Journal of Theoretical and Applied Information Technology
20th August 2015. Vol.78. No.2
© 2005 - 2015 JATIT & LLS. All rights reserved·
ISSN: **1992-8645** www.jatit.org E-ISSN: **1817-3195**

NEW EXPERT SYSTEM FOR SHORT, MEDIUM AND LONG-TERM FLOOD FORECASTING AND WARNING

[1]MAROUANE EL MABROUK, [1]MOSTAFA EZZIYYANI, [2]ZOUHAIR A. SADOUQ, [2]MOHAMMAD ESSAAIDI

[1]Mathematics and Application Laboratory, Faculty of Sciences and Technologies, Abdelmalek Essaadi University, Tangier, Morocco

[2]Laboratory, Faculty of Sciences, Abdelmalek Essaadi University, Tetuan, Morocco

E-mail: [1]elmabroukmarouane@gmail.com, [2]ezziyyani@gmail.com, [3]sadouq@ieee.org, [4]essaaidi@gmail.com

ABSTRACT

Floods are among the most powerful forces on the planet. Therefore, the need for a system that predict and warn about the flood occurrence is required. The combination of several approaches into a single system was our concern to design and develop an intelligent system that meets the demands of our research. After many studies, we decided to work with multi-agent systems to benefit of its advantages in terms of the distributed artificial intelligence, and we worked with expert systems to benefit of the concept of logic programming and the concept of facts and rules. In this paper, we present an expert system for real-time flood forecasting and warning that consists of two levels of processing. A first level for short-term forecasting and warning ie. for a time that does not exceed two to three days, using the proposed model, which is based on coefficients that will be calculated to do the flood forecasting and warning. A second level for medium (the time could be up to 10 years) and long-term (the time could be up to 1000 years) forecasting and warning via the empirical model of Hazan-Lazarevic.

Keywords: *Flood, Forecasting, Warning, Real-Time, Expert Systems, Agent, Multi-Agent Systems.*

1. INTRODUCTION

Floods now recognized as indispensable for the development of the ecosystem. Biodiversity cause floods that are responsible for most damage caused by natural disasters. Since forever, humans have suffered of floods. Many people died because of floods. This year, almost all parts of Morocco have suffered of flood disaster due to the large rainfall. Many people affected and dead in Morocco in November 2014. However, thanks to technological development, researchers developed the forecasting technique and the flood management to fight against this disaster.

Flood forecasting consists of anticipating as soon as possible periods at risk, using the weather forecasts and the state of water reserves in the watershed. For effective real-time forecasting, we must take into account several constraints, namely the data assimilation and a minimum calculation and response time

Therefore, the need to propose a system able to do the real-time flood forecasting and warning and takes into account all the constraints mentioned is required. In this paper, we present our proposed expert system for real-time forecasting and warning in short, medium and long term. The rest of the paper is organized as follows.

In the section 2, we will present the previous work presented by the other researchers in the literature. A state of art of multi-agents system, expert systems and Cramer method is presented in the section 3, 4 and 5. In section 6, we will introduce our proposed model for forecasting and warning. The proposed expert system, which comprises the two levels of forecasting and warning, will be presented in the section 7. The architecture of the proposed system, its algorithm, its analysis and its design will be presented respectively in section 8, 9 and 10. In the section 11, we will present the results of our work. Finally, we will present the conclusion in the section 12.

2. RELATED WORK

The author of [1] proposed a decision support system for flood management called FLOODDSS. This DSS analyzes data to predict the flood disaster, it anticipates also the effects and the impacts on the economical, social, environmental and cultural heritage. The FLOODDSS allows to:

- identify the areas at risk and anticipate the damages
- to do the real-time flood forecasting using the meteorological data
- to evaluate the decisions in order to reduce the damages

In [2], authors proposed an expert system based on the proposed Quantative Flood Forecasting model. This model used the multi-sensor data and the artificial neural networks in the mid-Atlantic region of the United States of America to predict and to forecast flood. The system aimed to modify the existing artificial neural network model to include the evolving structure and intense weather systems frequency for improved flood forecasting.

The authors of [3] proposed a new method for flood forecasting using the Genetic Programming (GP) and the Goup Method Data Handling (GMDH). This method predict and forecast the water level from ground-based or radar-derived rainfall automatically by learning the past data of river water level or dam inflow and rainfall.

3. MULTI-AGENT SYSTEMS AND REAL-TIME

The aim of this section is to provide basic theoretical information on multi-agent systems. We will focus on some concepts such as the concept of agents, multi-agent systems and the approach of real-time multi-agent systems by introducing an approach published by the authors of [4].

3.1 Agent and multi-agent system

An agent is a software entity which [5]:

- is in an open computer system comprising a set of applications, networks, and heterogeneous systems
- can communicate with other agents
- is driven by a set of specific objectives (it is in this meaning we can talk about intentional agent)
- has its own resources
- has only a partial representation of other agents
- has skills (services) that it may offer other agents
- has a behavior tending to meet its aims, taking into account both the resources and skills available, and also its own representations and communications that receives.

According to Ferber [5], an agent is essentially characterized by the way it is designed and by his actions, in other words, its architecture and its behavior.

A system that comprises several agents is called a multi-agent system (MAS). MAS is a generalization of an agent system where the main advantages of agents can be further exploited, namely the ability of an agent to execute autonomously and in parallel. MAS are perfectly suited for problems that can be executed in parallel or that can use several problem-solving methods.

3.2 Agent and multi-agent system

In [6], Kopetz defines a real-time system as a system that should meet the explicit constraints response time or risk serious consequences, including failure. A failed system is a system that can not meet one or more of the requirements in the specification of the formal system.

Depending on the concept of multi-agent systems and the concept of real-time systems, a Real-Time Agent is an agent that has temporal restrictions. It may be hard, soft or both. The real-time agent must guarantee the temporal restrictions and accomplish its aims and objectives. A multi-agent system is called Real-Time Multi-Agents System when it includes real-time agents.

In [4], authors proposed a multi-agents system called SIMBA. This approach is a real-time multi-agent system based on ARTIS agent architecture. This architecture comprises many techniques in the field of Real-Time systems. It guarantees that the response of the agents will satisfies the temporal restrictions. Many features make these agents provide the best answer.

SIMBA architecture is an evolution of the ARTIS agent architecture, because enables for the hard real-time environments, the development of different related agents.

4. EXPERT SYSTEMS

In this section, we will introduce and present expert systems. The author of [7] defines an expert system as a program that allows the exploitation of knowledge in a specific and rigorously limited field. It is used to perform intellectual tasks, work requiring knowledge and human experience. An expert system is then able to assist effectively the user. Another definition is presented by the author of [8]; an expert system is a computer system where data (the knowledge base) are well separated of the program that manipulates (the inference engine).

- **Knowledge Base**, which contains a fact base and a rule base, represents knowledge (permanent facts) and expertise (the rules of the expert). The fact base integrates two kinds of events: permanent facts of the field and the facts deduced by the inference engine that are specific to the case treated.
- **The inference engine** is a program responsible for operating the knowledge base to conduct reasoning about the problem based on the content of the fact base. For this, it contains an algorithm that examines the rules conditions and checks whether they are true or false. A rule whose premise (or some condition) is true is called "applicable"

5. SOLVING MATHEMATICAL SYSTEMS

According to Cramer [9], the system of n equations in n unknowns has the following general form:

$$\begin{cases} a_{1,1}x_1 + a_{1,2}x_2 + \ldots + a_{1,n}x_n = \lambda_1 \\ a_{2,1}x_1 + a_{2,2}x_2 + \ldots + a_{2,n}x_n = \lambda_2 \\ \vdots \\ a_{n,1}x_1 + a_{n,2}x_2 + \ldots + a_{n,n}x_n = \lambda_n \end{cases} \quad (1)$$

and is represented in the form of a matrix product:

$$A \cdot X = \Lambda \Leftrightarrow \begin{pmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,n} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n,1} & a_{n,2} & \cdots & a_{n,n} \end{pmatrix} \times \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{pmatrix} = \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \vdots \\ \lambda_n \end{pmatrix} \quad (2)$$

Where the square matrix A, contains the coefficients of the unknowns, the column vector X contains the unknowns and the column vector Lambda contains the right members of the system's equations, the coefficients and the unknown are part of the same body commutative.

The theorem says that the system admits a unique solution if and only if the matrix A is invertible (determinant is not null), and this solution is given by:

$$x_k = \frac{\det(A_k)}{\det(A)} \quad (3)$$

Where Ak is the square matrix formed by replacing the k-th column of A by the column vector Lambda.

$$A_k = (a_{k|i,j}) \text{ avec } a_{k|i,j} = \begin{cases} a_{i,j} & \text{si } j \neq k \\ \lambda_i & \text{si } j = k \end{cases} \quad (4)$$

6. PROPOSED MODEL FOR SHORT, MEDIUM AND LONF-TERM FLOOD FORECASTING AND WARNING

Our proposed system is divided into two levels to ensure the flood forecasting and warning. The first level for forecasting in medium and long term by using the empirical model of Hazan-Lazarevic [10]. The second level is for the flood forecasting and warning through our proposed model, which will be presented in the next section.

6.1 The medium and long-term forecasting stage

Hazan and Lazarevic [10] used data from fifteen hydrological stations distributed over different areas of Morocco. They extracted from this data the following characteristics: the acreage (A), the annual average rainfall, instant maxima runoff of return period T = 10, 100 and 1000 years, as well as the average of the observed maxima runoff (Qm).

For long-term forecasting, the runoff of the millennial flood is given by the following equation: Q (1000) = a x Ab, where the coefficients a and b the geographical area and the annual rainfall. Table I shows the various relationships obtained.

Table 1: Center Table Captions Above The Tables.

Relation Q $_{(1000)}$ = a x A^{b}			
Geographical area	**a**	**b**	**Pluviometry**
Central Rif	15.55	0.776	1000 - 1300
Occidental Rif	9.78	0.793	800 - 1000
Oriental Rif	7.58	0.808	600 - 800
Haut Saharian Atlas	9.38	0.742	200 - 400
Atlas Middle	14.94	0.636	700 - 900
Atlas Middle (Karst)	13.51	0.613	500 - 700

For the medium-term forecast, the runoff is given by the following equation:

$$Q_{(T_1)} = Q_{(T_2)} \times \frac{1 + k \ln T_1}{1 + k \ln T_2} \qquad (5)$$

With:

T1 and T2 are respectively the return period and k ∈ [0,8, 1,2[

6.2 The short-term forecasting stage

Our proposed model loads real-time data received from the wireless sensors and the historic of the area for a first forecasting of this new area. The historic is examined by our model, to the fact that takes just the cases where floods had occurred to calculate the coefficients (a, b, c) in order to make the forecasting and warning by the proposed model.

Since the decision in the historic of area would Boolean (yes or no) regarding the flood occurrence in a given area, such rainfall value with such runoff value gave floods, and since we just take the cases on which they had flood, so the equations of our proposed system will be equal to 1 (this means decision = yes).

Here is the proposed model in matrix form:

$$V_{33} \cdot C_3 = B_3 \Leftrightarrow \begin{pmatrix} X_1 & Y_1 & Z_1 \\ X_2 & Y_2 & Z_2 \\ X_3 & Y_3 & Z_3 \end{pmatrix} \times \begin{pmatrix} a \\ b \\ c \end{pmatrix} = \begin{pmatrix} 1+Cn \\ 1+Cn \\ 1+Cn \end{pmatrix} \qquad (6)$$

The forecasting system is the following:

$$(S) = \begin{cases} aX_1 + bY_1 + cZ_1 - Cn = 1 \\ aX_2 + bY_2 + cZ_2 - Cn = 1 \\ aX_3 + bY_3 + cZ_3 - Cn = 1 \end{cases} \qquad (7)$$

With:

(X1, Y1, Z1, X2, Y2, Z2, X3, Y3, Z3, Cn) ∈ □$^{*}_{+}$ et (X, Y, Z, Cn) are respectively the rainfall, the runoff, the water level and the evacuation of the area under control.

The solutions of this system are the values with which our expert system detects and makes the flood forecasting and triggers warnings based on the following generic function:

$$F(Z) = aX + bY + cZ - Cn \qquad (8)$$

7. PROPOSED EXPERT SYSTEM FOR SHORT, MEDIUM AND LONF-TERM FLOOD FORECASTING AND WARNING

As already said, our system is based on a generic function already presented in the previous section to make the real-time floods forecasting. The agents are responsible for making the processing in real-time proposed by the two levels of forecasting and they are also responsible for deciding about the flood occurrence by communicating with the knowledge base that contains the decision rules under decision tree format.

Some rules were designed to feed our knowledge base of the expert system in order to take decisions. Here are the rules to consider:

- If Runoff = 0 or Water Level = 0 Then there is no flood
- $Q = \frac{V}{t}$
- $V = S \times L$
- $V_T = V_{DR} + V_{QR}$
- If $F(Z)_{TR} \geq 90\% F(Z)_{\text{Generic}}$ Then there will be flood.
- If the runoff changes, the calculated time for floods occur must be recalculated. Therefor:

$$t_N = \frac{V_{QR}}{Q_N} = \frac{V_T - (Q_{AD} \times t_{TEJM})}{Q_N} \qquad (9)$$

With:

- Q Runoff (in $\frac{m^3}{s}$), V volume (in m^3), t time (in s)

- S (m^2) is the wet surface defined as the streams section taken perpendicular to the flow. The volume V is the product of the surface by the length in the direction of flow (L in m).
- V_T is the total volume of the area under control, the V_{DR} volume already filled and V_{QR} the volume that will be filled.
- $F(Z)_{TR}$ is the calculated function from data received in real-time from wireless sensor and $F(Z)_{\text{Generic}}$ is the generic function calculated from the area's historic.
- t_N is the new time for the floods occur, Q_N is the new runoff sent in real-time from wireless sensors, Q_{AD} is the old runoff sent and t_{TEJM} is the time elapsed since the announcement of the old time remaining for floods occur until the change of runoff.
-

7.1 Demonstration

We have

$$Q = \frac{V}{t} \qquad (10)$$

So

$$t = \frac{V}{Q} \qquad (11)$$

In addition, we have

$$V_T = V_{DR} + V_{QR} \qquad (12)$$

Moreover, we have

$$V_{DR} = Q_{AD} \times t_{TEJM} \qquad (13)$$

Therefore, (10), (11), (12) and (13) give

$$V_{QR} = V_T - V_{DR} = V_T - (Q_{AD} \times t_{TEJM})$$

Consequently, the new time for the floods occur is

$$t_N = \frac{V_{QR}}{Q_N} = \frac{V_T - (Q_{AD} \times t_{TEJM})}{Q_N}$$

Since we are dealing with and dangerous disaster, so we must design and propose an expert system that respect the temporal constraint. Consequently, we have used the real-time multi-agent system in the design and the implementation of our proposed system because of it advantage of the distributed computing, the cooperation and the collaboration concepts. We have used the SIMBA approach [4] to respect the temporal constraint. We have six agents responsible for all the processing inside the proposed expert system.

- **AGM agent** is responsible for the management of the areas and the Hazan-Lazarevic Model parameters.
- **AGIHA agent** is responsible for the importation of the historic of the area under control.
- **AGCC agent** is responsible for the calculation of the proposed model coefficients for a new area.
- **AGSTFW agent** is responsible for the process of the short-term flood forecasting and warning.
- **AGSTFWUR agent** is responsible for the calculation on displaying the new time when runoff is changed in the database.
- **AGMLTFW agent** is responsible for the process of the medium and long-term flood forecasting and warning.

8. ARCHITECTURE OF THE PROPOSED EXPERT SYSTEM

In this section, we will present in the figure 1 the architecture of our proposed expert system.

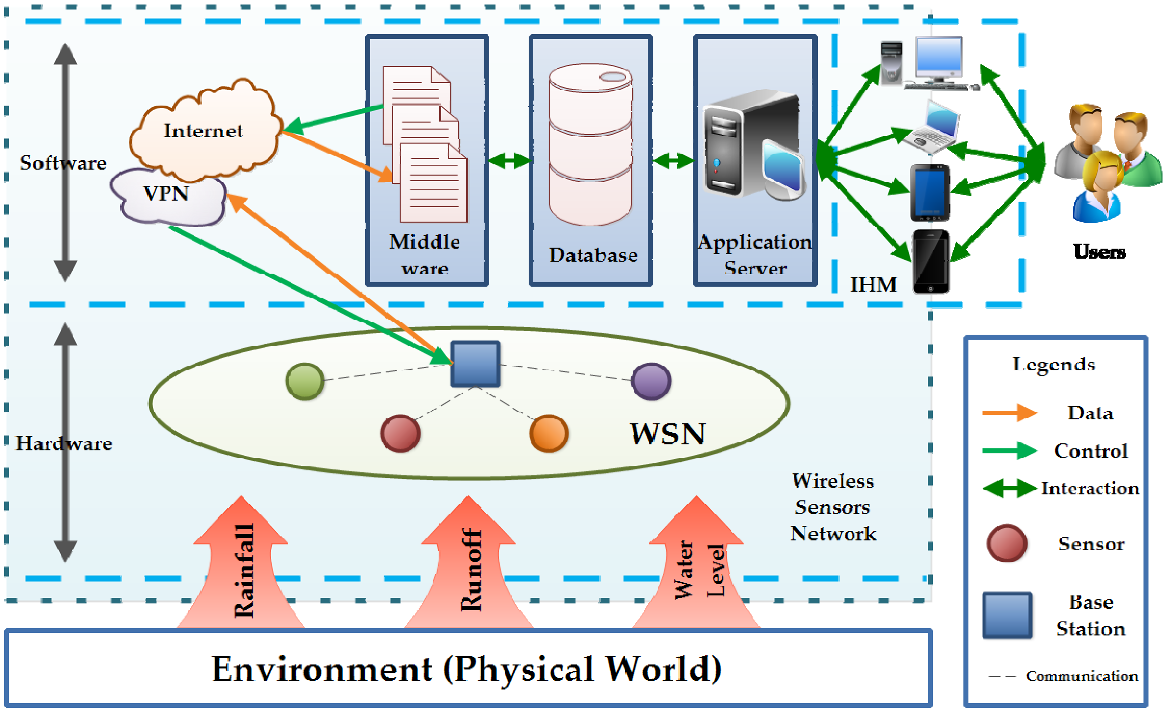


Figure 1: Architecture Of The Proposed Expert System

9. ALGORITHM OF THE PROPOSED EXPERT SYSTEM

In this section, we will present the algorithms of the proposed system for forecasting in short, medium and long-term. Here are the proposed algorithms:

```
Function SystemResolution(S : HistoricSystem) : CoefficientList
  Data: CoefficientList : List of Double;
  begin
    CoefficientList ← CramerMethod(S);
    return CoefficientList;
  end
```

```
Algorithm 1: CalculateCoefficients
  Data:
  CoefficientList : List of Double;
  S : HistoricSystem;
  begin
    if The coefficients of this area is already calculated then
      Print("This area has already its own coefficients!!!");
    else
      CoefficientList ← SystemResolution(S); AddInDatabase(CoefficientList);
    end
  end
```

Algorithm 2: ShortTermFloodForecasting

```
Data:
CoefficientList : List of Double ;
ValidDataList : List of Double ;
AreaUnderControl : Areas ;
Volume : Double ;
ResultOfFunctionZ : Double ;
TimeToGo : Second ;
Minutes : Minute ;
begin
    AreaUnderControl ← SearchForArea() ;
    CoefficientList ← SearchForCoefficients(AreaUnderControl) ;
    ValidDataList ← SearchForValidData(AreaUnderControl) ;
    Volume ← AreaAcreage × FlowLength ;
    ResultOfFunctionZ ← CoefficientList.getA() · X + CoefficientList.getB() · Y + CoefficientList.getC() · Z - Cn ;
    if $ResultOfFunctionZ \geq 90\% \ F(Z)_{Generic}$ then
        TimeToGo ← $\frac{Volume}{ValidDataList.getRunoff()}$ ;
        Minutes ← $\frac{TimeToGo}{60}$ ;
        Print("There will be floods in this area in ", Minutes, "Minutes") ;
        TriggerCountdown() ;
    end
end
```

Algorithm 3: UpdateRunoff

```
Data:
ValidDataList : List of Double ;
AreaUnderControl : Areas ;
TotalVolume : Double ;
OldTimeToGo : Second ;
NewTimeToGo : Second ;
OldRunoff : Double ;
NewRunoff : Double ;
Minutes : Minute ;
begin
    AreaUnderControl ← SearchForArea() ;
    ValidDataList ← SearchForValidData(AreaUnderControl) ;
    TotalVolume ← AreaAcreage × FlowLength ;
    NewTimeToGo ← $\frac{TotalVolume-(OldRunoff \times OldTimeToGo)}{NewRunoff}$ ;
    Minutes ← $\frac{NewTimeToGo}{60}$ ;
    Print("There will be floods in this area in ", Minutes, "Minutes") ;
    TriggerCountdown() ;
end
```

```
Function FunctionOfLongTerm(AreaUnderControl : Areas) : Double
  Data:
  HLParametersList : List of Double ;
  $Q_{(1000)}$ : Double ;
  Volume : Double ;
  begin
      HLParametersList ← SearchForHLParameters(AreaUnderControl) ;
      Volume ← AreaAcreage × FlowLength ;
      $Q_{(1000)} \leftarrow HLParametersList.getA() \times Volume^{HLParametersList.getB()}$ ;
      return $Q_{(1000)}$ ;
  end
```

```
Algorithm 4: MediumLongTermFloodForecasting
  Data:
  HLParametersList : List of Double ; AreaUnderControl : Areas ; $Q_{(1000)}$ : Double ; $Q_{(T)}$ :
  Double ; T : Double ;
  begin
      AreaUnderControl ← SearchForArea() ;
      HLParametersList ← SearchForHLParameters(AreaUnderControl) ;
      $Q_{(1000)}$ ← FunctionOfLongTerm(AreaUnderControl) ;
      Print("The Runoff for 1000 years of return time is : ", $Q_{(1000)}$) ;
      Print("Enter the return time") ;
      Read(T) ;
      $Q_{(T)} \leftarrow Q_{(1000)} \times \frac{1+HLParametersList.getK()\cdot\ln T}{1+HLParametersList.getK()\cdot\ln 1000}$
      Print("The Runoff for ", T," years of return time is : ", $Q_{(T)}$) ;
  end
```

10. SYSTEM ANALYSIS AND DESIGN

In this system analysis and design phase, we chose visual modeling as a design model for this system because of its many benefits regarding simplicity, universality, conciseness and expressiveness. The language used is the UML, which is a graphical language for modeling data and processing. The modeling was performed on two levels, structural modeling and behavioral modeling.

10.1 Structural Modeling

This kind of modeling models the static structure of the system. We conducted two structural diagrams that provide an overview of the objects and their relationships, the class diagram, the component diagram. The class diagram and the component diagram are shown in the figure 2 and 3.

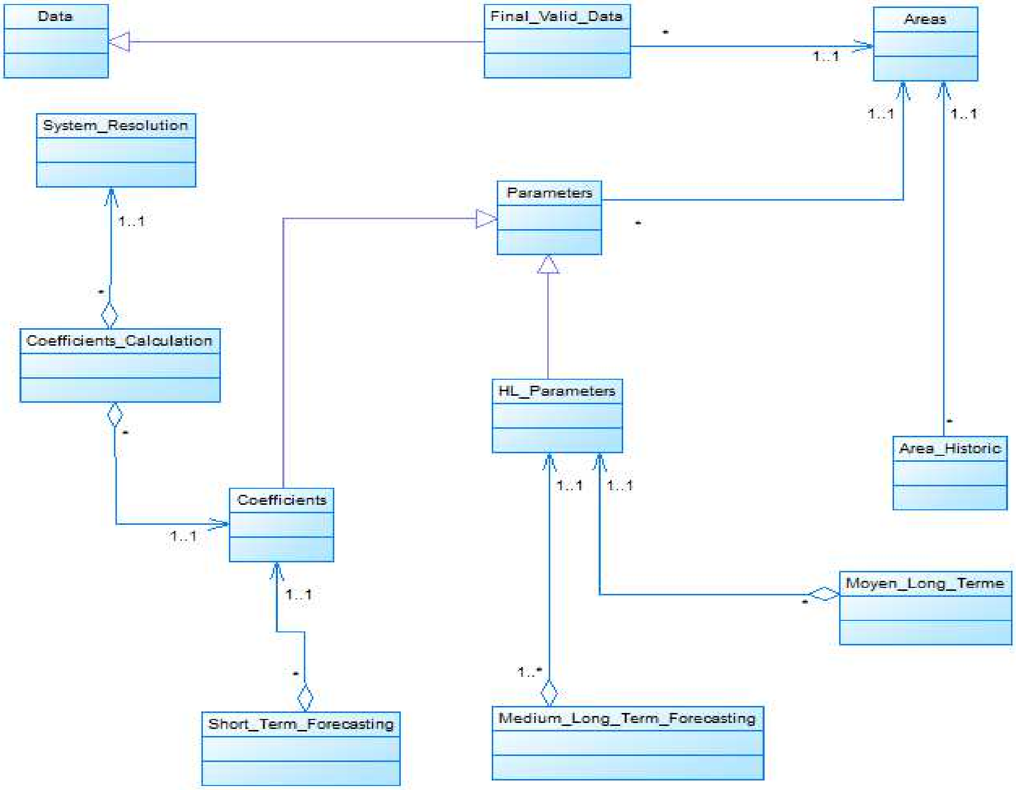


Figure 2: Class diagram of the proposed expert system

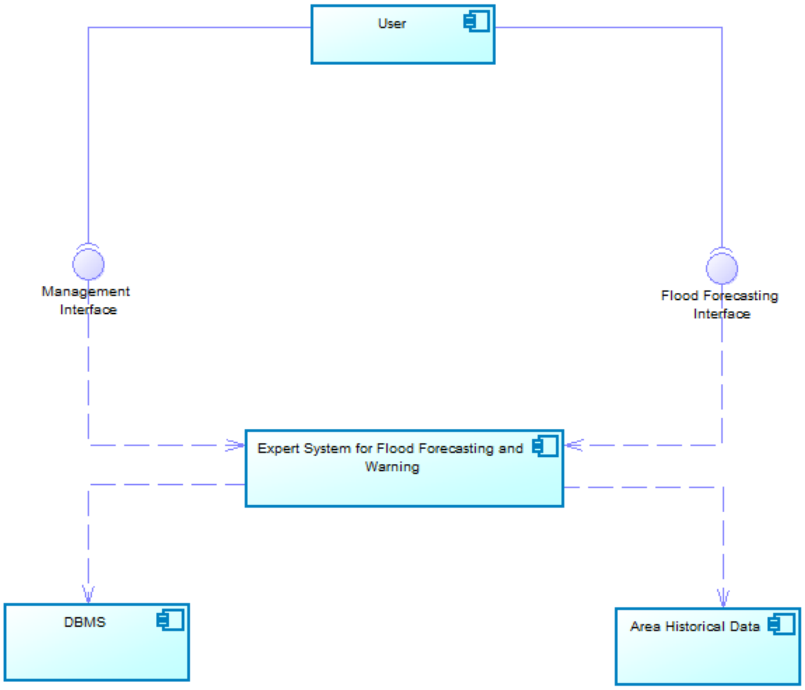


Figure 3: Components Diagram Of The Proposed Expert System

10.2 Behavioral modeling

Behavioral diagrams focus on the dynamic behavior of the system, the behavioral diagrams that we used are the use case diagram and sequence diagram. The main actors in our system are the decision makers who watch over the control and management of floods and administrators. The use case diagram and the sequence diagram are shown in the figure 4 and 5.

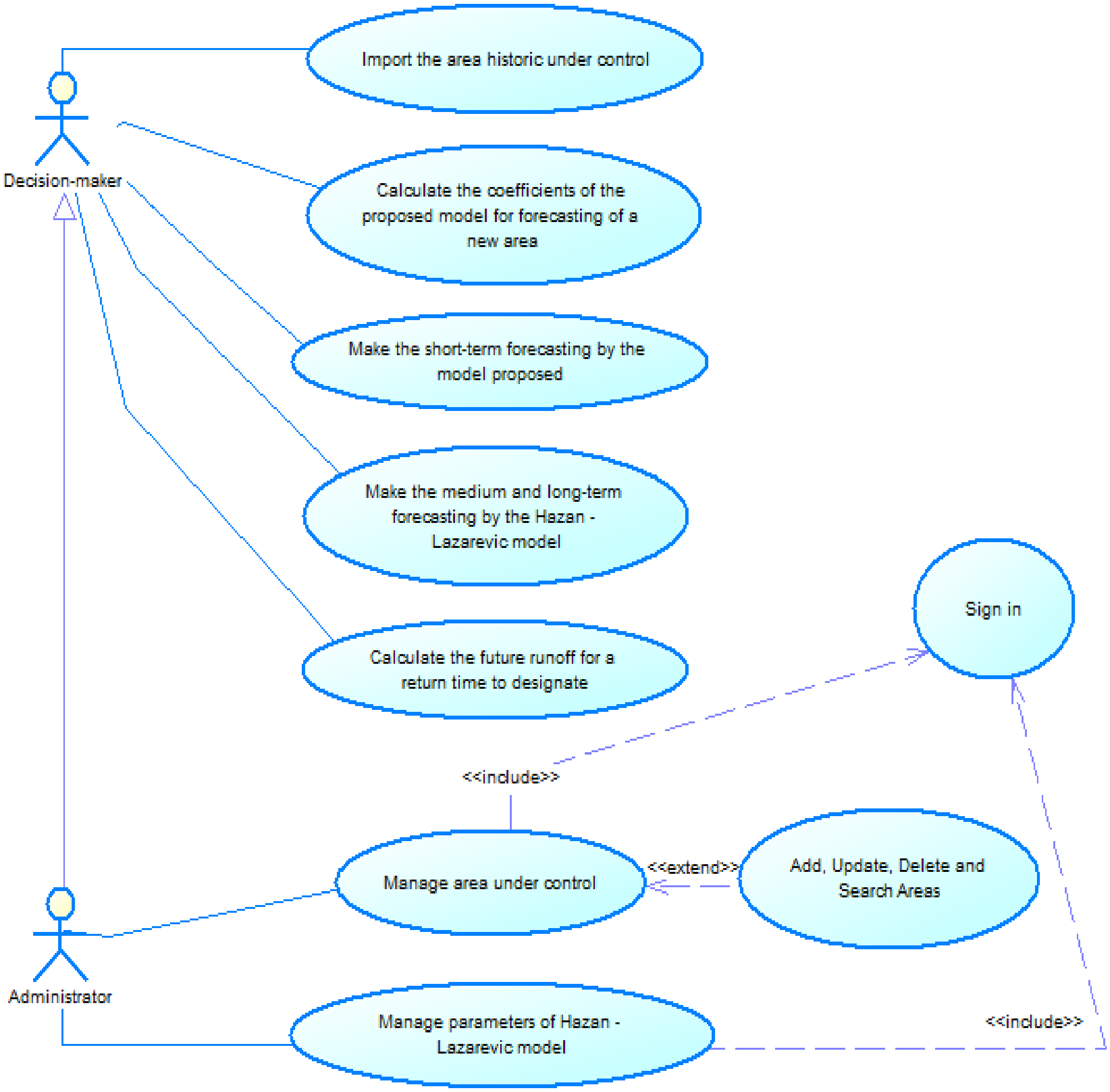


Figure 4: Use Case Diagram Of The Proposed Expert System

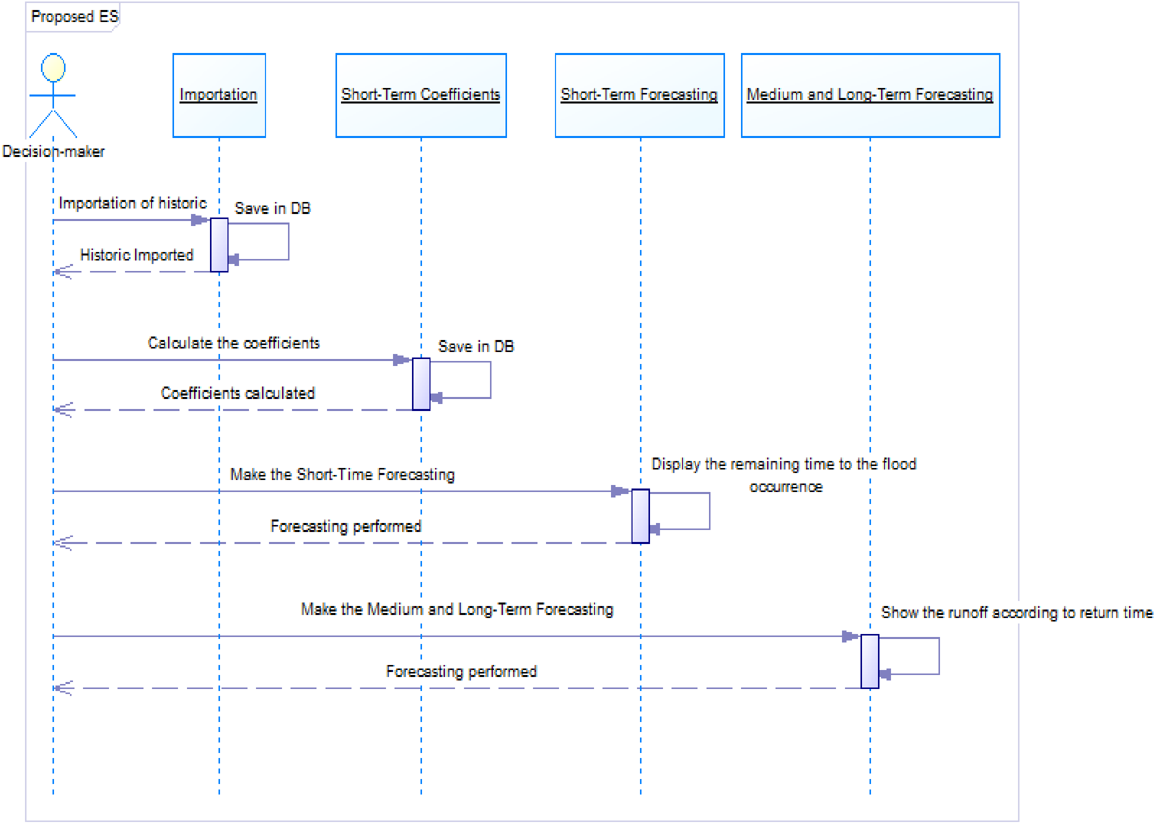
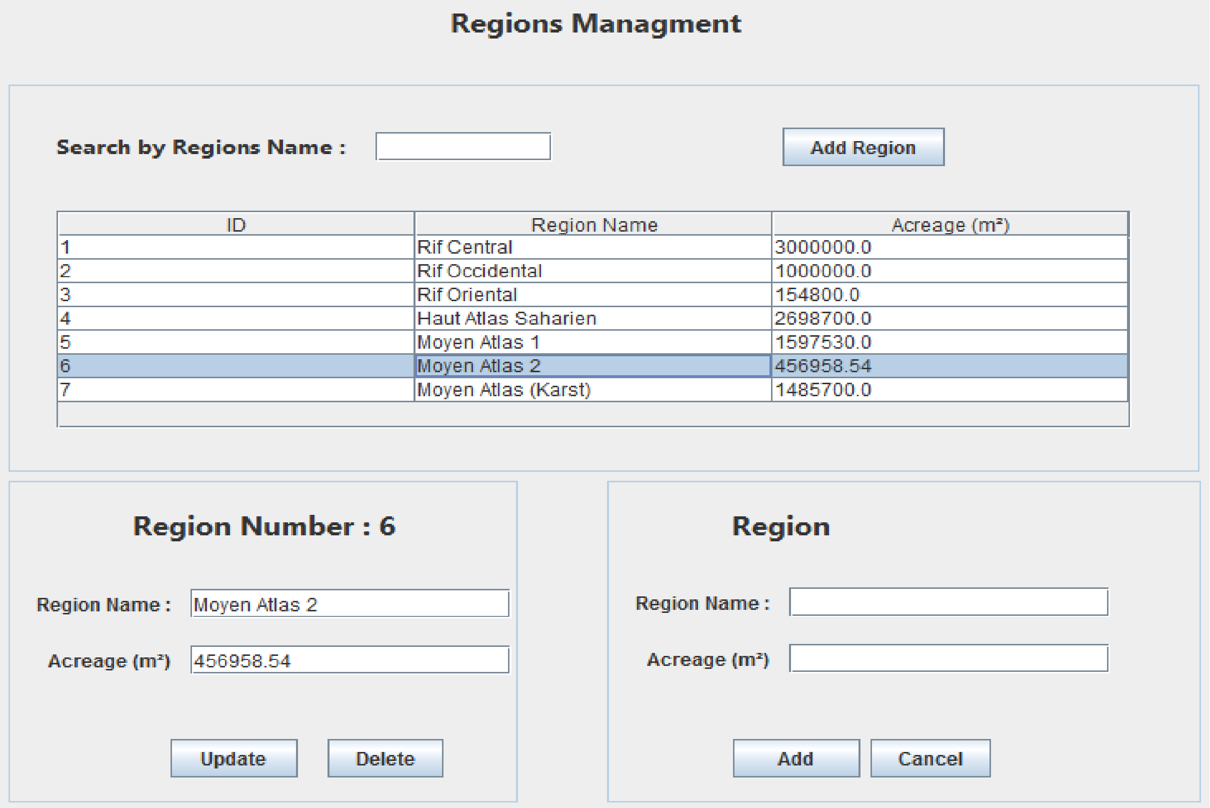


Figure 5: Sequence diagram of the proposed expert system

11. RESULTS

In this section, we will present our proposed system that has two levels for real-time forecasting and warning. In this system, we can manage the areas under control and the forecasting in medium and long-term parameters. For short-term coefficients, its management is not necessary because they are automatically calculated in a dedicated interface that will be presented later. For the delete operation, when an area is removed, all its coefficients are removed as well.



Regions Managment

Search by Regions Name :

ID	Region Name	Acreage (m²)
1	Rif Central	3000000.0
2	Rif Occidental	1000000.0
3	Rif Oriental	154800.0
4	Haut Atlas Saharien	2698700.0
5	Moyen Atlas 1	1597530.0
6	Moyen Atlas 2	456958.54
7	Moyen Atlas (Karst)	1485700.0

Region Number : 6

Region Name : Moyen Atlas 2

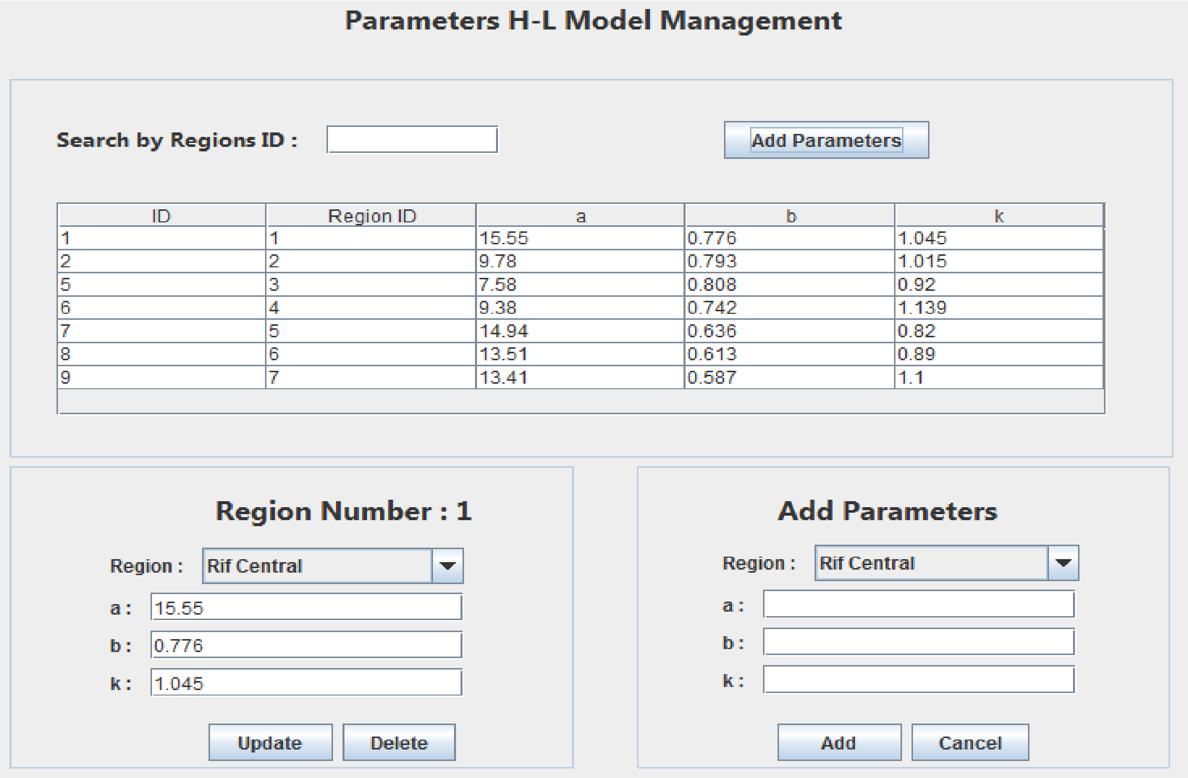
Acreage (m²) 456958.54

Region

Region Name :

Acreage (m²)

Figure 6: Regions Management



Parameters H-L Model Management

Search by Regions ID :

ID	Region ID	a	b	k
1	1	15.55	0.776	1.045
2	2	9.78	0.793	1.015
5	3	7.58	0.808	0.92
6	4	9.38	0.742	1.139
7	5	14.94	0.636	0.82
8	6	13.51	0.613	0.89
9	7	13.41	0.587	1.1

Region Number : 1

Region : Rif Central

a : 15.55

b : 0.776

k : 1.045

Add Parameters

Region : Rif Central

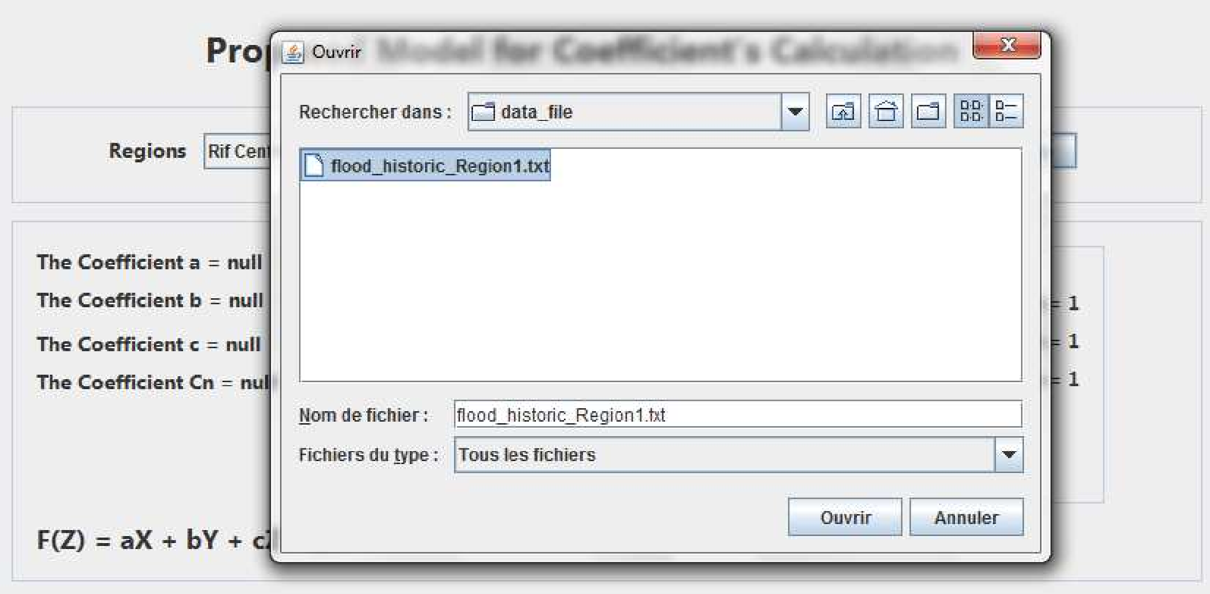
a :

b :

k :

Figure 7: Hazan-Lazarevic Model Parameters Management

For a new area, its historic is imported to calculate the forecasting coefficients by the proposed model. Here is the dedicated interface.



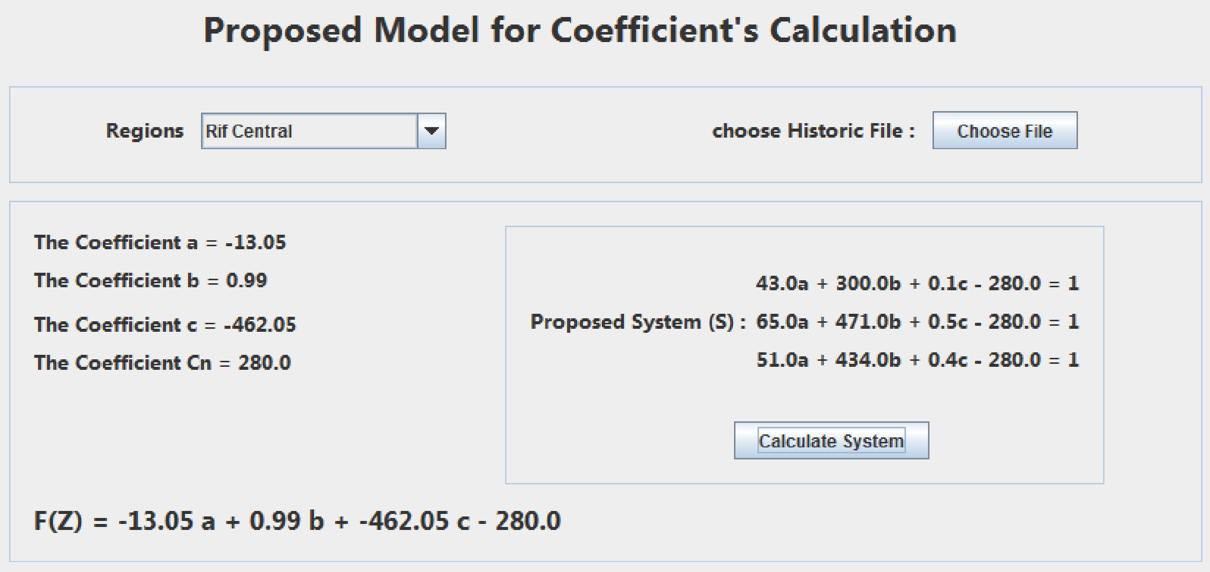
The Coefficient a = null
The Coefficient b = null
The Coefficient c = null
The Coefficient Cn = nul
F(Z) = aX + bY + c

Rechercher dans : data_file
flood_historic_Region1.txt
Nom de fichier : flood_historic_Region1.txt
Fichiers du type : Tous les fichiers

Figure 8: Operation of historic data importation of an area

Then the coefficients is calculated based on this history while using our proposed model.

Here is the result.



Regions: Rif Central
choose Historic File :

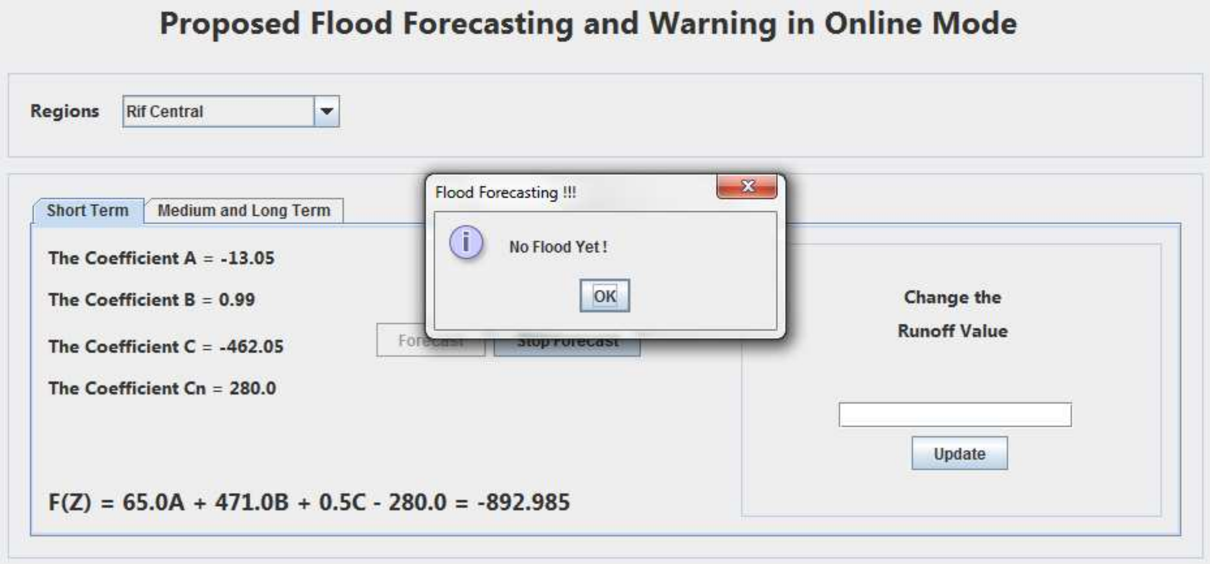
The Coefficient a = -13.05
The Coefficient b = 0.99
The Coefficient c = -462.05
The Coefficient Cn = 280.0

Proposed System (S) :
43.0a + 300.0b + 0.1c - 280.0 = 1
65.0a + 471.0b + 0.5c - 280.0 = 1
51.0a + 434.0b + 0.4c - 280.0 = 1

F(Z) = -13.05 a + 0.99 b + -462.05 c - 280.0

Figure 9: Process of calculating the coefficients of the proposed model

Now, we will present the short-term real-time forecasting and warning process. The first thing to do is to select an area to control. The following case is a case of an area where there is still no flood.



Proposed Flood Forecasting and Warning in Online Mode

Regions: Rif Central

Flood Forecasting !!!

No Flood Yet !

The Coefficient A = -13.05

The Coefficient B = 0.99

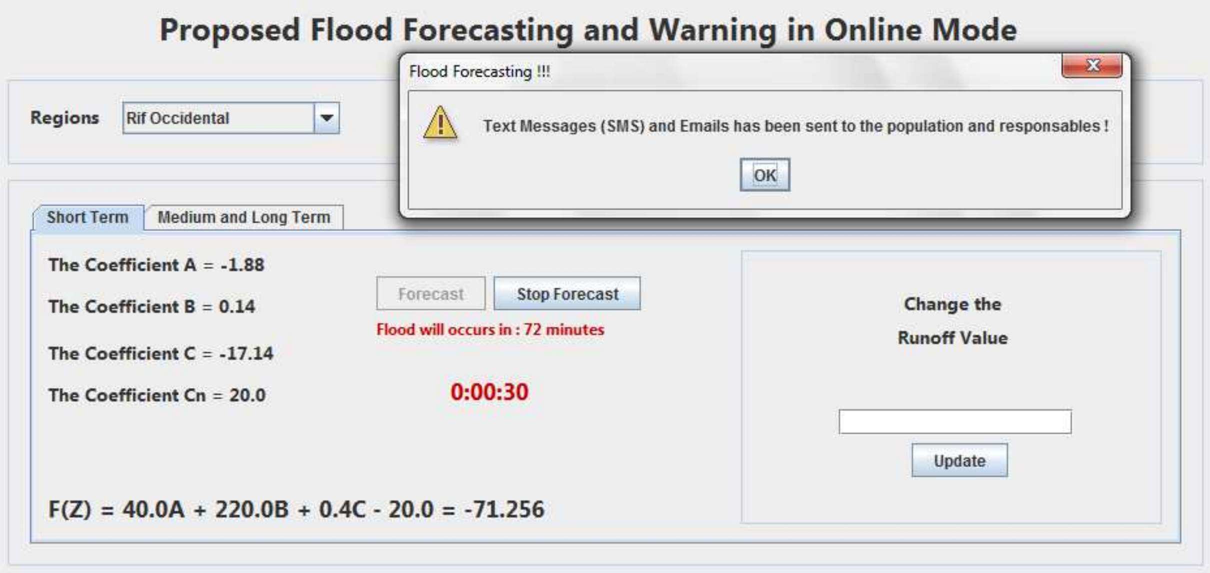
The Coefficient C = -462.05

The Coefficient Cn = 280.0

F(Z) = 65.0A + 471.0B + 0.5C - 280.0 = -892.985

Figure 10: Short-term forecasting and warning using our proposed model: Flood inexistence case

When changing area, the system detected that will have flood in 72 minutes. This makes the system triggered the warning and the countdown, and informed responsible to trigger the warning within the population.



Proposed Flood Forecasting and Warning in Online Mode

Regions: Rif Occidental

Flood Forecasting !!!

Text Messages (SMS) and Emails has been sent to the population and responsables !

The Coefficient A = -1.88

The Coefficient B = 0.14

The Coefficient C = -17.14

The Coefficient Cn = 20.0

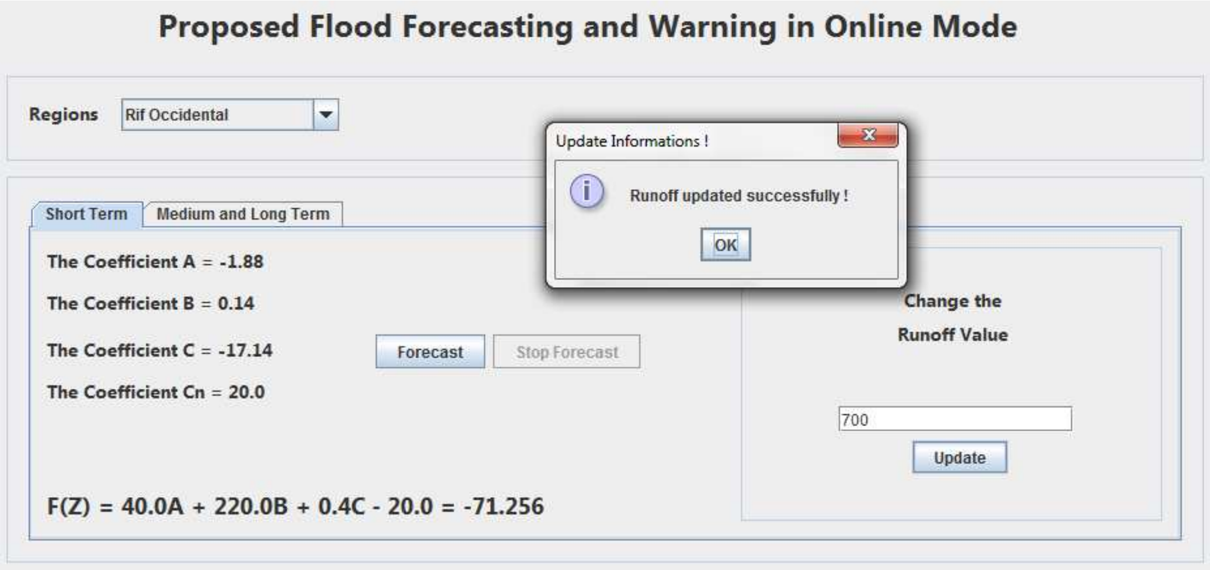
Flood will occurs in : 72 minutes

0:00:30

F(Z) = 40.0A + 220.0B + 0.4C - 20.0 = -71.256

Figure 11: Short-term forecasting and warning using our proposed model: Flood existence case

The system automatically detects the change in the database, however we have not yet installed the sensors to have automatically the data in real-time, so we designed to change the runoff value manually in order to validate our model is it answers and it redefines the remaining time for floods occur or not. We got the desired result showed in the interfaces below.



Proposed Flood Forecasting and Warning in Online Mode

Regions: Rif Occidental

Update Informations !

Runoff updated successfully !

The Coefficient A = -1.88

The Coefficient B = 0.14

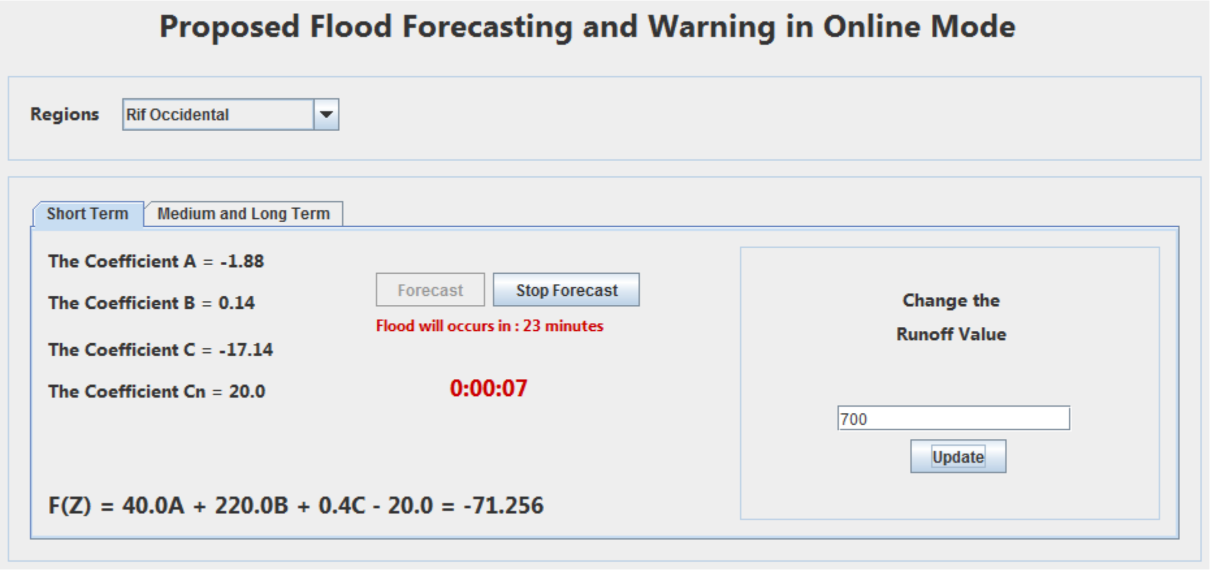
The Coefficient C = -17.14

The Coefficient Cn = 20.0

F(Z) = 40.0A + 220.0B + 0.4C - 20.0 = -71.256

Change the Runoff Value: 700

Figure 12: Short-term forecasting and warning using our proposed model: Runoff update case 1 / 2



Proposed Flood Forecasting and Warning in Online Mode

Regions: Rif Occidental

The Coefficient A = -1.88

The Coefficient B = 0.14

The Coefficient C = -17.14

The Coefficient Cn = 20.0

Flood will occurs in : 23 minutes

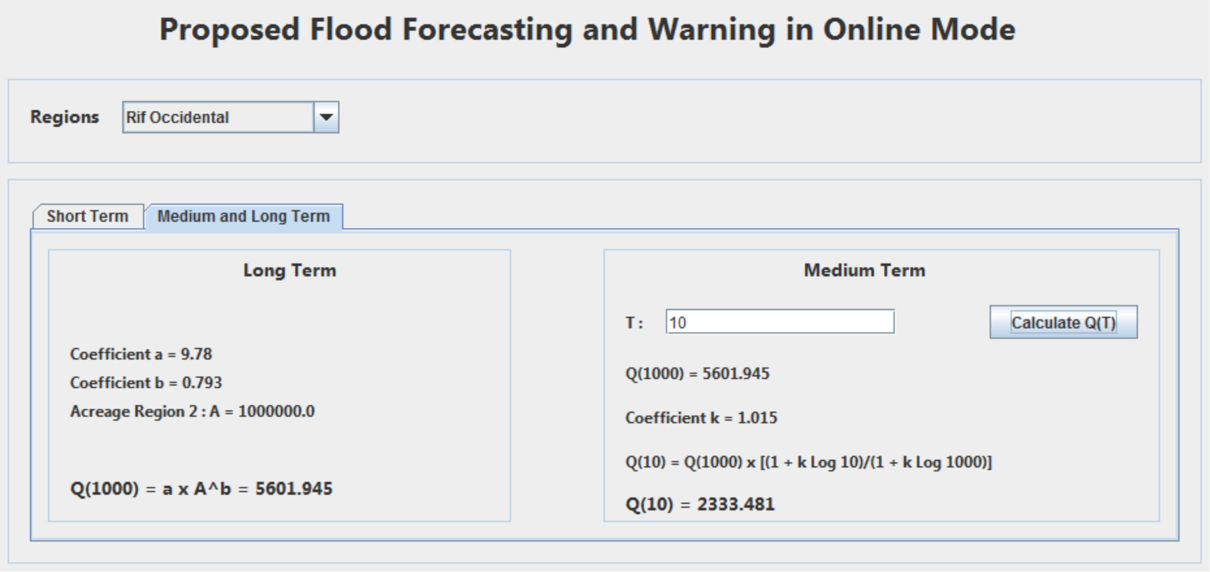
0:00:07

F(Z) = 40.0A + 220.0B + 0.4C - 20.0 = -71.256

Change the Runoff Value: 700

Figure 13: Short-term forecasting and warning using our proposed model: Runoff update case 2 / 2

Finally, we got to the last part of our proposed system for forecasting and warning of floods, the forecasting in medium and long-term. This is the interface of this level:



Regions: Rif Occidental

Coefficient a = 9.78
Coefficient b = 0.793
Acreage Region 2 : A = 1000000.0
Q(1000) = a x A^b = 5601.945

T : 10
Q(1000) = 5601.945
Coefficient k = 1.015
Q(10) = Q(1000) x [(1 + k Log 10)/(1 + k Log 1000)]
Q(10) = 2333.481

Figure 14: Medium and long-term forecasting and warning using our Hazan-Lazarevic model: Flood existence case

12. CONCLUSION

In this paper, we presented a proposed expert system for flood forecasting and warning, which has two level of forecasting. The first level is for the medium and long-term forecasting and warning. In this level, we implemented the Hazan – Lazarevic proposed model into our system to make this kind of forecasting and warning.

The second level is for the short-term forecasting and warning. In this level, we proposed a new model to make this kind of forecasting and warning. In addition, we presented the architecture, the algorithm and the analysis and design of our proposed system. Besides, we presented the different interfaces of the proposed system.

REFRENCES:

[1] Ezio Todini, An operational decision support system for flood risk mapping, forecasting and management, Urban Water, Volume 1, Issue 2, June 1999, Pages 131-143, ISSN 1462-0758, http://dx.doi.org/10.1016/S1462-0758(00)00010-8.
[2] Gwangseob Kim, Ana P Barros, Quantitative flood forecasting using multisensor data and neural networks, Journal of Hydrology, Volume 246, Issues 1–4, 1 June 2001, Pages 45-62, ISSN 0022-1694, http://dx.doi.org/10.1016/S0022-1694(01)00353-5.

[3] Watanabe, N., Fukami, K., Imamura, H., Sonoda, K., Yamane, S., "Flood forecasting technology with radar-derived rainfall data using Genetic Programming". In the proceeding of the International Joint Conference on Neural Networks, 2009 (IJCNN 2009), pp.3311, 3318, Atlanta, Georgia, USA, 14-19 June 2009.

[4] V. Julian, C. Carrascosa, M. Rebollo, J. Soler, and V. Botti, "Simba: An approach for real-time multi-agent systems," in *Topics in Artificial Intelligence*, ser. Lecture Notes in Computer Science, M. Escrig, F. Toledo, and E. Golobardes, Eds. Springer Berlin Heidelberg, 2002, vol. 2504, pp. 282–293.

[5] J. Ferber, *Multi-agent systems: an introduction to distributed artificial intelligence*. Harlow (England), New York, Toronto: Addison-Wesley, 1999, trad. de: Les systèmes multi-agents : vers une intelligence collective, pub. Par InterEditions en 1995. [Online]. Available: http://opac.inria.fr/record=b1116994

[6] H. Kopetz, Real-Time Systems: Design Principles for Distributed Embedded Applications, 1st ed. Norwell, MA, USA: Kluwer Academic Publishers, 1997.

[7] Laurence Negrello. Systèmes experts et intelligence artificielle. Schneider Electric. Vol. 157, 1991

[8] D. A. Waterman, *A Guide to Expert Systems*. Boston, MA, USA: Addison-Wesley Longman Publishing Co., Inc., 1985.

[9] Cramer G., Cramer frères & Philibert C., Provinciale B., and Topografico R. O., *Introduction à l'analyse des lignes courbes algébriques. Par Gabriel Cramer.* Chez les frères Cramer & Cl. Philibert, 1750.

[10] T. Ouarda, INRS-Eau, and M. Barbet, *Synthèse des méthodes simples de régionalisation*. Rapport de recherche / INRS-Eau. INRS-Eau, 2001.