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The Effectiveness of Utilizing Artificial Intelligence (AI)-Based Technologies and Applications in Improving Results for Arson Investigation

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ABSTRACT

This article aimed to determine the effectiveness of (Machine Learning, Artificial Neural Networks, Pattern Recognition and Data Analysis, and Fire Dynamics Simulations) in improving the results of arson investigations in the United Arab Emirates (UAE). The research relied on the descriptive method. The study community consisted of all members of the teams specializing in fire investigations. The research sample was taken using a simple random method that included (74) individuals from the research community. The researcher relied on the questionnaire as the main instrument for collecting data from the study sample. The results of the study showed that artificial intelligence techniques (Machine Learning, Artificial Neural Networks, Pattern Recognition and Data Analysis, and Fire Dynamics Simulations) can be effective in improving the results of arson investigations. The study recommended providing training programs to investigators on how to make full use of AI techniques in the investigation process.

Introduction

Fire incidents occur frequently in today's world because of human irresponsibility, the unpredictability of climate change, and the characteristics of both residential and industrial settings.(1) As a response, many states around the world have consistently allocated resources to enhance their fire prevention, fighting capabilities, and investigation processes (2). An investigation of the fire scene is the initial step for the effective utilization of tangible evidence by the forensic laboratory and the criminal investigation. That is to say, a thorough fire investigation is crucial for identifying the source, the reason for fire incidents and whether the fire is the result of an accident or arson (3, 4).

Accidental fire encompasses all fires that are not intentionally or maliciously initiated (5). Arson fires refer to fires that are believed to have been deliberately set with criminal intent and thus subject to investigation to determine criminal liability. The motivations behind arson fire include financial gain, retribution, insurance fraud, and hiding of other criminal activities (6). Arson fire can lead to extremely difficult and intricate criminal scenes. Fire's destructive nature causes chemical destruction of much physical evidence, while accelerants either fully burn or evaporate, and may be found in trace amounts in any of the disintegrated components. Modern analytical methods for investigation are required to determine the original substance and accelerant involved (7).

A wide range of modern technologies are now employed across several domains to facilitate the reconstruction of fire scenes and to investigate the underlying factors contributing to fire-related incidents (2). Among these technologies are artificial intelligence techniques (8). Artificial intelligence can be employed in forensic fire investigations to ascertain the source and reason of fire, whether they are the result of accidents or deliberate acts of arson. Fire investigators analyze burn patterns, fire debris, and witness testimonies to ascertain the origin and localization of a fire. Their efforts contribute to the identification of arsonists and the prevention of future fires (9). During arson investigations, DNA or fingerprints are frequently obliterated as evidence (10). From the analysis of nanogram quantities of DNA to the development of artificial intelligence databases with the ability to detect latent fingerprints, forensic science and arson investigation of extremely small amounts of physical evidence have had significant progress and enhancement. Governments have shown significant interest in the use of sophisticated science and technology, particularly artificial intelligence (AI), for the purpose of investigation efforts (2).

Statement of the Problem

Fire investigations are one of the components that influence the fire management system in the United Arab Emirates. The relevant authorities in the Emirates prioritise investigations of fire incidents to gather crucial information on the nature and causes of fires to prevent the recurrence of fires caused by the same factors (11). There are many competent authorities specialized in the examination of fire incidents in the United Arab Emirates. Their primary objective is to identify the source and cause of fires, whether they are accidental or deliberate (arson) (9). All sections and departments under these authorities have successfully incorporated contemporary technology, including virtual reality methods, into arson investigations as supplementary tools (12). Although these departments and sections have made notable progress, they still encounter some substantial obstacles. An inherent obstacle is the swift advancement of technology. To remain up-to-date, all competent departments must consistently upgrade the employed technologies (9). Recently, technologies based on Artificial Intelligence (AI) have shown considerable promise in improving investigation procedures worldwide by facilitating automated data processing, predictive modelling, and pattern identification. Despite the encouraging potential, there is a scarcity of research specifically addressing the efficacy of these AI systems for arson investigations in the UAE.

Questions of the Study

The main questions of the study can be reviewed as follows:

1. How effective is the use of (Machine Learning) in improving the results of arson investigations in the UAE?
2. How effective is the use of (Artificial Neural Networks) in improving the results of arson investigations in the UAE?
3. How effective is the use of (Pattern Recognition and Data Analysis) in improving the results of arson investigations in the UAE?
4. How effective is the use of (Fire Dynamics Simulations) in improving the results of arson investigations in the UAE?

Objectives of the Study

The main objectives of the study can be reviewed as follows:

1. Determining the effectiveness of (Machine Learning) in improving the results of arson investigations in the UAE.
2. Discussing the effectiveness of (Artificial Neural Networks) in improving the results of arson investigations in the UAE.
3. Shedding light on the effectiveness of (Pattern Recognition and Data Analysis) in improving the results of arson investigations in the UAE.

4. Exploring the effectiveness of (Fire Dynamics Simulations) in improving the results of arson investigations in the UAE.

Significance of Study

Implementing AI-based technology in arson investigations can significantly transform the process of investigation by enhancing accuracy in determining the source of fire, expediting evidence analysis, and simplifying the identification of suspects. This study aims to offer valuable insights into how artificial intelligence (AI) might improve the accuracy of investigations, therefore enabling law enforcement operations in the United Arab Emirates (UAE) to respond more efficiently to occurrences associated with arson. This study aims to assess the efficacy of AI-based tools in enhancing investigation results, therefore providing UAE law enforcement authorities with valuable support in using state-of-the-art technologies. Implementing a more efficient investigation procedure can result in expedited resolutions of arson cases, therefore mitigating threats to public safety and avoiding future occurrences. Consequently, this results in an improvement of general public trust in the investigation system of the UAE. This study will enhance the existing knowledge on the application of artificial intelligence (AI) in criminal investigations, particularly in cases of arson. This study aims to address the available literature gap on the efficacy of artificial intelligence (AI) in the United Arab Emirates (UAE). It will provide new perspectives and empirical evidence that might be valuable for future academic research and development in the fields of AI technology and forensic science. The research results can stimulate future technological advancement by emphasizing the domains where AI applications offer the greatest advantages and those that need more enhancement. This has the potential to stimulate inventive development in artificial intelligence technologies specifically designed for arson investigations, therefore improving forensic science methodologies not just in the UAE but also in comparable areas.

Literature Review

The literature review discusses the nature of fire incidents with a special focus on arson fires and how AI techniques can be used in arson investigation as follows:

I. Fire Incidents & Arson Investigations

In basic terms, a fire is a chemical reaction characterised by the fast oxidation of a substance (fuel) that generates heat (and frequently light). Most fires are characterized by the combustion of organic substances, which are composed of carbon. These materials may manifest as either natural, such as wood or artificial such as plastics(13). The Centre of Fire Statistics (CFS) of the International Association of Fire and Rescue Services (CTIF) reports that the global annual fire fatality rate is estimated to be 100-120 thousand individuals per year, while the annual fire injury rate is 300-350 thousand individuals per year (14). Instances of human fatalities and injuries resulting from flames and explosions persist. The property damages resulting from fires greatly surpass those caused by all categories of criminal activity and are comparable to those generated by hurricanes and earthquakes (15).

The investigation usually takes the structure of a pyramid. A substantial foundation of verifiable facts and evidence should be established at the base. These data establish the foundation for analysis based on established scientific concepts. The data and analysis collectively substantiate a limited set of conclusions that constitute the pinnacle of the pyramid.

Conclusions must be grounded in empirical evidence and analysis, rather than in alternative conclusions or conjectures. If the data are organized logically and systematically, the conclusions should be nearly self-evident (16).

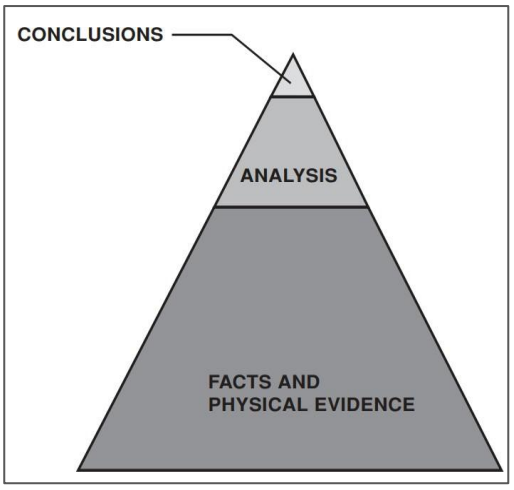

Fig 1: The Investigation Pyramid
Source: (16)

The fire investigator must adhere to a specified protocol for data gathering at the fire scene and subsequent assessments. The initial phase of the investigation involves data collecting, specifically the acquisition of preliminary information. This phase allows for the identification of the requirement and the definition of the problem to initiate the phases of the scientific process. Most fire investigators would initially survey the fire scene to identify the sections that remained unscathed by the flames. Identifying what remained unscathed by the fire facilitates the exclusion of numerous theoretical

points of origin. Thus, the second phase involves external assessment of the situation, collecting and classifying evidence. The third phase involves the examination of the fire-affected zone. During this step, the investigators will examine the fire patterns utilizing a Semiotic Fire Analysis (17).

Arson is the criminal act of deliberately starting a fire with destructive intent (18). In Latin, the word arson is derived from the verb ardere, which means "to burn" (19). Arson fires are the consequence of intentional purposeful human acts. Admitted guilt and firsthand accounts from witnesses may offer the most immediate connection to the perpetrator of the arson. They, yet are not the most dependable kind of proof. Artefacts and physical evidence found at the fire scene offer a more dependable but occasionally challenging to understand (18). The deliberate planning and organization of arson fires result in significant destruction, so posing considerable challenges for investigators in their quest for pertinent evidence (20). The investigators must possess comprehensive knowledge of all the concepts, norms, and methodologies that are to be used for the analysis of evidence. Arson investigators typically examine "burnt indicators" and consider it the predominant approach for establishing allegations of arson. Petrol is the predominant accelerant present in cases of arson. As compared to kerosene or diesel, it consists of lighter hydrocarbons. Upon ignition, it exhibits significant volatility and inflicts substantial damage. Petrol has distinct chromatographic patterns that set it apart from other accelerants (6).

II. The Use of AI Techniques in Arson Investigations

Artificial intelligence is an innovative and multifaceted interdisciplinary field. Over time, it has evolved into the central area of interest and research initiative among different researchers in varied societies (21). The incorporation of Artificial Intelligence (AI) techniques such as Virtual Reality (VR) and augmented Reality (AR) technologies, in conjunction with Machine Learning (ML), and Deep Learning (ML) has introduced revolutionary capabilities to science and technology research. Advancements in artificial intelligence techniques are quickly being employed to automate the analysis of digital evidence, therefore enhancing the efficiency of different investigations (8). These technological innovations can improve fire prevention, detection, investigation, and response skills, therefore mitigating the negative impacts of fires (22).

Conducting investigations at fire sites to ascertain the presence of arson poses significant challenges for both the forensic investigator responsible for collecting fire debris samples and the forensic scientist undertaking the analysis (23). Recent advancements have led to the emergence of novel liquids that complicate classification methods, and the introduction of new materials creates intricate matrix interferences. Fire debris examiners are increasingly required to test samples that go beyond the usual scope of ignitable liquid examination. While certain laboratories may at present have restricted instrumental capabilities, the prevalence of these nonroutine analyses is increasing. The analysis of fire debris is no longer restricted to a comparatively narrow range of ignitable liquid classifications. Complex detritus and liquid samples necessitate examiners to ascertain the most appropriate classification, while novel liquids present a challenge to the existing classification schemes (24). The research on the prediction of detritus flow occurrence may be revitalized by the implementation of new ML techniques, as ML is undergoing rapid evolution (25).

Early methodologies employed fundamental image processing techniques such as thresholding and colour-based segmentation to detect areas of fire. Nevertheless, their precision is limited, and they face difficulties in handling intricate fire situations and fluctuating lighting circumstances. In recent years, artificial intelligence (AI) methods have demonstrated encouraging outcomes in the identification of flames from photographs, therefore offering a prompt and effective reaction to possible fire cases (26). Thermal imaging cameras and digital image analysis techniques are new and modern ways to determine fire parameters, which greatly aids fire investigation. This technology can be implemented in the current fire investigation practice by employing algorithms for automated image analyses and the derivation of selected fire parameters (20).

To reach an accurate determination, forensic scientists must meticulously gather, scrutinize, analyze, and interpret samples of fire debris. Currently, the identification of intellectual property (IL) in fire debris involves the chemical analysis of the composition of the fire debris, followed by the scrutiny and interpretation of the analytical findings by a qualified forensic examiner. Chemoinformatics and artificial intelligence have gained significant importance over the past decade. In forensic examinations, machine learning approaches function as supplementary autonomous assessments for the examiner. Crucially, machine learning techniques continue to serve as a supplementary tool for the examiner (27). The implementation of machine learning systems has shown a potential remedy for addressing human fallibility in the categorization of flammable liquids using pattern recognition techniques, thereby reducing the overall duration of arson investigations and ensuring the

accuracy of the evidence obtained for court proceedings (4).

Field Study Procedures:
First: study methodology:
The research relied on the descriptive method defined by Al-dosary (28) as "a set of integrated research procedures to describe a phenomenon or topic based on collecting, classifying, processing and analyzing facts and data sufficiently and accurately to reveal implications and results."

Second: study community and sample:
The study community consists of all members of the teams specializing in investigations related to fires, and the research sample was taken using a simple random method that included (74) individuals from the research community.

Third: Characteristics of the study sample:
The following table shows the distribution of sample members according to their characteristics:

Table No. (1): Distribution of sample members according to their characteristics

Age	Frequencies	Percentages
Less than 30 years	15	20.3%
From 30 to 40 years	29	39.2%
From 41 to 50 years	19	25.6%
51 years and above	11	14.9%
Total	74	100%
Years of Experience	**Frequencies**	**Percentages**
Less than 5 years	15	20.3%
From 5 to 10 years	32	43.2%
10 years and above	27	36.5%
Total	74	100%

The above table shows that the highest percentage obtained by the sample members according to age is (39.2%) for (From 30 to 40 years category), followed by (25.6%) for (From 41 to 50 years category), followed by (20.3%) for (Less than 30 years category), followed by the lowest percentage (14.9%) for (51 years and above category). The highest percentage according to years of experience was (43.2%) for (From 5 to 10 years category), followed by (36.5%) for (the 10 years and above category), while the lowest percentage was (20.3%) for (The less than 5 years category).

Fourth: study tool:
The researcher reviewed the objectives of the study, which aimed to reveal The Effectiveness of Utilizing Artificial Intelligence (AI)-Based Technologies and Applications in Improving Results for Arson Investigation, and upon reviewing the theoretical literature and previous studies related to the subject of the study, he found that the most appropriate means of collecting data is (the questionnaire), and the researcher benefited from the theoretical literature and previous studies in constructing the questionnaire and formulating its statements, as the main axes and dimensions included in the questionnaire were identified, and the statements that fall under each dimension were identified, and the questionnaire came as follows:

Description of the study tool (questionnaire):
The questionnaire in its final form contained two main parts:

- **Part One**: comprises primary data about the study sample represented by demographic information and includes (age and years of experience).
- **Part Two**: It consists of the dimensions of the questionnaire, consisting of (4) dimensions, as follows:
  - **Dimension One: Machine learning**, consisting of statement No. (1) to statement No. (6).
  - **Dimension Two: Artificial neural networks**, consisting of statement No. (7) to statement No. (12).
  - **Dimension Three: Pattern Recognition and Data Analysis**, consisting of statement No. (13) to statement No. (18).
  - **Dimension Four: Fire Dynamics Simulations**, consisting of statement No. (19) to statement No. (24).

The five-point Likert scale (Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree) was used to correct the study tool, giving the responses Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly Agree (5).

Tool Validity and Reliability:
- **Validity of the Arbitrators:**

Upon completing the formulation of the questionnaire constructing its statements, and presenting it to a group of specialized arbitrators to verify the effectiveness of the tool and its achievement of the study objectives, to ensure the extent to which each of its statements is related to the dimension to which it belongs, and the extent to which each statement is clear and its linguistic formulation is correct and appropriate to achieve the objective for which it was formulated for, and to suggest ways to improve it by deleting, adding, rephrasing, or other action they deem fit.

Upon retrieving the peer-reviewed copies from the arbitrators and in light of the suggestions of some arbitrators, the researcher reformulated the questionnaire. In contrast, some statements in the questionnaire were deleted and rephrased, as agreed upon by more than (80%) of the arbitrators. Thus, the questionnaire in its final form after verifying its apparent validity, consisted of (24) statements distributed over (4) dimensions.

- **Internal consistency validity of the questionnaire dimensions:**

Internal consistency validity was calculated by calculating the Pearson correlation coefficient between the scores of each statement and the total score of the dimension to which the statement belongs in the questionnaire, as shown in the following table:

Table No. (2): Pearson correlation coefficients between the scores of each statement and the total score of the dimension to which the statement belongs in the questionnaire

No.	Correlation	No.	Correlation	No.	Correlation
The First Dimension: Machine learning					
1	.720**	2	.745**	3	.753**
4	.737**	5	.740**	6	.758**
The Second Dimension: Artificial neural networks					
7	.760**	8	.711**	9	.716**
10	.812**	11	.721**	12	.733**
The Third Dimension: Pattern Recognition and Data Analysis					
13	.749**	14	.798**	15	.772**
16	.746**	17	.778**	18	.726**
The Fourth Dimension: Fire Dynamics Simulations					
19	.739**	20	.771**	21	.743**
22	.738**	23	.742**	24	.761**

**Statistically significant at the significance level (0.01).

The above table shows that the correlation coefficients of the statements with the total score of the dimension to which the statement belongs in the questionnaire were all statistically significant at a significance level of (0.01), and all the values of the correlation coefficients were significant, as they ranged in the first dimension: Machine learning between (.758**-.720**), and ranged in the second dimension: Artificial neural networks between (.812**-.711**), and ranged in the third dimension: Pattern Recognition and Data Analysis between (.798**-.726**), and ranged in the fourth dimension: Fire Dynamics Simulations between (.771**-.738**), which indicates the availability of a high degree of internal consistency validity for the statements of the questionnaire dimensions.

- **General structural validity of the questionnaire dimensions**

The general structural validity of the questionnaire dimensions was verified by finding the correlation coefficients between the total score of each dimension and the general average, and the results are shown in the following table:

Table No. (3): Correlation coefficients between the total score of each dimension and the overall average of the questionnaire

No.	Dimensions	Correlation
1	The First Dimension: Machine learning	.762**
2	The Second Dimension: Artificial neural networks	.722**
3	The Third Dimension: Pattern Recognition and Data Analysis	.711**
4	The Fourth Dimension: Fire Dynamics Simulations	.713**

The previous table shows that the values of the correlation coefficients for the questionnaire dimensions came at high values, ranging between (.762**-.711**), and they were all statistically significant at a significance level of (0.01) indicating the availability of a high degree of structural validity for the questionnaire dimensions.

- **Cronbach's Alpha for Questionnaire Dimensions**

Cronbach's Alpha reliability coefficient for the questionnaire dimensions and the overall average were calculated, and the results are shown in the following table

Table No. (4): Cronbach's Alpha Reliability Coefficient for the Questionnaire Dimensions

No.	Dimensions	Cronbach's Alpha
1	The First Dimension: Machine learning	.836
2	The Second Dimension: Artificial neural networks	.837
3	The Third Dimension: Pattern Recognition and Data Analysis	.854
4	The Fourth Dimension: Fire Dynamics Simulations	.843
Overall		.896

The above table shows that the values of the stability coefficients for the questionnaire dimensions came with high values, ranging between (.854-.836), and the value of the overall stability coefficient reached (.896); These values of the stability coefficients indicate the validity of the questionnaire for application and the possibility of relying on and trusting its results.

Fifth: Statistical methods:

The researcher used the Statistical Package for Social Sciences (SPSS) program and extracted the results according to the following statistical methods: Pearson correlation coefficient, Cronbach's alpha coefficient, frequencies and percentages, means and standard deviations, and the range equation, where the response degree was determined so that it gives the degree very low (1), low (2), medium (3), high (4), very high (5), and the verification degree is determined for each dimension based on the following:

$$\text{Class length} = \frac{\text{Max. limit - Min. limit}}{\text{No. of levels}} = \frac{1-5}{5} = 0.80$$

- From 1 to less than 1.80 represents a response score (very low).
- From 1.80 to less than 2.60 represents a response score (low).
- From 2.60 to less than 3.40 represents a response score (medium).
- From 3.40 to less than 4.20 represents a response score (high).
- From 4.20 to less than 5 represents a response score (very high).

Presentation, discussion, and interpretation of the Study results:

First: Presentation, discussion, and interpretation of the results of the first question, which stated: "How effective is the use of (Machine learning) in improving the results of arson investigations in the UAE?"

To answer this question, the means and standard deviations of the Statements of the first dimension: Machine learning were calculated, and then these Statements were arranged in descending order according to the Mean of each statement, as shown in the following table:

Table No. (5): Means and standard deviations of sample individuals' responses to the first dimension: Machine learning

No.	Items	Mean	SD	Rank	Response degree
1	Machine learning helps improve the accuracy of predictions in fire investigations.	4.08	1.352	3	High
2	Machine learning helps identify factors that contribute to a fire.	3.65	1.548	6	High
3	Machine learning helps analyze images taken from a crime scene.	4.18	1.307	2	High
4	Machine learning helps identify recurring patterns to avoid them in the future through analyzing data.	3.76	1.469	5	High
5	Machine learning algorithms improve the response of investigation teams and reduce human error.	4.24	1.214	1	Very High
6	Machine learning helps provide models for new insights into how a fire develops and spreads.	3.82	1.186	4	High
Overall		3.95	.576	High	

The above table shows that the overall average of the first dimension: Machine learning, came with a mean of (3.95) a standard deviation of (.576), and a response score of (High).

The first dimension: Machine learning, obtaining a response score of (High) can be explained by the fact that machine learning contributes to improving the results of investigations into arson by providing powerful tools for analyzing data, identifying patterns, predicting events, and extracting accurate information, which ultimately leads to solving cases faster and more accurately, as machine learning can discover complex patterns in data that cannot be observed with the naked eye, which helps in identifying the factors contributing to the outbreak of the fire and identifying the focal points in the investigation. Machine learning-based models can also predict the likely places where the fire started

based on factors such as the type of building, materials used, and weather conditions, which helps focus investigation efforts. Machine learning can also identify the possible causes of the fire based on the analysis of available data, which provides investigators with strong starting points for the investigation. Bogdal et al. (27) have confirmed that machine learning techniques can serve as a supplementary tool for the fire investigators.

The occurrence of statement number (5) ranking in the first place, with a response score of (Very High), can be explained by the fact that algorithms can process huge amounts of data in record time, which allows investigative teams to reach faster results. They also reveal complex patterns and relationships in the data that human investigators may not notice, which leads to improving the accuracy of analyses. Algorithms can also predict the occurrence of certain events based on historical data, which allows investigative teams to take preventive measures.

Second: Presentation, discussion, and interpretation of the results of the second question, which stated: "How effective is the use of (Artificial neural networks) in improving the results of arson investigations in the UAE?"

To answer this question, the Means and standard deviations of the statements of the second dimension were calculated: Artificial neural networks, and then these Statements were arranged in descending order according to the mean of each statement, as shown in the following table:

Table No. (6): Means and standard deviations of the sample members' responses to the second dimension: Artificial neural networks

No.	Items	Mean	SD	Rank	Response degree
7	Artificial neural networks are used to simulate the human thinking process to analyze complex data.	3.95	1.281	4	High
8	Neural networks are trained to distinguish between different types of combustible materials.	4.38	1.179	1	Very High
9	Neural network techniques can analyze heterogeneous data, which helps provide reliable insights into the fire causes.	3.85	1.541	5	High
10	Neural networks are used to process data from sensors to analyze fires more effectively.	4.16	1.324	3	High
11	Neural networks can learn from historical data, which helps improve their performance in identifying fires.	3.78	1.264	6	High
12	Neural networks can provide accurate predictions about fire behaviour.	4.28	1.165	2	Very High
Overall		4.07	.694	High	

The above table shows that the overall average of the second dimension: Artificial neural networks, came with a mean of (4.07) a standard deviation of (.694), and a response score of (High).

The second dimension: Artificial neural networks obtaining a (high) response score can be explained by the fact that artificial neural networks are considered one of the promising technologies in the field of complex data analysis, which makes them a powerful tool for improving the results of arson investigations, as neural networks can process large amounts of data related to fires, including images of fires, video recordings, sensor data, and others, in a short time, and they can analyze temporal changes in the data, which helps in determining the sequence of events and determining the approximate time of the fire, and they can also reveal hidden evidence that may not be obvious, such as the presence of certain chemicals or traces of tampering with evidence, as they can help in determining the

possible causes of the fire by analyzing the relationship between different factors.

The occurrence of statement No. (8) ranking in the first place, with a response degree of (Very High), can be explained by the availability of huge databases containing high-quality images of combustible materials in different situations, extensive training of neural networks, where data is collected from different lighting conditions and different prospectives, which helps the network to recognize combustible materials in any environment, and the networks are trained to recognize a wide range of combustible materials, including solids, liquids, and gases.

Third: Presentation, discussion, and interpretation of the results of the third question, which stated: "How effective is the use of (Pattern Recognition and Data Analysis) in improving the results of arson investigations in the UAE?"

To answer this question, the means and standard deviations of the statements of the third dimension: Pattern Recognition, and Data Analysis were calculated, and then these statements were arranged in descending order according to the mean of each statement, as shown in the following table:

Table No. (7): Means and standard deviations of the responses of sample members to the third dimension: Pattern Recognition and Data Analysis

No.	Items	Mean	SD	Rank	Response degree
13	Pattern analysis can provide insight into how different materials interact with ignition sources.	3.74	1.385	4	High
14	Patterning techniques help improve the accuracy of fire scene forensics.	4.12	1.354	1	High
15	Data analytics provide tools to analyze evidence and deduce the real causes of fires.	3.55	1.376	6	High
16	Patterns help determine the temporal and spatial distribution of fires.	4.05	1.302	2	High
17	Data analytics helps uncover behavioural patterns related to the criminal behaviour of the arsonist.	3.68	1.406	5	High
18	Data analytics techniques help improve the accuracy of fire scene forensics.	3.92	1.352	3	High
Overall		3.84	.662	High	

The above table shows that the overall average of the third dimension: Pattern Recognition and Data Analysis, came with a mean of (3.84) a standard deviation of (.662), and a response score of (High).

The third dimension: Pattern Recognition and Data Analysis, obtained a response score of (High) can be explained by the fact that pattern recognition and data analysis techniques supported by artificial intelligence can handle huge amounts of data collected from crime scenes, such as high-resolution images, video recordings, and sensor data, which are difficult for a human investigator to fully analyze. They can also analyze large amounts of data in record time, which greatly speeds up the investigation process and reduces the time required to reach results, as the speed of analysis reduces the chances of human errors that may affect the accuracy of the results.

The occurrence of statement No. (14) ranking in the first place, with a response score of (High), can be explained by the contribution of pattern techniques

to a real revolution in the field of forensic analysis of the fire scene, as it increased the accuracy and speed of investigations, and provided stronger evidence in courts. This is because patterns help in determining the point from which the fire started with extreme accuracy, which facilitates determining the cause of the fire. By analyzing patterns, the path of the spread of fire can be accurately tracked, which helps in understanding how the fire developed. Patterns also reveal evidence that may not be visible to the naked eye, such as traces of heat or combustible materials. In a related context, Low et al. (4) have stated that using pattern recognition techniques reduces the overall duration of arson investigations and ensuring the accuracy of the evidence.

Fourth: Presentation, discussion, and interpretation of the results of the fourth question, which stated: "How effective is the use of (Fire Dynamics Simulations) in improving the results of arson investigations in the UAE?"

To answer this question, the means and standard deviations of the statements of the fourth dimension: Fire Dynamics Simulations were calculated, and then these statements were arranged in descending order according to the mean of each statement, as shown in the following table:

Table No. (8): Means and standard deviations of the sample members' responses to the fourth dimension: Fire Dynamics Simulations

No.	Items	Mean	SD	Rank	Response degree
19	Fire dynamics simulation provides insights into how a fire will develop under various conditions.	4.27	1.231	3	Very High
20	Fire dynamics simulation helps identify areas of weakness in building designs from a fire protection perspective.	3.93	1.209	5	High
21	Fire dynamics simulation supports investigations by providing hypothetical scenarios of the circumstances of an incident.	4.36	1.177	2	Very High
22	Fire dynamics simulation provides analytical data on the causes and spread of a fire.	3.86	1.307	6	High
23	Fire simulation helps improve the scenarios faced by emergency response teams.	4.46	1.125	1	Very High
24	Simulation models can be used to predict fire behaviour in buildings.	4.03	1.303	4	High
Overall		4.15	.581	High	

The previous table shows that the overall average of the fourth dimension: Fire Dynamics Simulations, came with a mean of (4.15) a standard deviation of (.581), and a response score of (High).

The fourth dimension: Fire Dynamics Simulations, obtaining a response score of (High) can be explained by the fact that the use of fire dynamics simulation, a technology that relies heavily on artificial intelligence, has achieved qualitative leaps in the field of investigating arson, as by simulating the behaviour and spread of fire, the exact point from which the fire started can be determined with high accuracy. The simulation also helps in estimating the time it took for the fire to spread to different places, which narrows the circle of temporal suspicion. Simulation can also determine the type of fuel used to ignite the fire based on the speed of spread and the pattern of combustion. Consistent with what has been mentioned above, Kumar et al. (26) have revealed that image processing techniques such as thresholding and colour-based segmentation can be used to detect areas of fire.

The occurrence of Statement No. (23) ranking in the first place, with a response score of (Very High), can be explained by the fact that fire simulation plays a crucial role in improving the response of emergency teams by providing a safe training environment, enhancing individual and group skills, and developing plans and procedures, which contributes to reducing human and material losses resulting from fires, as simulation allows teams to train on various fire scenarios in a controlled and safe environment, which reduces the risks to individuals and property during real training. Simulation also helps identify weaknesses in response plans and procedures followed, which allows the opportunity to make the necessary adjustments before a real incident occurs. By being exposed to various scenarios, team members can make quick and thoughtful decisions under the pressures of a fire, which increases the effectiveness of the response.

Summary of results:

- The overall average of the first dimension: Machine learning, came with a mean of (3.95) a standard deviation of (.576), and a response degree of (High).
- The overall average of the second dimension: Artificial neural networks, came with a mean of (4.07) a standard deviation of (.694), and a response degree of (High).
- The overall average of the third dimension: Pattern Recognition and Data Analysis, came with a mean of (3.84) a standard deviation of (.662), and a response degree of (High).
- The overall average of the fourth dimension: Fire Dynamics Simulations, came with a mean of (4.15) a standard deviation of (.581), and a response degree of (High).

Recommendations:

- Collect as much data as possible related to the fire, such as fire images, video recordings, sensor data, and emergency call logs.
- Use machine learning algorithms to analyze this data and discover patterns and trends that may indicate the presence of arson.
- Develop predictive models to predict when and where arson will occur, helping to prevent it.
- Develop AI systems to recognize objects and tools that can be used to start fires, such as flammable liquids or electronic devices.
- Develop algorithms to analyze images and videos of fires to determine the type of fuel used, the starting point, and the speed of the fire's spread.
- Use AI techniques to detect any tampering in images and videos.
- Use simulation programs to create 3D models of similar fires, and test different scenarios to determine the potential causes of the fire.
- Simulate the behaviour of a fire under different conditions to determine how it spreads and the impact of environmental factors on it.
- Link data related to fires to geographic data, such as area maps, and use GIS techniques to analyze spatial patterns of fires.
- Provide training programs to investigators on how to make full use of AI techniques in the investigation process.

Research proposals: Conduct future research on:

- Using machine learning to predict arson ignition points based on historical data.
- Analyzing the effectiveness of virtual reality applications in reenacting the crime scene and facilitating the investigation process.

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