ENHANCING DISASTER PREPAREDNESS: THE ROLE OF DATA VISUALIZATION AND TECHNOLOGY IN DISASTER DATABASES

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HARUTYUNYAN ELEONOR
Lecturer at the Chair of Information Technologies and Applied Mathematics, EUA and the Chair of Economic Computer Science and Information Systems, ASUE
e-mail: eleonorharutyunyan@gmail.com

This study seeks to mitigate the time constraints inherent in uncertain scenarios by streamlining data management. Efficient information processing in such situations is crucial for effective decision-making and response coordination. To avoid wasting time in uncertain situations, we need fast and easily manageable data. This study aims at developing an all-encompassing disaster data management system. This article presents research on the role of decision support systems (DSS) in emergency management, focusing on the collected information's optimal structure, benefits and processing. Based on the research, it presents the optimal approach of managing data classification and connection. The structure encompasses the creation of a relational database which captures information on various natural and human generated calamities. It further incorporates the use of data visualisation tools to offer insights for analysis during disaster preparedness and response. In the final part, I presented the derived version of the database of Decision Support System for Emergency Situations in Uncertainty.

Keywords: database management, uncertainty, emergency situations, risk assessment, disaster

Material and methods

Countries located in different geographical locations face an imminent danger of numerous types of natural and man-made disasters. Among these are earthquakes, floods, industrial accidents, wars, among others. These looming challenges highlight the urgent need to build a robust database. Such should not only provide storage for disaster-related information but also entail elements that ensure efficient data handling and visualisation. In this research, we shall examine the process known as Disaster Data Visualization Database regarding its optimization, advantages and shortcomings with a view to presenting readers with a holistic picture about its viability and associated risks.

It is important to understand how disaster data is collected and managed. This data originate from various sources, including government agencies, NGOs, international organisations, and local communities.

Disaster databases have been developed for both natural and human-made disasters, serving as repositories for this invaluable knowledge. They play a critical role in consolidating, organising and securing such database information. However, their true potential is realised when they combine technology together with data visualisation so as to convert raw figures into insights that can be acted upon.

Data visualisation involves representing data graphically so as to discover patterns, trends, relationships, etc. With regard to disaster databases, they assist policymakers to

Identify trends: This enables authorities to understand long-term effects of disasters and hence, make informed decisions on preparedness against different kinds of hazards.

Assess impact: Stakeholders can quickly evaluate severity of damage by carrying out intuitive mapping exercises using graphical representations.

Optimise resource allocation: Resources are allocated where they are needed most by visualizing them through graphics during rescue missions and other emergency response operations following a disaster. [1]

Research results

Here, we explore two key aspects within the context of Decision Support Systems (DSS):

Data Visualization:

- *Key Point Definition:* In the realm of DSS, data visualisation identifies crucial data values or observations that hold significance for decision-making processes.
- *Key Point Focus:* DSS visualisations emphasise these key points to direct decision-makers' attention towards important insights and trends within the data.
- *Key Point Examples:* For instance, in earthquake analysis within a DSS, a key point could be the maximum magnitude recorded in a specific region.

- *Key Point Value:* Identifying key points through data visualisation facilitates rapid comprehension of essential information, aiding decision-makers in formulating effective responses to seismic events.

Patterns:

- *Patterns Definition:* Within DSS, patterns refer to recurring relationships or trends in data that offer valuable insights into seismic activity and its underlying dynamics.
- *Patterns Focus*: DSS focuses on discerning these patterns to understand the broader context of earthquake occurrences and their implications for risk assessment and disaster management.
- *Pattern Examples:* For instance, in earthquake prediction models within a DSS, patterns might reveal recurring temporal or spatial trends in seismic activity.
- *Pattern Purpose:* Understanding patterns within seismic data is essential for DSS to provide decision-makers with predictive capabilities and actionable insights, enabling proactive measures to mitigate earthquake risks and enhance disaster preparedness. [2]

On one hand, there are key points which are specifically notable data values or observations within a dataset, often highlighted for their significance. On the other hand, patterns are recurring relationships or trends that take place when multiple data points are analysed together. Key points draw attention to significant data values while patterns reveal how data behave overall. Both are important aspects of visualising data and they serve different roles in helping users understand and interpret it. This corporation is important for creating a DSS Database.

Several technologies contribute to the effectiveness of disaster databases:

- *Geographic Information Systems (GIS):* GIS is able to combine information on geographical space with disaster details helping come up with maps which indicate how disasters affect different places; as a result, response strategies can be planned more effectively.
- *Big Data Analytics* leverages advanced technologies to rapidly process large volumes of disaster-generated datasets, enabling the extraction of meaningful insights.
- *Machine Learning and AI:* With these, disaster prediction is possible together with assessing their impacts and suggesting response strategies based on historical data.
- *Remote Sensing:* Satellite and aerial imagery, as well as remote sensing technology, provide real-time data for disaster monitoring and assessment

It is important to understand the pros and cons of comparison visualisations since it directly affects the effectiveness of data communication and decision-making. Comparison visualisations are often used to put several datasets, variables or scenarios side by side so that viewers can draw meaningful insights from them. This knowledge empowers decision-makers to harness the full potential of comparison visualisations to identify trends, make informed choices, and communicate complex information clearly. Another significance of understanding these constraints is that it prevents misinterpretation and ensures that comparisons are made accurately without any bias thus leading to more reliable decision-making processes which rely on data. [5,6]

Advantages:

Informed Decision-Making – Data visualisation together with technology allows authorities to make decisions based on facts, hence, improving preparedness for disasters.

Efficiency - Visualization tools streamline data analysis making it faster and more accurate.

Historical Analysis – Historical data visualisations offer insights into disaster trends thereby enabling long-term disaster management planning.

Disadvantages:

Data Quality – The accuracy/reliability of data cannot be compromised at all. Wrong/misleading results may arise from incomplete/false information.

Data Security - To ensure privacy as well as prevent any breaches in national security, sensitive disaster related materials must be handled with care.

Infrastructure Challenges - Not all regions may have the necessary infrastructure to support advanced technologies leading to difficulties in collecting data in such areas.

This suggestion will introduce a relational database that will handle the information related to disasters and other information associated with disasters. The database has been well designed to capture, store, and manage the crucial data points which will help the authorities and disaster response teams make informed decisions concerning disaster response efforts, planning for long-term disaster management. [3,4]

Let us establish connections between the entities (STATES, DISASTER CLASS, DISASTER, DISASTER PARAMETERS) using appropriate one-to-one, one-to-many, and many-to-many relationships. Here's how we can structure the database in Fig.1:

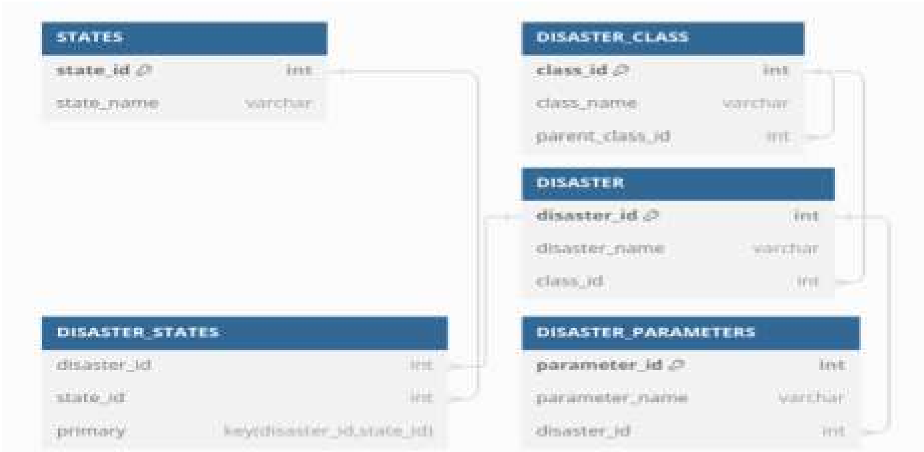

Fig.1: Designed relational database

STATES Table:

Table 1.

This table stores information about different states.

state_ID (PK)	state_name
1	State A
2	State B
...	...

DISASTER CLASS Table:

Table 2.

This table categorises disasters based on severity, nature, and cause.

class_ ID (PK)	class_name	parent_class_id (FK)
1	Catastrophic	NULL
2	Major	NULL
3	Moderate	NULL
4	Minor	NULL
5	Geophysical	NULL
6	Meteorological	NULL
7	Biological	NULL
8	Technological	NULL
9	Environmental	NULL
10	Natural	NULL
11	Human-induced	NULL

DISASTER Table:

Table 3.

This table represents specific disasters and their classifications.

disaster_ ID (PK)	disaster_name	class_id (FK)
1	Earthquake	5
2	Hurricane	6
3	Flood	9
...	...	...

DISASTER PARAMETERS Table:

Table 4.

This table contains parameters associated with each type of disaster.

parameter_ID (PK)	parameter_name	disaster_id (FK)
1	Water level	3
2	Discharge	3
3	Duration	3
4	Rainfall intensity	3
5	River discharge rate	3
6	Floodplain analysis	3
7	Flood recurrence intervals	3
...	...	...

DISASTER_STATES Table (Many-to-Many Relationship):

Table 5.

This table connects disasters to the states affected by them.

disaster_ ID (FK)	state_id (FK)
1	1
1	2
2	2
3	1
3	3
...	...

The use of appropriate relationships ensures data integrity and facilitates fast processing of information.

Optimality of the Case:

- Information on states, disaster classes, specific catastrophes, parameters and affected states is well organised in this database structure to optimise data storage and retrieval.
- One-to-one, one-to-many or many-to-many relationships maintain data consistency and support easy querying as well as analyses.
- Categorization of disaster types can be easily done by using hierarchical classification of disaster classes which also allows for the variations in grouping that may help navigate through different disasters.
- A many-to-many relationship between the states and disasters is preferable because some disasters may affect several states while others are caused by more than one state.
- The design ensures representation of comprehensive information related to disasters with minimum redundancy and scalability.

Comparison with Other Patterns:

- It is better organised, scalable and has high data integrity than a flat structure that involves all its information stored in one table.
- On the other hand, unlike denormalized systems where duplicated data exist in various tables, this normalised system has reduced duplicate data making it both efficient in terms of structure as well as when retrieving.
- When compared to a graph database model, which can be suitable for highly interconnected data, this relational model provides a simpler and more straightforward representation for disaster-related information that is easier to handle and query.

Working Cycle Output on Flood Case

Data Collection and Monitoring:

- Real-time water levels, rain intensities, river discharges et cetera should be gathered from monitoring stations, satellite imageries and weather reports.

Parameter Analysis:

- Collected data will be analysed to determine the current status of flood parameters such as water level, discharge, duration, rainfall intensity and floodplain analysis.

Risk Assessment:

- Severity of the flood and potential impacts are assessed using the analysed parameters along with historical data and recurrence intervals of floods. [7]

Decision Making:

Risk Assessment

Based on these decisions

- Emergency response plans can be activated,
- Flood warnings and evacuation orders can be issued,
- Resources could also be allocated for responses,
-Independently deploy emergency personnel along with necessary equipment.

DSS Response Implementation:

- Implement planned response actions externally, including those involving hardware components:
- Evacuation of at-risk populations, changing the place to safe locations,
- Reinforcement of flood defences and infrastructure,
- Provision of emergency services and assistance to affected communities,
- Coordination with local authorities and relief agencies.

Continuous Monitoring and Adaptation:

- Continuously monitor flood parameters and response activities to assess effectiveness and adapt strategies as needed.
- Adjust evacuation routes and shelter locations based on changing flood conditions.
- Coordinate with neighbouring jurisdictions and international organisations for additional support and resources, if necessary.

Post-Disaster Evaluation:

- After the flood event subsides, conduct damage assessments and post-event analysis to evaluate the effectiveness of response efforts.
- Identify lessons learned and areas for improvement in flood preparedness and response.
- Update flood risk models and emergency plans based on evaluation findings to enhance future response capabilities.

This working cycle outlines the iterative process of monitoring, analysing, decision-making, and response implementation for managing floods effectively. By following this cycle, emergency management agencies can mitigate the impact of floods and protect lives and property in flood-prone areas.

Conclusion

1. In this article, I brought out the structured database design, which shows data integrity and efficient information processing in the Decision Support System (DSS) for disaster management.
2. Optimal organisation of information in the database resolves interconnections between disasters, their classification, and related parameters. I have used one-to-

one, one-to-many, or many-to-many relationships to ensure efficient data storage, retrieval, and analysis within the Decision Support System (DSS) for disaster management.

3. I proposed a hierarchical classification of disaster types that allows for easy categorization and navigation, ensuring comprehensive representation of disaster-related information.
4. The article provides a relational database model that outperforms flat structures and denormalized systems, offering better organisation, scalability, and data integrity.

Bibliography

1. Bank T. W., Disaster Data: A Practical Guide to the Essential Data in the World of Natural Disasters, 2022.
2. Few S., Information Dashboard Design: Displaying Data for At-a-Glance Monitoring, 2006.
3. Hector Garcia-Molina, Jeffrey D. Ullman, Jennifer Widom, Database Systems: The Complete Book, Part II of the book, 2009.
4. Yau N., Data Points: Visualization That Means Something, 2013,.
5. David Alexander, Principles of Emergency Planning and Management, 2002, pp. 109-129.
6. Thomas A. Horan, Handbook of Research on Crisis Information Management and Communication, 2008, pp. 133-540.
7. David Etkin, Disaster Theory: An Interdisciplinary Approach to Concepts and Causes, 2015, pp. 204-300.

ՊԱՏՐԱՍՏԱԿԱՆՈՒԹՅԱՆ ԲԱՐՁՐԱՑՈՒՄԸ ԱՂԵՏՆԵՐԻ ԺԱՄԱՆԱԿ. ՏՎՅԱԼՆԵՐԻ ՎԻԶՈՒԱԼԻԶԱՑՄԱՆ ԵՎ ՏԵԽՆՈԼՈԳԻԱՅԻ ԴԵՐԸ ԱՂԵՏՆԵՐԻ ՏՎՅԱԼՆԵՐԻ ԲԱԶԱՅՈՒՄ

ՀԱՐՈՒԹՅՈՒՆՅԱՆ ԷԼԵՈՆՈՐ
ՀԵՀ տեղեկատվական տեխնոլոգիաների և կիրառական մաթեմատիկայի ամբիոնի, ՀՊՏՀ տնտեսագիտական համակարգչային գիտության և տեղեկատվական համակարգերի ամբիոնի դասախոս
էլփոստ՝ eleonorharutyunyan@gmail.com

Այս ուսումնասիրությունը վերաբերում է անորոշության իրավիճակներին բնորոշ սցենարների ժամանակային սահմանափակումներում իրականացվելիք տվյալների օպտիմալ կառավարման հարցերին: Նման իրավիճակներում տեղեկատվության արդյունավետ մշակումը վճռորոշ նշանակություն ունի՝ արդյունավետ որոշումների կայացման և արձագանքման համակարգման համար: Անորոշ իրավիճակներում ժամանակային մեծ կորուստը շրջանցելու համար մենք պետք է ունենանք արագ կառավարելի տվյալներ: Այս ուսումնասիրությունը նպատակ ունի մշակել աղետների տվյալների կառավարման համապարփակ համակարգ: Այս հոդվածը ներկայացնում է որոշումների աջակցման համա-կարգերի (DSS) դերի վերաբերյալ հետազոտություն արտակարգ իրավիճակների կառավարման մեջ՝ կենտրոնանալով հավաքագրված տեղեկատվության օպտիմալ կառուցվածքի առավելությունների և մշակման վրա: Հետազոտության հիման վրա այն ներկայացնում է տվյալների դասակարգման և կապի կառավարման օպտիմալ մոտեցումը: Հարաբերությունների բազայի ճարտարապետությունը ներառում է հարաբերական տվյալների բազայի ստեղծում, որը տեղեկատվություն է հավաքում տարբեր՝ բնական և մարդու կողմից առաջացած աղետների մասին: Այն նաև ներառում է տվյալների վիզուալիզացման գործիքների օգտագործումը՝ աղետներին պատրաստվածության և արձագանքման ժամանակ վերլուծության համար ընդհանուր պատկերացումներ տրամադրելու համար: Հոդվածում ներ-կայացված է անորոշության մեջ արտակարգ իրավիճակների որոշումների աջակ-ցության համակարգի տվյալների բազայի կառուցվածքի օպտիմալ տարբերակը:

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ПОВЫШЕНИЕ ГОТОВНОСТИ К БЕДСТВИЯМ: РОЛЬ ВИЗУАЛИЗАЦИИ ДАННЫХ И ТЕХНОЛОГИЙ В БАЗАХ ДАННЫХ О БЕДСТВИЯХ

АРУТЮНЯН ЭЛЕОНОР

Преподаватель кафедры информационных технологий и прикладной математики ЕУА и кафедры экономической информатики и информационных систем АГЭУ

электронная почта: eleonorharutyunyan@gmail.com

Данное исследование направлено на преодоление временных ограничений в условиях неопределенности путем оптимизации управления данными. Эффективная обработка информации в таких условиях имеет решающее значение для своевременного принятия решений и координации реагирования при чрезвычайных ситуациях. Чтобы обойти озеро потерь времени в ситуациях неопределенности, нам нужны быстро управляемые данные. Целью данного исследования является разработка всеобъемлющей системы управления данными о стихийных бедствиях. В этой статье представлены исследования роли систем поддержки принятия решений (СППР) в управлении чрезвычайными ситуациями с упором на оптимальную структуру, преимущества и обработку собранной информации. На основе исследования представлен оптимальный подход к управлению классификацией и связью данных. Эта структура предполагает создание реляционной базы данных, которая собирает информацию о различных природных и техногенных катастрофах. Кроме того, он включает использование инструментов визуализации данных, позволяющих получить информацию для анализа во время подготовки к стихийным бедствиям и реагирования на них. В работе нами представлена производная версия базы данных Системы поддержки принятия решений для чрезвычайных ситуаций в условиях неопределенности.

Ключевые слова: управление базой данных, неопределенность, чрезвычайные ситуации, оценка риска, катастрофа.

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