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Physics and Sociology: Neighbourhood Racial Segregation

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Abstract

We have extended the Schelling model of neighbourhood racial segregation to include agents who can authentically 'see' their neighbours up to a distance *R*, called 'vision'. By exploring the consequences of systematically varying *R*, we have developed an understanding of how vision interacts with racial preferences and minority concentrations and leads to novel, complex segregation behaviour. We have discovered three regimes: an *unstable* regime, where societies invariably segregate; a *stable* regime, where integrated societies are essentially stable; and an *intermediate* regime where a complex behaviour suggestive of a first order phase transition is observed.

Introduction

Racial neighbourhood segregation continues to be a problem of intense interest to social scientists in the United States(1). Many factors have been invoked to explain this complex sociological condition, but among these factors, preferences for like neighbours has been thought to be the most pertinent(2). In perhaps the first concerted application of what is now called the agent-based modelling approach to social systems, Schelling(3) introduced a model system of two distinguishable types of agents with discriminatory individual preferences, and quantitatively explored the dynamics of this model system. Schelling and virtually all researchers(4) who have extended Schelling's seminal work have reached the same conclusion – "…even quite color-blind preferences [produce] quite segregated neighborhoods." Such claims of inevitability of racial segregation have, by now, become so widely disseminated that they have found their way evn into literary magazines(5) and public political discourse.(6) We wish to qualify these claims of 'inevitability' and make explicit the contingencies surrounding assertions of this kind.

Our Model

The thrust of our work is to modify Schelling's model and to examine it with respect to one particularly interesting parameter. In the standard Schelling model of a two-race 'artificial society'(4) agents evaluate the racial composition of their *immediate* neighbourhoods to determine whether they will attempt to relocate. Our variant differs from this in that the agents in fact "*see*" their 'neighbourhood' up to a certain 'distance' *R* from their own home while evaluating their decisions to relocate. This modification was motivated by the analogy with Ising models, where the phase diagram of Ising models with random J_{ij} is known to depend upon the range of the interactions, and the anticipation that conserved *M*-dynamics at low tempertatures is also likely to depend upon the range of interactions.

Our model consists of an *NxN* cityscape with periodic boundary conditions in which rational agents of two lexicographic types, say "whites" and "blacks" reside. This short note focuses on the symmetric case (equal concentrations of the two types of agents) for the homogeneous version, where ALL agents are characterised by the *same* value of (*p,R*). {It is straightforward to extend the model further where *p* and *R* have quenched distributions and the minority concentration *c* is also varied. Our limited goal in this short note is to draw attention to qualitatively new behavior that is possible in this model.} The *R*-neighbourhood of an agent is defined to be the set of all sites that can be reached by travelling *R* spaces in any combination of the cardinal directions. We define *p* as the minimum fraction of like *R*-neighbours that an agent must have; failing which the agent will attempt to move into a region of *higher* concentration of like *R*-neighbours. All simulations presented in this short note correspond to *N*x*N* lattices with *N*=50, for the symmetric case, and a fixed vacancy concentration *v*=0.1. In the following, f_j represents the actual fraction of like neighbours of j^{th} agent. The segregation coefficient *S* is defined by

where f_w and f_b represent the expected fraction of white or black nearest neighbours, respectively, in a random initial society with the specified minority concentration *c*.

All simulations begin with a randomly generated and therefore racially integrated integrated cityscape with *S*(t=0) typically being 0.00±0.02. In this model, since agents only move into less diverse neighbourhoods, *S* can only increase with time.

Results

We find that, depending upon the values of p and R, the system evolves in one of two possible modes. In one region of the parameter space, the system displays the familiar mode [3,4,7] where initially integrated communities are unstable and quickly resegregate. We call this the *unstable* regime. But we have discovered that there is a large region of the parameter space (p,R), particularly for moderate values of R ($2 \leq R \leq 7$), where integrated communities remain stable for arbitrarily long times. We call this the *stable* regime. {We will return, later in the paper, to discuss a narrow region of the parameter space where the behavior is more complicated.}

Fig. 1 summarises our findings for the effect of varying R for the case of moderate preferences. Note that the prototypical case studied in all earlier work corresponds, in our notation, to p=0.5, R=1, corresponding to the top right panel in Figure 1. It is clear that as R increases, segregation gets "worse"—S increases from 0.62 for R=1 to 0.97 for R=5—and the pattern changes from dendritic local segregation to nearly total ghetto-like pattern that is the bane of major urban centres like Chicago and Detroit. This kind of worsening of segregation with R has also been found in a recent study of a related continous version[7] of the model.

If, however, the agents' preference is reduced to a *moderate* value of p=0.3, vision plays a dramatically different role. The panels in the left half of Fig. 1 demonstrate that for p=0.3, as R is increased, the tendency to segregate is drastically and monotonously reduced! In fact, for p=0.3, R=5, a total of only 9 moves occurred. Even for a modest vision R=3, we find a drastically suppressed segregation coefficient S=0.16±0.04! These new results are of strong interest to the social science community.

Fig. 2 summarises the behavior of equilibrium $S(p,R)$ for this model. Clearly, a bifurcation occurs between the *stable* and *unstable* regimes, and a complex behaviour is observed for simulations near p_c, the critical preference which divides the regimes. One can define p_c as the preference at which the initial slope of the $S(R)$ graph (Fig.2) changes from a positive to a negative value. By this definition and for c=0.5, we have $p_c \approx 0.35$. Note however that for the p=0.35 case in Fig. 2, the decrease of S at higher R (R>4) is preceded by a very small increase of S at smaller values of R, suggesting more rich, non-monotonic behavior for p near the transition region. Fig. 3 shows in greater detail this complex behavior for an illustrative case of p=0.4.

The initial increase in S with increasing R ($1 \leq R \leq 5$) can be qualitatively understood as follows. In these smaller R-neighbourhoods, statistical fluctuations in local concentrations are large enough that a significant fraction of agents, because of their narrower vision, are *unsatisfied* with the local racial composition. They move, and as a consequene, *incite* a small chain reaction of segregation, and the probability of such chain reactions initially increases with increasing R.

That equilibrium S must go to 0 for large values of R is also easily understandable as follows. For sufficiently large R, statistical fluctuations in the local concentration within the R-neighbourhood become so small that nearly every agent ought to 'know' that the concentration of its own kind in its R-neighbourhood is satisfactory, because (p=0.4) < (c=0.5). The agents therefore should not want to move. Thus, initially integrated, i.e. $S(0) \approx 0$ societies ought to persist, implying equilibrium $S \approx 0$.

And for intermediate values of R ($8 \leq R \leq 12$ for p=0.4), a competition between these two opposing effects of increasing R results in dramatically large run-to-run fluctuations in equilibrium values of S. These run-to-run fluctuations are characterized by metastability and an extremely bimodal distribution of S, consisting of two very narrow peaks near $S \approx 0$ (almost completely integrated) and $S \approx 0.9$ (almost completely segregated) respectively: the open symbols in Fig.3 show these peak values. The similarity to a first order transition from 'supercooled' liquid-like to a 'superheated' solid-like phase is striking.

It would be of interest to modify a related continuous-R version[7] of the model to allow for varying effective values of p, and see if the meta-stability and the corresponding possibility of "superheating" and "supercooling" persists.

Conclusion

We have introduced and studied an extended Schelling model of racial neighborhood segregation, in which the agents authentically 'see' their neighbors up to a distance R. We have discovered that the parameter space of this model has three regimes of behavior: the *unstable* regime, where the societies invariably segregate and segregation increases as vision, R, increases; the *stable* regime, where integrated societies are essentially stable and segregation decreases as vision, R, increases; and a narrow *intermediate* regime where a complex behavior is observed. The results in the intermediate regime have similarities to first order phase transitions in physical systems and suggest lines of exploration that could be of significant interest to the physics community.

References:

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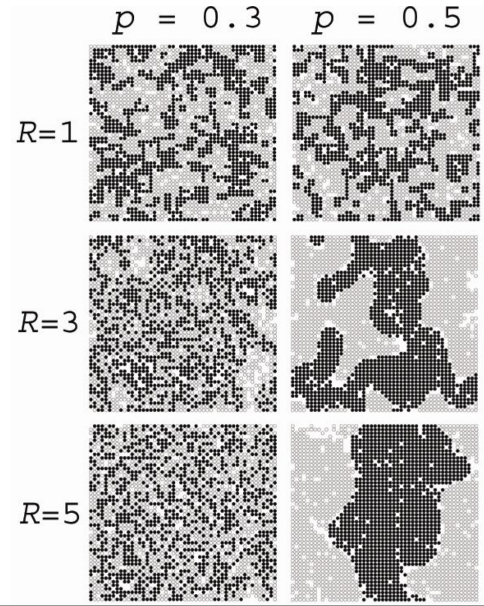

Fig. 1 - Equilibrium societies for different values of *R* and *p*

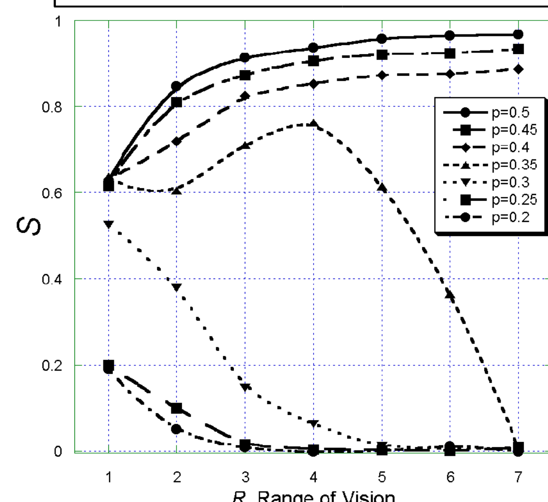

Fig. 2 - *S* vs. *R* for different preferences

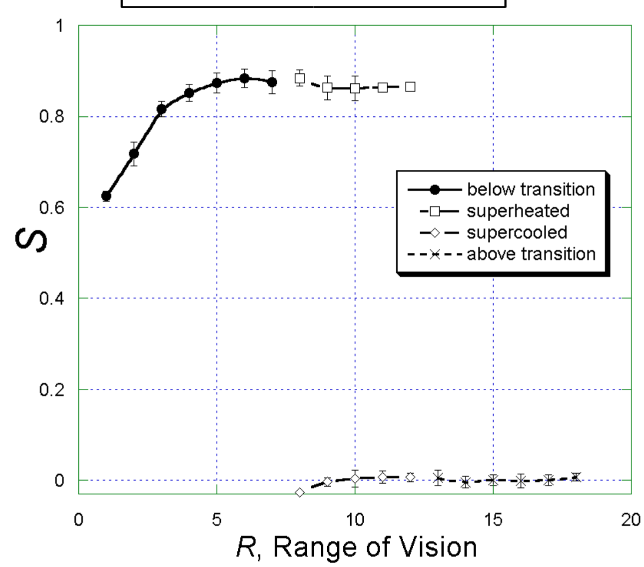

Fig. 3 - *S* vs. *R* in the Intermediate Regime