Analysis for an Agree-Disagree Model of a Political Party

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DECLARATION

I, E M C H Madushani, declare that the presented project report titled, " Analysis for an Agree-Disagree Model of a Political Party" is uniquely prepared by me based on the group project carried out under the supervision of Dr L. W. Somathilake Department of Mathematics, Faculty of Science, University of Ruhuna, as a partial fulfillment of the requirements of the level III Industrial Mathematics course unit (IMT3b1β) of the Bachelor of Science (General) Degree in Department of Mathematics, Faculty of Science, University of Ruhuna, Sri Lanka. It has not been submitted to any other institution or study program by me for any other purpose.

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Date:. . . . .

SUPERVISOR'S RECOMMENDATION

I/We certify that this study was carried out by E M C H Madushani under my/our supervision.

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ABSTRACT

When people interact with others and form beliefs that they can either agree with or disagree with, an agree-disagree model is frequently used to explain social dynamics and collective decision-making processes. These models try to describe the way that polarisation (disagreement) or consensus (agreement) changes over time. They can be represented using statistical frameworks or network topologies. These analyses enable the prediction of outcomes under various situations, comprehension of the Agree-Disagree Model's behaviour, and identification of the parameters that have the greatest impact on system dynamics. Opinion dynamics, sociology, and political science are a few disciplines where this can be especially helpful.

This project report provides an extensive review of the main objectives, methods, discussions, and results from the Stability and Global Sensitivity Analysis for an Agree-Disagree Model using Java. Developing a technique to assess stability was the main objective of this study, with an emphasis on polling conducted before elections through a mathematical model.A thorough methodology was used to accomplish these goals, which included the fundamental reproductive number and the next-generation matrix approach.According to the study's findings, elections can be significantly impacted by changes in the percentages of those who agree, disagree, and are ignorant.

Keywords: Basic reproductive number, Next generation matrix

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CHAPTER 1
Introduction

1.1 Background of the Study

According to the gazette of Democratic Socialist Republic of Sri Lanka, a 'citizen' is a person who must obey the laws of their [3] state and carry out their responsibilities. They are also entitled to all the legal rights and benefits bestowed upon the members of their constituency. Voting is a fundamental right for citizen above 18.

[2] Citizen will participate for political life if they receive benefits. A best individual economic, representation of interest, accountability, protections of rights, social change, strengthening democracy are some of them. While future outcomes allow participants to negotiate and discuss opinions based on a certain conclusion, opinion polls are surveys of intent for a sample of voters. By questioning people about their ideas, public opinion polls are frequently used to determine people's political views, voting patterns, and other behaviours. These days, polls are important for political campaigns. In here we study the conflict between voters' expectations and preferences while providing candidates with voter support evidence. In order to estimate the probability of outcomes, we first create a mathematical model that describes how opinions evolve. We then compute and examine the model's equilibrium points by determining significant stability thresholds for each equilibrium state. So we need to develop more efficient model through statistical and mathematical method. The most popular way is sensitivity analysis(SA) method. It is used to variety of reasons such as communicating, understanding, developing models etc. this poll model describes the opinions of 'Agree', 'Disagree' and 'Ignorant' regarding the idea.

Suppose there are some political parties as A, B, C and D. In here we consider A is one subset and B, C, D is another subset. Then the who vote for 'A' consider as 'agree' and who votes for the 'B,C or D' consider that is a 'disagree' and who doesn't like to vote both or doesn't have an idea about poll, it consider as an 'ignorant' vote.

1.2 Basic Reproductive Number

The average number of secondary cases of an infection is known as the basic reproduction number, or basic reproductive number (also known as the basic reproduction ratio or basic reproductive rate, or R_0). It is mostly used in Epidemiology. [5]

- $R_0 > 1$ - A populace will be able to begin experiencing the infection's spread. (epidemic occurs)

- $R_0 < 1$- Percentage of the populace that requires adequate immunisation. (No epidemic)

- $R_0 = 1$ - Remain stable in the population

Here we calculate the R_{D0} the average number of new disagreements produced by an individual disagreeing introduced in a population of ignorant. And also R_{AO} is the average number of new agreement produced by an individual agreeing introduced in a population ignorant. The rate of contact between susceptible and infected individuals, the likelihood of transmission per contact, and the length of infectiousness are some of the major variables that affect the value of R_0. Interventions like therapy, immunisation, or behavioural modifications that can lower the rate of transmission are not taken into account by R_0; instead, the effective reproductive number R_e accounts for these. Planning for public health requires an understanding of and estimation of R_0, as it aids in determining the appropriate amount of action needed to contain an outbreak and stop its spread. We can obtained the solution for reproductive number by using 'Next Generation Matrix'.

CHAPTER 2
Literature Review

Analysis of opinion dynamics has long been an area of interest in political science, physics, sociology, and other disciplines. Opinion dynamics models, like the agree-disagree and ignorant (ADI) model, aim to elucidate the processes by which opinions propagate and settle within a population. Specifically, stability analysis sheds light on how these viewpoints converge or diverge over time with varying beginning conditions and parameter values.

2.1 Stability Analysis in Opinion Models

Understanding stability analysis is essential to comprehending these models' long-term behaviour. Specifically, bifurcation analysis and Lyapunov stability are frequently used to investigate the circumstances under which a system will oscillate or reach equilibrium. Sobkowicz (2009), for instance, investigated the stability of beliefs in a society where people alternate between being in favour of and against a certain subject. These investigations have determined crucial points, at which a system's behaviour radically alters, utilising techniques like fixed-point analysis.

2.2 Early Opinion Dynamics Models

The field of opinion dynamics has its roots in the early research of French (1956) and Harary (1959), who employed graph theory to explain how members of a network could affect one another's opinions. This approach was advanced by DeGroot (1974) who introduced probabilistic models in which people change their beliefs based on weighted averages of the opinions of their neighbours. These seminal works mostly addressed the establishment of consensus or agreement among communities.

2.3 The Role of Disagreement

However, reaching total agreement is rarely possible in real life. Rather, groups frequently become stuck in polarised or disagreeable states. By allowing people to remain uninformed or neutral in addition to agreeing or disagreeing, the agree-disagree and ignorant (ADI) model accurately depicts this reality. Scholars such as Hegselmann and Krause (2002) have investigated models with disagreement. They created a bounded confidence model in which people engage only if their opinions are close enough.

2.4 Recent Developments

The use of network architecture and stochastic factors in ADI models has broadened the scope of stability analysis in recent years. Researchers that have examined the effects of random noise and heterogeneous networks on opinion stability include Castellano et al. (2009). These studies demonstrate how rich and varied behaviours, such as metastability and long-term fluctuations, can result from the introduction of randomness or more sophisticated social systems.

The agree-disagree and ignorant model's stability analysis emphasises the value of mathematical and computational techniques in comprehending intricate social phenomena. A more accurate representation of opinion dynamics in a variety of populations is now possible thanks to the addition of disagreement and ignorance to earlier models, which mostly concentrated on consensus formation. It is expected that future studies in this field will keep investigating how network structure, stochasticity, and outside factors affect the stability of opinions.

CHAPTER 3
Problem Statement

The mathematical model herewith has been formulated using three compartment such as,

- Ignorant (I) - people who don't know about the poll or abstain from voting.
- Agree (A) - people in agreement with the idea.
- Disagree (D) - people in disagreement with idea.

A set of assumptions has been used for the modeling process as follows:

1. The target population should be well mixed. So ignorant population also are homogeneously spread.
2. Mortality and recruitment are insignificant.Therefore no individual recruited or died.
3. Individual can communicate through the poll.
4. People who are unsure and abstain from voting are ignorant.

Every individual has their reason for agree, disagree or ignorant. An ignorant individual can be persuaded by someone agree, or someone disagree. Those parameters are written as follows:

- α_1 - Disagree to agree transmission rate
- α_2 - Agree to disagree transmission rate
- β_1 - Ignorant to agree transmission rate
- β_2 - Ignorant to disagree transmission rate
- γ_1 - Interest lost factor of agree individuals

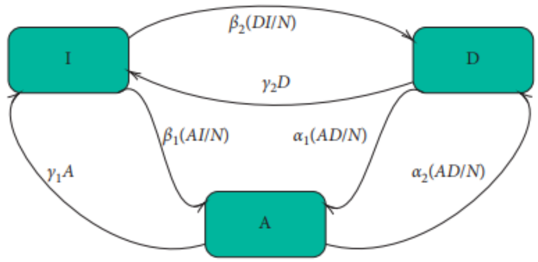

Figure 3.1: Flowchart for model

- γ_2 - Interest lost factor of agree individuals

There are few assumptions as follows:

$$\beta_1 - \gamma_1 > -\frac{\beta_1\gamma_2}{\alpha_1}$$
$$\beta_1 - \gamma_1 > -\frac{\beta_2\gamma_1}{\alpha_2}$$
$$\beta_2 - \gamma_2 > -\frac{\beta_2\gamma_1}{\alpha_2}$$
$$\beta_2 - \gamma_2 > -\frac{\beta_1\gamma_2}{\alpha_1}$$

By considering the all assumptions for this system, ordinary differential equations are written as:

$$I' = -\beta_1\frac{AI}{N} - \beta_2\frac{DI}{N} + \gamma_1 A + \gamma_2 D \tag{3.1}$$

$$A' = \beta_1\frac{AI}{N} + \alpha_1\frac{AD}{N} - \alpha_2\frac{AD}{N} - \gamma_1 A \tag{3.2}$$

$$D' = \beta_2 \frac{DI}{N} + \alpha_2 \frac{AD}{N} - \alpha_1 \frac{AD}{N} - \gamma_2 D \tag{3.3}$$

Where,

I(0) $\geq$ 0, A(0) $\geq$ 0, D(0) $\geq$ 0,

N = I + A + D,

N'= I'+ A'+ D' = 0

Where N is the population size

[1]

The solutions for above ordinary differential equations are non-negative. It is easy to verify that,

$$I = 0 \implies I' \geq 0,$$

$$A = 0 \implies A' \geq 0,$$

$$D = 0 \implies D' \geq 0.$$

Therefore all solutions of systems are non negative,

N = I+A+D is constant

$I \leq N,\ A \leq N,$ and $D \leq N$

For the study we assumed the population as follows:

- I - 10
- A - 45

- D - 45
- N = I+A+D = 100.

3.1 Objectives of the Study

The main objective of this study is to examine how different mathematical model parameters affect public opinion dynamics and stability, particularly agreement and disagreement, in political contexts. To achieve this, it uses methodologies from stability analyse.

CHAPTER 4
Methodology

4.1 Next Generation Matrix

The first step is to calculate the 'Disease Free Equilibrium' (DFE). From this equilibrium point we can calculate the basic reproductive number by using 'Next Generation Matrix'. In here we have to consider the equilibrium states when A = 0 and D = 0. Let R_{A0} be the agree-free equilibrium and R_{D0} be the disagree-free equilibrium. The epidemic model can be written as, [4]

$$\frac{\mathrm{d}x}{\mathrm{d}t} = F(x) - V(x)$$

where F(x) is the rate of new infections and V(x) is the rate of transfer of individual. Here

$$F = \begin{pmatrix} \beta_1 \frac{AI}{N} + \alpha_1 \frac{AD}{N} \\ \beta_2 \frac{DI}{N} + \alpha_2 \frac{AD}{N} \end{pmatrix}$$

and

$$V = \begin{pmatrix} \alpha_2 \frac{AD}{N} + \gamma_1 A \\ \alpha_1 \frac{AD}{N} + \gamma_2 D \end{pmatrix}$$

Let's consider the matrix F. Then assume

$$f(A.D) = \beta_1 \frac{AI}{N} + \alpha_1 \frac{AD}{N}$$

and

$$g(A,D) = \beta_2 \frac{DI}{N} + \alpha_2 \frac{AD}{N}$$

Here

$$F^* = \begin{pmatrix} \frac{\partial f}{\partial A} & \frac{\partial f}{\partial D} \\ \frac{\partial g}{\partial A} & \frac{\partial g}{\partial D} \end{pmatrix}$$

$$= \begin{pmatrix} \frac{\beta_1}{N} I + \frac{\alpha_1}{N} A & \frac{\alpha_1}{N} A \\ \frac{\alpha_2}{N} D & \frac{\beta_2}{N} I + \frac{\alpha_2}{N} A \end{pmatrix}$$

For the matrix 'V' we assume that,

$$m(A,D) = \frac{\alpha_2}{N} AD + \gamma_1 A$$

$$n(A,D) = \frac{\alpha_1}{N} AD + \gamma_2 D$$

By following previous steps wen can the following equations,

$$V^* = \begin{pmatrix} \frac{\alpha_2}{N} D + \gamma_1 & \frac{\alpha_1}{N} A \\ \frac{\alpha_1}{N} D & \frac{\alpha_1}{N} A + \gamma_2 \end{pmatrix}$$

4.1.1 Disagree Free Equilibrium

Suppose there D = 0 and no negative opinions. Then,

$$I^* = \frac{\gamma_1}{\beta_1} N, \tag{4.1}$$

$$A^* = \frac{N(\beta_1 - \gamma_1)}{\beta_1}, \tag{4.2}$$

Where I^* and A^* are numbers of ignorant and agree individuals. So disagree free equilibrium point is

$$e_1 = (\frac{\gamma_1}{\beta_1}N, \frac{N(\beta_1 - \gamma_1)}{\beta_1}, 0) \tag{4.3}$$

According to the above equations the following equation is implied for disagree free equilibrium.

$$F = \begin{pmatrix} \gamma_1 & \frac{\alpha_1}{N}(\beta_1 + \gamma_1) \\ 0 & \frac{\beta_2}{\beta 1}\gamma_1 + \frac{\alpha_2}{\beta_1}(\beta_1 + \gamma_1) \end{pmatrix}$$

$$V = \begin{pmatrix} \gamma_1 & \frac{\alpha_2}{N}(\beta_1 + \gamma_2) \\ 0 & \frac{\alpha_1}{\beta_1}(\beta_1 + \gamma_1) + \gamma_1 \end{pmatrix}$$

The next step is to calculate the FV^{-1}. Then need to find the eigenvalues of FV^{-1}. The eigenvalues of the systems are:

λ_1 = -1 and

$\lambda_2 = \frac{\alpha_2\beta_1 - \alpha_2\gamma_1 + \beta_2\gamma_1}{\alpha_1\beta_1 - \alpha_1\gamma_1 + \beta_1\gamma_2}$

So second generation approach for the R_{D0} is,

$$R_{D0} = \frac{\alpha_2\beta_1 - \alpha_2\gamma_1 + \beta_2\gamma_1}{\alpha_1\beta_1 - \alpha_1\gamma_1 + \beta_1\gamma_2}$$

4.1.2 Agree Free Equilibrium

By following the above steps for this system, the threshold can be obtained as,

$$R_{A0} = \frac{\alpha_1\beta_2 - \alpha_1\gamma_2 + \beta_1\gamma_2}{\alpha_2\beta_2 - \alpha_2\gamma_2 + \beta_2\gamma_1}$$

4.2 Euler Method

The Euler method is a numerical technique used to approximate the solutions to ordinary differential equations (ODEs). When differential equations describe the behaviour of the system, it is very helpful in initial value problems. Applying the Euler approach to your stability analysis might be useful when working with dynamical systems such as the agree-disagree and ignorant model. The general Euler differential equation is,

$$\frac{dy}{dt} = f(t, y)$$

and update rule is:

$$y_{n+1} = y_n + h.f(t_n, y_n)$$

Where:

- y_n - current value of the function
- h - step size
- $f(t_n, y_n)$ - derivative function

- y_{n+1} - new value of the function after one step

Suppose there is a system of differential equations that describe the dynamics of a model that is agree-disagree-ignorant. Assume the following differential equations reflect the system:

$$\frac{dy}{dt} = f_I(A, I, D, t)$$
$$\frac{dy}{dt} = f_A(A, I, D, t)$$
$$\frac{dy}{dt} = f_D(D, I, A, t)$$

Where I(t) is the number of individuals who ignorant, A(t) is the number who agree, and t is unit time. D(t) is the number of individuals who disagree.

We can write equations for the Euler method, as follows.

$$A_{n+1} = A_n + h.f(t_n, y_n)$$

$$I_{n+1} = I_n + h.f(t_n, y_n)$$

$$D_{n+1} = yDn + h.f(t_n, y_n)$$

f_I, f_A, f_D could be derived from the equations describing the rate of change of opinions in the system.

CHAPTER 5
Results

The following values are used to analyze the stability during political vote.

set no	β_1	β_2	α_1	α_2	γ_1	γ_2	R_{D0}	R_{A0}
1	0.0010	0.1010	0.1010	0.3010	0.5010	0.3010	1.9901	2.0730
2	0.5000	0.1010	0.1010	0.3010	0.5010	0.3010	0.3344	-13.5743
3	0.0010	0.5000	0.1010	0.3010	0.5010	0.3010	-1.9921	0.0657
4	0.0010	0.1010	0.5000	0.3010	0.5010	0.3010	0.4000	10.3864
5	0.0010	0.1010	0.1010	0.5000	0.5010	0.3010	3.9722	0.4028
6	0.0010	0.1010	0.1010	0.3010	1.0000	0.3010	1.9851	-0.4877
7	0.0010	0.1010	0.1010	0.3010	0.5010	0.5000	1.9979	0.5727

Table 5.1: Parameter values

This is the values of we get for the α_1, α_2, $\beta 1$, $\beta 2$, γ_1, γ_2. By substituting above values to equations we can get following graphs to analyse what will happen in future by analysing the values of R_{D0} and R_{A0}.

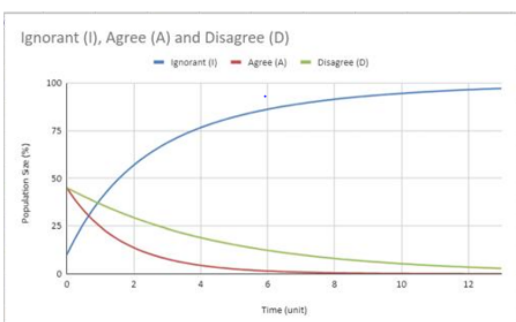

Figure 5.1: Graph of parameter set 1

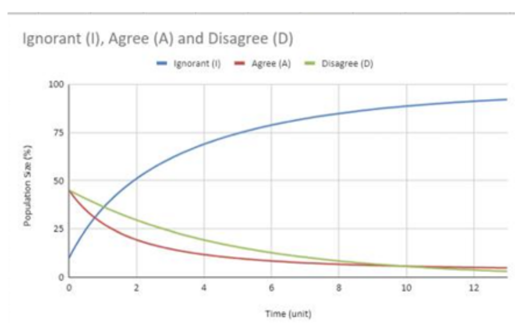

Figure 5.2: Graph of parameter set 2

Let's consider Figure 5.1 graph as initial graph. The rate of ignorant individual increase in here and both agree and disagree individuals decrease with the time.

According to the Figure 5.2 graph , the value of β_1 is increased. Ignorant percentage decrease and Agree percentage increase with the time.

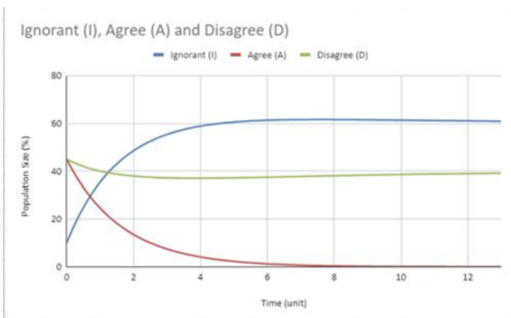

Figure 5.3: Graph of parameter set 3

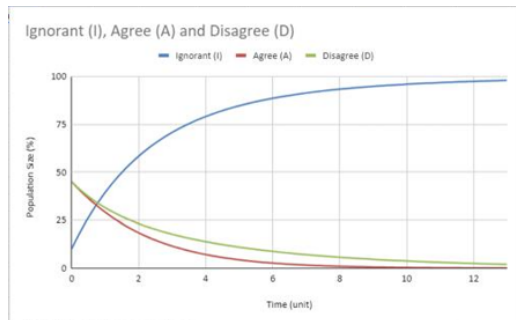

Figure 5.4: Graph of parameter set 4

According to the values of set 3 in above table Figure 5.3 shows increase of the Disagree percentage and decrease of Ignorant percentage. Here we increased the value of β_2.Also When increase the value of α_1 the Figure 5.4 show the increase of Agree percentage and decrease of the Disagree percentage.

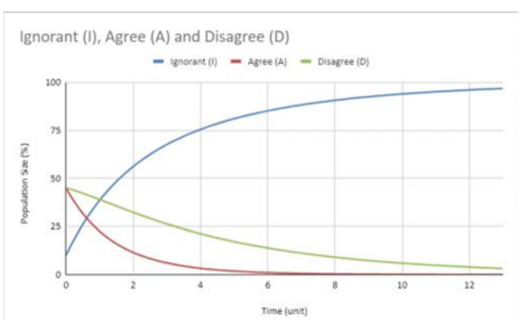

Figure 5.5: Graph of parameter set 5

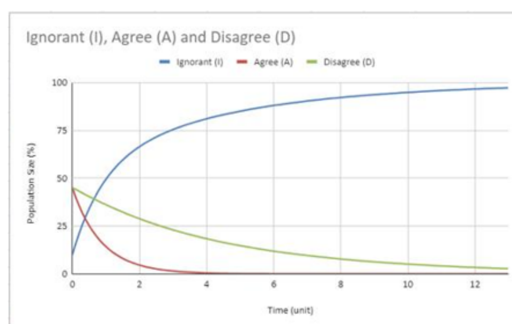

Figure 5.6: Graph of parameter set 6

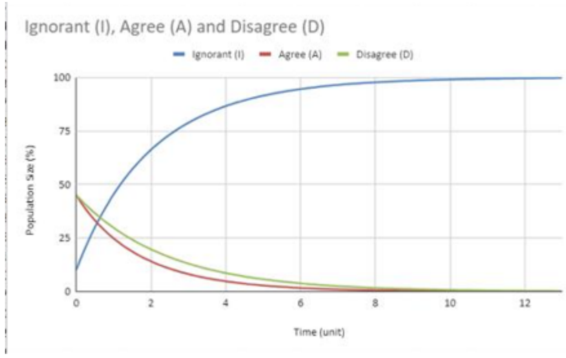

Figure 5.7: Graph of parameter set 7

While the increase of α_2 value the Figure 5.5 show the increase of Disagree percentage and decrease of the Agree percentage. Also when increase the γ_1 Figure 5.6 displays decrease of the agree individual percentage and increase of the ignorant individual percentage.

According to the final values of parameter set in table, the Figure 5.7 show the decrease of disagree percentage and increase of ignorant percentage.

By analysing the values of R_{A0} and R_{D0} or analysing the graphs we can guess what will happen in future for each political parties in unit time.

If $R_0 > 1$ - an epidemic occurs

If $R_0 < 1$ - there will probably be no epidemic.

CHAPTER 6
Discussion and Conclusion

6.1 Discussion

A political party's agree-disagree model seeks to represent the processes of opinion development within a population. According to this methodology, people can choose to support a certain political ideology, oppose it, or stay neutral (ignorant). It is likely that the research looks into what influences these states' transitions and how they come together to form a stable opinion distribution. The stability analysis's findings show the circumstances in which a certain level of agreement or disagreement takes hold inside the political party. For instance, one opinion may become the consensus while other opinions gradually disappear when specific parameters (such the rate of opinion adoption or abandonment) are adjusted.

Because the media is such a potent force in forming and influencing public opinion, its function in a "Agree-Disagree Model of a Political Party" is vital. Within the framework of this concept, media can have a substantial impact on the rates at which people adopt a political ideology, either by agreeing with it or not, or by staying ignorant (indifferent). So the role of media effect for the all parameters $\alpha_1, \alpha_2, \beta_1, \beta_2, \gamma_1, \gamma_2$.

6.2 Conclusion

A useful framework for understanding the dynamic processes of opinion formation inside a political party is the agree-disagree model. By classifying people into three states 'agree', 'disagree', and 'ignorant' the model accurately depicts the complexities of actual political processes as well as how polarisation and consensus change over time.

The stability analysis showed that the parameters influencing opinion change, like peer influence, media exposure, and people's stubbornness to change their views, have a significant impact on the likelihood of reaching consensus, polarisation, or maintaining a significant portion of indifferent members. The media, in particular, is very important since it may act as a catalyst to promote some viewpoints while stifling others, which can affect how political perspectives are distributed throughout the party.

To wrap it up, the agree-disagree model emphasises how crucial it is to comprehend the mechanisms underlying opinion dynamics in political contexts. Political leaders have the ability to steer their party towards more unity or take advantage of newly formed divisions for their own strategic gain by adjusting important criteria. In order to further improve the model's predictive ability, future research might concentrate on incorporating more intricate social variables, like personal identification or economic circumstances.

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CHAPTER 7
AppendixB

7.1 Java implementation of agree, disagree model of a political party

```
import java.io.FileOutputStream;
import java.io.IOException;
import org.apache.poi.ss.usermodel.*;
import org.apache.poi.xssf.usermodel.XSSFWorkbook;
import java.util.Scanner;


public class EulerBasic3 {

    public static void main(String[] args) {

        //Taking values for the parameters of the differential equations from the keyboard
        Scanner scanner = new Scanner(System.in);

        System.out.println("Enter alpha_1:");
        double alpha1 = scanner.nextDouble();

        System.out.println("Enter alpha_2:");
        double alpha2 = scanner.nextDouble();

        System.out.println("Enter beta_1:");
        double beta1 = scanner.nextDouble();
```

```

        System.out.println("Enter beta_2:");
        double beta2 = scanner.nextDouble();

        System.out.println("Enter gamma_1:");
        double gamma1 = scanner.nextDouble();

        System.out.println("Enter gamma_2:");
        double gamma2 = scanner.nextDouble();

        // Close the scanner after reading all inputs
        scanner.close();

        // Calculating R_D0
        double numeratorRD0 = alpha2 * beta1 - alpha2 * gamma1 +
    beta2 * gamma1;
        double denominatorRD0 = alpha1 * beta1 - alpha1 * gamma1 +
    beta1 * gamma2;
        double RD0 = numeratorRD0 / denominatorRD0;

        // Calculating R_A0
        double numeratorRA0 = alpha1 * beta2 - alpha1 * gamma2 +
    beta1 * gamma2;
        double denominatorRA0 = alpha2 * beta2 - alpha2 * gamma2 +
    beta2 * gamma1;
        double RA0 = numeratorRA0 / denominatorRA0;

        System.out.println("R_D0 = " + RD0);
```

```
        System.out.println("R_A0 = " + RA0);

        double N = 100.0;  // Total population

        // Initial values of I, A and D
        double I = 10.0;
        double A = 45.0;
        double D = 45.0;

        // Time parameters for euler method
        double dt = 0.1;  // Time step
        double T = 13;  // Total time

        // Number of iterations
        int steps = (int)(T / dt);

        // Creating a new Workbook
        Workbook workbook = new XSSFWorkbook();
        // Creating a new sheet
        Sheet sheet = workbook.createSheet("Euler Method Results");

        // Creating header row
        Row header = sheet.createRow(0);
        header.createCell(0).setCellValue("Time (t)");
        header.createCell(1).setCellValue("Ignorant (I)");
        header.createCell(2).setCellValue("Agree (A)");
        header.createCell(3).setCellValue("Disagree (D)");

```

```
        // Euler method loop
        for (int i = 0; i <= steps; i++) {
            double time = i * dt;

            // Creating a new row in the sheet
            Row row = sheet.createRow(i + 1);
            row.createCell(0).setCellValue(time);
            row.createCell(1).setCellValue(I);
            row.createCell(2).setCellValue(A);
            row.createCell(3).setCellValue(D);

            double I_prime = -beta1 * (A * I) / N - beta2 * (D * I)
 / N + gamma1 * A + gamma2 * D;
            double A_prime = beta1 * (A * I) / N + alpha1 * (A * D)
 / N - alpha2 * (A * D) / N - gamma1 * A;
            double D_prime = beta2 * (D * I) / N + alpha2 * (A * D)
 / N - alpha1 * (A * D) / N - gamma2 * D;

            // Update values
            I += I_prime * dt;
            A += A_prime * dt;
            D += D_prime * dt;
        }

        // Writing the output to an external excel file
        try (FileOutputStream fileOut = new FileOutputStream("
EulerResults.xlsx")) {
            workbook.write(fileOut);
```

```
        } catch (IOException e) {
            e.printStackTrace();
        } finally {
            try {
                workbook.close();
            } catch (IOException e) {
                e.printStackTrace();
            }
        }

        System.out.println("Results can be seen on EulerResults.xlsx
    ");
    }
}
```