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2018 Interdisciplinary Contest In Modeling (ICM) Summary Sheet
(Attach a copy of this page to each copy of your solution paper.)

An ICM Paper Made by 81743

Summary

Climate change, including but not limited to increased droughts, shrinking glaciers, changing animal and plant ranges, and sea level rise, tend to occur more frequently during the process of modernization, which has trigger an alert around the globe as it could have significant impact on a state's fragility in direct or indirect ways. So, how does it influence a state's fragility? From our point of view, climate change can be divided into two parts: disasters and other factors, where disasters make direct influence on a state's instability since it could deprive residents of life and property, thus causing severe social turbulence, while other factors have indirect influence on society by affecting a state's economy, security and other aspects. Moreover, these indexes should not mechanically be added up to evaluate a state's instability, since that among the indexes there are some complicated interactions which we are not able to specify yet.

Under such an idea, we develop a neural network model (NNM), where these indexes like economy, disaster and so on are mixed up in a nonlinear way to fit results of these years. Using this model, we test three countries: Afghanistan, Iran and Norway, to classify them and find out in which environment or disaster situation these countries will become fragile, vulnerable or stable. We get a quite satisfactory result, and draw a conclusion that to improve a country's environment does raise its stability, but quite limited, that is to say, environment and disaster scores only play a secondary role in a state's instability. In our essay we make 6 figures to display this result intuitively.

Overall, as for now, our model is quite successful since it has a high accuracy. However, there are still several subjective indexes which cannot be included in our research due to the lack of data, such as evaluating how satisfied the people are to their country or how unite they are, which apparently play a vital role in a state's stability. Thus, there is still a long road to solve this problem perfectly.

Contents

1 Introduction

1.1 Problem Background

Climate change has become a global topic during the past decades and will continue to be the focus of the whole world in the following years. All over the time, there exists a popular point of view that climate change, including abrupt ones and other climate change, may have a great impact on human society in various aspects, thus influencing regional instability in a direct or indirect way.

The definition of fragile states still remains unclear, while its evaluation criteria vary among academic fields. The conventional wisdom is that a fragile state means the government is unable or unwilling to provide public services and consequently losing its legitimacy and authority.

Nowadays, many countries and regions are busy coping with climate change problem, some claiming that the environmental problem are essentially a matter of developmental problem. However, the specific influence of climate change in society hasn't been completely unveiled yet, which leaves us a troublesome problem here: how does climate change influence regional instability? In other words, how is the stability of a state in connection with local climate change?

1.2 Our Work

Nowadays climate change tend to occur more frequently and last longer with the progress of society, which has trigger an alert around the globe. As is known to us, climate change could influence society in various aspects, thus having impact on regional instability which can not be ignored. Climate change can be divided into two parts: disasters and other factors, where disasters make direct influence on a state's instability since it could deprive residents of life and property, thus causing severe social turbulence, while other factors have indirect influence on society by affecting a state's economy, security and other aspects. So, our work is to build a mathematical model and reveal how climate change influence regional instability.

we develop a neural network model (NNM), where indexes like economy, disaster and so on are mixed up in a nonlinear way to fit results of these years. These indexes should not mechanically be added up to evaluate a state's instability, since that among the indexes there are some complicated interactions which we are not able to specify yet. Using this model, we test three countries: Afghanistan, Iran and Norway, to classify them and find out in which environment or disaster situation these countries will become fragile, vulnerable or stable. We get a quite satisfactory result, and draw a conclusion that to improve a country's environment does raise its stability, but quite limited, that is to say, environment and disaster scores only play a secondary role in a state's instability.

Our model is quite successful since it has a high accuracy, bur also there are still some deficiencies. For example, our model doesn't include subjective indexes because these indexes, such as evaluating how satisfied the people are to their country or how unite they are, which apparently play a vital role in a state's stability.

1.3 Literature Review

The evaluation criterion of the fragile state has not yet been unified. For example, the World Bank deems a sovereign state or country to be 'fragile' if it (a) is eligible for assistance from the International Development Association (IDA) (b) has had a UN peacekeeping mission in the last three years, and (c) has received a 'governance' score of less than 3.2 .

Schwartz and Randall reached a conclusion that abrupt climate changes could potentially aggravate the state's instability. Other researches have been carried on and most of them obtained the result that environmental stress does not necessarily change regional instability, but it can facilitate violent conflicts in society, thus leading to a fragile state.

1.4 Restatement of the Problem

We are asked to develop a mathematical model to figure out the connection between climate change and a country's stability. The problem contains 3 parts:

1. Build a model to identify a state's instability and how climate changes influence its instability.
2. Use the model to analyze some states' situation.
3. Determine whether the model can be used to different scale of states or adjust the model in order to apply it on states of different scales.

2 Preparation of the Models

2.1 Assumptions

In order to simplify the course of modeling and draw some reasonable conclusions from our model, we make assumptions as follows:

1. Our data come from The Fund For Peace (http://fundforpeace.org/fsi/data/) and Carleton University (https://carleton.ca/cifp/failed-fragile-states/country-ranking-table/), which are supposed to be accurate.
2. Those effects brought by climate change are divided into two parts: disasters and other factors, where disasters make direct influence on a country's fragility, and other factors have indirect influence on it by affecting a country's economy, security and so on.
3. In general we use the method of The Fund For Peace and consider that a country's fragility depends on following indexes: security apparatus, economy, public services, factionalized elites, group grievance, economic inequality, human flight and brain drain, state legitimacy, human rights, demographic pressure, refugees and IDPs, external intervention and the last one, environment, which are not considered in most Fragile States Indexes except Country Indicators for Foreign Policy (CIFP) of Carleton University.

4. We divide all countries into three parts: fragile countries, vulnerable countries and stable countries. Since we take environment into consideration, we use the classification of Carleton University.

2.2 Notations

The primary notations used in this paper are listed in **Table 1**.

Table 1: Notations

Symbol	Definition
X	An array of data from one sample. The figure below shows the data structure of it.
b_s	The amount of samples used for a training iteration.
W_1	The weight of first Full-connect Layer.
b_1	The bias of first Full-connect Layer.
W_2	The weight of Input Layer 2.
m	The output of Input Layer 2.
N	The neural network model we have developed, including hundreds of parameters of the network.
h	The number of neurons in the Hidden Layer.
t	Iteration times.
$label$	It shows what kind the sample belongs to.

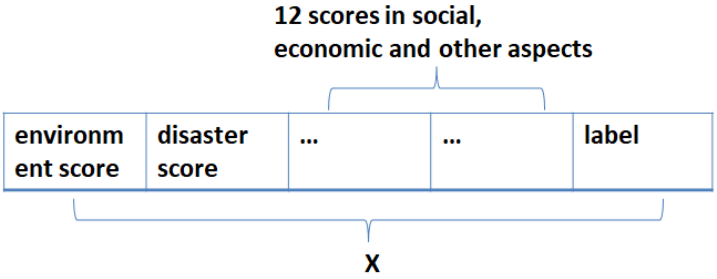

Figure 1

2.3 Definition of 'Fragility'

The fragility of a state refers to the attributes of the social situation. The definition of the fragile state still remains unclear. The conventional wisdom is that a fragile state means the government is unable or unwilling to provide public services and ultimately losing its legitimacy and authority. Its social consequences include economic recession, the decline in living standard and the increasing possibility of violent conflicts.

Based on the common view of the fragile state, researchers use several dimensions to refine the meaning of fragility in specific. These dimensions usually contain economy, security, politics, environment and other aspects. The evaluation criteria include comprehensive aspects of a country and society, which ensure that researchers can reach an overall conclusion. The process of the evaluation involves three steps: conceptualization, operation and calculation.

However, the defects in the existing evaluation criteria are apparent. Firstly, researches on the fragile state are mostly carried on in developed countries but fail to look at problems from the vision of developing countries, which are the majority part of the world. Secondly, though the researchers have taken different factors into consideration, their analysis still can't explain interactions between all the dimensions. Thirdly, with no accurate definition of the fragile state, how to assess a country seems rather a complex problem. And the existing evaluation criterion aren't convincing enough.

Although the procedure of the evaluation still exits various deficiencies, it's the most reasonable and comprehensive method to evaluate whether the country is stable, vulnerable or fragile. So our model assimilate the rational part of present evaluation method and divide the whole procedure into three parts: the systematical description of the science concept, the specification of indicators and the calculation of the overall scores.

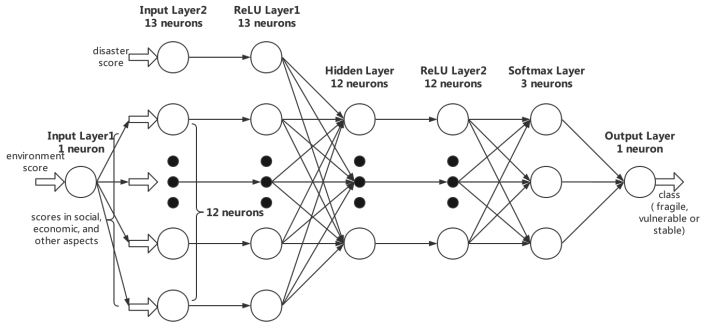

Figure 2

3 The Models

3.1 Neural Network Model (NNM)

In the above we have defined what is a state's fragility, and here, as shown in figure 2 and stated in assumptions, we consider 12 different factors in method of The Fund For Peace and add disaster score into them, which obviously have direct impact on a state's fragility, while other environment factors, including but not limited to the forest cover rate, the water resources, the carbon dioxide emissions, etc., usually have indirect impacts on its Fragile State Index (FSI) by affecting economy and other main factors listed above. Moreover, noting that most existed methods in this field just mechanically add up or take the weighted average of these indexes, which we think is not technical enough since that among these indexes there are some interactions and some indexes contain repeated information, we refuse to simply add them up. However, the interactions between these indexes are not clear yet, and we have no way to specify them, thus, we develop a neural network model (NNM), where we pay less attention on how these factors influence a country's FSI, but only focus on whether it can provide a good conclusion to fit the classification now. In NNM, actually there are two input layers, where these 13 main factors are in the second layer and other environment factors are in the first layer to provide information to 12 main factors to finally have influence on a countryâĂŹs FSI. Then the following part

is typical neural network, where we add some nonlinear functions to ensure the results are not mechanically the weighted average of these indexes. The results contain three scores: fragile score, vulnerable score and stable score, and then we choose the highest score to identify which class this country belongs to.

3.2 Summary of the Program

We input bs (batch size) samples at a time into this neural network, and each sample X is an array with 15 elements, where X[0] is Environment score, X[1] is disaster score, X[14] is a label representing the category of samples, and the remaining parts are scores in social, economic, and other aspects. We input X[0] into Input Layer1, and then it will pass through a 1*12-size Full-connect Layer, and finally get weight arrays W2 of 12 neurons belonging to Input Layer2, that is, W2= X[0]*W1+b1, where W1 and b1 are weight and bias of the first Full-connect Layer respectively with both size at 1*12. Next, each weight element in W2 multiplies its corresponding score in the 12 scores, and Input Layer2 outputs the array m, that is,

$$m(i) = \begin{cases} X(i) & i = 0 \\ W_2(i-1)X(i) & 1 \leq i \leq 12 \end{cases}$$

Then data will pass through the following layers and ultimately be output to show which class this country belongs to. Figure 2 shows the rate of each class. Since we take environment into consideration, we have to use CIFP to rank all the countries because it is the only one index containing environment factor. Unfortunately, it only provides rank of all the countries and does not classify which class a country belongs to. Thus we make Figure 3 and classify them from data of The Fund For Peace.

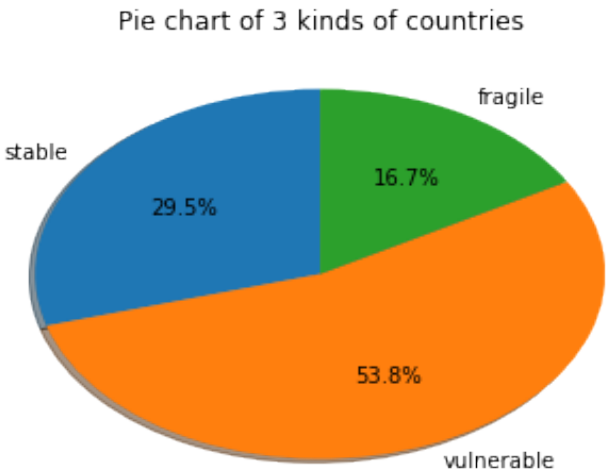

Figure 3

3.3 Training Process

We divided all the samples we've collected into training set and validation set approximately randomly, in which the number of samples in the validation set

is about 10 percent of the total dataset. And to make sure our model works on the top 10 most fragile states (South Sudan, Somalia, Central African Republic, Yemen, Sudan, Syria, Democratic Republic of Congo, Chad, Afghanistan, Iraq), we manually add some of the states'data sample into validation set. We can see the detail in Algorithm 1.

Algorithm 1: Algorithm 1

Output: best accuracy, best model
Net ← Neural Network(h) ; % use h(the number of hidden) to initialize the parameters of the neural network
best accuracy←0, best model←None ; % initialize the result
learning rate←0.001;
batch size←4;
$t \leftarrow 0$; % iteration times
repeat
  input←Randomly select a batch of samples in the training set;
  output←N(input);
  loss←Cross Entropy loss(output, label) ; % calculate cross entropy of output and label
  Back-Propagation(loss) ; % calculate the partial derivative of the parameters
  Stochastic-Gradient-Descent(parameters(Net), learning rate);
  if $t = 0\ (mod\ 500)$ **then**
    output←N(validation set) ; % validate the model
    accuracy←calculate accuracy between output and label;
    if *accuracy* > *best accuracy* **then**
      best accuracy←accuracy ; % record the best solution
      best model←Net
    end
  end
  $t \leftarrow t + 1$;
until *t is equal to 25000*;
return (best accuracy, best model)

4 Testing Results

Our neural network obtained a 100 percent accuracy rate on the test set and got a 93.8% accuracy rate on all samples. The parameters of the first Full-connect Layer are: W1=[-0.1798, 0.5612, -0.4593, -0.5999, 0.2822, 0.339, -0.1344, 0.0251, -0.7828, -0.2574, -0.1628, -0.7441]ïijŇb1=[0.3608, 0.1216, 0.3631, -0.5044, 0.0226, 0.2633, -0.4302, 0.8356, -0.3208, -0.3902, 0.5352, 0.7259], that is, the impact of the environment on weights of other scores, such as economic and social, is W2[i]=environment score*W1[i]+b[i].

Figure 4 is accuracy convergence curve of our model.

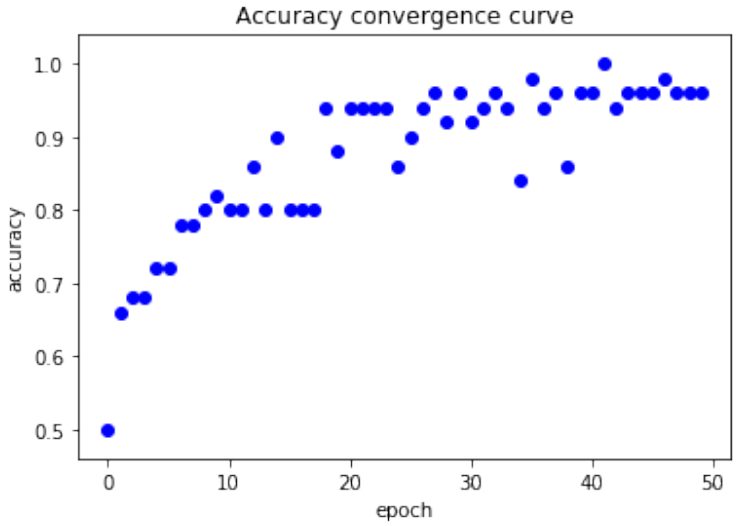

Figure 4

4.1 Overall Conditions

Figure 5 shows all countries' overall conditions. we can draw a brief conclusion from this figure: other factors play an important role in a country's situation, while environment and disaster scores play a secondary role.

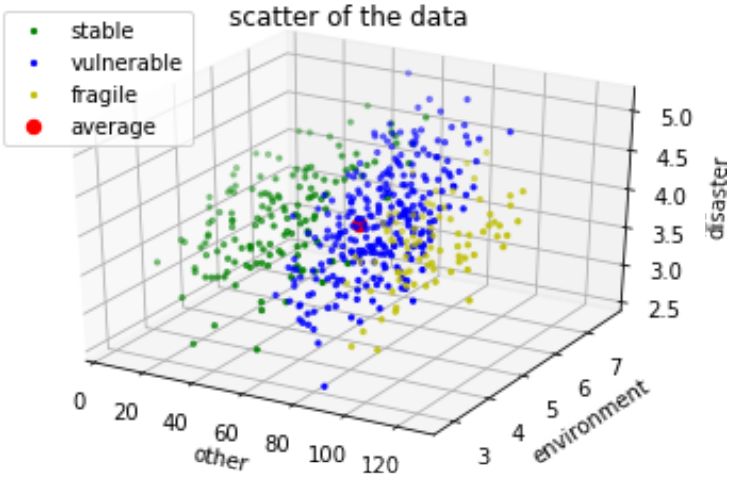

Figure 5

4.2 Afghanistan

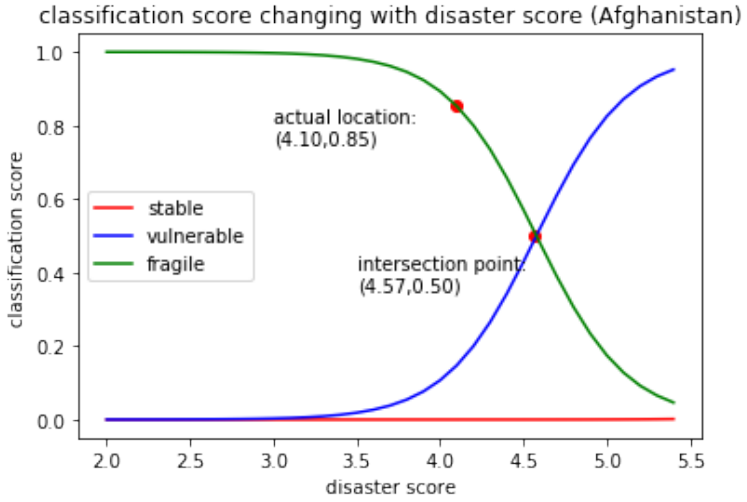

Figure 6

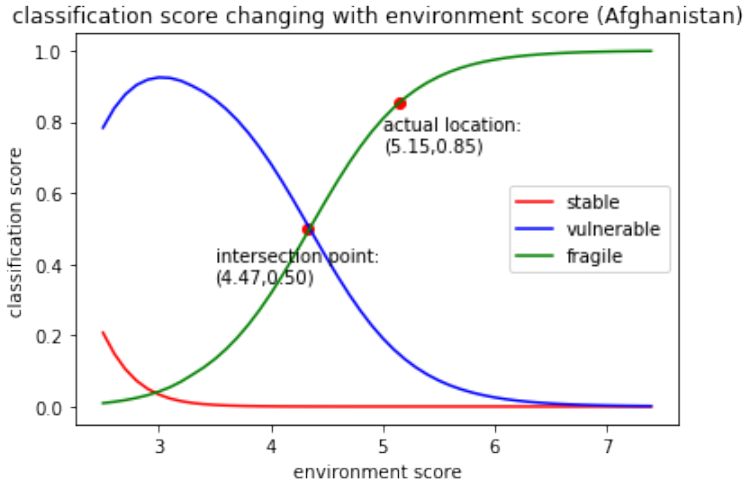

Figure 7

As shown in Figure 6, we can see clearly that now Afghanistan is a fragile country, and when its disaster score increases to 4.57 (here the higher the disaster score, the less impact it will bring to the country), it will become a vulnerable country. WhatâĂŹs more, if it can keep increasing its disaster score, it has a chance to become a stable country (not show in the figure), but it is impossible since many disasters are out of humanâĂŹs control. Thus, if Afghanistan does not make efforts to increase its economy and other scores, it has no way to become a stable country.

Then in Figure 7, we can also see clearly that Afghanistan has to decrease its environment score from 5.15 to 4.47 in order to be a vulnerable country (here the lower the environment score, the better the environment), and similarly, if it can keep decreasing its environment score it also has a opportunity to become a stable country. But unfortunately it is also impossible, since that most of the environment in Afghanistan cannot be changed by human, and in addition it

is quite hard to improve the environment in such a hard situation with such a turbulent society in Afghanistan.

4.3 Iran and Norway

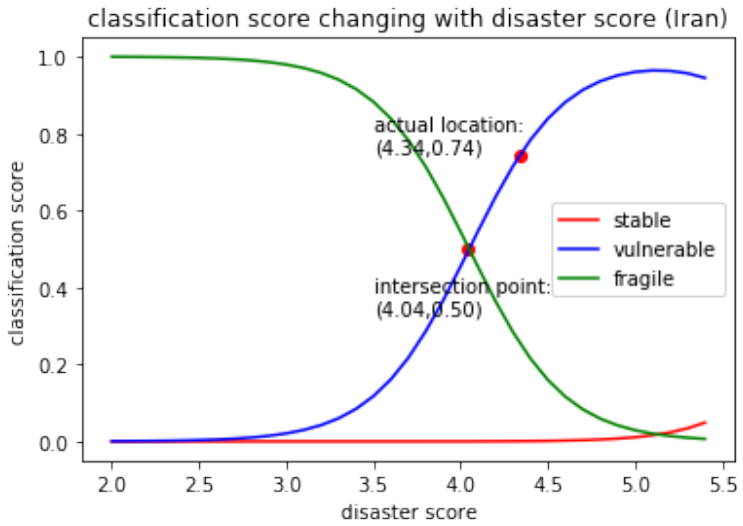

Figure 8

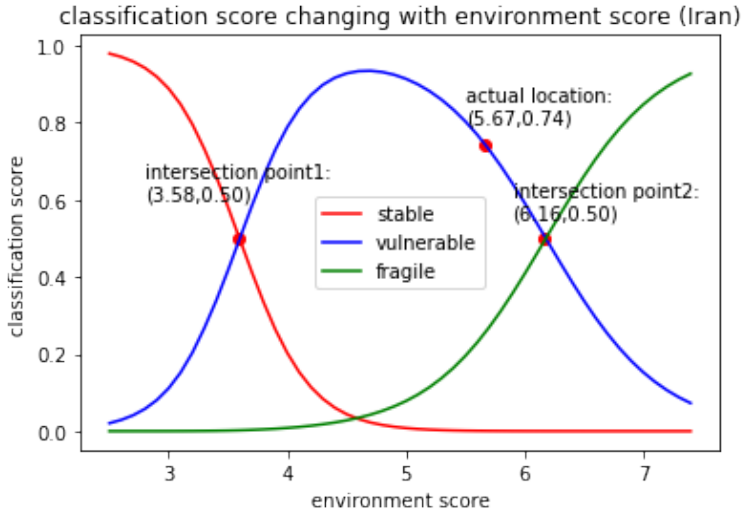

Figure 9

In task 3 we choose Iran and Norway to test our model. Just like what we do in the previous section, we can clearly see from Figure 8&9 that now Iran is a vulnerable country with a disaster score at 4.37 and a environment score at 5.67. Similarly, if Iran could increase its disaster score or decrease its environment score to 3.58, it will become a stable country. And on the opposite, if its disaster score decrease to 4.04 or its environment score increase to 6.16, it will fall down to a fragile country.

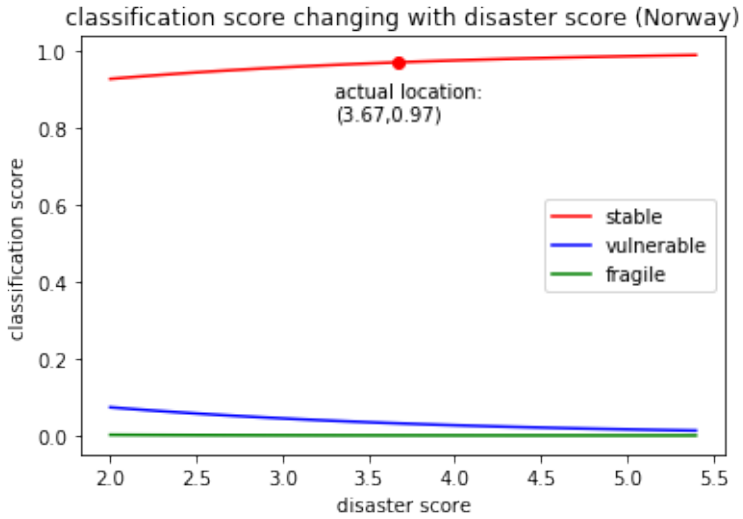

Figure 10

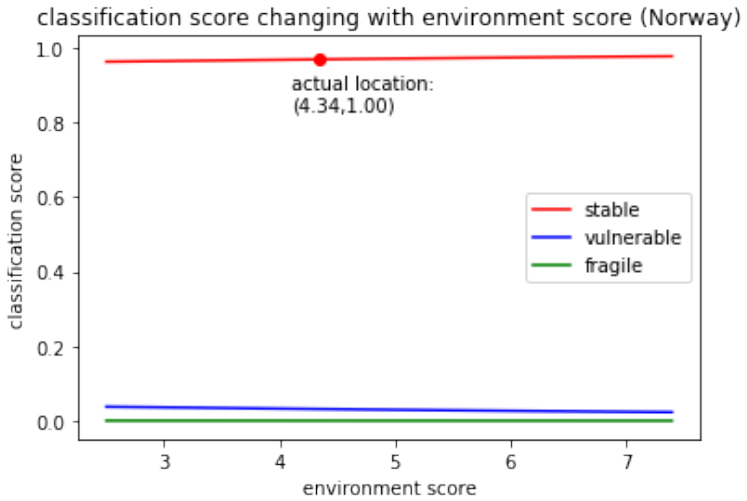

Figure 11

Then we come to Norway (Figure 10&11). It is apparently a stable country, and even its disaster score decrease to minimal value of all countries or its environment increase to maximal value of all countries, it still keep stable. WhatâĂŹs more, comparing Norway and Afghanistan we will find that their environment scores are quite similar and disaster scores are also about the same, but one is stable while another is fragile, which shows the other 12 main factorsâĂŹ importance.

4.4 Small ‘States‘ or Large ‘States‘

According to our model, it can apply to smaller ‘states‘ like cities if we could get accurate data of those cities. But when it comes to larger ‘states‘ like continents, this problem becomes much more complicated, not only because it is hard to get accurate data of a continent, but also because different countries have different situations as well as civilizations, and people have different views to many

issues, which will definitely have great influence on a country‘ s stability. As for now, we have no means to measure how satisfied the people are to the country, thus have no way to take it into consideration, let alone to consider a continent.

5 Conclusion

From our model, we reach the conclusion that climate change do can influence the regional instability, but environment factor itself doesn‘t necessarily change the state‘s stability, in other words, climate change seems to play a promoting role in the regional stability rather than a major source. What‘s more, though climate change play a secondary role to a state‘s stability, we are supposed to pay more attention to this field if we hope to make a country greater and more stable. If not, a stable country could become vulnerable or fragile faster than we expected.

6 Strengths and Weaknesses

6.1 Strengths

- We give thorough consideration to the evaluation method, taking various aspects of society into account. Therefore, our model is able to dig into the core of the problem and arrive at a relatively comprehensive conclusion.
- On the basis of absorbing the research results of domestic and international academic fields, our model logically reveals the connection of climate change and regional instability.
- Focusing on the systematized research, our model has a guiding role for the state and governance on how to strike a balance between environmental and developing issues.

6.2 Weaknesses

- Due to the lack of data, our model may not be completely accurate. There could exits a certain deviation between our analysis and actual conditions.
- The procedure of evaluation method still remains several complex technical problems, which may influence the validity of the results. Take the second step for instance, the boundaries between indicators and dimensions in the evaluation are being blurred and muddled, causing a certain duplication and omission in different dimensions.
- The calculation of the overall scores also contains its drawbacks. The calculation in our model is mostly based on the mechanical work and lacks technical characteristic.

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