

Investing in Artificial Intelligence to Manage Crowd, an Analytical Study for the Hajj season

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Abstract:

In order to manage the Hajj season 2023, the Kingdom of Saudi Arabia invested in the application of artificial intelligence to facilitate the performance of rituals and control crowds. This study aimed to determine the extent to which artificial intelligence applications contributed to facilitate the Hajj rituals, by presenting the technologies adopted by the Kingdom to ensure the success of the Hajj season.

The study concluded that despite some complications in the use of modern technology by some pilgrims, the preparations made by the Kingdom to receive pilgrims, such as providing modern means of transportation, a virtual hospital to monitor the health of pilgrims, and the use of cameras and drones in several places to transmit events as they occur to avoid accidents, and various smart electronic applications helped in the process of managing Hajj business and providing comfort to pilgrims.

Keywords: Artificial Intelligence, E-Services, Crowd Management.

Jel Classification Codes : J24 ; O15 ; O32.

Résumé:

Pour gérer la saison du Hajj 2023, le Royaume d'Arabie Saoudite a investi dans l'application de l'intelligence artificielle pour faciliter la gestion de l'événement. Cette étude vise à déterminer dans quelle mesure les applications de l'intelligence artificielle contribuent à faciliter l'accomplissement des rituels du Hajj, en présentant les technologies que le Royaume a adoptées pour assurer le succès de la saison du Hajj.

L'étude a conclu que malgré certaines complications dans l'utilisation de la technologie moderne par certains pèlerins, les préparatifs faits par le Royaume pour servir les pèlerins ont contribué au processus de gestion du Hajj et au confort des pèlerins. Tels que la fourniture de moyens de transport modernes, un hôpital virtuel pour surveiller la santé des pèlerins et l'utilisation de caméras et des drones dans plusieurs endroits pour transporter les événements immédiatement en temps réel afin d'éviter les accidents et diverses applications intelligentes.

Mots clés: Intelligence Artificielle, Services Electroniques, Gestion de la Foule.

Jel Classification Codes : J24 ; O15 ; M32.

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I. Introduction

During the Hajj season, many people gather in the holy places at specific times to perform the rituals. This can lead to accidents due to the large number of pilgrims and high temperatures in the area.

The Saudi Ministry of Hajj and Umrah relied on minimizing the number of pilgrims to maintain social separation during the Corona pandemic. However, after the end of the crisis and the lifting of restrictions by the Kingdom, the number of pilgrims arrived to perform the rituals increased during the 2023 Hajj season. So technologies based on artificial intelligence were adopted to manage the event.

In light of this context, the following main question is posed:

How did the use of artificial intelligence applications facilitate the Hajj season?

This study focuses on the Hajj season 2023, which corresponded to the year 1444 in the lunar calendar, specifically during the period from the 8th to the 12th of the lunar month of Dhu al-Hijjah. The study focuses specifically on the holy places in Mecca, where crowds were presented in different areas such as the Grand Mosque, Arafat, Muzdalifah, and Mina.

We will attempt to present a descriptive and analytical study of the Hajj season after the Corona pandemic by presenting various statistics related to the event, and displaying the latest technologies used in business management of Hajj, which greatly contributed to its success.

The study's topic is important because it is related to electronic crowd management, which necessitates the training and qualification of numerous stakeholders involved in event planning in the Kingdom.

II. Theoretical Framework

II.1 Literature Review

The crowd of pilgrims posed a great challenge to those in charge of managing the Hajj event (Yamin.M, 2015). In this context, Ayyad studied the application of digital management in the Hajj system, which contributed to raising the level of satisfaction among pilgrims (Ayyad.D.A.A, 2022).

One of the most prominent technologies presented by Sultan in his article "Crowd Management Techniques", is the "affective computing" which was used to determine the emotional state of crowd members (Sultan.A.B, 2019).

Al-Arishi and Al-Qahtani suggested a solution based on the use of the "Internet of Things", by collecting data on pilgrim's mobile phones in order to know their number and their locations. The solution could be used to monitor transportation data in the places of rituals, which allowed Hajj management

officials to make appropriate decisions at the appropriate time. (Alarishee.J.H & Alqahtani.S.H., 2019).

II.2 The Crowd of Pilgrims

The Hajj is performed from the eighth to the twelfth day of Dhul-Hijjah lunar month. It is done in holy places such as the Grand Mosque in Mecca and the holy sites in Mina, Muzdalifah, and Arafat.

During the Hajj, large number of people (different countries, different languages) crowded the holy sites at specific times. Those people come. This posed a challenge for those responsible for managing the event.

In order to maintain the safety and security of pilgrims during the performance of rituals, the Kingdom of Saudi Arabia has adopted the approach of artificial intelligence by developing specialized scientific capabilities in this field.

III. Methodology

In this part, the researcher will attempt to present an analytical study of the Hajj season 2023, by presenting various statistics related to the event, in addition to displaying the latest technologies used in business management of Hajj, which greatly contributed to its success.

III.1 Data of Hajj

In 2020 and 2021, the Hajj was limited to Saudi citizens and residents inside the Kingdom due to the implementation of quarantine measures to prevent the spread of the Corona virus infection. The number of pilgrims in 2020 was less than 1.000 pilgrims (because corona virus was at its peak), and the number reached 58.745 pilgrims in 2021 (General Authority for Statistics, 2021)

In Hajj season 2022 the Kingdom of Saudi Arabia received pilgrims from inside and outside via land and air and sea transport. Tables below and figure (01) present Hajj statistics for season 2022.

Table (01): Foreign pilgrims in season 2022

Number of male	Number female
421.999	359.410

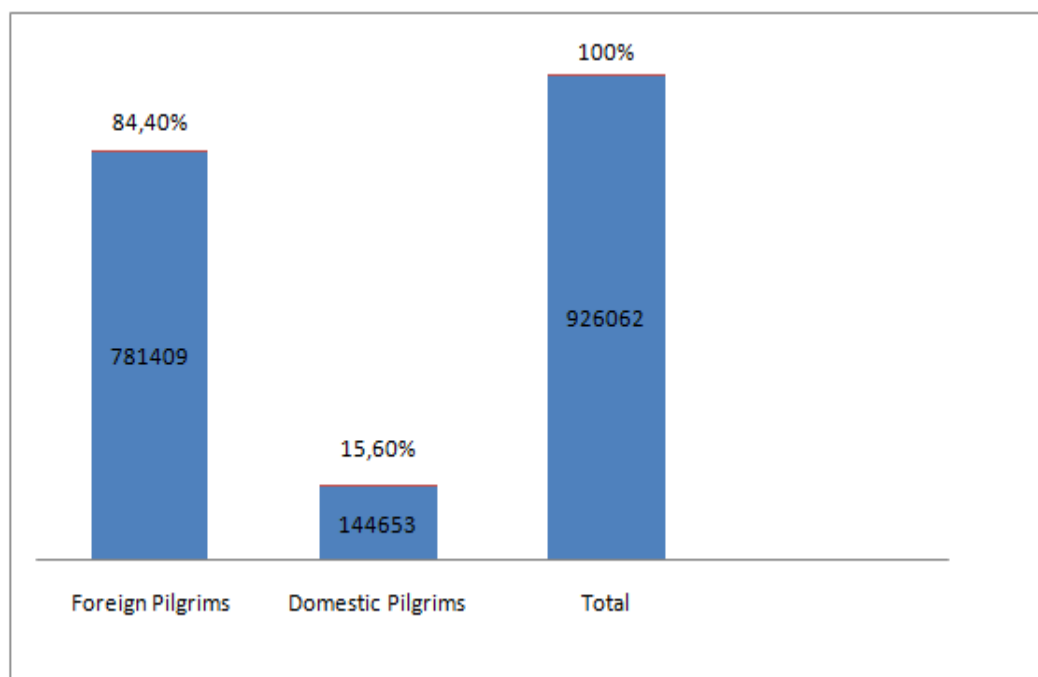
Source: Prepared by the researcher from (General Authority for Statistics, 2022)

Table (02): Domestic pilgrims in season 2022

Number of male	Number female
77.776	66.877

Source: Prepared by the researcher from (General Authority for Statistics, 2022)

Fig.(01): Total number of pilgrims in season 2022



Source: Prepared by the researcher from (General Authority for Statistics, 2022)

The Hajj season 2023 was considered as the first Hajj season after "Covid-19 pandemic". Table (03) presents pilgrim's statistics by residence (domestic/ foreign) and by gender (male / female).

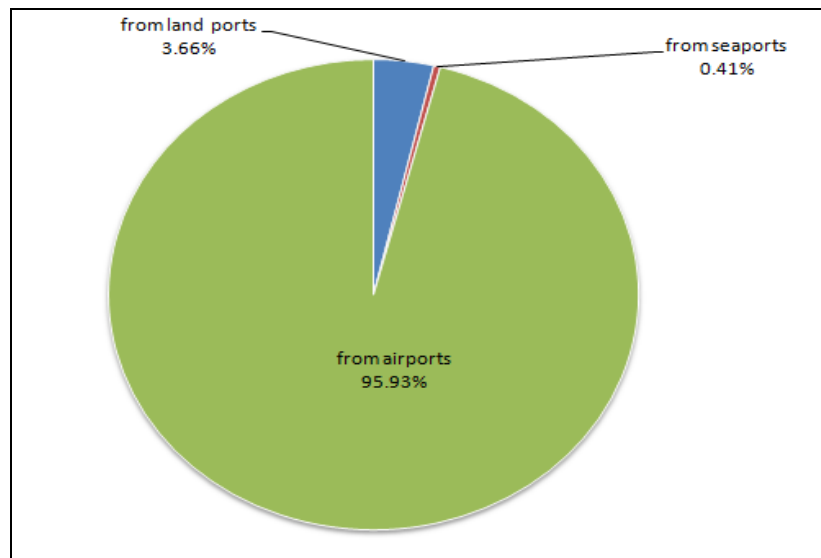
Table (03): Hajj statistics for season 2023

Statistics	Total Number of Pilgrims
184.130 Domestic Pilgrims (10% of the total pilgrims)	1.845.045
1.660.915 Pilgrims from Abroad (90% of the total pilgrims)	
969.694 Male Pilgrims	
875.351 Female Pilgrims	

Source: Prepared by the researcher with reference (General Authority of Statistics, 2023)

In 2023, the total number of pilgrims reached 1.845.045 pilgrims. The percentage of pilgrims from abroad reached 90% of the total pilgrims, they arrived through different ports, while the percentage of pilgrims from within the Kingdom reached 10%. (General Authority of Statistics, 2023)

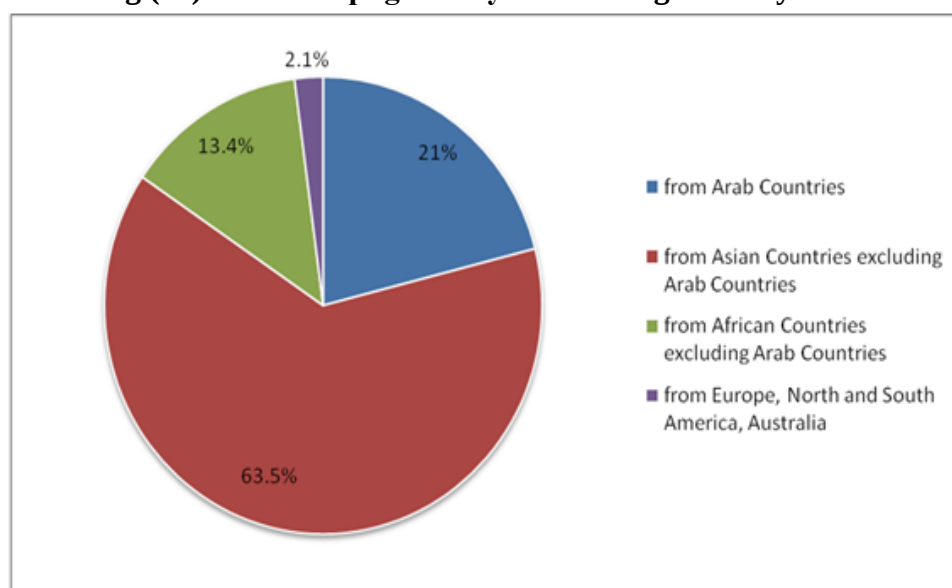
Fig.(02): External pilgrims received by port of entry



Source: Prepared by the researcher with reference (General Authority of Statistics, 2023)

- External Pilgrims were received from inside and abroad from different entry: (General Authority of Statistics, 2023)
 - 60.813 pilgrims arrived from land ports;
 - 6.831 pilgrims arrived from seaports;
 - 1.593.271 pilgrims arrived from airports.

Fig.(03): External pilgrims by world's-regions they came from



Source: Prepared by the researcher with reference (General Authority of Statistics, 2023)

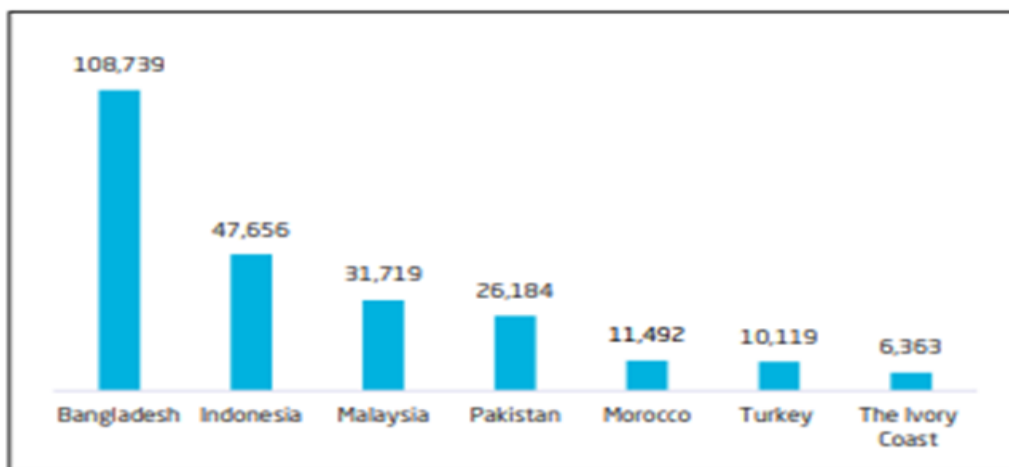
- External Pilgrims were received from different countries:
 - From Arab Countries;
 - From Asian Countries excluding Arab Countries;
 - From African Countries excluding Arab Countries;
 - From Europe, North America, South America, and Australia.

III.2 The Pre- Plan for Managing Pilgrims Crowd

In addition to the warm welcome for pilgrims, providing wheelchairs for the elderly, and distributing Zamzam water in several areas such as Arafat, Muzdalifah, and the Holy House of Allah, advanced technology has been relied upon in managing the Hajj by providing guidance robots that speak 11 languages (Arabic, English, French, Russian, Persian, Turkish, Malay, Urdu, Chinese, Bengali, and Hausa), in addition to electronic platforms such as the "Basir platform" that helped to organize crowds in the Grand Mosque according to the capacity of the different sites. (Leaders,E-Magazine, 2023)

The Makkah Road Initiative was also adopted. It aimed to facilitate travel procedures for pilgrims by issuing an electronic visa, and taking care of transporting them to their places of residence in record time.

Fig.(04): Numbers of pilgrims benefited of Makkah Road Initiative



Source: Prepared by the researcher with reference (General Authority of Statistics, 2023)

The number of pilgrims benefited of Makkah Road Initiative reached 242.272, from 7 countries (Bangladesh, Indonesia, Malaysia, Pakistan, Morocco , Turkey and Ivory Coast). (General Authority of Statistics, 2023)

In order to reduce harmful carbon emissions into the atmosphere, the Kingdom of Saudi Arabia relied on the Haramain High Speed Rail, an electric train to ease congestion on the roads between Makkah and Madinah, transported more than 2.13 million passengers between the nine train stations located in Mina, Arafat and Muzdalifah during 2.208 round trips. (Ministry of Transport and Logistic Services, 2023)

Table (04): Al-Haramain Railway statistics for Hajj season 2023

Operational Period	Number of trips
7 days Starting from 7 Dhul Hijjah to 13 Dhul Hijjah 1444	2208 Trips

Source: Prepared by the researcher with reference (Ministry of Transport and Logistic Services, 2023)

Table (05): Al-Haramain Railway movement's during Hajj season 2023

Total number of pilgrims transported	Number of pilgrims Transported by trip
Over 2,13 million pilgrims	Over 298700 pilgrims transported from Mina to Arafat
	Over 297000 pilgrims transported from Arafat to Muzdalifah
	Over 396000 pilgrims transported from Muzdalifah to Mina
	Over 1,12 million pilgrims transported during "the days of Tashriq" between Mina 1, Mina 2, Mouzdalifah3, Arafat 3 stations to Mina 3 station (Jamarat)

Source: Prepared by the researcher with reference (Ministry of Transport and Logistic Services, 2023)

The Ministry of transport and logistics services provided many services to pilgrims in order to facilitate the movement of pilgrims in the holy sites. Table (06) presents some transport efforts.

Table (06): Transport Efforts

In Service of pilgrims	Transportation Services	Drones	"Road Cooling" technology
40.000 Employees	6 Airports	Monitor vehicle movement	Reduce the temperature on pilgrims
	Equipping Jeddah Islamic Port		
	24.000 Buses	Inspect roads	
	17 Trains	Transport blood samples	
45 post offices in the holy sites	1.000 electric scooters		
	Self-driving Buses		

Source: Prepared by the researcher with reference (Ministry of Transport and Logistic Services, 2023)

III.3 Investing in E-Management to serve pilgrims

This included the introduction of artificial intelligence mechanisms. Table (07) and table (08) present some of techniques used.

Table (07): Intelligent Robots

Guidance Robot - Fatwas	Zamzam Water Robot	Other Smart Robots
Guidance and remote communication	Work without human intervention	Sterilization Robot
Translate into 11 languages	Distributes 30 bottles in one round	Disinfection Robot
		Smart Sanitization Sweepers

Source: prepared by the researcher from (Leaders,E-Magazine, 2023)

Table (08): E-Services in serve of pilgrims

Smart Ritual Card	E-Applications
Entering Camps	"Tanaqol Application" - buy tickets - book an electric car service
Using Transportation	"Turjuman Application" - translate instruction signs for foreign pilgrims
Paying through automated teller machines	"Al-Maqsad Application" - Locat the pilgrim - Find the way
Knowing gathering points	"Tarwiah Application" - water services

Source: prepared by the researcher from (Leaders,E-Magazine, 2023)

In order to maintain the health and the safety of pilgrims who suffered from some chronic diseases that could affect them during the performance of the rituals, the Kingdom has relied on the "Smart Bracelet" which contain all information about pilgrim's health, and the multi-services " Virtual Hospital" .

Table (09): Health services

"Seha Virtual Hospital"	"Smart Bracelet"
Priority to urgent medical intervention	Informations about pilgrim's health
Emergency Consultations	Contact emergency services
Specialized Consultations	Measures the level of oxygen in the blood
Supportive medical services	Measures heart rate
Care Services	
Medical imaging on cases	

Source: prepared by the researcher from (Saudi Ministry of Health , 2023)

III.4 Artificial Intelligence technologies utilized in previous Hajj seasons and those implemented in 2023

The Kingdom of Saudi Arabia used the technological approach in previous Hajj seasons (2020- 2021-2022), such as robots that receive pilgrims, Zamzam water distribution, and epidemic control measures, especially in light of the Corona pandemic at that time. Previous seasons also witnessed the use of the smart Hajj card, in transportation, payment via devices at points of sale, knowing gathering places, departure times, and various smart applications for booking tickets and means of transportation to reduce congestion and contact emergency services in the event of accidents, in addition to the smart bracelet that carries all information about the pilgrim's health. However, the Hajj seasons (2020-2021-2022) were characterized by the reception of a small number of pilgrims compared to 2023.

In 2023, the Kingdom relied on expanding the use of artificial intelligence technologies with a focus on quality standards in providing services, especially with the increase in the number of pilgrims. The year 2023 witnessed:

- The first use of self-driving buses, scooters to serve the elderly and disabled in moving between the holy sites;
- The first use of Drones to monitor events in real time, and "Road Cooling" technology to reduce the temperature on pilgrims;
- Expanding the Makkah Road Initiative to seven countries after the inclusion of Ivory Coast and Turkey;
- Providing digital infrastructure such as the "Basir Platform", this helped to accurately count the number of pilgrims according to their locations, and helped officials avoid crowding and congestion in the holy sites by directing pilgrims to less crowded places;
- The "Basir Platform" also helped to find lost pilgrims in record time;
- Smart robots that operate without human intervention to help pilgrims learn about the rituals and answer their questions, such as the Guidance Robot in 11 languages;
- Arafat sermon application to translate the Arafat sermon into the required language and listen to it.

All these technologies were for managing a successful Hajj season for everyone. However, the use of technology and artificial intelligence was not available to all pilgrims for different reasons.

III.5 Challenges and Limitations

The Kingdom of Saudi Arabia has relied on artificial intelligence to manage the Hajj season 2023 using the latest technological techniques, and providing electronic services and smart applications for all pilgrims to use during their movement, purchase tickets, find out the route and transportation schedules, and

other necessary services. However, the use of this modern technology was not available to all pilgrims for several reasons, including:

- Many of them such as the elderly, did not have smart devices;
- Many of them did not know how to use modern technology;
- Weak Internet services and excessive pressure on applications by users caused some malfunctions.

Those in charge of managing the Hajj must take these problems into account by:

- Helping the elderly through guides to obtain applications and how to use them;
- The necessity of providing specialists for immediate technical treatment in the event of malfunctions ;
- It is also preferable for different countries to conduct training courses for pilgrims to learn how to perform the rituals correctly, and how to use smart devices, and how to maintain them before traveling to Hajj.

IV. Results

- 1- The use of artificial intelligence technologies in the 2023 Hajj season has greatly contributed to improving crowd management and organization.
- 2- Cooperation between the various parties responsible for the event (public security, transportation and logistics, health, hygiene) has greatly contributed to the success of the season.
- 3- Among the most prominent technologies used in the 2023 Hajj season:
 - The use of technology to monitor the number of pilgrims quickly and accurately to manage crowds in the holy sites and avoid accidents ;
 - The use of drones to inspect roads and transmit events as they occur;
 - The launch of self-driving buses;
 - A virtual health hospital to monitor the health of pilgrims and treat emergency cases;
 - Translation services for non-Arabic speaking pilgrims.

V. Discussion

V.1 The difference between previous studies and the current study

There have been many studies focused on crowd management during the Hajj season. This study has agreed with previous studies that crowd management during the Hajj season is a major challenge.

This study differs from previous studies in that it focused on the 2023 Hajj season, which posed a major challenge for the Saudi authorities in order to make it a success.

The 2023 Hajj season was distinguished by the return to receiving pilgrims from outside the Kingdom after lifting the health restrictions that were in place

due to the Corona virus, which led to an increase in the number of pilgrims, as it approached two million pilgrims from different parts of the world, while the number of pilgrims did not reach one million pilgrims in 2022 and did not exceed 58,000 pilgrims in 2021 and was less than 1,000 pilgrims in 2020.

This study reviewed the various challenges facing those in charge of Hajj management, starting from prior organization by providing full human, material and technological capabilities, to welcoming pilgrims and providing them with comfort and health care.

This study focused on presenting the latest artificial intelligence technologies used in the 2023 Hajj season, which represented a qualitative leap compared to previous seasons, while other studies focused on presenting one of the technologies used, such as digital management (Ayyad.D.A.A, 2022), the Internet of Things (Alarishee.J.H & Alqahtani.S.H., 2019), and affective computing (Sultan.A.B, 2019).

V.2 Contribution of the study to the literature

This research contributes to the literature on the use of artificial intelligence by developing a new theoretical perspective to help manage large crowds of people, especially if they are of different nationalities and cultures, as is the case during Hajj seasons;

The research results also provide a model for managing crowd crises using modern technologies while taking into account environmental protection.

VI. Conclusion

In this study, we tried to present the management of large crowd of pilgrims in Hajj season 2023 in the Kingdom of Saudi Arabia, relying on artificial intelligence technologies.

The Kingdom provided all the necessary capabilities for the success of the season and adopted an operational plan based on advance preparation for the event by enhancing awareness in the fields of data and artificial intelligence, in order to ensure the safety of crowds by organizing the flow of people and preventing congestion at sites.

The use of the latest artificial intelligence technologies in various ways has contributed to facilitating the Hajj management process, but it is necessary to raise awareness among pilgrims to maintain the smart devices used to serve them. We concluded that the process of adapting to technology and applying it in performing Hajj rituals grows and adapts with every new technological development and event.

The knowledge related to the use of artificial intelligence in managing important events is still new and constantly evolving. It is an interesting experience for researchers in this field.

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