

## Mr. ZHANG Mingwei Professor



**Director of State Key Laboratory of Air Traffic Management System and Technology**

- **Air Traffic Management System Overall Design and Industry Top-Level Planning**
- **Chief Designer of Large District Air Traffic Management System**
- **Chief Designer of Air Traffic Management System of Daxing Airport**
- **Chief Designer of National Traffic Management System Project**
- **Awarded 9 provincial, ministerial and academic rewards**



空中交通管理系统与技术  
国家重点实验室  
State Key Laboratory of  
Air Traffic Management System and Technology

# Application of Knowledge Graph in Air Traffic Management

Prof. ZHANG Mingwei

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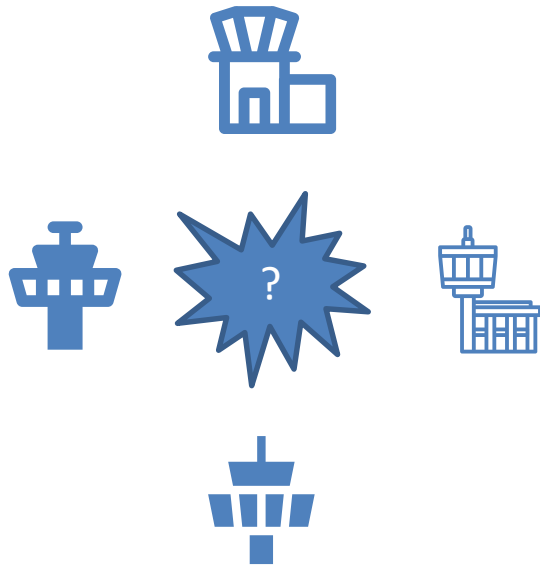
**Final Conclusion**

# 1. Brief Introduction

## (1) Motivation

Data Consistency

### Data Inconsistency Problems



Data Format

Data Name

Semantics

Temporal/Spatial  
Resolution

Data Unit

Organization  
Principles

Beijing Capital International Airport

ICAO: ZBAA

IATA : PEK

Departure Time:

Organization 1: DT

Organization 2: DepTime

Departure Time:

Organization 1 : Actual Departure Time

Organization 2 : Expected Departure Time

Organization 1 : Recorded every second

Organization 2: Recorded every minute

Organization 1 : Mile

Organization 2: Kilometer

Meteorology: Provide various date

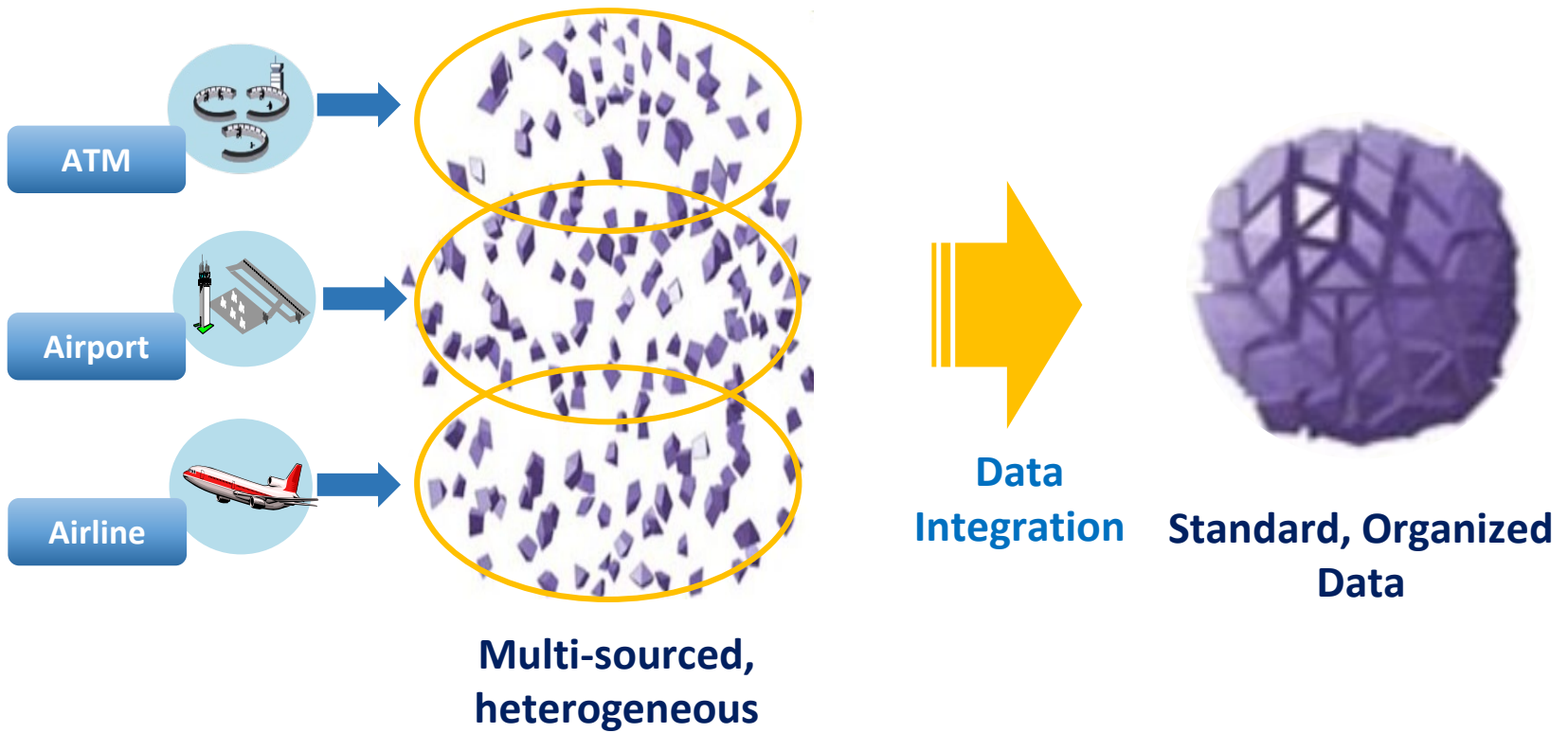
ATM: Only care about Meteorology related  
to ATM

Data consistency matters in  
collaboration!

# 1. Brief Introduction

## (1) Motivation

Data Integration



# 1. Brief Introduction

## (1) Motivation

Reasoning

Heterogeneous data



Figures



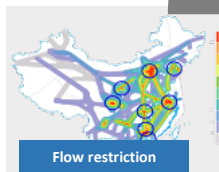
Voice



Bad weather



Airspace restriction

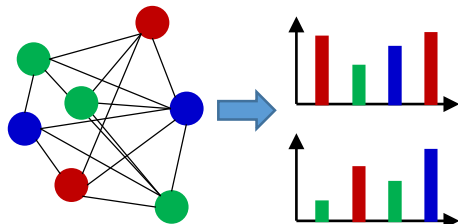


Flow restriction

Predict the trends by reasoning

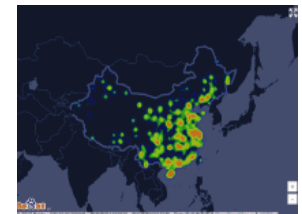
ATM event

Evolution of events



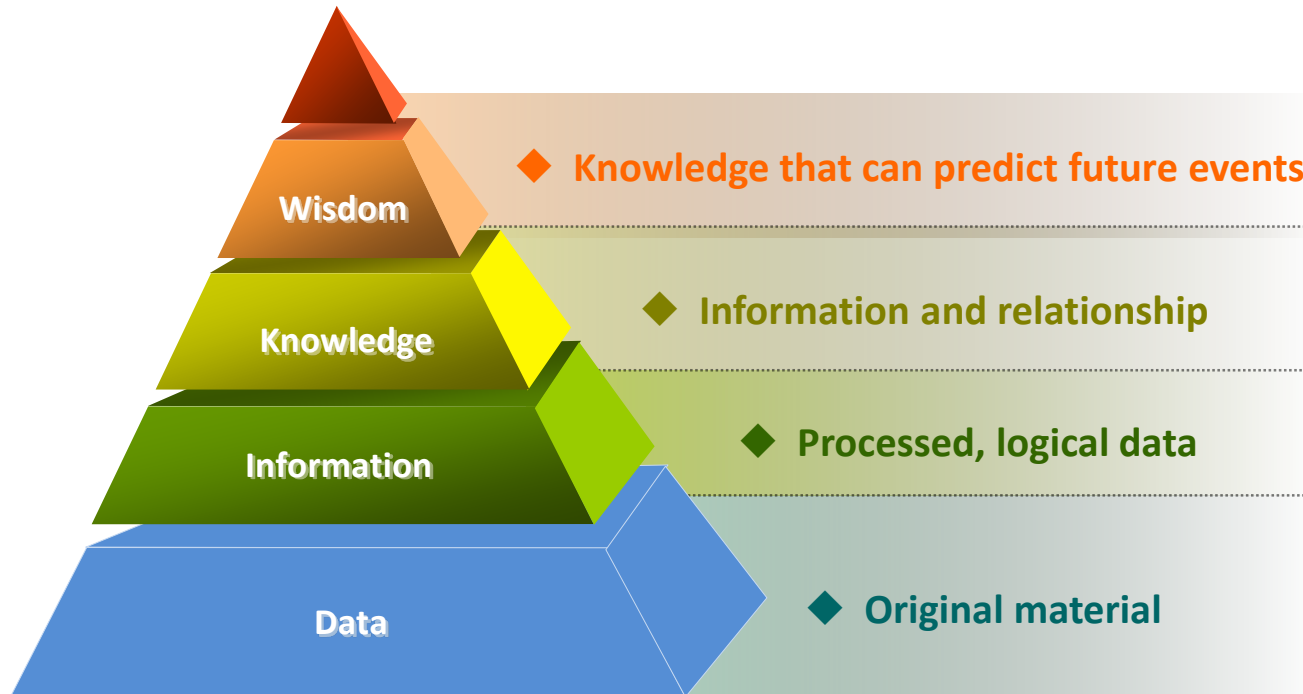
Network of ATM

Effect on the situation of network



# 1. Brief Introduction

## (2) What is Knowledge?

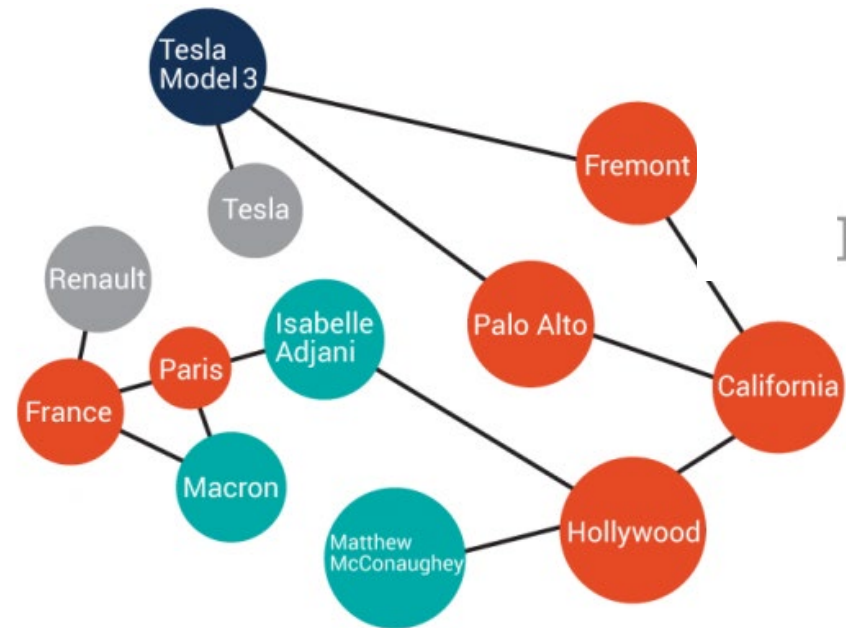
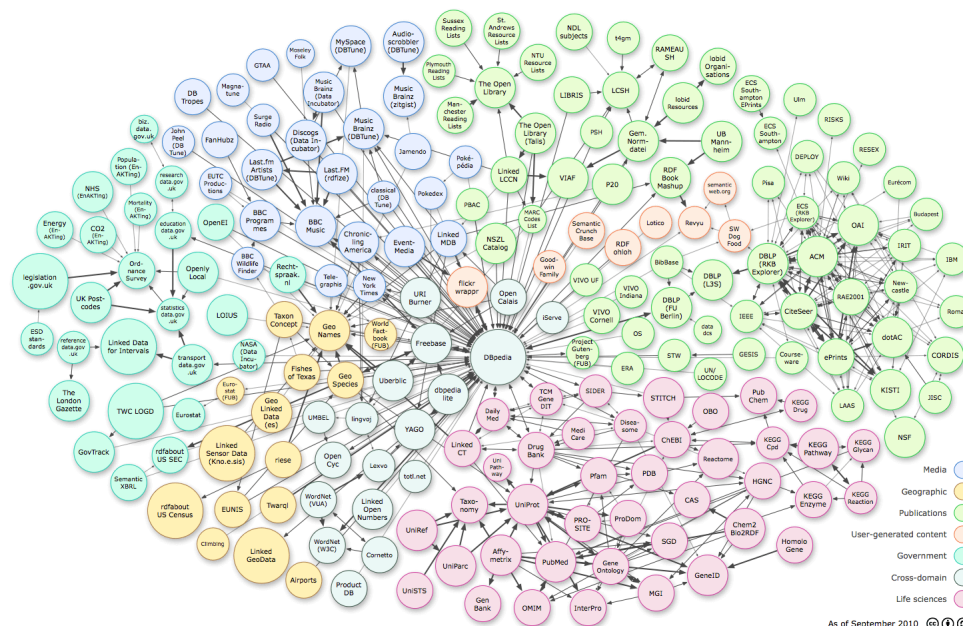


- ❑ **Data:** 38
- ❑ **Information:** The temperature of Alice is 38 °C.
- ❑ **Knowledge:** Alice has a fever.
- ❑ **Wisdom:** Alice must go to hospital and have a rest.

# 1. Brief Introduction

## (3) Knowledge Graph

The knowledge graph represents a collection of interlinked descriptions of entities – objects, events or concepts. Knowledge graphs put data in context via linking and semantic metadata and this way provide a framework for data integration, unification, analytics and sharing.

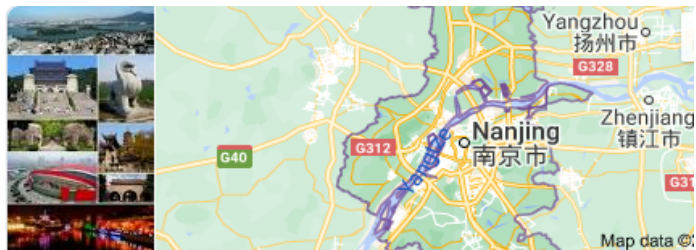


# 1. Brief Introduction

## (3) Knowledge Graph



Nanjing



### Nanjing

City in China

Nanjing, capital of China's eastern Jiangsu province, is roughly 300km up the Yangtze River from the city of Shanghai. It was the national capital during part of the Ming dynasty. Many monuments and landmarks remain, including Zhonghua Gate (Gate of China), a preserved 14th-century section of the massive wall that contained the old city's southern entrance. — Google

**Area:** 2,547 mi<sup>2</sup>

**Elevation:** 66'

**Population:** 8.506 million (2019)

**Province:** Jiangsu

**Local time:** Friday 9:38 AM

**Weather:** 79°F (26°C), Wind S at 3 mph (5 km/h), 68% Humidity  
[weather.com](#)

**Area code:** 25

capital of china

All Images Books News More

Tools

About 11,170,000,000 results (1.09 seconds)

China / Capital

### Beijing



### Beijing

Capital of China

Beijing, China's sprawling capital, has history stretching back 3 millennia. Yet it's known as much for modern architecture as its ancient sites such as the grand Forbidden City complex, the imperial palace during the Ming and Qing dynasties. Nearby, the massive Tiananmen Square pedestrian plaza is the site of Mao Zedong's mausoleum and the National Museum of China, displaying a vast collection of cultural relics. — Google

**Area:** 6,336 mi<sup>2</sup>

**Elevation:** 143'

**Local time:** Friday 9:40 AM

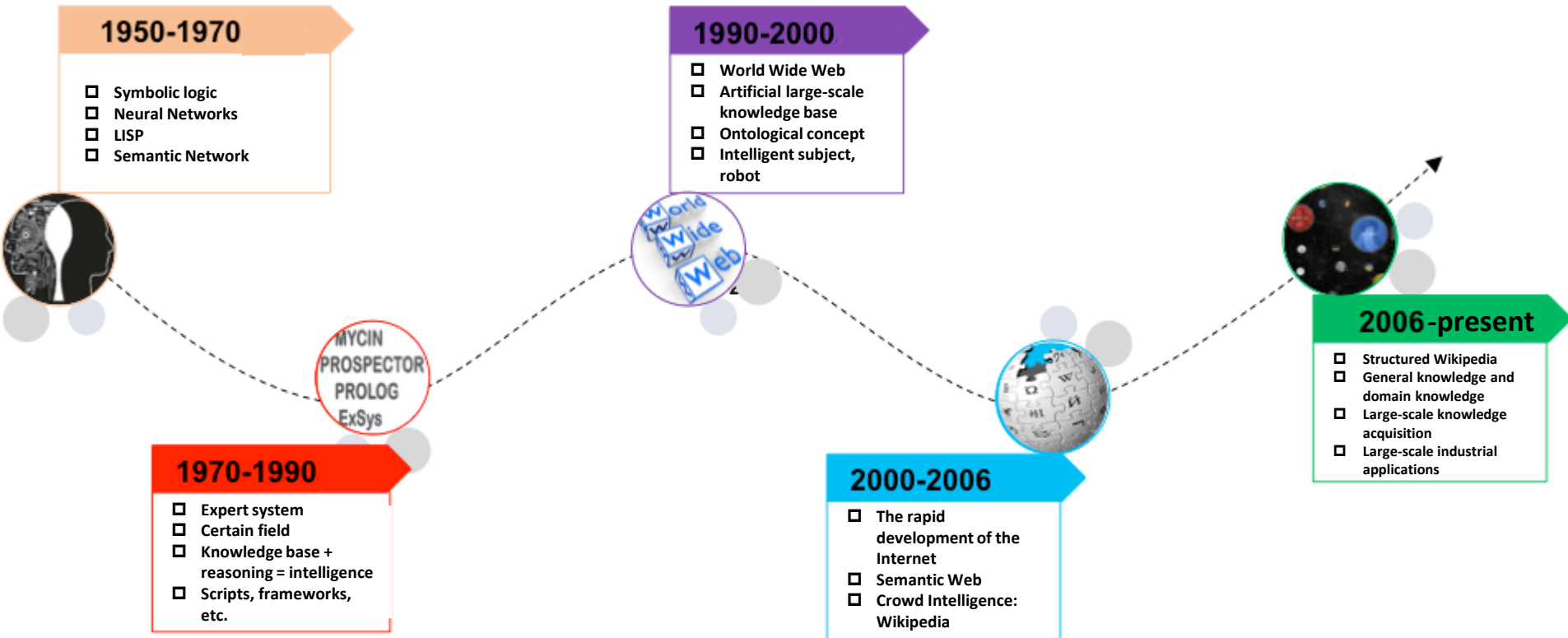
**Population:** 21.54 million (2018)

**Weather:** 67°F (19°C), Wind N at 9 mph (14 km/h), 39% Humidity  
[weather.com](#)

**Area code:** 10

# 1. Brief Introduction

## (4) History of Knowledge Engineering



## (4) History of Knowledge Engineering

### **The first stage: From weak semantics to strong semantics (pre-2006)**

From semantic network, to description logic, to OWL

From metadata framework, to RDF, to RDFS

### **The second stage: from strong semantics back to weak semantics (2006-present)**

Relational data, combined with existing standards commonly used in the Web industry

From RDF database to graph database

### **20 years of history show that:**

Summary from practice(JSON, graph database, etc.) is better than top-down design

Fully compatible with the existing tool system is better than the new framework

Simple is better than powerful

# 1. Brief Introduction

## (5) Relationship between AI and Knowledge Graph

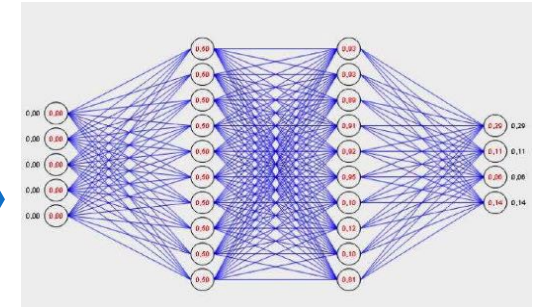


Smart AI

Perception

Recognition

Decision



Deep Learning

Thinking

Knowledgeable AI

Understanding

Reasoning



Knowledge Graph





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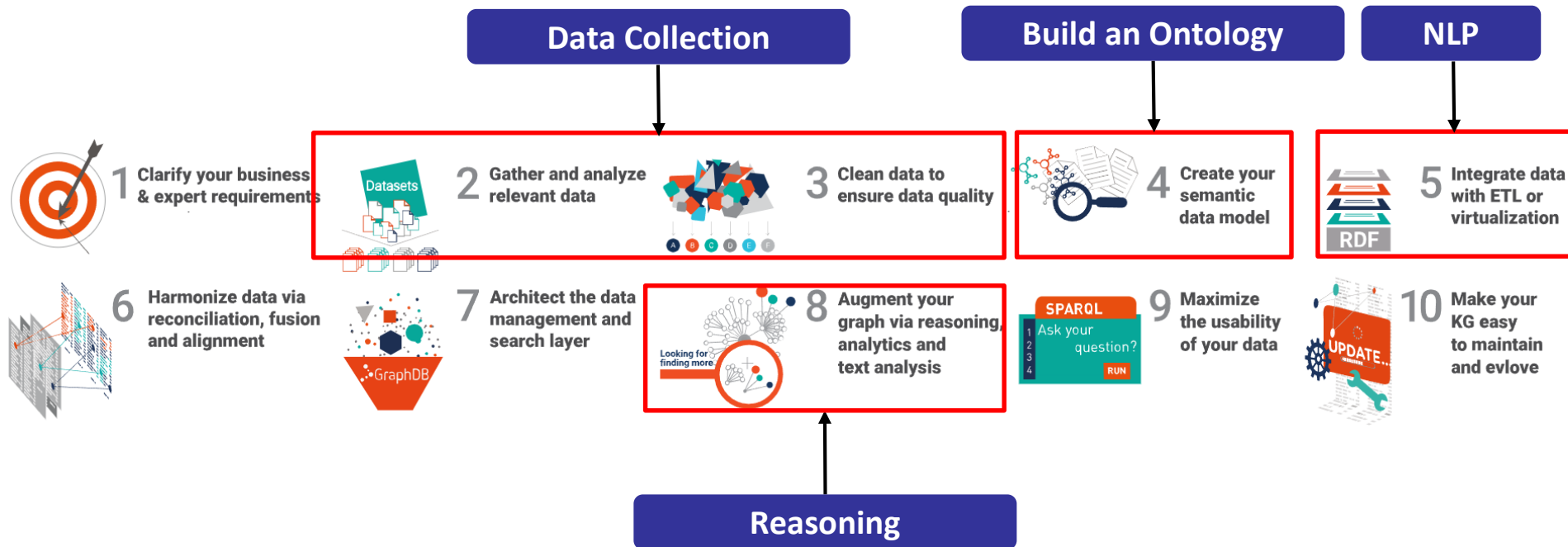
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## 2. Specific Methodology

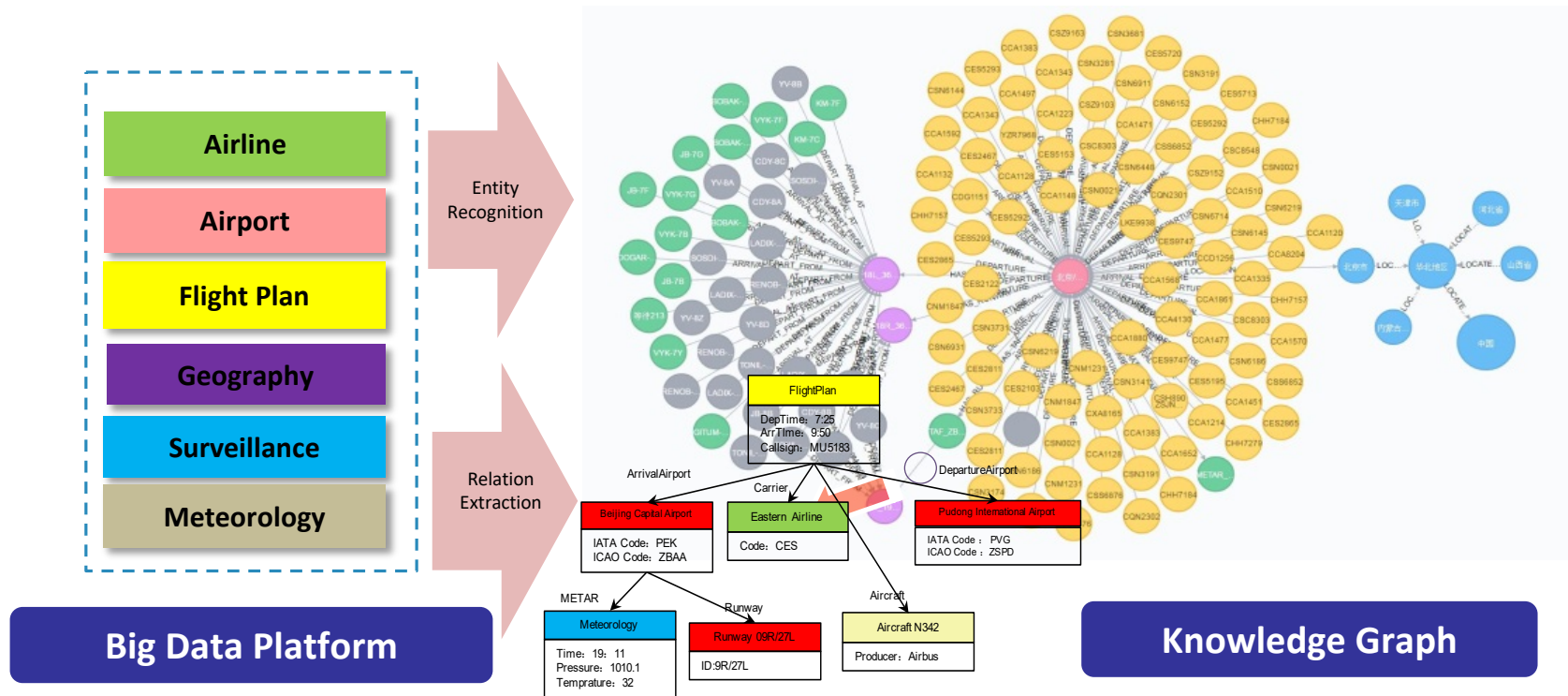
### (1) Process of Building a Knowledge Graph



## 2. Specific Methodology

### (2) Knowledge Graph of Air Traffic Management

The knowledge graph of air traffic management describes the relationships between massive, multi-source, heterogeneous information, e.g., airline, airport, flight plan, etc.



## 2. Specific Methodology

### (3) Ontology

An ontology is a **formal**, **explicit** specification of a **shared conceptualization**.

T. Gruber, 1993; R. Studer, V. R. Benjamins, and D. Fensel, 1998

**formal**: machine readable

**shared**: fact that the knowledge represented in an ontology are agreed upon and accepted by a group

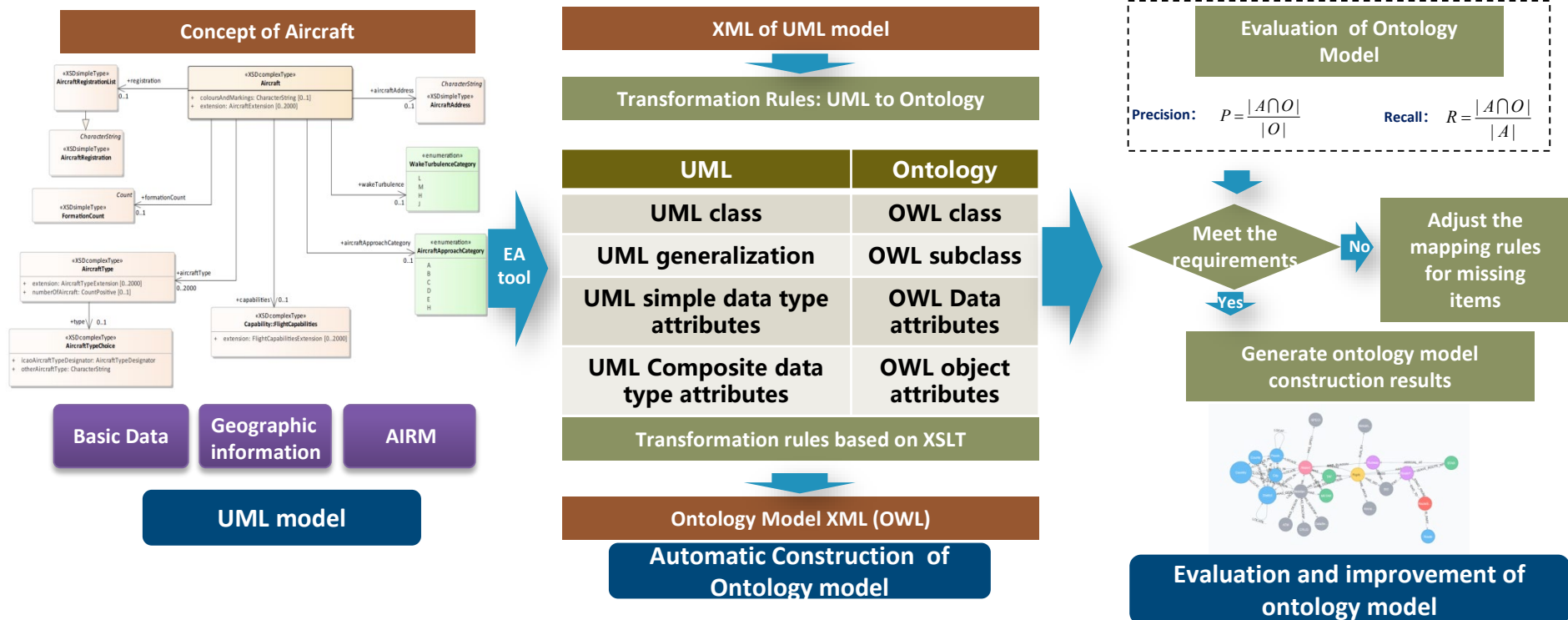
**conceptualisation**: an abstract model that consists of the relevant concepts and the relationships that exists in a certain situation

**explicit**: type of concepts used and the constraints on their uses are explicitly defined

## 2. Specific Methodology

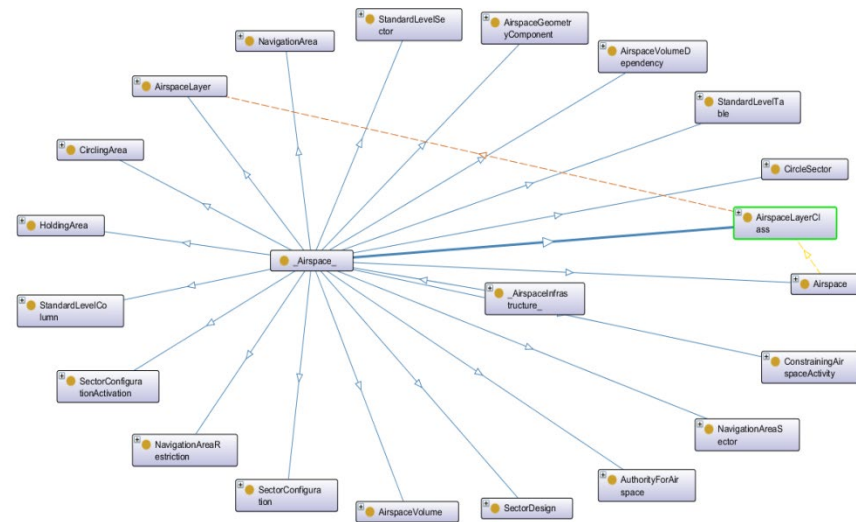
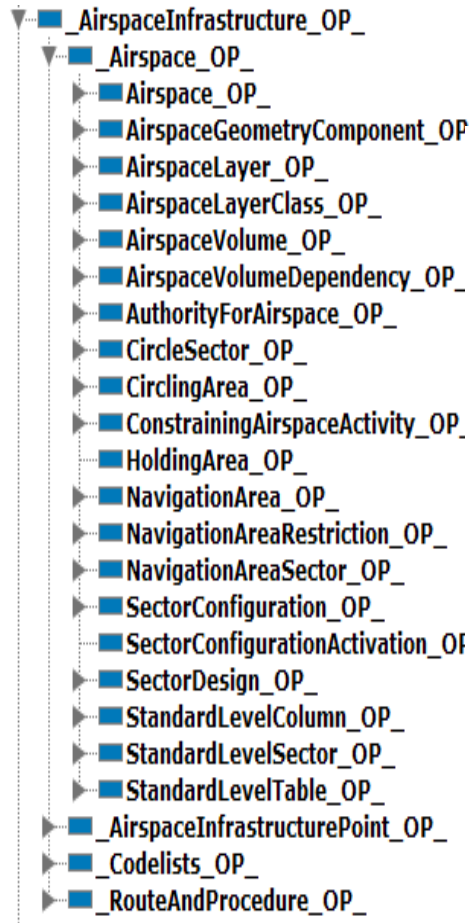
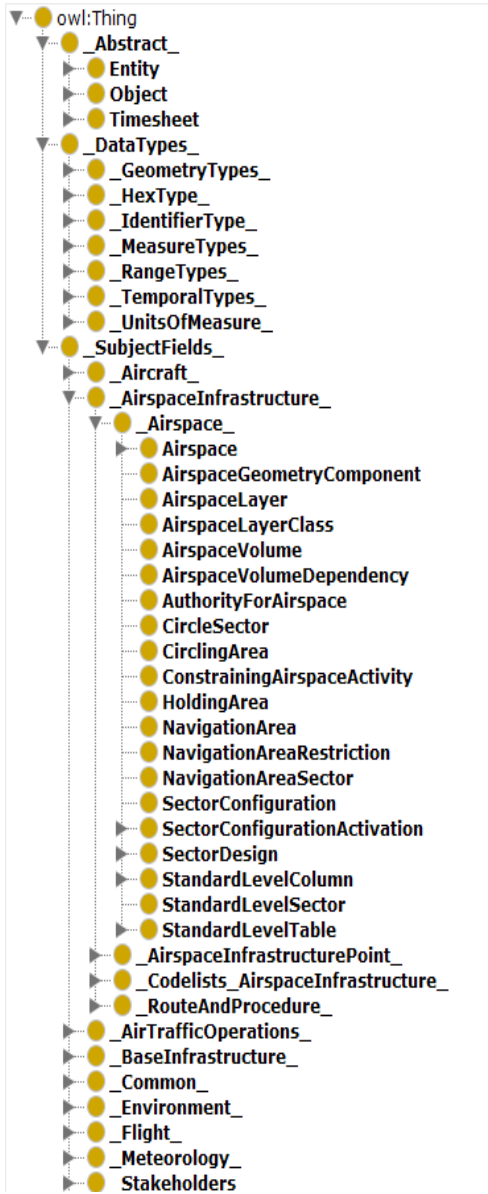
### (4) Ontology Construction in Air Traffic Management

Aiming at large-scale automatic construction of ontology in air traffic management, the automatic conversion rules and evaluation standards from UML to OWL are designed to realize the construction and optimization of the ontology.



## 2. Specific Methodology

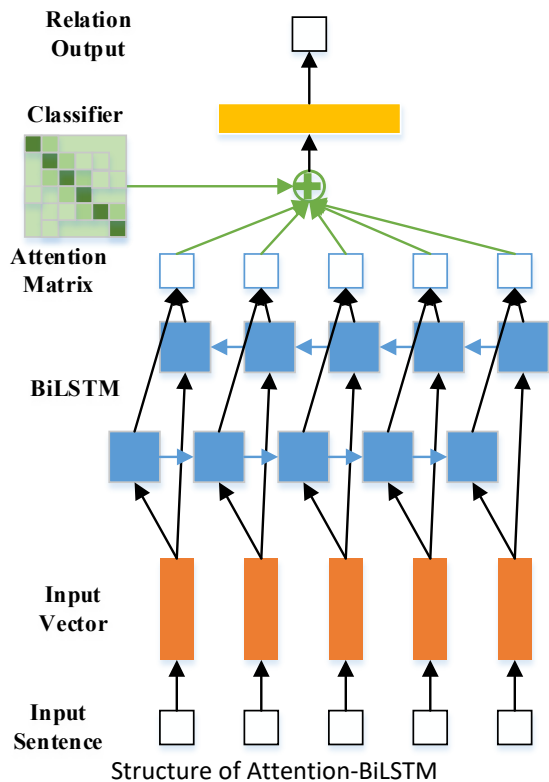
### (4) Ontology Construction in the Air Traffic Management Field



## 2. Specific Methodology

### (5) Knowledge Extraction

The body of the airport alert describes the type of weather, its appearance and duration, changes in weather conditions, changes in visibility, affected areas and locations. For this information, use entity extraction technology to extract the entities, and then identify the relationship between the entities.



Knowledge Extraction Mode

#### 机场气象警报

在北京机场西面52km处有对流云团，云团直径50km，云团顶高10km，以40km/h向东移动，强度无变化，预计北京时间10:10-11:10有雷暴伴随中雨影响北京机场。



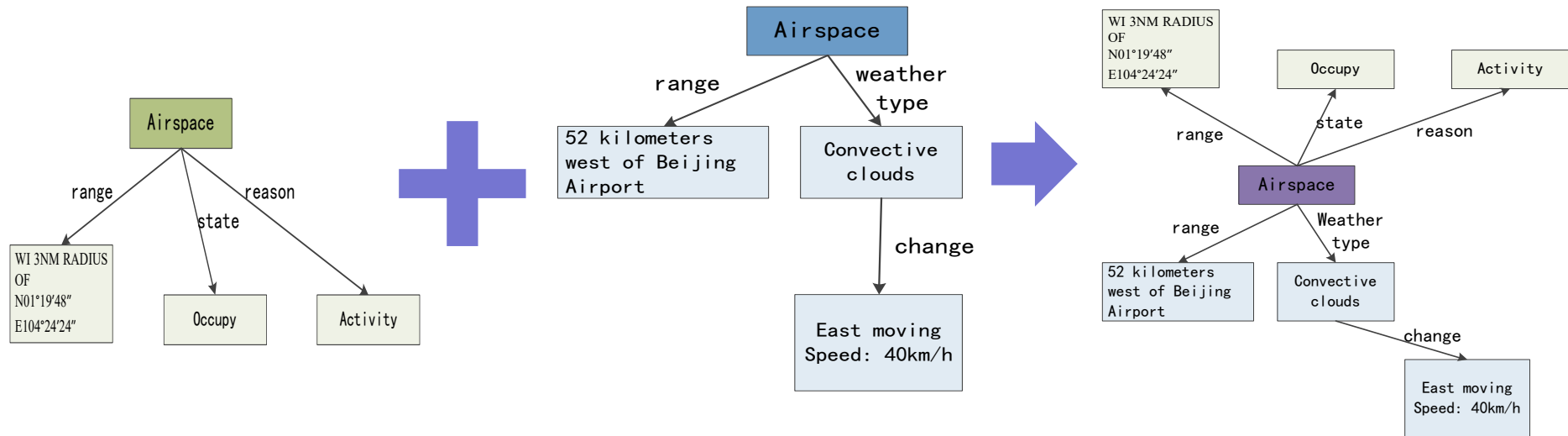
#### Weather Warning for Airport

There is a convective cloud group 52km west of Beijing Airport. The cloud group has a diameter of 50km and a cloud top height of 10km. It moves eastward at 40km/h with no change in intensity. It is expected that there will be thunderstorms with moderate rain from 10:10-11:10 Beijing time. Affect Beijing Airport.

## 2. Specific Methodology

### (6) Knowledge Fusion

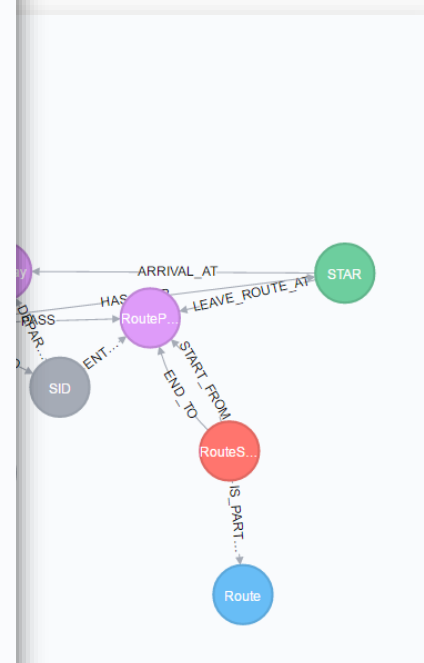
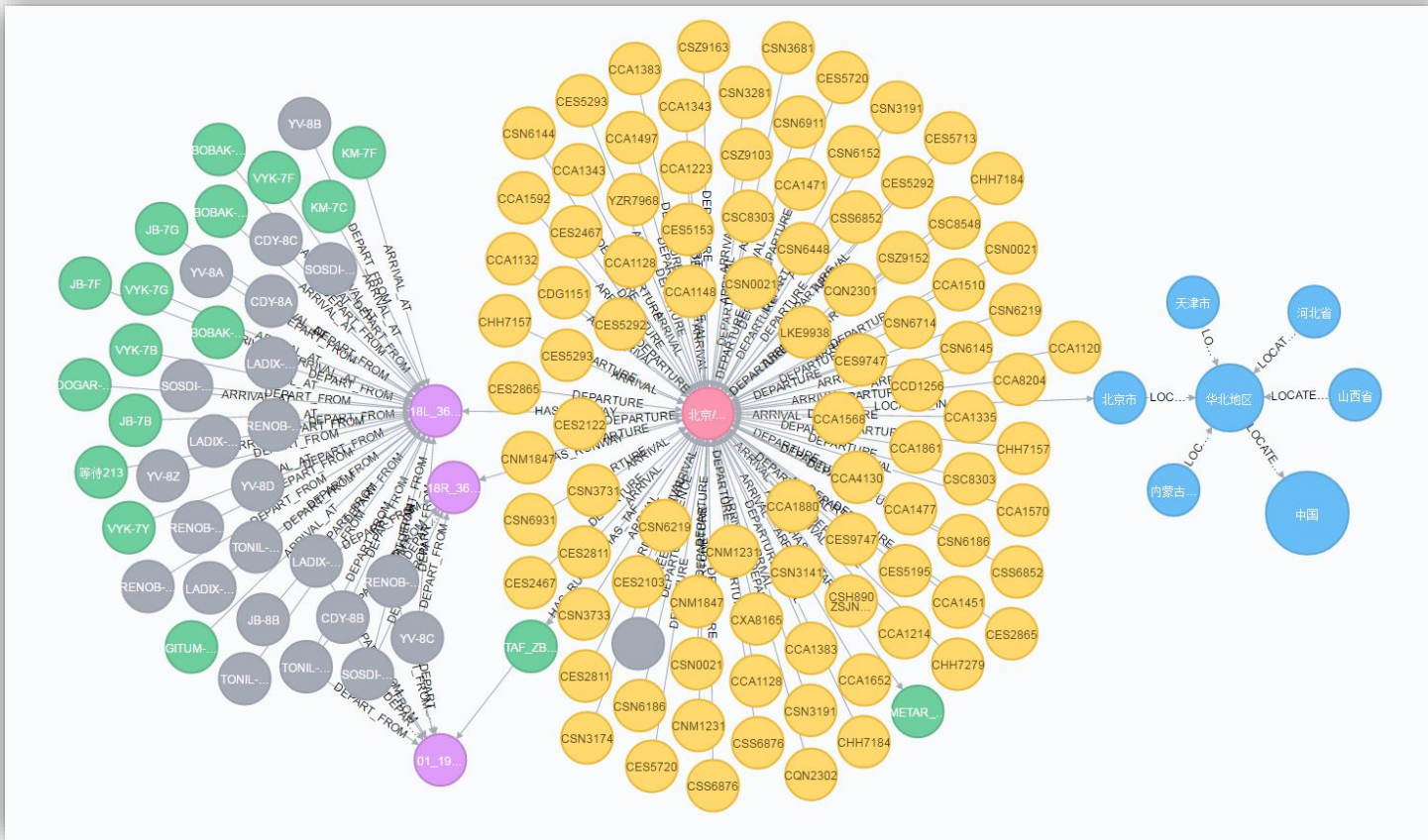
Different kinds of knowledge are merged to build a large knowledge graph.



## 2. Specific Methodology

### (7) Air Traffic Management Knowledge Graph Construction Results

Graph scale: 22 categories, 20,000+ entities, 50,000+ relationships



ontology based graph modeling





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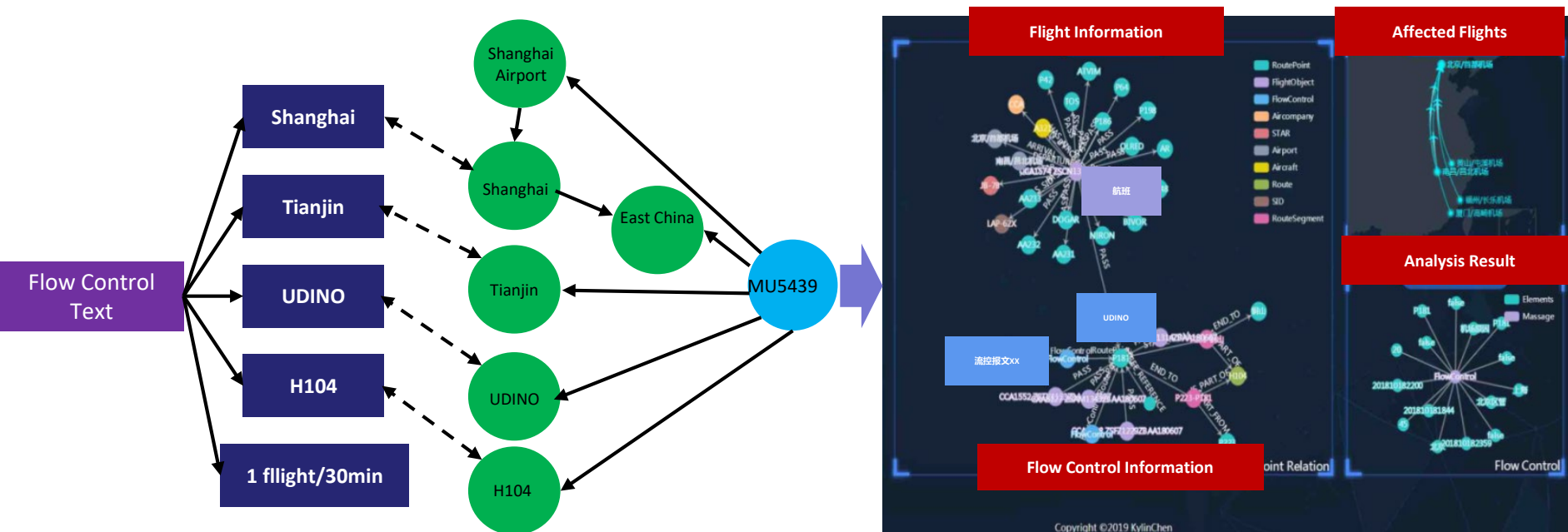
**Final Conclusion**



### 3. Method Application

## (2) Knowledge Graph Application-flow Control Message Analysis and Delay Prediction

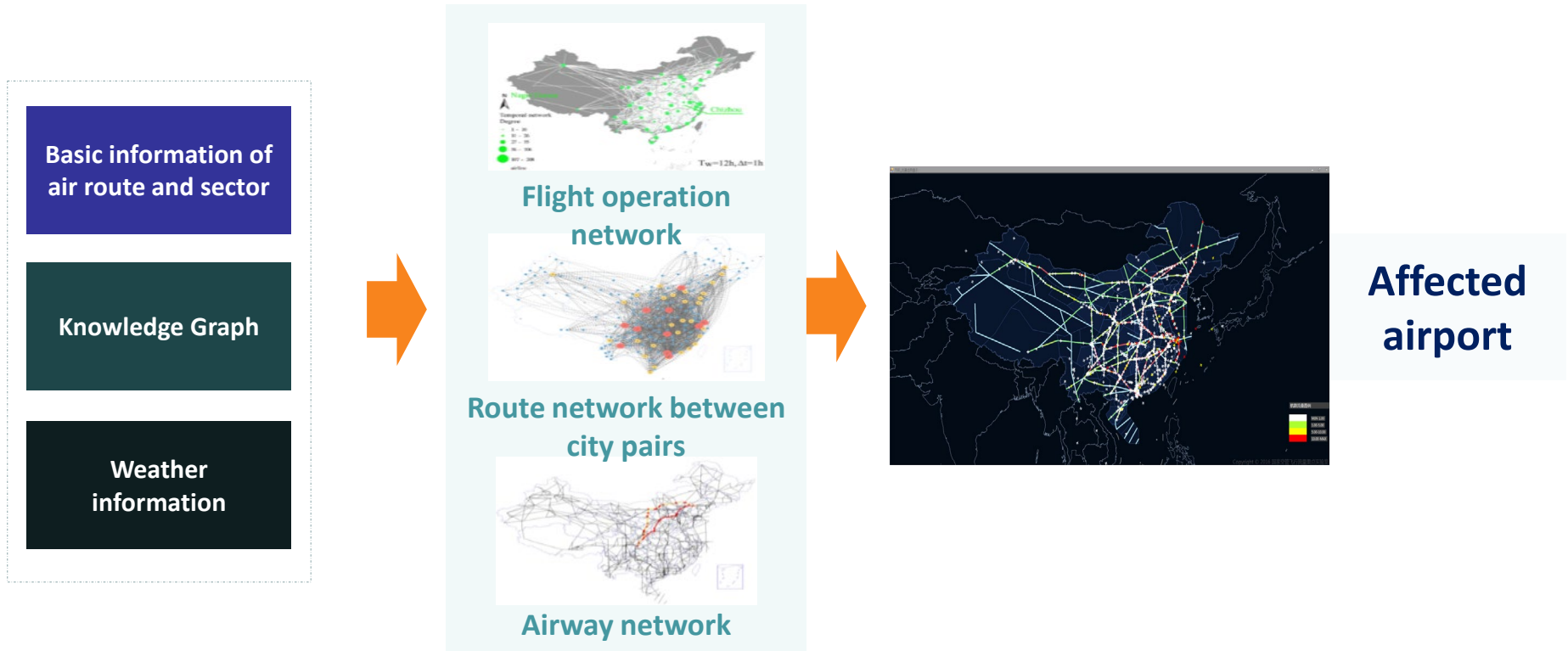
We implemented the analysis of the impact of flow control on flight delays in three steps. Firstly, the Beijing airport delay data and the parsed flow control message are added to the knowledge graph. Secondly, the training sets are generated from the flight-related features newly added to the knowledge graph. Finally, The machine learning model is trained and used to calculate the affected flights.



### 3. Method Application

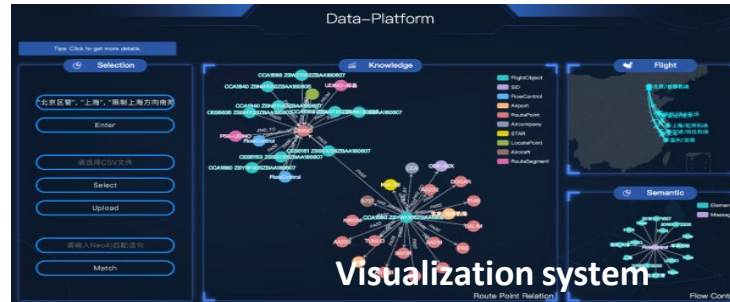
## (3) Application of Knowledge Graph-weather Message Analysis

Based on the weather information, flight delay propagation mechanism is studied, and the ability of the overall situation awareness of air traffic management system is improved.



# 3. Method Application

## (4) Framework



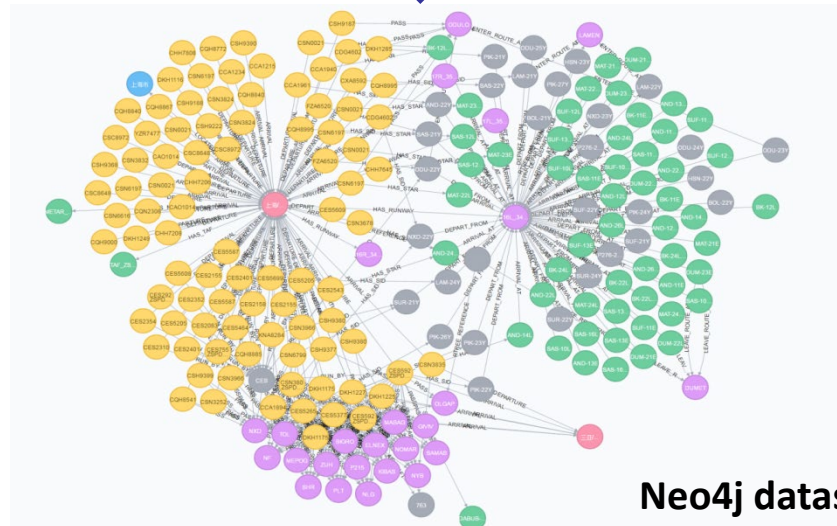
Intelligent analysis algorithm based on knowledge graph

Analysis of flow control packets

Weather warning analysis

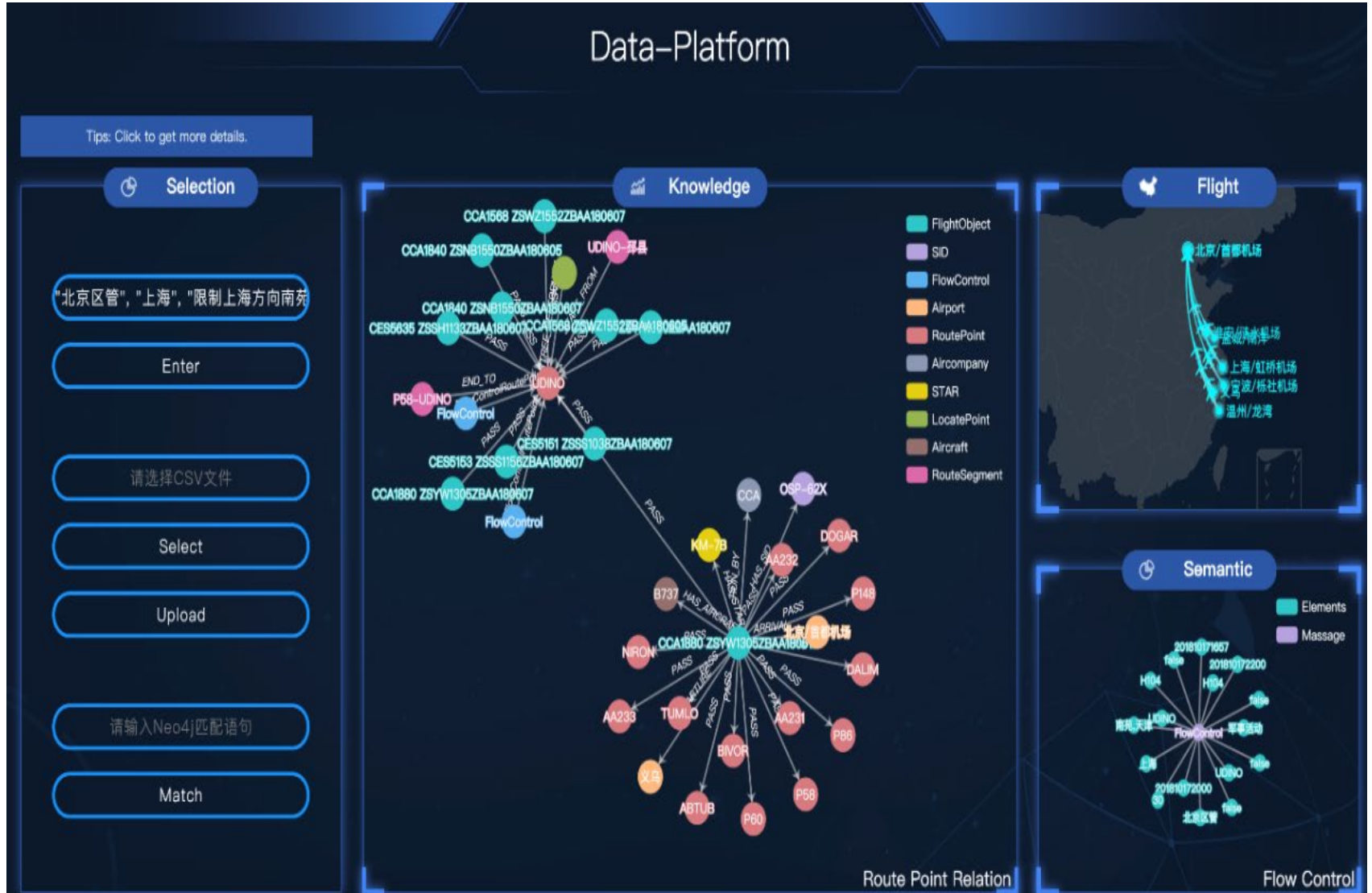
Intelligent retrieval algorithm

Delay prediction algorithm



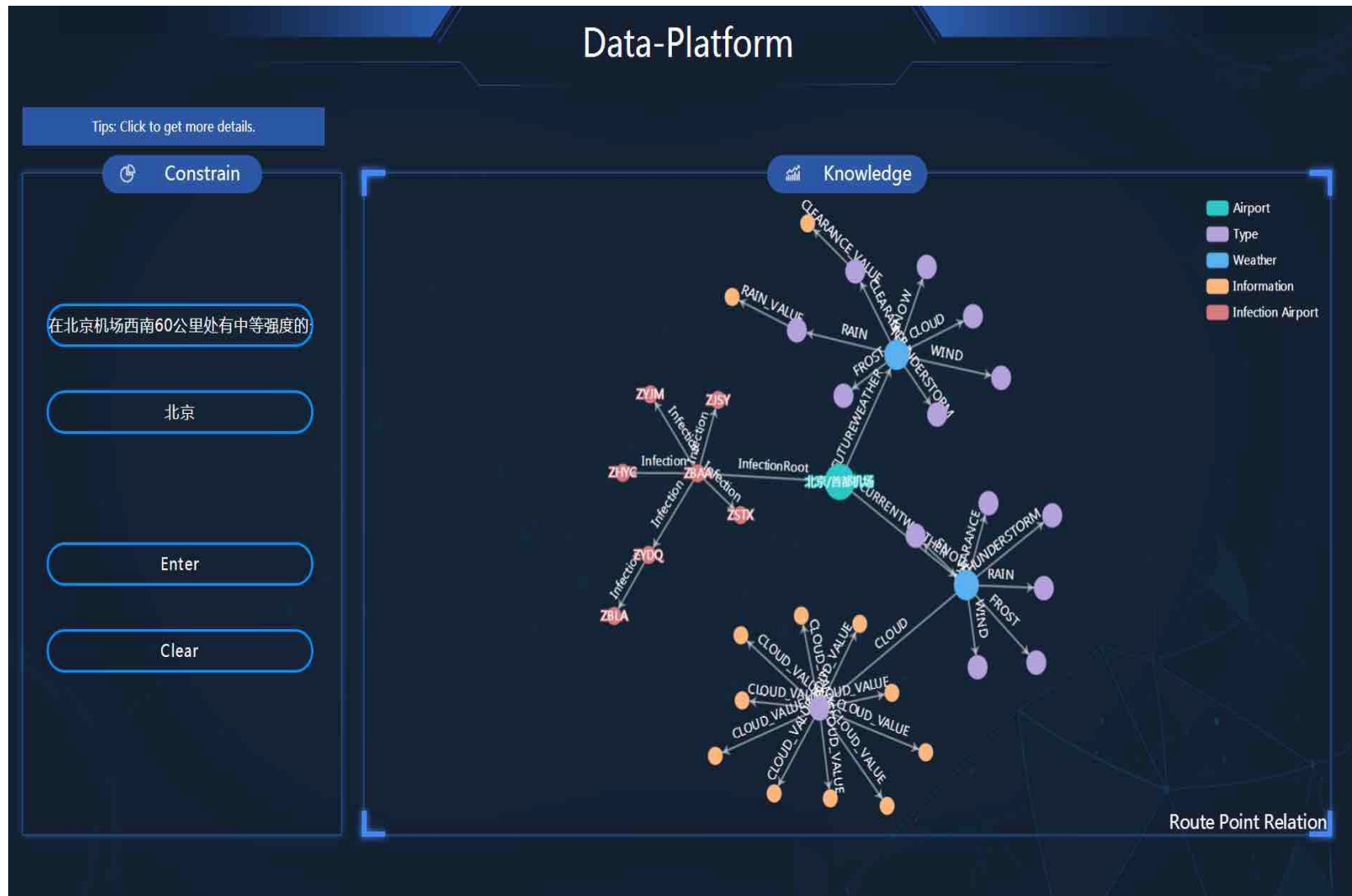
### 3. Method Application

## (5) Flow Control Message Analysis and Delay Prediction Interface



# 3. Method Application

## (6) Weather Warning Analysis Interface



# 3. Method Application

## (7) Smart Search Interface

Data-Platform

Tips: Click to get more details.

**Constrain**

中国

Enter

输入格式如下:  
搜索类别:具体名字

举例:  
Airport:ZUUU

**Knowledge**

Legend:  
District (Red)  
WebService (Green)  
Country (Blue)

The graph shows a central node '中国' (China) connected to regional nodes: '华北地区', '华中地区', '华东地区', '华南地区', '西南地区', '西北地区', and '东北地区'. Each regional node is further connected to specific service nodes. For example, '华北地区' is connected to '华北实况层查询信息MIT', '华北Meter', '华北气象咨询服务', '华北Taf', '华北流量管理GDP', and '华北预测层信息TSA'. '华东地区' is connected to '华东实况层信息TSA', '华东气象咨询服务', '华东Taf', '华东电子航行通告', '华东Motor', and '华东空域征用计划NOTAM'. '华中地区' is connected to '华中气象咨询服务' and '华东预测层信息NOTAM'.

Les Miserables



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## 4. Final Conclusion

Knowledge graph will enhance the ability of air traffic management system in the following aspects:





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**Thank you!**