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TOWARD AN EXPERT SYSTEM FOR AIRCRAFT LANDING SCHEDULING USING REAL-TIME ALGORITHMS SCHEDULING

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***Abstract*—** Sequencing and scheduling of aircraft landing is one of the complex problems of air traffic management. The Aircraft Landing Scheduling (ALS) problem consists of sequencing, scheduling and runway assignment decision problem. In practice, it can formulate as a constrained optimization problem that needs to be solved in real-time environment, also the ALS is non-regular complex problem so we can use the expert system for solve it. Expert systems using extracted cognitive data, inspiring from the human expertise and its best practices. They are based on the machine performance and its ability to carry out a very large number of complex iterations. The choice of a task scheduling algorithm in a variable and unpredictable real-time system such as air traffic management system requires the use of an intelligent expert system, having an evolving knowledge base and a creative inference engine.

In this paper we present a general architecture and conceptual concepts of our proposed expert system. This expert system allows the choice of the most optimal scheduling algorithm for aircraft landing scheduling.

***Index Terms*—Expert System, Aircraft Landing Scheduling, Real time system, real-time scheduling algorithms, real time task, air traffic management.**

I. INTRODUCTION

The expert system uses the knowledge corresponding to a specific field such as medicine, computers, aerospace… in order to provide a similar performance to the human expert. Then it is the representation of reasoning in sensitive areas which requires expertise.

In opposition to a classic computer system an expert system handles the important algorithmic knowledge and dependent or independent rules in a language close to the language of the expert, also an expert system must be capable of reproducing its reasoning and justifying these results to facilitate the access to the expensive and rare knowledge and protect knowledge which could disappear [9]

. In the real time system the accuracy of an application depends on the accuracy of the results it produces and the time of execution. The execution time and the scheduling policy are two factors that can affect the performance of a real time system such as air traffic management, flexible workshops, supply chains …. These complex systems require great expertise to manage correctly a set of tasks having severe temporal constraints imposed by their environment. This management can be performed by exploiting the power of real time scheduling algorithms and choosing the most optimal algorithm for each situation [5].

The aircraft landing scheduling problem consists to determine the landing time for a given set of aircrafts [12], is the important problem for air traffic control. In practice the controller uses the FCFS (First Come First Served) strategy rule that schedules the aircrafts in the same order as they enter in the TMA (Traffic Management Advisor). FCFS is a simple rule easily to implement but the aircraft with a low speed can affect the time landing the other aircraft with high speed. So in our future work we will study the aircraft landing scheduling problem and propose the other strategy based on real-time algorithm for scheduling the landing of a set of aircrafts and get a minimum landing cost.

In this contribution, we propose in the first a comparative study for principal real-time scheduling algorithms in order to highlight: their typology, the advantages and limitations of their use. We present thereafter a general architecture of a designed expert system for aircraft landing scheduling using real-time algorithms scheduling. At the end, we present the conceptual design of the knowledge base of the system using the UML meta-language. The proposed model includes a detailed classes diagram showing the entities characterizing the knowledge base, a Communication Diagram, an Activity Diagram and a Class Diagram describing the behavior of the expert system. To achieve the proposed results our method we deployed the appropriate design patterns.

II. COMPARATIVE STUDY FOR PRINCIPAL REAL TIME SCHEDULING

Real time tasks are the basic entities of a real time scheduling. They are periodic, sporadic or aperiodic. They may also be dependent or independent. Each task has some temporal constraints, if the process of scheduling doesn't respect these constraints, the real time system will be considered as a failure.

A real time scheduling is a description of the manner by which the execution of a set of tasks, this manner must respect the temporal constraints and dependence constraints of each task. The principal algorithms of real time scheduling are: [5] [6]

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RM (Rate Monotonic): preemptive, dynamic and fixed priority. **The priority of a task is inversely proportional to its period.**		
Feasibility conditions	**CS** : $\boldsymbol{U = \sum_{i=1}^{n} \frac{Ci}{Ti} \leq n(2^{\frac{1}{n}} - 1)}$	**CN** : **U≤ 1**
Benefits	- Optimal for periodic, independent and deadlines on requests tasks. - Easy to implement.	
Limitations	- Don't support aperiodic, sporadic and dependent tasks.	

DM (Deadline Monotonic): preemptive, dynamic and fixed priority. **The priority of a task is inversely proportional to its term.**		
Feasibility conditions	**CS1** : $\boldsymbol{U = \sum_{i=1}^{n} \frac{Ci}{Ti} \leq n\left(2^{\frac{1}{n}} - 1\right)}$ **CS2 :** $\boldsymbol{Ci + \sum_{j=1}^{i-1} \left(\frac{Di}{Ti}\right) * Cj \leq Di}$ $\boldsymbol{1 \leq i \leq n.}$	**CN** : **U≤ 1.**
Benefits	- Optimal for periodic, independent and deadlines on requests tasks. - Easy to implement.	
Limitations	- Don't support aperiodic, sporadic and dependent tasks.	

EDF (Earliest Deadline First): preemptive, dynamic and variable priority. **The priority is granted to the task which has the term is the closest.**	
Feasibility conditions	**CSN** : $\boldsymbol{U = \sum_{i=1}^{n} \frac{Ci}{Ti} \leq 1}$
Benefits	- The rate of use of CPU can reach 100% for the task deadlines on requests. - Less dead-time if we compare the EDF with RM or DM.
Limitations	- Difficult to implement. - Problems priority inversion can be generated.

LLF (Least Laxity First): preemptive, dynamic and variable priority. **The priority of a task at the given moment is inversely proportional ti its laxity. L(t) = ri + Di - (t + Ci (t)).**	
Feasibility conditions	**CSN** : $\boldsymbol{U = \sum_{i=1}^{n} \frac{Ci}{Ti} \leq 1}$
Benefits	- Optimal for a single CPU and better than EDF for multi-processors architecture.
Limitations	- Difficult to implement. - Problems priority inversion can be generated.

We note that each algorithm has its own scheduling policy, its conditions of feasibility, its advantages, its limitations and its application context. Our expert system will use these features and other rules imposed by experts in the field of air traffic management to choose the best algorithm for optimal aircraft landing scheduling [8][10][11].

III. THE GENERAL ARCHITECTURE OF THE PROPOSED EXPERT SYSTEM.

Our expert system consists of: [9]

- **An expert interface**: it's an IHM that allows an expert to impose rules of scheduling that will be formalized in a real time language. It also allows them to check, test and update rules previously imposed. This interface will be used by the expert of air traffic management.
- **A referred user interface**: that allows an air traffic controller to enter the sequence of aircraft and the constraints imposed by national and international institutions of civil aviation; also this interface can show the results of the aircraft landing scheduling.
- **A knowledge base or rules base**: contains all the real time algorithms such as DM, LLF, EDF… and rules of scheduling for example the minimum separation distance between two aircrafts.
- **An inference engine**: consists of a set of applications based on an Artificial Intelligence for the choice of optimal scheduling algorithm after the analysis of the algorithm conditions feasibility, temporal and independence constraints of the tasks and other parameters such as the number of aircrafts the gap between the speeds of aircrafts.
- **A fact base**: it's an intermediate base used by the inference engine and includes the calculation rules, the methods used by inference engine….
- **A journal of reasoning**: the files for storage in the way of reasoning followed by inference engine to find the results.

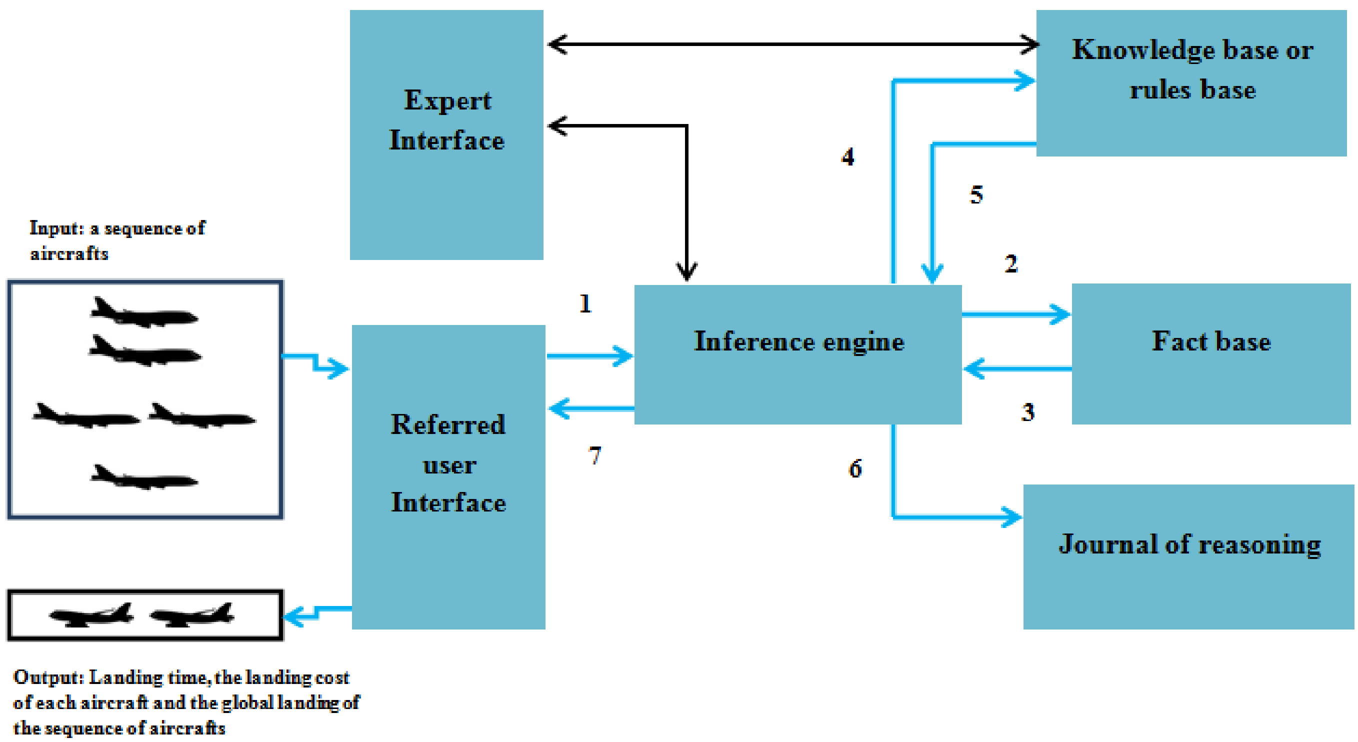

Fig 1: General architecture of the proposed expert system.

The process of aircraft landing scheduling followed by the proposed expert system is:

Step1: the air traffic controller or other referred user introduces the sequence of aircraft that fly in the TMA space.

Step2, Step 3 and Step 4: the inference engine analyzes the constraints of the sequence of aircrafts introduced, using the algorithms based on predicate logic, other rules imposed by the expert of air traffic management and the methods of calculation that defined in fact base. After that it chooses the optimal algorithm of real-time scheduling for the introduced situation of air traffic management.

Step 5: the inference engine execute the chosen algorithm.

Step 6: the inference engine saves this process in the journal of reasoning

Step 7: The expert system show in the Referred user interface: (i) the real landing time for each aircraft (ii) the cost landing value that the difference between the real time landing and theoretical landing time of each aircraft (iii) the total landing cost of the sequence of aircraft.

IV. CONCEPTUAL DESIGN OF THE EXPERT SYSTEM

For the design of our expert system, we use UML (Unified Modeling Language) as a meta-language to describe the general structure of the system. We propose the following communication diagram that presents the all interaction of our system, activity diagram that represents the dynamic structure of the system; also we give a class diagram of the expert system and another for knowledge base that represent the static structure of the system.

For our system, we identify two main actors: a referred user can add or delete tasks and scheduling a set of tasks after authentication and an expert who keeps the role of the referred user and can update the knowledge base by adding, deleting or checking a scheduling algorithm or rule.

The expert system is managed by an administrator who has the right to add or delete user or an expert [1].

1- Communication Diagram

The communication diagram presents the architecture of the internal structure of the proposed system and shows the messages passing between the system components.

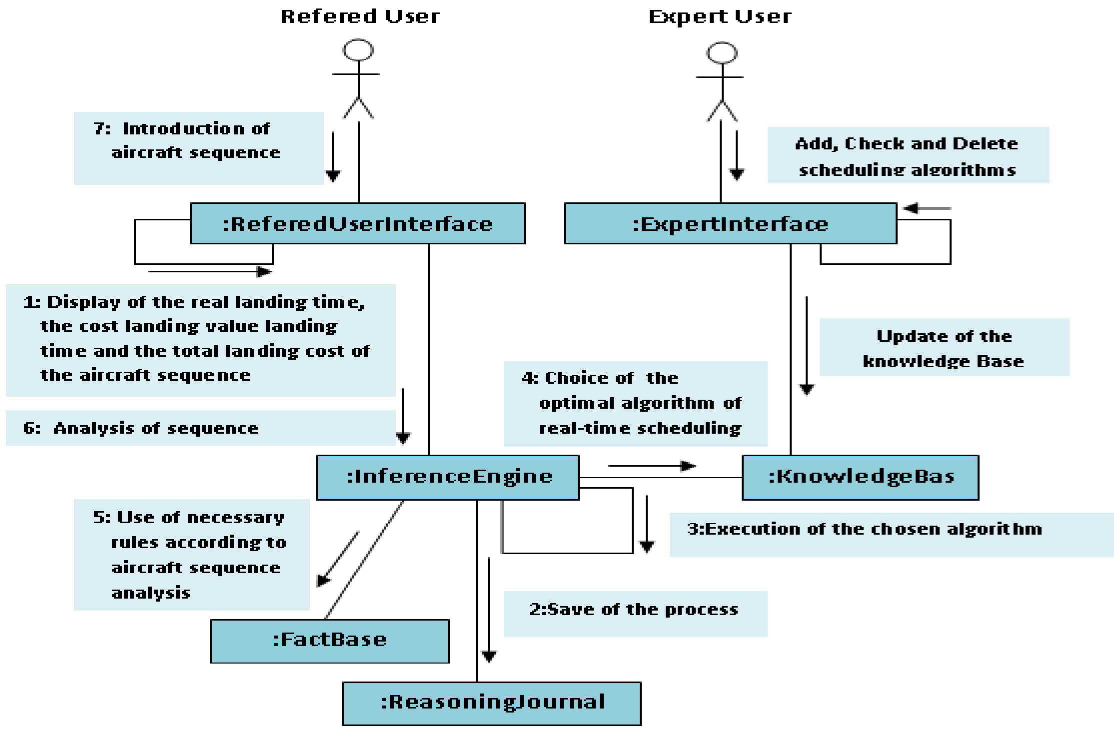

Fig 2: Diagram of communication

2- Diagram activity

The diagram activity shows the operating possibilities of our expert system. We tried to minimize the failure states and we use XML files for save, organize and transfer data.

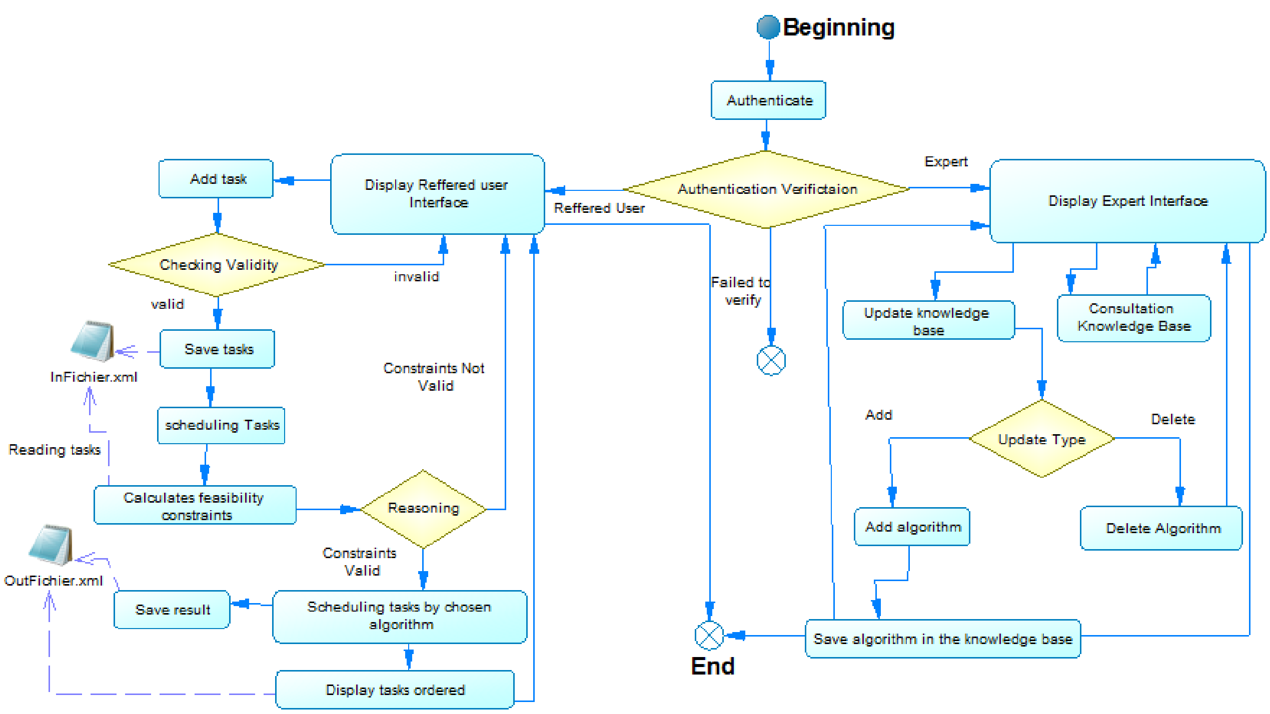

Fig 3: Diagram activity

To use the expert system the authentication is required, three states are possible either redirect to the expert interface or to the user interface or to the state of the authentication failure.

The interface of the expert has the following features: consulting the knowledge base or update, so the expert can add or delete and save an algorithm or a rule of scheduling.

The user interface allows the addition of a set of tasks, the task will be stored in an XML file if the task is conform to the requirements of the model of real-time task. The inference engine analyzes the constraints of each task and the feasibility conditions then it choose the most optimal algorithm to schedule the sequence of tasks. After that the system stores the results of scheduling in another XML file and the way of reasoning in a text file. If the conditions of feasibility are not checked, the system returns to the user interface [2].

3- Class diagram of the expert system.

This diagram describes the modules of the expert system; it gives an overview on the business layer of system composed by the inference engine, the knowledge base and the facts base it also describes the presentation layer of the system formed by two User class and Expert class, the first implement the UserInterface and the second implement ExpertInterface [3].

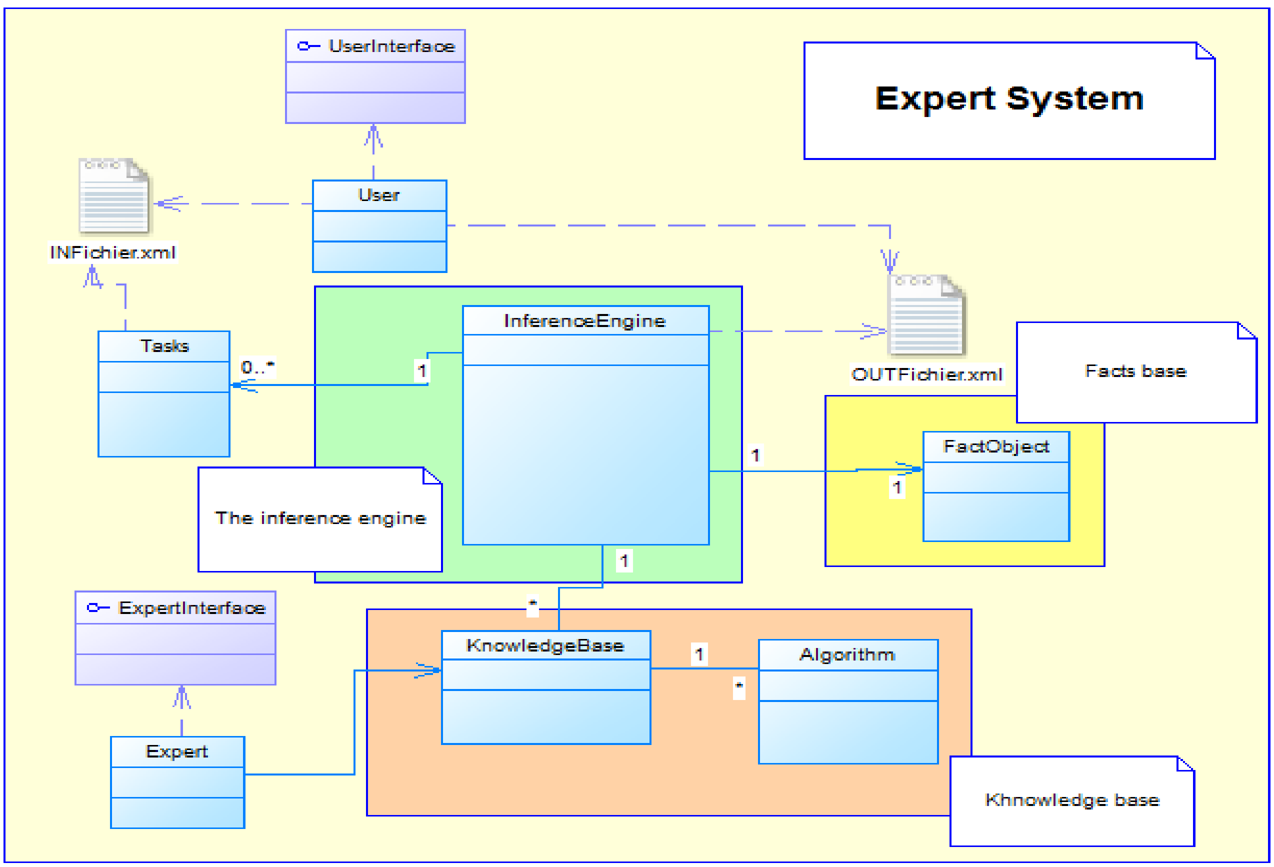

Fig 4: Class diagram of the expert system

4- Class diagram of knowledge base.

This diagram describes all the classes and interfaces of the knowledge base of the expert system. The class Task inherits from the RealtimeThread class and implements a the interface that include all methods for processing a task, then each task will be considered a real-time thread and it can use the all function predefined in the RealtimeThread class. Also the diagram manages the resources that will be shared by independent tasks.

This proposal is based on the concept of abstraction and inheritance, so our system will be open for extension so that it allows the enrichment of the knowledge base by algorithms and rules of scheduling [3][4].

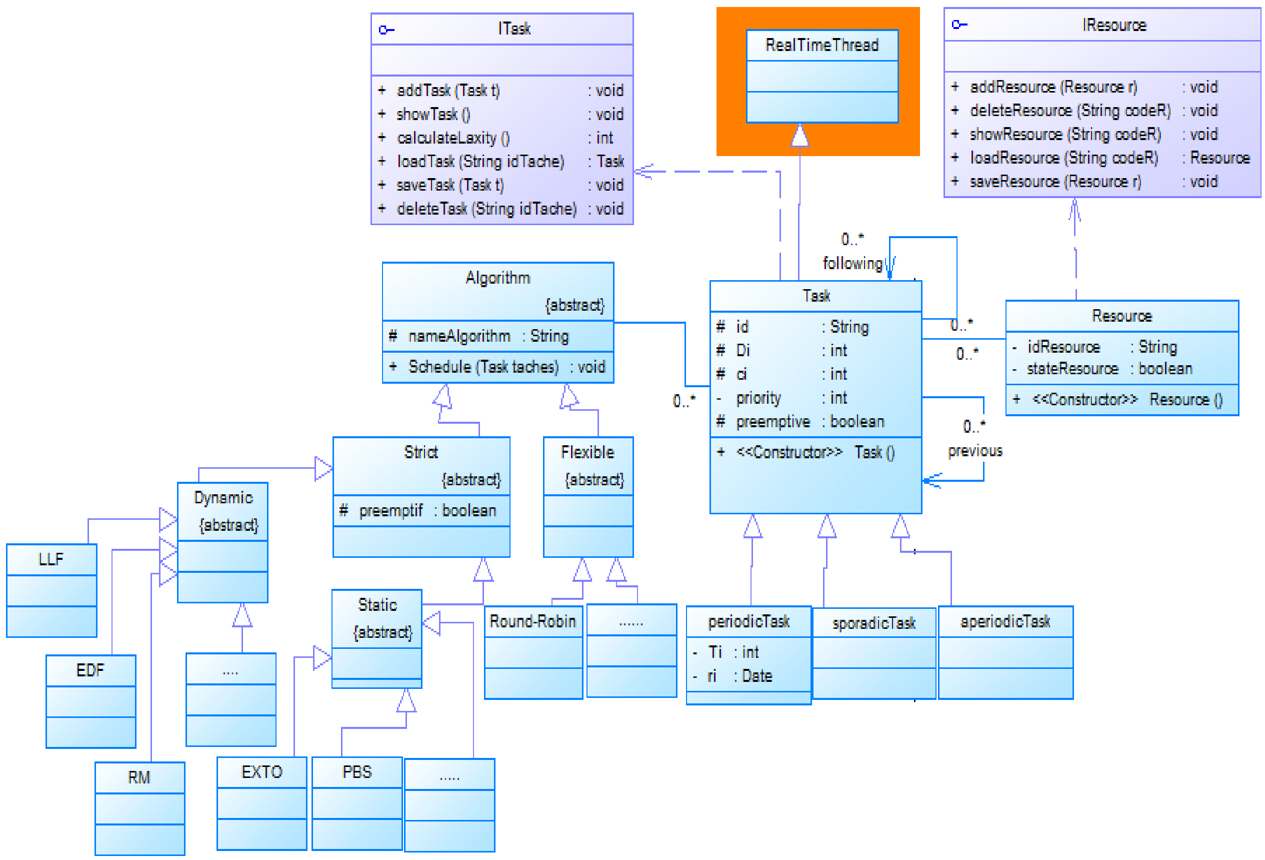

Fig 5: Class diagram of knowledge base.

V. Conclusion

This paper presents the global architecture and the conceptual design of an expert system for aircraft landing scheduling using real-time algorithms scheduling, the new system allow to solve the Aircraft Landing Scheduling problem by using the methods based on the real-time algorithms in order to have a minimum landing cost and ensuring aviation safety. Thereafter, we will develop the knowledge base by modeling the some situations of air traffic management and using of real-time scheduling algorithms for scheduling these situations, in the last step we develop the inference engine, it's a set of algorithms based on the Artificial Intelligence for the choice of optimal scheduling algorithm after the analysis of constraints and the rules of management of each situation of air traffic management.

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