CS250: PROJECT PROPOSAL

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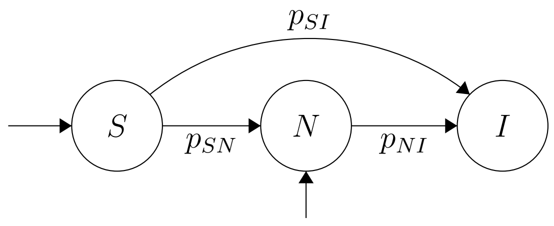
Abstract. In this simulation, I propose to model the spread of a computer worm that infects a network of routers via infected cellphones as users physically move and connect to different routers. Cellphones and routers will operate in one of three states: susceptible, infected, or immune with some probability function for their transitions. The movement of the cellphones in a world space with accompanying state changes will be determined via a cellular automata and an adjacency matrix determines the connections between the routers to determine the spread of the worm between the static routers.

Floor Proposal

World Space. Let C be a set of cell phones, R be a set of routers, and $I \subseteq C, R$ be a set of initially infected phones and/or routers. A $2n \times 2m$ world space is created by placing an $n \times m$ configuration of 2×2 blocks, where $\|R\| = n * m$. Each individual cell represents a location in the world space that a cellphone can occupy and the center of each 2×2 block is the location of a router. A cell is connected to the router if it is located within the router's 2×2 block.

Cellphones. Only one cellphone will be allowed per cell, thus a router can have a maximum of 4 connections. In the initial configuration of the system, the cellphones of C are placed randomly within the grid space such that no two cellphones occupy the same cell. We may extend the model to allow multiple cellphones if time permits.

Routers. Let G be the graph of the connections of the routers and M be an adjacency matrix of size $\|R\| \times \|R\|$ that represent the edges of the G. For the initial configuration of the system for the baseline model, we will ensure that there will only be one infected router and that it will be disjoint from the rest of the routers.



$$\begin{tikzcd} {} \arrow[r] & S \arrow[r, "p_{SN}"'] \arrow[rr, bend left, "p_{SI}"] & N \arrow[r, "p_{NI}"'] & I \\ & & {} \arrow[u] & \end{tikzcd}$$

Figure 1. State transition diagram for cellphones and routers with arbitrary transition probabilities.

Infection Vectors.

Cellphone-Router Vector. All cellphones and routers begin in the susceptible state, S, and one randomly chosen cellphone or router acts as the initial vector for the worm and will be in the infected state, N. A susceptible cellphone connected to an infected router (a cellphone located in the router's 2×2 block) has a transition probability, S_{SN}, to the infected state. Furthermore, a susceptible router connected to x infected cellphones has a transition probability, $x * T_{SN}$, to the infected state. By the same token, an infected cellphone and router have transition probabilities, S_{NI} and T_{NI}, for spontaneously becoming immune due to an application of a patch. Once a cellphone or router is patched, it will permanently stay in the immune state, I. Alternatively, a susceptible cellphone or router has a transition probability of being patched preemptively at a transition probability of S_{SI} and T_{SI}, respectively.

Router-Router Vector. Infected routers infect connected, susceptible routers at a transition probability, U_{SN}. Furthermore, immune routers immunize connected, susceptible or infected routers at transition probabilities, U_{IS} and U_{IN}, respectively.

Cellphone Movement Vector. The third and final vector for the worm is random movement of cellphones between routers. All cellphones will move in a random, Van-Neumann direction within the world space. To determine which direction to move for a given cellphone in position (i, j), positions $(i-1, j), (i+1, j), (i, j-1), (i, j+1)$ are evaluated for validity (beyond world border or another cellphone is going to move there) and randomly selected. Then, movement probability, V, determines whether or not the cellphone will move. A higher movement probability increases the volatility of the worm and vice-versa.

Evaluation Function. Algorithm 1 defines the evaluation steps at each time step. The three vectors are evaluated in order: router$\rightarrow$cellphone, cellphone movement, cellphone$\rightarrow$router, and router$\rightarrow$ router.

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Algorithm 1: Evaluation on Cellular Automata

```
foreach time step do
    foreach cellphone $\in C$ do
        if cellphone is susceptible then
            if local router infected then
                compute $S_{SN}$;
            compute $S_{SI}$;
            evaluate transition success, with immunity precedence;
        else if cellphone is infected then
            increment infected cellphone count in local router;
        else
            cell phone is immune, do nothing;
        end
        let valid_pos = {valid, Von-Neumann positions};
        choose random position in valid_pos;
        compute $V$;
        evaluate new cellphone position;
    end
    foreach router $\in R$ do
        if router is susceptible then
            let $x$ = number of infected cellphones in local area;
            compute $x * T_{SN}$;
            compute $T_{SI}$;
            evaluate transition success, with immunity precedence;
        else
            router is infected or immune, do nothing;
        end
    end
    foreach source, destination $\in M$ do
        if source is infected and destination is susceptible then
            compute $U_{SN}$;
            evaluate transition success;
        else if source is immune and destination is susceptible then
            compute $U_{SI}$;
            evaluate transition success;
        else if source is immune and destination is infected then
            compute $U_{NI}$;
            evaluate transition success;
    end
end
```

Extending the Model

The following additions can be made in order to increase the complexity of the model:

- Allowing for multiple cell phones in a space and model random diffusion of people.
- Allow for dynamic router rerouting such that connections between routers can be created or destroyed.
- Time dependent transition probabilities, for example the longer the simulation runs, the higher the immunization probability, or immunization is delayed (waiting for the patch), etc.