

## **LABORATORY REPORT**

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*Modeling of Dynamical Systems*

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## **Introduction**

One of the most problematic government issues is the Corruption among power positions, be them on a local or national level. This undermines the public trust on their own legal authorities, disrupts the economy, and aids on making the inequality gap even bigger as time goes by.

In 2022, Colombia ranked 91 out of 180 countries on the Transparency International Corruption Perception Index (CPI), which means, worldwide we are perceived as one of the most corrupt countries, difficulting the process of attracting international investors for national development projects. Even when the media, organizations led by citizens and anti-corruption agencies are doing what they can to revert this situation, it still holds a tight grasp around our government.

In order to contribute to this fight, we decided to create a discrete-time model that describes the corruption dynamics in Colombia for the purpose of getting to know better the impact of this issue and search for more approaches to it's solution.

## **Implementation**

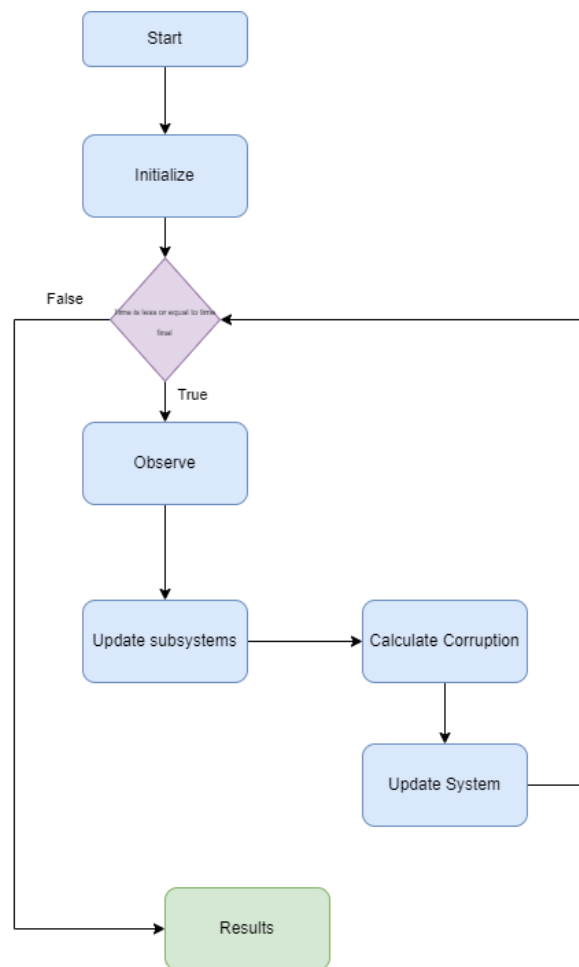
For the modeling of this system was used the coding language Python, in which three main classes were defined: *CorruptionEnum*, *Factor*, *CorruptionModel*.

*CorruptionEnum* is in charge of defining the Variables that are going to be considered in the model, such as the present Corruption Level of the country, the effect of the Government fighting this problem, the impact of the economic development, media exposure and law enforcement.

*Factor* defines the inherent values of each of the variables defined before. This values represent the constants of the equation for each one of the variables, the ratio at which they change over time and a way to always keep updating themselves.

*CorruptionModel* it's responsible of taking all these variables and their inherent values, to form a graphic model of the equation. This model it's represented by a change over time so the variables are always updating until they reach the maximum number of iterations (settled beforehand).

## Flowchart



## Analysis

To the corruption model we use the next difference equation:

$$C(t) = C(t - 1) - a \cdot C(t - 1) + b \cdot G(t) + c \cdot E(t) - d \cdot M(t) - e \cdot L(t)$$

Where we find four difference equations and are defined below:

- $G(t) = G(t - 1) + \Delta G$
- $E(t) = E(t - 1) + \Delta E$
- $M(t) = M(t - 1) + \Delta M$
- $L(t) = L(t - 1) + \Delta L$

Now, the variables delta are constants like the letters a, b, c, d, e in the principal difference equation, this lasts representing the impact of each variable on corruption. Also, we take hipotetic values to the constants. In this order of ideas, each variable present represent a different phenomenon in the real life.

- $G(t)$  is the goverance effectiveness. Specifically, the goverment fight against the corruption in the country.
- $E(t)$  is the economic development in Colombia, where if this index grow up the corruption decreases.

- $M(t)$  is the media coverage can be affect the corruption. We take this value considering the Colombia freedom status.
- $L(t)$  is the stronger law, because higher law enforcement efforts might lead to reduced corruption.

Continue with the principal difference equation, the meaning of part of the equation is defined below:

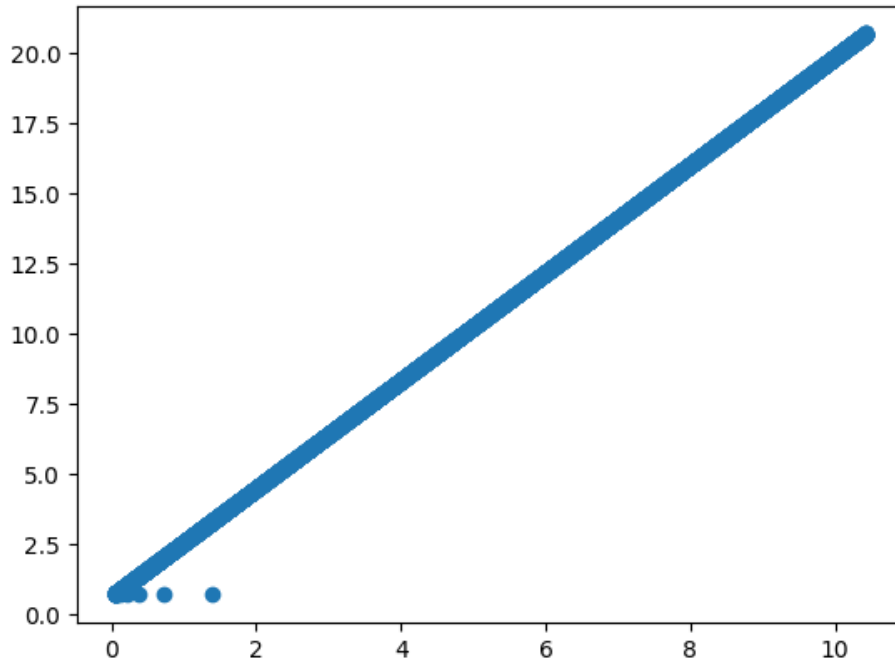
- $C(t - 1)$  is the level of corruption in the previous step.
- Where  $-aC(t)$  is the reduction in corruption due to natural decrease or reforms.
- $bG(t), cE(t), -dM(t), -eL(t)$  are the changes in corruption due to the influence of this four variables.

## Results

Using random data to the model, where we take the next inital values:

- $G(0) = 0.6, E(0) = 0.5, M(0) = 0.4, L(0) = 0.7, C(0) = 0.3$
- $a = 0.02, b = 0.1, c = 0.05, d = 0.03, e = 0.08$
- $\Delta G = 0.005, \Delta E = 0.003, \Delta M = -0.001, \Delta L = -0.002$

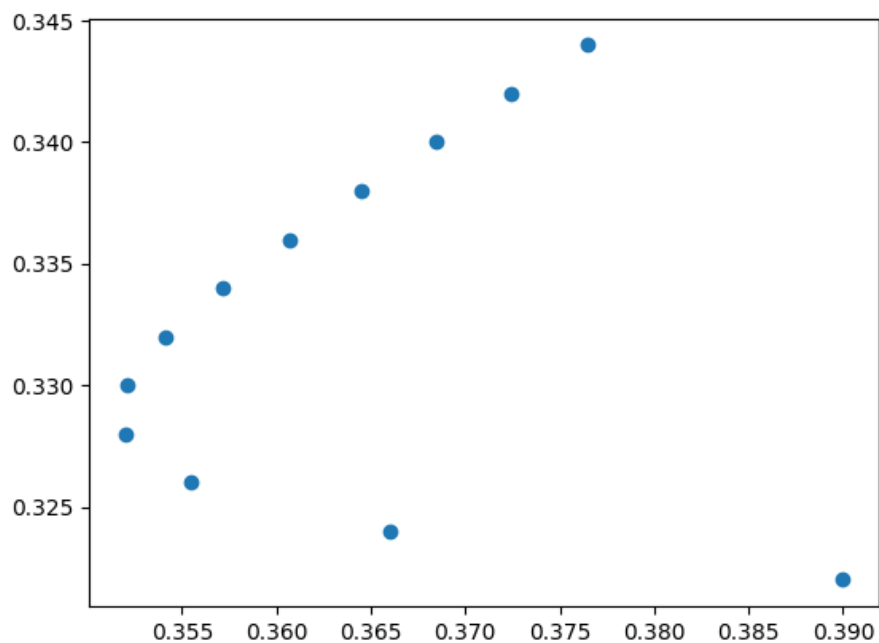
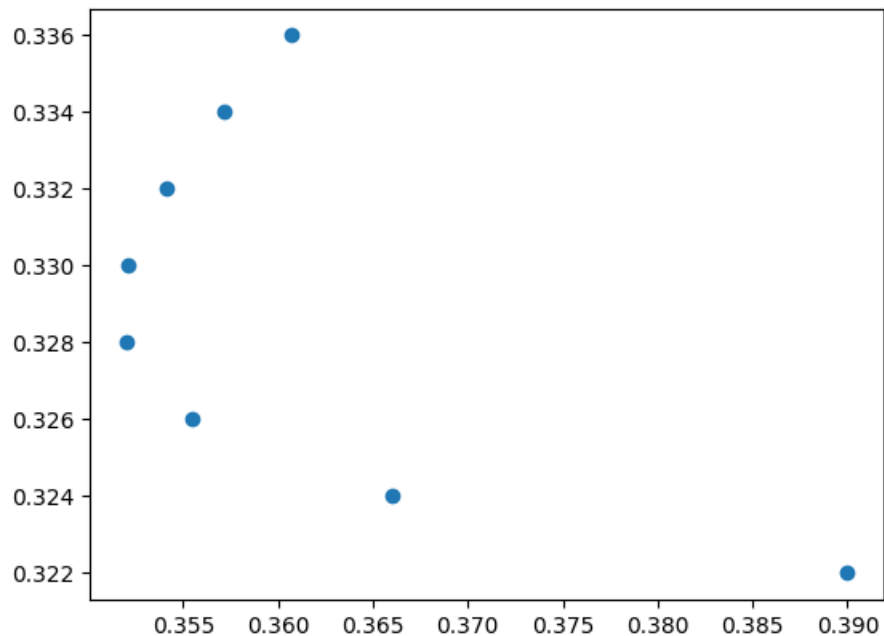
With this values we do no care if the data is real, because only we want to know if the model worked and see graphic represatation, the final result was 10.43 with  $t = 10000$  iterations. It is necessary clarify that the time t and the result are only examples and not representing the reality. For the other hand with the graphic we can see the model tends to grow up through the time how we can watch in the figure 1.



Now, using real values obtained through official websites, we take the next values and results:

- $G(t) = 0.48, E(t) = 0.073, M(t) = 0.64, L(t) = 0.32, C(t) = 3.9$
- $a = 0.48, b = 0.38, c = 0.017, d = 0.03, e = 0.01$
- $\Delta G = 0.005, \Delta E = 0.003, \Delta M = 0.001, \Delta L = 0.002$

The plots obtained when  $t = 8$  and  $t = 12$  is show below:



We can see the corruption is grow in a year and eight months, since 2022 until 2023. Also, with this model we can obtained a good result to analyze corruption in Colombia and the value is 0.36 when  $t = 8$  and 0.37 with  $t = 12$ , this meaning that probably the corruption this year continue grow up.

## Conclusions

- We can conclude that, although the difference equation was well defined with many state variables, which made it a robust equation. It has the problem, that those state variables are difficult to be assigned by real quantitative value to illustrate the problem from Colombia.
- Also, each of the variable can be seen as a new problem or function, with their own state variables, so this also generate a new study case for each. And this would make more complex study how the corruption is model.
- The model, also represents that some of the variables are correlated one with another and this generate that the study of the model will have a multidimensional focus. And, given that some of the variables are correlated, the impact of each factor would be bigger depending the level of impact of the other values.
- Finally, the proposed model shows that it would be not linear relationship between variables so the model would be a not linear model to get more precision.

## Bibliography

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