An Intelligent Decision Support System: EW Case Study

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Abstract

It becomes a challenge in modern battle to process a large information of Electronic Warfare (EW) in a small amount of time. The Information System is a rescue in this critical task. It is proposed by developing the Electronic Warfare Intelligent Information System (EWIIS) that deals with processing of electronic warfare, communications, radar, maps, war missions … etc. In this work, design and implementation of the (EWIIS) are offered. This system is aimed at achieving the best performance with a friendly system in spite of the existence of hostile actions. EWIIS deals with different sources of data. It helps visualize mission scenarios and suggests the best combination of weapons to successfully complete the mission with minimum loss. This work handles a nonlinear optimization problem with multiple number of variables and constraints. Closed form and exact Solutions of such problems are computationally difficult. Therefore, the paper proposes the knowledge-based approach to solve this problem.

The proposed system utilizes the Common KADS methodology to handle the class representation, relationships among objects and inferencing mechanisms. This methodology has not been traditionally used in solving such type of problems which involves huge data bases of moving objects.

Keywords: *Knowledge base; Radar; Electronic attack; Electronic protection; Jamming Pods; Storage Requirements.*

1. Introduction

Electronic warfare (EW) [1,4,5,6] is one of the most important aspects of modern warfare. This is because EW can affect a military force's use of communications, radar, avionics, guided weapons, reconnaissance and intelligence gathering systems. All of these systems use the electromagnetic (EM) spectrum to detect targets, or to provide information.

Potential enemies will also be using similar equipment for the same purposes. To combat this, we use EW to obtain information about threats to us, to counter those threats if they are used against us, and to protect our weapons against the enemy's EW.

A. Subdivisions of EW

There are three subdivisions of EW; Electronic Support, Electronic Attack and Electronic Protection.

Electronic Support (ES) [21]. The role of ES is to passively monitor the EM spectrum for signals that may be a threat to us. Once a potential threat has been identified, we can then decide what action or countermeasures to take against it.

Electronic Attack (EA) [1,6]. We use EA to attack enemy systems that use the EM spectrum. By doing this we prevent them from using the EM spectrum efficiently and therefore reduce the threat to ourselves.

Electronic Protection (EP) [1,6]. An enemy will attempt to prevent us from using the EM spectrum by using EA against us. To prevent them from being successful, and to ensure that our own EA does not affect our electronic systems, we use EP to protect ourselves.

B. *Paper Structure*

Section 2 will highlight the role of information technology in EW and some related previous work will be listed. Section 3 will explain the motivation of this work. Section 4 will review typical environment for the proposed system then the proposed system architecture will be introduced in section 5. Section 6 will show the data movement through the system. A case study will be displayed in section 7 to show the power of the knowledgebase associated with the proposed system. Finally in section 8 the conclusion of the paper is reached with some suggested future work.

2. The Role Of Information Technology In EW

There is no doubt that the information technology plays an important role in military activities specially EW. In the following paragraphs we demonstrate some research directions related to the role of information technology in EW:

A. Simulation in the EW Field

Simulation is the creation of an artificial situation that causes an outcome to occur as a corresponding real situation or stimulate were present. Using mathematical representations of friendly and enemy assets and sometimes operator responses, computers evaluate how they interact with each other. In modeling; neither signals nor representations of tactical operators control and displays are generated. The purpose is simply to evaluate the interaction of equipment and tactics that can be mathematically defined. Modeling is extremely useful for the evaluation of strategies and tactics. A situation is defined, and each of several approaches is implemented. The outcomes are the compared [1].

B. Artificial Neural Networks [ANNs] Uses in EW

ANNs have been widely used in many applications related to EW [19]. Signal detection and classifications, predictions, function approximation and data analysis are some problems of interest in EW that ANNs provide a robust solution to them.

C. EW and Information Warfare

Sindi [24] in his research article summarizes the relationship between EW and information warfare. He visualizes the future trends of EW systems as tactical information systems and communication continue to capitalize on the opportunities offered by the information revolution to become a true fully digitized battle field network..

D. Expert Systems in EW

Cramer and others [8] have get utilized the expert system technology in EW application using Ada language and the Clips expert system shell. The objective of their research was to specially get expert knowledge about the effective use of radar jamming equipment as a knowledge base, such that the knowledge may be used automatically to manage the use of that equipment.

3. Motivations

Design and Implementation of intelligent information system using decision support system approach (2,9,12,17) is the main goal of this work. This system can store, retrieve, process, report information about attacking scenarios that could be placed by users of the system. The system should be robust, efficient, and capable of working in a multi-user environment. Also the system should be capable of detecting and analyzing modern threats and developing the proper techniques. These systems can provide the developing countries with capabilities that not easily reachable. From now on we call our proposed system Electronic Warfare Intelligent Information System (EWIIS).

4. Typical Environment for EWIIS

As normal information system development life cycle [7,13,30], analysis of the requirements and tasks of the proposed system is needed [15]. Analysis includes declarations of different input sources, output expected in order to guarantee the fulfillment of the requirements. **Figure 1** shows the main input / processing / output of EWIIS and the different categories of users expected to interact with it. EWIIS missions are to suggest, to test tactics,

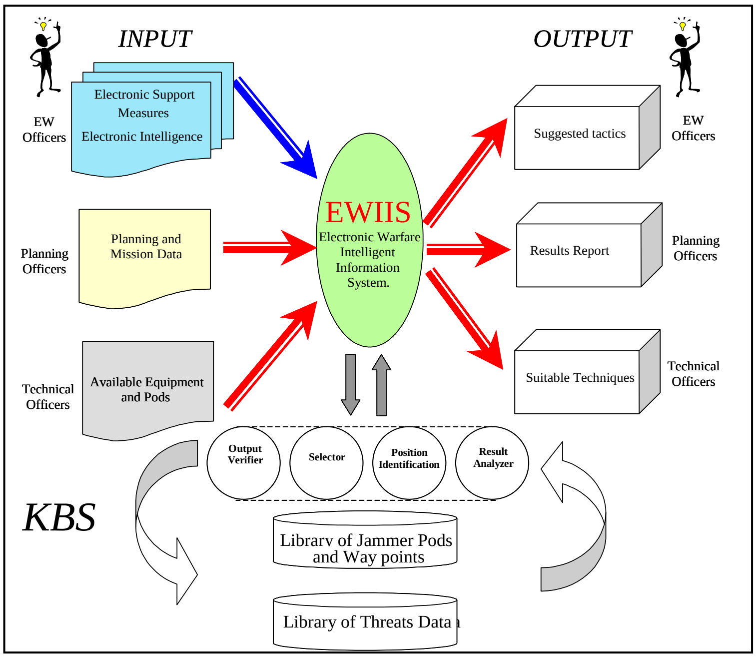

Figure 1. EWIIS Environment

and to complete a mission with the suggestion of the best platform to use among set of prescribed platforms. The system should be fed with parameters about the ESM. This input is supplied by the EW officers. Mission data and an initial plan is given by the Planning officers. Information about the different platforms available for the system is given once and may be updated by technical officers. EWIIS starts from the initial scenario and with the information given about the type and location of radar starts to analyze this scenario and looks for opportunities for enhancement. The successive enhancement processes depend on studying different parameters for all radar platforms, geographical area, and the target stored in EWIIS knowledge base. Possibly ending with more than one scenario; EWIIS recommends best path for certain platforms that guarantees successful completion of the mission. Suggested tactics, results reports and suitable techniques will be offered to EW, planning and technical officers. More elaboration of knowledge base system will be given in the next section.

5. The Proposed EWIIS Architecture

This section introduces the components of EWIIS and their functionality. It also describes the interactions among these components. **Figure 2** summarizes these components and their relationships.

A. Data Acquisition and storage requirements

This component is responsible for accepting all the data about threats, Electronic support measures of the scenario need to be tested. Most of these data are of visual nature such as maps, radar locations, target locations. It should be taken into consideration that they must be fed to the system in the same way as they are dealt with in real life. Due to Data visualization [23] and their huge volume, we have to store the following data, among others:

* Map information.
* Radar location.
* Target location.
* Mission path.

We have to choose between storing all these information in one container for each mission scenario, or to divide this information into layers where each layer is concerned with separate aspect of the mission data. The second choice provides high level of reusability. Reusability comes from the fact that the same map is needed to be stored once in the map layer and can be linked to more than one scenario. Indeed this also leads to another big benefit of storage optimization which is a challenge for any system that deals with massive information. For example in the case study, presented in section 7, the standalone data file needed 6443 KB every mission scenario (for the base map and fixed data) while the layered method (second choice) took only 5KB to store the differences between sequenced mission scenarios. The 6443 KB is stored once in all scenarios.

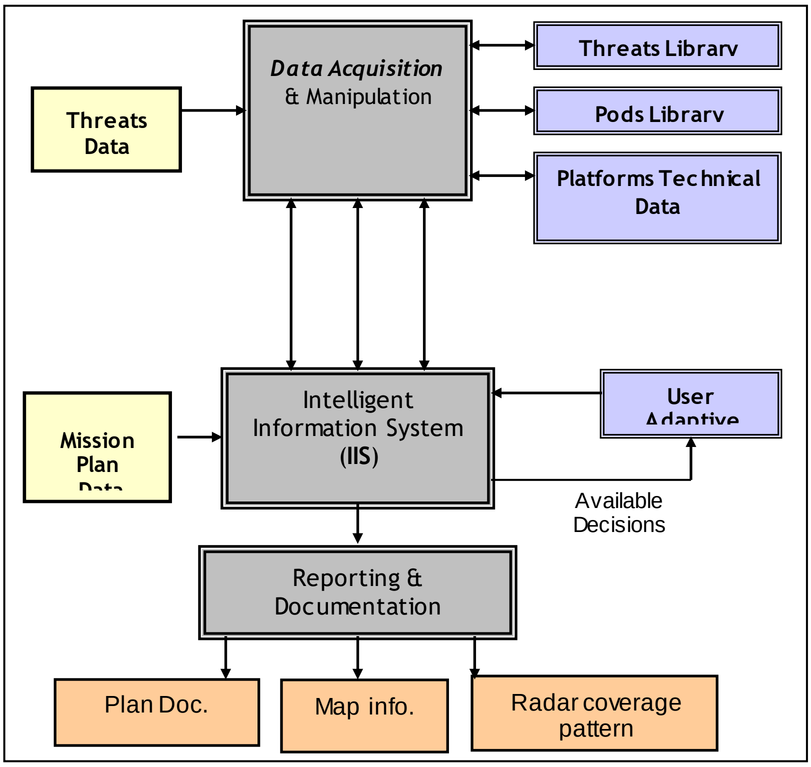

Figure 2 Overall Architecture of EWIIS

B. Intelligent Information System (IIS)

This is the major component of EWIIS that makes the analysis of mission paths and makes suggestions of enhancements. This is the component where the intelligence comes into the scene in EWIIS. The Knowledge Base contains four different parts; verifier , selector, position identifier , and result analyzer .

The Verifier: Plays two roles: First, it checks the input data consistency such as ensuring the correctness of radar parameters. Second, it ensures the consistency between the given input and the resulted output data based on set of rules which were given by the planner. For example aircraft should have 10% of fuel after finishing mission.

The Selector: Simply the objective of this part is to select between alternatives (choose best radar to be jammed by fighter) or select between mutually exclusive options (choose which radar will be jammed by support jammer and which radar will be jammed by fighter). The selection is done through a criteria based on the most effective radar (which cover the target) or close to the path.

The Position identification: specifies the optimum location of some activities such as optimum location of support jammer umbrella based on some rules related to the victim radar.

The Result analyzer: It analyzes and evaluates EWIIS results then proposes suitable recommendations to get better solutions.

6. Data Movement and System Components

From a data-oriented point of view we have developed a categorization of the different battle field variables:

* Radar
  - Early Warning radar.
  - Acquisition radar.
  - Fire control radar.

EWIIS uses the following list to differentiate between radar.

List of Radar parameters:

Min. Frequency	Max. Frequency	Pulse width
Power	Gain transmitted	Gain received
Polarization	Wave length	Band width
Pulse repetition frequency	Beam width	Listening time
Radar cross section	Scan rate	Transmission losses
Reception losses	Azimuth antenna coverage	Elevation antenna coverage
Max. range	ECCM techniques	

* Platforms: by platforms we mean the planes that will do the mission and it could be one from the following;

1) Bomber and fighter.
   * Bomber; which carry bombs in order to destroy the target in addition to self protection jamming pod.
   * Fighter; which carry missiles in order to protect the bombers in addition to self protection jamming pod.
2) EW Aircraft; which carry supporting jamming pods to deal with early warning radar from out of missile ranges.

EWIIS uses the following list to differentiate among platforms.

List of Platform parameters:

Range	Endurance	ECM pod
Armament	Speed	Ceiling
Radar type	EW equipment	
Max. weight	Base	

* Jamming Pods.
  - Self protection pods.
  - Supporting jamming pods.

EWIIS uses the following list to differentiate among jamming pods.

List of Jamming pods parameters:

Platform	Power	Frequency range
Azimuth antenna coverage	Elevation antenna coverage	Gain transmitted
Victim radar	Available techniques	
Losses	Internal / external	

Data moves as shown in **Figure 3** from users (raw mission data) and from library (radar, platforms, jamming pods, terrain heights, maps and restricted areas data) through interfaces module to calculation module.

Results will be verified by the rules which were fed to the knowledge base system. Then a report will be printed including recommendations for solving the possible problems. **Figure 4** shows the main two components of the system: data component and manipulation and control component.

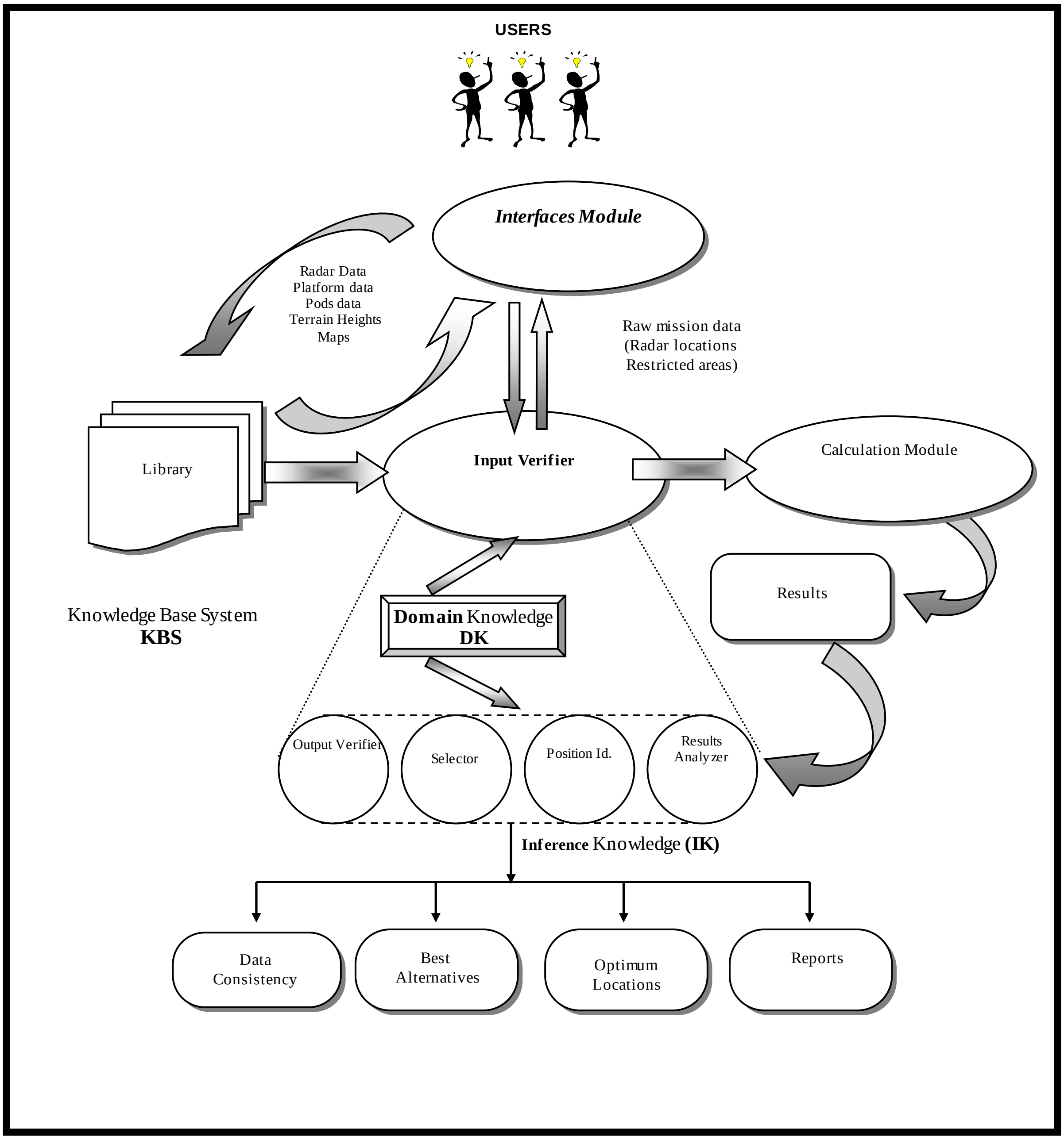

Figure 3 Data Flow and Interaction

A. Data Component

This component includes radar, platforms, jamming pods, mission and data maps which were stored in the library and updated frequently. These data were discussed in section 6 and some examples of parameters were mentioned.

B. Manipulation & Control Component.

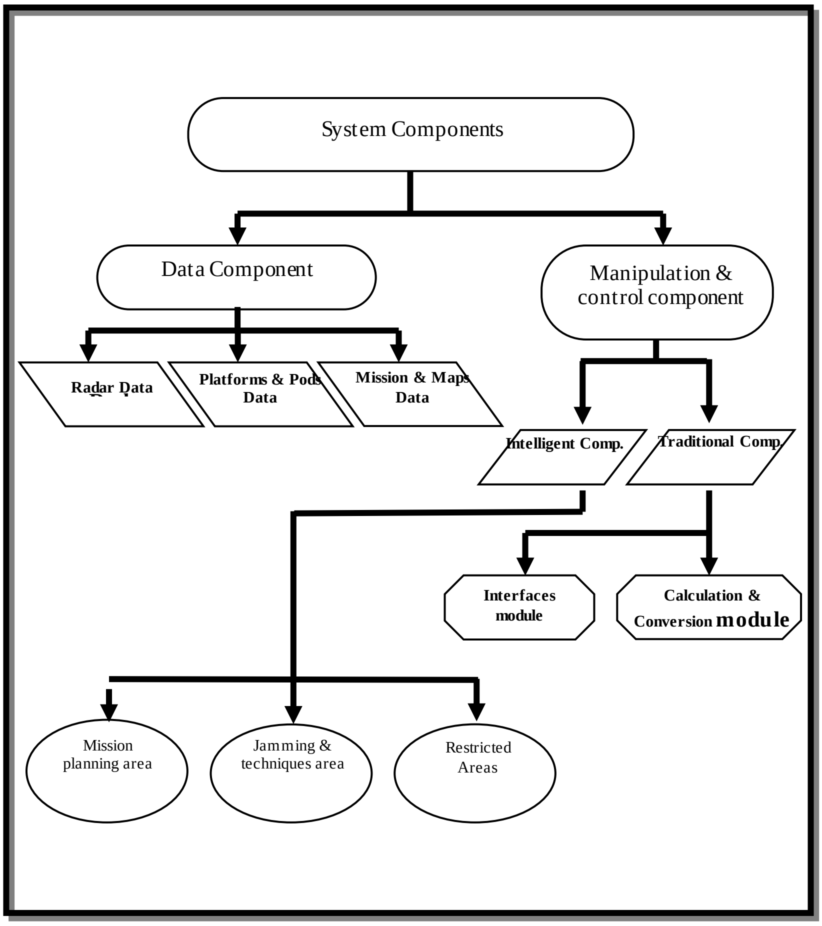

Figure 4 Main System Components

This component includes mainly different types of modules to provide an environment for mission data filling in addition to a set of aiding tools to support users with all utilities which cover their requirements. This component contains two main modules: traditional and intelligent modules.

Traditional module

The traditional module contains all interfaces module in addition to calculation module.

Interfaces module

This module will represent the main menus seen by the user. It is the connection between the user and the library, and the other modules.

```
Initialization  (default values, variables zeroising)
Get radar frequency (Fr)             : from radar library
Compute wave length (λ)              : λ = light speed / Fr
Get gain received (Gr)               : from radar library
Compute area equivalent(Ae)          : Ae = (2*λ)/ (4* π)
Get power transmitted (Pt)           : from radar library
Get gain transmitted (Gt)            : from radar library
Get radar cross section (σ)          : from radar library
Get radar sensitivity (s Min)        : from radar library
Compute radar range value =
((Pt * Gt * σ * Ae) / ((4 π)**3 * s Min))**0.25
```

Figure 5 The Algorithm for Radar Range Calculation

Mission plan generator

(calculation and conversion module). This module is used to calculate different required calculations such as radar ranges and jamming effects. Figure 5 shows the algorithm used for Radar range calculation and Figure 6 shows the algorithm used to calculate the effects of jamming pods on radar. [4,5]

```
Initialization  (default values, variables zeroising)
Get radar power transmitted (Pt)        :    from    radar
library
Get radar gain transmitted (Gt)         :    from    radar
library
Get radar cross section (σ)             :    from    radar
library
Get radar band width (Bwr)              :    from    radar
library
```

Figure 6 The Algorithm for Jamming Calculation

Intelligent module (Knowledge Base Component)

According to the common KADS methodology [3, 14,19,23,26], a knowledge base system is a collection of different component types (domain, inference and task knowledge), each of which has its own nature and role. Since our proposed tool is designed to be used in a specific application domain which is the Electronic Warfare field, the knowledge base component would contain the knowledge related to this application area.

Our knowledge base component plays an important role in three areas: mission planning, jamming techniques area and restricted areas avoidance.

1. **If** Fighter is close to built-in restricted areas by 15 Km **then** mission will not be accepted.*(Ex.for restricted areas rules).*
2. **If** the remaining fuel after calculating the required fuel for the mission is more than 10% from the total air craft fuel capacity **then** the mission is successful **else** mark the mission as not safe.*(Ex.for mission planning area rules).*
3. **If** radar type which protects the target equal fire control type or Acquisition type **then** deal with self protection jammer **else** deal with support jammer.*(Ex. for jamming area rules).*
4. **If** the platform carries the required jamming pod **then** accept the mission **else** reject.*(Ex.for jamming area rules).*
5. **If** the ground terrain height during the cross country is higher than flight height **then** mark the flight as not safe and suggest suitable actions.*(Ex.for mission planning area rules).*

Figure 7. Example of Rule Types

In these areas the knowledge base component plays three roles. First role is to check and fix any mission plan parameters such that the mission plan becomes verified and validated to form a safe plan at the end. The second role of the knowledge component is to monitor and verify the jamming activity. The third role is to monitor the selected set of way points such that they do not pass across some restricted areas. So, a part of this knowledge base contains knowledge about these restricted regions and how to avoid them.

Example of rule types used in this part are given in **Figure 7** [4, 5, 8, 25, 29].

The first rule, As shown in **Figure 7**, means that the fighter aircraft should fly away by 15 km from the built-in restricted areas. Indeed, the information required to activate this type of rules, is obtained by executing another type of rules (chained), which monitor and calculate dynamically the position of the plane from the center of any built-in restricted area. Also this type of rules activates its result which will be passed to another set of rules that concern the report generator to explain the reasons behind the acceptance / rejection of the mission plan. As indicated above we referred to the rules as types, not as occurrences, for instance there is a number of instances for the built-in restricted area (18 built-in restricted areas) and about 30 occurrences for the user-defined restricted areas).

The second rule means that after calculating the fuel used during the trip, 10% from the total quantity (capacity) should remain for safety to guarantee the safe return to the base. This type of rules is used to predict the safety factor of the mission. Calculating the fuel consumption for completing the mission safely is based on a set of flight parameters (height, velocity, weight). This rule type is highly related to another set of rules which generate reports about the actions to be taken when violation occurs.

The third rule means that the self protection jamming pod will deal only with fire control radar and acquisition radar but support jamming pod will deal with early warning radar.

The objective of this type of rules is to specify the jammer type based on radar type and target location. Again this type of rules has several instances according to the number of radars around the victim target (usually up to 35 radars).

The fourth rule means that the fighter aircraft should carry the suitable jamming pod.

This type of rule plays a role of hard constraint. It measures the mission plan compatibility between platform (air craft type) and jamming pod. This rule occurs several times in the knowledge base based on the number of available platforms and jamming pods types.

The fifth rule means that the fighter aircraft altitude should be higher than the terrain to guarantee safety. The goal of this rule is to specify the terrain heights through the flight path (cross country) and the plane height, The system reports submit a suitable recommendations in case of risks due to unsafe heights. This type of rules is related to cross country, height of flight and ground features heights during the flight path.

In fact all these mentioned type of rules are distributed among the four inferences knowledge; verifier, selector, position identifier, and result analyzer, which appear in **figure 3** and represented using a table structure in which the columns of this table play the role of rule premises (conditions) and conclusions (actions). In such representation a tuple of this table represents a single rule in which its premises are all “anded”. It is worth noticing that rules are running in a data driven (forward chaining) manner since they receive data and proceed toward their actions.

6. Case Study

This case shows the power of the knowledge base associated with EWIIS which can deal with a lot of radar at the same time in intelligent technique by choosing the ones which are affecting the mission success.

Activities

New radar Plotting

The system support adding a new radar parameters, and also plotting it on a background map. **Figure 8** shows the scene after plotting all radars. From this figure, it can be seen the complexity of dealing with this visually. So, it is very difficult to determine manually which radar we have to jam to avoid detection and we have to print EW report to support our decision.

Getting EW report

User role and EWIIS during getting EW report are explained as follows.

User role	EWIIS role
1 – Ensure system running normally.	1 – Read way points and radar parameters.
2 – Press EW report	2 – Activate EW report module.
3 – Insert mission name.	3 – Accept mission name.
4 – Print EW report.	4 – print.

From the EW report, we notice that there are 32 radar around the target and only 8 radar which detect the fighter during the mission and should be jammed. **Figure 9** shows the scene after jamming the 8 radar. It shows EW report after jamming and no detection for the fighter during the mission.

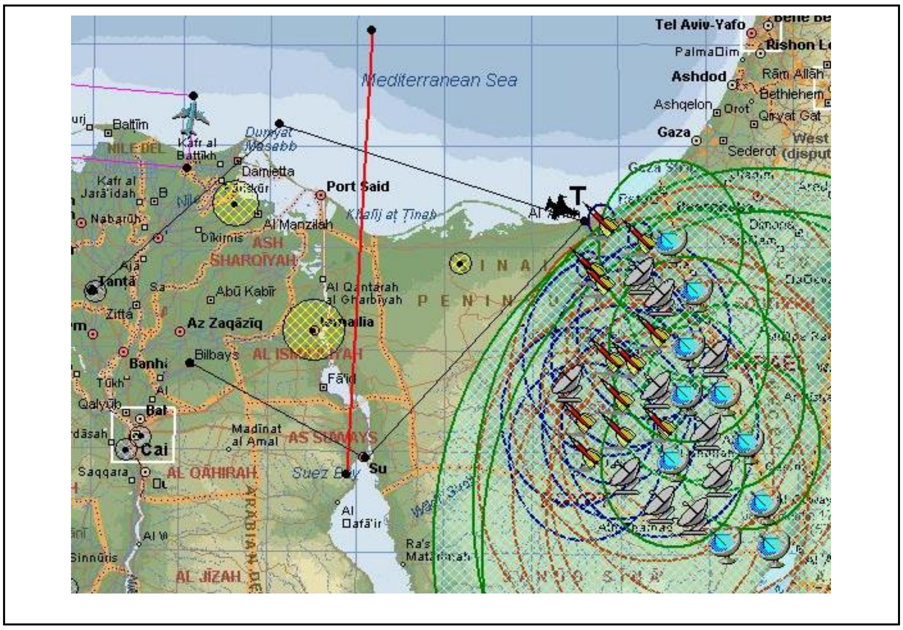

Figure 9 Shows The Scene After Jamming The Effected Radar

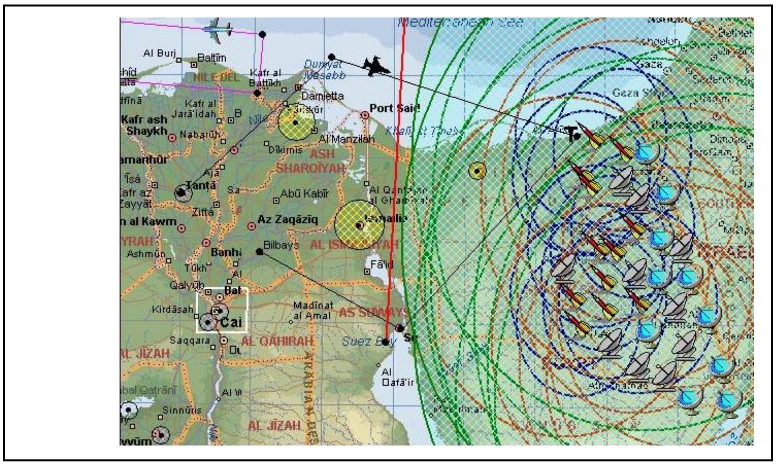

Figure 8 Battle field with radar effects

7. Conclusion and Future Work

This paper has addressed the problem of dealing with, and processing a huge amount of data using Intelligent Information System. These data are related to electronic warfare communications, radar, airplane missions ... etc. The proposed system combines more than one kind of knowledge/information with high dependency among them and sets rules for the combination and prioritization of these knowledge/information kinds to achieve the best possible decision which is passed to a human expert for final decision (as a tool for decision support)..

An intelligent information system has been designed and built to store, retrieve, process, correct, analysis and report information about attacking scenarios that could be placed by users of the system. The system is robust and efficient. It is capable of analyzing all kind of modern threats and capable of working in a multi – user environment. The proposed system is called Electronic Warfare Intelligent Information System (EWIIS) .

EWIIS deals with a graphical user interface in a convenient way. A case study is used to demonstrate the capability of EWIIS and to verify its normal operation. The case study has achieved accurate and promising results .

EWIIS currently supports missions that work with self protection pods where it selects the best platform for the mission. It selects best pods and mission path and the suitable altitude.

To summarize, the manual system of mission planning and execution suffers from slow processing and difficulties of choosing the best between the alternatives of the mission plans and also the possible errors in calculations. On the other hand the proposed system overcomes these shortcomings and makes use of the visual presentation and manipulation of the required maps. Also EWIIS provides the possibilities of saving and retrieving the different experienced situations to improve the productivity and the efficiency of the EW officers.

We suggest as future work to train and develop the system with different kind of threats, and automate the manual processing. The good thing about this system that it supports development in all its modules separately.

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