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Fuzzy UML and Petri Nets Modeling Investigations on the Pollution Impact on the Air Quality in the Vicinity of the Black Sea Constanta Romanian Resort

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Abstract—**The purpose of this research is to investigate the use of an intelligent neural-fuzzy modeling strategy based on Unified Modeling Language (UML) diagrams and Petri nets models of the pollution sources impact on the air quality along the Romanian coast of Black Sea, especially in Constanta vicinity. This is possible by monitoring the physical and chemical parameters of the air quality, such as temperature, wind speed, Carbon Dioxide (CO2), methane (CH4), Nitrogen Oxide, ozone, water vapours concentrations provided by several "in-situ" measurements stations spread in the critical points from Constanta area. Moreover, we will try to disseminate the information collected and to investigate adequate actions to prevent the continuous degradation of the environment. The values of air quality-monitored parameters vary with the position of the sampling sites in quasi-large range; consequently a direct correlation between these indicators will be useful. Air pollution sources cause the "greenhouse effect"with a high impact on the live and fauna, degrading progressively the Black Sea ecosystems. Closing, in our research we try to present the benefit of the UML diagrams in combination with Petri nets models developed on a wide database concerning the air pollution degree inside Constanta Romanian Black sea resort to predict the future results.**

I. Introduction

THE direct impact of pollutants discharged into the atmosphere by agents economic generally occur in areas relatively close by them, range from a few tens or hundreds of meters up to several kilometers according to physical parameters, the power output of the source and especially climatic conditions, intensity and wind. Considerable influence on the spread of pollutants in the air has the climate conditions for example: thermal stratification of air, turbulence, convection, precipitation and wind. Thermal stratification of the air may be stable or unstable, and affects the vertical dispersion of pollutants. Thus, a stable stratification prevents the diffusion of pollutants in height, and resulting in their concentration in the soil near the source, while the unstable stratification favors the diffusion of pollutants. Turbulence also occurs in the dispersion of pollutants, representing the disordered movements of the air in the form of small vortices. Dynamic and thermal convection is the most important process that produces heat exchange between terrestrial surface and the air above, and between different layers of the atmosphere. In addition, in the summer months heat exchanges in turbulent times, the thermal convection during the nights having a irregular character, predominantly downward movements. This is because solid particles which floating in the air are cooled by radiation, increasing their density and become more heavy being forced to get down on the ground. In winter time, during the night radiation's balance becomes negative, prevailing only downward movements and the turbulent exchange is very small and oriented to the terrestrial surface. In this case, the sediments of the irrespirable particles, along with other pollutants are deposited on the ground at night when the population is less exposed. In the same coastal Black sea area the cloud is also an important factor in pollutant dispersion, the frequency of cloudy days being greater than the sunny days, usually situated between 86 and 93 days on the coast and between 90 and 93 on the dry zone. The wind direction and intensity influence the horizontal spread of the pollutants. The parameters of wind analyzed are the average speed, wind gust, and wind direction recorded for a determined period in years.

II. The Pollution Impact on the Air Quality in Constanta's Metropolitan Area

The atmosphere air is a mixture of uncontaminated air, water vapours and different impurities. The natural impurities represent a small amount and could be: meteoric debris, natural powder particles, NaCl, NO_2, SO_2, HCl, H_2S, ozone, bacteria, pollen, powder, and condensation nuclei, and impurities created by the industrial activities. In this research we monitor the level of "greenhouse gas effect" emission, during 2006-2007, concerning the following air pollution agents: CO, NH_3, N_2O, ozone, H_6C_6, and the debris. The concentrations of all these air pollution agents were presented in the conference paper [7]. The air pollution agents with high impact on the air quality considered in our research, shown in Table 1, are also well documented and modeled in [2].

TABLE 1:
THE AIR QUALITY CLUSTER CLASSIFICATION [2]

Air quality	SO_2	NO_2	CO	O_3	PM_{10}
	1h [$\mu g.m^{-3}$]		8h [$\mu g.m^{-3}$]	1h [$\mu g.m^{-3}$]	
Very good	0-25	0-25	$0\text{-}1.10^3$	0-33	0-15
Good	25-50	25-50	1000-2000	33-65	15-30
Favourable	50-120	50-100	2000-4000	65-120	30-50
Satisfactory	120-250	100-200	4000-10000	120-180	50-70
Bad	250-500	200-400	10000-30000	180-240	70-150
Very bad	500-	400-	30000-	240-	150-

In this table the cluster classification of the air quality is based on the limits set for health protection, fauna and flora protection separately, and the dispersion conditions depend on the horizontal and vertical airflow, rain falls and wind direction, especially [2].

III. FUZZY-UML TO FUZZY-PETRI NET CONVERSION—MODELING STRATEGY

This modeling strategy could be applied successfully to model the impact of pollutant agents on air quality following the same development from [4] based on the idea presented in Figure 1.

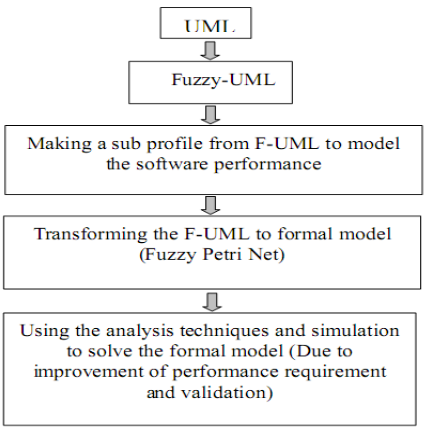

Fig.1. Fuzzy UML and Fuzzy Petri Net models conversion [4]

The UML diagram supports behavioral and structural aspects of the modeling systems, and consequently the fuzzy concept is concerning the both, the fuzzy structure (fuzzy data model) and the fuzzy behavior (the models are needed to support system functionality fuzzily). Concerning the data modeling the uncertainty in data structure is entered by presenting an UML class diagram fuzzily. The fuzzy behavior modeling is resolved by presenting the use case, sequence and state diagrams fuzzily [4], [11]-[12]. Several researches have been performed to deal with the semi-formal problem of UML. Some of these researches have only used a transformation algorithm, that transforms the created model into a Petri net as a mathematical and formal model that, in turn, contains the visual of modeling and pursues the verification operations with further ability [4], [8]. According to the season (scenario) we consider the sensor of parameter condition (UML diagram attributes) during the time intervals. Based on these values of the attributes the new fuzzy values of the condition and event parts will be generated, therefore the fuzzy UML diagram is also generated, as a support for the implementation of fuzzy Petri net model. The fuzzy UML state diagram created will be converted to a fuzzy Petri net model according to the steps presented in [8]: The Artificial Intelligence (AI) problems are typically solved via state-space approach to design algorithms intended for reaching one or more target states from the selected database initial states. The transition between the states is carried out by applying an appropriate set of fuzzy set rules selected according an expert knowledge from the given database, especially fuzzy IF-THEN production rules and database [3], [5], such in the following simple problem, implemented as a Petri-like net model in Figure 2:

Production Rules:
PR1: IF (P2) AND (P1) THEN P7,
PR2: IF P7 THEN P6,
PR3: IF (P7) AND (P3) THEN P4,
PR4: IF (P4) THEN P5
Database: P1, P2, P3

The most common operators of fuzzy applied to fuzzy sets are AND (minimum), OR (maximum) that have binary arguments, and Negation (complementation) having unary argument.A fuzzy set, unlike conventional sets, include all the elements of the universal set of the domain but with varying membership values in the interval [0, 1], and fuzzy logic introduced for the first time and well developed by Prof. Zadeh [1]. Sometimes it is possible to handle two or more output variables (places) that may occur as in the following linguistic description rule:

R4:=IF (P_{in1}) is E_1 THEN P_{out1} is E_{out1} AND P_{out2} is E_{out2} AND P_{outN} is P_{outN} This case can be modeled by two separate Fuzzy nets shown in figure 5.

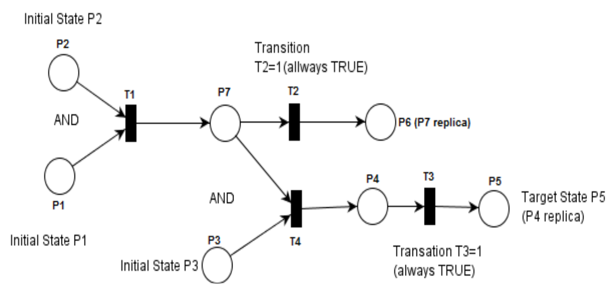

Fig.2 The generic overall Petri net model

In this model the token will be bearer of fuzzy sets, the edges (arcs) (**E**$_i$) will be evaluated by linguistic expression from IF THEN rules and the transitions (T_i) represent basically fuzzy relations according to the IF THEN rule.

Any IF-THEN rule defined by previous PR1-PR4 represents the simplified representation of two basic generic rules that could be modeled by the following Petri nets:

R1:= IF (P_{in1}) is E_1 AND (P_{in2}) is E_2 AND ..AND (P_{inN}) is E_N THEN P_{out} is E_{out}, with the Petri net model shown in Figure 3.

R2:= IF (P_{in1}) is E_1 THEN P_{out} is E_{out1} (missing edges), alone or together with similar rules, i.e.

R3:= IF (P_{in2}) is E_2 THEN P_{out} is E_{out2}, with the Petri net model shown in Figure 4.

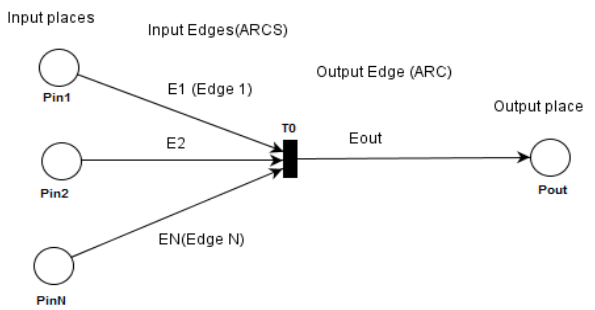

Fig.3 Petri net model implementation based on rule R1.

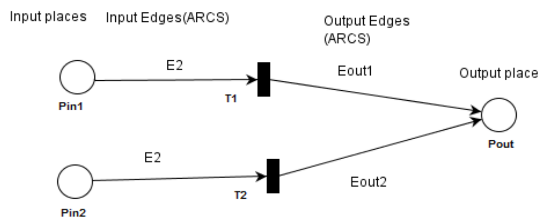

Fig.4: Petri net model implementation based on rules R2-3.

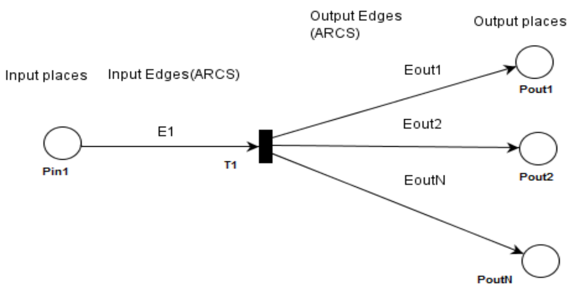

Fig.5 Petri net model implementation based on rule R4.

If the following linguistic description is necessary:
R5:=IF (P_{in1}) is E_{in1} THEN P_{out1} is E_{out1}
R6:=IF (P_{out1}) is E_{in2} THEN P_{out2} is E_{out2},
then it can be modeled as shown in figure 6.

Furthermore, we will formalize three basic forms of inconsistency due to incompleteness of Knowledge Bases [3]:

1. Dangling condition (Figure 7)

R7=: IF (P_1) is E_{12} AND (P_2) is E_{22} AND (P_3) is E_{32} THEN P_{out} is E_{out}

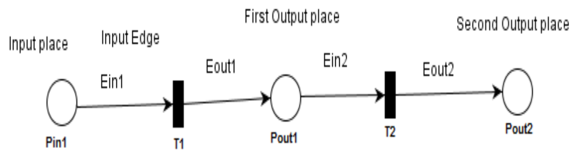

Fig.6. Petri net model implementation based on rules R5-6.

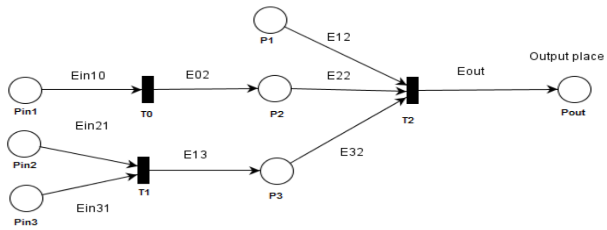

Fig.7: Dangling rule implemented by a Petri net model

From this description the predicate P_1 of the antecedent part of rule R7 is absent from the available database and the consequent part of any rule. Consequently, P_1 can never be generated by firing of any rules.

2. Useless conclusion

It occurs when the predicates in the consequent part of a rule are absent from the antecedent part of the rules in the knowledge base, such as in figure 8. The consequent predicate is called a useless conclusion as no other rules use it as an antecedent predicate.

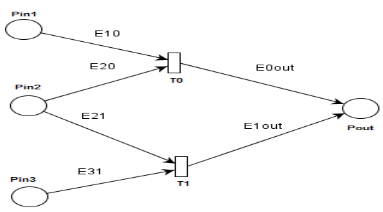

Fig. 8 Useless conclusion rule implemented by a Petri net model

R8.1=: IF (P_{in1}) is E_{10} AND P_{in2} is E_{20} THEN P_{out} is E_{0out}
R8.2=: IF (P_{in2}) is E_{21} AND P_{in3} is E_{31} THEN P_{out} is E_{1out}

A simplified fuzzy Petri Net model for our problem is implemented in figures 9-10 for the weather and for air quality cluster classification, similarly as in [5].

IV. Conclusion

This research work is dedicated to investigate the possibility of applying several Fuzzy UML and Petri Nets architectures for simulation and prediction of the performance of air quality of the Constanta Black Sea resort city environment. Therefore we explore different techniques to build several fuzzy Petri net models starting from fuzzy UML diagrams using the experimental data set provided by "in-situ" samples measurements sites.

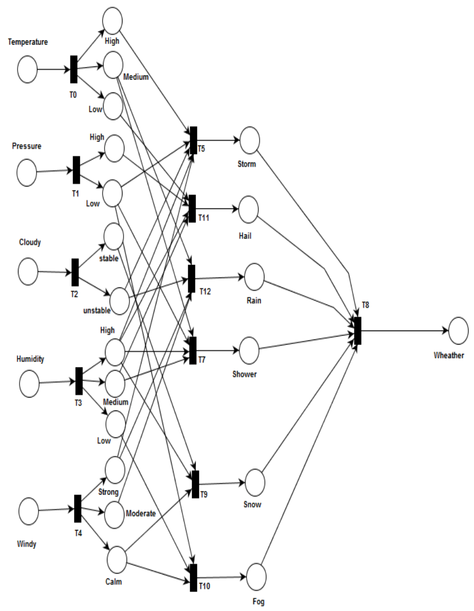

Fig. 9 The simplified weather forecast fuzzy Petri net model

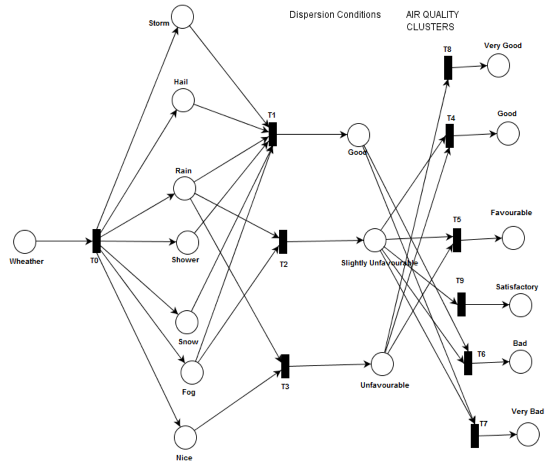

Fig. 10 The simplified air quality cluster classification fuzzy Petri net model

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