Research on Application Modeling and Visualization Based on Aviation Information Exchange Model

Xin Lai and Jingyu Hu*

College of Air Traffic Management, Civil Aviation Flight University of China, Guanghan 618307, China

*Corresponding author

Abstract. The Aviation Information Exchange Model (AIXM) is a data exchange standard proposed by the International Civil Aviation Organization for the digital modeling and application of various aviation elements in aeronautical information services. It is the global expression, storage and interaction of aviation information standards basis. AIXM defines various aviation entity elements covering the whole process of flight. Airspace, airport, flight procedures and other entities can implement spatial simulation using computer visualization technology based on AIXM modeling structured data. The simulation display can help flight operators, control personnel and other aviation operators to establish a better situational awareness and improve flight safety. This paper analyzes the technical points of the aeronautical information exchange model, and uses the abstract extended attributes in the AIXM structure to realize the modeling of the airport obstacle limit surface, and further realizes the visual simulation of the constructed airport obstacle limit surface AIXM model by using MATLAB.

Keywords: AIXM; Visual simulation; DOM; MATLAB; Obstacle restriction surface.

1. Introduction

With the development of aviation industry, the rapid growth of civil aviation transportation turnover and the increasing flight flight volume, the air traffic management system, airline operating system, and intelligence service system have proposed the transmission, safety and immediacy of aviation information. Higher requirements [1]. As early as 1996, the European Aviation Safety Organization began to prepare for the future aeronautical information business. Europe and the United States have already released aeronautical information products using the digital exchange standard based on aviation elements. At the same time, many countries have already prepared or are preparing to launch AICM/AIXM based on Aviation products [2] [3]. AIXM is a data exchange standard, including the Aeronautical Information Conceptual Model (AICM) based on UML (Unified Modeling Language) and the AIXM (Air Information Exchange Mode), an aeronautical information exchange model based on Extensible Markup Language (XML) [4]. At present, there are not many researches on AIXM related technologies in China. The existing researches mainly focus on the discussion and analysis of theoretical concepts. AIXM covers seven major areas of aviation: airport/helicopter airports, navigation facilities, terminal area flight procedures, route structures, airspace boundaries, air traffic control and NOTAM, and traffic restrictions. Covers all aviation fields, including airport/helicopter airport, airspace boundary, terminal area flight procedures, route structure and other fields can be modeled by AIXM, and related technologies are used to realize visual simulation in different application environments. The visualization of aviation elements enhances the situational awareness of pilots and controllers when using aeronautical information products, and enhances the support of aeronautical information products for aviation operations safety. This paper first introduces the related concepts of the aeronautical
information exchange model, and points out that the abstract extended attributes in the aeronautical information exchange model can add various attributes of the original basic entities based on the basic attributes. Based on the basis of the runway entity, the abstract obstacle extension attribute (AbstractFeatureExtension) is used to define the airport obstacle limit surface model, and the data structure coding of the airport obstacle limit surface is completed according to the rules of AICM to AIXM mapping. Finally, the relative positional relationship between the runway and the obstacle limit surface is analyzed. The MATLAB three-dimensional composition technology is used to realize the visual simulation of the airport obstacle limit surface based on AIXM modeling.

2. Aviation information concept and interaction model

2.1. Aviation Information Concept Model (AICM)
The Aviation Information Concept Model (AICM) is used to describe various concepts in the field of aeronautical information as a collection of elements (entities), attributes, and relationships [4]. AICM uses the UML diagram to display the aeronautical element entity-relational concept model. Figure 2-1 shows the UML diagram of the aeronautical element runway, which shows the physical properties of the runway, airport, runway centerline, runway center point, and the relationship between them. The attribute format of the constituent entities is:

\[
\text{Visibility / name: type}
\]

Figure 1. Runway UML view.

The UML diagram of AICM covers six stereotypes (Stereotypes) and three associations (Relationship). The styling classes are:

- **Feature**: An entity class that represents the elements of a real or virtual world and is the basis of AICM. Entity classes can change over time. For example, the runway, airport, runway direction, and runway centerline are entities.

- **Object**: An object that represents the abstract body of an entity, which is a feature of the entity. The generation of object classes is generally based on two reasons. First, when the multiplicity of an attribute of an entity is greater than one, such as a city served by an airport; Second, when an attribute of an entity has its own attribute value. The surface physical feature of Figure 1 is an attribute of the runway, and the object has its own unique property, so the surface physical feature belongs to the object class.

- **Choice**: Select the category to express the XOR relationship. For example, the projection of the airspace can be described as a surface, or other airspace having the same shape, and the like.

- **Datatype**: Datatype, which represents the underlying data type used by the entity attribute. For example, the runway attribute TextDesignatorType is derived from the Text data class.

- A list of codelists that represent a list of required data types, and which contains the other attribute to facilitate subsequent additions to the required data types.

- **AIXMFeature**: Abstract class, this class does not appear on the UML diagram, but appears as
a "build element" in AIXM. Each entity inherits from an entity abstraction class, such as runway entity inheritance and runway entity types.

The relationship is:

- **Composition**, which means that the object is part of the entity, and the object cannot exist separately from the entity. For example, the surface physical feature is the runway physical property.
- **Association**, expressed as a link between two entity classes. The name of the UML in the arrow relationship indicates the "role" of the entity relative to the other entity. The relationship between the runway and the airport is an association.
- **Inheritance**, indicating that a class (usually a specific class or a subclass) inherits another class (usually a generic class or a parent class). In AIXM, only inheritance between entities and entities, inheritance between objects and objects, cross-referencing is not allowed. For example, the point relative to the highest point (elevalepoint) is a more general concept, so the relationship is an inheritance relationship.

Through AICM, the composition, attributes and relationship with other elements are clearly displayed, which provides a logical mind map for AIXM coding, which is convenient for programmers to better understand the aviation information composition.

### 2.2. Aviation Information Exchange Model (AIXM)

AIXM is a technical method recommended by ICAO to convert the AICM model into a computer-readable language using the XML language. XML has unique advantages in various computer languages. It is a markup language promoted by W3C. It can be applied to different underlying modules of development platforms to facilitate the development and transmission of subsequent data. The core purpose of building AIXM is to achieve data sharing and exchange. Different fields have unified XML Schema requirements rules in this field. Only data structures constructed under the same XML Schema model can be identified and applied to each other on different platforms and departments. AIXM is an XML Schema for data encoding that reflects the logical relationship between aeronautical data. Implementing AIXM requires conversion to XML Schema based on AICM (UML diagram). Figures 2 and 3 show how the runway entities and objects are converted to XML Schema.

![Figure 2. How the runway entity maps to AIXM.](image2)

![Figure 3. How objects are mapped to AIXM.](image3)

The principle of mapping relationship transformation is to first declare a type and then assign features (including attributes and relationships) to the type. The main classes used in AIXM are entity classes
and object classes. In addition to the mapping rules of classes, there are two mappings of relational rules, as follows:

- The mapping to the object is encoded by creating an XML element with the same name as the character on the UML model. This is a type of object feature, and the type is ObjectPropertyType. For example, the relationship between a point and a line point in the runway is precisely by nesting a PointPropertyType to nest the attributes of the point in the center line point.

- A mapping between entities that provides rules for nesting entities. The role name in the UML diagram is used for the XML element name and the type is the entity feature class (FeaturePropertyType). For example, both the runway and the airport are physical classes. When the runway entity is written, the runway is at the airport, so the AirportPropertyType needs to be declared to nest the airport information in the runway entity.

In this paper, using the mapping rules of AICM to AIXM, Altova XMLSpy is used to construct the XML Schema (xsd) of the standard runway, as shown in Figure 4:

![Figure 4. Runway standard XML schema.](image)

The XML encoding of the core elements in the entity UML diagram provided by the AICM can be implemented according to the mapping relationship. However, in practical applications, in order to more flexibly reflect the user's modeling intent, the AbstractFeatureExtent part of the entity can be extended to the required object, which lays a foundation for user-customized modeling and innovative modeling on the basic AIXM model.

### 3. Airport Obstacle Limit Surface Modeling and Visual Simulation

AIXM is the underlying model and modeling language of aeronautical information business products, on the basis of which different applications can be developed\[5\]. Based on the basic airport runway entity, this paper extends the airport obstacle limit surface, which is not in the AICM basic model, to the AbstractFeatureExtent part, and realizes the innovation based on the basic AIXM. This paper first studies the spatial and geometric relationship between the airport obstacle limit surface and the airport, and then realizes the airport obstacle limit surface from AICM modeling to AIXM coding. According to the obstacle limit surface data of AIXM package, the MATALE technology is used to realize the limit surface. Visualization. The idea of this research process is shown in Figure 5:
3.1. Analysis of the Spatial and Geometric Relationship of the Obstacle Limit Surface

The airport obstacle limit surface is to ensure the aircraft's take-off and landing safety and the normal use of the airport, and to limit the imaginary plane to a set of obstacles defined in the airport and its vicinity. The spatial location of the obstacle limit surface depends on the spatial distribution of the specific runway and the way the airport is navigated [7]. Take the center point of the airport runway centerline as the origin, the Y-axis along the runway direction, the X-axis perpendicular to the runway direction, and the Z-axis perpendicular to the runway plane direction, and establish a spatial three-dimensional Cartesian coordinate system. The directions of the three axes conform to the right-handed coordinate system [8] specified by AIXM.

The eight major parts of the obstacle limiting surface are the conical surface, the inner horizontal plane, the inner approaching surface, the approaching surface, the transition surface, the inner transition surface, the go-around surface and the take-off climbing surface. The construction principle of each surface is constructed by the algorithm of parametric equation. This paper takes the take-off climbing surface as an example to analyze its spatial and geometric relationship. The spatial position of the take-off climbing surface relative to the airport runway is shown in Fig. 6.

The geometric parameters are shown in Table 1.

Table 1. Parameters of takeoff climbing surface.

| Obstacle restriction surface, size and symbol | Flight zone indicator I |
|---------------------------------------------|-------------------------|
| Starting width (W1)                         | 1                       |
| Length from the runway end (L1)             | 2                       |
| Dispersion rate (per side) (d)              | 3 or 4                  |
| Final width (W)                             |                          |
| Length (L)                                  |                          |
| Slope (S)                                   |                          |
| [Values provided in the table]              | [Values provided in the table] |
Figure 6. Top view and section view of the take-off climbing surface.

The second section of the take-off climb can be understood as the composition of the two methods. The first type consists of a line of equal length (without a change in the length of the X-axis) and a line of 0.02 height (relative to the Z-axis) along the Y-axis. Second, the fixed length (without the change in the length of the Y-axis) is composed of a spatial line having a constant value of 0.02 (relative to the plane composed of Y-X) arranged along the X-axis. The same point of the above two methods is to first determine a certain spatial line, and then arrange in the other direction to form a three-dimensional surface. The introduction of the variable a represents the interval (step size) arranged in a certain direction. The size of a determines the number of spatial lines that make up the face. The essence of the two methods is that the spatial lines are arranged in a certain direction to form a spatial surface. The second method of taking off the climbing surface adopts the first method, so the parameter equation of the surface is:

\[ 0 < a < 1800 \]
\[ 7790 < Y < 16310 \]
\[ x = -900 + a \]
\[ z = (y - 7790) \times 0.02 + 129.6 \]

Where: formula (1) represents the range of the space line in the X-axis; formula (2) represents the range of the space line in the Y-axis; formula (3) represents the line of space when the change along the X-axis is a. The range of values for the X-axis. Equation (4) represents a straight line when the values (or ranges) of the X-axis and the Y-axis are determined, and y represents a range of values of all the straight lines on the Y-axis.

For the first segment of the take-off climbing surface, we assume that the X-axis has a value range of "fixed range" and is arranged along the Y-axis, so the first-parameter equation of the take-off climbing surface is:

\[ 0 < a < 6480 \]
\[ y = -900 + a \]
\[ -90 - a \times 0.125 < x < 90 + a \times 0.125 \]
\[ z = (y - 7790) \times 0.02 + 129.6 \]

The meanings of the formulas (5) to (6) are consistent with the meanings of the formulas (1) to (4). The magnitude of the X-axis depends on the rate of expansion on both sides. For the other seven midplanes of the obstacle limit surface, the above method can also be used to construct the parametric equation.

3.2 Construction of XML Schema for Airport Obstacle Restriction Surface

There is no AICM map on the obstacle limit surface on the AIXM official website, and currently there is no specific XML Schema for a certain aviation module. The XML schema constructed in this paper is based on the runway UML diagram published in AIXM 5.1.1, combined with UML to XML mapping.
According to the mapping rule, based on the standard runway AIXM Schema, the obstacle limitation surface is extended to AbstractRunWayExtent, and the expansion code is as follows. Figure 7 shows:

Figure 7. Abstract RunwayExtent content map.

In Altova XMLSpy, XML Schema is a format file of XML text, so when you need to specify the corresponding XML Schema file in XML editing, the document data structure can be determined.

3.3. Reading and Visualization of AIXM Files of Airport Obstruction Restricted Surfaces
This paper selects an airport as an example (the airport runway is 2,500 meters long, 45 meters wide, runway number 27, class I precision approach runway) for the visualization of airport obstacles. XML Schema built with AIXM can form an XML file by simply filling in the corresponding table 3-1 parameter values. There must be a dedicated interface for the XML file to access the programming platform required. This paper uses the Document Object Model (DOM) [9] to identify the structure and data content of XML text. All parameters in MATLAB programming and AIXM construction are represented by the letters shown in Table 3-1, and the completed XML text is read into MATLAB using the DOM interface. The process is shown in Figure 8:

Figure 8. Using DOM technology to read the XML text process diagram.

Figure 9. Take-off climbing surface and runway.
For the rest of the obstacle restriction surface, the same method is used for construction. For the detailed display of the graphics, the distributed display is as shown in FIG. 10, FIG. 11, and FIG. In this process, a three-dimensional view of the obstacle-restricted surface based on AIXM is obtained, which provides a platform for the three-dimensional position display of subsequent obstacles, and also provides a research basis for airport clearance obstacle assessment. The simulation process model and the basic coding based on the AIXM database realize the separation of the model display and the data, and improve the security of the visual simulation.

**Figure 10.** Conical and inner horizontal plane.

**Figure 11.** The flyover surface, the inner transition surface and the inner approach surface.

**Figure 12.** Approach and inner transition surfaces.
4 Conclusion
AIMAICM/AIXM technology must be the development direction for China to meet the needs of aeronautical information business in the future. The basic research for it can lay the foundation for the immediacy and efficiency of future aviation business.

Based on the basic model of AICM, based on the practical application, the innovative extension of the obstacle limit surface to generate a practical aviation element XML Schema, and based on DOM technology to explore the AIXM file reading method, using MATLAB to achieve AIXM XML data Visualization and feasibility verification with specific examples.

In the above work, this paper focuses on the mapping process from AICM to AIXM, and gives a practical and complete scheme from basic modeling to practical application, and proposes new research ideas for the subsequent visualization of various AIXM entities. It has a positive effect on the research of various application fields based on AIXM.

5. Acknowledgment
This work was finally supported by National Innovation and Entrepreneurship Training Program for College Students of Civil Aviation Flight University of China (Grant Nos. 201810624008)

References
[1] International Civil Aviation Organization (ICAO). Outlook for air transport to the year 2025, accessed November 2010. http://www.icao.int/.
[2] FAA. Next Generation Air Transportation System (NextGen). November 2010. http://www.faa.gov/nextgen/
[3] EUROCONTROL. Weather Information Exchange Model (WXXM). August 2019. http://www.eurocontrol.int/aim/public/standard_page.
[4] EUROCONTROL. Aeronautical Information Exchange Model. August 2019. http://www.aixm.aero/.
[5] Yang Jing. Analysis of AIXM's goals, needs and design [J]. Air Traffic Management, 2006 (12): 22-23.
[6] Zhai Jie. Research on Evaluation Method of Airline Safety Information Management Level [J]. Safety and Environment Report, 2015, 15(06): 165
[7] Liu Xiaopeng. Design and development of civil airport clearance safety evaluation software [D]. University of Electronic Science and Technology, 2010.
[8] Liu Yingchao. Three-dimensional visualization of airport clearance analysis and its algorithm [D]. Chengdu University of Technology, 2009.
[9] Li Pengfei. Visualization and editing method of management information instance tree based on XML [D]. Beijing University of Posts and Telecommunications, 2018.