Modeling Civil Violence Implementation

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0.1 Introduction

Modeling Civil Violence (MCV) is a concept brought forth by Joshua Epstein, John Steinbruner and Miles Parker in their paper published by the Brookings Institute "Modeling Civil Violence: An Agent Based Approach"[1]. The principle goal behind the paper is that behavior of groups of people can be predictively modeled using a few simple formulae. The MCV paper describes a cellular automata implementation of their ideas and their results.

The MCV paper represents two models of behavior. Model I represents general rebellion against central authority. Model II is a likeness of inter-group violence.

In the MCV implementation each member of the general population is called an "agent". Enforcers of authority are referred to as "cops". Agents in the population are alloted different levels of grievance from an even distribution. This grievance combined with a measure of perceived government legitimacy and the proximity of cops determines the actions and movements of these agents.

In Model I the agent's grievances are with the authority and the perceived legitimacy of the government is a quantity equal across the entire population. Agents with high grievance levels coupled with the lack of local authority (cops), change to an active state if the calculated probability of arrest crosses a predefined threshold. If there is a cop within the allocated vision, it has a calculable probability to "arrest" the agent. If many aggrieved agents are in close proximity and one becomes active, it can be a catalyst for the other agents and escalate into a large group of active agents. These larger overall actions with groups of agents is suggestive of similar human behavior in protests or riots.

In Model II, there are two distinct groups of agents. Legitimacy is defined to be a measure of the other group's right to exist. The grievance level is targeted towards the "other" group of agents. In Model II, when an agent becomes active, it kills a random agent of the other group within its scope of vision. There are cops to arrest active agents, but the density and placement of the cops determines their effectiveness. Model II also implements reproduction in that agent members of the different groups should age, die, and be able to clone themselves into unoccupied spaces.

In the present implementation of Modeling Civil Violence, we address duplicating the results from Model I.

0.2 Implementation

This version of MCV is implemented as a cellular automata in Tcl/Tk. The implementation attempts to be faithful to executing the parameters provided in the appendix of the MCV paper.

There were a few questions about the cloning probability and aging referred to in the Appendix. These parameters implied there was some kind of reproduction, mortality, and fitness going on. An attempt to establish an email dialogue with Epstein was unsuccessful, and I was unable to find a way to communicate with the other authors. This implementation has no mechanism installed to regulate

births, deaths, or aging. I stipulate that with regard to the results, no reproductive/mortality system is required to implement Model I.

0.2.1 User Interface

The user interface is built using the general layout and parameters from the Civil Violence paper. The screen on the left is the Action Screen0.3.1. The Action Screen contains agents - blue squares and cops - black squares. When an agent becomes active, it's color turns to red. When an agent is arrested, its color is turned green. Jailed agents remain on the screen, but are not allowed to move for the number of years, i.e time cycles in their jail sentence. Jailed agents could have been removed from the screen. I am not sure how the original MCV implemented this feature.

The right screen is the Grievance Screen. This screen also contains cops (still black), but the agents are colored according to their grievance levels. My color formula shades agents with a low grievance level a dark green. Agents with higher grievance levels appear from a greenish to a light brown for agents holding the highest internal levels of grievance.

Operation of the model is controlled by inputs to the control area on the right of the screen. Default control values are placed according to the values given in Model I listed in the appendix of the MCV paper.

0.2.2 Implementation Challenges

Complications in the implementation were caused primarily by a personal lack of Tcl/Tk experience. The most serious implementation problem was the inability to obtain a uniform distribution of random numbers. The Tcl rand() function numbers to the lower end just enough to skew the results. This was partially remedied by lifting the BSD rand functions from a Tcl web site.

Execution of the script scales badly. The standard 40x40 array takes approximately four minutes to process one pass time cycle - over sixteen hours for one 200 time cycle run[1]. Simulations were run with the same time steps of 200 cycles, however the world state array was scaled down to 20x20 with regards to the slow execution of the simulation.

0.2.3 Implementation Parameters

Runs one, two, and three were staged to simulate runs two, five, and three respectively of Model #1 described in Appendix A. of the MCV paper. Run one features moderate legitimacy levels, moderate cop levels, and up to 30 year jail terms. Run two features low legitimacy levels, higher cop levels, and up to infinite jail terms. Run three features high legitimacy levels, high cop levels, and up to infinite jail terms.

0.2.4 Agent Behavior

Each agent occupies a single square of both the Action and Grievance screen. Each agent's behavior is determined by the following set of parameters.

1. H: The agent's perceived hardship is drawn from a uniform distribution (0,1).
2. L: The perceived legitimacy of the government. A fixed number between zero and one for this model. Legitimacy is equal across all agents during the run.
3. G: Grievance is H*(1-L). So if the legitimacy is high, the grievance value will low. This value is fixed for the life of the agent.
4. R: The agent's Risk Aversion, is a number chosen at random for each agent from a uniform distribution between zero and one.

[1] Since Tcl interfaces with a C library, it should be possible to get performance gains by making a library of some functions. After reading some literature I found that another cause for lousy performance was due to implementing array data structures rather than lists, which is the structure of choice for Tcl. Unfortunately these performance boosts weren't found out until too late.

Table 1: Separate Parameters for All Runs

Variables	Run 1	Run 2	Run 3
Cop Vision	7	7	7
Agent Vision	7	7	7
Movement	Rand Site in Vision	Rand Site in Vision	Rand Site in Vision
Legitimacy	0.82	0.8	0.9
Maximum Jail Term	30	Infinite (200)	Infinite(200)
Initial Cop Density	0.04	0.074	0.074

5. Va: The agent's Vision. The distance via number of lattice squares in any direction the agent can survey.

6. P: Arrest Probability, is the calculation 1-exp[-k(C/A)v]. Where C is the number of cops within vision Va. A is the number of active agents within the scope of Va. The constant k was provided to to establish a believable estimate such that P equals 0.9 when C and A both equal one. The arrest risk probability P increases as the number of cops increases or the number of active agents decreases. Conversely, if the number of active agents increases and the number of cops within Va decreases, the arrest probability decreases.

7. N: Net Risk is given by P*R, the product of risk aversion and arrest probability.

To calculate an agent's state transition: if G-N is greater than the transition threshold value2, the agent becomes or remains active. If the agent's G-N value is less than the transition threshold value, the agent with become or stay dormant. The MCV paper argues that it is not enough to start a civil disturbance with only a high grievance level. The decision to go active is also tempered by a lack of cops in the proximity and the number of other active agents within vision.

Once during each time cycle, each agent in the model surveys a subset of the grid defined by the scope of its vision, calculates whether to activate or be quiescent, and then moves to a random blank space within its vision.

0.2.5 Cop Behavior

The behavior of the cop is relatively simple, i.e. identify all active agents within its vision and randomly choose one active agent to arrest. The cop completes its action by a random movement to an empty space within its scope of vision.

Table 2: Parameters for All Runs

Matrix Dimensions	20x20
Matrix Shape	Torus
Arrest Prob. Constant	2.3
Max Age (time)	200
Agent Active Threshold	0.1
Population Density	0.7
Agent Updates	Asynchronous
Agent Activation	Serial

0.3 Results

These static snapshots of the system do not give justice to the real dynamics contained here. To see how it all works, one has to watch the behavior of a running system[2]. Watching the agents go active and then inactive near the presence of cops. Watching groups of agents coalesce into action and then break apart show the real power of the system

0.3.1 Run 1

Run one couples moderate legitimacy (8.2) with thirty year jail terms. The fig Run 1 depicts the simulation after thirty two cycles.

0.3.2 Run 2

Run 2 shows a low legitimacy (0.8) coupled with an infinite jail term. There were so many actives that even agents with low grievance levels became active and were subsequently arrested.

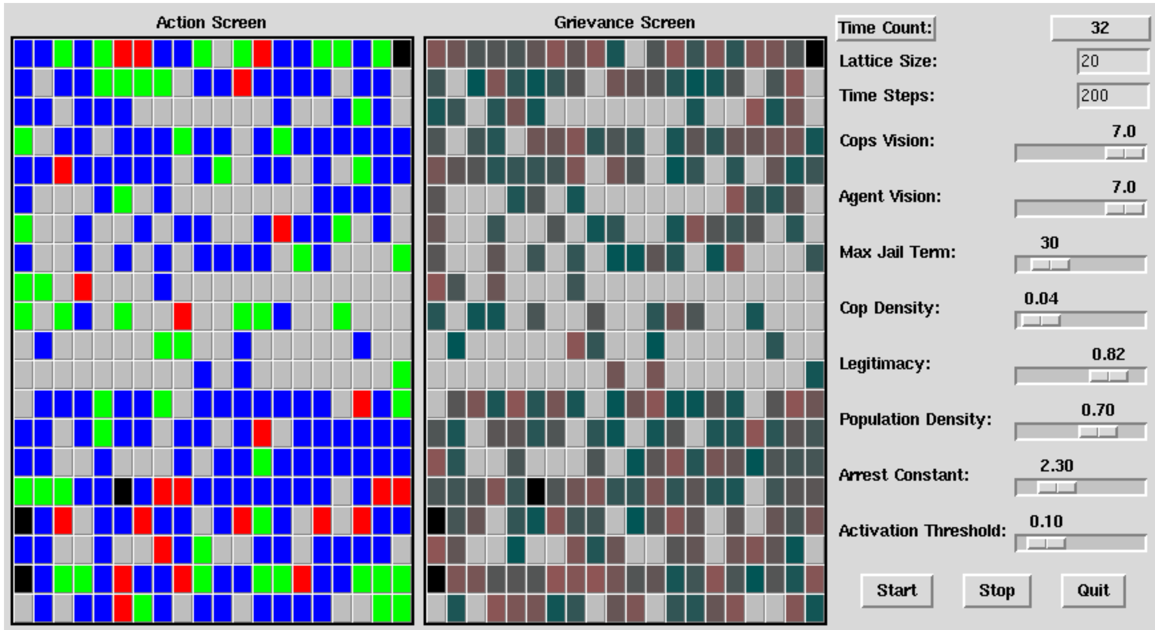
0.3.3 Run 3

Run 3 shows a high level of legitimacy with infinite jail terms. In this model no agents became active.

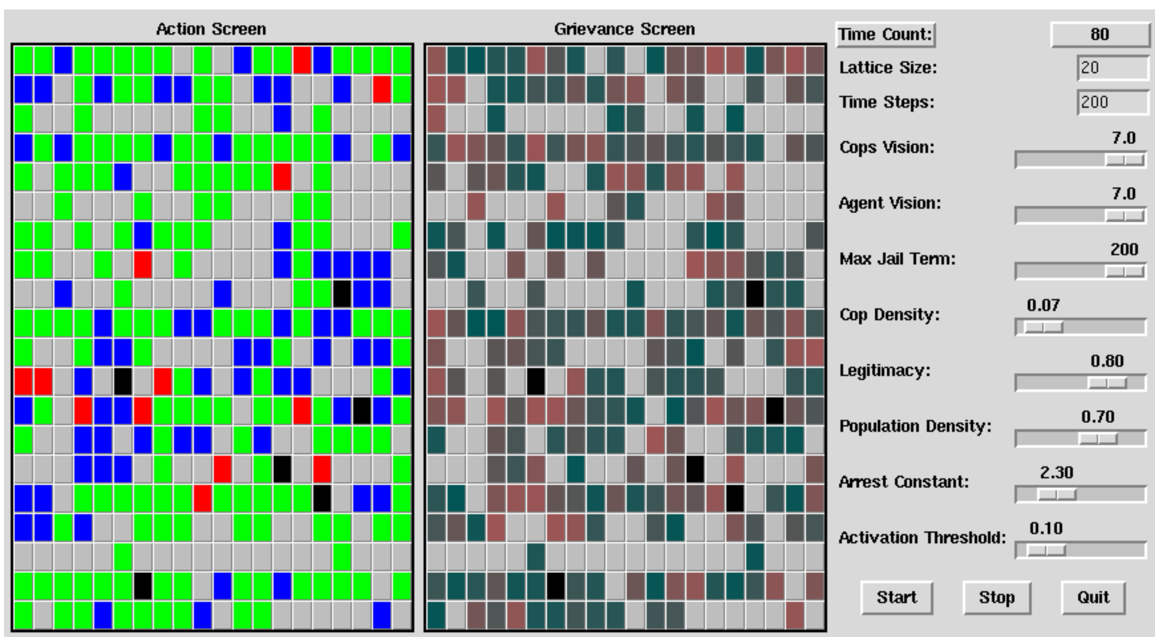
0.4 Analysis

Studying the results of runs one and two follows close to the results stated in the MCV paper. The results of run three differ significantly from the MCV run.

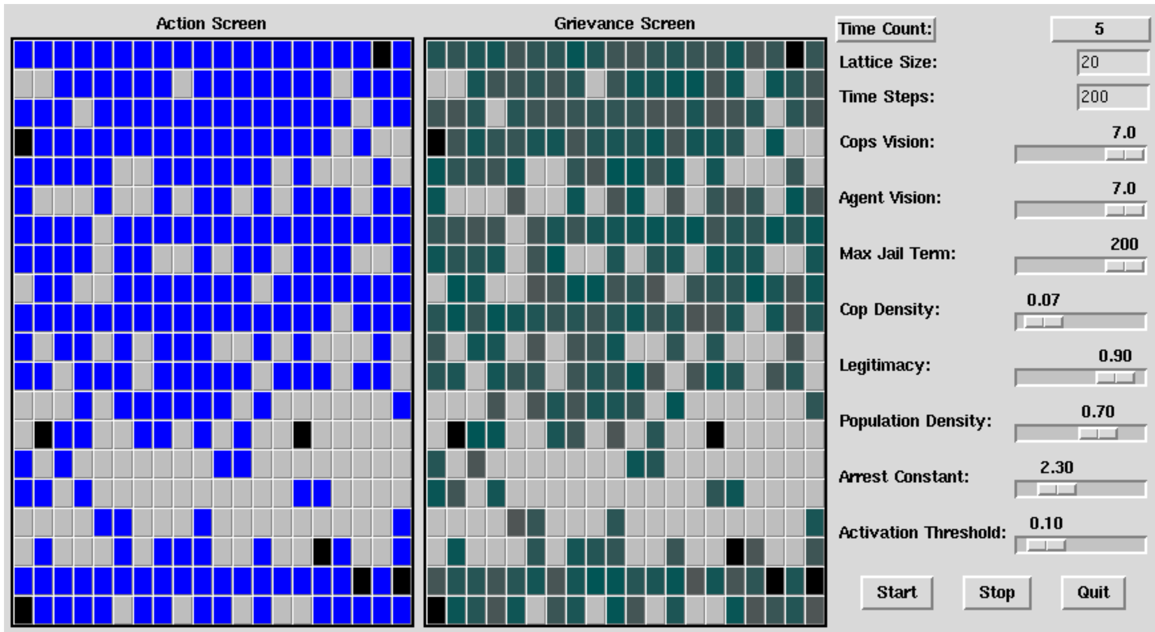
[2]If the system runs too slow, it becomes difficult to follow its behavior.



Run 1 Moderate Legitimacy - 30 Years Jail Terms



Run 3 Lower Legitimacy - Infinite Jail Terms



Run 3 High Legitimacy - Infinite Jail Terms

0.4.1 Run 1 Analysis

My Run 10.3.1 duplicates Run 2 from the MCV paper in which free assembly catalyzes rebellious outbursts. Agents with the highest levels of grievance would activate individually outside the presence of cops. These active agents would evoke other agents with lower grievance levels. The execution screen would show passing pockets of active agents after a few cycles. At that point larger groups of active agents would spontaneously appear. This behavior follows the paper exactly where a group of active agents will rapidly depress the local Cop/Actives ratio and catalyze larger groups of agents into action.

0.4.2 Run 2 Analysis

My Run 20.3.2 follows Run 5 from the MCV paper. This run models lowered perceived legitimacy in the system. The MCV paper labels this run as declining cops, but clearly shows declining legitimacy without lowering the cop density. Oddly enough, my results appear to be similar to the results reported in the MCV paper. What is striking about Run 2 is that lowering the legitimacy of the authority two percent over Run one is enough to cause massive outbreaks of active agents even though cop density is much higher. Note the high

numbers of jailed individual agents.

0.4.3 Run 3 Analysis

Run 30.3.3 is modeled on Run 3 from the MCV paper. This run is supposed to model incremental decline in legitimacy. There is little correlation between the results here and the MCV findings. Instead I have legitimacy at a state of 0.9, as specified by the paper. There is a high density of cops like Run 2, and not one agent turned active in the run.

0.5 Conclusions

The results from this implementation of the MCV paper, Model 1, suggests civil disturbance is more a matter of the degree of dissatisfaction or lack of perceived government legitimacy than it has to do with the proximity of cops in the society. The density of cops provided in Run 1 seem to mitigate the number of active agents, while in Run 2 the cops appear to have no effect on the number of active agents. The moderation of active agents in Run 1 infers that the cop/legitimacy ratio is close to an equilibrium for that run.

One point the MCV paper makes is that this is a model for decentralized rebellion. Rebellion, perhaps, akin to the Watts riots in Los Angeles and the Viet Nam War[3] protests in the late sixties and early seventies. It is clear that the central authority in the form of cops were not effective at that time in their attempts to abate these disturbances.

There is a connection between the agents' behavior and the Stag Hunt Dilemma[2, 291]. Which is a system of competition vs. cooperation where if an agent cooperates, then it will benefit more if the other agents cooperate. The Agents in Model I have a smaller probability of arrest if they all go active together. Agents that go active alone are easily picked off one by one by the cops. The dilemma is then when to become active.

0.5.1 Serious Questions

The Arrest Probability update equation uses the constant "k" to calculate the arrest probability "P". Ostensibly this constant is to give a plausible P= 0.9 when C=A=1. The problem is that k is only valid when the agent vision is equal to 1.0. All my runs used a vision of 7.0

[3] The author is happy to be counted as one of those protesters.

as specified in the MCV appendix. This seriously skews the results. For example, if you calculate probability P using vision 1.0 and have a 1 cop density in the area your arrest probability is about 0.9 just as reported in the MCV paper. On the other hand, if you calculate P using a vision of 7.0 and have one cop within vision, the arrest probability jumps to 1.0![4]

One way to solve this problem would be to make k a function of the ratio of the cop's vision to the ratio of the agent's vision. It seems to make sense that if you can see farther than your opponent, it would mitigate the threat. Conversely, if your opponent could see farther than you, it would imply a greater threat even if you saw only a few of them.

0.5.2 A Difference of Opinions

While I make no claim to attempting to Duplicate Run 1 from the MCV paper, I am disturbed by the conclusions that were reached by the authors. They initially claim that the agents are capable of unanticipated deceptive behavior. For an example, they show an agent between two cops with a high level of grievance in one picture and then show the agent going active in the next as soon as the cops move away. They go on to quote Mao and then state that its behavior was easily understood after looking at the math. This behavior was completely anticipated by me. I consider the suggestion that the agent behavior could be deceptive to be delusory.

0.5.3 Of Possible Future Interest

It would be interesting to implement a model that implements centrally controlled rebellion or disturbance. It could give insight into how some organized groups of fanatics operate.

[4]It is unfortunate that I did not discover this until the conclusion.

Bibliography

[1] Modeling Civil Violence: An Agent Based Approach, Joshua Epstein, John Steinbruner, and Miles Parker, Brookings Institute, Center on Social and Economic Dynamics, Working Paper #20, January 2001.

[2] The Computational Beauty of Nature, Gary William Flake, The MIT Press, 2001.