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AN AGENT-BASED EPIDEMIC MODEL FOR DENGUE SIMULATION IN THE PHILIPPINES

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ABSTRACT

Dengue is a mosquito-borne disease and a severe health issue in tropical and subtropical countries. Based on a literature search and data gathering, an agent-based model for simulating dengue epidemics is developed. It models human and mosquito agents with detailed agent's behavior, mosquito biting rules and transmissions. Featuring a modular approach, it provides flexibility and allows functionalities that are easy to manage and to communicate. The model is parameterized and calibrated to simulate the 2010 dengue epidemic in Cebu City, Philippines. This works fairly well and also provides insights into the spreading process of dengue. It reveals that the changing mosquito population during rainy season has a great impact on the epidemic. It suggests how further research on that matter using models and extended biological studies might lead to a better understanding of the dengue spreading process, and eventually to more effective disease control.

1 INTRODUCTION AND OBJECTIVES

Dengue is a mosquito-borne disease and causes frequent outbreaks in many tropical and subtropical countries and is reported as the leading cause of childhood hospitalizations. Intervention strategies include prevention of being bitten by mosquitoes and limit the mosquito population. Vaccinations are currently under development. To estimate the outcomes of interventions, there is a demand for simulations (del Angel and Valle 2013).

This study aims to develop an agent-based model for simulating dengue epidemics in a city or province of the Philippines and test it on the 2010 dengue epidemic in Cebu City. Analyzing the emergent behavior of the model gives further insight into the spreading process of dengue. In future, the model serves as a tool to test the impact of interventions and to make short-term and long-term predictions.

2 DATA AND INFORMATION

Information is gathered on the dengue virus, its hosts, its vectors, its epidemiology, and the relevant environment. There are four distinct dengue serotypes: DENV-1, DENV-2, DENV-3 and DENV-4. Humans are considered as the primary reservoir of the dengue virus. After infection with one serotype, humans can transmit the virus to mosquitoes, and some develop a clinical illness: dengue fever (DF), dengue hemor-

rhagic fever (DHF), and dengue shock syndrome (DSS). After recovery, infection with one serotype causes lifelong immunity to that serotype. Mosquitoes, specifically the Aedes aegypti, are the primary vectors of the dengue virus. Once infected, the dengue virus does not harm them but they remain infected for the rest of their life. Biological studies report a short lifespan of about 33 days, their biting behavior, and their reproduction cycles. The City Health Office of Cebu City provided hospital data about all reported dengue cases in the province of Cebu for the year 2010. It shows that most cases happen during rainy season from July to mid-October. Cebu City is a large city in the Philippines with a population of about 860 000.

3 THE MODEL

The model is an agent-based model that simulates humans and mosquitoes as individuals. Based on prior research, the model is built in a modular way that separates structures for population, contacts and diseases (Miksch et al. 2014). The number of humans, their age and their gender is assigned according to the demographics of Cebu City. Due to the short simulation time of one year, humans do not get older or die, no babies are born and no humans enter or leave the model. Mosquitoes die each day with a probability until they reach their maximum age. Female mosquitoes lay eggs that turn into newborn, non-infected mosquitoes. Each day, female mosquitoes bite a number of humans. The environment defines a rainy season where a higher capacity of mosquitoes is allowed. Various ways of births and deaths are tested to realize growth and shrinkage of the mosquito population.

The model simulates only one dengue serotype since it is shown that an outbreak is generally caused by a single serotype. Humans can get infected with a probability when they are bitten by an infected mosquito. Then, they can become viraemic and develop one of the symptoms DF, DHF or DSS, or remain symptomless. After several days they recover and become resistant. Mosquitoes can get infected upon biting a viraemic human.

4 RESULTS

Most model parameters can be computed from data. Six parameters are calibrated: probability of transmission for persons, probability of transmission for mosquitoes, number of mosquitoes, mosquito death probability per day, initially infected mosquitoes, and start and end of the rainy season. For calibration, parameter settings varied to reproduce the 2010 dengue epidemic in Cebu City. This reveals that the mechanics of a changing mosquito population between dry and rainy season has a great impact on the epidemic. Eventually, the calibration is possible but leaves an open question about mechanics of the mosquito population.

5 DISCUSSION

The advantage of the agent-based modeling is that the flexible and natural structure that allows modeling of a system as it is observed. This results in emergent behavior that can be analyzed to reveal the internal dynamics. Parameterization and calibration leads to an acceptable reproduction of the 2010 dengue epidemic in Cebu City. In the future, the model can serve as a basis to simulate the outcome of interventions against dengue and predictions on upcoming Dengue outbreaks.

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