# The Role Of Uninformed Individuals In Promoting Democratic Consensus in Animal Groups

**MTH 426/426A**
**Group Project**


## Group Members

Aditya Tandon – 11042 (BS PHY)

Gaurav Gupta -11272 (BT ME)

Aman Pandya – 11481 (BS ECO)

Tapas Agarwal – 11764 (BS MTH)

Roshni Agarwal – 12910 (MSc MTH)

## INTRODUCTION:

Social grouping has been observed in a wide spectrum of species in nature. It is known by various terminologies – flocking for birds, shoaling for fish, swarming for insects and herd behaviour for mammals. The benefits of grouping are varied and they are formed explicitly for specific purposes. There are also costs associated with flocking but the principal benefits of safety in numbers and increased foraging efficiency overcome these costs. So strong are the benefits that even multi-species flocking have been observed in closed habitats such as forests.

Strictly from the perspective of mathematical modelling, flocking is the collective motion of a large number of self-propelled entities. It is considered as an emergent behaviour arising from simple rules that are followed by individuals and does not involve any central coordination. Basic models of flocking behavior are controlled by three simple rules:

1. **Separation** - avoid crowding neighbors (short range repulsion)
2. **Alignment** - steer towards average heading of neighbors
3. **Cohesion** - steer towards average position of neighbors (long range attraction)

With these three simple rules, the flock moves in an extremely realistic way, creating complex motion and interaction that would be extremely hard to create otherwise.

A major cost associated with flocking is bullying of socially subordinate individuals by relatively more dominating individuals. Especially while making collective decisions; it is very common to observe conflicting interests among group members. Yet, failure to achieve consensus is a costly proposition. Under these circumstances, individuals may be susceptible to manipulation by a strongly opinionated or extremist minority. It has been traditionally been argued across species that social groups consisting of individuals who are uninformed or exhibit weak preferences are particularly vulnerable to such manipulative agents.

In this study, we examine theory and an experiment conducted by *Iain Couzin et al* to demonstrate that for a wide range of conditions, a strongly opinionated minority can influence and dictate group choice, but the presence of uninformed individuals spontaneously inhibits this process, returning control to the numeric majority. The results of this project emphasize the role of uninformed individuals in achieving democratic consensus amid internal group conflict and informational constraints.

## MODEL:

In our model we consider the system as a **2-dimensional surface** where each fish is uniquely defined by its position and velocity.
There are two separate targets in the 2D-universe that represent where the fishes may want to go. Some fishes have an intrinsic desire to go to target 1, others want to go to target 2 whereas the rest are uninformed and have no real personal motivation to go to either target.
The decision making process for each fish to decide where it should go depends on two factors - **social pressure** and its own **intrinsic choice.**

By varying the parameters in our model such as the number of uninformed individuals and the strength of preference, we can draw meaningful conclusions regarding the process of decision making in animal groups.

## SYSTEM CHARACTERISATION:

As a part of this study, we computationally simulate an environment consisting of a set of individuals (fishes in our case) and targets. Thus, the **system** consists of **fishes** and the **target.** No external factors affect this system and all the conditions are maintained to be constant.

Thus, this is a **Closed System.** Environment consists of water (again, stimulated.) The system is made to run and observed over time, from the initial position till the time fish reach their targets. Hence, we are dealing with a **Dynamic System.** Since we are simulating the system on a computer, our model is a **discrete** one. Now at first sight, it might seem that we are dealing with a deterministic system. But randomness is incorporated in the system by randomly assigning initial velocity to the shoal of fish. The interaction between fish depends upon depends upon their velocity and thus social influence and changes in opinion are depended indirectly on the initial velocity assigned to the fish. Thus, we see a **Stochastic System** in the simulated model. Now, following are the **variables** incorporated into the model:

$\mathbf{c_i(t)}$ = Position of individual *i* at time t
$\mathbf{v_i(t)}$ = Unit direction vector of individual *i*
$\mathbf{g_i}$ = Preferred direction of travel of individual
$\boldsymbol{\alpha}$ = Range of repulsion
$\boldsymbol{\rho}$ = Maximum range of social influence

The **parameters** defined in the model are:

*N* = Total population
$N_1$ = Majority population
$N_2$ = Minority population
$N_3$ = Uninformed individuals
$\omega_1$ = Strength of preference of $N_1$
$\omega_2$ = Strength of preference of $N_2$
v = Speed of every fish

## MATHEMATICAL FORMULATION:

Let the group be composed of N individuals.

Each individual *i* of the group at a time *t* is represented by

- position $c_i(t)$
- unit direction vector $\underline{v_i}$

Individuals modify their motion based on the orientations (heading) and/or positions of *j* within two zones.
In the smaller zone, with radius $\alpha$ centered on the focal individual, the repulsion rule applies, defined as turning away from individuals within this range.

$$s_i(t+\Delta t) = -\sum_{j\neq i} \frac{c_j(t)-c_i(t)}{\lvert c_j(t)-c_i(t)\rvert} \qquad \text{Equation 1}$$

$s_i(t+\Delta t)$ represents the social component of the individuals’ desired direction of motion in the subsequent time step.

If there are no individuals in the repulsion zone, however, the focal individual exhibits attraction towards, and alignment with the direction of travel of, neighbors *j* within radius $\rho$

$$s_i(t+\Delta t) = \sum_{j\neq i} \frac{c_j(t)-c_i(t)}{\lvert c_j(t)-c_i(t)\rvert} + \sum_{j} \underline{v_j}$$

Equation 2

In addition to these social interaction rules, individuals may have a preferred direction of travel $\underline{g_i}$ .
They reconcile social and goal oriented tendencies with a continuous weighting term, $\omega_i$ .

$$d_i(t+\Delta t) = \sum_{j\neq i} \frac{s_i(t+\Delta t)}{\lvert s_i(t+\Delta t)\rvert} + \omega_i \underline{g_i} \qquad \text{Equation 3}$$

Their desired direction of travel being unit vector : $\underline{d_i}(t+\Delta t)$

where $$\underline{d_i}(t+\Delta t) = \frac{d_i(t+\Delta t)}{\lvert d_i(t+\Delta t)\rvert}$$

- If $\omega$ = 0 , individuals either have no desire to move in a prefered direction or are uninformed/naïve.
- If $\omega \approx 1$, it tends to equally bias its tendency to move in its preferred direction with social interactions.

- If $\omega > 1$, individuals are more heavily influences by their preferred direction than by their neighbours.

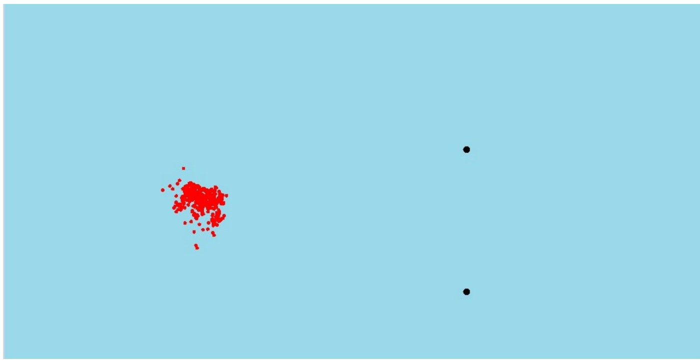
For our model we have 2 competing groups.

Variables:
$N_1$ = Majority population
$N_2$ = Minority population
$N_3$ = Uninformed individuals
$\omega_1$ = Strength of preference of $N_1$
$\omega_2$ = Strength of preference of $N_2$

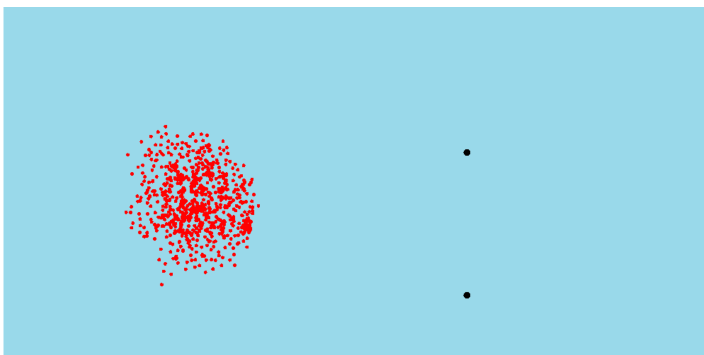
## SOLUTION:

The equations described above were simulated in JAVA with a GUI display used to visualize the results.
Unless stated otherwise the following parameters were used -
1) Total number of fishes, N = 1000
2) Body size of a fish = 5 units
3) Location of the targets = (650,200) and (650,400)
4) Time step size = 0.1 units
5) Initial position of the fishes follows a Gaussian distribution with mean (100,300) and standard deviation (10,10)

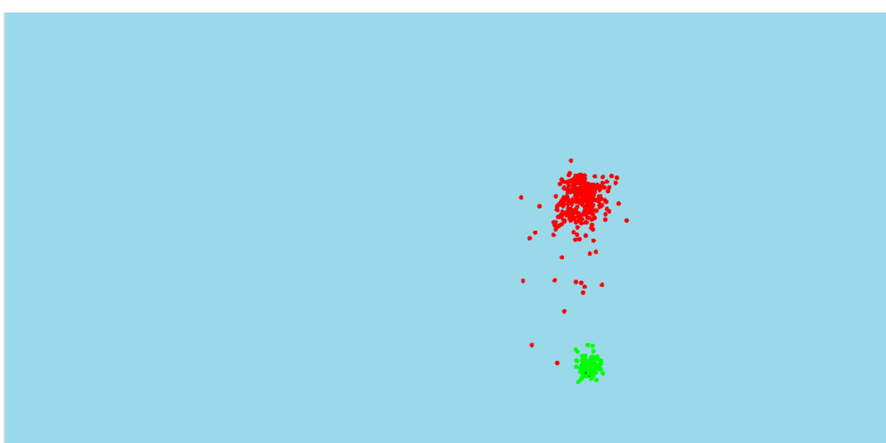
The positions and velocities of the fishes were re-calculated after each iteration (using the model described above) and the new output was displayed on the screen. This was repeated till the fishes reached the



target.



*In the first image, $\alpha$ =5 while in the second image $\alpha$ =10. It can quite clearly be seen that the average separation is more in the second case*

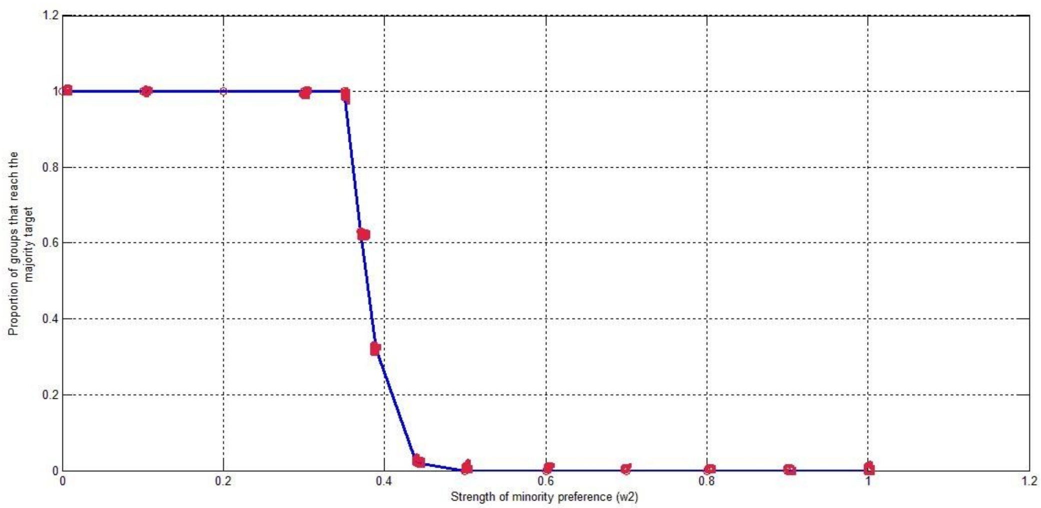


*Here, for the red group $\omega_1$ = 0.2 and $\omega_2$ = 0.4 and $N_1$ = $N_2$ = 500. The alignment radius, $\rho$, has been reduced substantially so that the group can split. We can see that the second group has already reached their target whereas the first group is pretty scattered.*

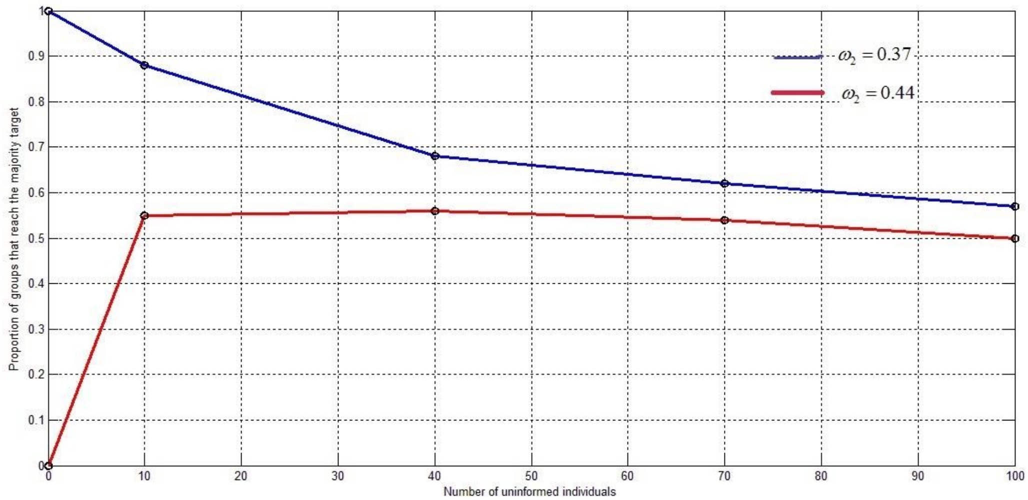
## RESULTS:

Using the simulation developed we used the following parameters to verify our results with the ones obtained in [1]

1) Here, we just have two groups with $N_1$ = 6 (majority) and $N_2$ = 5 (minority). Strength of majority preference, $\omega_1$ = 0.3 and $\omega_2$ is varied. For each value of $\omega_2$ the simulation was run 100 times and the proportion of groups that reached the majority target was plotted.




Through this graph we see that in the absence of uninformed individuals, the minority preference dominates over the majority if the strength of minority preference, $\omega_2$ is sufficiently high.




2) Here, we have three groups with $N_1$ = 6 (majority) and $N_2$ = 5 (minority) and $N_3$ (number of uninformed individuals) is varied. Strength of majority preference, $\omega_1$ = 0.3 and $\omega_2$ = 0.37 and 0.44 corresponding to two sets of data. For each data point the simulation was run 100 times and the proportion of groups that reached the majority target was plotted.

Through this graph we see that in the presence of uninformed individuals, no particular group is able to completely dominate the entire population all the time.

## APPLICATIONS:

The flocking model finds applications in various segments of life. It is being extensively used to understand high-speed trading. The individuals involved in this profession follow similar herd behaviour which can be governed by simple laws and thus dynamic changes in stock prices can be interpreted. It can also be used to speculate traffic patterns at busy intersections. A very practical application of the studied model would be to predict results of an election. There would be a group of voters who would have very strong opinions about a particular candidate and there would be another group who would be neutral, weakly supporting or politically uninformed. Voter preference could change by interaction or by external factors such as media, etc. Thus, voter behaviour would follow very similar outcomes to that of the studied model.

## SCOPE OF IMPROVEMENT:

An adaptive network(AN) model could have been used instead of the spatial model to compute inferences. It is very similar to the currently used model but in this case, reinforcement and positive feedback is deliberately incorporated, whereas it arises as an emergent property in spatial model. AN model employs tools from network science and describe the system as a set of nodes and edges. The nodes correspond to individuals, whereas a link (edge) between two nodes indicates mutual awareness between the corresponding individuals.
The network model evolves in time according to simple heuristic rules designed to capture-
a) Change of each individual's opinion due to interactions with its topological neighbours
b) Change of the topology due to individuals encountering and separating from one another.

Another model that could have been used instead of spatial model is the conventional model. Originally this model was proposed as an aid in the study of the evolution of conventions or social norms, and is relevant to situations where it is desirable to adopt the same strategy as the majority of the population. At each timestep an individual is selected at random from a population of size ***N***. This individual then observes the population and switches to the currency held by the majority of individuals. To introduce a stochastic element this occurs with probability 1-ξ, and with probability ξ a random currency is selected.

## REFERENCES:

[1] “Uninformed Individuals Promote Democratic Consensus in Animal Groups” - Science 334, 1578 (2011)
[2] http://en.wikipedia.org/wiki/Flocking_(behavior) - Wikipedia

# APPENDIX:

1. Java code used for running the simulations is available here - home.iitk.ac.in/~gaurag/mathprojectcode.txt