Firefighter Advisory System
Maya Al-Darai, Shadha Al-Shamsi, Tamadher Al-Harrasi, and Kamla Ali Al-Busaidi
Pages 197 – 204
DOI: http://dx.doi.org/10.21700/ijcis.2016.123

Firefighter Advisory System

Maya Al-Darai, Shadha Al-Shamsi, Tamadher Al-Harrasi, and Kamla Ali Al-Busaidi

Information Systems Department, Sultan Qaboos University, Muscat, Oman
P.O. Box: 20, PC: 123, AlKhod, Muscat, And Sultanate of Oman
[u098363, u089611, u094131] @student.squ.edu.om, kamlaa@squ.edu.om

Abstract: *This study aimed to present the development of a pilot expert system for firefighters using eXpertise2Go software. Development of this system started by eliciting knowledge from domain experts in firefighting from the Public Authority for Civil Defense and Ambulance in Oman, as well as a literature review. To apply this knowledge, decision tables were created to write if-then statements, which represented the link between input and output of the system. The system includes eight causes of fire. Depending on the cause of the fire and the inputs (detainees, electricity, type of building, and so on) the system will work as an expert who directs firefighters to extinguish the fire. This pilot firefighter advisory system has been evaluated by experts who offered valuable feedback.*

Keywords: *Firefighting, Expert System, Knowledge, Firefighters Expert System*

Received: May 01, 2016 | ***Revised***: August 10, 2016 | ***Accepted***: August 25, 2016

1. Introduction

The first of March is World Civil Defense Day, the purpose of which is to show the importance of all aspects of civil defense in every society. There are always many dangers caused by national disasters and accidents, which have a huge impact on human lives. The main purposes of civil defense are to protect and serve. These two objects can only achieved when there are experts with advanced skills and abilities eager to perform this function [14]. According to Royal Decree No. 3/2013, the Public Authority for Civil Defense and Ambulance was established by Royal Decree No. 3/2013 [13]. The authority includes many responsibilities such as firefighting; search and rescue, which includes ground, surface water, and national search and rescue teams; ambulance; fire prevention; and hazardous substance incident management [15].

Fire has been considered one of the major accidents due the more frequent occurrence of such accidents compared to other incidents. Its effects usually cover shorter distances and often impact other equipment [15]. So, it is important to have a model to analyze the kinds of risk that can exist after a fire. A historical analysis about process plants and the transportation of hazardous materials showed that 40% of accidents included the presence of a [17]. There are many types of fire accidents depending on the conditions and on the materials involved.

Fires can happen for many different reasons, including electricity, smoking, gas leak, use of incense; children; chemical reaction; self-ignition; heaters; ironing; cooking; fireworks; traffic accidents; welding; scattered sparks; lightning; mechanical and technical faults, water leakage inside electrical components; fuel leaks, delivery to a heat source and connection to a heat [16].

An expert system is an interactive system that acts as a human being would act, asking the same questions that an expert would ask while diagnosing a certain issue [7]. The area responsible for creating a working process like a human being is the artificial intelligence (AI) [4]. AI aims to comprehend intelligence by building computer programs that display smart behavior [8]. According to Becerra-Fernandez et al. [4], an expert system consists of three components from the user's perspective (i.e. the intelligence program, the user interface, and a work space) and two components from the developer's perspective (i.e. the intelligence program and the development environment).

Implementing a new program in any organization is always critical. The employees must adapt to the new program and make changes to their workflow. The experts at the Public Authority for Civil Defense and Ambulance had no previous experience with intelligence programs in firefighting, which created some challenges. The major challenge was for the firefighters to adapt to the new system. As the firefighters had no previous experience with intelligent firefighting systems, they were used to following their leader's instructions when dealing with a fire. The new expert firefighter system allows firefighters to make decisions to extinguish fires by themselves without instructions from their leader. These decisions need to be made very quickly but not all firefighters are capable of acting as a leader and making such decisions; some prefer to depend on others. Another challenge is that becoming too dependent on the system might make firefighters lazy.

On the other hand, there are many benefits that can be gained from using a firefighter advisory system. For example, sometimes firefighters do not have enough experience to make a decision when facing a fire, so the advisory expert system will help them make faster decisions. Another benefit is to reduce the dependency on the domain expert. Domain experts are not always available, but an expert system is theoretically available at all times. Furthermore, capturing knowledge and converting it from tacit to explicit knowledge that can be stored in a safe place is another benefit. This will allow users to take advantage of expertise gained by myriad owners of experience in this field [10].

The current system of firefighters in the Public Authority for Civil Defense and Ambulance relies entirely on manual guidance, meaning that the domain expert has a paper-based system rather than a computerized system. However, an online search about an existing system in this field revealed that Al-Ghamdi [2] from the General Directorate of Civil Defense in Saudi Arabia wrote a paper concerning the use of AI in fire incident management. Al-Ghamdi showed how expert systems could help make firefighting faster and more accurate, potentially diminishing or avoiding possible fire damage. The study outlined a system in the form of scenarios that shows how to deal with fires in various circumstances.

Furthermore, Al-Ghamdi [3] published another paper about using an expert system in the management of fires in houses. This paper covered the same issues as his previous paper, but more precisely focused on home fires and how to combat them. He also included several scenarios using different situations and conditions that would clarify how to deal with these differences. Such an expert firefighter system could be a great asset for the Public Authority for Civil Defense and Ambulance by enhancing the firefighters center performance, improving their response times, and providing clear information and directions about fighting fires. They currently rely on the oldest expertise for making decisions in emergency situations, especially in fires. Long, complicated processes must be considered, but they do not have a system that facilitates and summarizes these processes. An expert firefighter system that includes all the necessary inputs and outputs related to fire accidents would help them make faster, more accurate decisions.

2. Expert System Prototype Development

The objective of this expert system is to help firefighters make decisions after they receive notification of a fire and accumulate the experience of domain experts in a more reliable and accessible way. For example, after a fire captain retires, it's useful to have a reference that contains most of the positions and situations that can occur during a fire. This system will focus on eight types of fire: buildings, gas leaks, petroleum liquids, combustible minerals, burning plastics, farms, burning vehicles and electrical equipment, with a special focus on building fires.

2.1 Knowledge Elicitation Techniques

There are many ways to elicit knowledge such as protocol analysis, repertory grids, multidimensional scaling, interviewing, case-study reviews, observation, and card sorting [1, 12]. This study used interviewing, which is the most popular type, observations, and reviewing literature. First, it was necessary to extract knowledge from meetings conducted with domain experts. Simulations were also used to consider certain cases in order to solve a problem. The domain experts were employees from the Public Authority for Civil Defense and Ambulance with expertise about the subject and responsibilities as firefighters. The domain experts were asked questions about hypothetical problems, then asked to consider certain situations and then describe how they would resolve them. Next, the domain experts were observed receiving reports in their operation management room and researchers recorded the kinds of information they asked of the people reporting the fires.

Interviewing the domain experts initiated a discussion about the different classes of fire. For example, a class "A" fire is a solid ordinary combustible material like wood, paper, or cloth that can be controlled by water when it burns [5]. Most fires that occur in any type of building are considered Class "A" fires. As described by Voelkert [18] water is the best way to suppress a fire if the material has a burning ember or leaves an ash. What matter most in this type of fire is the life of the people potentially detained inside the building. As Coleman [6] explained, civilian life is the most important considered and they need to be rescued before the fire is addressed. After such an evacuation, the most important strategic task becomes preventing the fire from spreading and capturing the dominant vertical channel.

Class "B" fires involve flammable liquid or gas [18]. The domain experts explained that the type of fire can be caused by petroleum liquids, which can be suppressed by foam, or a gas leak, which can be simply suppressed by opening the area to dissipate the gas. This class of fire can also include fires at petrol stations, but these are mostly suppressed by trained staff of the petrol company.

A class “C” fire involves electrical wires or equipment, which can both be suppressed using foam [5].

Class “D” fires include minerals fires that can be suppressed with graphite powder, talcum powder, dry powder, carbon dioxide, or water no matter where it is located, though it is highly recommended to remove any flammable material located near the fire [11]. Often, this type of fire can be suppressed with a powder fire extinguisher, which is especially effective on combustible metals, such as magnesium, titanium, and sodium.

Farm fires are highly influenced by wind direction and can be suppressed with water or a combination of water and soil if the damage is huge. Similarly, plastic fires can be suppressed using water spray, foam, soil, or powder. Vehicle fires can be suppressed by power and soil, but this requires first disconnecting the vehicle battery and ensuring that no other power supply is connected to the vehicle.

The last major type of fire, the class “K” fire, is the combustion of electric equipment (i.e. lights or cables), which can be suppressed by water or powder depending of the power [9].

2.3 System Design

All the information that in the below part are collected from the domain expert that have been mention above.

Outputs:

Recommendation of Old Buildings
Continue or stop the extinguisher
Evacuation Plan
Risk Recommendation
Extinguisher Type

Inputs*:*

Type of fire?
"Buildings"
"GasLeaks"
"PetroleumLiquids"
"CombustibleMinerals"
"BurningPlastic"
"Farm"
"BurningVehicles"
"ElectricEquipment"
Type of building?
"new"
"old"
Status of the electricity?
"On"
"Off"
The fire path?
"Clear"
"Not clear"
Is there any detainees?
"yes" "no"
Any risk nearby?
"yes" "no"
The wind availability?
"yes" "no"
Is it a Flammable materials?
"yes" "no"
Is it a Petroleum materials?
"yes" "no"
The number of floor
"0" "10"
Is a car close to the slope?
"yes"
"no"
Status of cylinder
"NotExposedToFire"
"ProneToFire"
"HeatedDueToFire"

Middle:

Decision tables were used to illustrate the middle – reasoning logic based on the knowledge acquired from the domain experts and the literature. Table 1 and Table 2 show decision tables that illustrate a sample of the reasoning logic for fighting fires in new buildings and petroleum liquids cylinders.

The following rules represent a sample of rules used to code part of the logic of the decision tables shown in Table 1.

```
RULE [Rule31]
IF [TypeOfFire] = "Buildings" and
  [TypeOfBuilding] = "new" and
  [Electricity] = "Off" and
  [FirePath] = "Clear" and
  [Detainees] = TRUE and
  [NumberOfFloor] >= 4 and
  [RiskNearby]= TRUE and
  [Flammable?]= TRUE and
  [Petrolem?] = FALSE and
  [Wind] = TRUE
```

THEN [Extinguisher Type] = "water" and [Risk Recommendation] = "1- FlammableMaterial: send two fighters to separate these materials from the fire location. 2- Choose suitable position for the fire trucks 3-Place a widely protection scope that extent to 200 meters in all directions" and

[EvacuationPlan] = "Evacuation plan is needed"

Table 1. New buildings [RiskNearby] = TRUE and

Type of fire	Buildings	Buildings	Buildings	Buildings	Buildings	Buildings
Type of building	new	new	new	new	new	new
Electricity	on	on	off	on	on	on
fire path	clear	clear	clear	clear	clear	clear
detainees	no	no	yes	yes	no	no
# of floors	>=1 and <= 3	>=1 and <= 3	>= 4	>= 4	>= 4	>= 4
if risk near	yes	no	yes	yes	yes	no
Flammable Material?	yes		yes	yes	yes	
Petroleum Materials?	no		no	no	no	
wind			yes	yes	yes	yes
RECOMMENDATION	1- Flammable Material: send two fighters to separate this material from the fire location. 2- Switch off the power supply	1- Switch off the power supply	1- Flammable Material: send two fighters to separate this material from the fire location. 2- Choose suitable position for the fire trucks 3-Place a widely protection scope that extent to 200 meters in all directions	1- Flammable Material: send two fighters to separate this material from the fire location. 2- Switch off the power supply 3- Choose suitable position for the fire trucks. 4-Place a widely protection scope that extent to 200 meters in all directions	1- Flammable Material: send two fighters to separate this material from the fire location. 2- Choose suitable position for the fire trucks 3-Place a widely protection scope that extent to 200 meters in all directions. 4-Switch off the power supply	1-Choose suitable position for the fire trucks. 2- Place a widely protection scope that extent to 200 meters in all directions 3- Switch off the power supply"
Evacuation plan			needed	needed		
Continue or stop the extinguisher	stop the extinguishing process because the firefighters should not be exposed to danger	stop the extinguishing process because the firefighters should not be exposed to danger				
Extinguisher type	water	water	water	water	water	water

RULE [Rule32]
IF [TypeOfFire] = "Buildings" and
[TypeOfBuilding] = "new" and
[Electricity] = "On" and
[FirePath] = "Clear" and
[Detainees] = TRUE and
[NumberOfFloor] >= 4 and
[RiskNearby]= TRUE and
[Flammable?]= TRUE and
[Petrolem?] = FALSE and
[Wind] = TRUE
THEN [Extinguisher Type] = "water" and
[Risk Recommendation] = "1- FlammableMaterial: send two fighters to separate this material from the fire location. 2- Switch off the power supply 3-Choose suitable position for the fire trucks. 4-Place a widely protection scope that extent to 200 meters in all directions" and
[EvacuationPlan] = "Evacuation plan is needed"

The following rules were coded in the eXpertise2Go expert system shell to represent the logic of the decision table shown in Table 2

RULE [TypeOfFire4PetroleumLiquids]
IF [TypeOfFire] = "PetroleumLiquids" and
[Flammable?] = TRUE and
[CylinderStatus] = "NotExposedToFire"
THEN [Extinguisher Type] = "Foam" and
[Risk Recommendation] = "1- FlammableMaterial: send two fighters to separate this materials from the fire location. 2-Locked, separated and move it to a safe place"

RULE [TypeOfFire4PetroleumLiquids]
IF [TypeOfFire] = "PetroleumLiquids" and
[RiskNearby] = TRUE and
[Flammable?] = TRUE and
[CylinderStatus] = "ProneToFire"
THEN [Extinguisher Type] = "Foam" and
[Risk Recommendation] = "1- FlammableMaterial: send two fighters to separate this material from the fire location. 2- Cooled, sprayed with water until you close the main valve, and move it to a safe place"

Table 2. Petroleum liquids

Type of fire	petroleum liquids	petroleum liquids	petroleum liquids
Risk nearby?	yes	yes	yes
Flammable Material?	no	no	no
Cylinder Status?	Not Exposed To Fire	Prone To Fire	Heated Due To Fire
Cylinder Recommendation	There must be a flammable risk , And lock, separate ,and move the cylinder to a safe place	Cool ,spray the cylinder with water until you close the main valve and move it to a safe place + There must be a flammable risk	Cool the cylinder behind the protective shield because of the possibility of exploding + There must be a flammable risk
Risk Recommendation	Separated,		
Extinguisher type	foam	foam	foam

2.4 System development

As shown in Figure 1, this system interface provides a choice of fire and the user should choose one of them based on their situation. For example, here the user choses buildings type. After that the system will ask about the type of building (whether old or new) as shown in Figure 2.

Figure 1: Choosing type of fire

Figure 2: Choosing type of building

Figure 3: Recommendation interface

Figure 4: Evacuation plan

Figure 3 illustrates the recommendation interface that will display for the user. By clicking on the Evacuation plan link, the user will be taken to a new page that includes four steps for applying the evacuation plan, as shown in Figure 4.

3. System Evaluation

3.1 User evaluation

About five users from Civil Defense and Ambulance About five users from the Public Authority for Civil Defense and Ambulance were asked to test the Firefighters system and evaluate it by responding to a questionnaire. The aim of this stage was to get user feedback and apply it to improve the system to meet user expectations. Indicators related to inputs, outputs, and overall system quality were assessed based on 5-points Likert scale (s1-strongly disagree to 5-strongly agree).

Table 3: User Evaluation

	Strongly Disagree (1)	Disagree (2)	Normal (3)	Agree (4)	Strongly Agree (5)
INPUTS Relevancy				40%	60%
INPUTS Accuracy				20%	80%
INPUTS Completeness				40%	60%
INPUTS Understandability				40%	60%
Output Relevancy				60%	40%
Output Accuracy				60%	40%
Output Completeness				80%	20%
Output Consistency		20%		40%	40%
Output Understandability				40%	60%
Output Trust				60%	40%
System Reliability				60%	40%
System User Friendly-Interface			20%		80%
System Response time				80%	20%
User Satisfaction				40%	60%
System Usefulness				40%	60%
Usage				60%	40%
System Trust				40%	60%
Awareness			20%	40%	40%

Table 3 illustrates the results of the user evaluations. Overall, the user response was quite good. About 60% of the users strongly agreed that the system inputs were relevant and 40% of them agreed. Also, 80% of the users strongly agreed that the system inputs were accurate, while 20% of them responded that they agreed. About 60% of the users strongly agreed that the system inputs were complete, while 40% of them agreed. About 60% of the users strongly agreed that the system inputs were understandable and 40% of them agreed.

Regarding the system output' quality, 40% of users strongly agreed that the system output was relevant, and 60% of them agreed. Also, 40% of the users strongly agreed that the system output was accurate, while 60% of them agreed. When asked about the completeness of the system output, 20% of the users strongly agreed that it was complete, while 80% of them agreed with. About 40% of the users strongly agreed that the system output was consistent, while 40% of them agreed with this claim and 20% disagreed. About 60% of the users strongly agreed that the system outputs were understandable, and 40% of them agreed. About 40% of the users strongly agreed that they trusted the system output, and 60% agreed. About 40% of the users strongly agreed that the system outputs were reliable, while 60% registered their agreement.

Moreover, in terms of the overall system quality, 80% of the users strongly agreed that the system included a friendly interface, but 20% of them were neutral on this claim. On the other hand, 20% of users strongly agreed that system had a good response time, while 80% agreed.

Overall, 60% of the users strongly agreed that they were satisfied with the system and 40% agreed. About 60% of users strongly agreed that the system was useful and 40% only agreed. Regarding system usage, 40% of the users strongly agreed that they intended to use it, and 60% agreed. Results showed that 60% of the users strongly agreed that they trusted the system and 40% of them agreed. About 40% of users strongly agreed that the system improved their awareness, while 40% agreed, and 20% were neutral.

In a response to an open-ended question on the benefits and limitations of the system, the respondents indicated that the system was useful, helpful, faster, clear, accurate, and good. However, the users also mentioned one critical limitation that they faced: the need for the system to be in Arabic, since most of them were not English speakers.

When the users were asked whether they preferred the expert system or a human expert, 57.1% preferred the expert system and 42.9% preferred a human expert. When asked about their reasons for preferring the expert system, the users gave a variety of responses, including “we can use the system easily anywhere and everywhere"; "people forget and get confused"; "it makes it easy to make decisions"; and it is "helpful when the human expert is not around."

Moreover, the users who preferred the human expert noted that human experts were "more accurate and available". Ultimately, most the users who completed the questionnaire preferred the expert system because they believed the expert system offered more benefits than a human expert.

4. Conclusion

The expert firefighter system described here can provide a great help to the Public Authority for Civil Defense and Ambulance by enhancing firefighter center performance, improving their response time, and providing clear information and directions about fires. This system was especially developed for the firefighters in the Public Authority for Civil Defense and Ambulance, who currently rely on senior staff expertise to make decisions in an emergency. In situations like a fire, many large, complicated processes must be considered and existing staff has no system to facilitate and summarize these processes for them. This understanding led to the creation of a knowledge-based system that includes all of the inputs and outputs related to all types of fires.

This pilot firefighter advisory expert system has proven to be a useful system that satisfied the domain experts who tested it. It is clear, however, that a truly useful system must be developed in a way that meets the needs of the Public Authority for Civil Defense and Ambulance. More development rounds are needed to finalize the reasoning logic, and needed interface. The current system was developed in English since the software does not support other languages, but the domain experts expressed a preference for a system in Arabic. To meet this request, a more sophisticated software package will be used to design the next iteration of the system, which will enable a more professional character, as well as more accurate and effective results. It will also be helpful to expand the system to consider other important functions of the Public Authority for Civil Defense and Ambulance such as the ambulance and rescue operations.

Moreover, it is necessary to add more details to make the recommendations more robust. The evacuation plan documented in the current system only the primary steps based on the presumption that the firefighters already knew these details. A more complete system, however, should include more specific recommendations like different ways to evacuate the building depending on the number of floors, the size of fire, and other criteria. A truly useful expert firefighter system must include many different scenarios and situations. Therefore, part of the enhancements will be to improve the system's ability to interact with different environments. Furthermore, based on the advice of the domain experts in this study, the system must be expanded to include options to extinguish the fire based on similar previous cases. Finally, further development should also focus on the ability to run the system on any platform.

In conclusion, this study demonstrated a case where an expert system application can add value in the context of firefighting. The main focus of this expert system is on fires, but it could eventually be improved to include other responsibilities of the Public Authority for Civil Defense and Ambulance.

5. Acknowledgement

We would like to thank the domain experts at the Public Authority for Civil Defense and Ambulance for their great collaboration and valuable contribution during the knowledge acquisition and evaluation.

References

[1] P. Akhavan, and M. Dehghani, Knowledge acquisition techniques selection: A comparative study, IUP Journal of Knowledge Management, vol.13, no.3, pp.17-30, 2015.

[2] Y.A. Al- Ghamdi, The use of the artificial intelligence in a fire incident management: Workshop on Modern firefighting techniques, presented at General Directorate of Civil Defense, Riyadh, 2008.

[3] Y.A. Al- Ghamdi, Management of fire accidents in houses: Seminar in expert systems in the fight against fire incidents of civilian facilities, presented at General Directorate of Civil Defense, Riyadh, 2011.

[4] I. Becerra-Fernandez, A. Gonzalez, and R. Sabherwal, *Knowledge management: Challenges, solutions and technologies,* Pearson Education Inc., New Jersey, 2004.

[5] L. Channing and C. Bete, What everyone should know about fire extinguishers. In South Deerfield, 1985.

[6] J. Coleman, Managing Major Fires, PennWell Corporation, Tulsa, US, 2001

[7] B. K. Duval, and L. Main, Expert systems: What is an expert system?, *Library Software Review*, vol.13, no.1, pg.44, 1994.

[8] E. Feigenbaum, et al., Knowledge-based systems in Japan, Report of the JTEC Panel, 1993.

[9] J. Gerling, Portable fire extinguisher selection and use. In, OSU extension facts; 9402

Stillwater, Okla.: Oklahoma State University, Cooperative Extension Service, 1977.

[10] K. Mansiya, et al., The methodology of expert systems, *International Journal of Computer Science and Network Security*, vol.14, no.2, pp.62-66., 2014.

[11] C. A. McMillan, Fire Safety: The Abcs, Ds, And Ks Of Fire Extinguishers, *Occupational Health & Safety,* vol.73, no.8, pp.42-44, 2004.

[12] J. W. Moody, J. E. Blanton, and R. P. Will, Capturing expertise from experts: The need to match knowledge elicitation techniques with expert system types. The Journal of Computer Information Systems, vol.39, no.2, pp.89-95, 1999.

[13] Pacdaoman, Related royal decrees, http://www.pacdaoman.gov.om:8080/en/about/related-royal-decrees, 2015.

[14] Pacdaoman, Vision & mission, http://www.pacdaoman.gov.om:8080/en/vision-mission-en, 2015.

[15] Pacdaoman (2015c). Services, http://www.pacdaoman.gov.om:8080/en/about/pacda-services, 2015.

[16] Pacdaoman, Annual statistics, http://www.pacdaoman.gov.om:8080/images/pdf/st.2014.pdf, 2015 .

[17] E. Planas, and J. Casal, Fire Accidents In Process Plants: Mathematical Modeling And Research Needs, 2009.

[18] C. J. Voelkert, Fire And Fire Extinguishment A Brief Guide To Fire Chemistry And Extinguishment Theory For Fire Equipment Service Technicians, http://amerex-fire.com/wp-content/uploads/2011/12/Fire_and_Fire_Extinguishment.pdf , 2009.

Maya Al-Darai graduated from the Information System Department at Sultan Qaboos University in Oman. Her research interest includes expert system, knowledge management, firefighting expert system and application development.

Shadha Al-Shamsi graduated from the information systems department at Sultan Qaboos University. Her research interest includes expert system, firefighter’s expert system and application development.

Tamadher Al-Harrasi is a graduate of the information systems department at Sultan Qaboos University. Her research interest includes expert system and application development.

Kamla Ali Al-Busaidi is an Associate Professor of information systems at Sultan Qaboos University in Oman. She received her PhD in management information systems from Claremont Graduate University in California. Her research interests include knowledge management systems, knowledge economy, learning management systems and the deployment of information and communication technologies in Arab countries.