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Authors: Emre ÇİNTAŞ, Barış ÖZYER, Y. Sinan HANAY
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Ontology-based Instantaneous Route Suggestion of Enemy Warplanes with Unknown Mission Profile

Emre ÇİNTAŞ[*1,3], Barış ÖZYER[2], Y. Sinan HANAY[3]

Abstract

The routes of warplanes are planned confidentially, and they are not shared with any organization in advance. In some cases, border violations may occur, and as a result, it increases the tension between two states. This situation puts many people at risk and impairs the prestige of the state both economically and socially. In this paper, Ontology-Based Instantaneous Route Suggestion System (SUARSIS) based on semantic approach is proposed to predict and plan routes of warplanes before they reach their target. In the proposed system, we developed an architecture called Ontology-based Route Suggestion by using the OWL (Web Ontology Language) language with realistic data. The aircraft model, aircraft fuel system, features of the military field, and the relations in the semantic context are logically defined through ontology. Synthetic scenarios were created to validate the accuracy of the proposed method. Experimental results show that the proposed system has a good performance on predicting warplane routes.

Keywords: Route suggestion system, semantic web, ontology, intelligent search engines, warplanes

1. INTRODUCTION

Aircraft follow predetermined routes in flight around the world. States share their airspace data with the International Civil Aviation Organization (ICAO) and the European Organization for the Safety of Air Navigation (EUROCONTROL). The headquarters of ICAO is in Montreal, Canada, and the headquarters of EUROCONTROL is located in Brussels, Belgium. Each country defines short, medium, and long-term flight strategies, developing the set routes based on the intended use of the aircraft. Predetermined trajectories are registered in aircraft radar systems, allowing for individual users to track these predetermined aircraft routes via respective web applications [1]. However, it requires a completely different procedure for warplanes. Routes of warplanes are not shared with other countries, keeping them confidential to protect the political, social, and economic interests of individual countries and to ensure security.

*Corresponding Author: emrecintas@atauni.edu.tr
[1]Atatürk University, Department of Computer Engineering, Erzurum, Turkey.
ORCID: https://orcid.org/0000-0002-4954-5816
[2]Atatürk University, Department of Computer Engineering, Erzurum, Turkey. E-Mail: baris.ozyer@atauni.edu.tr, ORCID: https://orcid.org/0000-0003-0117-6983
[3]Erzurum Technical University, Department of Computer Engineering, Erzurum, Turkey. E-Mail: sinan.hanay@erzurum.edu.tr, ORCID: https://orcid.org/0000-0002-3331-5936

A warplane may change its regular and predetermined routes, violating the borders of neighboring countries even under conditions other than special ones like terror and war. A border violation may provoke international tension in countries sensitive to geopolitical fluctuations. A critical step in analyzing the tension to determine whether the act is intentional. In this paper, our goal is to estimate warplane routes based on semantic rules and ontology. In this context, very limited and irregular ontologies are developed in the military domain [2]. To the best of our knowledge, there is no research in the literature based on the ontology and semantic approach to estimate the routes of enemy warplanes according to aircraft propellant model and maximum range calculations and suggest routes. In this study, we have proposed a real warplane ontology database by using real-world military data. We have developed a platform-independent application; which predicts flight routes (PFR) and proposes flight routes (PRFR) by using the ontology data.

The main objective of a semantic web [3] study is to create ontologies specific to the field of study and to ensure their utilization in information systems. Ontologies allow the machines to interpret knowledge in a manner understandable to humans, facilitating communication among people. The basic objective of the ontology development is to create a common dictionary, serving for information sharing in a specific field. Much research on ontology in the healthcare domain has been studied in the literature during the last decades [4]. Ontologies developed in the healthcare field are used in making diagnoses, offering preventive measures, and recommending proper foodstuff relevant for particular diseases [5]. According to Çelik's research project on mobile safe food consumption system (FoodWiki) [5], it is discussed that it performs its inference semantic rules in its knowledge base. The developed rules examine the side effects that are causing some health risks: heart disease, diabetes, allergy, and asthma as initial. In another research [6] a semantic-based information extraction system was proposed to match resumes with business areas. The system planned to operate on several million free-format textual resumes to convert them to a semantically enriched version.

On the other ontology research, Samperetal [7] use ontologies to associate traffic information, and support users with visualization and search tasks. They define a road traffic ontology, covering vehicle and road classifications, geography, location, people, events, and routes. Recently, the semantic web using for products such as Good Relation ontology [8], CEO (Consumer Electronics Ontology), and onto Product [9]. Product Types Ontology provides approximately 300,000 precise definitions for product types or services that extend the schema.org and Good Relations. Another large ontology knowledge bases have been created including DBpedia [10], Freebase [11], YAGO [12], Wikidata [13], NELL [14] and the Google Knowledge Graph [15]. Although they use different data formats to represent their data, most use an ontology graph structure.

Syntactic methods which do not have any semantic rules have been carried out in autonomous systems to estimate the route plans in the literature for several years. Tracking, estimation, and calculating the shortest route for aircraft or unmanned air vehicles are some popular studies interested by researchers [16-17-18]. In these studies, the well-known Potential Field Algorithm, Probabilistic Route Planning, Voronoi Diagrams, and Searching Algorithms have been implemented [19-20]. Coefficient rules and ant colony optimization algorithms were used to offer solutions for route planning problems [21-22] have combined genetic algorithms with local search heuristics in their study to determine the shortest route between two points in Turkey, covering destinations all over 81 provinces in the country [22]. Analyzing large data sets, Kasturi et al. (2016) [23] have determined key criteria for the aircraft and set new route plans. Data about the aircraft load, passengers, and airports were used for determining the key criteria. Bakhtyar and Holmgren (2015) [24] achieved to estimate new routes at a high level of precision based on the data of the previously used routes by mobile objects. Different from the studies in literature, we have utilized the semantic inference techniques instead of syntactic methods in our study. In our approach, we tested our scenarios to estimate possible routes of virtual enemy warplanes before they reached their destination. The studies in the literature address the aircraft with fully or partially known mission profiles only. Furthermore, no studies utilizing a semantic approach have been found in the literature, studying how to estimate the routes and destinations of an enemy warplane (EW) with an unknown mission profile and no studies have examined the best methods to propose new routes to pilots in the decision-making process.

Being motivated with these issues in mind; we propose an ontology-based, platform-independent system, called "Instantaneous Route Suggestion System for Warplanes" (SUARSIS). The system is based on semantic search and semantic inference techniques [3]. This proposed system has the following contributions given as below:

- A new real aircraft ontology database based on semantic rules was developed. In this database, propellant forces, aerodynamic parameters, flight range equations, manufacture values, and arms capacity of warplanes were used to develop the ontology and SWRL (Semantic Web Rule Language) rules.

- We propose an algorithm that analyzes the data obtained from the ontology and then it finds the possible routes of enemy aircraft to stakeholders.

- We developed a unique platform-independent SUARSIS software application using the Secondo system to simulate the estimated routes.

The rest of the paper is organized as follows. The details of the proposed SUARSIS system, ontology methods, SWRL rules, and algorithms are described in Section 2. Section 3 shows the experimental results of the proposed approach. Lastly, we conclude and discuss potential future directions for our study.

2. PROPOSED SUARSIS DESIGN

In the proposed SUARSIS application system, at first, we developed an ontology to be used in the field of warplane and military to suggest possible routes of the plane from databases. Then, we combined the ontology with Semantic Web techniques using OWL 2.0. The proposed system includes three main phases given as below:

1. **Aircraft Ontology Knowledge Base:** The system uses the ontology, to obtain all data about a selected EW in the selected scenario. Then, it searches the manufacturer specifications of that EW in the aircraft ontology. The ontology estimates and proposes the remaining amount of propellant in the aircraft along with its maximum flight range based on predefined semantic rules, concepts, and associations in the ontology. Proposed values are instantly transferred to the SUARSIS system.
2. **Suggestion Algorithm:** The algorithm intelligently analyzes the data obtained from the ontology along with the proposed data. Then, it proposes the possible routes of the EW to the relevant stakeholders. This set of information provides guidance to the pilot, the navigation officer, and the security intelligence units in tracking the proposed routes, making a decision, and obtaining counter-intelligence.
3. **Simulation with Secondo:** SUARSIS uses the platform-independent Secondo system to simulate proposed routes and provides them to stakeholders.

Synthetic scenarios for the ontology are generated in the proposed system to be used in a potential state of border violation. Manufacturer specifications of enemy warplanes (i.e. bomb mass, maximum loading capacity, the wing surface area, wingspan, and engine characteristics) and the propellant model of the aircraft system (i.e. propellant consumption) are used to define semantic rules with a logic-based approach. The average velocity and altitude of the aircraft, which are received from the radar, are added as a parameter in the semantic rule. We assume that the radar parameters including latitude, longitude, direction measurements are changed instantaneously.

The Semantic Web (Web 3.0) approach is used for determining the semantic rules and relations in the ontology. The flowchart of the proposed system is shown in Figure 1. The detailed information about the proposed model is provided in the following sections.

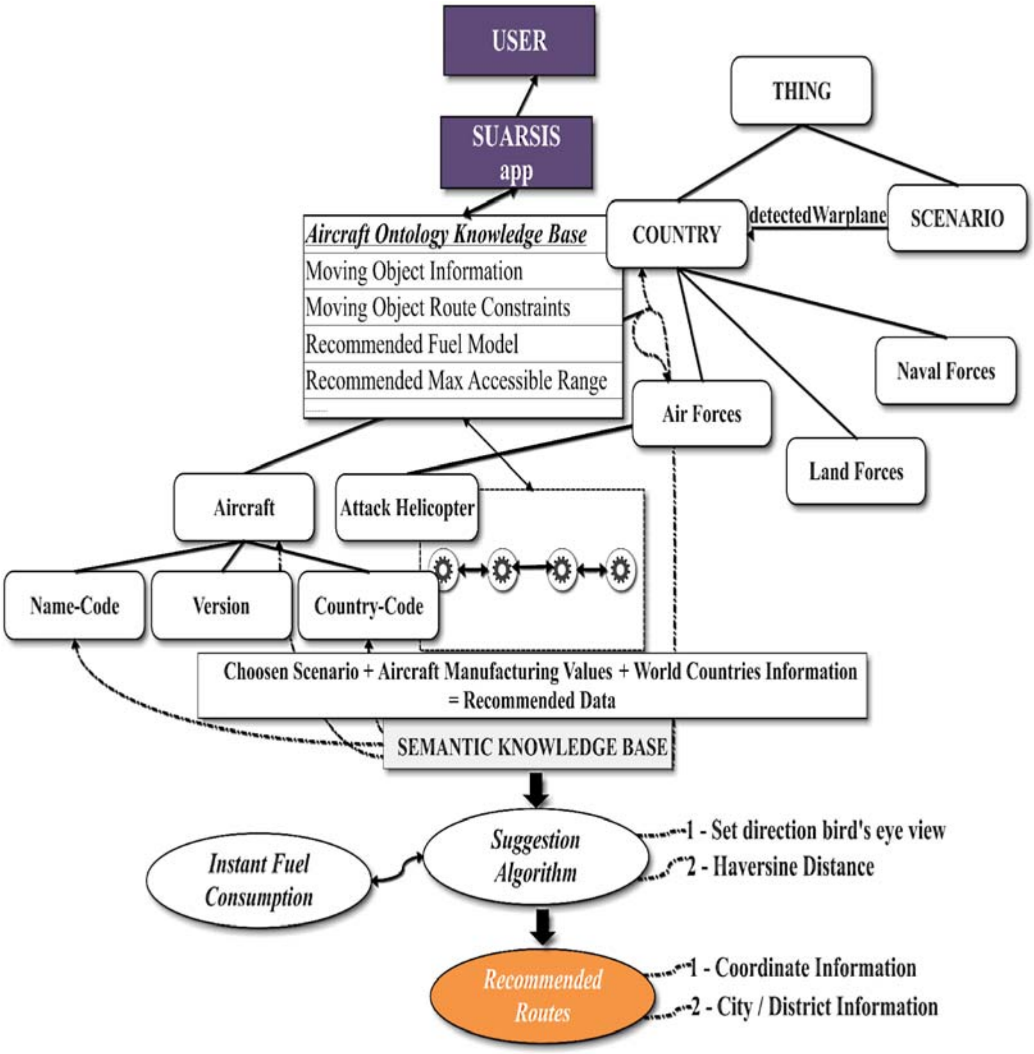

Figure 1 System working mechanism

2.1. Aircraft ontology knowledge-based and inference mechanism of the SUARSIS

Ontology is a new approach in information technologies to facilitate communication between people and allow interoperability computer systems. Also, ontologies aim to enable machines to understand the information in a manner interpreted by humans. In this context, we developed an authentic ontology database that comprises three main phases; semantic search, inference engine, and starting the engine as shown in Figure 2. In the semantic search phase, manufacture information of detected warplane is specified. These data are then transferred to the inference engine. In the next inference engine phase which is the main contribution of the study, the semantic rules are created in the ontology. After running the inference engine, semantic information is obtained according to the semantic rules. These obtained rules are transferred into the starting engine. In the last phase, the suggestion algorithm suggests aircraft routes that are simulated with SECONDO.

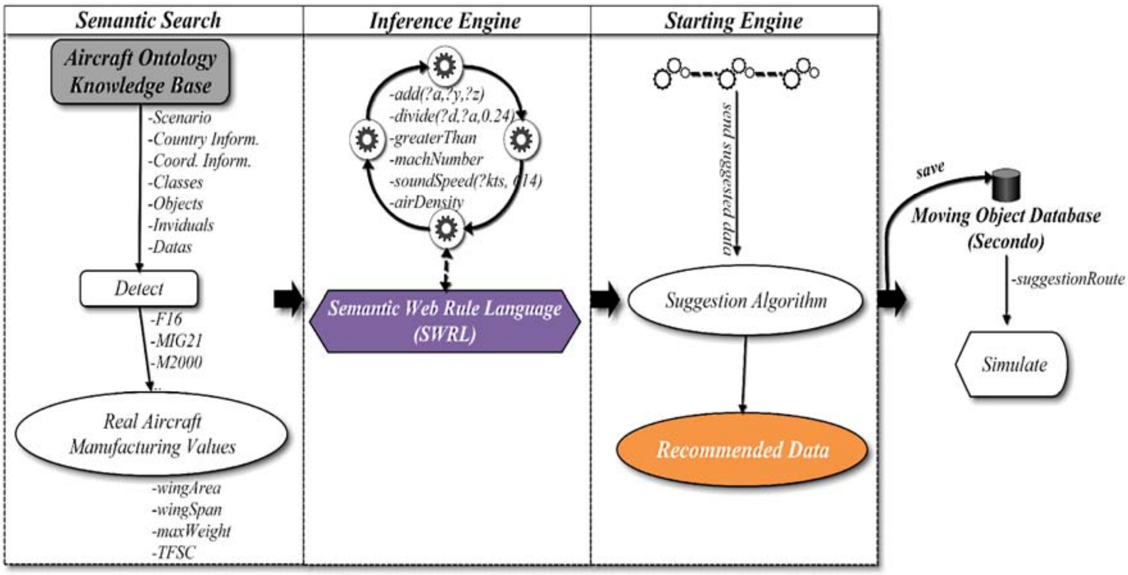

Figure 2 Semantic search, inference engine, and starting engine are the stages of developing an ontology knowledge base

The structure of the aircraft ontology and its respective semantic rules were developed in Semantic Web Rule Language (SWRL) which is a robust and deductive rule definition language [25] and Protégé (https://protege.stanford.edu/download) editor by using OWL2.0 web ontology language programming.

The semantic aircraft context are described in the aircraft ontology using OWL semantic tags such as <owl:class> <rdfs:subClassOf>, < owl: DatatypeProperty> and <owl:ObjectProperty> as semantic data contexts. Table 1 shows **80 concepts** and **246 components** in the aircraft ontology using OWL 2.0 web language such as "Country ", "City ", "Airforces"," Landforces", "Navalforces","Airport". For each concepts include sub-classes and properties. For instance, "Airforces" concept includes "Version", "ActivePieces", and "CountryName" sub-classes and "hasownAircrafts","specificfuelConsumptionofAircraft","isenemyAircraft ","requiredfuelforTakeoff" properties. The aircraft ontological data is comprised of the propellant model of EW such as air density, the speed of sound, maximum range etc. As an example of defining aircraft ontological rule is given by:

If(aircraftInstantAltitude>=34000.00 OR aircraftInstantAltitude<35000.00)}->Case:soundSpeed -> AIRCRAFT ONTOLOGY suggests the "579 kts"

where recommend "soundSpeed" is set to 579 kts in the case of instant aircraft altitude range is measured between 34000 and 35000 feets. The SWRL form of this rule is described as follows:

Name-Code(?kts),aircraftInstantAltitude(?kts, ?z), greaterThanOrEqual(?z,"34000"),lessThan(?z,"35000")->soundSpeed(?kts,"579" xsd:double)

Semantic search is a searching process extracting relevant values of interest in all classes, components, and rules created in the ontology. At first, the user selects a synthetic scenario in the ontology. According to the selected scenario, EW's official manufacturer informations are then searched and retrieved from the ontology to transfer the inference engine. At this point, the proposed SUARSIS system infers in line with the components and relationships defined in the aircraft ontology. For obtaining meaningful information from the the aircraft manufacturer specifications during the operation of the inference engine, semantic rules are determined according to the aerodynamic forces affecting the

Table 1
A small portion of aircraft ontology in OWL

```
<Ontology xmlns="http://www.w3.org/2002/07/owl#" >
xml:base=".../ontologies/routeOntology"
<Class IRI="#Country"/>
<Class IRI="#City"/>
<Class IRI="#Airforces"/>
<Class IRI="#Landforces"/>
<ObjectProperty IRI="#detectedAircraft"/>
<ObjectProperty IRI="#hasownAircrafts"/>
<DataProperty IRI="#isenemyAircraft"/>
<SubClassOf>
<Class IRI="#ActivePieces"/>
<Class IRI="#Airforces"/>
</SubClassOf>
<SubClassOf>
<Class IRI="#CountryName"/>
<Class IRI="#Airforces"/>
</SubClassOf>
<SubClassOf>
<Class IRI="#Type"/>
<Class IRI="#Airforces"/>
</SubClassOf>
<SubClassOf>
<Class IRI="#Aircraft"/>
<DataProperty IRI="#isenemyAircraft"/>
<Class IRI="#Name-Code"/>
</SubClassOf>
</Ontology>
```

fuel consumption and flight range [26-27-28]. Figure 3 depicts the aerodynamic force components affecting an aircraft on a sample aircraft.

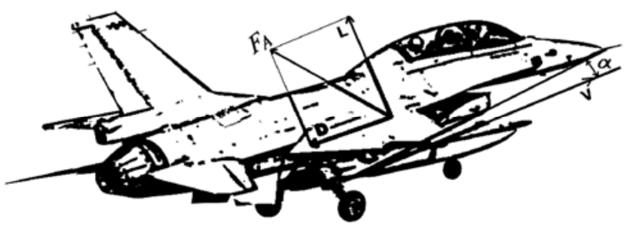

Figure 3 Aerodynamic force and components

F_A is the aerodynamic force resultant affecting a solid object calculated by,

$$F_A = q * S \tag{1}$$

where S refers to a reference surface area of the solid object and q refers to dynamic pressure and calculated with the below equation.

$$q = C_A \frac{P}{2} V^2 \tag{2}$$

where C_A is the dimensionless aerodynamic force coefficient comprising the effects of the angle of attack (α), the viscosity of air, the compressibility of the air, and the shape of the aircraft, P refers to the air density, V refers to the velocity of air flowing around the solid object. As seen in Figure 3, α is the angle of attack of the aircraft, L is the lift which is the component of the aerodynamic force perpendicular to the air velocity, D is the drag force of aerodynamic force that is the component parallel to the air velocity [26-27-28].

Accordingly, the magnitudes of the lift and drag forces are calculated with the equations below:

$$L = C_L \frac{P}{2} V^2 S \tag{3}$$

$$D = C_D \frac{P}{2} V^2 S \tag{4}$$

where C_L is the dimensionless carriage coefficient and C_D is the dimensionless drag coefficient. The inference engine takes all aerodynamic parameters and other drag parameters into consideration along with the fines parameter and the Oswald factor which is the wing efficiency factor. The estimated maximum flight distance is calculated by the information of the propellant system and the flight range that are specific to individual models of the warplane. Since the mission profile of an EW is not possible to be known in advance, we assume that three flight scenarios mainly adapted in real-world air transport are individually extracted with the semantic rule. These are extracted from the following three cases described as below;

1. Flight at a constant altitude with fixed lift coefficient,
2. Flight at constant velocity with fixed lift coefficient,
3. Flight at a constant altitude with a constant speed.

Algorithm **1** presents to calculate the maximum range of flight at a constant altitude with the fixed lift coefficient, defining the aerodynamic parameters and flight types in the ontology. Transactions regarding the motion of the aircraft at a constant velocity and fixed lift coefficient are shown in Algorithm **2**. Pseudo-code of its flight at a constant speed and the constant altitude is shown in Algorithm **3**. The calculation maximum range of multistage flights are shown in Algorithm **4**. The Semantic rules based on the aerodynamic forces and algorithms are presented in Table 2.

In this stage, after obtaining information of all class hierarchy, data attributes, object attributes, and individually and semantically extracted data in the ontology are transferred to the starting engine using the OWL API [29] and Pellet API [30] libraries. For this purpose, we developed an interface developed in the Java environment to enable aircraft-related information retrieval from the ontology in SUARSIS.

2.2. Suggestion algorithm

The suggestion algorithm suggests aircraft routes by retrieving semantic associations between terms that enable the users to search semantically for any relevant information. Figure 4 depicts the flowchart of the suggestion algorithm. At first, semantic information is transferred from the starting engine. The aerial view of the aircraft is then determined in the direction of point coordinates in the world coordinate system. We assume that aircraft location is obtained in every 5 seconds. Fuel consumption and direction of aircraft are instantaneously obtained in the scenario. The next, instantaneous coordinates of EW are parametrically passed to the Haversine distance method [31], which is calculated by the following equation,

$$r = 2Rsin^{-1}\sqrt{sin^2\left(\frac{x_2 - x_1}{2}\right) + cos(x_1)cos(x_2)sin^2\left(\frac{y_2 - y_1}{2}\right)} \tag{5}$$

where, x_i and y_i refer to x and y coordinates of the point i, (x_1, y_1) is the starting point and (x_2, y_2) is the destination point in polar coordinate space. The world radius (R) is taken as 6,371 km. The distance between world coordinates and instantaneous coordinates of EW are then measured. At last, the algorithm suggests possible routes of the plane after comparing distance between the measured coordinates and the proposed flight range of EW.

3. EXPERIMENTAL RESULTS

The proposed SUARSIS system was developed with the Java programming language in Netbeans [32] editor. The proposed system initially requires the users (e.g. pilots etc.) to log in. Secondly, a synthetic scenario should be selected from the pilot. The system semantically searches the technical specifications of EW, radar data, the proposed fuel consumption, and flight range data in the aircraft ontology database. Finally, the SUARSIS system returns estimated route information based on inferential data. A synthetic scenario is given to describe the details of the proposed system

Algorithm 1. The maximum range of flight at a constant altitude with a fixed lift coefficient ($R_{max_{clcc}}$) pseudo-code

entry Scenario, radar (routeAverageSpeeds, aircraftInstantAvgAltitude), ontology aircraft manufacturing values
output MaxRange
rule set aircraftTotalAvgSpeed
method
define count=0
while count<=1 **do**
add(km/s, route1AvgSpeed**)**
add(km/s, route2AvgSpeed**)**
add(km/s, route3AvgSpeed**)**
divide(aircraftTotalAvgSpeed, km/s,3**)**
count++;
endwhile
rule set requiredFuelforTravel
method
add(kg/requiredFuelforTakeoff, requiredFuelforLanding)
substract(requiredFuelforTravel, kg, insideFuelVolume)
/*detect available fuel*/
detect air density from standard atmosphere table
method
if aircraftAverageAltitude greaterThanorEqual(20000ft) and lessThan(21000ft) then airDensity, SET 0.5328 kg/m^3
rule C_{D0} find dimensionless drag coefficient
method
if M greaterThanOrEqual(0) and lessThan(0.8) then /*M (mach) number*/ C_{D0}, SET; 0.014
K find the drag coefficient
$\boldsymbol{K} = \frac{1}{\pi A_R e}$ *and* $\boldsymbol{A_R e} = \frac{b^2}{S}$, SET;
/*K CAL, S:wing area*/
$\boldsymbol{W_0} = 9.81 * \ (maxtakeoffMass - requiredFuelforTakeoff)$, CAL; /*mass*/
$\boldsymbol{V_{md_0}} = (\frac{K}{CD_0})^{1/4}\sqrt{\frac{2W_0}{\rho S}}$ CAL; /* min drag speed */
$\boldsymbol{E_{max}} = \frac{1}{2\sqrt{KCD_0}}$, CAL; /* aircraft's max fines */
$\boldsymbol{f} = \frac{W_F}{W_0}$, CAL; /* fuel ratio */
$\boldsymbol{R_{max_{clcc}}} = \frac{3^{\frac{3}{4}}}{c} Vmd_0 E_{max}(1 - \sqrt{1-f})$, CAL; /* max range*/
END

Algorithm 2. The maximum range of flight at constant velocity with a fixed lift coefficient ($R_{max_{cvcc}}$) pseudo-code

entry Vmd_0, E_{max}
output MaxRange
begin
calculate
$\boldsymbol{R_{max_{cvcc}}} = \frac{3^{\frac{3}{4}}}{2c} Vmd_0 E_{max} ln(\frac{1}{1-f})$, CAL;
/* max range */
END

Algorithm 3. The maximum range of Flight at a constant altitude with a constant speed ($R_{max_{crcl}}$) pseudo-code.

entry Vmd_0 , E_{max}
output MaxRange
begin
calculate
$$R_{max_{crcl}} = \frac{3^{\frac{3}{4}}}{2c} Vmd_0 E_{max} \left(\frac{f}{(1-f)^{1/4}}\right),$$
CAL; / max range */*
END

Algorithm 4. The maximum range of flight cascade travel ($R_{max_{ct}}$) pseudo-code.

entry Vmd_0 , E_{max}
output MaxRange
begin
calculate
$$R_{max_{ct}} \cong \frac{R_{max_{clcc}} + R_{max_{cvcc}} + R_{max_{crcl}}}{3},$$
CAL;
END

Table 2
A cross-section of the SWRL rules defined during the preparation of the semantic web rule base

(1) Name-Code(?kg), requiredFuelForTakeoff(?kg, ?y1), requiredFuelForLanding (?kg, ?y2), insideFuelVolume (?kg, ?y3), add(?a, ?y1, ?y2), subtract(?s, ?y3, ?a) -> requiredFuelforTravel (?kg, ?s)

(2) Name-Code(?kgm3),aircraftInstantAltitude(?kgm3, ?z),greaterThanOrEqual(?z,"20000"^^xsd:double), lessThan (?z,"21000"^^xsd:double)-> airDensity(?kgm3,"0.5328"^^xsd:double)

…

(11) Name- Code(?kts), aircraftInstantAltitude (?kts, ?z), greaterThanOrEqual(?z,"34000"^^xsd:double),lessThan(?z,"35000"^^xsd:double)-> soundSpeed(?kts,"579"^^xsd:double)

…

(20) Name-Code(?m), AircraftTotalAvgSpeed (?m, ?z), divide(?d1,?z, "1.852"^^xsd:double),soundSpeed(?m,?sh), divide (?d2,?d1,?sh)-> machNumber(?m,?d2)

…

(35) Name-Code(?x), dragCoefficient (?x,?k), dimensionlessDragCoefficient (?x,?bs), aircraftWeightBeforeTakeoff (?x,?sba),airDensity(?x,?hy),aircraftWingArea(?x,?uca), divide(?dvd,?k,?bs),multiply(?ml,?sba,2),multiply(?ml2,?hy,?uca), divide(?dvd2,?ml,?ml2),pow(?sq,?dvd, "0.25"^^xsd:double),pow(?sq2,?dvd2, "0.5"^^xsd:double),multiply(?ml3,?sq,?sq2, "3.6"^^xsd:double), divide(?dvd3,?ml3, "1.852"^^xsd:double)->minumumDragSpeed(?x,?dvd3)

…

(76) Name-Code(?x), maxRangeConstantLevelwithFixedCarriageCoefficientofAircraft (?x,?rmax1), maxRangeConstantVelocitywithFixedCarriageCoefficientofAircraft (?x,?rmax2), maxRangeConstantRatewithConstantLevel (?x,?rmax3),add(?a,?rmax1,?rmax2,?rmax3),divide(?dvd,?a,3)-> remainingRangeCascadingFlight(?x,?dvd)

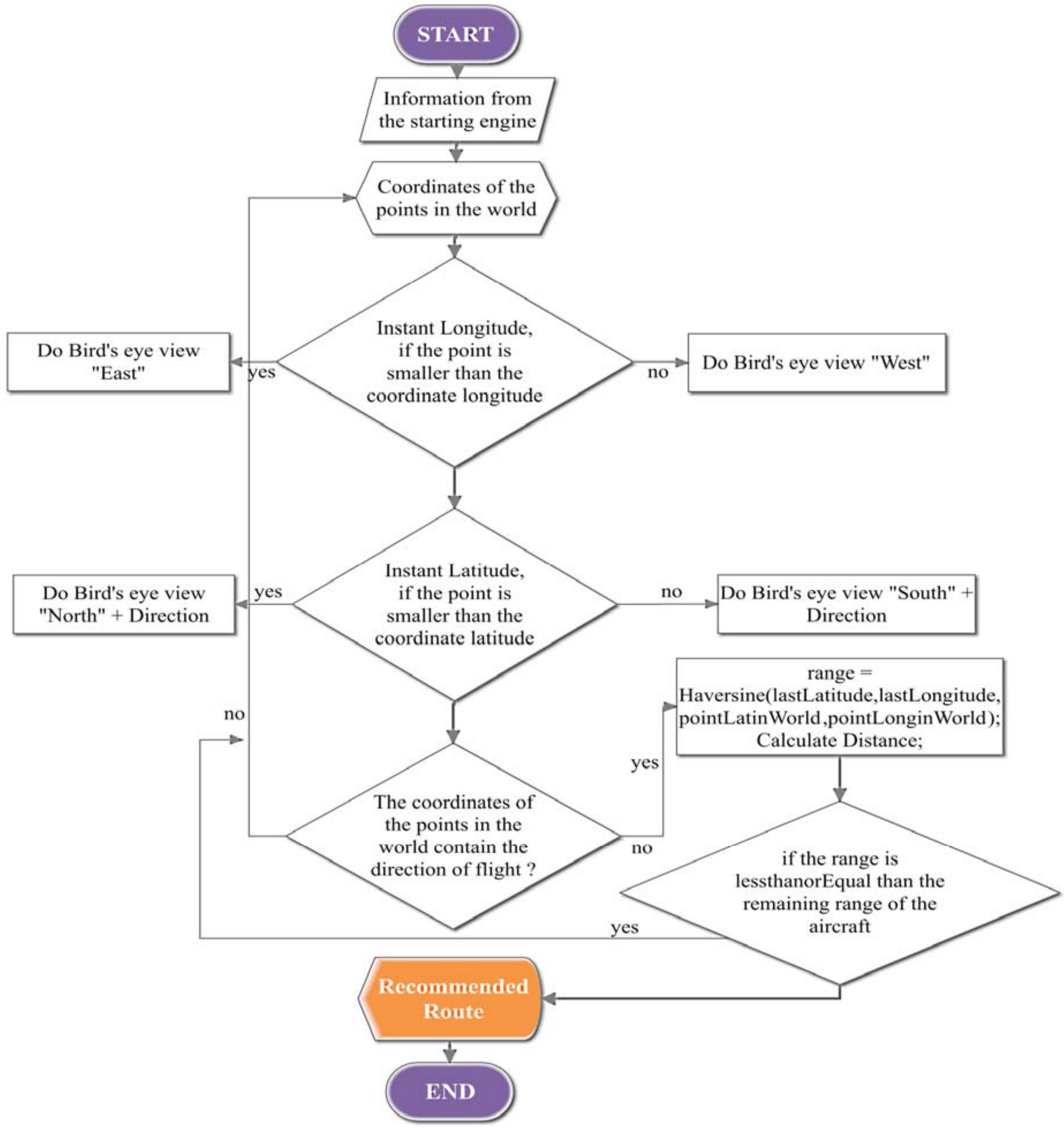

Figure 4 Flowchart of the suggestion algorithm

3.1. Scenario: Airspace Border violation between Syria and Turkey

We assume that the airspace border violation is noted between Syria and Turkey. The following assumptions are defined in the scenario:

1. A Syrian MIG-21/BIS model EW takes off near Aleppo starts and moves towards to Kilis without using the afterburner. The aircraft flies into the Turkey borders and violates Turkey airspace in a short period of time. Then, the aircraft returns and lands to Aleppo without refueling.

2. The aircraft engines run during their stay on the runway. Then the aircraft takes off again, flying towards the Turkish border.

3. Weather conditions are suitable for the takeoff and landing of the aircraft.

The fighter pilot initially logs into his account, using his or her private password in the SUARSIS system. The SUARSIS system suddenly detects a Syrian MIG- 21/B1S heading towards 'Northeast' after taking off from Aleppo. The real-world manufacturer specifications of this warplane are semantically searched in the ontology as seen in Table 1. The extracted semantic data is inferred with SWRL. The rules are then instantaneously transferred to the SUARSIS system. The radar parameters are added to these rules. The SUARSIS system suggests possible routes of the aircraft considering the remaining fuel of the aircraft when the "suggestion algorithm" runs. The maximum distance that the aircraft would fly with the remaining fuel is estimated based on SWRL rules and radar parameters. Since the result of the suggestion, the algorithm is dependent on the radar parameter, the accuracy of the suggestion algorithm is slightly decreased under the assumption that the radar data is immediately lost.

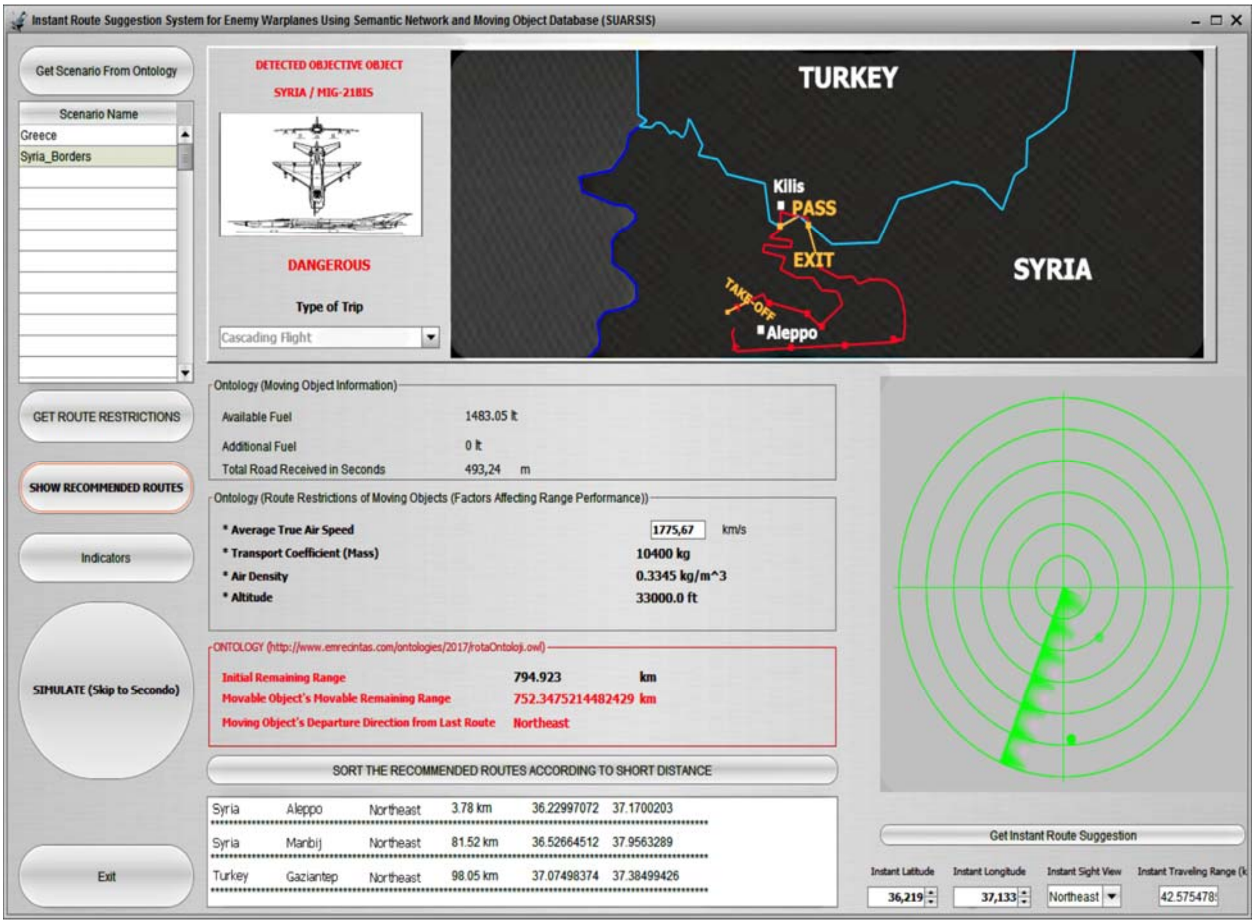

Figure 5 Estimated routes proposed to the pilot/navigation officer

Figure 5 depicts an example of a visualization of the proposed SUARSIS system. The route followed by aircraft is displayed on the screen.

The fighter pilot clicks the 'Show Recommended Routes' button, which will provide the estimations based on the technical data about EW. The inferential rules in Table 2 are used for finding the possible routes of MIG-21/BIS EW. The possible routes of EW are displayed on the screen of the SUARSIS system based on the inferential data transferred to and analyzed by the suggestion algorithm Table 3. Using the data displayed on the screen, the pilot responds to the incident in coordination with his stakeholders. Consequently, necessary measures are taken via the counter-intelligence method before EW accomplishes the respective route. SUARSIS Node (0) represents the instant position of EW. SUARSIS Node (1), (2), (3) represents 3 different possible routes of EW.

Table 3
The results of the suggestion algorithm in the Syria boundaries scenario

SUARSIS Node	Country	Place	Direction	Remaining Distance (km)	Latitude	Longitude
(0)	Aircraft Instant Position	Aircraft Instant Position	Northeast	----------	36.21702201	37.1310420
(1)	Syria	Aleppo	Northeast	3.78	36.22997072	37.1700203
(2)	Syria	Manbij	Northeast	81.52	36.52664512	37.9563289
(3)	Turkey	Gaziantep	Northeast	98.05	37.07498374	37.3849942
			Average Working Time 1.8 (ms)			

Table 4 represents the closest route retrieved from the nearest neighbor algorithm considering the instantaneous altitude, longitude, direction of the last aerial viewpoint, and the remaining flight range. As shown in Table 4, the average working time is calculated as 3 ms. Suggestion tour has been found that from SUARSIS Node (1) to KNode 0 and from SUARSIS Node (3) to KNode 2. Also node queue is obtained as 1-2-3. The total tour cost is obtained as 2.568. When the results obtained from the suggestion algorithm and nearest neighbor algorithm are compared, it is observed that even if the suggestion algorithm processes more data such as world coordinates, Haversine distance, and remaining flight range, the performance of average working time is better than the closest neighboring algorithm.

Table 4
Comparison of the results of the proposed algorithm in the Syrian borders scenario with the nearest neighbor algorithm

SUARSIS Node	Nearest Neighbor	Nearest Neighbor Distance (km)
(0)	KNode 3	0.894
(1)	KNode 0	0.041
(2)	KNode 1	0.840
(3)	KNode 2	0.791
	Average Working Time 3 (ms)	

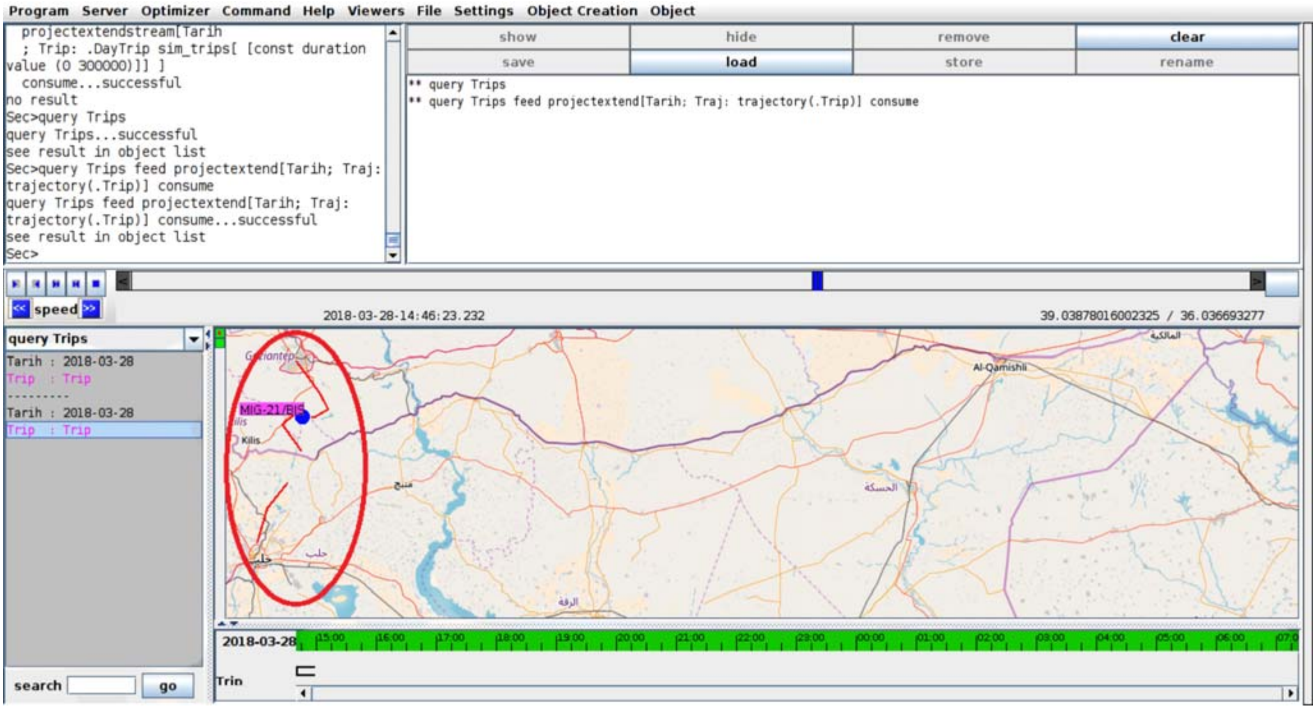

Figure 6 Simulation phase with Secondo

At the end, the routes suggested from the proposed SUARSIS system are simulated with Secondo shown in Figure 6.

4. CONCLUSION AND FUTURE WORK

In this study, we proposed a new platform-independent SUARSIS system that has been developed with the new generation Semantic Web Technology (Web 3.0). The main contribution of the system is to estimate possible routes for EW with an unknown mission profile based on the ontology and SWRL rules. The possible routes are estimated through the propellant model and the manufacturer specifications of EW along with radar data. The real data of aircraft such as the wing area, wingspan, engine type, reaction force of the engine, specific propellant consumption, the amount of propellant needed per flight, flight to propellant ratio, maximum take-off mass, propellant volume, bomb and arms mass, air density, gas constant, stall loss, and aerodynamic parameters are used to generate an authentic ontology and define SWRL rules. The proposed system can distinguish the allying or enemy aircraft considering the country's information.

Synthetic scenarios are created to evaluate the performance of the proposed system. We assume that the airspace border violation has been noted on the southern border of Turkey. Semantic data of the aircraft based on the designed ontology are initially extracted. The proposed SUARSIS system produced synthetic radar parameters and observed its respective instantaneous changes. Possible routes of EW are then estimated after adding the radar measurements. In the case of the aircraft not detected in the radar and departure location is manually stored in the system, SUARSIS will automatically suggest the possible location of the aircraft through its path. It is observed that SUARSIS performs more accurately when the radar measurement can provide instant information to the system. The experimental results show that the proposed system has satisfied the high success rate of the suggestion algorithm. In order to validate the accuracy of results, the proposed method is compared with the closest neighboring algorithm. We observed that while the success rate is similar in both algorithms, the operating time of the proposed method is better than the closest neighboring algorithm.

As a future work, real radar data is integrated into the SUARSIS system that provides to user enable the system dynamically in the real-world.

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No conflict of interest or common interest has been declared by the authors.

Authors' Contribution

EÇ: investigation, literature review, methodology, data analysis, simulation, writing-initial draft. BÖ: supervision, conceptualization, methodology, investigation, writing-revision and finalizing. YSH: supervision, conceptualization, methodology, design, writing-revision.

The Declaration of Ethics Committee Approval

The authors declare that this document does not require an ethics committee approval or any special permission.

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The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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