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An agent-based simulation of the L.A. 1992 riots

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Abstract – *The Los Angeles riot in the spring of 1992 remains an ever-haunting example of the destructive manner in which some individuals handle social rage. While understanding some of the myriad of reasons for social rage could help address the psychological nature of such a problem, this work focuses on developing a model of the physical interactions that may precipitate a riot. In particular, an agent-based model is used to create both a car physics model and a social force model that are used to simulate a riot at an intersection. An example is given where emergent behaviors that closely match those in a riot situation, i.e., where cars are stopped and drivers are attacked, are obtained by choosing appropriate parameters for the models.*

Keywords: riot control, traffic simulation, agent-based modeling, pedestrian flow modeling

1. Introduction

“On April 29, 1992, the City of Los Angeles was enveloped in a riot in response to the ‘not guilty’ verdicts in the trial of Los Angeles Police Department (LAPD) officers accused of unlawfully beating Rodney King. Six days later, when the fires were finally extinguished and the smoke had cleared, 54 people had been killed, more than 2000 injured, in excess of 800 structures were burned, and the profile of police work in the City of Los Angeles and the United States was forever changed. The 1992 riots in the City of Los Angeles were arguably the most devastating civil disturbance in the history of the United States.”[1] While this is only one example of uncontrolled social rage leading to a riot, history has been a witness to such civil disturbances on more than one occasion, enough to demonstrate the need for studying riots and coming up with techniques that will lead to ways of protecting life and property.

Very few or no previous attempts have been made to simulate a riot. Most of our work is based on studying the videos of the L.A. 1992 riots [2]. We have used a social force model as a foundation for our simulations of pedestrian flow and rioters [3] with a car physics model for simulating vehicle dynamics at

an intersection. The car physics model is augmented with a model of driver behavior that emulates adherence to traffic lights based on the threatening behavior of rioters and collective behavior of pedestrians.

The remainder of this work is structured as follows—we first describe the underlying social force and car dynamics models. This is followed by a discussion of a simple pedestrian, rioter, and traffic simulation model. Finally, an example of emergent rioting behavior is presented followed by the conclusions of this work.

2. The Social Force Model

The social force model was first introduced by Helbing and Molnár [5] and has been expanded to include physical contact forces (with similarities to granular flows) for panic situations [6], [7]. The social force model to describe pedestrian flow has its origins in gas-kinetic models [4]. It consists of self-driven particles, i.e., people that interact through social rules. Each person adapts his or her current velocity to match a desired direction and a desired speed; furthermore, each crowd member simultaneously tries to avoid bumping into other crowd members and any environmental boundaries. The social interactions produce changes in the velocities and reflect a change in motivation rather than physical forces acting on the person. These social forces can be influenced by the environment, other people, and internal states. The total force on each agent is given by

$$f_i = f_i^S + \sum_{\substack{j=1 \\ i \neq j}}^N f_{ij}^I + \sum_{k=1}^M f_{ik}^O + \sum_{h=1}^R f_{ih}^C \quad (1)$$

where f_i^S is the self-driven force for the i th particle, f_{ij}^I is the repulsive interaction force on agent i due to agent j , f_{ik}^O is the repulsive force on the agent i due to an obstacle k , and f_{ih}^C is the cohesive force on agent i due to agent h .

The self-driven force gives the agents ‘seek’ behavior, i.e., they move towards a desired velocity or in a desired direction. Desired velocity is the velocity

the agent would need to reach the target position in an ideal world and is scaled in magnitude to maximum possible speed the agent can achieve. This force is modeled by

$$f_i^S = \frac{m_i(s_i\hat{e}_i - v_i)}{\tau_i} \quad (2)$$

where m_i is the mass of the i th individual, s_i is the desired speed, \hat{e}_i is the desired direction, v_i is the current velocity, and τ_i is a parameter that determines how fast an individual responds. The desired direction is set by an error term between the current position of the agent and the desired end location.

These simulations utilize two basic types of interaction forces. The *repulsive force* is modeled as follows:

$$f_R = \left[A \exp\left(-\frac{d_{ij}}{B}\right) + k g(d_{ij}) \right] \hat{n}_{ij} - \left[\kappa g(d_{ij}) \Delta v'_{ij} \right] \hat{t}_{ij} \quad (3)$$

$$d_{ij} = \|x_i - x_j\| - r_i - r_j \quad (4)$$

where A is the magnitude, d_{ij} is the distance between the object i and object j , r_i is the radius of the i th particle, and B is a parameter that affects the rate of decay of the force. In high-density situations, physical contact can occur, and k and κ are used to model a compression term and tangential friction term. Whether or not the particles are in contact is determined by the function $g(x)$, which is zero if x is positive and one otherwise. The terms n_{ij} and t_{ij} are the normal and tangential components of the vector between two particles. The other important force is the *cohesive force*, which is modeled as:

$$f_C = C \exp\left(\frac{-(d_{ij} - D)^2}{E}\right) \quad (5)$$

where C is the peak magnitude, D controls how far away from the center of the object this peak occurs, and E affects the rate of decay of the force.

3. The Car Physics Model

The car physics model is based on three main forces – traction, drag and rolling resistance [10]. As in the pedestrian model, the total force acting on a vehicle is the sum of these component forces. We call this force, the *longitudinal force* as it acts along the length of the car and is given by the following equation:

$$f_l = f_t + f_d + f_r \quad (6)$$

where f_l is the longitudinal force, f_t is the traction force, f_d is the drag force and f_r is the rolling-resistance. Traction is the applied mechanical force used to achieve motion due to friction between the

vehicle's tires and the road. This has been modeled as a measure of the engine force if the car is accelerating or braking force if the car is decelerating and is given by:

$$f_t = u(\pm E) \quad (7)$$

where $+E$ is the engine force or $-E$ the braking force and u is the unit vector in the direction that the car is moving. If this were the only force the vehicle would accelerate to an infinite speed, but a vehicle's speed is also controlled by the resistive forces that act in the opposite direction of the traction forces. The first one being the *aerodynamic drag* or *air-resistance* which is approximated by the following formula [8]:

$$f_d = -0.5C_d A \rho v^2 \quad (8)$$

where C_d is the coefficient of friction which depends on the shape of the car and is determined by a wind tunnel test, A is the frontal area of the car, ρ is the air density and v is the velocity of the car. The negative sign indicates that this force acts in the opposite direction of the car's motion.

The rolling resistance is caused by the friction between the rubber of the tires and the road surface, and friction in the axle and other frictional forces that impede the travel of the car. This is modeled as a linear force that is proportional to the velocity as:

$$f_r = -C_r v \quad (9)$$

where C_r is the coefficient of rolling resistance and v is the velocity of the car.

It is seen from Figure 1 that for a constant engine force, the rolling resistance and drag forces keep increasing as velocity increases. Since they act in the direction opposite of traction, at some point the combined forces of rolling resistance and drag cancel out the effects of traction, and hence the car cannot accelerate indefinitely for a given engine force.

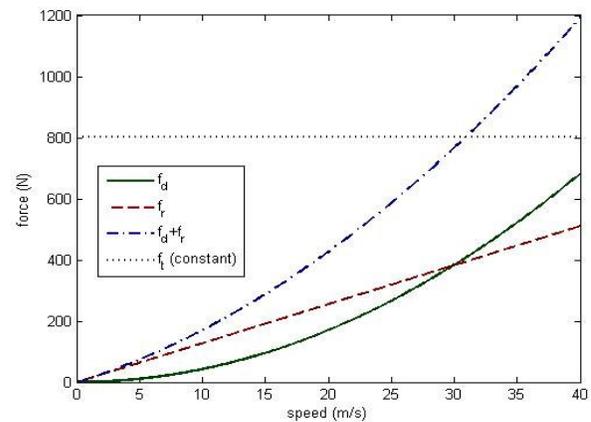


Figure 1: The plot shows the three forces acting on a vehicle and their change with respect to speed

4. Simulation Results

The purpose of our simulation is to determine if our model is capable of emulating the rioting behavior seen at traffic intersections during the L.A. riots. Thus our simulated world, shown in Figure 2, consists of a four-way intersection with traffic lights and pedestrian/crosswalk lights. All objects are to scale except for the traffic signals, which are enlarged to improve visibility. The vehicles (blue/dark rectangles) on the W-E road have stopped because they have a red signal. Other vehicles on the N-S road have a green signal, and hence are moving. The pedestrians (cyan circles with black border) generally make use of the sidewalks. They cross a road when permitted by the crosswalk light (white); while others who do not have the ‘walk’ signal wait at the street corners. This is a peaceful scenario typical of everyday life at an intersection.

By contrast, Figure 3 shows a situation of a riot where cars have been stopped and are under attack by rioters. Two types of rioters are depicted in the simulation that we refer to as either ‘high level’ or ‘low level’. The modeling of two such rioters is motivated by previous studies of riot scenarios. According to David Haddock and Daniel Polsby [9], “Having many people who want to riot and believe that others also want to riot is necessary but not sufficient condition to begin a riot. One more condition has to be met. Even in an unstable gathering, the first perpetrator of a misdemeanor is at risk if the police are willing and able to zero in on him. Thus, someone has to serve as a catalyst.”

The high-level rioters (maroon/dark squares with black border) are modeled to serve as the catalysts. They are fewer in number than the low-level rioters (yellow/light squares with black borders) but serve the purpose of raising the willingness of the low-level rioters or the passive bystanders to join in the riot by being the first to stop a vehicle and approach the driver.

In this example simulation, we have confined the definition of a riot to a situation where rioters impede traffic and attack the drivers as they are stopped at an intersection. This is intended to simulate the riots that took place on the busy intersection of Florence and Normandie, in south-central Los Angeles in the spring of 1992. Figure 3 shows a high-level rioter stopping a car at the intersection and attracting the low-level rioters to join him in stopping more vehicles. Because the intersection is a busy one, the drivers have very limited opportunities to escape and hence are subjected to direct attack from rioters. Pedestrians play a very passive role in the simulation by usually avoiding the areas under tension.

Tables 1 and 2 show the parameters that were used to model high and low level rioters, pedestrians and vehicular interactions. For all people—pedestrians and rioters—we used the Helbing model for basic movements that involved two positions—current and destination—for computing the desired velocity. Goal-oriented behavior was provided by Dijkstra’s algorithm that was used to find a shortest or favorable path (depending on the number of rioters in the way) between the start and the end nodes that were randomly picked.

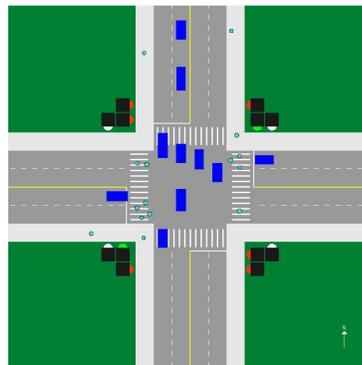


Figure 2: Snapshot of simulated intersection

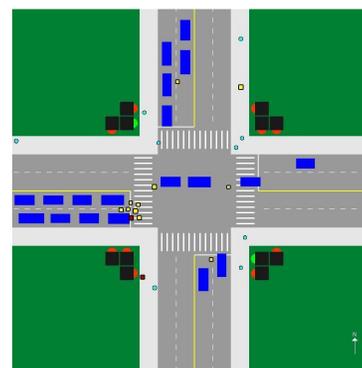


Figure 3: Snapshot of a riot at an intersection

Interaction		Person/Agent	
A	2000 N	m	80.0 kgs.
B	0.08 m	s	1.2 or 3.0 m/s
C	-600 to 0 N	τ	0.5 s
D	0.5 m	r	0.25 to 0.35 m
E	0.05 m ²		
k	$1.2 \times 10^5 \text{ kg/s}^2$		
κ	$2.4 \times 10^5 \text{ kg/ms}$		

Table 1: Simulation parameters for pedestrians

Vehicle Dynamics	
C_d	0.3
A	2.2 m ²
ρ	1.29 kg/m ³
C_r	12.77

Table 2: Simulation parameters for vehicles

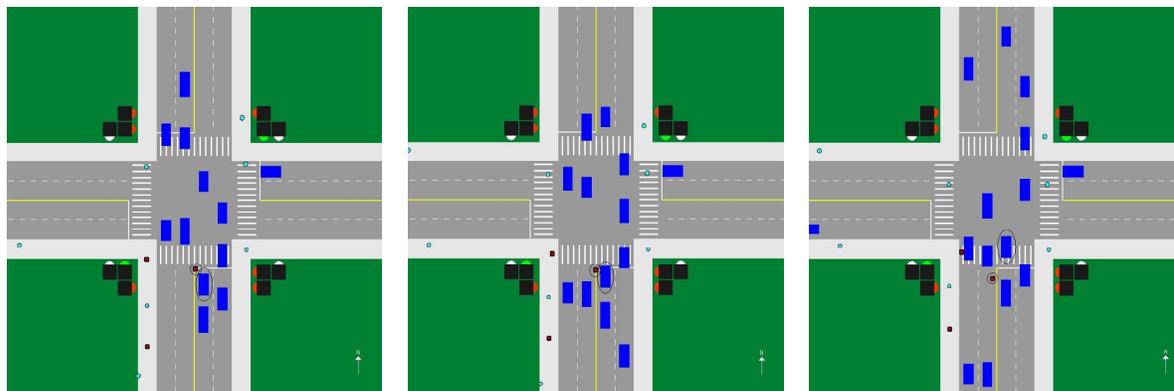


Figure 4: (a) Snapshot of a rioter stopping a car. (b) Snapshot of a rioter walking towards the driver position with intent to attack him. (c) Snapshot of a rioter losing his target

As for high-level rioters, the motivation came from vehicles that were easiest to target. Targets were identified based on the vehicle speed and proximity, i.e., easy targets were those that were closest to the rioter and moving at a low speed. Thus, traffic intersections were a typical place for easy targets, as was seen in the L.A. 1992 riots. The low-level rioters were attracted to ‘spots of interest’ that were identified by the presence of high-level rioters. Thus, low-level rioters were motivated towards a vehicle under attack by a high-level rioter.

While Figure 3 shows a successful attempt of rioters to stop and attack vehicles, there are also situations where high-level rioters’ actions are thwarted if there is a way for the vehicle to escape. Our simulation was successful in showing this when a rioter stopped a vehicle by standing in front of it but lost his target when he approached the driver with the intent of attacking him without another rioter blocking the vehicle’s path as seen in Figures 4 (a) – (c).

5. Conclusion

Simulations indicate that the social force model combined with other agent-based techniques can be extended to study complicated scenarios with interesting behaviors. Though the results shown in this work are very preliminary in nature, they show a great deal of promise towards building a more comprehensive model for a riot that could be analyzed to develop useful control strategies. The success of the model in simulating a riot at an intersection is cogently realized by watching the videos of the L.A. 1992 riots [2], as both successful and unsuccessful attempts of rioters have been effectively captured by relatively simple rules.

Future work might be focused towards developing and including more complex behaviors and different scenarios that might be employed in wide-scale applications for military, police and other law-enforcement agencies.

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