An Agent-based Model of Crisis-Driven Migration

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Michael Makowsky[1], Jorge Tavares[2] Tamas Makany[3] and Patrick Meier[4,5]

[1]*Economics Department, George Mason University, Virginia, US*
[2]*Department of Computer Science, University of Coimbra, Portugal*
[3]*School of Psychology, University of Southampton, UK*
[4]*The Fletcher School of Law and Diplomacy at Tufts University, Boston, US*
[5]*Center for Study of Civil War (CSCW), Peace Research Institute, Oslo (PRIO), Norway*

Abstract

The literature on ethnic migration suggests that natural disasters, armed conflict, economics and cultural networks are key drivers of migration. The dearth of geo-referenced ethnic data, however, limits the value of econometric analysis. We build an agent-based model to simulate crisis-driven migration. Agents within a multi-ethnic population monitor their spatial environments to formulate perceptions of the risk of being persecuted. The expected utility of staying within a given neighborhood is inversely related to the perceived probability of persecution. Cultural networks temper an agent's security calculus, with strong social ties dampening the human security dilemma. Agents express preferences regarding the different ethnic groups in their spatial environment and social network. Social networks expand over time, but are often negatively impacted by exogenous social shocks. The resulting migratory patterns and ethnic clustering is a product of the confluence of event location and magnitude, ethnic tension, demographic factors and breadth of networks. Initial finding suggest that crisis-driven migration patterns are influenced by shock size and magnitude.

Introduction

Natural disasters and armed conflicts continue to produce millions of displaced individuals each year. Between 1990 and 1999, an estimated 188 million people per year were affected by natural disasters, 31 million by armed conflict" (Purvis and Busby 2004, 68). These phenomena, and others similar to them in scope and impact, are associated with event driven migration. Previous research shows that human ethnic migration depends on complex interactions between different factors of social network formation (Byrne 1998; Spicker 2001; Vaughan and Penn 2006; Vaughan et al. 2005). The literature on transmigration and conflict suggests that violence, economics and cultural networks are key drivers of migration (Schmeidl 1997; Davenport, Moore and Poe 2003; Moore and Shellman 2004). Of those variables, violence and cultural networks are empirically the biggest predictors of forced migrant episodes (Shellman and Stewart 2006).

With a notable lack of geo-referenced micro level data, there are considerable challenges in constructing models directly from our empirical understanding of these realities. An alternative is to construct a rules-based model that, as a theoretical construct, generates an abstract outcome representative of the observed reality. We seek to model agents within a multi-ethnic setting that monitor their *spatial* environments to formulate expectations about becoming a victim of persecution. The expected utility of any one location is resultant of a security calculus derivative of mixed ethnicity neighborhoods and cultural networks, wherein strong social ties may dampen the security dilemma.

The Model

The Ethnic Migration Model (EMM) is composed of agents with exogenously assigned ethnicity tags operating on a two dimensional lattice. There are a set number of ethnicities, each represented in equal numbers. Agent migration occurs via random exogenous selection or motivated by agent dissatisfaction with the ethnic status of their neighborhood. This dissatisfaction may be a product of the coincidence of other agent geographical decision making or the occurrence of an exogenous shock to the region; a scheduled event that affects a certain number of agents, in a region of the world, during a particular amount of time. Ethnic migration movements initiated by exogenous shocks is the investigative subject of this model.

The model was implemented using the MASON[1] toolkit, a single-process discrete-event simulation core and visualization library, and aimed at large multi-agent simulations. The model comprises the existence of a single shock. Agents exist in a 50 by 50 cell, toroidal lattice that serves as the world in the EMM without occupying the same coordinates. An individual agent, a_i, is defined by its permanent ethnicity, e_i, spatially represented local neighborhood, and social network. An agent's neighborhood includes the spaces that surround it (above, below, left, right and respective diagonals)

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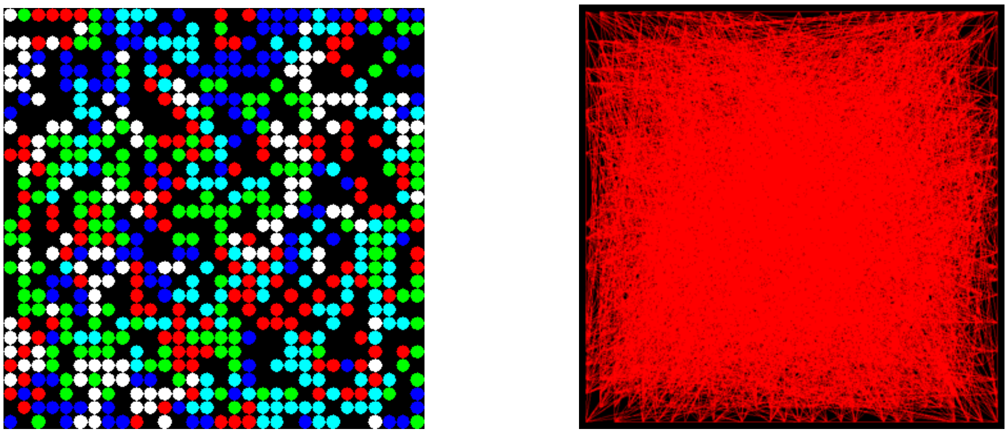
[1] Available at http://cs.gmu.edu/~eclab/projects/mason/.

within a pre-defined radius[2]. The population, existing spatially on a lattice, is simultaneously represented graph theoretically as nodes, whose connecting edges serve to define each agent's social network. For the purposes of this model we will define an agent's network as a first-degree network: only those agents with whom an agent is directly connected to.



1a. **1b.**

Figures 1a and 1b. The lattice and network graphs at t=0.

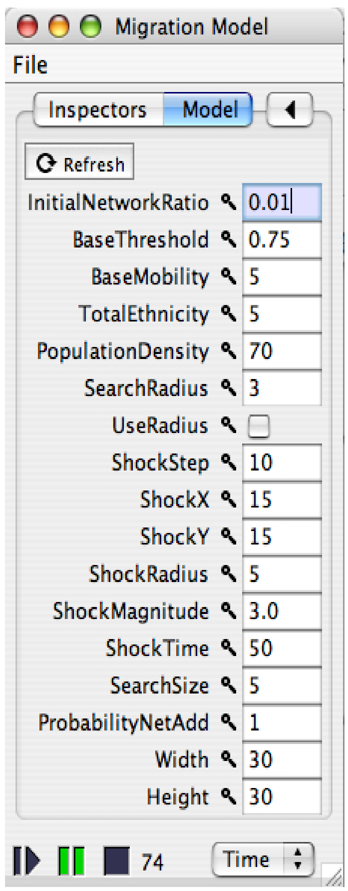
The motivation underlying the model is identical to that found in the seminal Schelling (1978) construct: agents have a local neighborhood and a threshold, h_i, as to the percentage of differing ethnicity agents they are able to cope with before they search for a new location to move to. From this basic motivation, however, we make several key departures.

1) *All different agents are not viewed the same.* An agent's neighborhood, relative to her threshold, is evaluated with regards to the number of agents of differing ethnicity *who are not within the evaluating agent's social network*. As such an agent may happily abide in an extremely diverse neighborhood, so long as many of her neighbors are part of her network.
2) *Exogenous movement*. Agents do not always have control of their location. A fixed percent of the population is randomly chosen to move every turn.
3) *Selective Search and generic location preference.* Agents when moving evaluate v randomly chosen spaces within a given radius r, comparing which spaces offer the largest number of same ethnicity neighbors. Spaces with identical counts same ethnicity neighbor will be compared based on proximity to the center. Agent preference to favor more central locations is analogous to the financially, politically, and socially preferred dimensions of most regions.
4) *Tolerance thresholds are not consistent*. In the event of an exogenous shock, an agent's threshold may lower, prompting movement where previously there was contentment.
5) *Social networks exist beyond spatial dimensions*. Agents are able to grow their networks beyond their own ethnicity. This portends for potential stability.

[2] A radius of one would result in the standard Moore neighborhood.

Conversely, ethnically motivated movement comes at the detriment of network connections to different ethnicity agents.

Figure 2 depicts the model's individual parameters. These are exogenously assigned by the user at the time of experimentation.



Parameter Explanation
- Number of edges in the initial network configuration
- Migration threshold expressed in percentage
- The probability of an agent moving in a random way
- Number of ethnic groups mapped on the lattice
- Density of cells occupied
-An agent's search radius when evaluating migration
- Use search radius (Boolean operator)
- Number of time steps before shock
- X-coordinate of shock location
- Y-coordinate of shock location
- Radius of shock impact
- Magnitude of shock
- Time steps during which shock time impacts lattice
- Number of cells agent considers migrating to
- Probability of an agent adding another to social network
- Width of lattice
- Height of lattice

Figure 2. The console panel and parameter explanations.

The exogenous shock mechanism is the point of exploration in the EMM. Shocks are scheduled events, with specified event times t_j, durations d_j, magnitudes m_j, and radius r_j. During a turn within d_j turns of time t_j, an agent whose location is within distance r_j of the location of the shock will have increased fear of persecution manifested in having their threshold recalculated to equal the model's base threshold divided by the magnitude, m_j, of the shock.

$$(1)\ \left[\sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2} < r \cap t_j \le t < \left(t + d_j\right)\right] \rightarrow h_i = \frac{h_{base}}{m_j}$$

During the course of a realized model run, an agent's social network will change. An agent is initialized with a set probability, which any agent within her local neighborhood may be in her social network. Over the course of the model, agents may add to their network during any turn in which the agent does not move, with a given probability, that a randomly chosen neighbor will be added to its network. Conversely, in any turn where the agent chooses to move based on its threshold for different ethnicity agents being exceeded, it will lose all of its connections to agents of differing ethnicities.

Experimentation

Preliminary exploration of the model was carried out with the parameters found in Table 1. Shocks occurred at time step 100 in the center of the lattice. Note that shock radius is the dimension explored in these initial tests.

Table 1. Baseline Parameterization

Agents and Global Attributes	Exogenous Shock Attributes
Neighborhood Radius = 1	Shock Radius = 3
Exogenously Mobility = 5%	Shock Magnitude = 3, 6, 20
Threshold = 75%	Shock Duration = 100 steps
Population Density = 70%	
Number of Ethnicities = 5	
Probability of Adding to a Network = 1%	
Search Size = 5 locations	

The multiple screen shots depicting the model's numerous simulations are included in the appendix. In the section that follows we discuss the patterns noted in the simulations.

Preliminary Results

In visually evaluating the preliminary results there are two key dimensions that present themselves as salient characteristics: cluster size and ethnic homogeneity. Seen in the appendix and summarized in Table 2, the homogeneity of neighborhoods correlates to the size of the shock, whereas the capacity for ethnic groups to form large, monolithic clusters, as opposed to a distribution of smaller clusters, correlates to the range of agent searches.

Table 2 Visual Results

Specification	Cluster Size	Homogeneity
Small shock, limited search	Small	High
Small shock, unlimited search	Large	High
Medium shock, limited search	Small	High
Medium shock, unlimited search	Large	High
Large shock, limited search	Small	Low
Large shock, unlimited search	Large	Low

Further, when agent search is unlimited in radius, we observe regionally limited network structures with ethnically homogenous regions, indicating that multi-ethnic networks have not reformed since the shock event.

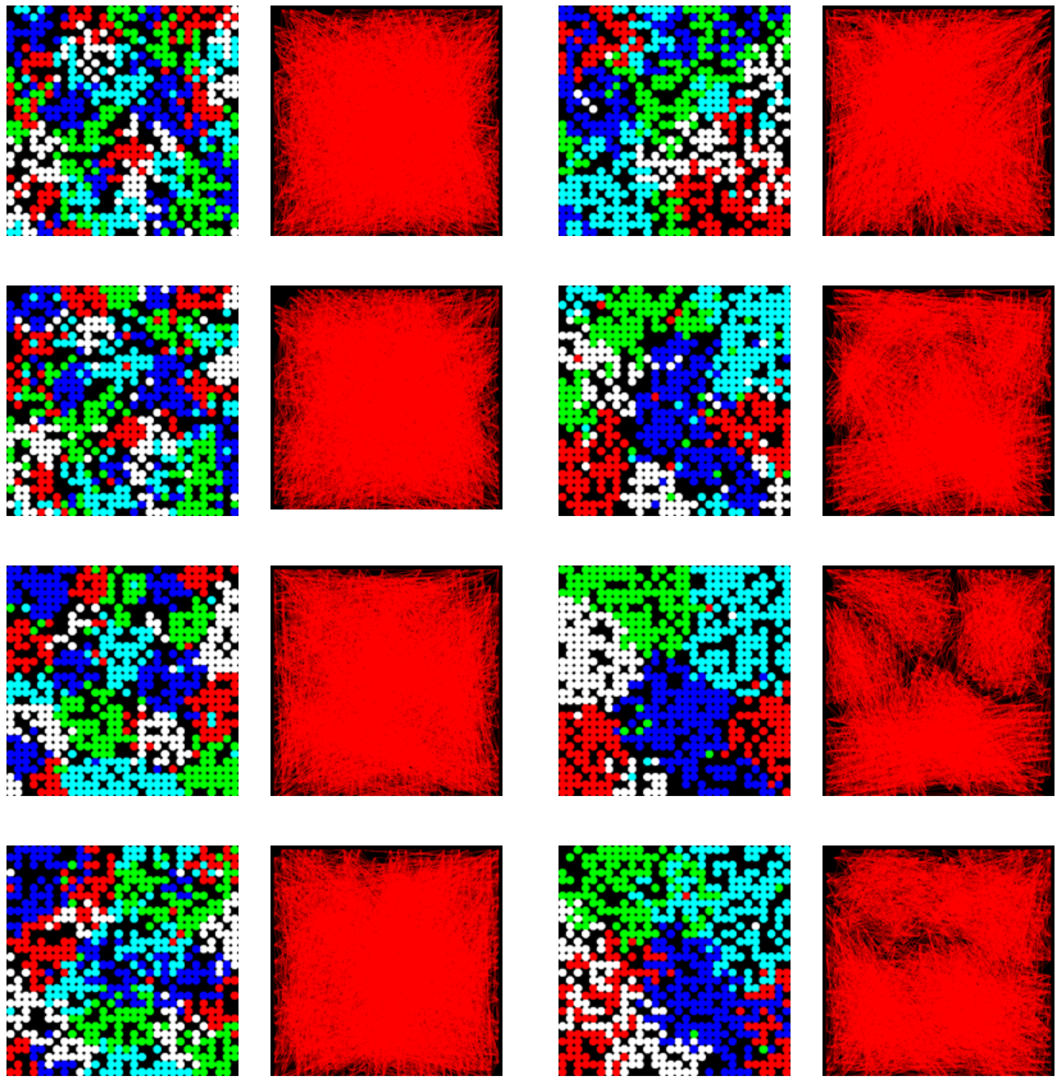
Conclusion

Smaller shocks appear to have an impact disproportionate to the range of direct impact. This unto itself is not an altogether new observation. When observed in a network and limited mobility context, however, we find that the size of the shock has a great deal of impact with regards to the future stability of the region. Along these lines, the capacity to exercise greater choice with regards to the range within which an agent can move is relevant to the formation of large, permanent ethnic regions versus smaller, more transitory neighborhoods. Networks benefit from the presences of smaller, heterogeneous ethnic clusters. Agents within larger, homogenous ethnic "regions" are members to isolated social networks that are slower to "heal" than those that incorporate different ethnicity agents. This reductions in cross-ethnicity social ties results in a social landscape considerably less stable with regards to future shocks. This is of particular concerns as all resulting outcomes lead to the economically favored central regions serving as mixing locales. Shocks originating in these locales are muted only in the face of social networks rich in cross-ethnicity relationships.

It is perhaps counterintuitive that the model offers support to the notion that the spatial mixing of ethnicities lends itself to *greater* stability, but this is derivative of the less controversial assumption that proximity lends itself to the formation of social ties. These ties are both the promoters of local security and victims of large scale shocks. In keeping with the predictions of this comparatively simple, albeit heavily parameterized model, it would appear that the biggest concern should be not simply the ramifications of the first shock, but for those that follow, as a society's robustness against future shocks may be compromised for extended period of time. The formation of not merely homogeneous, but singularly large homogeneous regions can result in scenarios where only the few agents on the periphery of the most sought after locations will have the opportunity to extend their networks outside their own ethnicity. These regions acquire a certain amount of permanence; whereas the smaller neighborhood clusters tend to be more mobile – the neighborhoods themselves shift around the landscape. Thus a certain amount of "action" within the model begets stability, versus stagnation, which is itself a sign of instability.

Appendix

Small shocks:



Medium shocks:

Search radius = 3
Search magnitude = 6

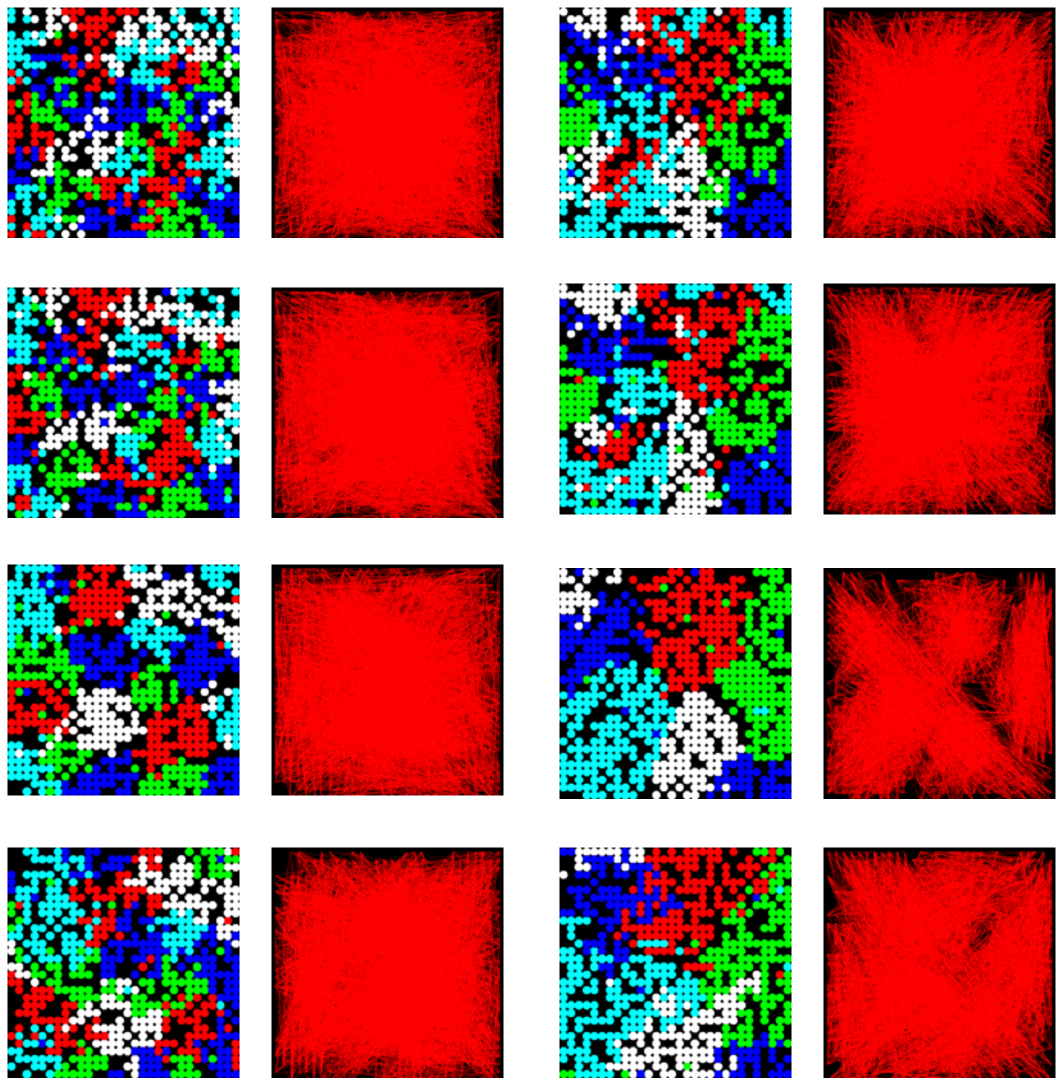
Search radius = off
Search magnitude = 6

Time step 99:
(just before shock)

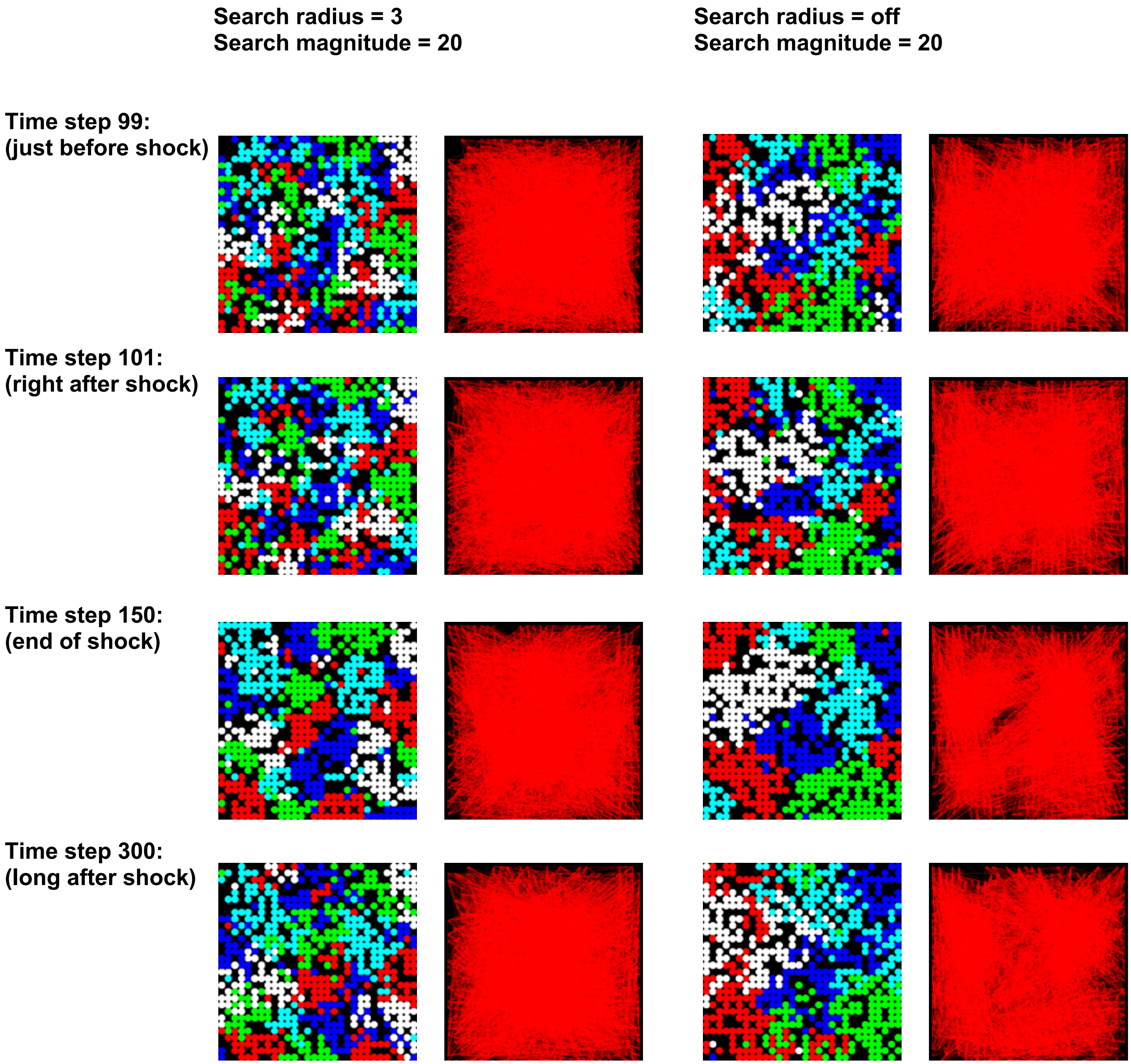
Time step 101:
(right after shock)

Time step 150:
(end of shock)

Time step 300:
(long after shock)



Large shocks:



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