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A decision support system for the management of accidental mushroom and plant poisoning☆

Mirca Zotti [a], Sandro Zappatore [b,*], Anna M. Caviglia [a], Monica Tosa [a]

[a] *Dipartimento per lo studio del territorio e delle sue risorse (DIP.TE.RIS), University of Genoa, Corso Dogali 1m, I-16136 Genoa, Italy*
[b] *Dipartimento di Informatica Sistemistica e Telematica (DIST), University of Genoa, Via Opera Pia 13, I-16145 Genoa, Italy*

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Abstract

In this paper the discussion focuses on a decision support system to be used as a tool in the treatment of poisoning cases attributable to mushrooms, plants and animals. In this first release, attention is focused on the risks related to fungi. Problems involved with mushroom poisoning and identification are analyzed to highlight which elements or characters must be taken into account in devising a computerized expert system. The components of such a system are presented, the different approaches are discussed and the choices made are motivated. Some preliminary results are also presented. © 2001 Éditions scientifiques et médicales Elsevier SAS

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1. Introduction

Every year, all over the world, healthcare facilities, such as First Aid and Poison Information Centers, receive hundreds of thousands of calls related to poisoning or toxic exposures involving humans, pets and animals. The categories of potentially hazardous substances include household cleaning and body-care products, plants, mushrooms, insecticides, chemicals and many other materials. The serious and life-threatening risk from poisoning or toxic exposure depends on the inherent toxicity of the substances involved.

Plants and mushrooms are included among the high-risk categories owing to their potential toxicity. This is due to the fact that they are difficult to classify and some poisonous species are easily mistaken for edible ones. Furthermore, plant and mushroom poisoning may be difficult to diagnose because they may produce non-specific clinical symptoms that must be differentiated from other disease conditions. In addition, the prodromal gastrointestinal symptoms of intoxication attributable to the more toxic mushrooms (e.g. *Entoloma lividum*, *Amanita phalloides* and *Cortinarius orellanus*), that appear in hours or days, may be underestimated. When they are followed by signs of severe impairment of hepatic and renal function, the prognosis is grave and, often, death occurs in a few days.

The experience of a pool of scientists, such as a physician, a botanist and a mycologist, is often needed to correctly identify a toxicant. For this reason, accidental poisoning attributable to mushrooms or plants represents an extremely critical task for doctors working in first aid centers because they must quickly identify the correct toxic agent involved and, consequently, choose the most effective treatment therapy.

Furthermore, since in this case time plays a crucial role to ensure a good prognosis, it is quite clear that a critical aspect is the constant availability of a pool of experts to solve this multi-disciplinary problem.

In Italy, some Poison Information Centers, called ‘Centri Anti-Veleni’ (CAV), as well as various ‘regional reference mycology units’ have been established to cope with this kind of emergency. Nevertheless, up to now, CAVs operate only in the most important hospitals; ‘Mycology Units’ are present in a very limited number of regions, while ‘plant poison centers’ are completely

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* Corresponding author.
E-mail address: zap@dist.unige.it (S. Zappatore).

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non-existent. In such a scenario, it is not easy to obtain information about the toxic substance involved or to obtain the related antidote in time.

Based on the previous remarks and from the experience obtained through cooperation with the staff of some healthcare facilities in Genoa, we decided to come to grips with the above-mentioned poisoning problems by taking advantage of the advances in information technology. Thus, we propose to use a decision support system (specialized PC software) to simplify the procedure to identify a toxicant on the basis of the input furnished by a non-expert user. For this purpose, the system exploits the 'knowledge' that is suitably coded and filed in a database. The user interfaces with the system by means of a user-friendly environment, i.e. a common multimedia browser, such as Internet Explorer or Netscape Communicator. These applications have become very popular because the Internet is no longer considered a research area for a restricted group of scientists, but a communication tool to be used efficiently by everyone in their fields of work.

In the past, the lack of these powerful user interfaces probably limited the widespread use of the expert systems. Furthermore, the computational burden demanded by an expert system can be supplied today by any sufficiently equipped personal computer, available at a relatively low cost.

Finally, it should be pointed out that expert systems have been utilized to solve a wide range of problems in areas such as medicine, chemistry, geology and education. Within each field, they have been used to solve many different types of problems. These include diagnosis (of a disease due to a blood infection, etc.) and interpretation (of chemical compounds of molecular structures, of geological data, etc.).

First, we focused on a prototype expert system to be used as a decision support tool to treat the cases that occur most frequently (mushroom poisoning) in our region (Liguria, Italy). After an initial tuning phase, the expert system will be gradually improved to take into account poisoning by plants and animals.

It should be mentioned that a modified version of the proposed system should be efficiently utilized, for instance, as a learning tool to train specialized mycology technicians, taking them through various example cases and checking their conclusions.

2. Experiment

2.1. Methodology and mushroom identification problems

First, we gathered all statistical data concerning mushroom poisoning to select a limited, but significant set of toxic agents to be inserted in an expert system database. For this purpose, we consulted some hospital archives (first aid archives of 'Gaslini' Hospital and Genova-Voltri Hospital, both in Genoa) from which we determined the most widely used clinical and laboratory procedures and, consequently, the prescribed therapies.

In poisoning caused by ingestion of toxic mushrooms, the first task to be carried out is to try to identify the species of mushroom that caused the poisoning. Therefore, the mycologist working at the first aid center must identify the genera and the species of the mushroom, analyzing different samples that can be classified as follows: raw mushrooms (whole or sliced, pieces of the stem or altered pieces of the carpophore, mushroom residues after cleaning and/or consumption, collected from the garbage can); treated mushrooms (dried, conserved in oil or brine, frozen); residues of meals containing mushrooms; expelled mushrooms (with spontaneous vomit or feces); gastric juice with or without mushroom residues; feces, with or without mushroom residues.

In the worst case, the only conclusions that can be reached will be based on the descriptions that the patient or his family members provide of the mushrooms eaten.

The expert system must be able to provide a step-by-step procedure with graphic and photographic aids relative to the macroscopic, microscopic, macro-chemical and micro-chemical morphological characters to identify fresh material according to the dictates of classical mycology. In addition, it must provide information concerning analysis methods (e.g. Poder and Moser tests [1]) and reference pictures for identification starting from biological material.

Refs. [2–6] contain extensive documentation concerning mushroom toxicology to which reference was made during the system design phase. Instead, it was decided to omit the references to the tests normally used, for example Ref. [7], to identify mushrooms according to the dictates of classical mycology.

2.2. Expert system architecture

Identifying a toxicant based on a description of a plant or mushroom can be considered a particular 'patter recognition' problem. Therefore, it is possible to devise a system, represented by a suite of algorithms, which will automatically find the most likely solution (i.e. the most likely toxicant) of the case studied. Such a system can be called a 'decision support system' or 'expert system'. The basic architecture of an expert system is diagrammatically depicted in Fig. 1. The most relevant components include the database, the model of research rules, the 'search' engine and the user interface.

The user interacts with the system through an interface that may use menus, natural languages or any other style of interaction.

Furthermore, almost all expert systems also have an explanation subsystem, which allows the program to explain its reasoning to the user.

2.2.1. Model of research rules

The research rules are extensively used by the 'search' engine to find the best solution for the current problem (i.e. identification of a toxic fungus). Obviously, the model of the research rules and the rules themselves depend on the kind of search engine adopted.

For instance, if the adopted approach conforms to the so-called artificial intelligence [8,9], a widely used knowledge representation consists of a set of 'IF–THEN' rules; on the contrary, if the search engine is based on a neural network [10,11], no explicit rules are needed, as these are implicitly determined by the neural connections and their weights (learned during the training phase). For the expert system that adopts statistical schemes [12,13], the model of rules is represented by the multidimensional correlation functions that the search engine employs to compare the set of noise features, extracted from the unknown toxic agent, with a noise-free set of features (stored in the expert system database) available for each toxicant. In this context, a crucial issue is the choice of both significant features and effective correlation functions.

It should be pointed out that, typically, an expert system does not generate certain conclusions, as they are affected by some degree of uncertainty: so the result of a search process is a set of solutions, each of them associated to a number representing the related certainty. The hope is that a solution exists with a certainty significantly higher than 50%.

In our proposal, we verify the effectiveness of an approach based on statistical methods and consequently selected a suitable set of features. We designed, tuned and tested a group of correlation functions as well as some strategies to select the best solution.

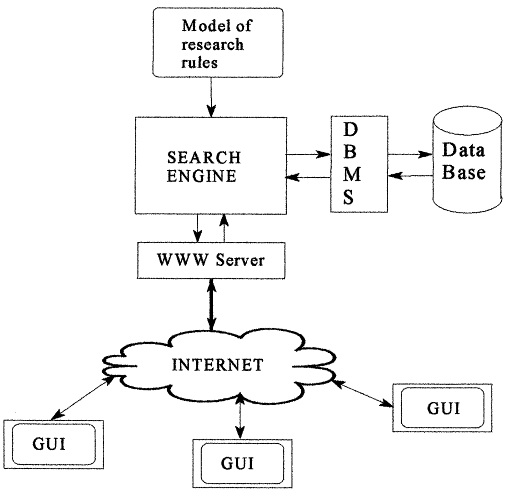

Fig. 1. Basic architecture of the expert system.

2.2.2. Search engine

The purpose of the search engine was to determine the toxic agent with the lowest degree of uncertainty. The engine consists of a process implementing a search algorithm which, for each record of the database, evaluates a cost function expressing how many features of the known toxic agent meet the noise-free features associated with the current toxicant (i.e. the current record of the database). The higher the match, the lower the value assumed by the function. At the end of the process, the best solution, i.e. the likeliest toxicant, is the one with the lowest cost.

Statistical methods appear to be quite interesting for our goal, especially those based on pattern-recognition techniques utilizing fuzzy logic.

Fuzzy systems, including fuzzy logic and fuzzy set theory [14], provide additional extensive and meaningful information to standard logic data. The mathematics generated by these theories is consistent, and fuzzy logic may be considered a generalization of classical logic. There is a broad range of applications that can be implemented with fuzzy logic, providing the opportunity to model conditions that are inherently imprecisely defined, despite the concerns of classical logicians.

Since numerous problems in the real world are intrinsically vague and lack solutions that strictly belong to any specific class, many systems may be modeled, simulated, and even replicated with the help of fuzzy systems, not the least of which is human reasoning itself.

Regarding our system, we expect that a fuzzy-logic-based search engine should make it possible to find, at least in most cases, a good final solution even if a limited set of features is input by the user. Otherwise, whenever the input data are too incomplete or vague, the system will not supply a unique solution as output. Instead, it will provide a set of likely solutions, each of them characterized by the degree of uncertainty. In this case, the user must carry out the final validation and/or confirmation of the toxic agent: for this purpose, a detailed description of each agent will be presented with extensive iconographic and photographic documentation (filed in the global database).

2.2.3. Database

The database consists of all the information needed by the search engine to find the best solution to the problem. In our approach based on statistical techniques, each record of the database contains the features necessary to identify the toxic agent. For instance, for fungi or plants, the features should consist of: the geographic distribution of the fungus or plant, the period of the year during which we have the highest probability of finding the mushroom, the symptom latency time, the relevant (microscopic and macroscopic) morphological characters, the most suitable therapy, etc. Each feature has a number that specifies

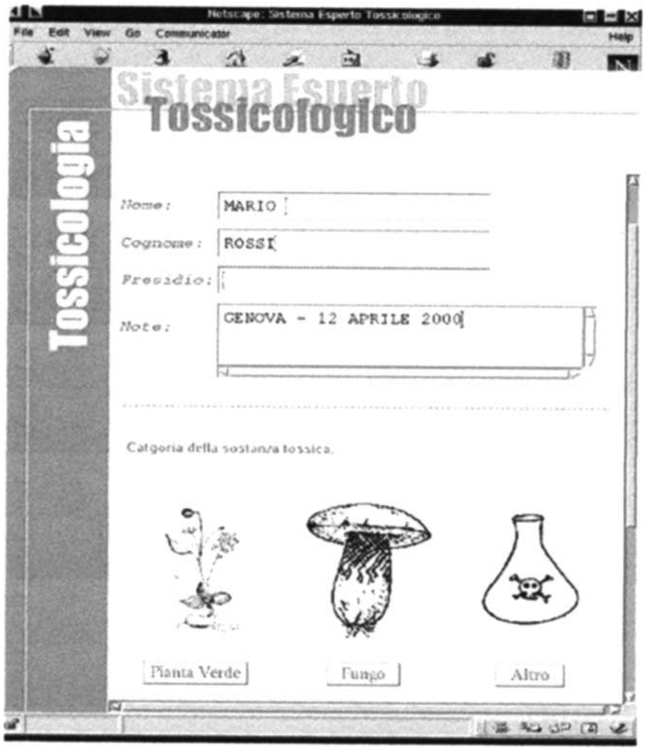

Fig. 2. Example of a web page presented by the proposed expert system.

the degree of relevance of the feature itself. The information filed in the database progressively grows whenever new feedback from users becomes available. Feedback represents the so-called follow-ups, derived from the experience acquired during/after treatment of a poisoning case, that can be effectively utilized by other mycologists/doctors in future cases.

Furthermore, the database contains a lot of pictorial information, thus providing both an interactive control/validation of the data supplied by the user and a final check of the identified toxic mushroom.

The information stored into the database is maintained by the Database Manager System (DBMS) that ensures that the filed information is always consistent. It also supplies the user with a set of functions that simplify and guarantee the most frequent operations, such as data entry, deletion and updating.

2.2.4. User interface

As mentioned in Section 1, we decided to use a Graphic User Interface (GUI) based on the well-known communication protocol called Hyper Text Transfer Protocol (HTTP).

Since this protocol is part of the TCP-IP suite, the system can be accessed not only from the host computer (i.e. the computer where the expert system software is actually running), but also from any remote (client) station, connected to the host by means of the Internet. In this manner, the services offered by the expert system can be shared potentially among a large number of users who, in turn, can contribute to the follow-up of the actual system.

3. Results

In order to evaluate the impact of using the proposed decision support system on non-expert people, we prepared some web pages consisting of forms, text and 'clickable' figures. The pages are implemented by means of the standard Hyper Text Markup Language (HTML), Java applets and PHP3 scripts, that increase the effectiveness of the interface and meet any dynamic page requirements.

Fig. 2 shows a page reproduced by Netscape Communicator. The user can choose and/or modify all the possible selections (by clicking on the corresponding icon) and browse the explanatory text. Furthermore, the system helps to select all morphological characters by presenting pictures or drawings. For the most complex selections, some text pages are used to focus the user's attention on those elements to be observed and analyzed before completing the selection.

For some questions, the system can accept multiple answers, thus associating a sort of uncertainty level to the character considered. In fact, a patient or his relatives often do not exactly recognize a character from any of the displayed icons.

In other cases, a multiple choice is motivated by the actual presence of more than one character: for instance, the user can select several kinds of spores because it is actually possible to find different kinds of spores in the vomit of a patient at the same time.

The user can run a search procedure at any time to know if the inserted characters are sufficient to provide a solution with a low level of uncertainty. If results are too uncertain, it is possible to continue to insert new data (morphological features, symptoms, etc.) or to refine the description of previous data, also on the basis of the solutions proposed by the system.

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