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Symbolic interface for pollutant forecast. An evaluation.

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Abstract *– This paper presents a new 3-D visualization system planned to visualize the trend of the hazard index (HI) for a given area emphasizing the correlation between the wind and the concentration of some pollutants.*

The visualization system is a step for a city-dweller oriented air pollutants forecast system, developed in an industrial town (Taranto – Italy) declared by the National Government "territory with high environmental risk". 3)

The metaphor, used in this paper, is the well-known weather forecast that is as an important aid for everyday life; actually this service is based on a simple 2-D interface (video and/or iconic).

I. INTRODUCTION

One of the most important challenges relevant to the information technology is the development of new interfaces suitable to provide new scientific insight trough visual methods [1].

Considering the ever-growing size of available information, coupled with wide and wider variety of potential users, it is mandatory to provide the access based on human spontaneous communication abilities [1,2].

Generally, this type of interfaces is based on visual (often metaphor or symbol-based) or graphic constructs. The system must be able to be questioned by using "buttons", often software-simulated, and to answer by using an adequate representation of available information in a graphical way [3,4]. An example is the WIMP (Windows Icon Mouse Pointer) Microsoft-Office interface [5].

In the data visualization the tools have been categorized into three groups [6]: presentation, interaction and analysis. Instead, in [7] two classes of maker/users are defined: visualization scientist and scientist and engineers; currently the objectives of the two classes converge on the development and usage of visualization environments running on advanced workstations. In these approaches, the "common user" has been neglected because of his lack both in terms of knowledge and in terms of hardware availability [8].

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In this paper, an interface for visualization of pollutant concentrations, running on a PC and oriented to an unproved user is presented. The basic elements of this interface are three metaphors:

1) High == Big, many, elevated;
2) Red == danger;
   Movement → presence of wind (the well now film "Gone with the wind", uses in the title the same metaphor).

The pollutant data visualization has two classes of problems. The first one is related to the high dimensionality of the data obtained from the urban monitoring system (according to the Italian pollutant regulation) that must be referred to specific localizations. The second one is relevant to the interpretative capacity of all people for this kind of information, excluding any specific qualification. Classical questions are:

- Is this pollutant more or less dangerous than another one?
- Is this concentration greater than the established maximum exposure level?

The paper is organized as follows: the paragraph II presents the real case. In the paragraph III there is a brief introduction of the problem concerning the air quality estimation, in the paragraph IV there is a discussion about the active research topics in human machine interface, while the paragraph V shows the proposed interface for pollutant forecast. Finally, conclusive remarks are given in section VI.

II. HUMAN MACHINE INTERFACE

The rapid and continuous development of the information technology has enormously increased the number of computer applications. Indeed, the computer is becoming more and more present in every day life for many people. In order to allow this computer intrusion in every day life, it is mandatory to study and realize a considerable number of human machine interfaces that satisfies a number of requirements.

An important example of this kind of studies is the evolution of the operative system interface for the PC. Indeed, the first PCs used an operative system with a textual interface, but their evolution uses a graphic user interface.

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It is evident that the textual interface has a cardinality that is greater than that of graphic interface. On the other hand the use of a textual interface requires the user to known a great number of commands, while, typically, a graphic user interface is based on the philosophy of the mouse point & click. Despite the loss of cardinality, the graphic interface has won the user's favour and it has given a big contribution to the diffusion of the PC.

Today, the research of friendly user interfaces is a fertile field, because it has a large number of applications. Just for example, the user interface is a driving technology for the successful application of various robotic technologies. Currently, a large part of the robot community does not know what to do for the user's inability to take advantage of robot technologies [9].

Today there are several design standards for human machine interfaces. For example, the Department of Defence MIL-STD-1472E establishes general human engineering criteria for the design and the development of military systems, equipment and facilities. A similar initiative has been taken by NASA to define the interface for space-based systems.

Another application where the development of a friendly user interface has reached marked improvements is the field of the programming languages. Indeed, the introduction of the visual programming paradigm (together to the object oriented programming) has led to the creation of the Rapid Application Interface Development (RAID) environments. This environment allows the programmer to develop the front-end of its applications quickly and to concentrate himself in the developing of the back-end.

A significant field of research has developed technologies that rely on computer-generated displays. While some of this work deal with the display or rendering aspect (i.e. the virtual reality), another significant portion focuses on the use of sophisticated displays to present simulation and high-level control information to the user (i.e. the remote view in remotely operated mobile and underwater vehicles).

Another interesting framework for the study of user interfaces is the World Wide Web. Indeed, in Internet, every site gives to the user a great number of information (i.e. available data for download, image, services like e-commerce, chat-line, sms and so on). The point of question is how to present these information to all the possible users in an effective way (this is the classical communication scheme of one to many). Today this problem is treated very seriously, indeed the development of a web site is a job of group and in every group there is an expert of communication.

Last point is the remarkable improvement that the software for data analysis has led to the insight of many environmental problems. Indeed, these kinds of problems are characterized by the absence of a Galilean model that

describes them. For this reason the researches use black box models in order to treat this kind of problems (i.e. the flood of an hydrographical basin). The result of this approach is often the collection of a multitude of measured data that are rarely self-explicable. An example of this problem is certainly the visualization of the air quality forecast. The solution that the authors propose is the object of the next section.

III. REAL CASE

The starting point for the analysis of the developed interface is the well-known format used in the weather forecasts, in which icons or animate satellite pictures are used to represent the past and the future in terms of weather on a geographical map.

In this work, the environmental data, recorded in several monitoring stations installed in Taranto (Italy), are measured, analyzed and post-elaborated to generate a similar presentation.

Taranto, "territory with high environmental risk", owing to a lot of industrial areas (cement factories, steelworks, oil refinery and so on) placed near the urban area, is an area that can be considered very interesting for environmental monitoring. Moreover, this situation presses the municipal administrators to exercise a large control of air quality by means of a continuous monitoring of pollution level.

The existing network is based on seven stations performing continuous automatic acquisition and recording operation on environmental data. This network is able to measure both chemical substances (SO_2, NO, NO_2, NO_X, CH_4, NMHC, THC, PM10, Benzene, Toluene, Xilene, IPA, O_3, RAD, PAN, CO) and meteorological quantities (temperature, velocity and direction of the wind, pressure). These stations are placed in various typologies of urban areas (parks, residential areas, sub-urban areas), according to national prescription laws [10,11], oriented to long-term evolution of pollutant biological effects. So, these stations record sets of data (one for each station; everyone stores sequences of measured values for every considered pollutant) at regular time, typically every hour [12].

To improve the measurement acquisition grid, a dense net of suitable sensors has been described and characterized [13] based on nano-structurated sensors, made by using SnO_2. The electric conductivity of this sensor increases in the presence of a specific gas mixture. Thanks to this process it has been possible to achieve a feasibility study about the realization of a dense monitoring net of Taranto area, suitable for a real-time monitoring. At the same time, it has been possible to produce a pollution model of the urban area too.

IV. THE PROBLEM OF AIR QUALITY ESTIMATION

Air toxics can constitute dangerous threats in urban areas because of the large number of people and the variety of sources of toxic air pollutants, such as cars, trucks, large factories, gasoline stations, and dry cleaners. Individually, some of these sources may not emit large amounts of toxic pollutants: that is way the described interface must not display the concentration of a single pollutant.

However, all these pollution sources, if they are combined, can potentially pose significant health threats, particularly to

sensitive subgroups such as children and the old. For this reason it is very important to do a characterizing risk to compare estimated exposure intakes with toxicity values for each chemical of potential concern. This determines the likelihood of adverse effects in potentially exposed populations. This characterization is done separately for carcinogenic and non-carcinogenic effects because the human organism responds in a different manner to the exposure to these substances (USEPA, 1989; 1990).

The models, used by EPA, for estimating the risk derived from the exposure to carcinogens, assumes that it is directly proportional to exposure intake. Indeed, for non-carcinogens, there is a threshold of exposure below which it is high likely to be no appreciable risk of adverse health impacts.

In order to evaluate the level of concerns for a pollutant, the CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act, a law enacted by Congress on December 11, 1980) recommends comparing the estimated exposure intake to the reference dose (RfD) of each chemical of concern (USEPA, 1986a; 1986b; 1989). The RfD is defined as an estimate (with uncertainty spanning an order of magnitude or more) of a daily exposure level for human populations, including sensitive subpopulation, that is likely to be without an appreciable risk of adverse effect over the period of exposure (USEPA, 1989). The value of RfD is retrievable in tables organized from the EPA.

The question became more difficult to handle when we consider a complex mixtures of pollutant agents. Despite the effort of the researchers in this field, today is not available a solution to this problem, and in [Neal, 1983] the author states: "with current techniques and the present state of knowledge, there is no ideal way of approaching the problem of assessing the toxicity of exposure of man to mixtures of chemicals; it is a goal which will not be obtainable in the foreseeable future".

For this reason, CERCLA recommends that: doing a risk characterization, the assessor estimate the level of risk to human health from exposition to a mixture of pollutants, evaluating the toxic or carcinogenic property of every single component of the mixture. This choice has been done because there is not an adequate quantity of toxicological data to derive RfD for all possible chemical mixtures as a whole. In order to define a risk characterization of a mixture composed by carcinogenic elements, EPA recommends calculating the total carcinogenic risk simply adding the estimated carcinogenic risk for each substance of concern.

For non-carcinogens, there is another procedure, because as above stated, for this kind of substances, there is a threshold of exposure below which it is high likely to avoid appreciable risk of adverse health impacts. This fact results in the calculation of a hazard index (HI) given by the sum of the hazard quotient (HQ) relative to each pollutant in the mixture that produces similar effects. Hazard quotient is defined as the ratio of the single substance exposure level to a reference dose for that substance, while hazard index is defined as the sum of the HQs for multiple substances and/or multiple exposure pathways. It is calculated separately for chronic, sub-chronic, and short-term exposures.

Of course various concerns have been expressed about this methodology. Indeed, the interactions among more chemical substances are not totally known. The guidelines of the CERCLA assume: the dose additivity as long as substances elicit similar effects, and the absence of any kind of synergistic or antagonistic interaction among these.

If the compounds in a mixture do not have the same mode of toxicologic action, the guidelines recognize that dose additivity is not "the most biologically plausible approach," and "can lead to substantial errors in risk estimates if synergistic or antagonistic interactions occur."

As stated in the previous paragraph, in Taranto there is a network of measurement stations. Each one of these stations is able to monitor a number of air pollutant concentrations.

It is foreseeable that this situation is common to many Italian towns because there are a great number of acts that go in this direction. This fact allows the implementation for each town of a service of pollutant forecast. Indeed, through a series of pollutant concentration given by a station, it is possible to compute the HI for the pertinent zone of the same station.

At this time, the problem of finding an effective way to visualize these results in a user-friendly manner is the following step of this research.

V. DESCRIPTION OF THE PROPOSED INTERFACE

The monitoring stations give us a series of data that represents the measurement of the concentrations of many pollutants [8,9,14].

Current WIMP (Windows Icon Mouse Pointer) office interface has considerable limitations due to the use of a 2-D representation, so it is unsuitable for TV broadcast. 2-D space is not an effective method for displaying a massive amount of data. Available 2-D techniques, such as windows overlapping and iconic representation of information, do not solve complex visualization problems adequately [5]. Our idea is to build a 3-D animated interface (fig. 1) in which it is possible to visualize three parameters simultaneously; this procedure is also suitable to find some eventual correlations among them [15].

Let XY be the horizontal plane and Z the vertical axis. In our interface, in the plane XY it has been drawn a map of Taranto area where the monitor stations locations are highlighted.

The 3-D animated interface is designed to display, simultaneously and in an intuitive manner, the following parameters: hazardous index (or of any other pollutants), the spatial coordinates in which the measurement has been done, its time, the actually wind direction and intensity.

We believe that the aim of this interface is to give to a common user (in the sense of a user that is not an expert of the field of the air pollution) the possibility to understand quickly and in an unambiguous way the evolution of the pollution processes that invest the zone under observation [3].

In our interface we use the following metaphors in order to create a single frame of the 3-D animation:

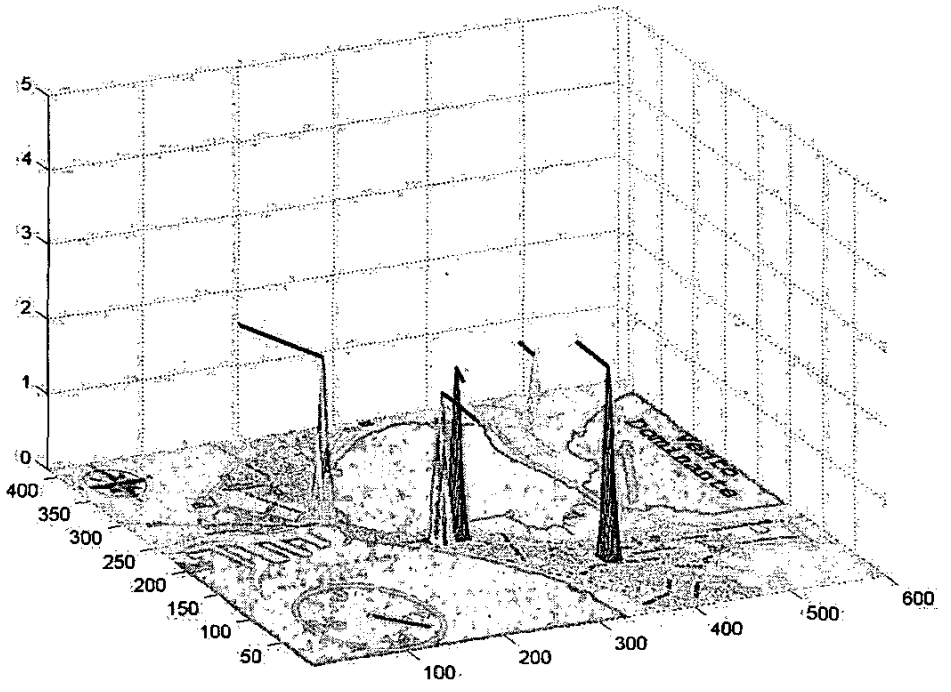

Fig. 1. An interface view for pollution forecast application

- High == the concentration of the main parameter under observation (i.e. HI) is represented by a deformation of the map in the plane XY, at the coordinates in which the monitoring stations are placed. This deformation will display as a hill, whose height will be proportional to the concentration of the pollutant with a correct uncertainty level. This hill will be colored using texture mapping technique, where the applied texture is extracted from the zone of the map in which the under observation monitoring station is located.
- Red == In a given instant of time, if the value of the concentration is higher than the RfD, the hill will be colored in red, in order to allow all the users a direct perception of the warning.
- Movement →an arrow drawn on the top of the hill represents the direction and the intensity of the wind. The direction of the arrow is the same of that of the wind and the length of the arrow is proportional to the wind intensity.

Other elements present in this interface are:

- In the bottom left part of the interface an analogical clock has been drawn, in order to refer the above representation to the time.
- In the right part of the interface an arrow representing the dominant wind direction has been drawn, for characterizing the whole site under observation from the point of view of the weather phenomena.

There are two possible origins of the data that the interface shows:

i. The database stores all the data measured, in each monitoring station; this data can be used to determine (and to display) the last evolution of the air pollution phenomena and to give a series of statistical evaluations allowing us to build a model that is able to forecast the next phenomena evolution.
ii. The data extracted from a forecast model of the under observation phenomena; these models are already known in literature [16,17] and are used in many currently applications.

VI. CONCLUSIONS

Thanks to the presented approach, a new 3-D visualization system planned to visualize the trend of the concentrations of a set of high-risk air pollutants or of the hazardous index emphasizing the correlation between the wind and the concentrations of some pollutants, has been realized. The main applications of this measurement system can be: 1) pollutant forecast, to create a public service similar to the weather forecast; 2) data analysis, to identify the correlation

between the wind and the concentration of some high-risk pollutant chemical mixture.

The wind is characterized, in the Mediterranean area, by a daily cycle, then a short-term forecast should be suitable for all the people.

Furthermore, as the working cycles of the industrial factory can be modified to produce human-perceptible pollutants (like visible vapors, stinks and emission) in the night, it is strongly effective to make an interface available, like the described one does, which can be used to evaluate the real exposition to the pollutant.

The natural evolution of the proposed interface is the field of the artificial intelligence. Indeed in [18] the authors describe an agency that works in order to: acquire, validate and store the environment data sampled by a number of measurement stations placed in Taranto.

At this time it is possible to think of a multi-agent environment for Internet environmental data retrieval services. The purpose of this agency is to consult the database of environmental measurement validated by the previous agency in order to determine the real RfD for each user of the system. Indeed, the daily exposure level for human populations is a parameter that depends on many factors. For example RfD must consider the age of the exposed people, the time of exposition, the type of exposition (cycling, randomness, continuous), the health status of the subject and so on. It is clear that all these parameters can been easily treated by a personal agent. The work of this agent must be that of:

- Storing in a local database the personal data of the user (a set of this data is that described above)
- Interacting with other agents in order to collect the data necessary to determine the real RfD and HI for the zone of interest for the user.

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