Medical Emergency Assisted decision support system using matrix-based classification

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Abstract—Medical emergencies are considered to be one of the most critical situations to deal with for health care providers and most challenging and frightening for the rest of us that are no expert in the field. In this paper, we introduce a medical emergency assistance decision support system that aims to help individuals face some serious and urgent medical situations while calling or waiting for professional medical intervention. Our proposed system relies on a matrix-based classification that is obtained using a binary representation for the medical knowledge and a similarity calculation that stands for the identification probability of a target category. In order for our classification model to work in an optimal way, we also propose another phase which consists of selecting unqiue features for the target categories and will be used as inputs for the system.

Keywords —Artificial intelligence, Decision support system, Emergency diagnosis, Intelligent systems, Matrix-based classification, Rule-based classification, Matrix representation, Unique Feature selection

1 Introduction

A Medical emergency is a serious health related situation that happens unexpectedly and demands immediate medical intervention. Dealing with these emergencies is a crucial task for professional health care staff and medical school students, that requires not only a good knowledge of the situation but also rapidity in taking actions while keeping calm which is only achieved after a certain experience in the medical field. However, most emergency situations occur outside health care insitutions, and call for instant first aid and urgent actions in a limited time that can help save a life o reduce the impact and consequence of the incident [1].

This is why learning how to deal with emergency situations is not and should not be reserved to professional health care providers but also be the concern of the whole population. Nevertheless, most people remain unprepared to deal with medical emergencies, according to statistics published on British Red Cross about an online research [2], only 5% of questioned people would feel knowledgeable, confident and willing to act on some medical emergencies in case of heavy bleeding injuries, unresponsive and breathing or not breathing situations. The same research relates that 81% of people also said they lack the knowledge and confidence to act if a baby was choking, a situation that any parent can face no matter how vigilent a person is.

Many reasons could explain why most people can't or won't intervene in a medical emergency situation, the most commonly reported is the lack of knwoledge for the actions to take and recommendations to adopt, another reason could be the fear of interfering in the wrong way and worsening the situation, in addition to that, there are factors like shock and stress that may block the logical reasoning and slow actions unless a person has followed a professional training that prepare him to face such circumstances.

Medical fields have gained an increased interest as application domains for computer science technologies especially in the artificial intelligence applied field.

For over the last years, many studies and computer applications in the artificial intelligence domain have improved and facilitated various medical tasks, like medical diagnosis [3],[4], prediction of medical complications [5], image processing [6] and many others. Having proved their efficiency and good accuracy in medical fields, we propose a medical emergency computer-assisted diagnosis that aims to identify the medical category of an emergency based on some input data and propose to the enduser the adequate actions and recommendations to adopt in order to provide the right first aid to the specific situations.

This tool could be used by non professional people to assist them deal with emergency cases while they wait for experts' intervention, as it could be adopted in emergency centers as a support system to facilitate and gain time in the process of emergency admission.

2 Related work

Many recent researches in artificial intelligence fall in the category of medical intelligent systems, whether they are used in hospitals to assist in medical diagnosis and increase their accuracy, or to facilitate the personal living and personalized health care services. An intelligent system is a computer system that can simulate the human abilities like reasoning, problem solving, learning, decision making etc. using different models and techniques. In the context of medical domain, decision making is considered to be the most important task for health care providers, this is why most intelligent systems are dedicated to decision making or decision support.

There are different types of decision support systems, rule based support systems like expert systems are the most known and first ones that were introduced in the market [7],[8]. Another type of decision support systems are those

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based on neural network models [9],[10], this type of system is considered to be a black box when it comes to its reasoning, the neural network require a large set of data to be trained, and cannot offer any justification to how the solution was achieved, although they offer a high accuracy even in cases of some missing data.

In this paper, another type of decision support systems will be introduced, which consist mainly on mathematical concept and representation.

3 Medical Emergency Knowledge Modeling

Proposing a solution to a health problem situation starts with understanding the human problem-solving process in such situations in order to build a similar reasoning artificial intelligent system. As health problem emergencies differ in their context (the person concerned (patient), the environment, etc.), solutions also vary and should be customized giving the circumstances of the problem.

When facing medical emergencies, it is vital to have some information about the context of the situation like the cause of the problem and the visible signs, these would permit an adequate intervention as fast as possible. Therefore, we propose to divide emergency situations into different categories like it is shown in Fig.1 below.

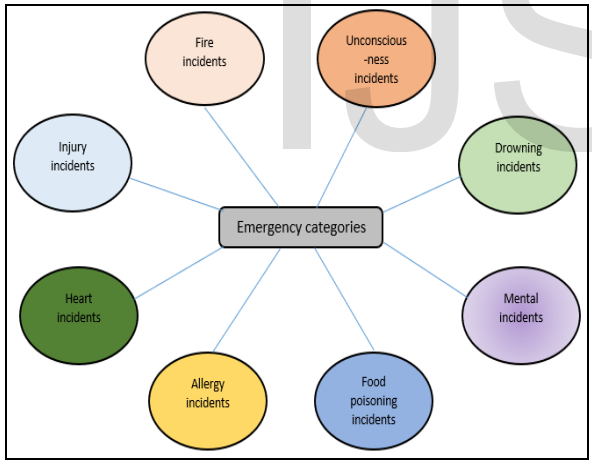

Fig. 1. Example of medical emergency categories

Dividing medical emergencies into classes has many advantages, it offers a better identification of the problem, due to the fact that it limits the number of the specific situations to consider, as we focus only on the conditions that are in the pointed class and ignore all others. In our study, identifying a category among others can immadialty provide the user with the right derectives and actions to adopt, because most of the first aid recommendations are applied to a context of a situation without the need of a specific diagnosis [11].

In this study, we have selected 6 medical categories. In Table1, we present the medical categories we consider for our decision support system, where each medical category is associated with a set of signs that help identify a category among others.

However, for this identification task, the signs characterizing each category should be unique, therefore, no all the signs showed in table1 are good candidates to work as unique characteristics for a category.

TABLE 1
MEDICAL CATEGORIES USED IN OUR SYSTEM AND THEIR MEDICAL SIGNS

Category	Signs
Fire related incident	Skin is red, skin is swelling, Pain, Fever sensation, Burn, Skin waxy/Leathery
Food Poisoning incident	Abdominal cramps, Diarrhea, vomiting, loss of appetite, mild fever, weakness, nausea, headaches, bloody urine, severe dehydration.
Allergies incident	Itchiness, Eczema, Redness around eyes, Nasal congestion, Runny nose, Sneezing, Dry cough, Obstructive swelling of the lips, Obstructive swelling of the tongue, Obstructive swelling of the throat, Trouble swallowing, Difficulty breathing, Turning blue, Faint, weakness, Chest pain
Unconsciousness related incident	Unresponsiveness without visible injuries, Unresponsiveness with visible injuries, Lack of awareness, complete disorientation
Injury related incident	Bleeding, Abnormal bone shape, visible wound, pain, fracture, Joint Pain, ecchymosis
Heart related incident	Chest pain, Heartburn, Headaches, Fatigue, Sweating, dizziness

4 Architecture and Methologies

A computer assisted decision support system applied to medical emergencies is basically a computer system dedicated to assist users identify a medical emergency based on a specific input data and provide the right recommended actions to follow.

The ability to identify a specific class (in our case a medical category) among others using data entries as identifiers is a typical classification problem type [12]. Most classification tasks depend on a three-layer structure that consist on input selection, the classification model and the definition of target outputs like illustrated by Fig.2.

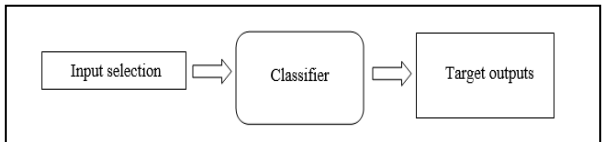

Fig. 2. Structure of a classification task

Input selection consist on defining the input data, witch is the set of features that hold the data values of the user or any other external program that would be pushed to the classifier and used to influence the identification of a specific class.

The classifier is a cognitive model that performs the classification task, the type of the classifier is a choice that depends on the type of problem and knowledge, therefore, a classifier could be modeled as a black box, like is the case of neural networks as much as it could be a rule-based classifier, where the domain knowledge is well structured and allows a classification through pre-defined rules.

The target outputs are defined by the type of classifier used, in black box models for instance, the target outputs are derived from the training data during the learning cycle, as for models that rely on rules, or other structures that don't use learning cycles, target classes are considered part of the domain knowledge and therefore known or defined beforehand.

In our proposed medical emergency assited decision support system, we use a matrix based representation as a rule-based classifier where target outputs depict the different medical categories illustrated in Table1, and the input data are the charactersitics of the target classes presented to the user as a checkbox list, that get pushed to to the classifier as a binary vector to be matched with the knowledge matrix.

For this model to function in an optimal way, it is important that target outputs contain unique features so that their representation as a vector would be different from each other. In a medical context some symptoms can be associated with different medical categories like for example pressure sensation, vomiting, headaches among many others, these kind of generic symptoms, should not be given as input data, as they may only create confusing in the classification.

The accuracy of the matrix classification depends indeed on the uniqueness of the features associated with a specific category. Mathematically speaking, if we consider three groups to be our categories where each group is defined by a set of elements, having unique elements is perceived as illustrated by the example in Fig3 below :

$$A=\{e_1,e_2,..e_k\},\ B=\{e_i,..e_p\} \text{ and } C=\{e_j,..e_q\}$$
$$\text{If } A \cap B \cap C = \emptyset \Rightarrow \forall e \in A,\ e \notin B \text{ and } e \notin C,$$
$$\forall e \in B,\ e \notin A \text{ and } e \notin C$$
$$\forall e \in C,\ e \notin A \text{ and } e \notin B \text{ If } A \cap B \cap C = \emptyset$$

Fig. 3. Mathematical exemple of 3 groups with unique elements

Based on this perspective, the selection of the accurate input data seems to be a crucial step in identifying the output category, therefore we first start by defining the target classes and their characteristics that we refine to obtain unique set of identifiers. Then we offer the user a list aff all identifiers to select from via an interface, the data input from the user is then given to the classifier to start the classification task.

These cognitive steps are represented in the functional architecture in Fig.4.

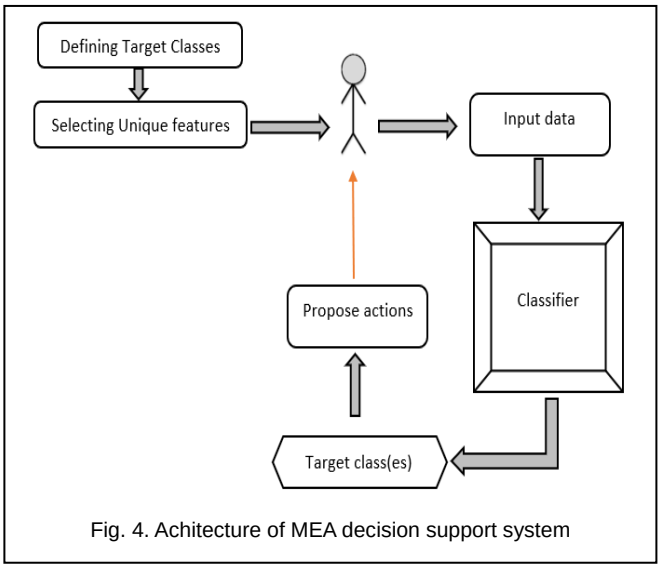

Fig. 4. Achitecture of MEA decision support system

5 MEDICAL EMERGENCY ASSISTANCE SYSTEM

5.1 Selecting unique features

A medical situation is represented by a set of signs, symptoms, reactions, medical results, etc, that we call characteristics, or features. Each medical category is associated with a set of features, mostly built from the common characteristics of the medical conditions contained within. For both implementation and test purposes, we use the categories presented in Table1 as our target categories.

```
public static void initCategoryWithKeywords() {
    initData();
  C1.setKeyWords(Arrays.asList("Red skin", "Swelling",
    "Pain", "Fever","Burning","Blistered skin","Pressure",
    "Bone exposure","Leathery skin","Skin dry"));

  C2.setKeyWords(Arrays.asList("Abdominal Cramps",
    "diarrhea", "Vomitting", "Nausea","Desydratation","Fever",
    "Pain","Appetite loss","Weakness","Stomach acke"));

  C3.setKeyWords(Arrays.asList("Itchiness", "Eczema",
    "Nasal congestion", "Runny nose","Sneezing","Dry cough",
    "Lips swelling","Throat swelling","Difficulty breathing",
    "Tongue swelling","Pressure"));

  C4.setKeyWords(Arrays.asList("Chest pain","Dilated pupils",
    "Unsteady walking","Difficulty breathing", "Headeaches",
    "Fatigue","Blue ends","Nausea","Arm pain"));

  C5.setKeyWords(Arrays.asList("Bleeding","Bruises",
    "Abnormal bone shape","Wound","Swelling","Desorientation",
    "Nausea","Shaking","Visible injury"));

  C6.setKeyWords(Arrays.asList("Loss conciousness","Desorientation",
    "Memory loss","Weakness","Faint","Seizures"));
  }
```

Fig. 5. Achitecture of AMA decision support system

We can spot in Fig.5 that some keywords are present for different categories, which doesn't qualify them as unique identifiers and as consequence, these categories should be purged by getting rid of common features they share with other classes.
This step is the one indicated in the architecture schema in Fig.5 as selecting unique features. For that we use the logic in the algorithm presented in Fig.6, that takes in all keywords, searches for redundant features in categories and results in a list of keywords to delete. Then for every category we remove the elements of the purge list.

```
Foreach Keyword in AllKeywords do
    Foreach targetkeyword in targetClass do
        If targetClass.keyword exist in other categories then
            Add it to purge list
        EndIf
        Remove purge list elements from category
    EndForeach
EndForeach
```

Fig. 6. Algorithm to obtain unique features from target classes

The unique feature selection algorithm has for purpose to set unique identifiers for each target output, and set the input data that will be provided to the user or another program. It is an independent unit, that could be used on any other classification problem.

5.1 Classification using matrix representation

Classification as an overall term is defined as the process of organizing and arranging objects into groups or classes to facilitate their access. In computer science, classification stands for the task of identifying and recognizing a specific class based on some input data.

There are several ways to perform classification for a problem, most of the classifiers known and used are machine learning algorithms like : Linear classifiers [13], Support Vector Machines [14], Decision Trees [15], Nearest Neighbor [16], and many others, however, classification could also be achieved by rules by implementing a rule-based classifier [17].
In this study, we propose a matrix-based classifier, where the knowledge regarding the different medical categories is represented as a binary matrix like illustrated by Fig.7 :

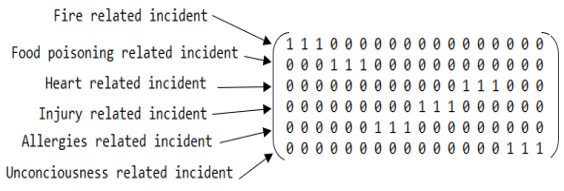

Fig. 7. Matrix binary representation of medical categories

The input data obtained from the Unique Feature Selection Algorithm is represented with a binary vector, where the numbers 1and 0 represent respectively the existence or absence of a characteristic in the user selected choices, like for example the vector below :

$$V = \{1,1,0,0,1,0,0,0,0,0,0,0,0,0,0\} \quad (1)$$

The classification in our decision support system is achieved by a matching algorithm that calculates the degree of similarity between each category and the input vector. A category is identified as a match when the probability of of the input vector reprensation is 100% the representation of the category vector. In case no match is found, the system returns each category with its probability. In both circumstances, the assistance support system returns the actions and directives adequates for the category/categories identified.

4 Experiment and Results

As discussed earlier, before the classification task, comes the unique feature selection phase, where the goal is to set unique identifiers for the emergency categories and establish the input data characteristics that will be presented to the enduser.
In our study, we have implemented this as a sperate program, this will allow us to use it by any other decision support system applied to other classification problems, as an integrated module or as a services in a library.
For testing purposes, we have also developed a user interface to be able to show the step by step results obtained although when used from our classification module, there will be no user interface.

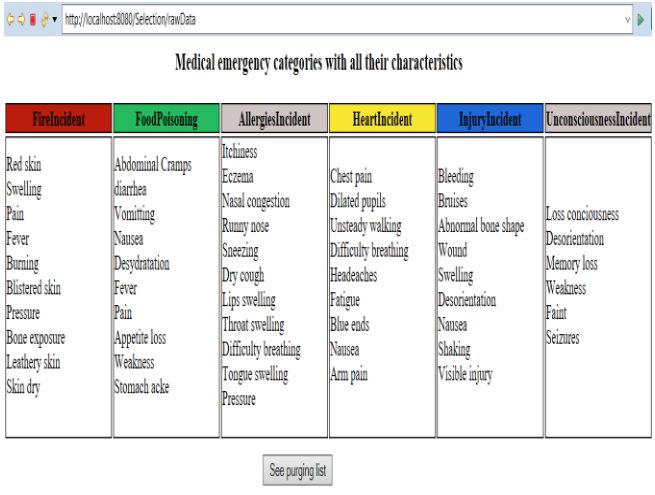

Fig. 8. Medical emergency categories with thier characteristics

Fig.8 illustrates the six medical categories we have chosen in our study, each category with all its possible identifiers.
Many of the caracteristics are present in more than a category, this is why the unique feature selection uses a purging list

method, whitch results are displed in Fig.9 :

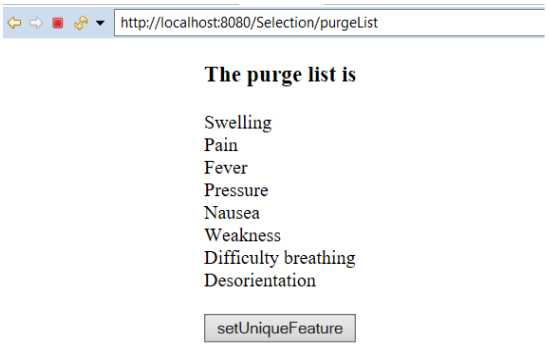

Fig. 9. List of characteristics that don't qualify as identifiers

The caracteristics in this purge list are those common in between different categories and by consequence, each category containing one or more of these items will have them removed in the last step of our unique feature selection. This will result in the redefined categories as shown in Fig.10:

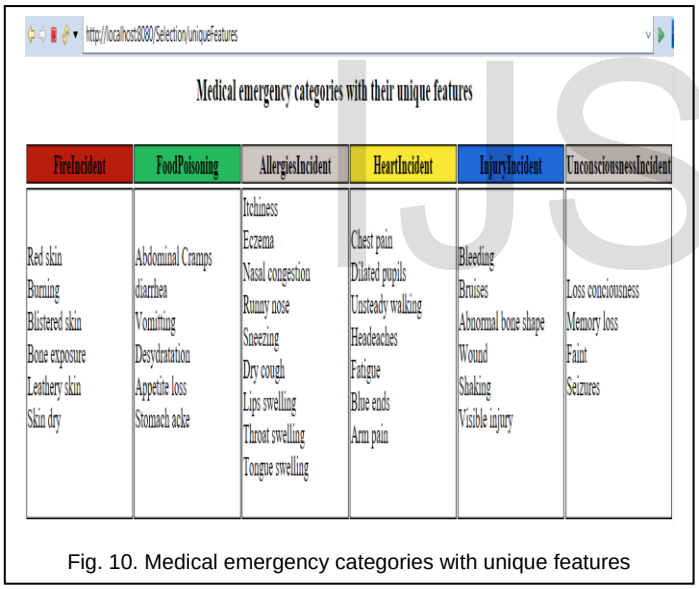

Fig. 10. Medical emergency categories with unique features

The second part of the experiment consists on the matrix-based classifier that will perform the task of diagnosing a medical emergency category and propose the adequate actions to help deal with the concerned situation.

Fig.11 shows the main menu presented to the user, who can choose a specific category, and get the recommended actions to do or use the emergency medical assisted decision support system when he selects 'Unknown inident'.

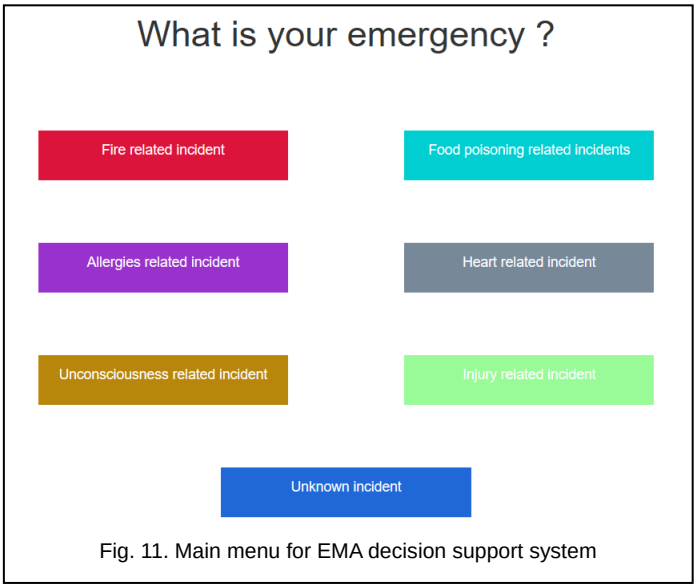

Fig. 11. Main menu for EMA decision support system

The diagnosis support system we propose, redirects the user to a list of signs from witch it is possible to select 3 signs like shown in Fig.12.

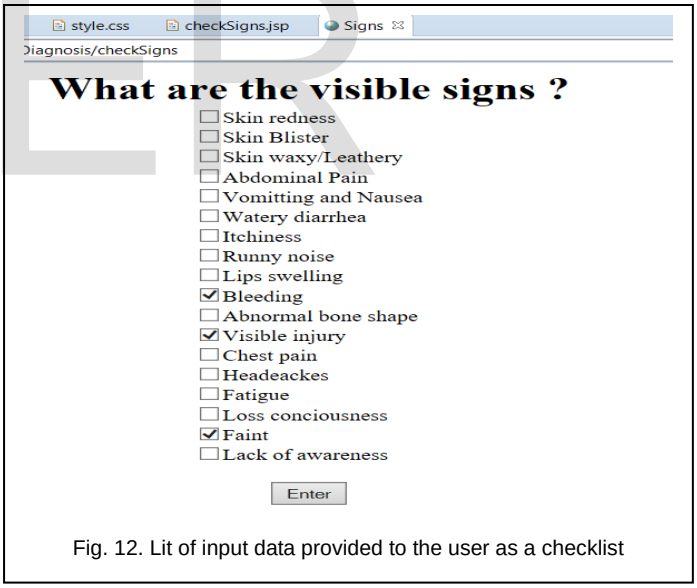

Fig. 12. Lit of input data provided to the user as a checklist

What user selects as visible signs are transformed into a boolean vector representation, where 1 stands for the selected signs and 0 is affected to all unchecked signs. If we consider the case of Fig.13, the input vector for our system will be as below :

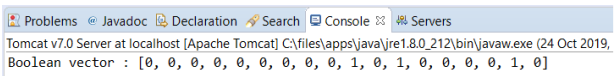

Fig. 13. Input data transformed to a binary vector

The classification used in our diagnosis support system relies on rule-based classifier, where knowledge is represented by a binary matrix and the rule of classification consist on matching the input vector to the knowledge matrix. Wich can result in a perfect match (one medical category is returned) or a set of plausible target classes based on the degree of similarity.

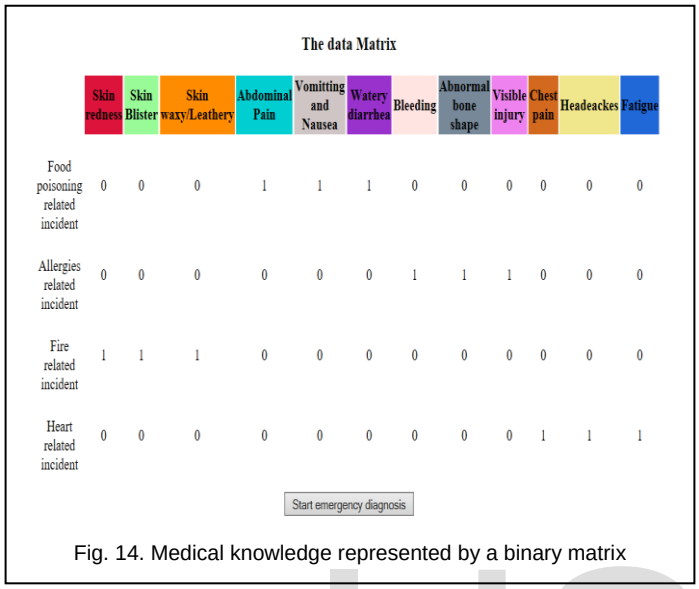

Fig. 14. Medical knowledge represented by a binary matrix

Fig.14 illustrates how each medical category is represented in our system, and what does tha matrix knowledge consist of. The matrix will not be displayed to the user, we only present the display as part of our technical testing.
Although we consider in our experiment all 6 categories, we have limited the number of categories to display to four, because the higher number of categories we take, the larger our matrix gets and less readable are the text and numbers displayed.

The results of matching the input vector to the knowledge matrix when considering the values shown in Fig.12 are presented in Fig.15 below :

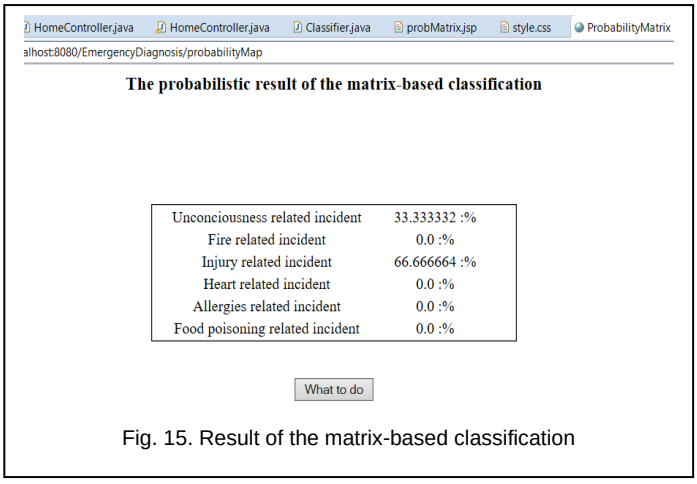

Fig. 15. Result of the matrix-based classification

As the main purpose for MEA decision support system is to identify the emergency category to offer guidance to the user, we have associated each target category with the recommended actions to adopt in a specific situation.
Fig.16 shows the result we obtain for the example studied earlier where the probability of user situation being an Injury related incident is 66.66% and 33.33% for Uncounsciousness related incident.

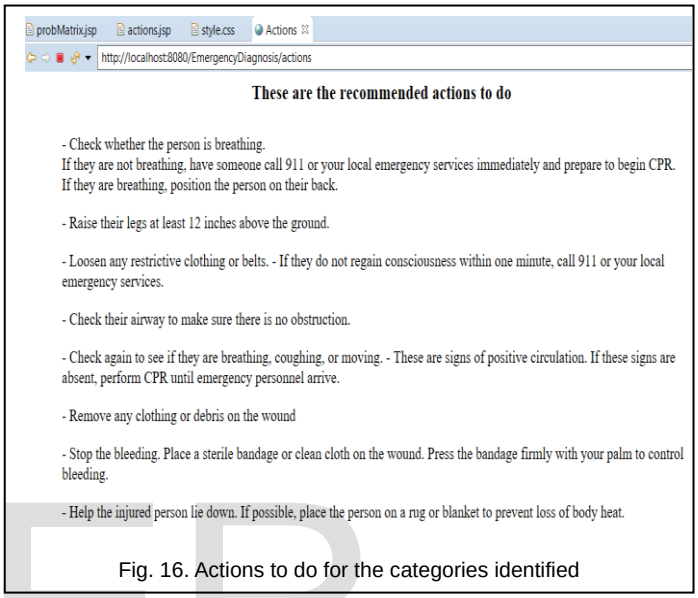

Fig. 16. Actions to do for the categories identified

4 Conclusion and Discussion

The importance of knowing how to deal with medical emergency situations and the difference that some actions can make in a life threatening circumstances, inspired us to propose an emergency medical assistance decision support system we named (MEA), which is an online service able to identify one or more medical emergencies among others with a probability degree based on user input data, and provide the user with the actions to do or to avoid for the resulted categories. MEA decision support system relies on a matrix-based classification we have introduced that takes place after selecting unique features for medical categories, another algorithm we have developed for this study.

As a perspective to this work, it would be interesting for us to consider implementing the MEA decision support system with all other medical and non medical emergency situations, considering that the model used in this study has offered us satisfactory results for the six categories implemented.

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