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A Matrix-oriented Approach to CA Modelling in ARGESIM Comparison C17 'SIR-type Epidemic' with MATLAB

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Simulator: MATLAB (version 6.05) is a powerful programming language and very suitable for CA modelling and analysing cellular automata (CA).

Model. For implementing the different cellular automata models, similar matrix structures are used. For *LGCAs* we are using a matrix with elements 0, 1, 2, 3, (0 - no element there, 1 - susceptible, 2 - infected and 3- recovered individual).
In the *HPP* model every cell includes four positions (up, down, left, right), characterised by a 2 x 2 matrix per cell. Thus, the *HPP CA* is modelled by a $2m$ x $2n$ matrix (m, n grid size). In the *FHP* model every cell includes six positions (up-left, up, up-right, down-left, down, down-right,), represented by a 2x3 matrix for each cell of the grid. The following main model shows a very dense MATLAB code: spatial update, random changes, spread of infection in the CA update.

```
for k=1:time
    A = HPP_Step(A);
    if deflrdn A = HPP_Deflrdn(A); end;
    [A,nS,nI,nR] = HPP_Infection(A,r,a);
end;
```

A - Task: CA and ODE solutions. For the ODE solution, MATLAB's standard algorithm ode45 was used. The CA grids were updated in single time steps. The results are qualitative similar, but have different time constants. In the ODE model, the desease spreads at fastest - 7000 infected (maximun) after 10 days, while the CA models show more smooth behaviour (FHP: 4000/14 days, HPP: max 3000/16 days). If in the CA models additionally random motion takes place, the system again slows down (HPP motion: max 2500/25 days) - the more spatial movement, the slower the model (Figure 1).

B - Task: Vaccination strategies in CA models. Vaccination is implemented complex additional update rule when performing a step with the CA.

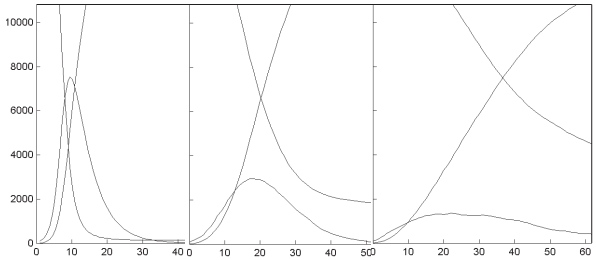

Figure 1: ODE model, HPP model, FHP random deflection.

Three experiments work with 100 infected individuals in the upper half domain, and with 16.000 susceptible individuals uniformly distributes in the whole domain:
- Experiment 1: vaccination of every fourth (eigth, etc) in the whole domain
- Experiment 2: vaccination of every second (fourth, sixth, ...) in the 'infected' halfdomain
- Experiment 3: vaccination of 4.000 individuals nearest to the border of the infected area.

Experiment 1 and 2 show similar results, vaccination clearly smoothes down the infection. In principle, in both experiments the same number of individuals is vaccinated, but the denser vaccination in the infected halfdomain works faster. The third vaccination strategy is the best, because the desease is primarily attacked there, where most infected people stay. Although only one fourth of individuals is vaccinated, less people are infected; but the overall recvery process takes more time (Figure 2).

C - Task: Convergence of CA solutions to ODE solution. Rearrangement of indiviuals in each update step is implemented by simple random distribution at the grid after the update. As result, the FHP CA solution (Figure 3) is very similar to the ODE solution as well as the DE solution.

Classification: Matrix-based directly programmed approach

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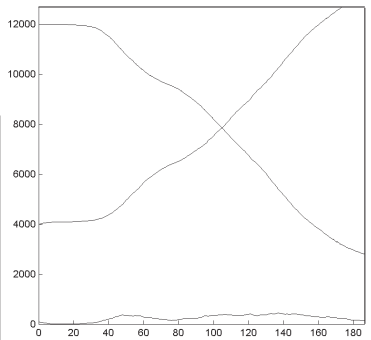

Figure 2: Best vaccination on border to infected region.

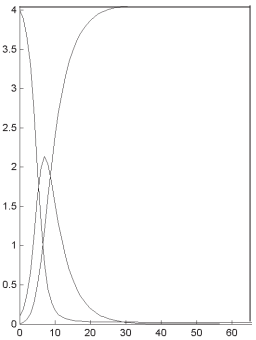

Figure 3: FHP solution with random reordering.