Massive Turtle Nesting Modeling

Jose Quesada
School of Computer Science
University of Costa Rica
San Pedro, San Jose (506) 2511-8000
Email: jose.quesada2464@gmail.com

William Soto
School of Computer Science
University of Costa Rica
San Pedro, San Jose (506) 2511-8000
Email: williamsotomartinez@hotmail.com

***Abstract*—Turtles exclusively nest on beaches located in temperate and tropical zones around the world. The amount of turtles that nest in a certain beach is usually an unknown number, given that some of them nest in a massive way. So there's been an interest on trying to estimate the amount of turtles that actually nest at a given time in a certain beach. There's three methods that are been used to estimate this arrivals of turtles, with quadrants [1], transects in the berm [2], and transects in the tide line [3]. All of these methods try to estimate the real amount of turtles that nest, so determining which one is more accurate or precise is the objective.**

I. Introduction

Turtles exclusively nest on beaches located in temperate and tropical zones around the world. The amount of turtles that nest in a certain beach is usually an unknown number, given that some of them nest in a massive way. So there's been an interest on trying to estimate the amount of turtles that actually nest at a given time in a certain beach. There's three methods that are been used to estimate this arrivals of turtles, with quadrants [1], transects in the berm [2], and transects in the tide line [3]. All of these methods try to estimate the real amount of turtles that nest, so determining which one is more accurate or precise is the objective.

II. ODD specification

A. Overview

The model represents a beach's geography, it's tides, and a turtles arrival. The model also simulates the process of taking measures with different sampling methods.

1) Purpose: Statistically compare, using their estimates, which sampling method is better to estimate the number of turtles that nest in a massive arrival.

2) Entities, states and scales:

- Entities:
  1) Turtle
     - **Properties:** Position (x, y), nesting phase, time to change phase, point to stop, upward velocity, downward velocity.
  2) Beach Square Meter
     - **Properties:** Position (x, y), height, vegetation, quadrant, transect in the berm, transect in the tidal line.
- States:
  - Turtle phases:
    1) Upward Walking.
    2) Bed Building.
    3) Nest Digging.
    4) Nesting.
    5) Nest Covering.
    6) Nest Camouflaging.
    7) Downward Walking.
- Scales:
  - **Time scale:** Each tick represents a minute in real time.
  - **Space scale:** Each patch represents a square meter.

3) Process overview and scheduling: The goal is to simulate as similar as possible the moment of arrival and nesting of a group of turtles in certain given time to correctly simulate the three different measuring methods to further compare their estimates with the actual amount of turtles nesting and finally determine which of them is better at estimating the real amount of turtles nesting.

- Turtles Scheduling:
  1) Turtle enters the beach at the sea level.
  2) Turtle advances upwards, at the given upward velocity, to the predefined point to stop.
  3) Turtle decides, according to the current phase probability to continue, if it advances to the next phase, or if it returns to the sea.
  4) For each phase, repeat step 3 when the current time reaches the time to change phase.
  5) When is time to return to the sea (last phase), the turtle returns, at the given downward velocity, until it reaches the sea level.
- Simulation Scheduling:
  1) Build the beach according to the predefined beach characteristics and sectors properties.
  2) In each minute:
     - Move sea level.
     - Add new turtles to the beach.
     - Follow each turtle's scheduling as specified above.
     - Capture measurements for the estimation methods (only at certain times).
  3) At the end of the simulation (where the given tidal movement has finished) report each method estimation, what are the real numbers,

and which method was better according to real numbers.

B. Design

1) Basic principles:

- **Sector:** a given part of the beach with certain characteristics. Each sector has the same horizontal size, but varies in the distance to the beach, berm location, and distance to the vegetation.
- **Berm:** zone that works as a border between the intertidal zone and the part of the beach more close to the vegetation.

2) Emergent properties: Doesn't apply.

3) Adaptability: Doesn't apply.

4) Goals: Nest and go back to the beach.

5) Learning: Doesn't apply.

6) Predictability: Doesn't apply.

7) Sensibility: Doesn't apply.

8) Stochasticity: The model is stochastic, given all the random variables that describe the turtles behaviour, like the duration of each phase or the probability to continue.

9) Collectivities: None.

10) Outputs: The model generates a file with:

1) Amount of nesting turtles estimated with the quadrants method.
2) Amount of nesting turtles estimated with the transects in the berm method.
3) Amount of nesting turtles estimated with the transects in the berm tidal line.
4) Real amount of nesting turtles.
5) Real amount of turtles generated.

C. Details

1) Initialization: The model is initialized with values from a file as well as some sliders available in the interface. Further information can be found in the *Inputs* section.

2) Inputs: The model has several data inputs. From files that define the geography of the beach and the tidal movements to sliders that specify every detail of the turtles behaviour. A more specific explanation of each input can be find in the following list:

- **Terrain information:** A file with information of each beach sector in order to build it's terrain, containing the berm's distance to the sea level, berm's height, berm's distance to the vegetation, and vegetation height.
- **Tidal movement:** A file with information of the tidal movement in order to simulate the sea level at all time, containing maximum and minimum tide height with their associated time given in minutes.
- **Zones to measure:** A file with information of the zones to use for the estimating methods, containing x and y coordinate for the bottom left corner, and x and y coordinate for the top right corner of each of the quadrant to measure.
- Beach sector size.
- Amount of time between each measuring method interval.
- Average amount of turtles to generate per minute.
- Average upward velocity for a given turtle.
- Standard deviation for the upward velocity for a given turtle.
- Average downward velocity for a given turtle.
- Standard deviation for the downward velocity for a given turtle.
- Duration and standard deviation for each of the non-moving phases(Bed Building, Nest Digging, Nesting, Nest Covering, Nest Camouflaging).
- Probability of not continuing to the next phase in each phase(Upward Walking, Bed Building, Nest Digging, Nesting, Nest Covering, Nest Camouflaging).
- Average amount of turtles that nest by zone (Intertidal zone top and bottom, zone above the berm, zone closest to the vegetation).

3) Submodels:

1) Tidal movement: The tidal movement was estimated using the maximums and minimums of the tidal cycle in a certain time, then the rest of time using a linear estimation of the slope in the given time.
2) Quadrants measurement methods: In this method we measured the turtles in three different 100 square meters quadrants along the beach and above the berm.
3) Transects in berm measurement methods: In this method we measured the turtles in twenty different transects along the beach, each going from the berm to the line of vegetation.
4) Transects in the tide line measurement methods: In this method we measure the turtles in the zone where the beach gets wet by the ocean and reflects light as a mirror, which according to empirical data it is being estimated as 15 meters from the coast line.

III. Experiment design

First, a NetLogo model was made to represent a beach, its tidal movements and the turtles arrival. The model loads information about the beach's geography such as distance to the sea and height as well as about the tides for a specific period of time from different files. Then by means of different sliders the turtles behaviour can be set.

Once the beach has been set a complete tidal cycle is simulated and measurements are taken in order to provide the necessary information for each of the estimation methods, at the end of the cycle the three methods are used to calculate the total amount of turtles. The exact same simulation is repeated a hundred times to provide enough data to make an statistical analysis of the scenario portrayed in it.

Once all the information is ready, the error of each estimation is calculated (being the error the difference among the real and the calculated amount of turtles). After that a ANOVA test is performed to determine whether or not there is a statistical difference between the errors of each method.

If a difference is found among the error of each method a Tukey HSD (Honestly Significant Difference) is applied to find out which methods are the one that differ and by how much they do it. If, on the other hand, no difference is found more research would be needed to determine if the methods are indeed significantly different.

IV. Data analysis

We run the experiments but the results obtained were far too inaccurate to even proceed with the ANOVA test. While each simulation produced around 7 000 turtles the different methods estimated amounts completely different, the quadrants method produced numbers around 1, the transects in the berm method produced numbers around 70 000 and the transect in the tide line method produced numbers around 115.

The obtain results point to an incorrect implementation of the measurement methods in our model and thus prompted us to meet again with the expert on the methods to try to find and solve the mistakes that we made.

V. Conclusion

Given the unfinished state of the experimentation phase, no conclusions have been reached yet.

References

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[2] R. A. Valverde and C. E. Gates. *Population Surveys on Mass Nesting Beaches*, K. L. Eckert, E. K., Bjorndal, K. A., Abreu-Grobois, F. A. (Eds.), Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group, pp. 15, 1999

[3] Chaves and Morera 2007