Leveraging Social Networks to Improve Participation in Crowd sensing Activities

CSL426: Game Theory

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Introduction

Crowdsensing, also known as participatory sensing or citizen sensing, is a paradigm that involves gathering data from a large group of individuals using their mobile devices or other sensing equipment. Crowdsensing allows for the collection of vast amounts of data that can be used to improve various aspects of urban planning, transportation, healthcare, and environmental monitoring, among others.

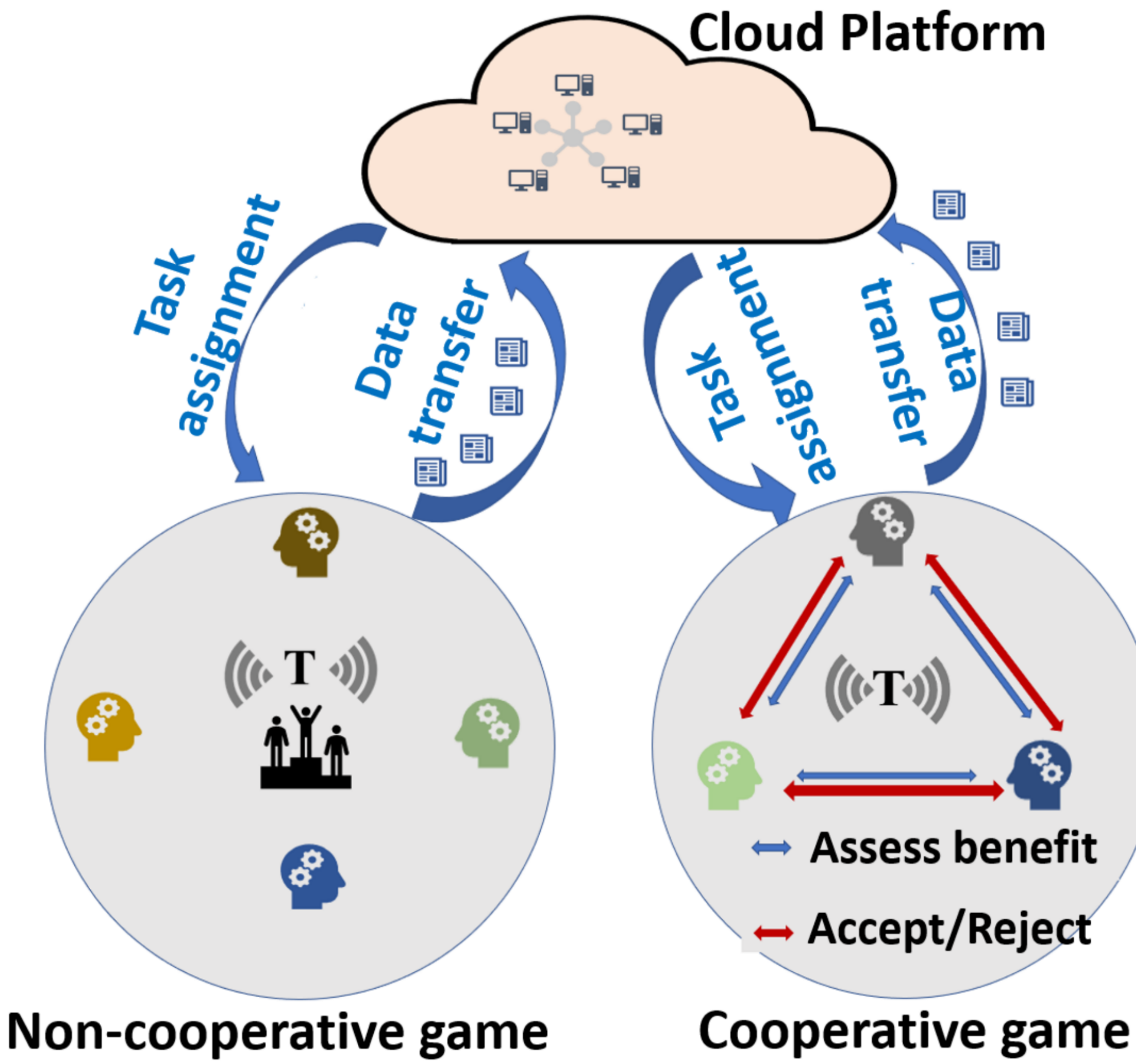

Fig: Crowdsensing modelled using game theory [1]

It must be noted that crowdsensing activities are only successful when a large number of members participate in them. The critical advantage of crowdsensing is that it allows participants to benefit from the shared information of others. For instance, a driver may want to know about traffic conditions along a route to make a better decision. By sharing GPS information with other drivers, the platform can provide real-time traffic updates and help drivers make more informed decisions. Overall, crowdsensing leverages the collective power of individuals to provide better solutions and services.

Problem Statement

Crowdsensing can be modelled using game theory so that participants can either contribute to a public good (such as sharing their sensing data) or keep their resources for themselves. The collective benefit is maximised if all participants contribute to the public interest.

Aim: To maximise the sum of contributions of all the participants in the game.

Approach

Our problem statement can be modelled as a collective goods game, where the collective benefit reaped by all is shared equally amongst all participants. We have a network of players, and a player's playoff depends on the amount of contribution they will make and an additional quantity of "pressure". We have another component of "pressure", which denotes a person's influence on their social circle. So the contribution of a person's neighbours is also included in an individual payoff. So a player benefits by having a higher capacity to apply social pressure and gain benefits from the social network. We decided not to have a cost associated with these activities because constant costs are redundant. The cost, which scales with the amount of contribution and pressure, also makes the equations redundant as it does not matter in maximising overall social welfare. However, specific situations can be modelled using the associated costs of applying pressure and contributing.

Implementation

I. Important Terms

A. Participant Set

$$N = \{x_1, x_2 \ldots. x_n\}$$

B. Contributions

$$C = \{c_1, c_2 \ldots. c_n\}$$

C. Pressure

$$P = \{p_1, p_2 \ldots. p_n\}$$

D. Friend Set

Fr(i) - All the friends of player “i”, i.e. all the nodes connected to node i in the network graph

E. Social Incentive Payoff for Player “i”

$$\mu(x_i) = c_i + p_i * \sum c_j \ (j \in Fr(i))$$

F. Social Welfare

$$S = \sum(\mu(x_i)) \ (i \in [1,n])$$

II. Game Mechanism

A. The game is played in multiple rounds where in each round.
   1. Each player calculates their payoff.

2. Amongst its friends, it considers the players whose payoff is more than their own and updates its contribution to match that of the player.
3. Updates its pressure to match the friend with the higher payoff,

Dataset

Dataset Link: https://www.kaggle.com/competitions/learning-social-circles/overview

Considering the dataset following are the essential components:

1. **User:** It is a target individual whose network is the focus of the task. In this case, the user is a player applying pressure on the social circle.
2. **Friend:** A friend of the target individual (user) needs to be placed in a circle. In this case, they are people in the user's social circle, those on whom the User can apply "pressure".

The dataset comprises ".egonet" files which are converted to text files and look like this:

```
File  Edit  Format  View  Help
1: 146 189 229 201 204 60 215 35 91 238 88 28 166 218 156 6 2 8 231 165 184 20 221 128 39 48 109 84 15 139 21 108 207 161 147 155 140 41 12 160 127 227 47 65 105 62 182 79 90 100 148 137 17
2: 146 191 229 201 204 60 215 35 95 91 141 235 88 166 218 156 6 231 165 184 1 221 46 128 210 39 48 109 84 15 139 21 108 207 161 147 155 140 126 12 160 127 227 47 129 65 205 105 62 79 90 100
3: 185 80 61 188 22 222 118 4 223 138 52 212 213 226 117 103 18 154 43 176 181 33 59 17 44 89 36 232 224 114 145 228 66 199 34 209 101 78 225 190 112 169 113 11 157 120
4: 72 61 187 163 177 138 212 226 117 18 154 176 33 59 44 89 232 224 114 145 106 199 34 16 3 92 225 58 112 11 42 174 120
5: 111 71 137
6: 146 229 201 204 60 215 35 95 91 141 235 132 88 28 166 218 156 2 8 231 165 184 1 221 46 128 210 39 48 109 84 15 31 139 21 108 207 161 81 147 155 140 126 12 160 127 227 47 129 65 205 105 6
7: 216 142 104 194 233 217 203 219 197 195 67 23 121 180 58 85 42
8: 146 189 25 204 111 60 13 215 122 35 141 132 88 28 166 6 33 184 20 1 40 221 39 234 74 116 109 84 15 31 161 81 147 155 140 12 127 227 47 65 105 62 79 90 148 137 170 76 158 97 58 123 167 45
9: 185 188 22 222 213 193 198 181 17 36 66 209 78 119 169 200
10: 25 192 12 205 236 167 162
11: 72 61 146 163 4 177 138 212 151 226 117 133 18 154 176 33 44 89 232 224 114 145 106 199 34 168 3 92 225 180 112 42 174 120
12: 146 25 201 204 60 215 115 10 122 35 153 95 91 38 132 88 28 166 218 156 6 2 8 231 165 184 20 164 1 40 221 128 39 48 84 15 31 161 81 147 155 140 160 127 227 47 65 205 105 62 182 79 90 100
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14: 86 211 96 189 142 203 71 77 175
15: 146 191 229 201 204 60 215 122 35 95 91 141 38 235 238 88 28 166 218 156 6 2 8 231 165 184 20 164 1 221 128 210 39 48 34 109 84 31 139 21 108 207 161 81 147 155 140 126 12 160 127 227 4
16: 4 110 135 69 183 66 171 50
17: 185 186 80 188 152 237 22 222 118 9 159 223 52 213 193 198 103 220 71 43 150 181 36 228 183 66 209 101 78 3 119 99 169 113 42 157 200
18: 61 187 163 4 177 138 212 151 226 117 133 154 176 33 59 44 89 232 224 114 145 106 199 34 3 92 225 180 112 11 42 174 120
19: 144 214 142 178 121 68 190
20: 146 191 25 201 204 60 215 115 122 35 95 91 141 132 88 28 166 156 8 165 184 1 40 221 128 39 48 84 15 31 21 108 161 81 147 155 140 41 12 127 227 47 129 65 205 105 62 182 100 148 137 170 7
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22: 185 186 80 188 152 237 222 118 9 159 223 52 213 193 198 103 220 43 150 181 17 36 228 66 209 101 78 3 119 99 169 113 157 200
23: 87 216 104 194 233 203 69 7 219 195 67 74 58 42
24: 80 209 149 101 42
25: 146 215 10 153 8 20 221 31 140 126 12 205 182 97 236 167 230 162 37
26:
27: 216 189 52
28: 146 201 93 204 60 122 95 91 141 235 132 88 166 6 8 231 165 184 20 164 1 40 221 46 128 39 84 15 31 207 81 147 155 140 12 160 127 227 47 65 205 62 182 90 148 137 170 76 158 134 123 167 51
29:
30: 87 13 98
31: 146 229 25 201 204 60 215 122 35 95 91 141 38 235 132 88 28 166 218 6 8 231 165 184 20 164 221 128 39 84 15 161 81 147 155 140 41 12 160 127 227 47 129 65 205 62 182 90 100 148 137 170
32: 112
33: 72 61 187 163 4 177 138 212 151 226 194 117 133 18 154 176 8 59 44 89 197 232 224 195 114 145 106 199 34 168 98 3 92 225 180 58 112 11 42 174 120
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38: 191 229 93 35 91 141 132 218 231 165 221 46 128 210 48 109 84 15 31 139 21 108 207 161 140 12 160 47 205 79 90 100 137 76 97 58 134 123 167 51 85
39: 146 191 229 201 204 60 215 115 122 35 95 91 141 235 132 88 28 166 218 156 6 2 8 165 184 20 164 1 40 221 128 210 48 109 84 15 31 139 108 207 161 81 147 155 140 41 12 160 127 227 47 65 20
40: 146 201 60 215 115 122 35 95 141 132 88 28 166 8 165 184 20 221 46 128 39 48 84 161 81 119 147 155 140 12 160 127 227 47 62 90 148 137 170 158 97 58 167 45 51 230 162 37
41: 146 191 201 204 215 122 95 91 141 132 88 218 231 165 184 20 164 1 221 39 31 161 81 147 155 140 127 227 129 205 105 62 182 148 158 97 134 123 167 51 230 37
42: 61 222 216 211 163 4 110 177 138 212 104 13 194 117 133 233 18 203 33 59 17 206 44 7 219 36 197 232 195 67 114 106 23 199 34 119 124 190 125 137 24 112 169 57 11 162 174
```

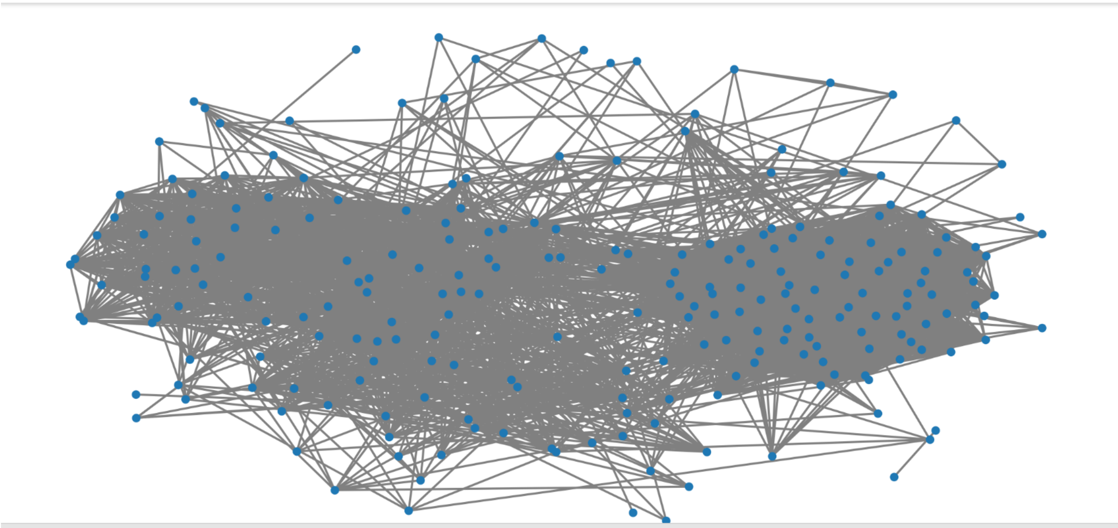
Elaborating it more:

```
UserId: Friends
1: 4 6 12 2 208
2: 5 3 17 90 7
```

This contains a network of all the users, i.e., a list of connections between their friends.
In the above example, it shows that 4, 6, 12, 2, 208 are friends of User 1.

Our dataset consists of 1000 users and a list of friends in their social network. And this data is stored in the form of an adjacency list for further processing. This adjacency list is used to create a graph that gives the social circle of every user. Following is the layout of the graph:

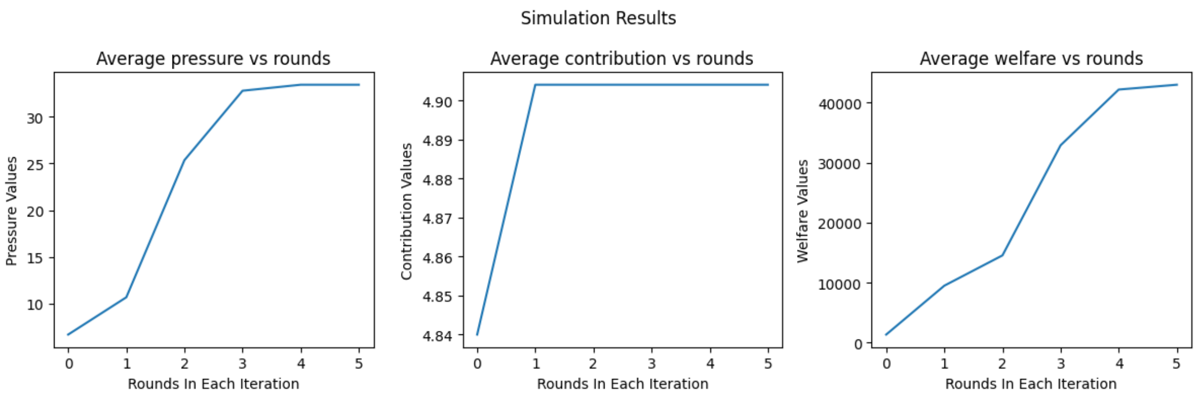
Visualisation of the dataset:



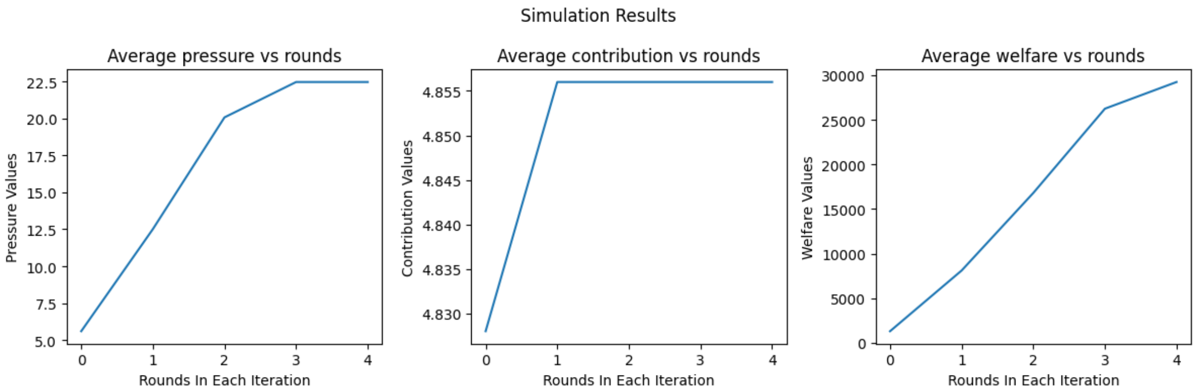
Results

1. CASE 1 - Average pressure and contribution

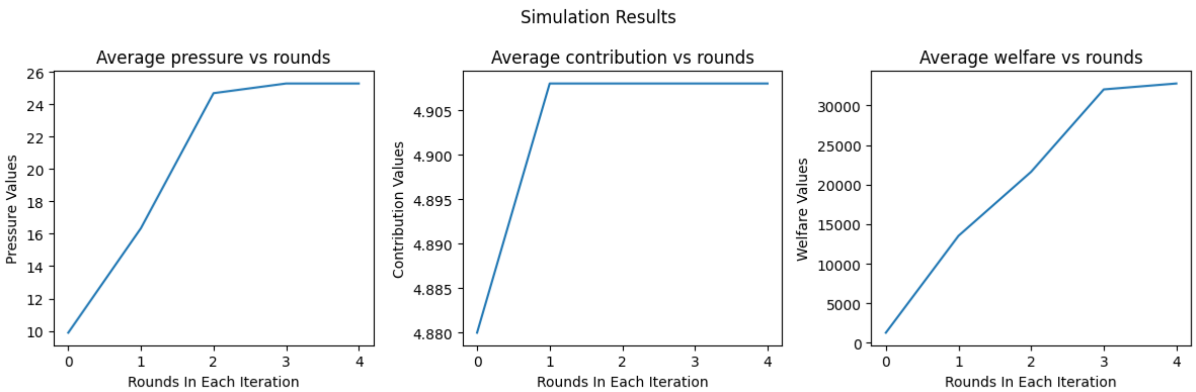
a. Iteration1



b. Iteration 2

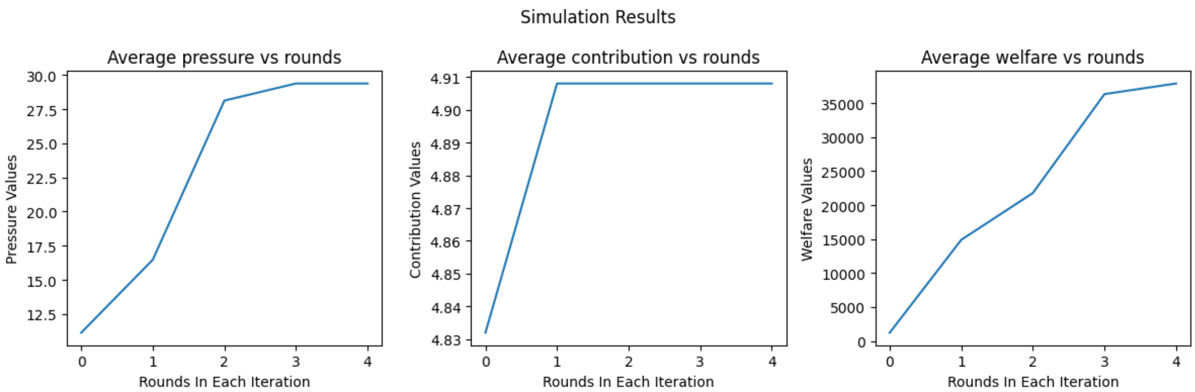


c. Iteration 3

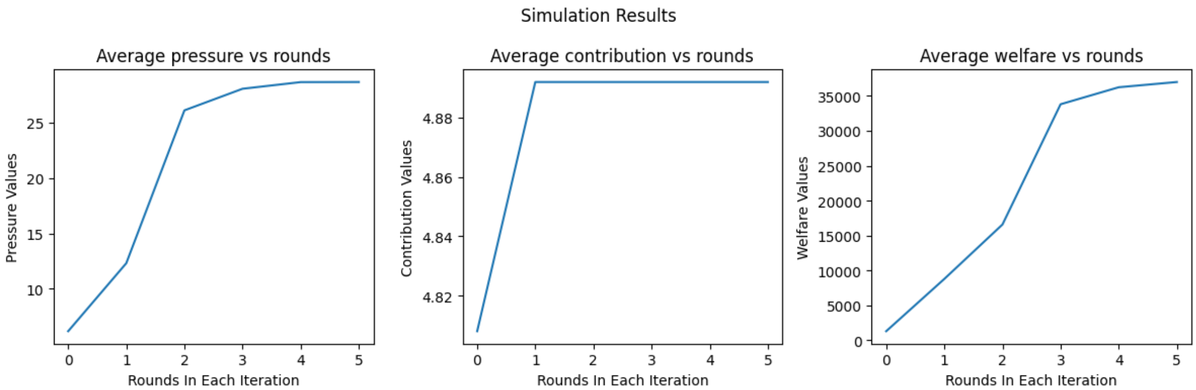


2. **CASE 2 - Individualistic Players - Low pressure**

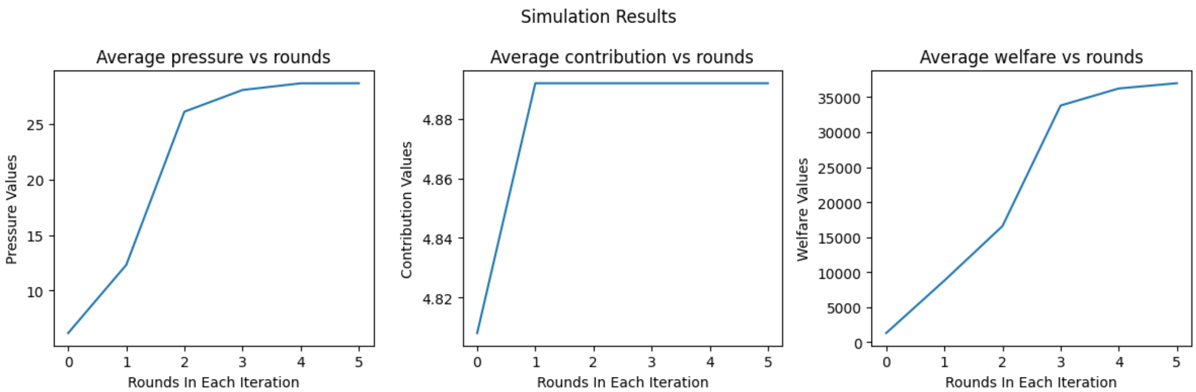
   a. **Iteration 1**



   b. **Iteration 2**

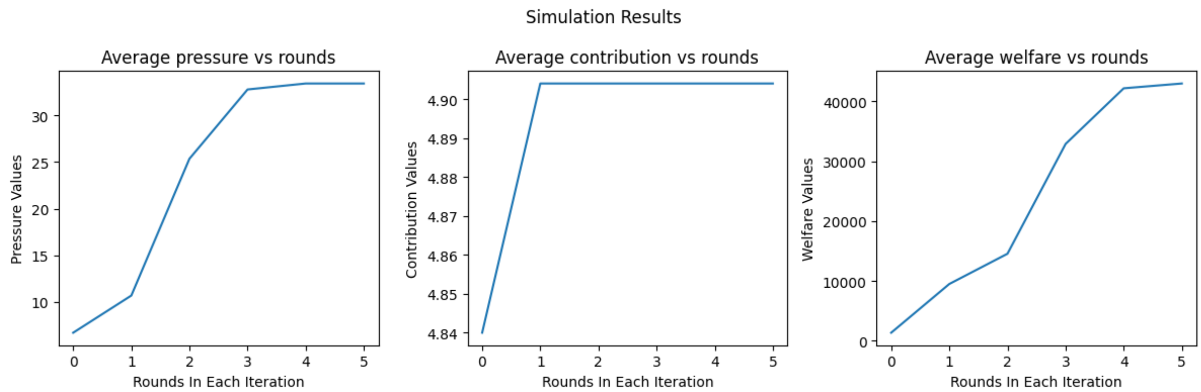


   c. **Iteration 3**

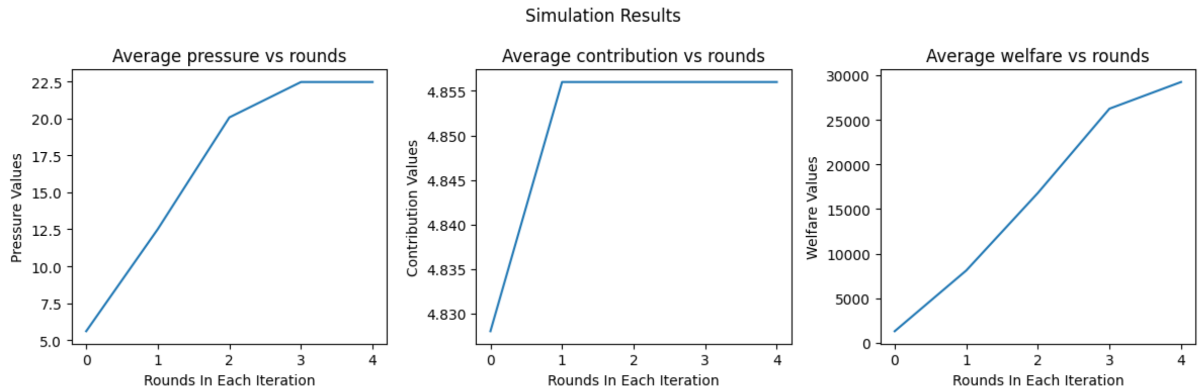


3. CASE 3 - Collaborative Players - High pressure

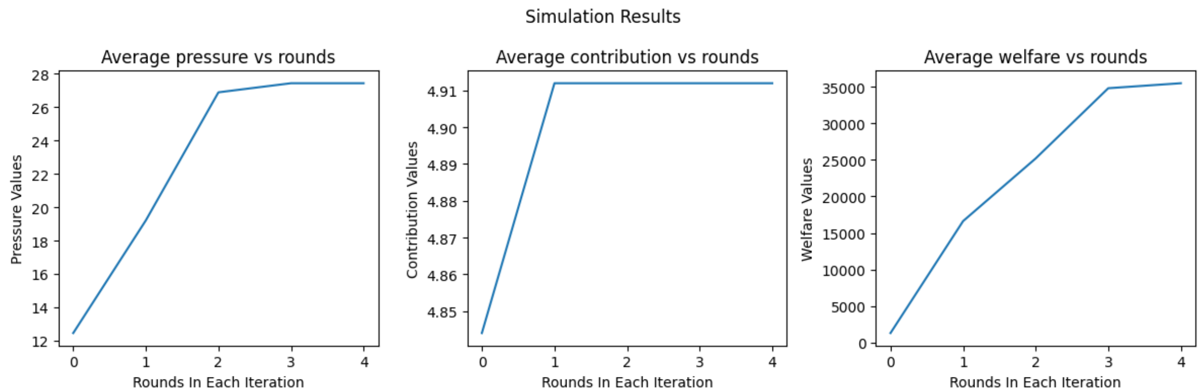
a. Iteration 1



b. Iteration 2



c. Iteration 3



Analysis of Result

Here we can see that even though the contribution plateaued after 1st iteration, the value of social welfare increased with each iteration due to pressure. This implies that even without much personal contribution we can get a higher social welfare. Here the important factor is that due to advent of social media, **cost of applying pressure** is significantly lower than the **cost of contributing.** This is because pressure or social influence is easy to achieve in the highly connected world in which we live today.

Practical Use-case

Let us first see what mobile crowdsensing can be used for:
Mobile crowdsensing is a technology that enables mobile devices to gather and share data about the physical world around us using their built-in sensors and other capabilities. Here are some potential applications of mobile crowdsensing:

1. **Traffic monitoring:** Mobile crowdsensing can monitor traffic conditions, including congestion, accidents, and other events that affect traffic flow.
2. **Air quality monitoring:** Mobile crowdsensing can collect data on air quality, including pollutants such as particulate matter, ozone, and nitrogen dioxide.
3. **Noise pollution monitoring:** Mobile crowdsensing can monitor noise pollution levels in urban areas, including traffic noise, construction noise, and other sources of noise pollution.
4. **Disaster response:** Mobile crowdsensing can collect data on the impact of natural disasters such as earthquakes, floods, and hurricanes, enabling first responders to prioritise their efforts and allocate resources more effectively.
5. **Public health monitoring:** Mobile crowdsensing can track the spread of infectious diseases, including flu and other viruses, and identify potential outbreaks.
6. **Environmental monitoring:** Mobile crowdsensing can monitor the environment, including weather, water quality, and soil conditions.
7. **Cultural heritage preservation:** Mobile crowdsensing can document and preserve cultural heritage sites and artefacts, including historic buildings, monuments, and archaeological sites.
8. **Personalised services:** Mobile crowdsensing can provide personalised services based on the user's location, preferences, and behaviour, such as personalised recommendations for restaurants, shopping, and other activities.

Exploratory Work

1. **Dynamic networks**: We can introduce dynamics in the network structure by allowing players to make connection decisions during the game. To do this, we could add a mechanism that allows players to connect or disconnect from other players, and update the adjacency list accordingly.

2. **Different types of players**: We could consider that players belong to different types, which affect their behavior and payoff. For instance, some players may be more cooperative than others, or some may be more likely to follow social norms. To do this, we could assign different strategies to different types of players and model their behavior accordingly.

3. **External shocks:** We could introduce external shocks that affect the game outcome, such as unexpected events that change the cost or benefit structure of the game. To model this, We can add a random element to the payoff function that simulates the effect of external shocks.

4. **Different payoff functions**: We can experiment with different payoff functions to see how they affect the game outcome. For instance, we can try a linear payoff function, or a function that discounts contributions from more distant friends.

Conclusion

In conclusion, our study focused on the problem of maximizing the contributions of participants in crowdsensing activities by leveraging social networks. We modeled the problem as a collective goods game and used game theory to develop a mechanism that encourages players to contribute to the public good while taking advantage of their social influence.

We implemented our mechanism on a dataset of 1000 users and their social networks, and we evaluated its performance under three different scenarios. Our results showed that players who applied social pressure, even with minimal personal contributions, could significantly increase the overall social welfare. This is because social influence is easy to achieve in today's highly connected world, and the cost of applying pressure is significantly lower than the cost of contributing.

Overall, our study provides insights into how crowdsensing activities can be improved by leveraging social networks and demonstrates the potential for game theory to develop effective mechanisms for encouraging participation in collective activities. Our work can be applied in various fields such as urban planning, healthcare, and environmental monitoring, where crowdsensing plays a crucial role in gathering data and improving services.

References

[1] Dasari, V.S.; Kantarci, B.; Pouryazdan, M.; Foschini, L.; Girolami, M. Game Theory in Mobile CrowdSensing: A Comprehensive Survey. Sensors 2020, 20, 2055. https://doi.org/10.3390/s20072055

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