Plastic movements in oceans using an agent based approach

The model description follows the ODD (Overview, Design concepts, Details) protocol for describing agent-based models (Grimm et al., 2010,2006). The model was implemented in Netlogo and the program used to simulate plastic movement in oceans.

1. Overview

1.1 Purpose:

The purpose of the model is to understand the movement of the plastics in oceans. We observe how the plastics get carried away by the surface ocean currents and air currents. With the modeled movement we observe where the plastics end up forming clusters of plastics when they are dumped at different coastlines locations based on the real world scenarios.

1.2 Entities, state variables and scales:

The model includes two types of entities: grid cells describing ocean and land areas, individual agents describing plastics. Each entity has the state variables mentioned in table 1. The entities of grid cells are square spatial units with size 3 and plastic of triangular shape of size 2.

Entity	Variable Name	Description	Possible Values	Units
Grid cells	area	Area of the land	Nan for ocean, number>0 for land	km^2
	speed-east	The speed of ocean currents in east direction	Number	km/day
	speed-north	The speed of ocean currents in north direction	Number	km/day
	magnitude	The resulting dist for a day	Number	km
	direction	The resulting direction	0-360	degrees
	p_lat	Latitude of the location	90°N - 90°S	
	p_long	Longitude of the location	180°E - 180°W	
Plastic agent	t_lat	Latitude of the plastic	90°N - 90°S	
	t_lon	Longitude of the plastic	180°E - 180°W	

Scales:

- Temporal resolution : Each tick corresponds to a day
- Spatial resolution : kms => changes w.r.t each patch according to latitude and longitude.

We observed the movement of plastics for upto 2 - 5 years.

1.3 Process overview and scheduling :

For each step(1 day) the plastic movement happens according to the given order(Fig.1). Plastic entities are processed in a randomized order and the changes in the state variables are updated immediately. The submodel implementing this plastic movement is mentioned in the submodel section below.

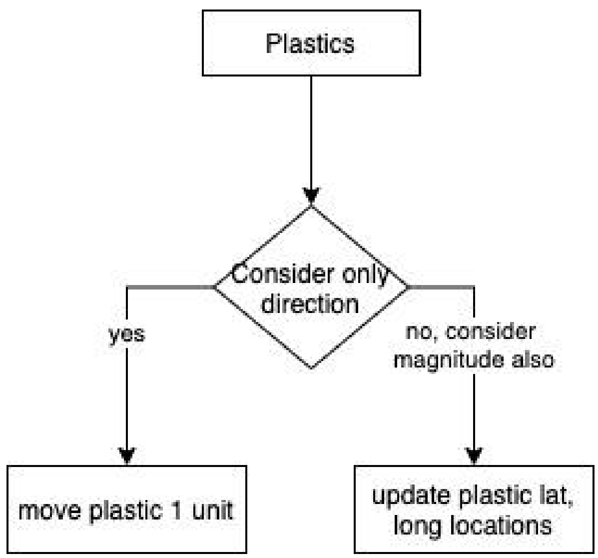

Fig.1 Overview of model process

2. Design Concepts

2.1 Basic principles:

In general, the plastics in the oceans get carried away by the surface water currents and the air flow just above the water. We have used this information in the plastic movement. More details are given in the submodel below. Having our model based on basic principles related to general physics, can be adapted and re-used in other contexts.

2.2 Emergence:

The plastics keep circling at the oceans and a cluster is formed at particular locations. The plastics move according to the currents that keep floating and moving in the oceans.

2.3 Adaptation:

Based on the environmental changes of ocean current and wind directions, the plastic movement is affected. Each plastic agent behaviour is changed by the underlying environmental data.

2.4 Objectives:

The agents are not explicitly programmed to meet any objective.

2.5 Learning:

Agents do not change behaviour traits over time.

2.6 Sensing:

Plastics do not perceive any information.

2.7 Stochasticity:

All the entities' data are acquired from the data-set.

2.8 Observation:

As clusters are formed in different locations, the information of latitude and longitude contribute to environmental study.

3. Details

3.1 Initialization

The initial setup at time = 0 is given in the below flow diagram(Fig.2). The land regions are set according to the world map. The land has patch color of white whereas oceans have patch color blue.

From the global drifter program (gdp, 2011) data the ocean patches are given velocity north, velocity south, lat, long. We additionally derive magnitude, direction from velocities for movement.

Even the positions of plastics can either be set from the data available or randomly.

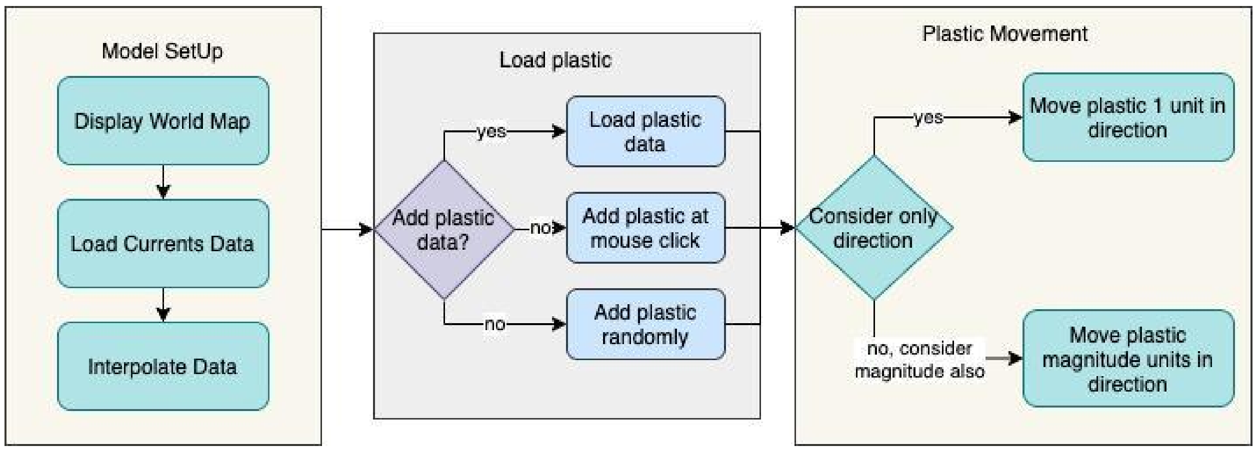

Fig.2

3.2 Input data

We didn't use data to represent processes that change over time. The data used is the part of initialization.

3.3 Submodels

Plastic Movement :

The magnitude and direction calculated for ocean patches are used for the displacement of plastics.

For a plastic turtle

- The resultant plastic displacement is directed by the calculated magnitude and direction from ocean currents.
- Resultant Velocity^2 = Velocity in North Direction^2 + Velocity in East Direction^2
- Distance Magnitude = Resultant Velocity * Time
- Direction = $\tan^{-1}$(Velocity in North Direction / Velocity in East Direction)

Experiments are conducted for two cases

1. Only the direction of ocean currents is considered
    - The heading of the plastic is updated with the ocean currents data and the movement is displaced with 1 unit(i.e km) in the set direction.
    - Minimum of 1 unit is considered as it is the distance required to move to another patch.
2. Both the direction and magnitude and direction is considered
    - The heading of the plastic is updated with the ocean currents data. For the displacement of plastic the location of plastic is updated.
    - The direction and magnitude, along with current latitude and longitude attributes of plastic, are considered to calculate the next latitude and longitude position of plastic using the haversine formula.

- Haversine Formula

$$\phi' = \sin^{-1}((\sin(\phi) * \cos(\frac{d}{R})) + (\cos(\phi) * \sin(\frac{d}{R}) * \cos(b)))$$

$$\lambda' = \lambda + \tan^{-1}(\frac{\sin(b) * \sin(\frac{d}{R}) * \cos(\phi)}{\cos(\frac{d}{R}) - (\sin(\phi) * \sin(\phi')})$$

Where, Φ is the initial latitude, Φ′ is the final latitude, λ is the initial longitude, λ’ is the initial longitude, R is the radius of earth(mean radius = 6,371km), b is the direction to move and d is the magnitude (distance to move).

b and d are the magnitude and direction acquired from ocean currents data.

- The latitude and longitude are projected to netlogo world coordinates and the plastic position is updated accordingly.

4. Cite us

Murukutla S.A., Koushik S.B., Chinthala S.P.R., Bobbillapati A., Kandaswamy S. (2021) A Simple Agent Based Modeling Tool for Plastic and Debris Tracking in Oceans. In: Dignum F., Corchado J.M., De La Prieta F. (eds) Advances in Practical Applications of Agents, Multi-Agent Systems, and Social Good. The PAAMS Collection. PAAMS 2021. Lecture Notes in Computer Science, vol 12946. Springer, Cham. https://doi.org/10.1007/978-3-030-85739-4_12

Data References:

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2.Plastic dumps in Indian and Pacific Ocean: Eriksen, Marcus (2014): Plastic Marine Pollution Global Dataset. figshare. Dataset. https://doi.org/10.6084/m9.figshare.1015289.v1

3.NOAA: National oceanic and atmospheric administration’s global drifter program home page. https://www.aoml.noaa.gov/phod/gdp/index.php. Accessed 01 July 2021