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PRELIMINARY MODEL AND SIMULATION TOWARDS CROWD DYNAMICS IN VIRTUAL ENVIRONMENTS

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This paper is a part of the project entitled Model and Simulation of Crowd Dynamics in Virtual Environments and will approach crowd model through some traffic models. It is aimed to catch the nature of crowd ahead of a crowd simulation, thus, will attain the most significant crowd variables or parameters in controlling crowd movement. The paper will discuss real world representation, model development, model implementation and validation. Eventually, some expected contribution of this work will be summing up this research proposal. The model of environment as real world representation is built based on comparative picture measurement and satellite images. To derive the model, a segment of simulated length ***dx*** along a path (area) of crowd events is given. Let ***ρ(x,t)*** denote density in units of agents/meter at time ***t***, and ***v(x,t)*** denote the velocity of agents in the path with coordinate **x** at time **t** in units of meter/second. Also ***q(x,t)*** denote the number of agents flowing the path during the time period ***dt.*** The conservation laws applied in the model. Whereas, the model will implement crowd during Hajj/Umrah and will be validated by using real parameters.

Key words: *traffic model, crowd, virtual environment, conservation laws*

1. Introduction

Any gathering of two or more persons is a group and a large group is called a mass. If they occupy a single location and share a common focus, they form a crowd. In the project, the crowd refers to a large number of agents or characters in VE terms or pilgrims in real world term and they are considered together. Moreover, crowd is an animated character in the form of batches or represents a group of agents that move around in VE.

The research will model the Hajj/Umrah performance on a smaller scale. The model will simulate pilgrims' movement in the real large number of agents or characters in Virtual Environment [VE] Hajj/Umrah by a computer program. However, this paper is only a part of the on-going project ([1], [2], [3], [4], [5], and [6]) and will focus on some principles model used.

The motion of a crowd can be modeled 'physically' by a description of the paths of all agents. This does not imply that those agents' trajectories can be represented in the homogeneous direction. However, agents share common features with them that allow employing some of the concepts used there. Whether or not they follow the provided paths, they are still there. It means, the conservation law applied. Therefore, the paper will approach crowd model through some traffic models.

Many traffic problems can be resolved by controlling traffic flow with giving various traffic control measures. Executions of the models through simulation will catch the nature of crowd and will attain the most significant crowd variables or parameters in controlling crowd movement.

2. Basic variables

Instead of individual agent motion, a concern is more with streams of traffic. For such circumstances it is usually convenient to describe the traffic situation as seen by an observer on the side of the paths. Such a description is referred to as an *Eulerian* description, as opposed to a *Lagrangian* description, which describes the motion (position, velocity etc.) of individual agents. The *Eulerian* scheme is usually more appropriate for describing fluid motion, whereas the *Lagrangian* (or particle following) scheme, is normally used in mechanics. The variables will be defined initially for uniform, steady, single lane traffic flow circumstances. All agents are assumed to be the same size and moving at the same speed. Such circumstances are of course extremely unrealistic but in an appropriate average sense the definitions extend. The variables used are:

• The Traffic Speed, *v*: units m/s, which simply corresponds to the agent's speed.

• The Traffic Density, ρ. The traffic density on this lane associated with a given position x and time t, is the average number of agents per unit length of lane at the position and time specified. The traditional symbol for fluid density, namely ρ, is used for the traffic density. Thus ρ (x, t) is the average number of agents per unit length at the position x and time t.

• The Traffic Flux *F*, or flow rate q(x, t): units agents/s, is the number of agents passing a given point on the lane in one second. The performance of the lane system is often gauged in terms of the flux "through" the system.

3. Traffic model based on conservation laws

The fundamental idea is:

$$\frac{d}{dt}[\text{Amount of Agents}] = [\text{Agents entering}] - [\text{Agents leaving}] \quad \text{[Eq. 1]}$$

Consider traffic between Safa and Marwah on Sa'ey lanes as an example. The coordinate *x* is used to denote distance along the lane. The *density, ρ(x, t)* , is the number of pilgrims per length. In the interval *a < x < b* the total number of pilgrims is

Number of agents in the interval a<x<b=

$$\int_a^b \rho(\mathrm{x}, \mathrm{t})\mathrm{dx} \quad \text{[Eq. 2]}$$

There is *continuum approximation* by assuming that there is a well defined density which is a smooth function of positions. If an agent is 1.5 meters long it makes no sense in [Eq.2] to pick an interval of length 1 meter. The introduction of the density ρ(x, t) requires a separation in length scales between the distance over which ρ(x, t) changes appreciably (e.g. hundred meters) and the distance between agents (e.g. a few centimetres).

Applying the principle of conservation law in [Eq.1] by picking an interval of lane a <x < b, and counting the number of agents which pass x = a in a time dt. Thus, the flux (agents per second passing x = a) is defined as f(a, t). The same is applied at the other end of the control length and so determined f(b, t). Ignoring off-ramps and on-ramps which introduce agents into the middle of (a, b), equation [1] expresses that

$$\frac{d}{dt}[\text{Number of agents in the interval } a < x < b] = f(a, t) - f(b, t). \quad \text{[Eq. 3]}$$

In other words

$$\frac{d}{dt}\int_a^b \rho(x,t)dx + f(b,t) - f(a,t) = 0 \quad \text{Eq. 4]}$$

Letting a → b in [4], with x sandwiched in the middle, the differential statement of the conservation law can be obtained:

$$\rho t + fx = 0 \quad \text{[Eq. 5]}$$

4. Traffic flow and Burger's equation

Burger equation has been widely studied ([7], [8]). In a very simple model for traffic flow, the real interval [a; b] stand for a lane and v(x) and ρ(x) are defined for all x within [a; b] as the velocity and traffic density in point x. It is assumed that all changes in velocity can be computed from the traffic density alone. Dividing the interval [a; b] in subintervals will get $I_i = [x_i; x_{i+1}]$ of equal length Δx .

The traffic density on interval I_i is denoted by ρ_i, the velocity by v_i (both are assumed to be constant on the interval). The temporal variation of ρ_i is caused by traffic leaving the interval into the next interval I_{i+1} and traffic entering from I_{i-1}; in a time interval of length Δt the quotient $\frac{v_j \Delta t}{\Delta x}$ of the N_j agents in interval I_j moves out to the next interval

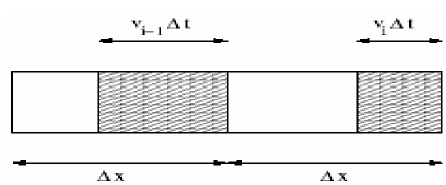

Figure 1. Interval illustration

The variation of density Δρ can be computed by dividing by Δx, and finally an equation below can be achieved.

$$\frac{\Delta\rho}{\Delta t} = -\frac{\Delta(\rho v)}{\Delta x} \quad \text{[Eq. 6]}$$

Let

$$v(\rho) = v_0 \cdot (1 - \frac{\rho}{\rho_\infty}) \quad \text{[Eq. 7]}$$

and substituting this into the differential equation gives

$$\frac{\partial\rho}{\partial t} + v_0 (1 - \frac{2\rho}{\rho_\infty}) \frac{\partial\rho}{\partial x} = 0 \quad \text{[Eq. 8]}$$

Using the substitution of

$$u = 1 - \frac{2\rho}{\rho_\infty} \quad \text{[Eq. 9]}$$

(u is thus defined as a dimensionless variable); will get

$$u_t = -\frac{2}{\rho_\infty}\rho_t \text{ and } u_x = -\frac{2}{\rho_\infty}\rho_x \quad \text{[Eq. 10a,b]}$$

so that after multiplying with $-\frac{2}{\rho_\infty}$ there is the differential equation

$$u_t + v_0 u u_x = 0 \quad \text{[Eq. 11]}$$

In order to transform x and t to dimensionless $\tilde{x}$ and $\tilde{t}$ the equation is divided by a characteristic length L and time $\frac{L}{v_0}$, respectively.

$$\tilde{x} = \frac{x}{L} \text{ and } \tilde{t} = t\frac{v_0}{L} \quad \text{[Eq. 12]}$$

Substituting these new variables in the differential equation and multiplying by $\frac{L}{v_0}$ yields **Burger's equation** ([9] [10]) cited in [11],

$$\frac{\partial u}{\partial t} + u \cdot \frac{\partial u}{\partial x} = 0 \quad \text{[Eq. 13]}$$

5. Model Environment

Sa'ey environment is built based on comparative camera snapshots picture measurement. The model is valid for one lane only.

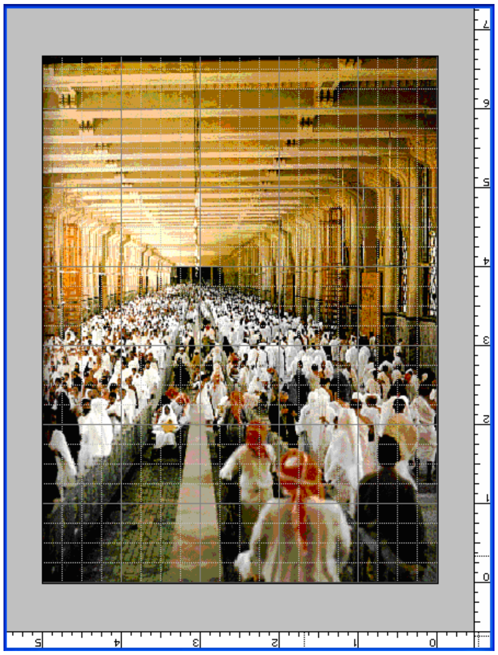

Figure 2. Sa'ey snapshot

Satellite images are used to grab the distance and wide of the environment. The distance between Sa'fa and Marwa is 394 metres.

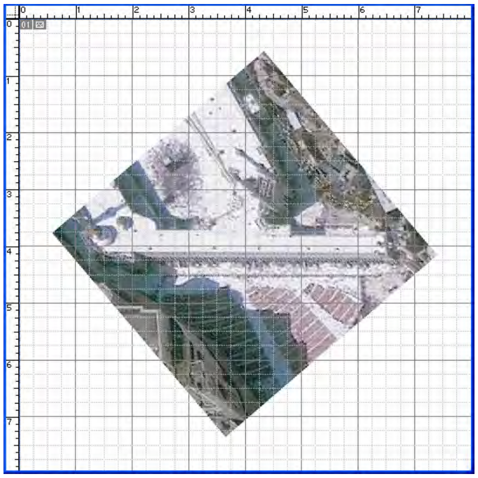

Figure 3. Processed from a satellite images of Al-Haram [Credit to DigitalGlobe]

6. Model Simulation

With length of Sa'ey 394 meters with hundreds of pilgrims, some results are shown in figures below.

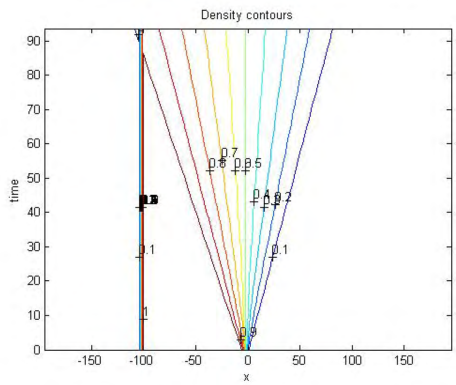

Figure 4. Density contours

If the velocity field for the lane is known the movement of an individual agent can be found. First the agent must be specified. One way to do that is to choose a particular time, say $t = t_0$, and a particular position on the lane, say $x = x_0$, and identify an agent as being at that spot at that time. To know where this agent is located at times $t > t_0$, the velocity field must be scrutinized, which implies how fast any agent is going when at position x and time t. Thus if x(t) is the position of the agent, it is known that $x(t_0) = x_0$ but also that

$$\frac{dx}{dt} = u(x(t),t) \text{ [Eq. 14]}$$

This equation relates the overall velocity field to the function x(t) for the particular agent which was located at x_0 at time t_0. Refer to basic variables before, x(t) is called the *Lagrangian* coordinate of the agent, and u(x, t) is called the *Eulerian* velocity field.

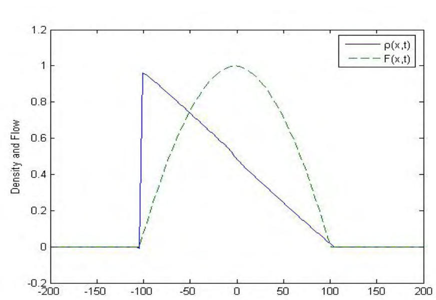

Figure 5. Density and flow versus x

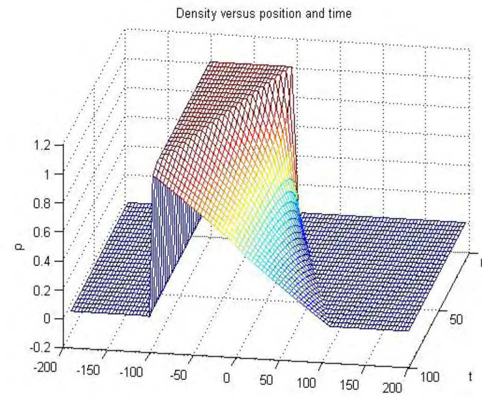

Figure 6. Density versus position versus time

Note that the problem of locating the position of our agent, summarized as

$$\frac{dx}{dt} = u(x(t),t), \qquad x(t_0) = x_0 \text{ [Eq. 15]}$$

where u(x, t) is a given function, amounts to solving an ordinary differential equation of first order with an initial condition at the time t_0.

7. Conclusion and future works

The model simulation has depicted the overall situation and captured some main features but not visualised individual simulation. Visualization is a further work and will be conducted after model satisfied and validated.

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References

[1] Widyarto, S. "The Comparison between In-Line and Off-Line Rheometry for ABS Lustran QE1455 in Different Temperatures" Published by Institute for

Science and Technology Studies [ISTECS] December, 2003, *ISTECS JOURNAL Science and Technology Policy* Vol. IV / 2003 ISSN 1345-58981, Pp 56-70

[2] Widyarto. S., Abd. Latiff, M.S., "Traffic Model of Internet and Mobile Communication" Proceeding of the 1st Conference on Telematics System, Services, and Applications 2004 [TSSA2004] Institut Teknologi Bandung, 15 May 2004, ISSN:1693-993x, A29 176-181.

[3] Abd. Latiff, M.S., Widyarto. S., "The Crowd Simulation for Interactive Virtual Environments", Proceeding of ACM SIGGRAPH International Conference on Virtual-Reality Continuum and its Applications in Industry [VRCAI2004] NTU, Singapore, 16-18 June, 2004, Stephen N. Spencer [Eds], 278-281.

[4] Abd. Latiff, M.S., Widyarto. S., "Collision Free Multi Agents Motion Planning in Complex Virtual System", Proceeding of the 7th International Conference on Work With Computing Systems, WWCS 2004, Kuala Lumpur, June 29- July 2, 2004 H.M. Khalid, M.G. Helander, A.W. Yeo [Editors]. Kuala Lumpur: Damai Sciences, 849-854,

[5] Setyawan Widyarto, Muhammad Shafie Abdul Latiff. "Traffic Model for Multi Agents", Poster Session International Conference Computer Graphics, Imaging and Visualization [CgiV] 26 –29 July 2004 Penang Malaysia [excluded from the conference proceeding, it is in book of abstract].

[6] Setyawan Widyarto, Rohayanti Hassan, Mohammed Zakiamani Mat Yusoff, Muhammad Shafie Abd. Latiff, "Implementation of Hajj Traffic Model in Virtual Environment", the 14th International Conference on Computer Theory and Applications [ICCTA] 28- 30 September 2004, Alexandria – Egypt

[7] Bor-Lih Kuo, "Application of a Hybrid Method to the Solution of the Nonlinear Burgers'Equation", *Journal of Applied Mechanics November 2003, Vol. 70 926-929.*

[8] Panagiotis Stinis, "A Hybrid Method for the Inviscid Burgers Equation", *DISCRETE AND CONTINUOUS. DYNAMICAL SYSTEMS*, *Volume 9, Number 4, July 2003 pp. 793–799.*

[9] J. M. Burgers, A mathematical model illustrating the theory of turbulence, *Advances in Applied Mechanics*, Academic Press, New York, 1948, pp. 171–199.

[10] ------The Nonlinear Diffusion Equation. Asymptotic Solutions and Statistical Problems, D. Reidel Publishing, Massachusetts, 1974.

[11] Nejib Smaoui, "Controlling the Dynamics of Burgers Equation with a High-Order Nonlinearity", *International Journal of Mathematics and Mathematical Sciences* [IJMMS] 2004:62, 3321–3332,