorIATA >PEK</aixm:designatorIATA>
      <aixm:type>aerodrome only</aixm:type>
      <aixm:certifiedICAO >YES</aixm:certifiedICAO>
      <aixm:privateUse >NO</aixm:privateUse>
      <aixm:controlType>civil control</aixm:controlType>
      <aixm:fieldElevation uom="ft">15.2</aixm:fieldElevation>
      <aixm:verticalDatum nilReason="12">12</aixm:verticalDatum>
      <aixm:magneticVariation >121.666</aixm:magneticVariation>
      <gml:validTime>
        <gml:TimePeriod gml:id="CY01_TS02_TP01">
        <gml:beginPostion>2013-09-01T21:00:00<gml:beginPostion>
        <gml:endPostion>2013-09-02T02:00:00<gml:endPostion>
  <gml:TimePeriod>
   <gml:validTime>
 <aixm:interpretation>TEMPDELTA</aixm:interpretation>
 <aixm:sequenceNumber>46</aixm:sequenceNumber>
  <aixm:availability>
  <aixm:AirportHeliportAvailability>
      <aixm:operationalStatus>
            AERODROME CLOSED
      </aixm:operationalStatus>
    </aixm:AirportHeliportAvailability>
  </aixm:availability>
 </aixm:AirportHeliportTimeSlice>
</aixm:timeSlice>
</aixm:AirportHeliport>
```

5 Conclusion

This article mainly introduces AIXM in the SWIM platform information exchange model. At the same time, combined with the modeling process and related technologies, the model mapping algorithm is used to build a model that conforms to the AIXM data standard. The preliminary modeling and experiments are performed to complete the conversion from XSD to XML documents.

In future research, efforts can also be made from the following aspects: First, based on the analysis of the basic rules of the information exchange model, the extensibility of the data model can be used to expand the corresponding data structure and definition from the elements, entity attributes and data types according to the characteristics of different national air traffic control systems according to the special business requirements, so as to adapt to the requirements of aviation elements of different countries. In addition, the designed AIXM can be connected to the actual system for testing and optimization. After the model is established and tested, the AIXM is tried to be deployed.

The establishment of AIXM can not only standardize and structure data, reduce the cost of information exchange, but also provide a reference for the construction of other information standards in the future.

References

1. Bian, B.: On the information island problem in enterprise informationization. China Manag. Inf. Technol. **4**, 22–25 (2007)
2. SWIM Concept – DRAFT Version 0.9 ICAO Air Traffic Management Requirements and Performance Panel (ATMRPP)
3. EUROCONTROL and Federal Aviation Administratio. Aeronautical Information Exchange Model (AIXM) Exchange Model goals, requirements and design (2006). http://aixm.aero/sites/aixm.aero/files/imce/AIXM50/aixm_5_proposal_20060620_whitepaper_pdf
4. Liu, B.: Research and design of aeronautical information dynamic information processing system. M.S. dissertation, University of Electronic Science and Technology of China, China (2014)
5. W3C.XMLSchema [EB/OL]. https://www.w3.org/standards/xml/schema
6. Unified Modeling Language. What is UML [EB/OL]. https://www.uml.org/index.htm. Accessed 25 Jan 2020
7. CAAC Air Traffic Control Bureau.Guidance Manual for issuance of Notices to Mariners, pp. 4–17 (2008)