International Civil Aviation Organization

The Third Meeting of System Wide Information Management Task Force (SWIM TF/3)

Bangkok, Thailand, 07 – 10 May 2019

Agenda Item 3: d) Task 1-4: SWIM governance

SEMANTIC TECHNOLOGIES IN THE CONTEXT OF SWIM

(Presented by USA, Federal Aviation Administration (FAA))

SUMMARY

This paper surveys how Semantic Web technologies are used in the aviation community and introduces an open repository (semantics.aero) as a platform to facilitate collaboration among Semantic Web technology practitioners in the SWIM community.

1. INTRODUCTION

1.1. *Semantics* is the study of meaning. *Semantic technologies* utilize the meanings of computational data by representing meaning separately from data content and application code, and by establishing a common format for combining information from various sources of data.

1.2. The Semantic Web is an extension of the current Web that utilizes semantic technologies and services. It allows the integration of online information which was not previously connected by creators, and it provides a way for machines to derive meaning from information available on the Web. [1]

1.3. A challenge to effective data sharing within the global aviation community is that stakeholders use organization-specific and independently managed data models, messaging standards, and business vocabularies. Semantic technologies offer a foundation for integrating these inherently heterogeneous sources.

1.4. In this paper, we survey how Semantic Web technologies are used in the aviation community, and we introduce an open repository of semantic artifacts (semantics.aero) as a means for facilitating collaboration among practitioners in the SWIM community.

2. DISCUSSION

2.1. Background

2.1.1. Semantic Web technologies enable software agents to understand the meaning of the data exchanged between services. Central to these technologies is the Resource Description Framework (RDF) [2], an extensible and flexible standard model for data interchange.

2.1.1.1. RDF is used to describe and model resources. At its most generic level, a resource is any item of interest in the context of an information domain. Examples of resources include a document or file (e.g., a Web page or an image) or a concept or “thing”, such as a flight, a runway or a SWIM service.

2.1.1.2. Resources and their relationships are unambiguously identified across the entire Web using Universal Resource Identifiers (URI). [3] Furthermore, relationships among concepts can serve as links to allow a software agent to navigate from one resource to related resources, forming a web of linked data. [4] An example is shown in Figure 1.

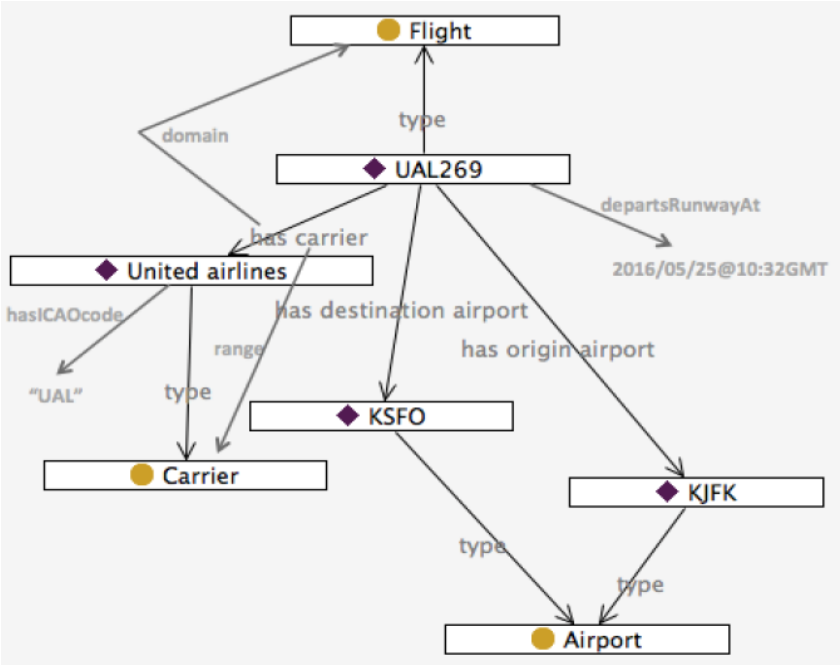

Figure 1 Linked data describing a flight[1]

2.1.1.3. Together, URI and RDF allow the development of flexible and extensible data models that scale as the World-Wide Web itself.

2.1.2. RDF is used to develop machine-understandable vocabularies. In these cases, resources being modeled are concepts within an information domain. Depending on the business needs, the vocabularies can have different degrees of expressiveness.

2.1.2.1. A controlled vocabulary (CV) is the simplest type of such vocabularies. A CV is a managed list of terms (concepts) that have been enumerated explicitly. Organization policies often require that only terms in the CV be used in a domain.

2.1.2.2. A taxonomy is a controlled list of concepts organized as a hierarchical structure for categorizing or classifying objects. Taxonomies are commonly used to facilitate the search, administration, and analysis of a large collection of entities. A taxonomy of Flight Phases is shown in Figure 2.

[1] Source: Keller, Richard M. "Ontologies for aviation data management." IEEE/AIAA 35th Digital Avionics Systems Conference (DASC). IEEE, 2016.

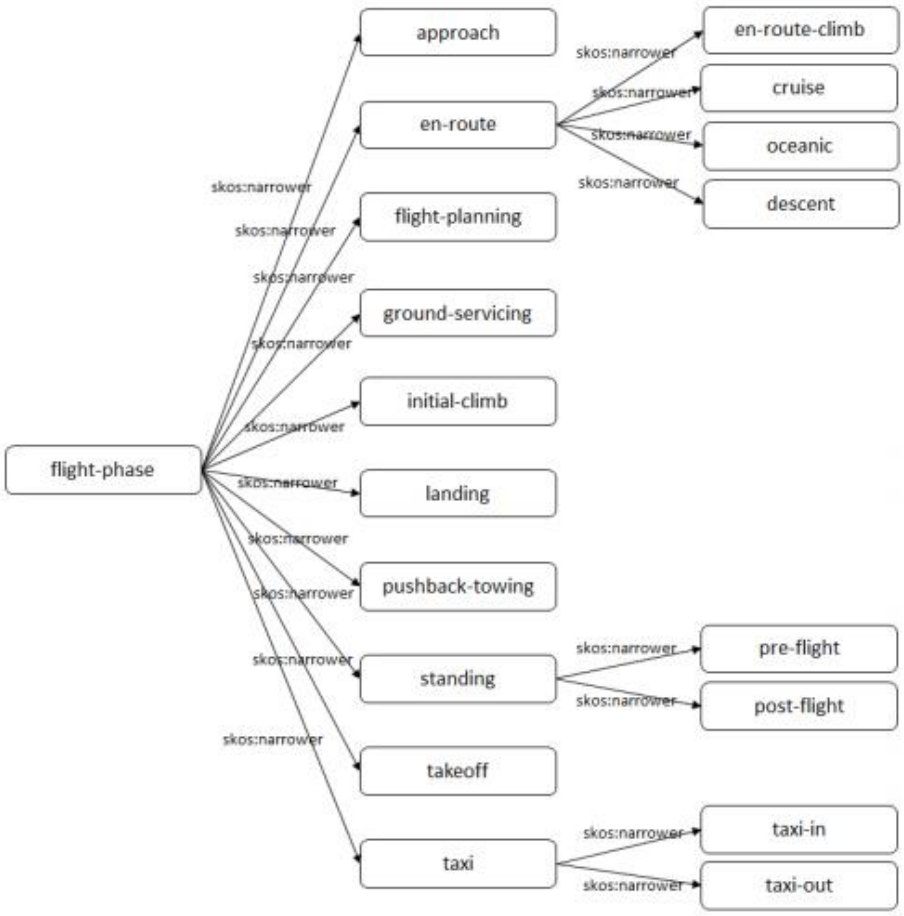

Figure 2 Flight Phase Taxonomy

2.1.2.3. CVs and taxonomies often follow the Simple Knowledge Organization System (SKOS) standard [5], a standard for organizing concepts using RDF.

2.1.2.4. An ontology is a set of concepts and categories in a subject area or domain that shows their properties and the relations between them. Ontologies are the most expressive and the most complex form of such vocabularies. Based on the Web Ontology Language (OWL) standard [6], they can represent rich and complex knowledge about things, groups of things, and relations between things. The example in Figure 1 is based on a fragment of US National Aeronautics and Space Administration's (NASA) Air Traffic Management Ontology. [7]

2.2. Semantic Web Technologies in the Aviation Community

2.2.1. The benefit of vocabularies based on Semantic Web technologies has been long recognized by the aviation community. There have been several efforts to develop semantic data models and vocabularies for aviation data exchanges.

2.2.1.1. FAA has developed a SWIM Controlled Vocabulary (SWIM CV) with the goal of giving FAA organizations, support contractors, vendors, and business partners a uniform understanding of terms employed in the SWIM environment. The CV contains a comprehensive list of terms with clear and unambiguous definitions. Each term is globally uniquely identified by a dereferenceable URI so that it can be related semantically to other terms, vocabularies, or resources. [8]

2.2.1.2. The NASA ATM ontology, shown in Figure 1, supports integration, query, and search over multiple sources of heterogeneous ATM data.

2.2.1.3. FAA and the Single European Sky ATM Research (SESAR) have jointly developed SKOS-based taxonomies to classify SWIM services by the type of data products delivered, service availability status, and service interface type. [9] These taxonomies are used to help describe services published in FAA's and EUROCONTROL's SWIM registries.

2.2.1.4. FAA has developed the Web Service Description Ontological Model (WSDOM) [10], based on standards such as OWL-S [11]. WSDOM is a basis for model-driven implementation of a service description.

2.2.1.5. The Open Geospatial Consortium (OGC) has produced a number of taxonomies using SKOS under its Interoperability Testbed program. Examples include taxonomies for US Airways, ICAO Regions, US Flight Information Regions, and Airspace Classes. [12]

2.2.2. Instead of requiring organizations to agree on the same message format and business vocabulary before exchanging data, semantic technologies can help bridge the differences in data models and terminologies.

2.2.2.1. For example, based on their own SWIM governance processes, FAA and SESAR have defined different terminologies for expressing lifecycle stages for services published in their respective registries. In developing a mechanism for exchanging service description data between their registries, FAA and SESAR used the SWIM service availability status taxonomy to ensure that service lifecycle stages are interpreted correctly despite the terminology difference, as illustrated in Figure 3. [13]

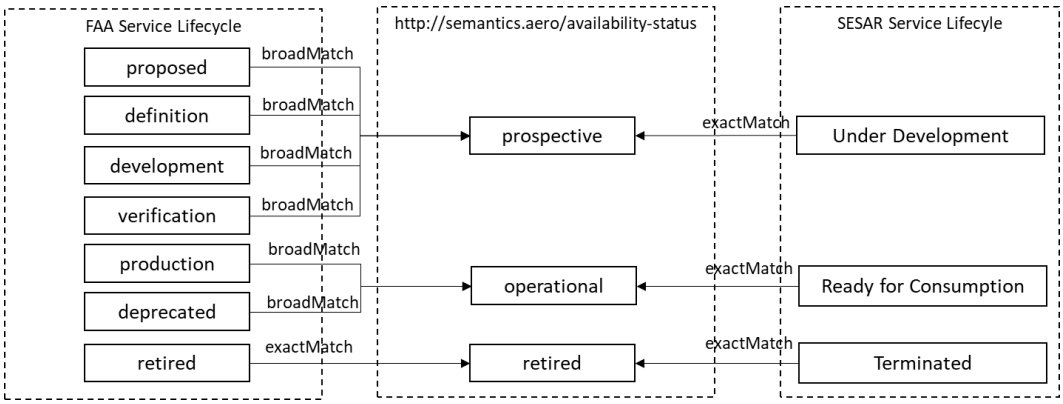

Figure 3 Mapping FAA and SESAR Service Lifecycles to Common Taxonomy by using SKOS-defined relationships

2.3. Semantics.aero

2.3.1. Semantic data models and vocabularies are usually published in repositories that are easily accessible by both human users and software agents.

2.3.2. Consistent with Semantic Web best practices, these repositories ensure that URIs identifying the concepts are *dereferenceable*[2], i.e., the URI resolves to a document that directly or indirectly describes that concept. [14] For example, when a URI such as http://semantics.aero/availability-status is requested by a software agent such as a browser, the repository should return an appropriate document representing the concept, such as a machine-readable version of the Service Availability Status taxonomy.

2.3.3. For example, the repository may return the RDF document shown in Figure 4 when the URI http://semantics.aero/availability-status operational is requested by a software agent:

[2] URI Dereferencing is the process of looking up a URI on the Web in order to get information about the referenced resource. See [15]

```
as:operational a skos:Concept;
    skos:prefLabel "operational"@en;
    skos:altLabel "运行"@zh;
    skos:definition "This status indicates that the
service is employed in its operational environment,
monitored for satisfactory performance, and modified as
necessary to correct problems or to respond to changing
requirements."
```

Figure 4 RDF Representation of a concept

2.3.4. FAA has established http://semantics.aero as an open repository and has made it available for use by the aviation community to publish artifacts developed using Semantic Web technologies. Nine SWIM taxonomies and a controlled vocabulary have already been published at semantics.aero, as described in the Appendix.

<table>
<tr><td colspan="3">Daft Conclusion/Draft Decision/Decision XX/XX - SEMANTIC TECHNOLOGIES IN THE CONTEXT OF SWIM</td></tr>
<tr><td colspan="2">What: Semantic Web technologies is an important element of the APAC SWIM interoperability approach.</td><td>Expected impact:
☐ Political / Global
☐ Inter-regional
☐ Economic
☐ Environmental
☒ Ops/Technical</td></tr>
<tr><td>Why: Semantic Web technologies can enable effective data sharing within the APAC aviation community.</td><td colspan="2">Follow-up: ☐Required from States</td></tr>
<tr><td>When: 6-May-19</td><td colspan="2">Status: Draft to be adopted by PIRG</td></tr>
<tr><td colspan="3">Who: ☒Sub groups ☒APAC States ☐ICAO APAC RO ☐ICAO HQ ☐Other: XXXX</td></tr>
</table>

3. ACTION BY THE MEETING

3.1. The meeting is invited to:

3.1.1. Review the contents of this working paper;

3.1.2. Consider Semantic Web technologies as part of the APAC SWIM interoperability model; and

3.1.3. Encourage the APAC SWIM community to leverage semantics.aero for collaboration.

REFERENCES

[1] Mark Kaplun, “Semantic Technologies – Introduction and Perspectives in FAA”, Presented at Air Transportation Information Exchange Conference, August 2011 http://aixm.aero/sites/aixm.aero/files/imce/library/ATIEC_2011_08/33_day3breakoutsession_introduction_to_semantics.pdf

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https://www.w3.org/TR/owl-features/

[7] Richard M. Keller, The NASA Air Traffic Management Ontology (atmonto), March 2018
https://data.nasa.gov/ontologies/atmonto

[8] FAA, SWIM Controlled Vocabulary, November 2014
https://www.faa.gov/air_traffic/technology/swim/vocabulary/

[9] Available at http://semantics.aero

[10] FAA, Web Service Description Ontological Model (WSDOM)
https://www.faa.gov/air_traffic/technology/swim/governance/service_semantics/

[11] Martin, David, et al. "OWL-S: Semantic markup for Web services." W3C member submission 22.4 (2004).
https://www.w3.org/Submission/OWL-S/

[12] OGC Testbed-13: Geospatial Taxonomies ER, 2018-01-11, OGC, January 2018
http://docs.opengeospatial.org/per/17-036.html#_terms_and_definitions

[13] FAA, SESAR, Registry Integration Module (RIM) 1.0.0, Implementation Specification October 2017
http://swim.aero/rim/

[14] Mark Kaplun, Guidelines for SWIM Service Identifiers, to be presented at APAC SWIM TF/3

[15] W3C, Dereferencing HTTP URIs, Draft Tag Finding, August 2007
https://www.w3.org/2001/tag/doc/httpRange-14/2007-08-31/HttpRange-14

APPENDIX SEMANTICSAERO

As shown in Figure 4, a number of semantic artifacts, such taxonomies and controlled vocabularies, have already been published on semantics.aero. For each artifact, both human-readable (HTML) and machine-readable versions (RDF) are provided, as shown in Figure 5 and Figure 6.

semantics.aero

Introduction

This document defines the namespace `http://semantics.aero`. It also serves as an open repository for use by the international aviation community to publish artifacts developed using Semantic Web technologies.

Resources

Taxonomies

SWIM Service Product	A classification of services based on the type of SWIM data product that they deliver.	RDF	HTML
Service Availability Status	A classification of services based on their current, past, or future availability for provisioning.	RDF	HTML
Service Interface Type	A classification of services based on the type of technological solution that they deploy.	RDF	HTML
Flight Phase	A classification of services or other artifacts based on the flight phase, or period within a flight, during which the artifacts are used or provide support. See also [1].	RDF	HTML
US Airways	A classification of US Airways based on airway identification prefixes. See also [2].	RDF	HTML
ICAO Region	A classification of geographical regions as defined by the International Civil Aviation Organization (ICAO). See also [2].	RDF	HTML
US Flight Information Region	A classification of the US Flight Information Regions as defined by the International Civil Aviation Organization (ICAO). See also [2].	RDF	HTML
Airspace Class	A classification of airspaces as defined and applied by the US Federal Aviation Administration (FAA). See also [2].	RDF	HTML

Controlled Vocabularies

SWIM Controlled Vocabulary	A list of concepts employed in Federal Aviation Administration (FAA) implementation of System-Wide Information Management (SWIM). Each concept is uniquely identified and has an unambiguous, non-redundant definition. See also [3].	RDF	HTML

References and Publications

[1] Notes on the Flight Phase Taxonomy, FAA, Carol Uri, January 2018

[2] OGC Testbed-13: Geospatial Taxonomies ER, 2018-01-11, OGC, January 2018

[3] Guidelines for Using the SWIM Controlled Vocabulary, FAA, Carol Uri, February 2019

Last modified at 2019-04-01. Please contact info@semantics.aero for questions and comments.

Figure 5 semantics.aero home page

Taxonomy Metadata Attributes

title:	Service Availability Status
identifier:	http://semantics.aero/availability-status
description:	A classification of services based on their current, past, or future availability for provisioning.
version:	2.0.1
creator:	Carol Uri (The SEMCON Group, LLC)
creator:	Mark Kaplun (FAA)
creator:	Wen Zhu (NIRA Inc.)
creator:	Pedro Fernandez Sancho (EUROCONTROL)
publisher:	FAA-SESAR CP2.1
date issued:	2018-01-02
format:	HTML

Concepts

availability status

URI:	http://semantics.aero/availability-status#availability-status
Preferred Label:	availability status
Alternative Label:	服务可用性状态
Alternative Label:	service availability status
Definition:	An indication of the service's availability for provisioning.
Narrower:	prospective
Narrower:	operational
Narrower:	retired

prospective

URI:	http://semantics.aero/availability-status#prospective
Preferred Label:	prospective
Alternative Label:	预期
Definition:	This status indicates that the service is being designed, developed, or tested for operational activities and is expected to be available in the future

Figure 6 Human-readable version of Service Availability Status Taxonomy

```
@base <http://semantics.aero/availability-status>.

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>.
@prefix owl: <http://www.w3.org/2002/07/owl#>.
@prefix dc: <http://purl.org/dc/elements/1.1/>.
@prefix skos: <http://www.w3.org/2004/02/skos/core#>.
@prefix as: <http://semantics.aero/availability-status#>.

<http://semantics.aero/availability-status>
        rdf:type owl:Ontology;
        dc:title "Service Availability Status"@en;
        dc:alternative "服务可用性状态"@zh;
        dc:version "2.0.1";
        dc:description "A classification of services based on their current, past, or future availability for provisioning.";
        dc:creator "Carol Uri (The SEMCON Group, LLC)";
        dc:creator "Mark Kaplun (FAA)";
        dc:creator "Wen Zhu (NIRA Inc.)";
        dc:creator "Pedro Fernandez Sancho (EUROCONTROL)";
        dc:publisher "FAA-SESAR CP2.1";
        dc:issued "2018-01-02";
        skos:changeNote [
                rdf:value "Added Chinese labels for terms."@en;
                dc:publisher "FAA";
                dc:date "2018-02-27"
        ];
        dc:format "RDF".

as:availability-status a skos:Concept;
        skos:prefLabel "availability status"@en;
        skos:altLabel "service availability status"@en;
        skos:altLabel "服务可用性状态"@zh;
        skos:definition "An indication of the service's availability for provisioning.";
        skos:narrower as:prospective;
        skos:narrower as:operational;
        skos:narrower as:retired.

as:prospective a skos:Concept;
        skos:prefLabel "prospective"@en;
        skos:altLabel "预期"@zh;
        skos:definition "This status indicates that the service is being designed, developed, or tested for operational activities and
is expected to be available in the future.".

as:operational a skos:Concept;
        skos:prefLabel "operational"@en;
        skos:altLabel "运行"@zh;
        skos:definition "This status indicates that the service is employed in its operational environment, monitored for satisfactory
performance, and modified as necessary to correct problems or to respond to changing requirements.".

as:retired a skos:Concept;
        skos:prefLabel "retired"@en;
        skos:altLabel "退休"@zh;
        skos:definition "This status indicates that active support for the service has been withdrawn, the service has been partially
or totally replaced by a new service, or an upgraded service has been installed.".
```

Figure 7 Machine-readable version of the Service Availability Status Taxonomy