The Knowledge Modelling of Traffic and Industry Emission from the Air Pollution Control Aspects

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Abstract: Generally, in present time the identification and control of air pollution attains a main impact in the research of environmental sciences. The traffic and industry pollutants cause air pollution which depends on different factors, as for example, geographical location, temperature, wind, etc. The solution of this problem described in the paper, for example in urban region, is based on the ontology approach. The methodology considers the following steps: data collection from air pollution monitoring; building a database (DB), which contains all factors of ontology elements; generating a database of decision rules and their utilization; determination of the decision factors to establish what action is needed to be taken and where.

Keywords: air pollution, knowledge engineering, ontology, decision making

1 Introduction

Air pollution is an environmental problem of great importance for each city and for the whole nature. Growth of motor-car traffic and industry in regions has contributed to aggravation of the situation during the last year. Many authors and institutes address the air pollution control problem [1]. The pollutants emission influences air quality very significantly air quality. The deterioration of air quality causes susceptibility to lung infections and respiratory diseases of population in the regions with high degree of air pollution. Car density and industry cause air pollution which depends on different types of cars and industry emission, on geographical location, meteorological conditions, such as on temperature, wind, and other factors. For the determination of air pollution emission, dense monitoring systems are operating in many urban regions. The purpose of the monitoring system is to inform responsible authorities about the air quality within the region. The data from the monitoring systems are used by air pollution experts to solve the problem and to accomplish tasks such as short term prediction of pollution level, making decision on emergency counter-measures, etc.

The decision making is based on quantitative information, derived and integrated from measurements and observations, which provide information about frequency and size of change and whether the established standards are kept.

I order to provide an efficient decision support for air quality management, a mathematical model has to be created, based on the relationships between environmental protection and the air pollutants (CO, CO_2, smog, SO_2, etc.). Naturally, there are a lot of unpredictable factors that may influence the degree of air pollution, and it is difficult to establish with certainty which are the causes of a decrease or an increase of an air pollutant indicator. Traditional numerical modelling approaches require heavy computational resources and complex data that often are not easily available at run time. Using artificial intelligence methods, namely expert systems and knowledge-based techniques, is very promising approach not only in this area [6]. These techniques are efficiently used in various fields of science [5]. The air quality management systems consist of environmental models and modules for data management and processing and problem solving components. A knowledge-based approach offers an alternative to the numerical models, integrating multiple sources of knowledge in a knowledge base used by an inference engine that can deal with uncertainty. Using an ontology approach, a coherent, consistent and non-redundant knowledge base may be designed.

2 Building of Ontology for Air Pollution Control

Creating ontology is not a trivial problem. It requires not only skills in information technologies but also deep knowledge in the modelled domain. The process of knowledge system development is structured in a couple of models that have to be created. On the 'context' level of abstraction three models are suggested: Organizational model, Task model and Agent's model. The organizational model describes the organization with the aim to discover the problems and opportunities of knowledge management. The Task model represents task that are performed within the organization. A task is anything that has to be executed by an agent. The agent model describes all agents – executors of tasks - their roles, competencies, capabilities, and limitations.

Ontology development methodologies help creating ontologies in various domain oriented applications. Several methodologies have been developed in order to formalize creating ontologies for industrial or other applications. Although ontology development methodologies are not mature enough, they can be helpful in developing ontology based knowledge systems [7].

2.1 Basic Static Ontology for Air Pollution Control

The application presented in this paper considers the following classes and their properties, which are defined in ontology: source of pollutions, air pollutants, meteorological factors and prevention level. Sources of pollutions which are covered by the *Pollution_source* class encompasses all sources which produce some kind of pollutants covered by the *Pollutants* class. Sources can be divided in numerous ways; we decided to divide them in to two main following categories: traffic and industry. Traffic encompasses five transportation facilities: ship, car, bus, lorry, lorry, aeroplane. Each of this traffic pollution sources produce some type of pollutant. From air pollution control view, this part of taxonomy can be effectively used in local traffic air pollution control. However in the *Industry* concept, we define the traffic concept which describes air pollution control from broader aspect. In ontology, *Traffic* siblings are various industrial branches with serious impact on air pollution [1].

Air pollution control system tries to maintain concentrations of pollutants within precisely defined intervals. As mentioned in previous paragraph, pollutants are covered by the *Pollutant* concept which encompasses seven main pollutants. Carbon monoxide (*CO* concept) is toxic gas produced mainly by traffic, industry and commercials, which in concentration higher than 1% can cause death in several minutes. Other pollutants are volatile organic compounds (*VOC* concept) mostly generated by traffic, residential areas and industry, which can cause breath difficulties and the result of long-term exposure may caused cancer. Also, VOC with nitrogen dioxide (*NO2* concept) causes a raise of ground level ozone (*O3* concept) which is another pollutant described in the ontology, although it is the result of chemical reaction of other human generated pollutants. Nitrogen dioxide is the result of fuel and power industry, which causes acid rains. Another important pollutant is Lead, which is covered by *Lead* concept. This pollutant is generated by traffic and waste. The pollutant fine particles (concept *PM10*) is produced by many types of pollution sources, nevertheless the most important sources are metal, fuel and power sector and traffic. Power and oil industry are the most significant producers of sulphur dioxide (*SO2* concept) which causes acid rains together with nitrogen dioxide. All these pollutants have a standard which has to be followed. Note that these standards can vary from location to location, e.g. national parks have usually stronger restriction on air pollution than industrial parks. Also, we have to distinguish short term and long term objective in air pollution control. In the following table, comparison of standards in the United Kingdom and the Slovak Republic can be seen. There are very important differences, although both countries are in the European Union and are tring to achieve common air quality standards.

It is important to store threshold knowledge from Table 1 in the ontology, because these values can be changed in order to follow the new standards. The next class proposed in general ontology is *Factor* which covers meteorological factors.

These factors are meaningful just in a relation to the location where they are measured, which is described by the *Location* class, the main concept of location ontology. This concept is top level concept of reused location ontology. Each pollutant has standard concentration which has to be followed in each location.

Pollutant	**United Kingdom**		**Slovak Republic**	
	Thres hold	**Measuring time**	**Threshold**	**Measuring time**
Sulphur dioxide	266 ug/m3	15 minute mean	350 ug/m3	1 hour mean, max. 24 times p. a.
			125 ug/m3	1 day mean, max. 3 times p.a.
			20 ug/m3	annual mean
Nitrogen dioxide	200 ug/m3	1 hour mean	200 ug/m3	1 hour mean, max. 18 times p.a.
			40 ug/m3	annual mean
Fine Particles	50 ug/m3	24 hour mean	50 ug/m3	1 day mean
			20 ug/m3	annual mean
Carbon monoxide	11.6mg/m3	8 hour mean	10 mg/m3	8 hour mean
Benzene	16.25ug/m3	annual mean	5 ug/m3	annual mean
1,3-Butadiene	2.25 ug/m3	annual mean	-	-
Lead	0.25 ug/m3	annual mean	0.5 ug/m3	annual mean
Ozone	100 ug/m3	1 hour mean	120 ug/m3	8 hour mean, max. 25 times p.a.

Table 1
Comparison of standards in the United Kingdom and the Slovak Republic

In previous paragraphs description of ontology's static part has been proposed. However, control system has to react on changes in the environment, thus such behaviour has to be defined in structural way. Hybrid description of dynamic part of the control is considered in this paper, which is based on Knowledge Information Format (KIF) extension - Process Specification Language (PSL) ontology. PSL uses the following four concepts for basic description of process' dynamics: *action, action_occurrence, time_point, object.* This ontology also supports several ontological layers which make it more specific. Figure 2 shows layered ontology for air pollution control.

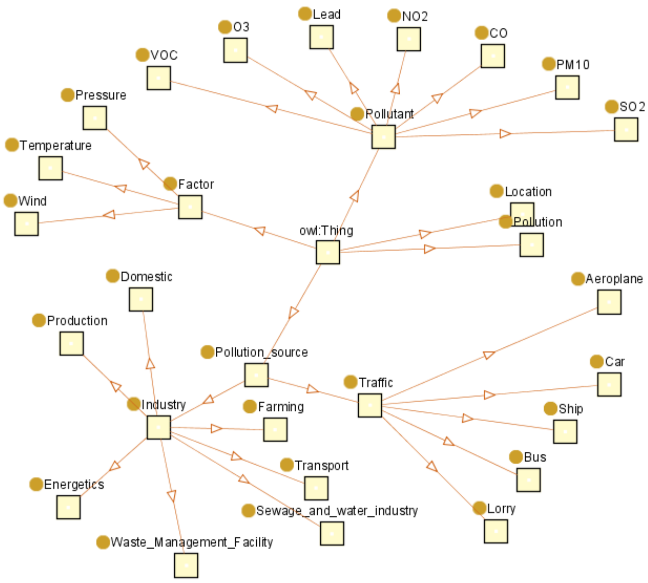

Figure 1
Air Pollution Ontology Tree

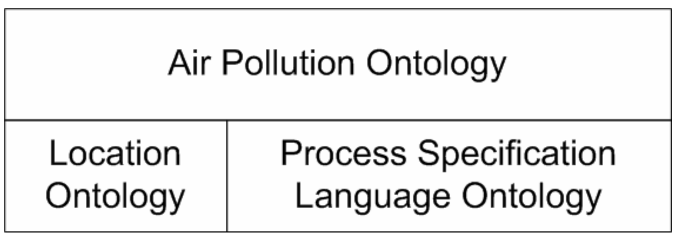

Figure 2
Ontology layers in central ontology

2.2 Decision Making in Air Pollution Control

Decision making in air pollution control utilizes the *Pollution* concept which encompasses instances of particular measurements [3], [4]. Each instance of this concept defines the following properties:

- instance of the *Pollutant* concept which is used is measured with its standards and bounds,
- actual concentration of the pollutant in measured location, with type of measurement,

- time point of pollutant measuring covered by individual of the *Time_point* concept from PSL ontology,
- instance of the *Location* concept which determines a source of information and
- meteorological factors in defined *Location*.

The objective of decision making is to find out the optimal action of the air pollution control system. These decisions are made in two steps: evaluate pollution factor, and evaluate control action or recommendation.

The pollution factor describes air pollution in defined location using precisely defined heuristics, which can be written as the following general equation:

$$m_{p,l,k} = f(p_k, t_k, M_{lk}, l), \tag{1}$$

where $m_{p,l,k}$ is pollution factor of pollutant $p \in P$ from set of all pollutants, location $l \in L$ from set of all locations and measurement time point t_k, p_k is concentration of pollutant *p* at time *k*, M_{lk} denotes meteorological factors in location *l* and time *k*.

The objective of the air pollution control process is to keep pollution factor under the defined threshold $T_{p,l}$ for certain pollutant *p* and location *l*. This fact is written in the following equation:

$$m_{p,l,k} \leq T_{p,l} . \tag{2}$$

There is also a global objective which takes into account the global point of view on air pollution:

$$\sum_{l \in L} m_{p,l,k} \leq T_{p,l} . \tag{3}$$

After evaluation of pollution factors, right decision or recommendation can be made. The first step is decision towards goals of the air pollution control; however, the second step is towards actions. In this step, air pollution control has to perform right decision which minimizes the following objective function:

$$u_{p,l,k} = \min_{u \in U} f(m_{p,l,k}), \tag{4}$$

where $u_{p,l,k} \in U$ is the optimal action performed in location *l*, in time point *k* and on pollutant *p*. In case of a hysteretic or predictive control, previous equation can be generalized as follows:

$$u_{p,l,k} = \min_{u \in U} f(\overline{m}_{p,X}), \tag{5}$$

where $\overline{m}_{p,X} = (\overline{m}_{p,X,k}, \overline{m}_{p,X,k-1}, ..., \overline{m}_{p,X,k-d})$ denotes a vector of last $d+1$ pollution column factors' vector for all locations $l \in X \subseteq L$.

2.2.1 Recommendation Rules in Hybrid Ontology

Beside control system which is very important for air pollution control a message system displaying warning and caution messages is very important. The message system briefly informs about critical state of the air pollution in a particular area. Afterwards prevention actions can be taken in parallel with the air pollution control system. Each message is emitted firing a particular activation rule which creates a fact in *world memory*. This fact is removed from memory when deactivation rule is fired. Examples of activation rules written in *jess* are proposed in the following picture.

```
(defrule warning
      ?fact <- (pollution)
      (test (testViolation ?fact warning_bounds))
=>
      (printout t "Warning air pollution bound is violated"
      crlf)
      (assert (action (type warning) (location (fact-slot-
      value ?fact location) (pollutant (fact-slot-value
      ?fact pollutant))))
      )
(defrule regulation
      ?fact <- (pollution)
      (test (testViolation ?fact regulation_bounds))
=>
      (printout t "Warning air pollution bound is violated,
      regualtions are needed" crlf)
      (assert (action (type regulation) (location (fact-
      slot-value ?fact location) (pollutant (fact-slot-value
      ?fact pollutant))))
      )
(defrule caution
      ?fact <- (pollution)
      (test (testViolation ?fact caution_bounds))
=>
      (printout t "Caution air pollution bound is violated"
      crlf)
      (assert (action (type caution) (location (fact-slot-
      value ?fact location) (pollutant (fact-slot-value
      ?fact pollutant))))
      )
```

Each activation rule consists of two parts: condition and consequence, which are divided by '=>'. Condition tests whether every pollution fact violates particular bound defined by standards (Table 1). If they are violated, message is displayed and fact of *action* concept is saved in world memory. Note that the instance of *action* encompasses type of action, location and pollutant breaking the rule.

Conclusion

The paper presents an ontological approach to creationg of air pollution control knowledge base. The main advantage of the ontology utilization is that the created ontology can be reused in many similar application areas and for solution of other environmental problems. The main reasons why the ontology approach is suggested for modeling knowledge-base for air pollution control systems is that a symbolic knowledge-base can express the domain expert´s knowledge without the risk that the implicit knowledge will be lost in a huge amount of available historical data. The problem of air pollution control is highly distributed. Many monitoring stations from different regions are involved. There is a lot of redundancy, e. g. the values do not change dramatically over short time measurements. The information collected is noisy and imprecise. Constructing ontology helps overcome some problems connected with the above-mentioned aspects.

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