Air Crash Simulation in Dehradun Airport caused by Birds

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1. Introduction:

A bird strike is defined as a collision between an airborne animal and a man made vehicle. Bird strikes are a significant threat to flight safety. Mostly, the investigated result often shows the vulnerability of air crash due to unprecedented strike of birds. In this report, a simulation has been performed with the object of identifying the rate of occurrence of bird strike in a specific predefined time span. The study area has been chosen as Dehradun airport, located about 22 km southeast of Dehradun, Uttarakhand, India. A simulation is defined as a replication of real world phenomena or functioning of a system based on mathematical model (set of differential equations or a set of algorithms etc) in order to extract crucial intended information from a set of predefined environment for the analytical interpretation of dynamic behaviour as a whole. A computer simulations reproduce the response of a system using a mathematical model.(Tisue & Wilensky, 2004) In this study, with the help of agent-based modelling(ABM), an artificial modelling environment has been established to assess the actions and interactions between agents as well as system as a whole, based on purely defined mathematical formulations. Initially, two agents(birds and planes) have been chosen to explore the aforementioned environment. A two dimensional system is often useful for simplifying the complex physics based equations like two body collision (Stonedahl, Tisue, & Wilensky, 2006). So in view of establishing a profound stimulating scenario, Dehradun airport data has been imported in the multi-agent programmable environment - NetLogo (open source). After importing the vector layers, extracted from QGIS, an initial set of conditions have been imposed on the NetLogo.

Firstly, the initial number as well as direction of each randomly generated bird which use to fly from surrounding forest area towards airport. The ratio of velocity of birds and airplanes have been clearly defined. Now if a bird comes closer to an airplane, the event of crashing of both agents will take place. So based on the count of clash between two agents, the frequency of occurrence of accidents have been displayed.

1.1 Objective:

i) The first objective of this study is to build an environment for air crash simulation.

ii) The second objective of the study is to extract a pattern of number of crashes in Dehradun airport due to bird strike, keeping a fixed takeoff of planes as 11 per day, at a span of 10 days. As in respect of 2017 report, the number of aircraft movements was 7850. So the average number of takeoff per day is near about 11 (*Air Transport;— Yearly Statistics*, n.d.).

1.2 Problem Statement:

Understanding the interaction between the behaviour of different agents in a predefined environment and extracting out prolific information is the key to design a problem statement. Bird strike is often treated as a very fundamental cause of air crash. In the hope of revealing an important pattern of crash in a simulated multidimensional environment, NetLogo has been chosen as a platform to define and simulate the probability of occurrence of air crash with respect to a specific time domain.

1.3 Selection of Study Area:

Dehradun Airport is a domestic airport located about 22 km southeast Dehradun, Uttarakhand, India. Nestled in the foothills of Himalayas. The airport resumed commercial operations on 30 March 2008 after a runway extension to accommodate larger aircraft. The data set has been collected from openstreetmap. The maximum and minimum latitude of the study area ranges from 30°9'59.04" N, 78°8'45.96" E to 30° 12' 48.96" N, 78° 12' 45" E. The length of the runway is 2140 m.

Fig 1: Area of Interest

2. Concepts and Terminologies:

2.1 Model:

A model is an abstraction of reality with operational potentials. The main purpose of the model is to understand the existing scenario as well as future prediction. A computer model is a simplified version of abstraction of complex reality. The model can act as a blueprint for reality.

2.2 Agent Based Modeling:

Agent based models simulate the actions of heterogeneous population of agents and their interactions. It is a style of modeling in which agents and their interactions with each other and their environment are represented in a program. Agents can be separate programs or distinct parts of the same program that represents social actors. These actors may be people, animals, groups, households, nations depending on the application. Agents should be identified and their behavior should be defined. A set of decision rules are specified that define the behavior of agents. Each agents have specific parameters with which it will interact with different agents.

In this project the identified agents are birds and aeroplane. The behavior of these agents are defined in the program.

2.3 NetLogo:

The simulation of identified scenario is done using Netlogo. Netlogo is a platform for agent based modeling. It is an agent based programming language as well as an integrated modeling environment for simulating natural and social phenomena. It has a graphical interface. It is well suited for modeling complex systems evolving over time. In Netlogo, commands and reporters tells the agents what to do. A command is an action for an agent to carry out, resulting in some effect. A reporter is instructions for computing a value, which the agent then "reports" to whoever asked it.

2.4 Simulation:

Simulation is the imitation of the operation of a real-world process or system over time. Generally it is carried out to understand the dynamic behaviour of attributes keeping a holistic view over the system.

3. Methodology:

The methodology adopted for classification has been shown as workflow diagram with the best possible representation as below:

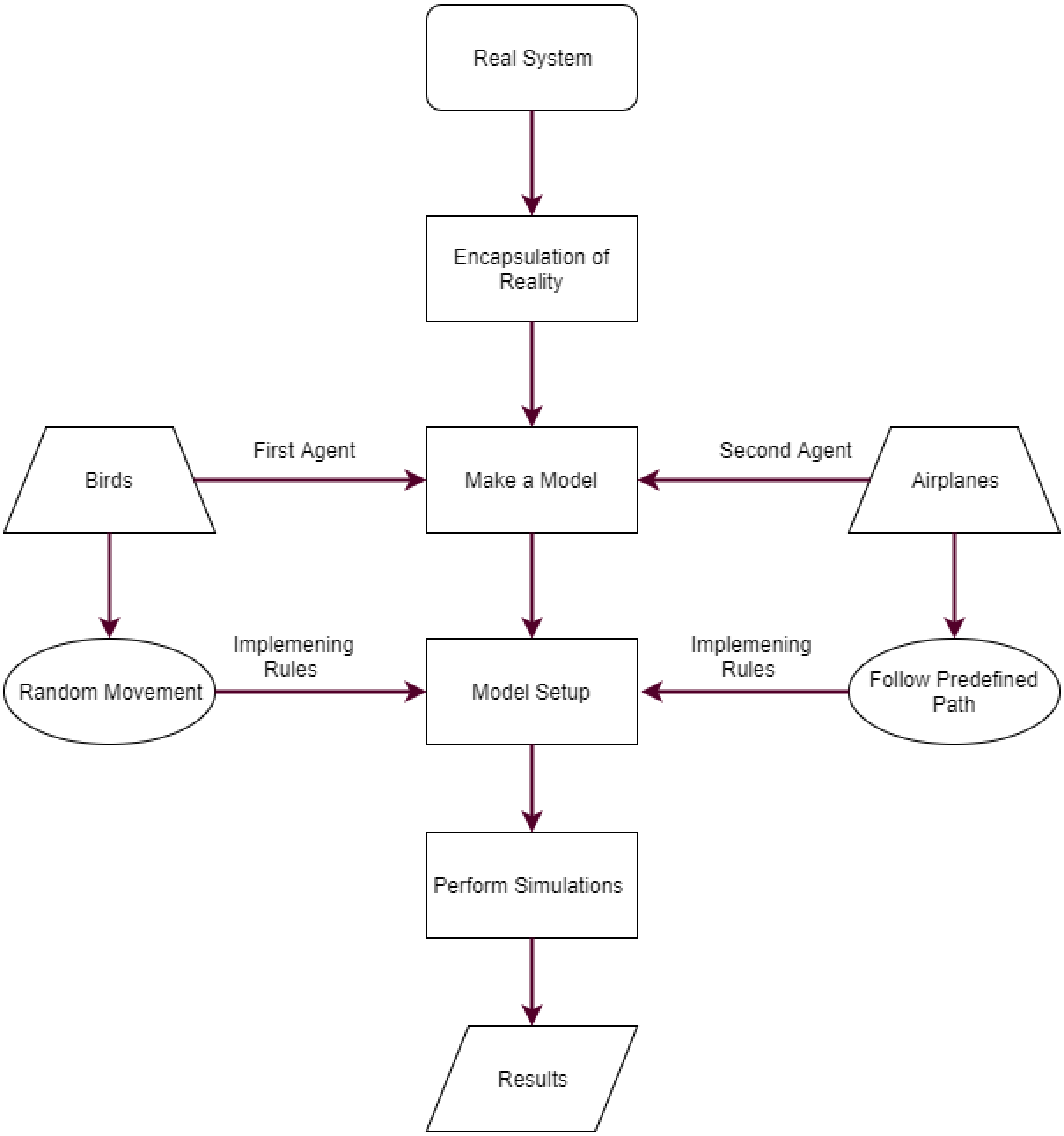

Fig 2: Workflow Diagram

3.1 Schematic Workflow Elucidation:

The procedure being adopted for simulating the model, has been shown below.

3.1.1 Real System:

Real system can be defined as an environment where the interaction between the dynamic behaviour is perceived as existed in the state but not as a theoretical or imaginary. The study which has been conducted to extract dynamic changes on a system based on the reality or tried to theorize the reality or abstract the diversity scientifically. The data which had been chosen to replicate the reality was the shapefile of Dehradun Airport.

3.1.2 Encapsulation of Reality:

Needless to say that, the entire 3-dimensional framework has been encapsulated to 2-dimensional in order to minimize the mathematical complexity. So the bird strike which use to happen in 3-dimensional scenario, has been abstracted to 2-dimension in this case.

3.1.3 Make a model:

The model has been made in respect of reality. As we always know that, in respect of bird strike, a lot of accidents happened in all around the world. So the objective which was chosen to simulate the collision between birds and airplanes, had been investigated by assuming a set of rules which was being assigned to each and every agent to act and interact in a pseudo-random fashion. Based on aforementioned technique, an encapsulated scenario of collision had been established as model. The agents which had been chosen to construct the scenario was birds and airplanes.

3.1.4 Model Setup:

Setting up a model is inextricably linked with the meaningful abstraction of reality to visualise as well as extract prolific information. In this case, at first in NetLogo, a 30 * 20 window had been defined. The following steps which had been followed to build up are as follows:

a) On the window, 3 layers of vector data (forest, roads, airport) of Dehradun Airport and surroundings had been imported.

b) After importing, 2 agents which were chosen to achieve the aforementioned objective, are:

i) Birds

The set of rules which had been assigned to study the behavior are,

- The birds will be distributed randomly over the forest.
- The birds will start moving randomly from its initial state.

ii) Aeroplanes

- The airplanes will start from a specific point and it will go straight to the end of the airport.
- After the end point, it will follow one of three predefined path which will be either a straight line or curve lines.
- Altitude has been taken as a parameter for airplanes.
- After reaching to a certain distance, the chances of collision between birds and planes have been assigned to zero as birds won't fly after a certain altitude.

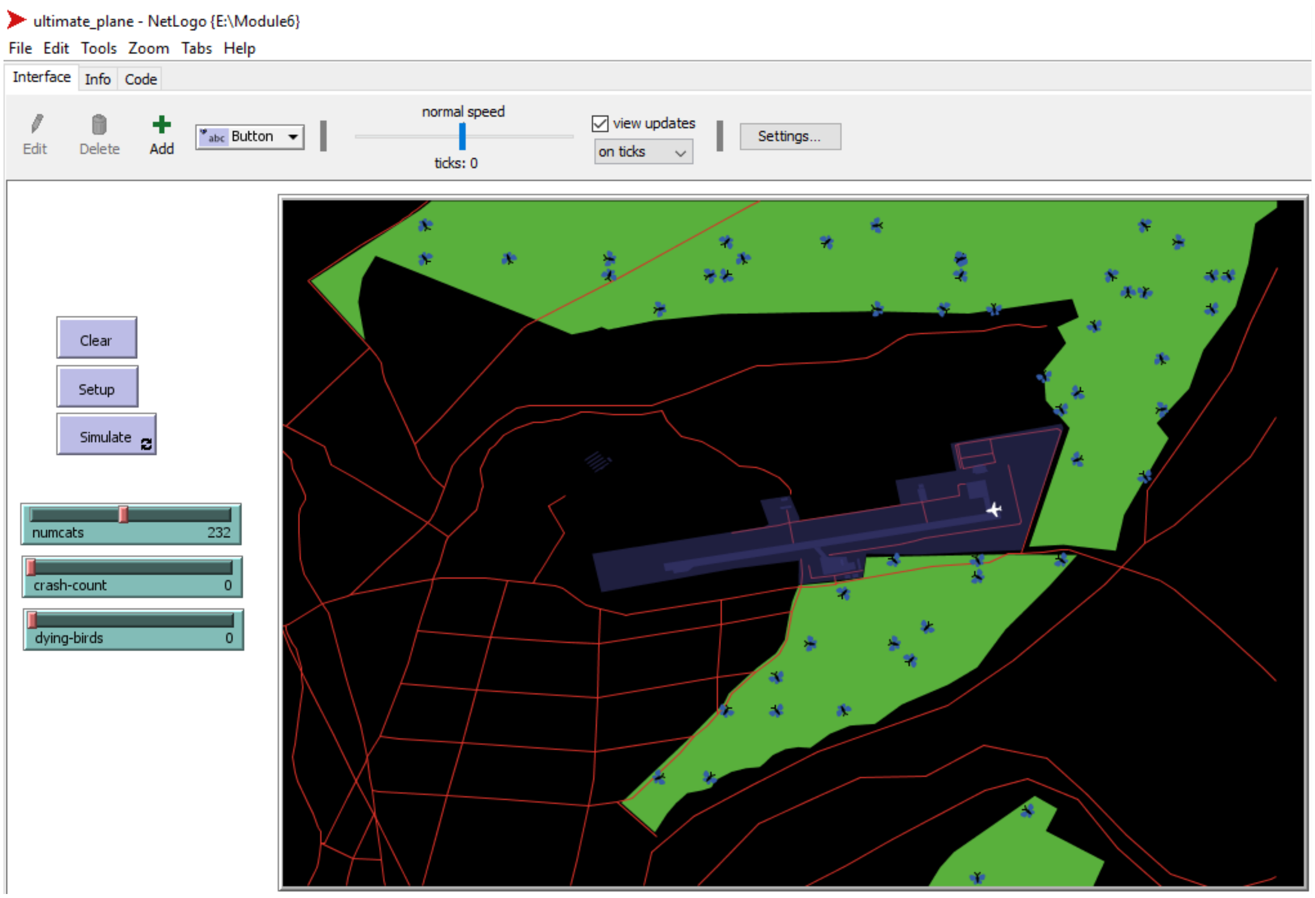

Fig 3: Model Setup

On the above figure, three buttons, and three sliders have been defined in order to understand and perform the simulation. The first button Clear is for executing the command clear-all. The second button Setup is for executing and setting up the environment in order to prepare for simulation. The Simulate button is for running the code for simulation. The numbirds button is for producing random birds within a certain predefined interval.

3.1.5 Perform Simulations:

The simulation is being carried out to execute the behaviour of the system. The sliders are used for identifying the number of bird dying on the environment as well as the number of plane crashes for this.The figure which has been shown below, is a snap of simulation going on in a specified loop. As it has been clearly shown that, the number of randomly generated birds varies between 500. Also the

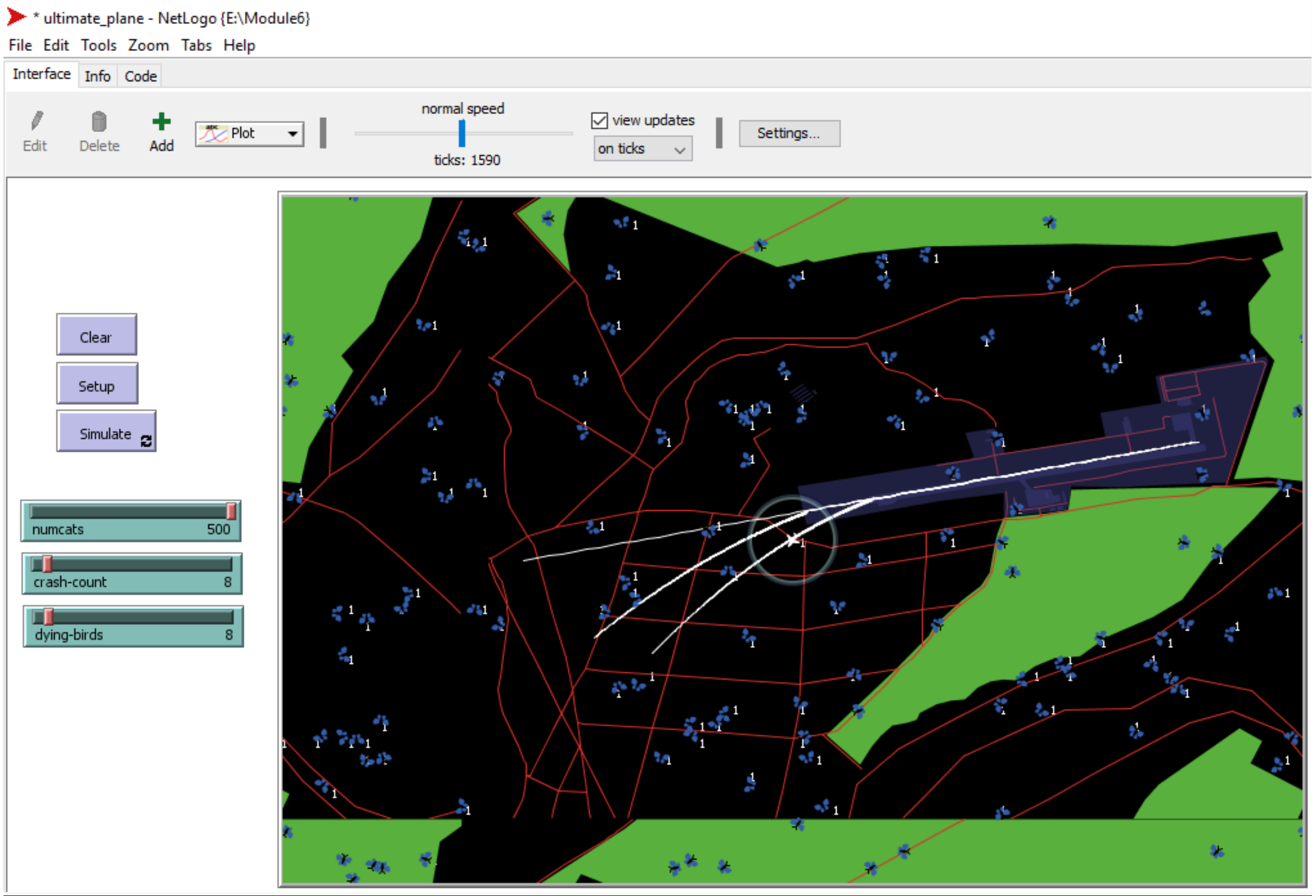

Fig 4: Performing simulations

4. Code:

4.1 NetLogo Code:

```
extensions [gis]
;GIS extension is being used in order to import Dehradun data
breed [birds bird]
breed [planes plane]

patches-own [
  forest
  roads
  airport
]

globals [
  forest-data
  road-data
  airport-data
  speed
  takeoff-speed
  curve-type
  genplanes
  num_planes
  altitude
  speed_incr
]

to new_plane
  create-planes genplanes [
    set altitude 0
    set speed 0
    set speed_incr random-float 0.001 + 0.015
    set takeoff-speed 0
    set color white
    set xcor 12
    set ycor 2
    set pen-mode "down"
    set shape "airplane"
    set heading 260
    set curve-type random 4
  ]
  set num_planes num_planes + 1
end

to new_birds
```

```
  create-birds numbirds [
    set color blue
    let max-x-extreme 30
    let min-x-extreme -30
    let max-y-extreme 20
    let min-y-extreme -20
    set xcor random (max-x-extreme - min-x-extreme) + min-x-extreme
    set ycor random (max-y-extreme - min-y-extreme) + min-y-extreme
    set pen-mode "up"
    set shape "butterfly"
    create-link-with one-of planes
  ]
  ask birds [
    ifelse gis:contains? forest-data self []
    [ die ]
  ]
end

to init_values
  set num_planes 0
  set crash-count 0
  set dying-birds 0
  set genplanes 1
end

to init_spatial
  resize-world -30 30 -20 20
  set forest-data gis:load-dataset "FinalData/forest.shp"
  set road-data gis:load-dataset "FinalData/roads.shp"
  set airport-data gis:load-dataset "FinalData/airport.shp"
  gis:set-world-envelope gis:envelope-of forest-data
  gis:set-drawing-color green
  gis:fill forest-data 5
  gis:set-drawing-color red
  gis:draw road-data 1
  gis:set-drawing-color [ 64 64 128 125 ]
  gis:fill airport-data 1
end

to setup
  ca
  init_values
  init_spatial
  new_plane
```

```
  new_birds
  ask links [ set hidden? True ]
end

to curve-2
  ifelse  xcor >= -7 [
    set heading 260 forward takeoff-speed
    set takeoff-speed takeoff-speed + 0.000075
  ]
  [
    set altitude altitude + 1
    set takeoff-speed 0
    set ycor (-(xcor ^ 2) / 2) / max-pycor
    set heading atan  (2 * ycor)  xcor
    set speed speed_incr
    forward speed
    if ycor < -19 and ycor > -20 [ die ]
  ]
end

to curve-3
  ifelse  xcor >= -11 [
    set heading 260 forward takeoff-speed
    set takeoff-speed takeoff-speed + 0.000075
  ]
  [
    set altitude altitude + 1
    set takeoff-speed 0
    set ycor (-(xcor ^ 2) / 3) / max-pycor
    set heading atan  (2 * ycor)  xcor
    set speed speed_incr
    forward speed
    if ycor < -14 and ycor > -15 [ die ]
  ]
end

to curve
  set heading 260 forward takeoff-speed
  set takeoff-speed takeoff-speed + 0.000075
  if xcor <= -10 [ set altitude altitude + 1 ]
  if ycor < -5 and ycor > -5.5 [ die ]
end

to crash
```

```
  if altitude < 100 [
    let current-bird self
    ask planes with [ distance current-bird < 1 ] [
      if xcor < -9 [
        set crash-count crash-count + 1
        ask current-bird [
          set dying-birds dying-birds + 1
          die
        ]
        die
      ]
    ]
  ]
end

to go
  let planelist []
  let bird_list[]
  ask birds [ set bird_list lput self bird_list ]
  ask planes [
    let current-plane self
    set planelist lput self planelist
    if curve-type <= 1 [ curve ]
    if curve-type = 2 [ curve-2 ]
    if curve-type  = 3 [ curve-3 ]
  ]
  if length planelist = 0 [ new_plane ]
  ask birds [
    forward 0.005
    set heading ( heading + ( random 3 - 1 ) * 10)
    ifelse num_planes < 7 [ crash ]
    [ foreach bird_list [ die ] ]
  ]

  ask patches [
   ifelse (count turtles-here) > 0 [
     set plabel count turtles-here
    ]
    [ set plabel "" ]
  ]
end
```

4.2 R Code:

```
options(java.home="C:\\Program Files\\Java\\jre1.8.0_162")
library(RNetLogo)
library(ggplot2)
nlDir <- "C:/Program Files/NetLogo 6.0.2/app"
setwd(nlDir)

nl.path <- getwd()
NLStart(nl.path,gui = TRUE, nl.jar = 'netlogo-6.0.2.jar')

model.path <- "E:\\Module6\\ultimate_plane.nlogo"
NLLoadModel(model.path)
num_crashes = matrix(nrow=365, ncol=3)
for( i in 1:20){
    birds = round(runif(1, 1000, 3000))
    NLCommand("set numbirds", birds)    # set density value
    NLCommand("setup")              # call the setup routine
    NLDoCommandWhile("num_planes < 7","go")
    num_crashes[i,]=c(i,birds, NLReport("crash-count"))
}
x11(height=7,width=8)
par(mfrow=c(1,2))
plot(num_crashes[,1], num_crashes[,3], xlab='Day', ylab='Crashes')
lines(num_crashes[,1],num_crashes[,3])
plot(num_crashes[,2], num_crashes[,3], xlab='Bird', ylab='Crashes')
lines(num_crashes[,2],num_crashes[,3])
```

5. Results:

5.1 Simulated Air Crash for the year 2017 using NetLogo and R(Consecutive 5 days):

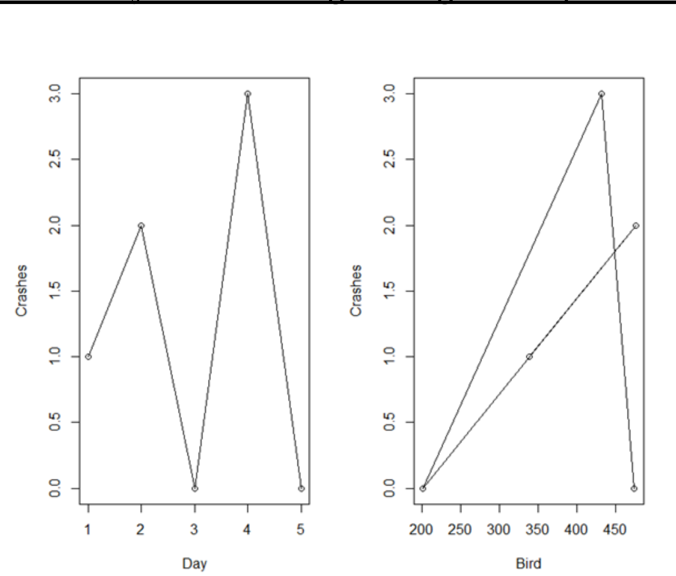

Figure 5: Accident statistics of bird strike for first trial

In the first trial (for simulation 5 days' flights) as shown above, the flight altitude has not been taken into consideration. In respect of the aforementioned criteria, the maximum number of crash occurred on day four which was 3.

5.2 Simulated air crash(for consecutive 5 days):

In the second trial(for simulation 5 days' flights) as shown above, the flight altitude has been taken into consideration. In respect of the aforementioned criteria, no crashes occurred.

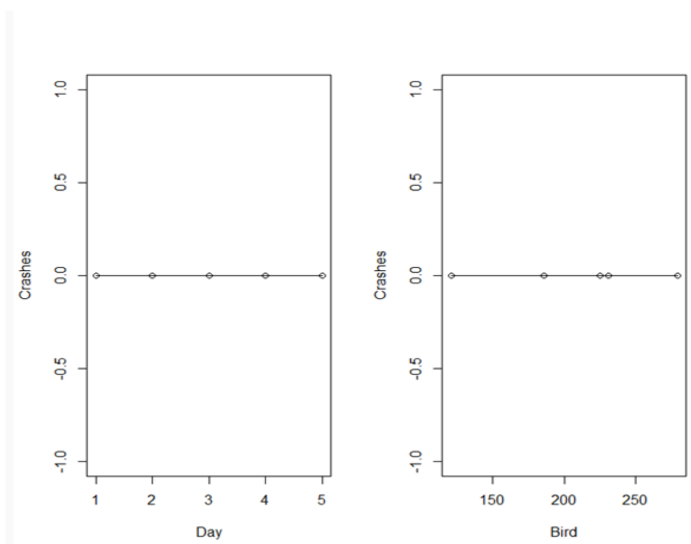

Figure 6: Accident statistics of bird strike for 2nd trial

5.3 Simulated air crash(for consecutive 10 days):

In the third trial(for simulation 10 days' flights) as shown above, the flight altitude has been taken into consideration. In respect of the aforementioned criteria, no crashes occurred.

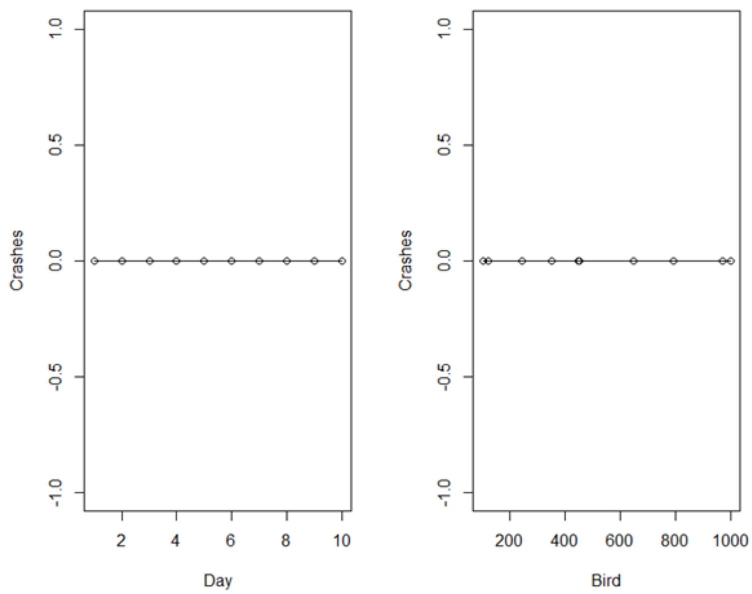

Figure 7: Accident statistics of bird strike for 3rd trial

5.4 Simulated air crash(for consecutive 10 days):

In the fourth trial(for simulation 10 days' flights) as shown above, the flight altitude has been taken into consideration. In respect of the aforementioned criteria, only two crashes occurred.

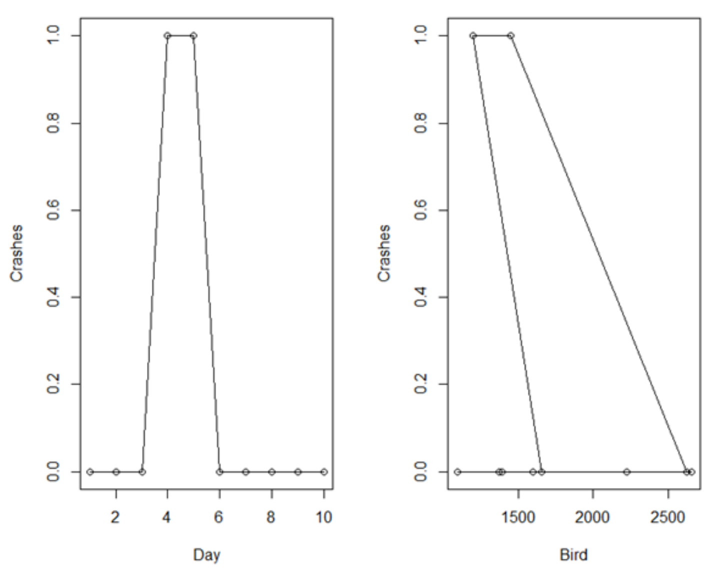

Figure 8: Accident statistics of bird strike for 3rd trial

5.5 Simulated air crash(for consecutive 20 days):

In the fifth trial(for simulation 20 days' flights) as shown above, the flight altitude has been taken into consideration. In respect of the aforementioned criteria, four crashes occurred.

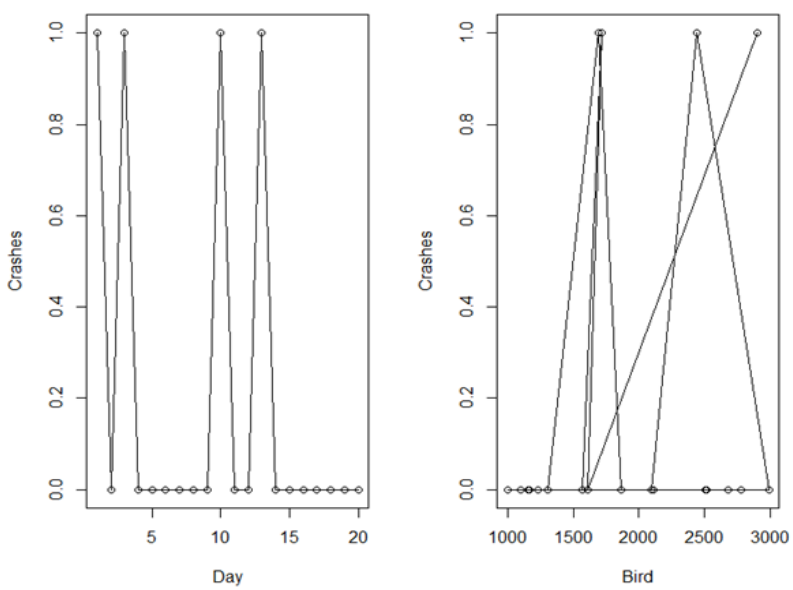

Figure 9: Accident statistics of bird strike for 3rd trial

5.6 Simulated air crash(for consecutive 30 days):

In the sixth trial(for simulation 30 days' flights) as shown above, the flight altitude has been taken into consideration. In respect of the aforementioned criteria, the number of crashes increased in respect of the increase of number of days.

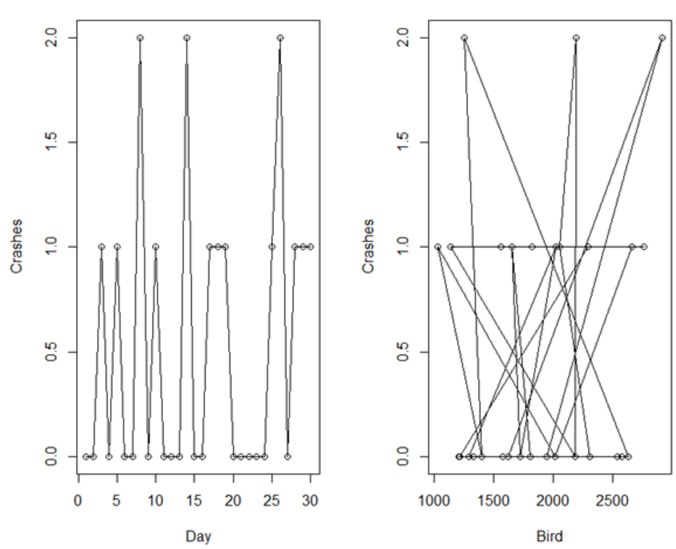

Figure 10: Accident statistics of bird strike for 3rd trial

6 Conclusions:

The obtained results simulate air crash and accident pattern of the study area for the year 2017. Although, in reality, as per current scenario, the chances of bird strike is very less. In this study, after multiple trial run with respect to certain predefined rules, the occurrence of air crash accident is very less. However, the 3 dimensional environment of collision has been constricted to 2 dimensional scenario as well as the pattern of movement of birds have been randomised, the desired result would have been more realistic if and only if the defined set of rules were synchronized more specifically with the reality. As there is no doubt about the fact that, probability of occurrence of accident increases with the increase of span of a given trial, the desired result has been reflected as similar to the fundamental rules of mathematics.

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Tisue, S., & Wilensky, U. (2004). *NetLogo: Design and Implementation of a Multi-Agent Modeling Environment*. Chicago, IL. Retrieved from http://ccl.northwestern.edu/papers/agent2004.pdf