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A COMPUTATIONAL REAL-TIME VIRTUAL ENVIRONMENT MODEL FOR CROWD MANAGEMENT

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ABSTRACT

During the annual Islamic pilgrimage (Hajj), the movement of vehicles and pedestrians from Arafat to Muzdalifah during the Nafrah of pilgrims is thought to suffer from severe bottlenecks that usually lead to the arrival of thousands of pilgrims to Muzdalifah well after dawn. This paper proposes a framework for developing an intelligent real-time virtual environment model for facilitating efficient and timely vehicular traffic movement during the Nafrah utilizing various movement scenarios, simulation, and optimization methods. The model utilizes intelligent agents within a real-time 3D virtual environment that represents the Nafrah from Arafat location coverage. The proposed framework has three primary phases each of which has specific components: (a) spatial analysis of current pedestrians and vehicles access within the Nafrah location coverage from Arafat to Muzdalifah; (b) evaluation of movement efficiency of current scenarios of the Nafrah using computational simulation; and (c) development of a multi-agents system within a real-time 3D virtual environment for improving the movement efficiency of vehicles traffic within the Sarah. The proposed model will be utilized by decision-makers (Hajj authorities) during the Nafrah from Arafat to Muzdalifah to attain an efficient performance of crowd management.

Keyword; Movement of vehicles, Efficient Crowd Management, Intelligent Computational.

1.INTRODUCTION

The annual Islamic Pilgrimage (Hajj) could be a unique gathering of its kind for innumerable Muslims from round the globe to be at one place (city of Makkah, Saudi

Arabia), within specific days per annum. Hajj is during all|one amongst|one in every of} the five pillars of Islam and it's a collection of acts of worship to be performed in and around Makkah a minimum of once in a lifetime by every Muslim satisfying certain condition. The management of Hajj could be a very complex task wherein a serious challenge is planning the movement of vehicles and mass transit during the amount of Hajj. There are several activities where overcrowding must be better managed. as an example, each year, because of overcrowding, thousands of pilgrims go missing for days or weeks. Reuniting the pilgrims with their groups may take considerable time thanks to various reasons. Many of the pilgrims cannot spatially navigate to return to their place of stay. At present, the Hajj managers provide every pilgrim with a wrist band that has an positive identification. The positive identification is linked only to very limited data within the local organizers' office, and these details don't seem to be easily accessible to the police and help agencies. Most of the pilgrims don't speak the local language. The police and other help agencies in these situations don't seem to be during a position to reunite them unless they contact the local organizers' office (Mutawwif), which is typically done only in emergencies [1]. Every year, local authorities must provide a traffic awareness plan that may be implemented during Hajj to avoid hold up. a conventional means to distribute awareness of the traffic plan is to publish textual matter maps and distribute them to local authorities and also the public before each Hajj season. This method requires extensive time and resources [2].

Since Hajj is taken into account one among the world's largest mass movements whereby over two million pilgrims converge once a year at the identical time to perform their religious duty then it requires substantial planning and energy to supply support and infrastructure especially managing the movement of vehicles and mass transit. Local authorities have worked on various solutions to resolve traffic problems. for instance, small cars don't seem to be allowed to enter Makkah and therefore the Holy Environs (Mashaer) during peak periods. Although some solutions are implemented and work, with the increasing number of pilgrims more problems continually arise. tie up during Hajj could be a phenomenal and high problem within the city of Makkah and therefore

the Mashaer areas (examples are shown in Figure 1). The Masher areas include Arafat, Muzdalifah, and Muna. Congestion is more severe during two periods: Taseid and Nafrah. Taseid is that the movement of pilgrims from Makkah and Muna to Arafat during the 9th day of the twelfth month of the year named Thul Hijjah. Nafrah is defined because the movement of pilgrims from Arafat to Muzdalifah and Muna during the 10th night of Thul Hijjah [3].

Figure 1. An example of tie up during Hajj: (a) vehicles congestion and (b) pedestrians congestion

Saudi authorities are satisfactorily managing Hajj. The Hajj crowd management could however be further refined by utilizing the most recent information and communication concepts and technologies. This paper focuses on one amongst the foremost bottlenecks of crowd management during the Hajj period, which the Nafrah from Arafat to Muzdalifah.

2.. CROWD MANAGEMENT DURING THE NAFRAH FROM ARAFAT

The movement of vehicles and pedestrians from Arafat to Muzdalifah during the Nafrah of pilgrims is understood to suffer from severe bottlenecks that always lead to the arrival of thousands of pilgrims to Muzdalifah well after dawn “Fajr”. The Hajj traffic department develops once a year a group of traffic plans including the one for the Nafrah from Arafat to Muzdalifah, an example is shown in Figure 2. to unravel the traffic jam, the Hajj authorities introduced various initiatives including constructing expensive corridors

along roads to be used by buses carrying the pilgrims such the road isn't accessible to pedestrians, orienting the traffic in one direction for many roads, restricting the change of roads, organizing the parking in Arafat to ease the return journey, preparing vast parking lots in Muzdalifah, restricting small and medium cars for entering Arafat-Muzdalifah roads, etc. for example, the traffic department of Hajj authorities specifies two roads to be used by pedestrians and five roads to be used by vehicles. In 2010 a newly established Mashaer Railway which links the holy sites of Mina, Arafat, and Muzdalifah with Makkah was launched. The new railway will have a capacity to move 72,000 pilgrims in an hour. Nine stations are constructed in Arafat, Muna, and Muzdalifah, each having three stations. the particular impact of Mashaer Railway on the general performance of crowd management must be investigated and can be taken under consideration within the proposed framework presented during this paper.

Figure 2. Traffic plan of Nafrah from Arafat within the Hajj of 1431 Hijri Calendar (i.e. 2010) [4].

Before sunset, the pedestrians gather near or at the entrances to those two roads. At sunset, those pedestrians walk towards Muzdalifah. About half 1,000,000 pedestrians value more highly to walk. Initially, vehicles are spread everywhere the Arafat area. At sunset, there'll be an enormous amount of traffic within this area. Intersections will have traffic jams and traffic police fail to arrange this massive mess caused by the drivers. On the road, the vehicles are moving near one another. A slow vehicle causes the entire column to slow and a failing vehicle stops thousands of vehicles behind it. At one point on the road, Wadi Oranah, the road level rises slightly. Some vehicles will have difficulty going over this short stretch of the road, thus causing more delay to several other vehicles. Some passengers get disappointed with the slow march towards Muzdalifah and judge to steer the remainder of the space. Since the edges on the roads are plain dirt, those passengers turned as pedestrians walk on the identical roads assigned to vehicles causing more delay to the traffic.

Having reached the borders of Muzdalifah, most drivers stop their cars as soon as they recognize that they need reached their destination. a number of the drivers feel the requirement to try and do it at the request of their passengers and a few will stop fearing that they'll exit Muzdalifah if they still drive. The vehicles that stop right after entering Muzdalifah lead to narrowing the roads which lead to slowing the traffic even further. finally, each Hajj season, thousands and possibly many thousands of pilgrims reach Muzdalifah well after sunrise. The Ministry of Hajj, in face of those problems, developed what's called shuttle trips. during this system, a road are fenced from either side in order that pedestrians from other roads cannot have access. Then, within the Arafat area, several bus-stops are built; each has a neighborhood sufficient for 50 standing persons. Buses owned and operated by large fleet companies, will stop ahead of those bus-stops and obtain the waiting pilgrims. These buses make several rounds between Arafat and Muzdalifah. this technique works very nicely and about 100,000 pilgrims can reach Muzdalifah well before midnight. The shuttle system is expensive to create. Furthermore, there's no control over the drivers at Muzdalifah where they drop off their passengers near the borders causing the issues described earlier.

Smaller cars owned by individuals, even those who have 25-seat passengers, don't seem to be allowed within the shuttle system. the tiny vehicles cause traffic jams among themselves.

The crowd in Hajj and therefore the problems related to it are addressed by many re-searchers over the last three decades. Most of this work is published by The Custodian of the 2 Holy Mosques Institute for Hajj, Um-AL-Qura University. Some related topics include Makkah [5]:

•"Automated count of vehicles in Arafat area"

•"Connecting Jeddah and Makkah by a Railway"

•"Problems related to the pedestrians in Muna and Muzdalifah"

•"Traffic in Arafat: number of vehicles versus the quantity of exits"

•"Analysis and evaluation of traffic during Nafrah"

•"Assessment of the operation services of public transportation in Makkah"

•"Assessment of vehicular movements in Makkah and Muzdalifah-Arafat and vehicle parking in Muzdalifah"

•"Characteristics of pedestrian movement in Hajj and its impact of vehicular traffic"

•"The feasibility of using electrical conveyors for moving pedestrians between Hajj sites"

•"A feasibility study of shuttle service between Hajj sites"

•"The feasibility of preventing vehicles of capacity but 25 passengers from entering hajj

zone and its impact of managing congestions"

•"Time-series analysis of vehicles leaving and entering Makkah"

•"Evaluating shuttle service in terms of uploading and downloading time and shuttle time for Arafat-Muzdalifah-Muna"

The works cited above is classified into two categories. One category is worried with diagnosing the group and congestion problem supported collected data. the opposite category proposed an answer supported intuitions. there's no try to model the group to characterize it and furnish a scientific ground for the proposed solutions. This paper aims to stipulate a framework for developing an intelligent computational model for optimizing crowd (vehicles and pedestrians) flow during Nafrah of pilgrims to assist in achieving efficient crowd management within the Nafrah of pilgrims from Arafat.

3.. INFORMATION TECHNOLOGY APPROACHES FOR ADDRESSING CROWD MANAGEMENT DURING THE NAFRAH FROM ARAFAT

Information Technology (IT) approaches are extensively utilized within the literature to addressing the gang management problem, samples of literature include:

•Yamin and Ades [1] introduced a management framework for giant and dense crowds using RFID (Radio Frequency Identification), wireless technologies, and database systems. These technologies are already getting used in managing and administering many activities of lifestyle. However, the effectiveness of those technologies is yet to be tested for managing dense crowds and poses a challenge to the industry. it's suggested that with the grant of the Hajj visa, every pilgrim in his or her country of origin should be supplied with an acceptable RFID tag, within the sort of an arm or waistband. The arm or waistband should be devised to be attached either at the waist or at the upper arm of the pilgrim, rather than the wrist as is completed currently. this is able to ensure its attachment even during the ablution. To receive and transmit information, tag read-

ers, sensors and processors would be required to be installed in sufficient numbers the least bit strategic locations (such as roads, checkpoints, shopping centers, hospitals, and every one other suitable places of congregations). Mobile tag readers and scanners would be required to be used by several stakeholders. Large display screens may also be installed at a number of these locations to display warnings and other important information. These measures, once in situ, will provide solutions to several problems related to the identification of pilgrims. With the assistance of the tag sensors and monitors, the movements of pilgrims are tracked regularly and therefore the information is often collected within the Hajj database. At the time of implementation, decisions will have to be made to make your mind up the intervals and duration for storing the data within the database. Once these measures are in situ, just in case of missing pilgrims, the Mutawif, police, and other help agencies (that have access to the system), can track the last movements of the concerned pilgrims. Data collected during a pilgrimage would be a useful resource for better planning of future pilgrimages. By mining historical data, many other problems is solved. Also, Mohandes et al. [6] introduced a proposal to regulate the access of vehicles to the Hajj zone using RFID technology. Each authorized car are going to be issued an RFID tag to be displayed on the windscreen of the vehicle. At checkpoints, the tags are read automatically, and only authorized vehicles are let in. the identical tags will be wont to monitor the movements of vehicles between Hajj sites, and thus help to anticipate the congestion. A trial is being deployed by the Hajj authority.

•Bandini et al. [7] introduced a multi-agent approach to crowd modeling and simulation. the rules to the group modeling approach are introduced as how to support communication among the various actors that are a part of the simulation project team. The approach is then applied to explain a posh scenario providing a mix of competitive and cooperative behavior for pedestrian agents. A module supporting the effective 3D visualization of simulated crowd dynamics is introduced, as an instrument for the communication of simulation results to decision-makers and non-experts in crowd phenomena.

•Paris et al. [8] addressed the matter of virtual pedestrian autonomous navigation for crowd simulation. They described a technique for solving interactions between pedestrians and avoiding inter-collisions. Their approach is agent-based and predictive. Each agent perceives surrounding agents and extrapolates their trajectory to react to potential collisions. Agents aim at obtaining realistic results, thus the proposed model is calibrated from experimental motion capture data. This method is shown to be valid and solves major drawbacks compared to previous approaches like oscillations thanks to a scarcity of anticipation. Agents first describe the mathematical representation utilized in their model; they then detail its implementation, and at last, its calibration and validation from real data.

•Koshak [2] introduced a web-based Geographic data system (GIS) which will be utilized to produce a broader and easier distribution of the traffic plan. Such a system will facilitate understanding and ease the flow of the traffic plan. Awareness of the plan will help implement and reduce holdup thanks to unawareness. The web-interface offers both static and dynamic digital maps which will be utilized by urban planners and designers, different local authorities, and personal entities who are participating in managing and operating the movement of pilgrims. Internet interfaces can even help individual pilgrims to realize knowledge about the traffic plan from their own countries before even arriving in Saudi Arabia. This access will facilitate the understanding of specific traffic plans. Earlier and more precise awareness of the plan will help in its implementation and reduce further holdup thanks to unawareness. Besides, urban planners and concrete designers can easily access the annual Hajj traffic plans to support research and investigation.

•Braun et al. [9] presented a completely unique approach to simulate virtual human crowds in emergencies. The approach focuses on the treatment of complex environments and their implications on agents' movement, the management of alarms distributed in space, the virtual agents endowed with the perception of emergency events, and their consequent reaction still as changes in their individualities. The prototype reads an

XML file where different scenarios may be simulated, like the characteristics of the population, the virtual scene description, the alarm configuration, and therefore the properties of hazardous events. As an output, the prototype generates information to live the impact of parameters on saved, injured, and dead agents.

•Zhang et al. [10] developed an agent-based model for crowd flow dynamics supported the social force model and therefore the crowded pedestrian flow behavior rules to use computer techniques to breed collective effects and help designers to style and optimize egress systems. A program was developed for simulating crowd flow supported this model and performed supported the adaptive grid technology. the pc simulation program supported the agent-based model for crowd flow dynamics will be accustomed reproduce collective effects, and run fast thanks to the utilization of the adaptive grid machine technology.

•Ulicny and Thalmann [11] discussed the challenges involved in creating crowd simulations, especially the requirement to efficiently manage variety. They introduced the concept of levels of variety. Then, they presented their work on crowd behavior simulation geared toward interactive real-time applications like computer games or virtual environments. They defined a modular behavioral architecture of a multi-agent system allowing autonomous and scripted behavior of agents supporting variety. Finally, they showed applications of their system in an exceedingly computer game training system and a virtual heritage reconstruction.

•Other information technology approaches that are utilized in crowd management problems include:

•Lozano et al. [12] proposed a genetic approach for distributing the semantic database of crowd simulations in such the way that the dependencies among the computers hosting the pieces of the database are minimized. The proposed approach avoids the saturation of those computers by ensuring that the dimensions of the pieces assigned to eve-

ry computer are correctly balanced. The performance evaluation results show that the proposed approach significantly reduces the resulting overhead regarding other local search methods, irrespective of the movement pattern of the agents. Therefore, it allows a good partition of the semantic database.

•Lee and Hughes [13] developed a method to boost the protection of pedestrians in densely populated situations. The results of simulations performed on two cases of accidents involving trampling, which occur when pedestrians are moving, illustrate the flexibility of this modeling strategy for minimizing predicted crowding risks in such situations. This study demonstrates that effective control is also achieved either by adjusting the dimensions of the gang or the complexity of the environment within which pedestrians walk, which effectively influences their speed.

•Jeong et al. [14] proposed a practical implementation of the virtual crowd simulation system. Conventional commercial crowd simulation software is complex and has program-like script interfaces, which makes it animator hard to be told and use it. supported the observations that almost all crowd scenes include walking, running, and fighting movements, they need implemented a crowd simulation system that automatically generates movements of virtual characters given the user's minimal direction of the initial configuration. The system was implemented as a plug-in of Maya which is that the commonest 3D software for movies. Because generated movements are supported optically captured motion clips, the results are sufficiently natural.

The above approaches of data technology addressing the matter of crowd management provided promising potentials of utilizing intelligent systems as means for improving the traffic movements and decreasing the group congestion whereby the traffic safety are going to be accordingly enhanced. However, there's a desire to boost the capabilities of such intelligent systems in three dimensions: (a) the simulation of traffic movement is to be supported real-time data; (b) the traffic management is to be conducted via tangible, accessible, and portable, and real-time interfaces (e.g. 3D real-time virtual environ-

ments); and (c) the behavioral analysis of traffic safety parameters (roads, vehicles, and pedestrians), is to be incrementally incorporated within the intelligent system which can make such system a self-learning system that adapts its knowledge-base over time and supported use and exposure. This paper proposes a framework of an intelligent real-time virtual environment that integrates these dimensions to realize efficient crowd management of vehicles during one in every of the key bottlenecks of Hajj which the Nafrah of pilgrims from Arafat to Muzdalifah.

4.. PROPOSED FRAMEWORK FOR DEVELOPING AN INTELLIGENT REAL-TIME VIRTUAL ENVIRONMENT FOR EFFICIENT CROWD MANAGEMENT OF VEHICLES within the NAFRAH OF PILGRIMS FROM ARAFAT TO MUZDALIFAH

The proposed framework for developing an intelligent real-time virtual environment model for efficient crowd management of vehicles within the Nafrah of pilgrims incorporates three phases:

•Phase I: Spatial analysis of current pedestrians and vehicles access within the Nafrah location coverage

•Phase II: Evaluation of movement efficiency of current scenarios of the Nafrah using computational simulation

•Phase III: Development of a multi-agents system within a real-time 3D virtual environment for improving the movement efficiency of both pedestrians and vehicular traffic within the Nafrah.

Each Phase has specific milestones to be reached as illustrated in Figure 3 to successfully implement the proposed framework into a practical and useful computational system to be utilized by the Hajj traffic authorities and anxious stakeholders during the Nafrah from Arafat to Muzdalifah. to realize such successful implementation of the proposed framework, the subsequent subsections articulate the distinctive features of the

proposed framework of an intelligent real-time 3D virtual environment for efficient crowd management of vehicles during the Nafrah from Arafat to Muzdalifah.

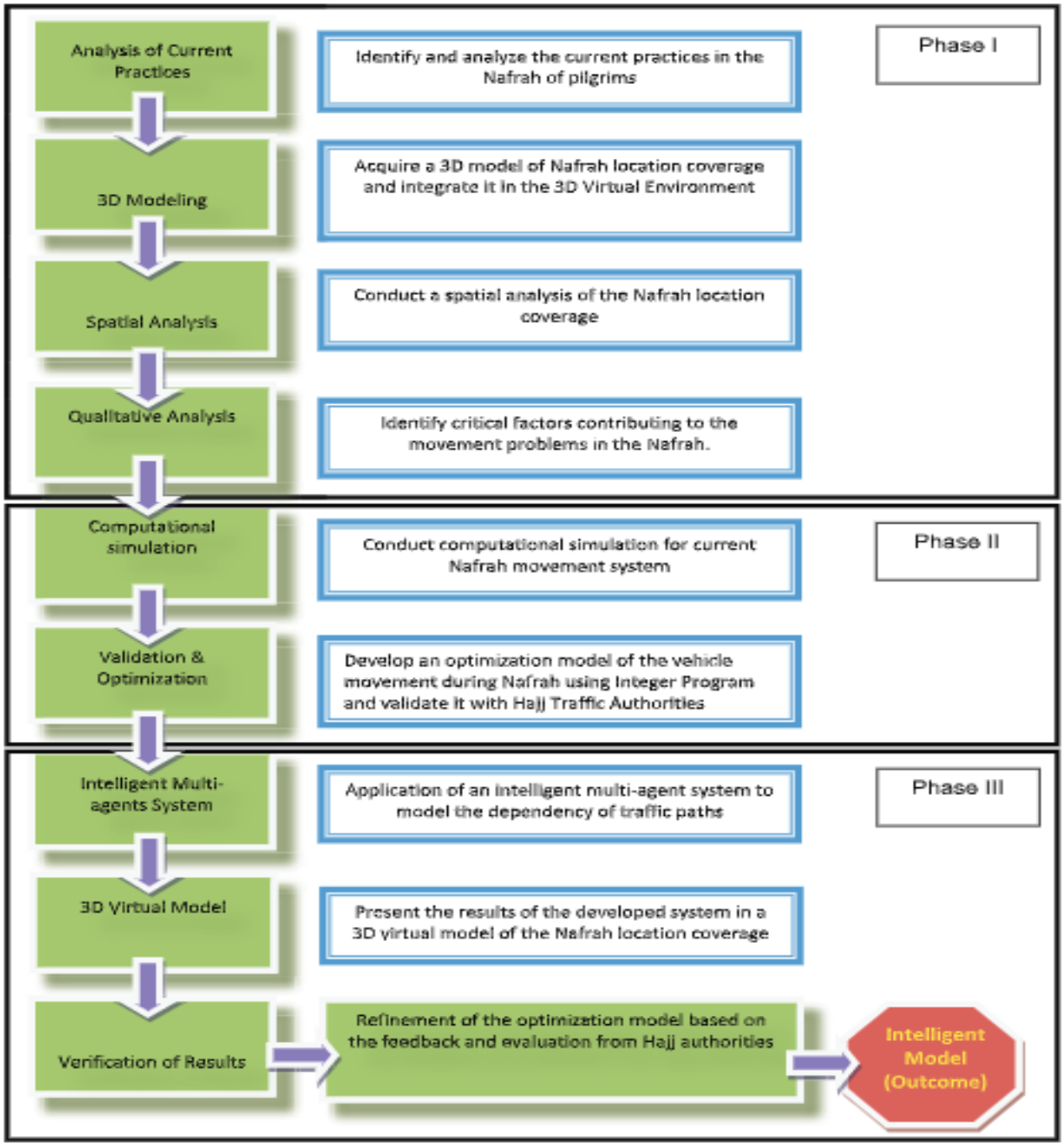

Figure 3. Primary phases and their associated components of the proposed framework for developing an intelligent real-time 3D virtual environment for efficient crowd management of vehicles during the Nafrah from Arafat to Muzdalifah [Author].

4.1. The Optimization Model

In the proposed framework an integer program are developed for the proposed optimization model. The input to the program is the quantity of vehicles on each road segment in Arafat. These segments represent the starting positions for vehicles stationed there. Another input is that the road network from Arafat to Muzdalifah and also the travel times to traverse different roads. These travel times will take into consideration the specified traffic service levels. The output of the model are going to be the ultimate area in Muzdalifah where vehicles of a given road segment in Arafat should occupy Muzdalifah in addition because the route to require from the starting road segment to the ultimate area. The integer program will minimize the longest period of time from Arafat to Muzdalifah for vehicles in each starting segment. Verification of the constructed model and validation of the results are going to be conducted unitedly with the Ministry of Hajj and Traffic Police within the Arafat-Muzdalifah area and using real-life data that are available or that may be collected within the nearest Hajj season. If the most period of time is taken into account long by these authorities, what number extra roads are needed are going to be determined, and so decide their starting and ending locations together with the trail of every road. the selection of those will take into consideration the topography of the realm where changes within the level of the terrain are minimal.

The data needed for the model like the road network and therefore the number of vehicles on each road segment are already available with the Traffic Police of the Arafat-Muzdalifah area while considering the allocations and percentages of both pedestrians and railway passengers. the small print of the terrain are obtained from Google earth which has already been contacted for an estimate of the price. the present system has separate roads for pedestrians. Therefore their movement are going to be studied sepa-

rately from that of the vehicles. Again, supported the traffic service level we'll estimate the specified number of roads which will end in having acceptable trip time as determined by the Ministry of Hajj. in keeping with our experience, we all know that more pedestrian roads are needed. the quantity and path of every of those roads are going to be determined using the available land and again keeping in mind that level changes should be kept at absolutely the minimum.

4.2. Integration of 3D Real-Time Virtual Environments and therefore the Intelligent Multi-Agents Systems

This proposed framework aims to develop a multi-agents artificial intelligent system with scripting capabilities to model the dependency of traffic paths (while each agent represents a particular traffic path), and to detect possible bottlenecks within the traffic movements during the Nafrah from Arafat, and to check several hypotheses on efficient crowd management. Generally terms, an agent may be a software entity that's placed in an environment and operates under a nonstop perception-reasoning-reaction loop with the said environment [15]. It then first receives as input some stimulus from the environment by using its own perceptual system; it processes it by adding the new information to its previous knowledge and goals and eventually reacts by selecting one during a set of possible actions, which successively might alter the environment, thus generating new stimuli. The virtual environment for the agents relies on 3D geometry. A graphics engine handles this layer of the model, whereas the multi-agents engine extracts information from the environment and feeds it to the agents (such as there's an obstacle ahead).

4.3. Alignment of the Proposed Framework with Recently Developed Framework on Pedestrian Crowd Management in Hajj

The proposed framework is in alignment with the approach of the foremost recent developed framework for pedestrian crowd management in Hajj by the Crystals Project [16]. the most focus of the Crystals Project is that the investigation using the adoption of agent-based and cellular automata-based pedestrian and crowd modeling approach,

combined with contributions of cultural studies and existing results on the research on crowd dynamics, on how the presence of heterogeneous groups influence emergent dynamics within the context of the Hajj and Omrah. The implications of particular relationships among pedestrians in a very crowd are generally not considered or treated in an exceedingly very simplistic way by current approaches. particularly, the framework of the Crystals Project organization are often applied to pilgrims' flows during the Nafrah from Arafat, wherein communication between the agents of pedestrian paths and vehicular paths is established to assist in achieving an overall optimization for efficient crowd management of both pedestrians and vehicles. within the Crystals project, the realm of the Mashaer Line stations was the precise subject while the main target is to significantly employ the thought of grouping pilgrims to raised manage their movement from and to the station. Furthermore, studying the implications of the fundamental features characterizing crowds within the Hajj but also in other situations is that the main aim of the Crystals project.

4.4. Limitations of the Proposed Framework

The limitations of the proposed framework include:

• The 3D virtual model isn't intended for optimization. The 3D virtual model may be a presentation environment that enables presenting the results of optimizing vehicle flow in a very 3D format that's tangible and understandable to the target users. Furthermore, the event of a 3D virtual model of Nafrah location coverage facilitates the spatial analysis of the world and helps inappropriately introducing new roads to facilitate the flow since the Nafrah location coverage is hilly and 2D models won't be efficient for such purposes.

•The proposed framework focuses on the simulation and optimization of auto movement from Muzdalifah to Arafat while pedestrians and Mashaer railway passengers are considered as a part of the whole movement scenario in terms of percentage but not computationally simulated or presented within the 3D Virtual model. this can

be supported the idea that if the movement of the vehicle is efficiently optimized it'll certainly improve the movement of pedestrians and Mashaer railway passengers taken into consideration that the roads allocated to pedestrians are appropriate for his or her expected percentage. Furthermore, the implementation of the proposed framework may suggest alterations to the pedestrian roads if required and /or altering the passenger's capacity of the Mashaer railway to realize efficient movement for both vehicles and pedestrians within the Nafrah.

4.5. Adaptation of the Proposed Framework to Changes on ground During the Nafrah from Arafat

The conditions on the bottom during the Nafrah from Arafat to Muzdalifah may continuously change. The changes can be because of vehicles break down, accidents, security threats, or environmental disruptions, like rain. The proposed model can expand to be interfaced with the conditions on the bottom captured using remote and direct sensing technologies together with data processing techniques integrated with a virtual environment. The acquired data are going to be fed to the model and consequently, the model will provide updated and more responsive traffic plans. Integrating the model with real-life data provides the Hajj authorities with (a) a tool to raised facilitate the resources for managing the pilgrimage activities; (b) pre-warning on potential crowd disasters, and (c) strategies to manage crowd problems either from within or outside. The model presents its leads to a real-time virtual environment to facilitate its accessibility and value by the Hajj authorities. the final word goal of this proposed framework is to attain an efficient and safe real-time management supported real-time data and real-time simulation for decision-makers and at the identical time provides individual navigation for users using portable devices like cell phones in using signage-based visualization interface to interact with the most system to spot a best suited time and route supported individual user (pilgrim) inputs and current circumstances.

5.. CONCLUSION

This paper introduced a framework for developing an intelligent real-time virtual envi-

ronment model for facilitating efficient and timely traffic movement during the Nafrah. The model utilizes intelligent agents within a real-time 3D virtual environment that represents the Nafrah location coverage. The proposed framework has three primary phases: (a) spatial analysis of current pedestrians and vehicles access within the Nafrah location coverage; (b) evaluation of movement efficiency of current scenarios of the Nafrah using computational simulation; and (c) development of a multi-agents system within a real-time 3D virtual environment for improving the movement efficiency of both pedestrians and vehicles traffic within the Nafrah.

The proposed model is employed by decision-makers (Hajj authorities) of the Nafrah to attain an efficient performance for the vehicle's traffic movement. a number of the potential benefits of developing a computational model for optimizing vehicles flow during Nafrah of pilgrims include:

•Providing a computational model that may allow Hajj authorities to adopt successful scenarios to attain efficient movement of vehicles within the Nafrah of pilgrims.

•Providing a computational model that has a user-friendly interface with a 3D virtual model of the Nafrah location coverage which facilitates the utilization of the developed model by the Hajj authorities.

•Developing innovative computational models with technical solutions that address local critical problems within the Hajj activities.

•Paving the road for a possible tool to be developed within the future expansion of this proposed framework geared toward achieving efficient real-time management supported real-time data and real-time simulation for decision-makers and at the identical time provides individual navigation for users using portable devices like cell phones in using signage-based visualization.

The target end-users of utilizing the outcomes of the proposed framework include Hajj Traffic Authorities, The Custodian of the 2 Holy Mosques Institute of Hajj Research, Ministry of Hajj, and vehicle drivers. The adaption processes that allow the conditions on the bottom to be captured using remote and direct sensing technologies together with data processing techniques integrated with a virtual environment makes the proposed intelligent model capable of responding to the 000 needs presently and within the future. Hence, the intelligent model will always provide updated and more responsive traffic plans and can provide the Hajj authorities with a tool to raised facilitate the resources for managing the pilgrimage activities, pre-warning on potential crowd disasters, and methods to manage crowd problems either from within or outside.

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