Multi-agent Systems
CS785A
Project Report

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1 Introduction

Religious conflicts is one major cause for the disruptions in our society. In this work we try to mathematically quantify the amount of conflict that exists between any two religious agents who are bound to mutual interaction by the constraints of their geographical location. To do this, we do a game theoretic analysis. The players of the game are different religious agents and the move available to any player is either to Co-operate or to Defect.

2 Iterated Prisoner's Dilemma

Interaction between different groups in society has often been modelled by Prisoner's Dilemma game. We also use it to model the interaction between different religious groups. The players in the game include members of the religious groups and the two actions available to any player are:

- Cooperate
- Defect

Cooperate-Cooperate leads to highest harmony between the groups and similarly, Defect-Defect leads to highest conflict. The following table describes the payoffs involved in the game: However, this is a one-shot game which can model only one instance of the interaction between the different groups. But, in reality, that is not the case and the interaction happens multiple times. Therefore, we use the iterated Prisoner's dilemma game for this problem, where the players play the same game repeatedly. This can effectively model the evolution of cooperation between the groups and give us a convergent solution.

	C	D
C	d,d	c,b
D	b,c	a,a

Figure 1: Prisoner's dilemma payoff matrix ($b > d > a > c$) and

3 Religion in Games

The players of the game always belong to a religious group and therefore, it motivates us to include some if its features into the game. We identify three main features which can effectively capture the behaviour of religious groups.

3.1 Belief Systems

Religious members believe that their actions will have repercussions. This directly interferes with their choice of action in every iteration of the game. To model this, we introduce two new parameters into the game:

- q_c : player's estimate of the probability of being punished for co-operating
- q_d: player's estimate of the probability of being punished for defecting

However, the degree of belief of each individual in a group varies. Therefore, we use Gaussian distributions to model it. The mean and variance of these distributions was set by us manually by considering what their religious texts preach. For example, the notion of "karma" is very strong in Hinduism where good deeds are rewarded and bad deeds are penalized. Therefore, in made sense for us to have a low value of expected q_c and a high value of expected q_d.

3.2 Utility Shock

To quantitatively include the effects of religious beliefs, every player receives some additional shock, ϵ in addition to the payoff from the prisoner's dilemma game. This shock can be negative, $-\epsilon$, i.e. the player will be punished for the performed action, or positive, ϵ, i.e. the player will be rewarded for that action. This ϵ value for a religion is fixed, which was set manually. It indicates the severity of the religious scriptures.
Combining the belief systems and the utility shock:

- The payoff for cooperating is increased (decreased) by $-\epsilon * q_c + \epsilon * (1 - q_c) = \epsilon * (1 - 2q_c)$
- The payoff for cooperating is increased (decreased) by $-\epsilon * q_d + \epsilon * (1 - q_d) = \epsilon * (1 - 2q_d)$

3.3 Final Modified Model

Taking the belief systems and the utility shock, the final model becomes:

	C	D
C	d+$\epsilon(1-2q_c), d+\epsilon\prime(1-2q_c\prime)$	c+$\epsilon(1-2q_c), b+\epsilon\prime(1-2q_d\prime)$
D	b+$\epsilon(1-2q_d), c+\epsilon\prime(1-2q_c\prime)$	a+$\epsilon(1-2q_d), a+\epsilon\prime(1-2q_d\prime)$

3.4 Pre-conceived notions

Every group in the society has some pre-conceived notions about how the opponent group will behave or what action will they perform. Based on their expectation of the opponent's action, they play their current action in order to maximize their payoff. These notions are based on the results of the previous iterations of the prisoner's dilemma game. To capture this idea, we introduce b_i for players which represents the probability that the opponent will co-operate. Therefore, before the opponent plays the move, they calculate their expected payoffs as follows:

- Payoff expected for co-operating $\pi_c = b_i * (d + \epsilon(1 - 2 * q_c)) + (1 - b_i) * (c + \epsilon(1 - 2 * q_c))$
- Payoff expected for defected $\pi_d = b_i * (b + \epsilon(1 - 2 * q_d)) + (1 - b_i) * (a + \epsilon(1 - 2 * q_d))$
- Agent plays co-operate if $\pi_c \geq \pi_d$ and defect otherwise
- b_i modified after every iteration of game: increased by α if opponent co-operated, decreased by α if opponent defected

4 Game Simulations

We simulate the game for any two religious organizations. We run iterated prisoner's dilemma for 100 iterations and report the convergent solution. The initial conditions need to be set for the simulation which is done as follows:

- b_i is initialized keeping in mind the dynamics of the religions involved
- ϵ is set keeping in mind the doctrines of the religion and the intensity of reward/punishment aspect of religion
- We simulate the game for all possible values of $q_i = q_c - q_d$ of the players

4.1 An example

We consider the dynamics between two religions: Hinduism, Islam.

4.1.1 Initial values

Parameter values for these and their justification is as follows:

- $b_H = 0.3$
- $b_I = 0.5$
  Muslims consider Hindus to be more cooperative than the reverse.
- $\epsilon_H = 5$
- $\epsilon_I = 7$
  Utility shock of Islam is higher relative to Hinduism
- α is set to 0.02
- $a = 3, b = 6, c = 1, d = 5$
  To maintain the relative order of the values of a, b, c, d. We h

4.1.2 Results

The key for the graph is as follows:

- 1 represents cooperate by both players
- 2 represents cooperate by Hindu and defect by Muslim
- 3 represents defect by Hindi and cooperate by Muslim
- 4 represents defect by both players

4.1.3 Discussion of Results

- High negative q_i leads to an increase in tendency to co-operate
  Belief that co-operation is highly rewarded and defection is penalized
- High positive q_i leads to an increase in tendency to defect
  Belief that co-operation is penalized and defection is rewarded
- On increasing ϵ tendency to co-operate increases with lesser negative value of q_i

5 Graph-Based Model

The model described above models interactions between individuals of different religious organizations. However, in order to capture the interaction between the populations, we need to extend the model. The parameters q_c, q_d, b_i are drawn from Gaussian Distributions with their mean, variance set depending on the religions of the participants. Given the geographical information of a region, a graph is constructed to model who interacts with whom. The particulars of the model are described as follows:

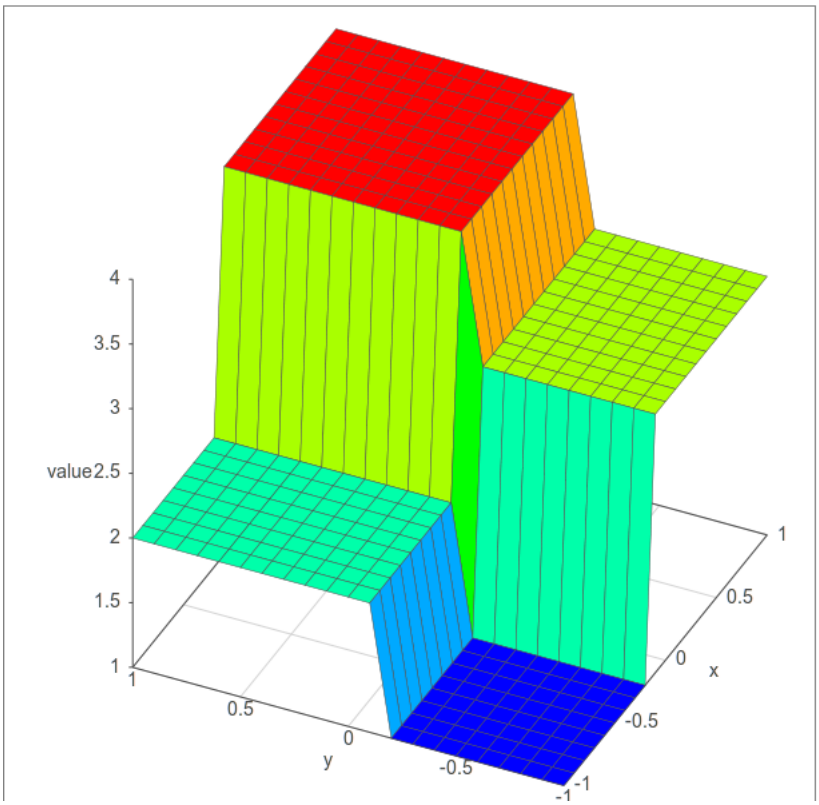

Figure 2: Graph showing the dependence of strategy on q_i of both players

- Every node is a religious agent whose q_c, q_d, b_i are drawn from Gaussian Distributions of their religion.
- Number of nodes correspond to the geographic population of the religion they represent.
- An edge occurs between 2 religious agents if they are neighbours geographically and also if they seem to show interactions in the real world.
- Every agent plays against the nearest k neighbours of the opposite religion. Hence, pay-off for an agent is the sum of pay-offs received in each of these individual interactions.
- The strategy used by an agent remains same across all the players he plays.
- An agent updates his strategy by looking at how successful his peers have been in adopting an alternative strategy.

6 Simulations using Graph-based model

We ran two simulations using the graph-based model.

6.0.1 Uttar Pradesh: Hindu-Muslim Interactions

Majority of population in Uttar Pradesh consists of Hindus or Muslims. Hence, we only considered these two religions while modeling religious interactions in U.P.

- We considered 9 districts in Uttar Pradesh and the percentage of Hindu and Muslim population in each as obtained from the census 2011 data.

District	Node ratio (Hindu: Muslim)
Baghpat	7:3
Meerut	6:4
Muzzafarnagar	6:4
Ghaziabad	7:3
Aligarh	8:2
Mathura	9:1
Agra	9:1
Rampur	5:5
Bareilly	6:4

The edges were formed based on the geographical information i.e. which districts are neighbours with which. Even though, in today's world the interaction can be done between non-neighbouring districts, we do not model it as it adds to the complexity. Hence, this model can be justified to be applicable for older times where proximity was a leading factor in deciding the frequency of interactions.

- Every region was represented by 10 religious agents with (Hindus : Muslims) ratio accounting for the population of these two religions in that region.
- Interaction between different religious agents is not explicitly available to us via any data. Hence, to complete this information we made logical assumptions i.e. the interactions are limited to agents of the same district and that of the neighbouring districts.
- We measure the harmony of a region by measuring the inverse count of the number of $Defect - Defect$ links in that region as it signifies highest degree of conflicts or clashes in the region.

The initial parameter values were set as:

- μ for q_c of Islam was taken to be 0.4 whereas that of Hinduism was taken to be 0.25. The value of q_c being less than 0.5 indicates that amongst the general population of that religion there is a belief that they will be rewarded if they cooperate with fellow human beings.
- μ for q_d of Islam was taken to be 0.6 whereas that of Hinduism was taken to be 0.75. The value of q_d being greater than 0.5 indicates that amongst the general population of that religion there is a belief that they will be punished if they defect with fellow human beings.
- The values are taken such for these two religions because, going by the text of these two religions - Hinduism emphasizes a lot on *Good Karma* and *Bad Karma* whereas, the Islamic text suggests to support Defection with Non-Muslims.
- σ for q_c of Islam was taken to be 0.8.
- σ for q_d of Islam was taken to be 0.7.
- σ for q_c of Hinduism was taken to be 0.2.
- σ for q_d of Hinduism was taken to be 0.3.
- The above value reflects the idea that extreme beliefs in Islam has a higher number of followers than that of Hinduism.
- μ for b_i of Islam was taken to be 0.7.
- μ for b_i of Hinduism was taken to be 0.6.
- The value of mean was taken such to capture the idea that Islam's expect a more cooperative behaviour from Hindus than otherwise.
- σ for both of these distributions were taken to be 0.5 as we had no prejudice about this distribution.

The results of this simulation averaged over 1000 runs is as follows:

District	No. of defect-defect links
Baghpat	152
Meerut	155
Muzzafarnagar	116
Ghaziabad	114
Aligarh	64
Mathura	100
Agra	67
Rampur	59
Bareilly	28

Thus, Baghpat, Meerut and Muzzafarnagar are the most conflict prone regions. This in some way, demonstrates the actual scenario where the regions are often the site of communal clashes. Note, that the results are slightly different from what was shown in the presentation as the averaging out was not done before. This step was later introduced as to eliminate the disparity in values being drawn from the distribution.

6.0.2 Punjab: Hindu-Sikh Interactions

The population ration in Uttar Pradesh is highly skewed. Hence, we consider another state, Punjab, where the ratio is lesser skewed and also to see the interacions between other religions.
Majority of population in Punjab consists of Hindus or Sikhs. Hence, we only considered these two religions while modeling religious interactions in Punjab. The initial parameter values were set as:

- μ for q_c of Sikh was taken to be 0.1 because there is a high belief of reward for cooperation among Sikhs.
- μ for q_d of Sikh was taken to be 0.5 because apparently they does not seem to have any severe punishment for defecting.
- σ for both q_c and q_d of Sikh was taken to be 0.2.
- The above value reflects that there is not much difference in the variance amongst Hindus and Sikhs.
- μ for b_i of Sikh was taken to be 0.8 because Sikhs consider everyone to be very cooperative with them.
- σ was maintained 0.5 for b_i as there was no prejudice about it.

The results of this simulation averaged over 100 runs is as follows:

Population Distirbution	No. of defect-defect links
Hindu (100%) - Sikh (0%)	480689
Hindu (0%) - Sikh (100%)	99980
Hindu (35%) - Sikh (65%)	549359

Thus, it is clear that the Sikh-Sikh interaction is most peaceful, followed by Hindu-Hindu, followed by Hindu-Sikh. This was expected as the interaction between a single religion society is expected to have lesser conflicts as compared to a society where multiple religions co-exist. Also, Sikh-Sikh interaction is more harmonious as they are taught to be more tolerant in their religious scriptures.

7 Conclusion

We saw that our model can capture some aspects of inter-group religious interactions successfully inspite of the lack of the actual data of the real-world scenario. Hence, this model if trained on enough datasets with past conflict information and real-world interaction information, can become useful to predict regions of conflict that might arise in future.

8 References

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