Occurrence of epidemics by events attracting mass movement

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PROBLEM AND MOTIVATION

In both modern society and the natural world there are attractor events which draw interest from participants across large geographic distances. Facilitated by modern transport, national and international gatherings bring hundreds, thousands or even millions of individuals into close proximity for relatively short periods of time. In the natural world seasonal migrations are a similar phenomenon, whilst in agriculture large-scale monoculture farming creates mass flowering events requiring pollination services. These gatherings create patterns of mass movement that facilitate the spread of disease, thus allowing epidemics to occur.

In developing epidemiological models, one of the key considerations is to model the process by which an infected individual is brought into contact with a susceptible individual; this is known as the contact process. Mathematical models tend to assume full mixing of populations or subpopulations where the likelihood of transmission between any two individuals is equally likely (Newman et al. 2006). In the last two decades, these models have been refined using contact network representations. A contact network model restricts contact between individuals (nodes in a graph) to only be possible via contact links (edges in a graph). These representations tend to be static in nature and therefore reflect either a snapshot of time or the sum of all possible contacts occurring over a period in time.

To incorporate patterns of movement, these contact models need to be extended to incorporate both dynamic processes and dynamic structure. Where movement has been incorporated explicitly into these models (Boccara and Cheong 1993; Ahmed and Elgazzar 2001; Belykh et al. 2004), the nature of this movement has been random and therefore not representative of real movements in geographic space. In particular, random movements do not demonstrate any correlation between the movements of individuals, such as the mass movement towards attractor events.

Research question

The hypothesis to be tested is that epidemics are more likely to occur, and spread more rapidly, as movements become less random in the presence of attractor events.

Proposed approach

A simplistic contact model, and one that has been frequently analysed using both mathematical and simulation techniques, is that of a two-dimensional lattice. In this research a modification has been made to the standard lattice model to use a quarter of the node density but double the interaction range to a distance of two links (see figure). This modification provides identical results for conventional analyses but provides holes for mobile individuals to occupy. At each timeslot, an attractor event location is randomly chosen and a proportion of the population chosen at random and designated as mobile. These mobile individuals then move in response to the attractor event, as shown in the figure.

The characteristic pattern of movement in response to these attractor events is assumed to have a long-distance range, be discontinuous in nature and feature a return-to-base for the mobile individuals. The definition of long-distance is taken here to mean several orders of magnitude greater than normal interaction distances. In the lattice model, in a single time step a mobile individual may move any distance within the lattice with no predefined range for movement. This discontinuous movement reflects the nature of modern transportation whereby an infected individual is often quarantined whilst mobile, and the duration of the time in transit is relatively small compared to the duration of the event. An example of this would be an individual driving their own car 300km to a week-long event. By returning to their original base, the mobile individuals periodically restore the structure of the original lattice. As only a proportion of the population is mobile at any one time, there will also be other non-mobile individuals in the vicinity of the attractor event.

A challenge in even such a simplistic representation is isolating the effects of the attractor event. For this reason, it is proposed to model the effects of the attractor on movement (and hence the epidemic) by observing the trend as the movement tends from random to attracted by introduction of an attractor factor. This factor varies from 0 (attractor event ignored) to 1 (all mobile individuals attempt to move to the location of the attractor event).

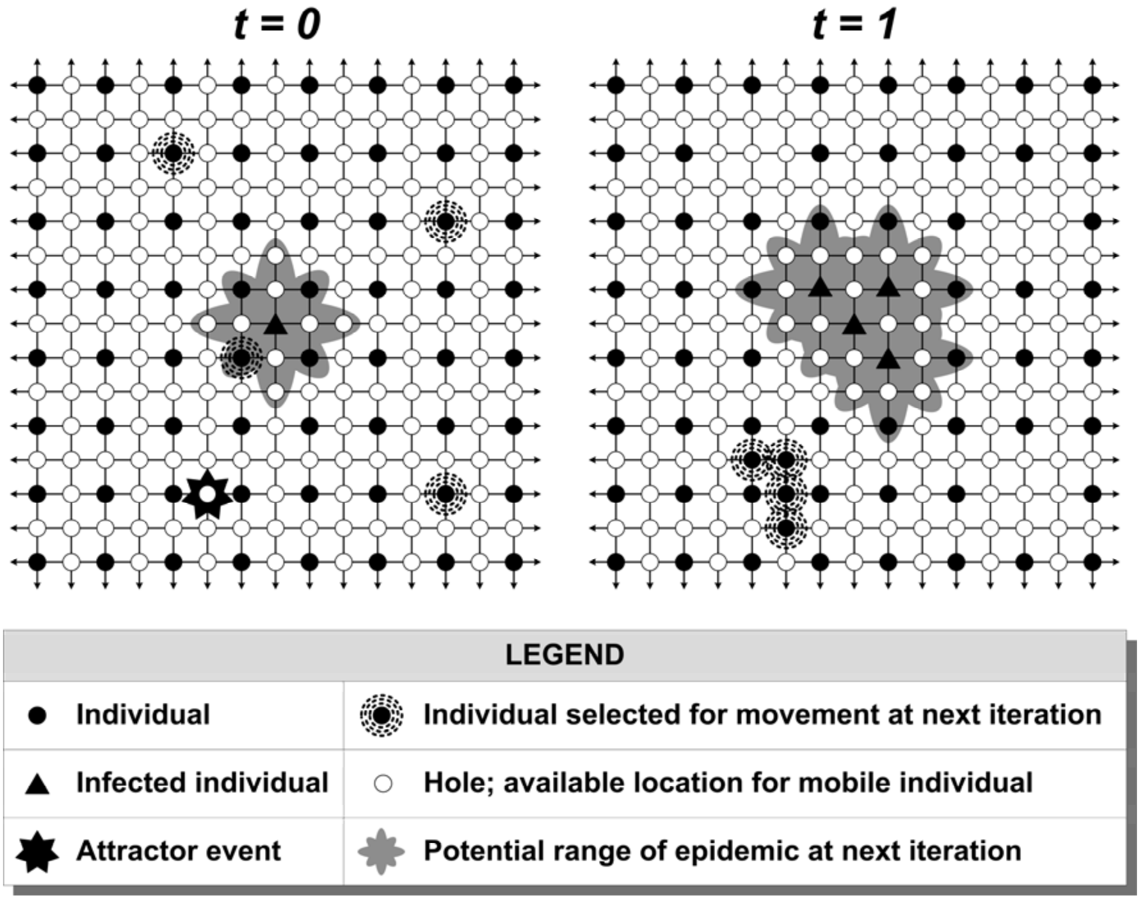

Figure: First two simulation iterations

EXPECTED RESULTS

The simulation model is currently implemented. At the conference we will present results from the simulation and outline the effect of attractor events on epidemic spread. The expected results are that as more individuals align their movements in response to the attractor event, the epidemic threshold is lowered and the rate of spread of any resulting epidemic increases. This result will add to our understanding of how this pattern of movement, which can be observed in the real world, facilitates the occurrence and spread of an epidemic. It will also illustrate that random models of movement are not sufficient to understand dynamic processes occurring in geographic space. Further research will address the question of the extent to which the importance of movement depends on the transmission rate of the disease.

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