Effect of mobility on violence in a bi-communal population.

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ABSTRACT

We develop a multi-agent based model to simulate a population which comprises of two ethnic groups and a peacekeeping force. We investigate the effects of different strategies for civilian movement to the resulting violence in this bi-communal population. Specifically, we compare and contrast random and race-based migration strategies. Race-based migration leads the formation of clusters. Previous work in this area has shown that same-race clustering instigates violent behavior in otherwise passive segments of the population. Our findings confirm this.

Furthermore, we show that in settings where only one of the two races adopts race-based migration it is a winning strategy especially in violently predisposed populations. On the other hand, in relatively peaceful settings clustering is a restricting factor which causes the race that adopts it to drift into annihilation.

Finally, we show that when race-based migration is adopted as a strategy by both ethnic groups it results in peaceful co-existence even in the most violently predisposed populations.

Categories and Subject Descriptors

I.6.5 [**Simulation and Modeling**]: Model Development, Modeling methodologies J.4. [**Social and Behavioral Sciences**]: Sociology.

General Terms

Experimentation, Human Factors.

Keywords

Description level: experimental/empirical: simulations

Inspiration source: social sciences

Focus: Comprehensive/Cross-cutting (multi-agent based simulation), Social/Organizational (groups and teams, emergent behavior), Environment (environment modeling & simulation)

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1. INTRODUCTION

Agent-based models have long been used to simulate social phenomena: ethnic tension is one such example. In T.S. Schelling's classic model of segregation [1], mild preferences to be near to members of one's own racial group quickly lead to complete self-segregation. Starting from a fully integrated state, each agent acts in turn and examines its position within the grid. If the adjacent cells contain less than a predefined number of common agents, the actor moves to a cell meeting this criterion. If this behavior holds true in peacetime, it can be reasoned that these actions are even more likely during inter-ethnic civil violence when random movement takes nothing of the environment into account.

Segregation has been used as a way of attempting to curb racial tensions several times in the real world: the Turkish invasion of Cyprus in 1974 led to the widespread migration of dissatisfied Turkish Cypriots from ethnic enclaves as well as racially integrated villages scattered about the country into the island's north, while until July 2008 California prisons segregated inmates along racial lines as a method of controlling race and gang-related violence [2].

The paper is arranged as follows: in section 2 we evaluate relevant work in the context of our model, with particular focus on the effect of crowd formation ("clustering") on levels of violence. Section 3 deals with the specifications of the model and details the rules that govern the behavior of the actors within it. Section 4 explains the experimental procedure and initial assumptions of the model for each experiment undertaken, while section 5 presents and analyses the results. Finally, a summary of the data presented is offered in section 6.

2. BACKGROUND

The basis of the model described in this paper is a recreation of the inter-group violence model detailed in Epstein's *Modeling Civil Violence* [3]. This model, which is composed of two adversarial ethnic groups of actors ("agents") occupying a grid patrolled by "cops" who move about the grid attempting to quell violence between the groups, provides a useful starting point for a study of this kind.

Several attempts at expanding upon Epstein's work in this area have been made, including Goh et. al's game theoretic approach [4] which combines Epstein's approach to defining grievance with prisoner's dilemma-inspired decision rules for agents. They were able to replicate and expand on Epstein's results by allowing civilians to learn from past actions. Epstein's civil violence model is simple and easy to implement; this simplicity means additional behaviors may be added with a low risk of confounding factors influencing results. It therefore offers a suitable and standard starting point for civil violence-related experiments which might otherwise be difficult to conceptualize and implement.

Other works have examined migration and mobility in a civil violence context: Jager et. al [5] examine the effect of including different sets of actors who move to form clusters in an inter-race violence scenario. In this model agents are divided into three subclasses: bystanders, hangers-on and hardcore. All actors within the Jager et. al model possess the tendency to move close to members of their own crowd. An interesting finding of this work was the fact that even when the hardcore and hanger-on agents were greatly outnumbered, they tended to account for a disproportionate level of violence within the model. Clustering in this model serves to increase tensions and leads to higher levels of violence than would otherwise be observed. As in our model, actors' decision of whether to become violent or not is governed by the likelihood of being caught – bigger crowds lead to less chance of being caught and so more violence.

Similarly, Cameron and Parikh [6] propose that without the ability to congregate into large groups, civilians are less likely to engage in civil violence. They suggest that the members of small clusters are only likely to become violent if they are so aggrieved that they would do so regardless of the actions of the other group members. Large crowds are posited to be potentially more dangerous because a lower level of grievance is required to ignite large-scale violence, though coordination of attacks increases in difficulty with the size of the crowd. While our model is able to replicate the behavior of otherwise peacefully disposed individuals engaging in violence when a part of large violent crowds, we also show that congregation along racial lines prevents aggressors of opposite races meeting, which often denies them the chance to become violent.

This paper will compare and contrast the relative effects of random movement and racial migration on levels of violence within a civil violence simulation. We will also aim to identify the optimum strategy for peaceful coexistence and the movement methods that give the highest chance of individual survival given more or less violently disposed populations.

3. MODEL

The model comprises a grid containing two sets of agents: civilians and peacekeepers. Civilians represent members of the population and are further divided into two distinct (though functionally identical) racial groups. Civilians are able to move and, given the right combination of utility values, to kill members of the other racial group (to "go active"). Peacekeepers are members of a military force deployed to act as a deterrent against inter-group violence and to arrest those who engage in it. Each agent acts once per simulation step.

3.1 Peacekeepers

Peacekeepers roam the grid searching for active civilians to arrest. At each step, they inspect the cells within their radius of vision (V_p) and compile a list of civilians in those cells who are active at that step. The peacekeeper then chooses randomly from that list and arrests the civilian, temporarily removing it from the grid. The peacekeeper then moves into the grid location occupied by the arrested civilian. If no active civilians are found, the peacekeeper moves to a random free location within their radius of vision.

A civilian that has been placed under arrest is removed from the grid for a certain amount of time steps. This models the civilian being removed from the community and placed in jail. The jail term for an arrested civilian is determined as a random number drawn from the range $(0, J)$ – where J is the maximum jail term. J is exogenous and the same for all civilians. When a civilian is released from jail they are returned to a random location within the grid in a non-active state.

3.2 Civilians

Civilians are split into two racial groups, nominally "blue" and "green". In this model, the groups are roughly equal in number and possess identical attributes and behaviors. Civilians may either go active and kill a member of the opposite race or migrate to another grid location.

3.2.1 Violence between civilians

A civilian's decision to go active is taken by comparing two utilities, the utility of being inactive (U_I) and the utility of being active (U_A), and choosing the action which carries the highest utility value:

U_I is the utility of being non-violent (inactive) and is exogenous, uniform across all civilians and remains constant throughout the simulation.

U_A is the civilian's utility of going active and is a composite variable, given by equation 1 below:

Equation 1: $U_A = P_{AR}U_{AR} + P_{NAR}U_{NAR}$

U_{AR} is a constant, exogenous and uniform value specifying the utility of, if targeted, getting arrested by one of the peacekeepers after going active and killing another civilian.

U_{NAR} is the perceived benefit of killing another civilian and escaping without retribution from peacekeepers. This utility value is drawn from a Gaussian distribution of the values $(0,1)$. This value represents the spectrum of personal beliefs from absolute pacifism ($U_{NAR} = 0$) and unbridled aggression ($U_{NAR} = 1$), with a middle ground of uneasy tension. Values are assigned to each race separately to avoid bias.

P_{AR} represents the estimated probability of getting arrested while P_{NAR} is the estimated probability of going active but escaping arrest. The values of these are given by equations 2 and 3.

Equation 2: $P_{AR} = 1 - P_{NAR}$

Equation 3: $P_{NAR} = \left(\frac{\alpha - 1}{\alpha}\right)^P$

Where P represents the number of all the peacekeepers this civilian's radius of vision, and α represents the number of active civilians within this civilian's radius of vision. This probability calculation is only an estimate of the real probability and it is based on the civilian's assumption that what it observes within its radius of vision is representative of what happens in the rest of the field. This behaviour is similar to that presented of the actors in the studies of both Jager [4] and Cameron [5].

3.2.2 Migration

There are two types of migration allowed for in this model: random migration and race-based migration. In both cases, before any movement occurs the civilian compiles a list of empty cells within its vision range (V_C).

Random migration is, as the name suggests, untargeted movement about the grid in which the civilian's choice of location is selected randomly from the list of empty cells within its V_C.

Race-based migration involves an evaluation of all the free cells within the civilian's V_C. The civilian moves to the location surrounded by the greater number of members of its race (see [2]). If a number of locations have the same number of same-race neighbors, one is chosen at random.

3.2.3 Differences to Epstein's model

This model eschews the somewhat arbitrary hardship, legitimacy variables and calculation of the probability of arrest of Epstein's model in favor of a simpler game theory-inspired utility approach to defining civilian grievance. This allows for a more transparent determination of whether a particular civilian is likely to go active or not. Additionally the utilities in our model are drawn from a Gaussian distribution whose mean elegantly represents the violent predisposition of the entire population. We investigate the effect of this predisposition on the levels of violence occurring in the system.

We have been able to recreate the experiments of Epstein [1] where peaceful coexistence, ethnic cleansing and safe heavens emerge given a certain sets of initial conditions. The civilians in our model as presented in section 4.2.1, exhibit the same behaviour as Epstein's while maximising their expected utility. The difference is that they do so while following rational behaviour.

The additional factors influencing migration contained within this model allow for the markedly varying characteristics of different conflicts to be more accurately recreated than in a typical model which restricts movement to adjacent cells only.

4. EXPERIMENTS

In this paper, we are investigating the effect different migration methods have on civil violence through a range of average inter-group tensions. Three sets of experiments were conducted, each seeking to explore the effect that race-based migratory behavior of civilians had upon inter-group violence within the simulation. Under random migration, movement is untargeted, while in race-based migration, civilians display a propensity to (given the right conditions) move towards members of the same race.

We examine levels of violence when civilians migrate randomly, when they migrate towards members of their own race, and the two types of behavior are run together to produce a comparison of the relative merits of each behavior.

Each experiment was run over the full range of mean average civilian U_{NAR} values, in steps of 0.1. Ten runs for each incremental U_{NAR} value from 0 to 1 were conducted; each data point in the graphs represents an average value for each set of ten runs. In all experiments both races start with equal numbers of civilians. At the end of each run in each experiment the "finishing state" is recorded. This is a measure of the number of civilians belonging to the most populous race at the final step of the simulation, or when all members of the other race are killed, whichever occurs first. This metric enables us to analyze the levels of violence within the experiments and gives a like-for-like barometer of the effectiveness (in terms of civilian survivability) of each method.

Tables 1 and 2 include detailed initial conditions for all the experiments run.

Table 1. Individual simulation parameters for experiments

	Blue civilian migration model	Green civilian migration mode
Experiment 1	Random	Random
Experiment 2	Random	Race
Experiment 3	Race	Race

Table 2. General simulation parameters for all experiments

Constant	**Value**
Grid size	120x120
Topology	Torus
Simulation length	1000 steps
Initial population density (blue civilians)	0.3
Initial population density (green civilians)	0.3
Initial population density (peacekeepers)	0.005
Civilian vision	5
Peacekeeper vision	5
Civilian U_I	0.5
Civilian U_{AR}	0.01
Mean U_{NAR}	0 -1 in steps of 0.1

5. RESULTS

In this section we analyze the findings from our experiments. For each of the three experiments, two graphs are presented. The first is a numerical measure of, when the results of each set of ten runs are averaged out, the average number of each race at the finishing state. The second shows this value as a percentage figure of remaining agents to better illustrate the winning race and their margin of victory. Screenshots of the simulation are included, allowing for intuitive judgments about the progress of a typical run in each experiment to be made. The grid shows a collection of blue and green dots on a grid: each represents one civilian of that ethnic group. Black dots represent peacekeepers.

5.1 Random only

To establish a baseline, this experiment presents an investigation into the finishing state of runs in which both races migrate randomly.

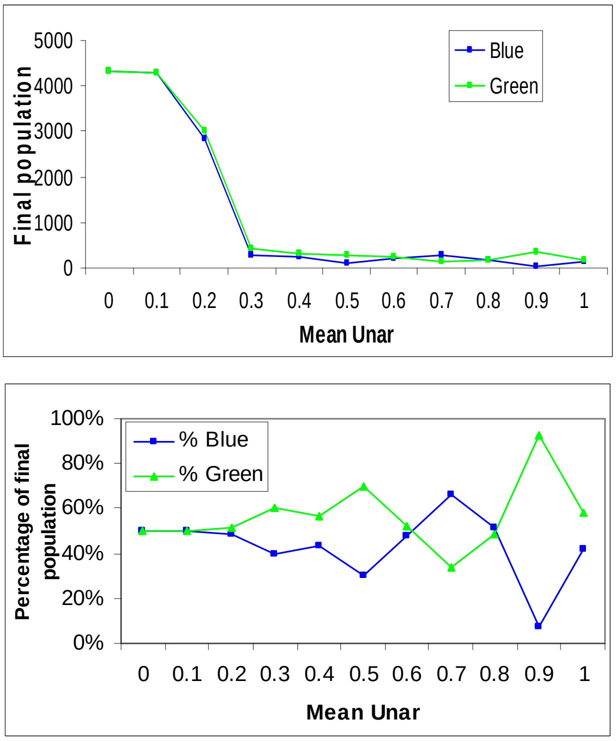


Figure 1. Random migration for both races: final populations.

Both races follow the same trends, but the "winner" is random.

Low final population values, with a narrow "win" by one race as they manage to kill all of their competitors before they are wiped out themselves, are frequent when mean U_{NAR} values above 0.3, i.e. when civilians are on average moderately to strongly predisposed towards violence. As disposition towards violence rises, many more civilians are created whose U_A value exceeds their U_I, suggesting that random migration of both races produces large amounts of violence, including frequent occurrences (and near-misses) of complete ethnic cleansing. Random migration means neither race is afforded the opportunity to actively segregate themselves and create a large cluster of members of the same race. This results in the eventual "winner" being entirely down to chance.

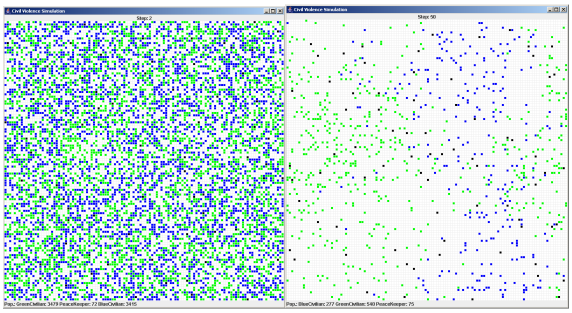


Figure 2. Screenshots of a typical random migration run.

Both races are still integrated at early steps, but as the simulation proceeds, inter-group violence both thins out the population and leads to unplanned segregation

5.2 Race only

In this experiment race-based migration was enabled for both civilian races.

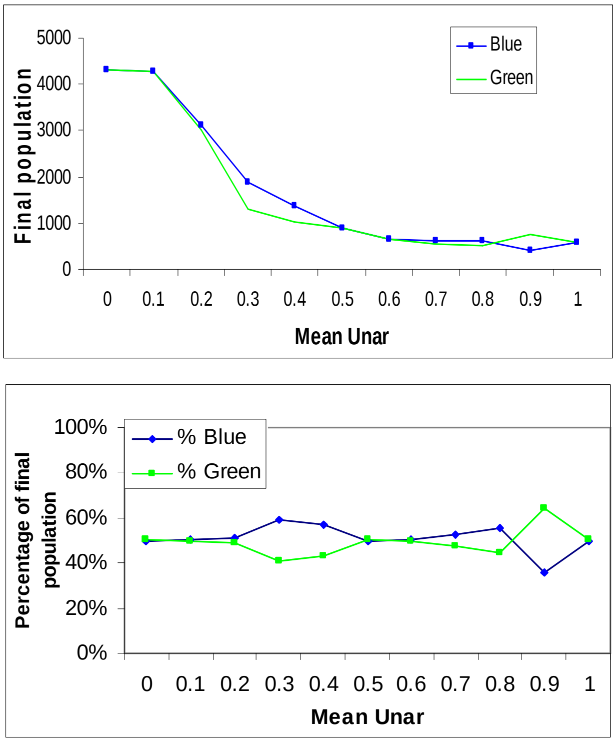


Figure 3. Race migration for both races: final populations

Both races continue to follow the similar trends, and once again the "winner" is random.

Violence was significantly lower than under random migration. Even at the very lowest point in the first graph in figure 3 there are still in the order of 500 remaining survivors, a great deal more than in random migration. We can see that from the higher number of survivors that for both peacefully and violently predisposed populations, civilians are content to cluster into contiguous, segregated groups. Once these clusters have formed, the predominant form of violence observed is when the "buffer zones" between the clusters become too small. This may lead to either violence at the edges of the two groups until a big enough buffer is created, or, if the buffer becomes small enough, the complete destruction of one of the clusters with the numerical disadvantage (or both, at higher U_{NAR} levels).

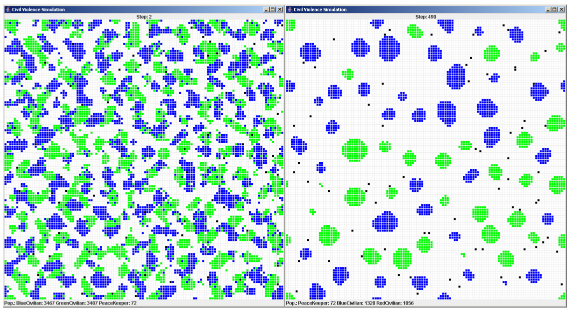


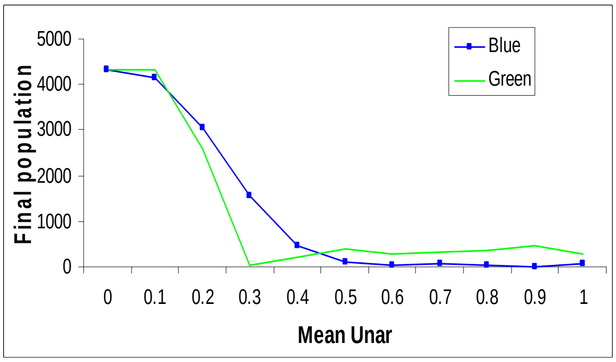
Figure 4. Screenshots of a typical race migration run

Clustered civilians establish buffer zones at early steps as clusters impinge on one another's territory. Once the buffer zones are established, violence is greatly reduced.

When "buffer zones" are large enough the two race groups are clearly segregated in isolated clusters scattered around the grid community. In this case, the two races never come into contact, violence does not break out and we observe peaceful co-existence if at high U_{NAR} values (where the populations would have high tendency to engage in acts of violence). As in the experiment described in section 5.1, when both races adhere to the same migration method, the finishing state (in this case, the race with the numerical edge – the final result of these runs is always peaceful existence) at each U_{NAR} value depends on starting positions and is therefore random: this is borne out in Figure 3.

5.3 Random vs. Race

In this experiment, racial migration is enabled for green civilians, while migration for blue civilians remains random. In conducting this test, we demonstrate the difference a civilian's migratory decision-making makes to its chances of surviving in times of civil violence.



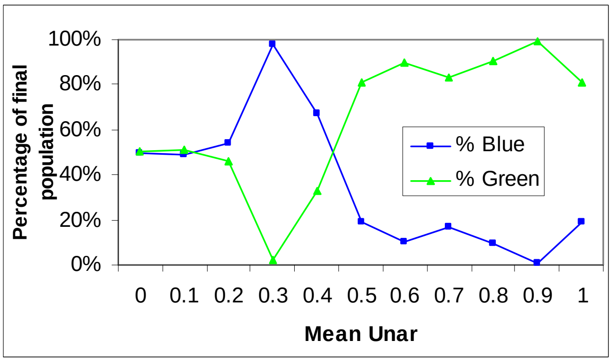


Figure 5. Race migration for greens vs. random migration for blues: final populations

Random clustering is the clear winner for low Unar values, while racial clustering wins at higher values.

Figure 5 shows an interesting trend towards increased survivability using random migration in more peacefully disposed populations, with racial migration faring better under increased violence. On inspection of the simulation, the reason for this becomes clear. At lower U_{NAR} levels, as would be expected, less fighting occurs at the crucial stage before green agents are able to form clusters, which as a result leaves the grid quite densely populated. When the clusters do form, they are relatively immobile in comparison to the swarming blue civilian agents unconstrained by a proclivity towards segregation, meaning they are able to do little more than defend their territory.

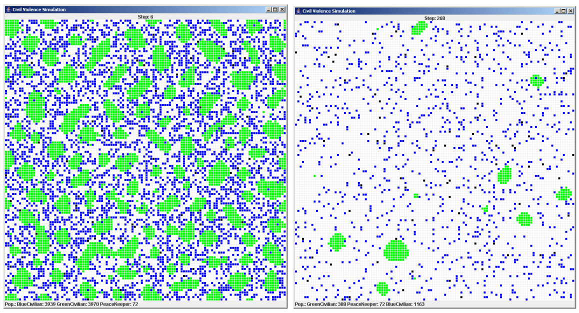


Figure 6. Screenshots of a run combining random and race-based migration at low violence levels

Most civilians survive the violence before clusters have time to form, leading to a densely populated grid. Blue civilians are easily able to find clusters to attack, which allows them to create a decisive numerical advantage.

This defense is made difficult by two factors. The first is a numerical disadvantage – at equal racial populations, the number of green civilians actually able to fight is significantly less than that of the blues, due to the fact that many of their civilians are encased within large clusters and are either unwilling to move to a location containing less than the required number of green agents (as the borders tend to, especially when under heavy attack), or unable to move outwards from center positions due to not being able to see the fronts in clusters with diameters of civilians larger than the vision radius.

Secondly, because initial blue placement and movement are both random, fighting tends to occur in small but significant amounts across all clusters rather than be focused at a few points, peacekeepers are left with too many separate engagements in proportion to their numbers to be able to police them all effectively.

At higher U_{NAR} values however, the clustering of the greens lends them a significant advantage. Because higher violence levels at the steps prior to clustering being completed mean, more casualties leaving the grid is more sparsely populated, peacekeepers are given fewer violence hotspots to be drawn to, increasing their effectiveness.

However, peacekeepers are not the sole reason for the relative success in terms of survivability of clustering at higher U_{nar} levels. With denser populations, the random movement pattern of blue civilians matters little: they are usually not far removed from a cluster of greens, so they tend to be able to stumble upon one in a matter of a few steps. This becomes much less likely when populations are sparse - the relative size of clusters is not altered, just their ubiquity – meaning large amounts of blue agents are left to wander for much longer periods before they are able to find a target. This, of course, means a proportional reduction in blues killing greens at any given step, and clusters, with the help of peacekeepers, are remarkably good at defending themselves against frequent attacks by solitary blue civilians. With blues unable to coordinate their strikes, the clusters of greens simply lie in wait as their numerical disadvantage at lower U_{NAR} levels becomes a numerical advantage at higher ones – there are always several greens able to fight in a cluster, compared with proportionally fewer blues.

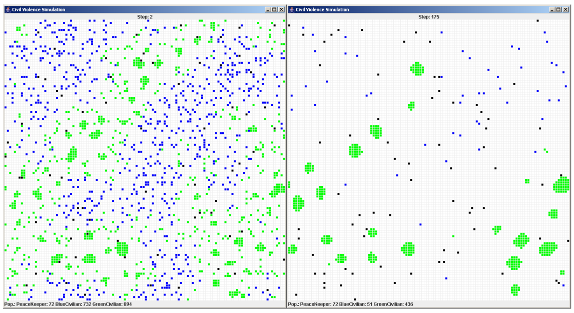


Figure 7. Screenshots of a run combining random and race-based migration at high violence levels

High initial levels of violence leave the grid sparsely populated. The clusters are left with more space in which to defend themselves and emerge victorious.

Therefore, it is reasoned that the survivability of clusters under race migration vs. random migration largely depends on initial violence levels. The relative differences between the two ranges before and after the crossing point at $U_{NAR} \approx 0.5$ could be compared to a siege at the lower range, while higher levels might be likened to the Powell doctrine, a military policy dictating the use of overwhelming force at the outset of a war to minimize civilian and friendly casualties [7]. In this case, siege tactics are the clear winner if the blue civilians are regarded as the aggressor. The problems with using overwhelming force in this scenario are twofold: first, the blue civilians don't possess the required edge in terms of numbers, nor do they have the ability to kill greens any more effectively than they may be killed themselves. In this case, the attempt at overwhelming force becomes a simple bayonet charge – just as many blue civilians are killed as greens, and the resulting loss of numbers greatly impairs the effectiveness blue assaults on the fortified green positions.

6. CONCLUSIONS

In this study, we presented an agent-based model of civil violence based upon a model created by Epstein which was established as a simple and reliable starting point for a model of civil violence. We enhanced the decision-making abilities of Epstein's agents using a utility-maximising approach, and added into the model the ability for agents to migrate towards members of their own race based upon the rules of the actors within Schelling's model of segregation.

Using the results of our model, we were able to establish a link between the relative success of random and race-based migration in peacefully or violently predisposed populations. Given a starting point of racial integration with equal numbers on each side, race-based migration was found to be the optimal strategy when civilians are more violently predisposed, while random migration gave a better chance of survival in relatively peaceful populations.

We also found that peaceful coexistence arises when civilians have the compulsion to be near to those of their own race. Not wanting to abandon their "safety in numbers" means that those civilians stuck at the borders of each cluster engage in violence until acceptable buffers of empty cells are established, behavior which is reminiscent of the creation of demilitarized zones at the boundaries of previously hostile countries in reality.

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