Including Risk Perception in Agent's Cognitive Decision-Making Processes

Introduction

Over the years a range of spatial agent-based models (ABMs) have been developed to simulate a wide variety of disease diffusion processes. However, most models:

- Are based on simple (rule-based) agent behaviour unable to capture the change of behaviour during a developing epidemic due to e.g. increasing risk awareness;
- Do not model explicitly behaviour change as a result of media attention and increasing risk awareness;
- Include individual decision making and social interaction but no group behaviour;
- Only include social intelligence but lack the element of "spatial intelligence"

by: exploring how the introduction of cognitively-rich agents perceiving risks (and potentially acting upon them) impacts the spread and prevention of a disease.

Case Study

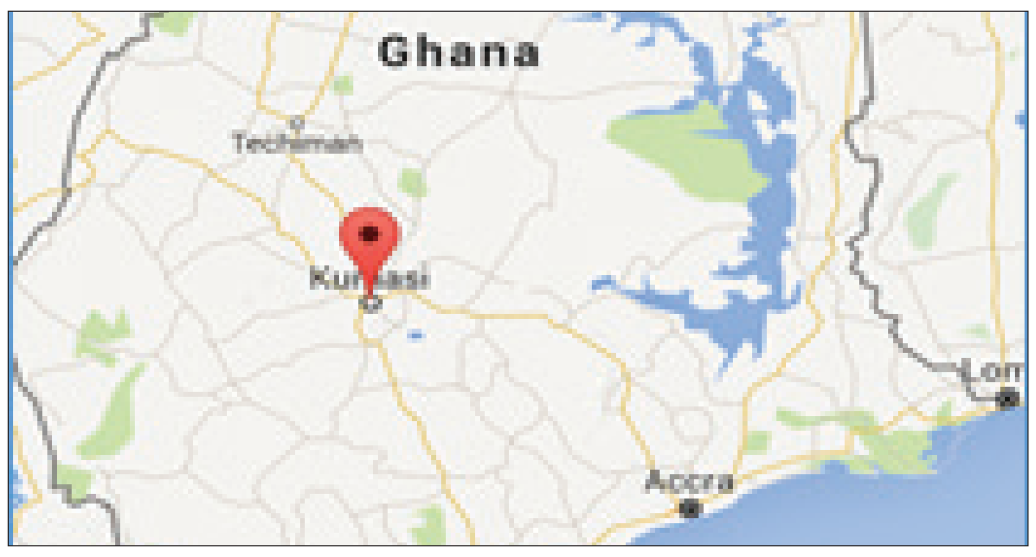

Figure 1: Study Area (Kumasi, Ghana)

- A city if Kumasi, which was hit by a severe outbreak of Cholera in 2005;
- Kumasi is the capital city of Ashanti Region located in South central Ghana with a population of 3.5 million.
- Cholera epidemic started in the last week of September and lasted for a period of 72 days, which was during the rainy season;
- The cholera data was obtained from the Kumasi Metropolitan Disease Control Unit (DCU), since it is mandatory for all reporting facilities (i.e. hospitals, clinics, and community volunteers) to report weekly cholera cases to the DCU.

Current Model

Simulates cholera diffusion by means of dumpsite runoff and river flow in the highly urbanized area of Kumasi, Ghana (Figure 2). In the model, cholera diffusion is fuelled by:

- Rainfall causing polluted runoff from dumpsites leading to infection of the river water
- Rainfall cases mall functioning of piped water leading to (higher) use of river water increasing the number of cholera cases.

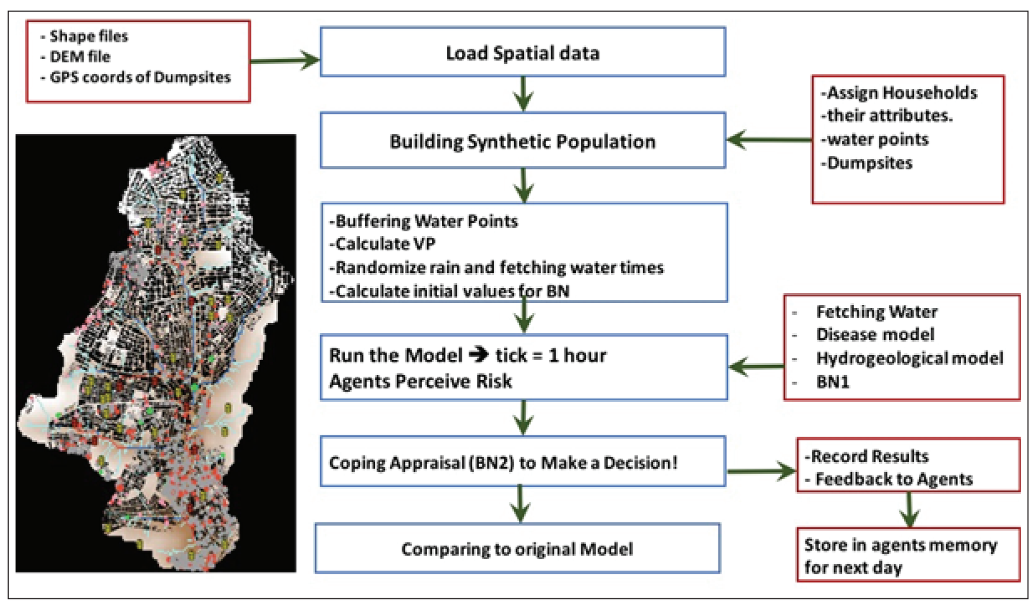

Figure 2: Main Steps of Current Model

Household as a group collects water but:

- Water is collected at the nearest water point – even if this water looks visually polluted;
- A growing number of disease cases does not induce the agent to reconsider the type/place of water collection.

Methodology

The Cholera diffusion model is originally developed by Augustijn et al. However, some developments have been added to include both the risk perception of agents and the simulation of their cognitive decisions:

1. We adjusted the existing model by introducing:
   a. New Media agent;
   b. Households educational status was added;
   c. Randomization of the time for fetching water during day hours;
   d. Randomization of the time of rainfall during rain-days was randomized;
   e. Communication between households about illness was introduced;
   f. Ability of households to perceive the visual pollution (VP) of river water, which is computed as:

$$f(VP) = \sum_{i=1}^{N} xg/d$$

where: N is the number of dumpsites around the river water points
x is the number of households who use the dumpsite
g is the amount of garbage produced by each household
d is the distance from the dumpsites to the water point

   g. A feedback to the household decision on where to collect water based on experience (own and that of relevant others).

2. Design two Bayesian Networks (BNs) for risk assessment and decision making (Figure 3):
   a. Households assessing infection risks and potentially changes their behavior – learn to reduce or avoid this risk – based on changing risk perception.
   b. Protection motivation theory (PMT) is used to assess the risk and it consists of cognitive processes that are useful in predicting health behavior of individuals.
   c. BNs are used to implement the two stages of PMT: threat appraisal (BN1) and coping appraisal (BN2) as shown in the figure below:

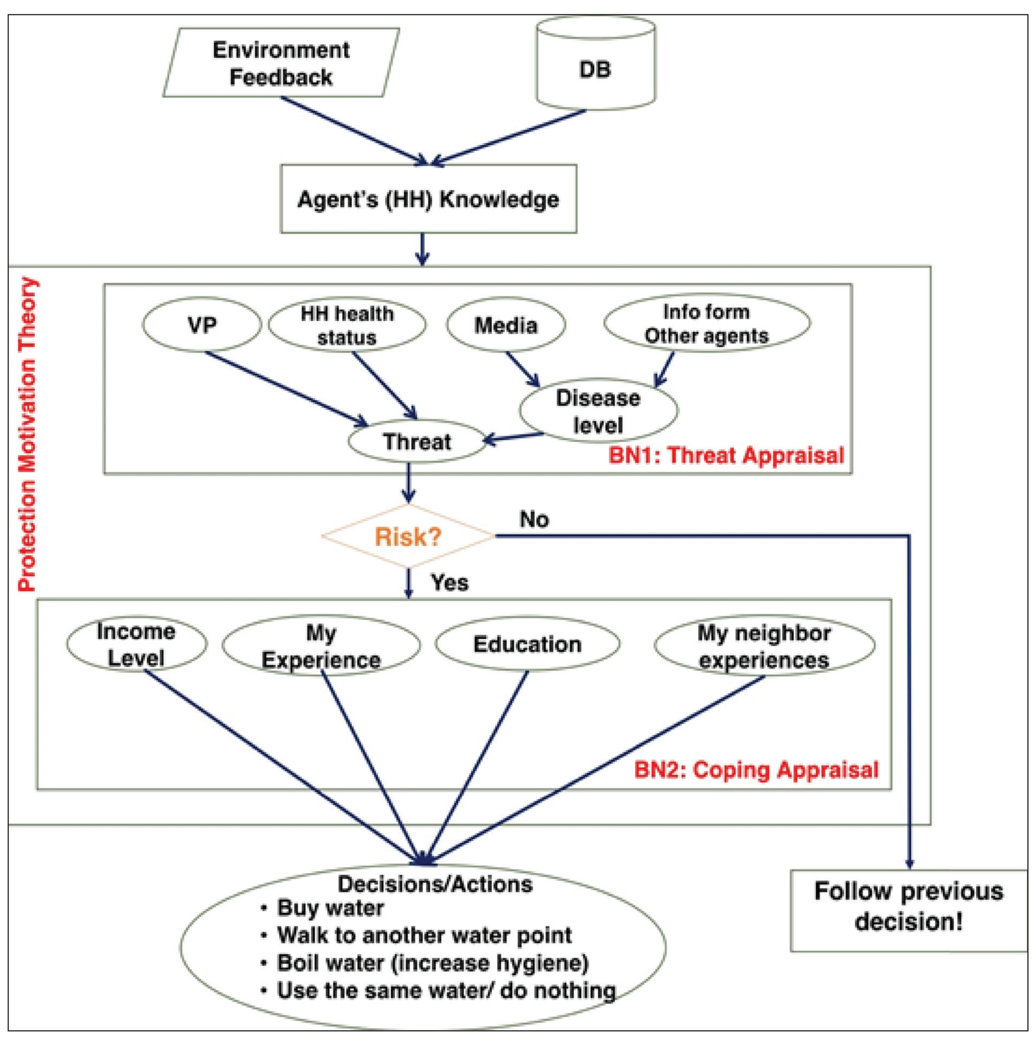

Figure 3: Agent's cognitive model (Bayesian Network including Threat Appraisal (BN1) and Coping Appraisal (BN2))

Results

Currently only the first Bayesian network is implemented (BN1) using R. The results include two elements:

- Geographic distribution of the simulated visual pollution (Figure 4)

Figure 4: left: Geographical Distribution of VP indicating the density of the pollution. The right photo shows the real situation of some river's banks in Kumasi, Ghana

- Threat Appraisal (BN1) compute the risk perception of agents (Figure 5). The risk perception of households developed during the time. While the cholera cases increase people start to feel risk more especially if illness occurs in one of their family member. In addition, during the communication with their neighbor households and the attention of media lead people to the seriousness of the epidemic. Moreover, since only 2.2% of the metropolis population's wastes are collected (i.e. house to house collection) therefore, the pollution around the river increased motivating households to perceive the threat around them.

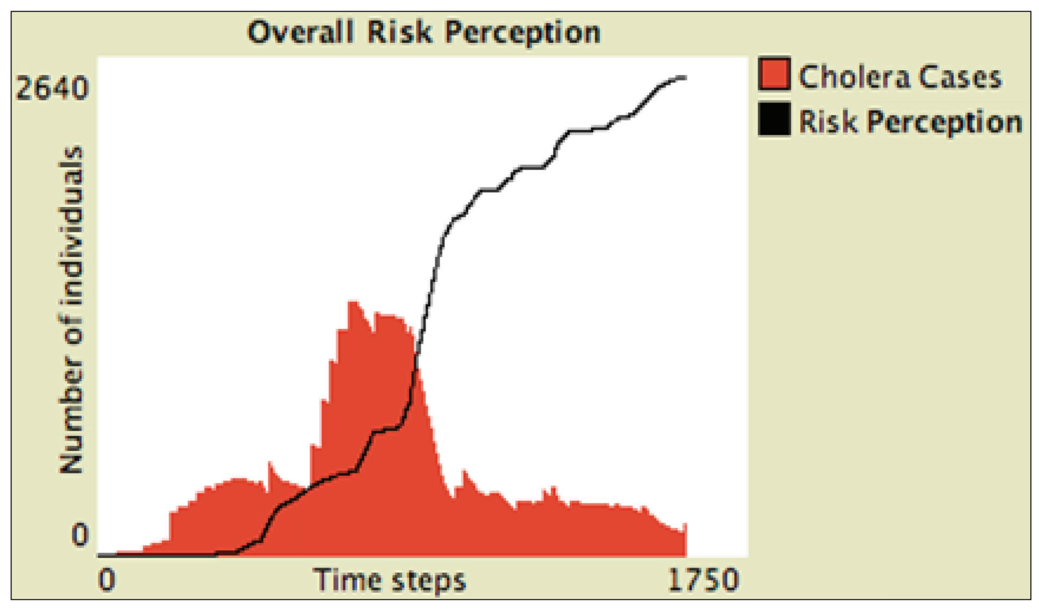

Figure 5: Development of Agents Risk Perception over time

Further Work

- The ChoDiSim will include a dynamic element in the VP to simulate downstream flush of the pollution during and after raining.
- The implementation of BN2
- Comparing results of ChoDiSim with the original Cholera Model.

Reference:

E.-W. Augustijn-Beckers, J. Useya, R. Zurita-milla, and F. Osei, "Simulation of Cholera Diffusion to compare transmission mechanisms," Proc. 11th Int. Conf. Geocomputation, pp. 39–42, 2011.

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For more information

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