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Julio-Diciembre, 2011 **TELE-EPIDEMIOLOGY**

SOFTWARE DEVELOPMENT FOR THE USE OF SPACE INFORMATION IN SPATIAL AND TEMPORAL SIMULATION OF RODENT POPULATION DYNAMICS

DESARROLLO DE SOFTWARE PARA EL USO DE INFORMACIÓN ESPACIAL EN SIMULACIONES ESPACIALES Y TEMPORALES DE DINÁMICA POBLACIONAL DE ROEDORES

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ABSTRACT

The space technology and the use of space science products offer a vast range of research topics and applications for computer scientists. These research applications are of mandatory interest at the Gulich Institute, a CONAE (Argentine National Space Agency) and UNC (University of Córdoba) dependency.
One of these applications is the use of satellite data in early warning and response to health risks and emergencies. In this study, it has been developed a software tool that allows the user to process information coming from satellite images to determine the incidence of rodent transmitted diseases. The behaviour and infection rate of rodent populations in a given area determine the incidence of the rodent-transmitted diseases such as the Argentine Hemorrhagic Fever (AHF). In this study, two complementary models have been used to integrate satellite data into the analysis and prevention of vector-borne diseases. The first is a spatial probabilistic model which estimates the distribution of rodents over a given region. The second is a temporal model which calculates the dynamic of rodent population and the incidence of AHF infection.

RESUMEN

La tecnología espacial y el uso de productos de las ciencias espaciales ofrecen una amplia gama de temas de investigación y aplicaciones para los científicos computistas. Estas aplicaciones de investigación son de interés obligatorio en el Instituto Gulich, una Dependencia del CONAE (Agencia Espacial Nacional de Argentina) y de la UNC (Universidad de Córdoba). Una de estas aplicaciones es el uso de datos de satélites de alerta temprana y respuesta a los riesgos de salud y emergencias. En este estudio, se ha desarrollado una herramienta de software que permite al usuario procesar información procedente de imágenes de satélite para determinar la incidencia de las enfermedades transmitidas por roedores. La tasa de infección y comportamiento de las poblaciones de roedores en un área determina la incidencia de las enfermedades transmitidas por roedores como la Fiebre Hemorrágica Argentina (FHA). En este estudio, dos modelos complementarios se han utilizado para integrar los datos de satélite en el análisis y la prevención de enfermedades de transmisión vectorial. El primero es un modelo espacial probabilístico que estima la distribución de los roedores de una región dada. El segundo es un modelo temporal que calcula la dinámica de población de roedores y la incidencia de la infección AHF.

Keywords: satellite images, population dynamic, rodent as reservoir of disease, Argentine Hemorrhagic Fever (AHF), spatial and temporal disease modelling.

Palabras clave: imágenes de satélite, dinámica poblacional, roedores como reservorios de enfermedades, Fiebre Hemorrágica Argentina (FHA), modelaje espacial y temporal de enfermedades.

INTRODUCTION

Landscape Epidemiology is an interdisciplinary approach that involves the characterization of eco-geographical areas where diseases are transmitted. More specifically, it examines the relationship between remotely obtained values of environmental variables (moisture, vegetation, altitude, temperature, etc.) and the vectors of viral diseases. The remotely sensed data can be used in the development of mathematical models in order to simulate the dynamics of the vector population (Barrera et al., 2001; Porcasi et al., 2005). These models have two applications of great interest: (Scavuzzo and Fea, 2005; Polop et al., 2005), i) the location of the most densely populated reservoirs of the pathogen and the deduced risk of the infection contagion. This is because higher chances of contact between humans and the infected animal increase the possibilities of contagion; ii) the possibility of expanding the scope of analyzing and studying a phenomenon. Modifying the simulation parameters, the ecological and viral aspects that are related to the dynamics of the viral population and transmission of the virus can be investigated.

This study aimed to develop knowledge and tools to predict the behaviour of the Argentine Hemorrhagic Fever (AHF) vector, the rodent *Calomys musculinus*. Specifically, this paper describes a software tool that integrates environmental and ecological information, providing results about the spatial-temporal dispersion of the rodents, and implements two simulation models. The software also integrate several elements of analysis in a highly configurable tool achieving a breakthrough in the AHF studies.

RESULTS AND DISCUSSION

For the software development, two models already available to us have been used: a spatial model, which uses Landsat TM 5 remotely sensed data to model the distribution of the rodent population in a given place and a temporal model which uses satellite information provided by the SPOT constellation to model the evolution of these rodent populations.

Spatial Model. The model estimates the spatial distribution of *Calomys musculinus* on a particular geographic region (Figure 1). Carrying out an analysis of the ecological characteristics of that area and the preferred habitat of the vector carrying the AHF virus, it is possible to identify the points with dense rodent populations and consequently the potential sources of infection. This model is based on a cellular automaton (CA) that in every transition estimates the "movement" of the rodents in a given area. It uses rules derived from the ecological knowledge of the vector habitat and from statistical arguments [ProEtal]. More specifically, the CA runs on a two dimensional lattice corresponding to the satellite image of the area under study, each cell representing a pixel on the image. The state of every cell corresponds to the density of rodent population in the area that it represents. The function of the transition that determines the evolution of the system is subjected to probabilistic calculations on neighbouring cells taking into account the environmental benefits of these cells and how busy they are.

Temporal Model. The temporal model (Figure 1) simulates the rodent population dynamics and the viral infection due to Junín virus, the etiologic agent of AHF in its host, *Calomys musculinus*. It is a continuation of the model described in [PorEtal]. It incorporates satellite-derived environmental data and biological characteristics of the host such as birth rate and longevity. This model is based on a series of differential equations that express the variations in the rodent populations throughout time. Different sub-populations are considered distinguishing age groups (young, young adults and adults) and their infection potential (non-infector, infector or immunizer). There is a great interdependence between different sub-populations and the parameters that determine the rates of birth, growth, infections and deaths. These parameters are closely related to the rodents' habitat and are associated to environmental features that can be remotely sensed.

This establishes a connection between the satellite data and the population dynamics of the species. In our case, NDVI values are used to estimate the biological parameters such as population density and rodent longevity. This is because the vegetation index integrates environmental information such as temperature and precipitation which influences reproductive parameters and longevity of the host. Besides, it is also related to food availability and refuge conditions.

Software Tool. The system was designed in such a way that the Space Model and the Temporal Model constitute separate modules. In the first case, the program runs with three data sources: image, initial distribution of rodents and carrying capacity of the image area (extracted from ecological rules and image information).

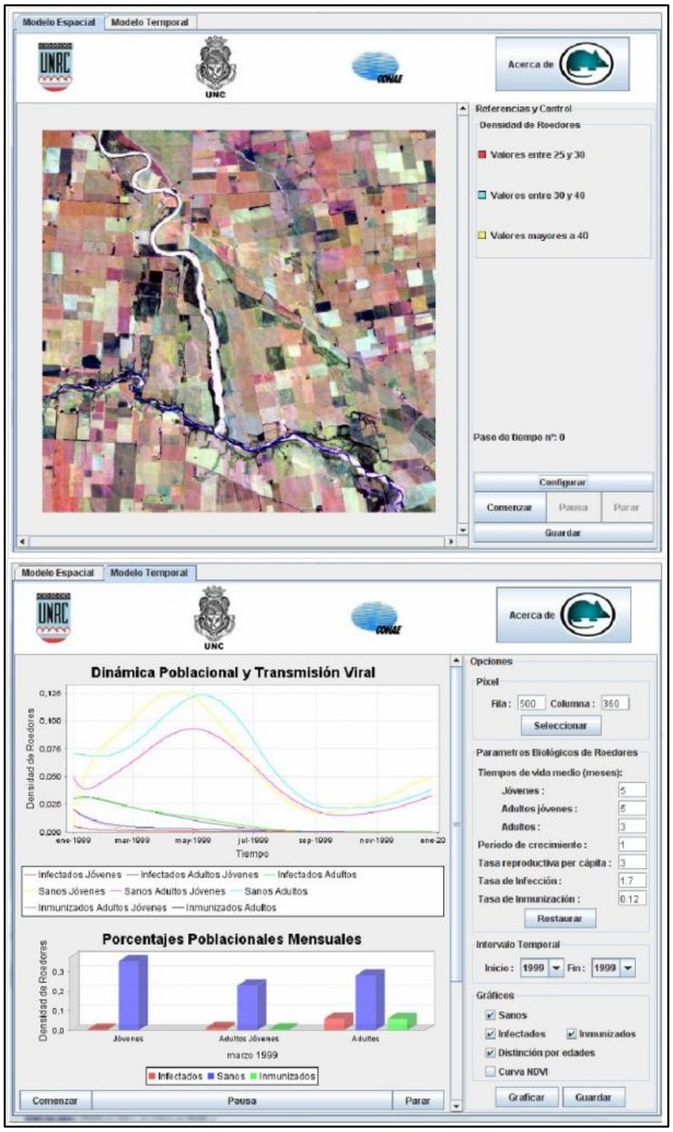

Figure 1. Implementation of Space and Temporal Models.

Each transition of the model is displayed through an animation which uses three colours to show the pixels of the images with higher population densities. These values can be stored according to several criteria, for example, keeping the distribution on the scene as a figure of extension jpg, gif, bmp, etc. In the second case, each implementation of the temporal model is performed on a single pixel in a given time period. Therefore, users must choose one of the pixels in the endemic area and a time span. To facilitate the location of the desired pixel, the software provides a satellite image of the investigated area with layers that add mapping information (provincial boundaries, cities and routes). Moreover, the user can change the biological parameters inherent in the model. This tool shows the population dynamics of rodents through graphic lines making distinctions according to age groups and infection level. It also provides information on the composition of the population through histograms. In addition, as the main data used are the NDVI values, it includes the option of viewing these values graphically.

CONCLUSIONS

In this paper we describe a tool that incorporates remotely sensed data in the study of rodent population dynamics related to the Argentine Hemorrhagic Fever. The system implements two models to analyze the phenomenon from two complementary perspectives, space and time. As described, the first model consists of a cellular automaton that simulates the distribution of rodents in physical spaces, using information from the satellite Landsat TM 5. It provides interesting conclusions about the preferred habitat of the AHF vector and therefore allows the prediction of possible outbreaks of infections.

The second model studies the dynamics of the rodents throughout time using data from the SPOT satellite. It analyzes factors of birth, growth and death, and their relations with the processes of infection and immunization of the Junín virus, the etiologic agent of the AHF. The information obtained from the models is processed to facilitate its understanding. Therefore, it is possible to visualize the results of each simulation through linear and statistical graphics and animations. The tool enables to save and print the results of the simulations, facilitating the user in the continuation work in other applications. In addition, the software allows a qualified biologist user to adjust the input parameters and obtain significant results. For this reason the tool can be used for the study of the AHF and its vector as well as for designing control strategies for the benefit of public health.

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