Automated Decisions Affecting Public Infrastructure Quality in a Behavioral Economics Experiment

POL 495 Final Project Report

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Background

Focussing on the main research experiment, David Yu's research work consisted of understanding how social feedbacks for declining public infrastructure service quality can affect long-term infrastructure state and community resilience. In a public infrastructure water irrigation experiment, two main social roles were examined (the user and the provider) and their decisions embodied a behavioral experiment to analyze this important question. This experiment is initially modeled with human subjects playing the role of a farmer or a provider. The question that I delved deep to answer is "How will users-provider interactions surrounding public infrastructure be affected when the provider is controlled by computer programmed decisions instead of a human subject?" To answer this question and delve into the research material relating to automation in other behavioral experiments, it is first necessary to understand the background of Dr. David Yu's research work and paper on the experiment.

The main premise of the article, "On the Relative Effectiveness of Coping Strategies for Inadequate Public Water Supply: A Behavioral Experimental Study," showcases how public water supply systems involve two major social roles: a user and a provider. The Background briefly describes the paper and the key concepts important to understand the structure and the design of the experiment.

Part 1: Introduction

The dynamic between a user and provider is crucial in understanding how public water supplies work. There are many ways in which users and providers can both navigate these social roles. For instance, the article discusses how a user can find alternate ways of water supply (other than the centralized one) where they can petition, appeal and voice their opinions. And as Abubakar discusses, this will lead to improved infrastructure quality as providers want to avoid extra costs of dealing with user discontent. There were also various pros and cons to having a centralized provider discussed in the article. There were other studies that looked at one or the other in terms of the provider, but this article takes note how the behavioral responses and interactions between users and providers were not looked at and studied. For instance, delving deep into the effects of user-level strategies and the relationship between the user and provider affecting infrastructure quality was not thoroughly studied in previous articles. Conditional cooperation and Hirschman's exit-voice strategy are together useful for understanding these types of interactions. The article points out that there are only a few studies noted to have used this strategy for water supply challenge specifically. The key components of the experiment are the users' exit, voice strategy and the combination of those managed by providers. Also, how the mutual interaction between the user and the provider (and the social outcomes) affect and are affected by water conservation strategies and decisions made.

Part 2: Experimental Design

The main focus of the experimental design is to focus on the action situation where the adequacy of the water supply system is tested. This system can be unreliable if providers decide to not fulfill the requirement of system maintenance. This is a deliberate decision in order to receive short term profits. The other way it is unreliable is if the user decides to stop paying the fees to the providers. This is a reciprocal issue and critical in maintaining mutual social satisfaction or conditional cooperation. This is a controlled behavioral experiment, following standard experimental economics. The vicious cycle or social trap which causes unreliable water supply is captured and showcased through this experiment in terms of farmers and providers having choices and payoff structures.

The main examination of the experiment: was to examine how different coping strategies impact this social trap as a society, and how these strategies affect user-provider interactions at individual levels. For each treatment, human decisions are observed and compared with paying fees and the infrastructure quality. Details of the experiment are also provided in other documentation provided by Dr. Yu where I have gone through the method of the experiment in further detail. Overall, there are 10 baseline rounds and 10 treatment rounds.

Experiment:

First Round:
Players: 4
How stakeholders interact in use and maintenance of public infrastructure.

Farmers:

- Take water from shared irrigation infrastructure to grow crops. This gives them their earnings to use irrigation infrastructure.
- They need to pay a fee to the provider who is in charge of maintaining the irrigation structure.
- Farmers can hold payments and keep fees as earnings instead

Provider:

- Must decide how to use the collected fees.
- The provider can either invest the fees to maintain the infrastructure or keep the collected fees as its earnings.

- When the provider makes an investment, the earning is the amount of leftover fees that remains after investment.
- More water is available for farmers to grow if irrigation infrastructure is maintained.

The 4 players will play the game multiple times or rounds. There are 3 farmers and 1 provider. Each player is randomly assigned one of the roles as a provider or a farmer. The irrigation infrastructure is fully functional or minimally functional depending on the decisions made.
If fully functional, 15 tokens are invested for maintenance. If not, it is minimally functional.
Each farmer receives 10 tokens and can choose to either hold this to earn the money. The other option is that the farmer pays 10 tokens to the provider. Once he chooses to pay the provider:

- The irrigation infrastructure is fully functional, the farmer will earn 15 tokens.
- If it is minimally functional, the farmer will earn 5 tokens and the provider collects tokens paid by the farmer.

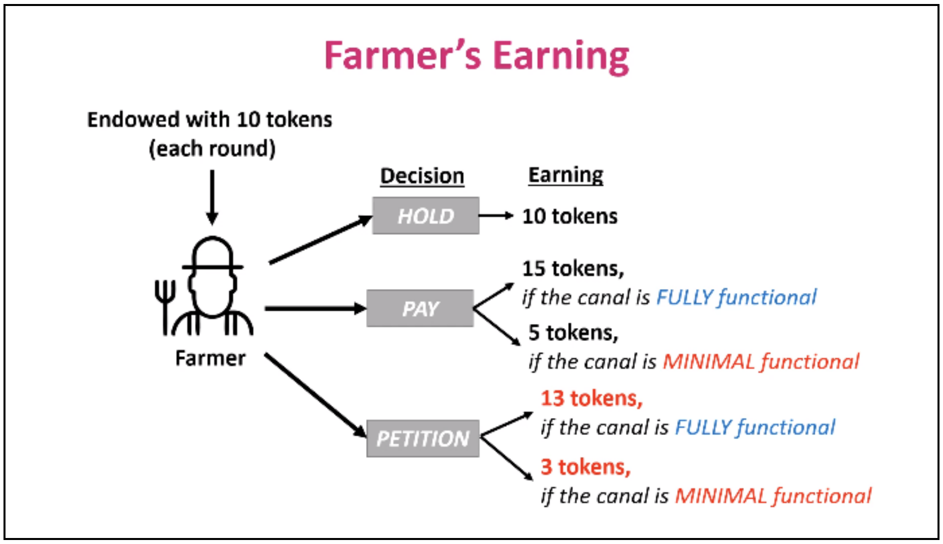
The provider decides what to do with the tokens:

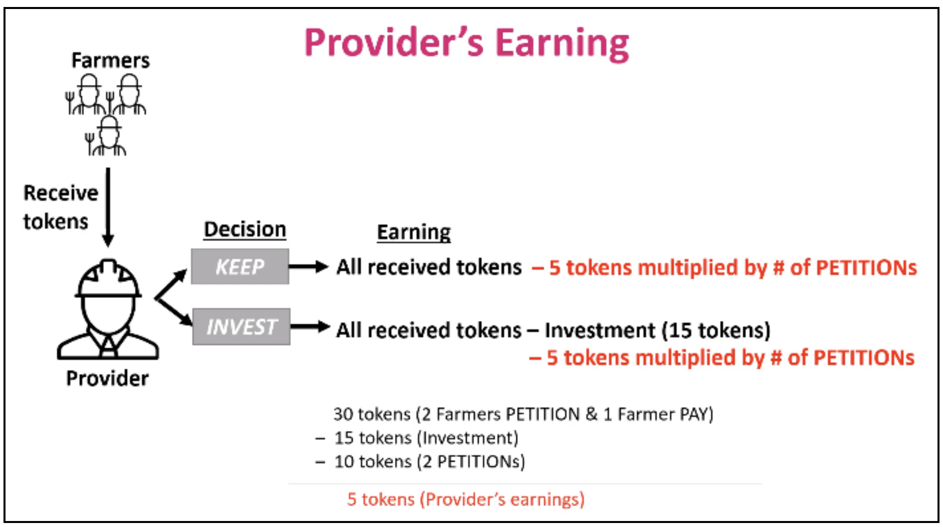
- Keep for themselves as earnings
- Invest in the water irrigation
- It takes 15 tokens to make needed investment to irrigation infrastructure
- Provider's earnings cannot be less than 0

There is also a time constraint: one minute.

Second Round:
Farmers can:

- Hold payments
- Pay 10 tokens to the provider to use the public irrigation system
- Petition the providers to improve the infrastructure while still paying the providers 10 tokens to use the water.
    - Costly to farmers because they are wasting their time and energy and 2 tokens will be deducted from their earnings.
    - Costly to providers because the provider has to spend time and energy to handle the petition and 5 tokens will be deducted for each petition.

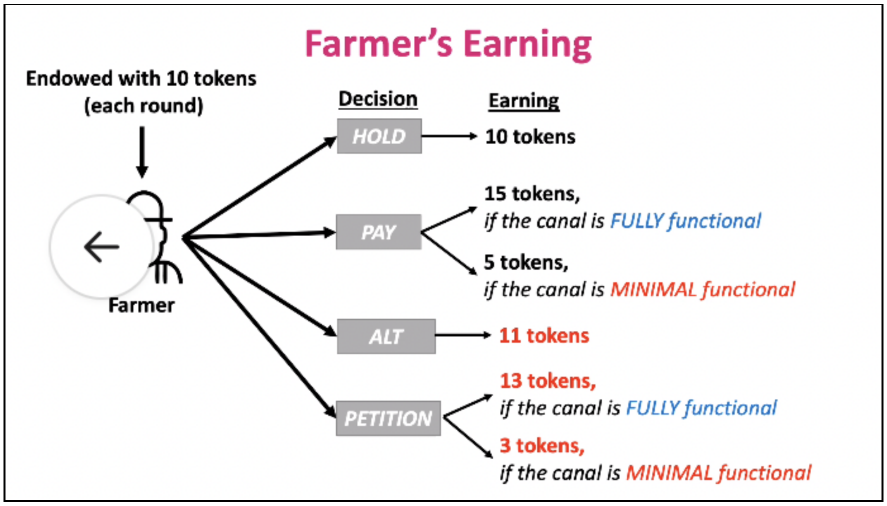


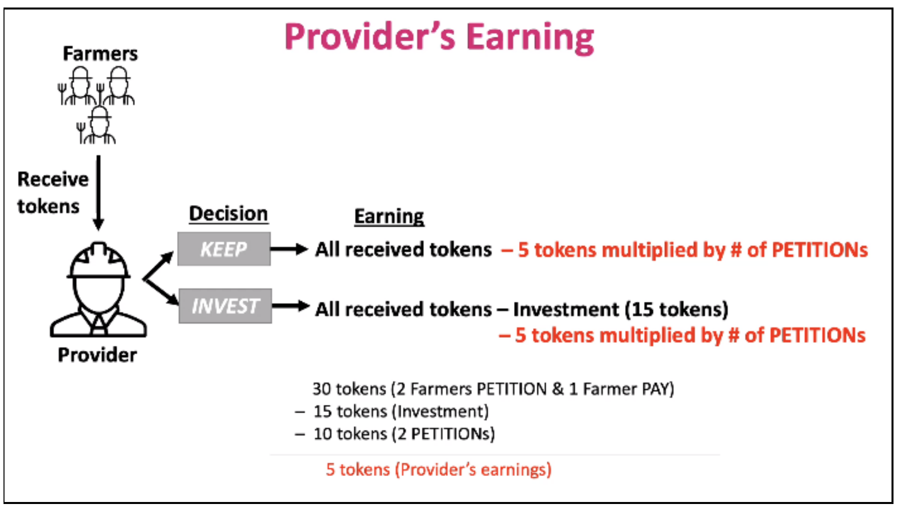


Third Round:

Farmers have 4 options for this round:

- Hold payments of 10 tokens
- Pay 10 tokens to the provider to use the public irrigation system
- Does not pay provider and invest in alternative water sources (private owned)
- Petition to improve infrastructure





Preliminary Literature Review

I researched some papers in Google Scholar and identified papers that incorporated machine learning and artificial intelligence into experiments. In total, I read 3 different articles that incorporated this.

One of the papers I read that stood out to me and gave me a great introduction to this is "The Behavioral Economics of Artificial Intelligence: Lessons from Experiments with Computer Players," written by Christoph March. The article discusses how experimental economic research is utilizing computer players and AI to help shape the research and experiments now more than ever. In summary, it is also interesting to note how human behavior changes when it is known that the other players are computers. They act more selfish and tend to exploit the players. There are a few factors in taking note of AI in experiments.

- First, AI can be used to identify behavioral variables that affect behavior.
- Second, difficulties in implementing AI can help us understand common limitations of human cognition.
- Behavioral economics is necessary to understand and predict how automation and AI can overcome and exploit human limitations.

There are many important questions that will arise in terms of AI and how the agents in the experiments will work in the field and how the interactions between the machine and humans will form. Understanding how human behavior will change and strategies will translate to HCI is important in predicting patterns and outcomes in economic behavior and experiments using AI.

In Section 3.3 Public Good Games, the author discusses how computers or CP interact with humans and vice versa. This section is relevant to the water irrigation experiment since they fall under the same categories. The conclusion of this section is that CPs reduce the impact of human altruistic behavior and show how humans try to take advantage of the machine. The contributions are 50% lower and human subjects act more selfishly.

The article also talks about different ways CPs are designed to follow in the experiment. They can be categorized as:

- Fixed type: CPs draw actions randomly based on the domain
- Adaptive algorithms: repeated game strategies like tit-for-tat
- Mimic Human Subject: depends, but CP can draw a full sequence of choices or CPs mimic human subjects in the game.

Overall, there are many pros and cons to using AI in experiments and it can be noted that CPs increase experimental control and help in testing behavioral economics. However, it should also be noted that real world interactions and decisions made by humans do not coincide with AI and CPs automated to perform their tasks and decisions.

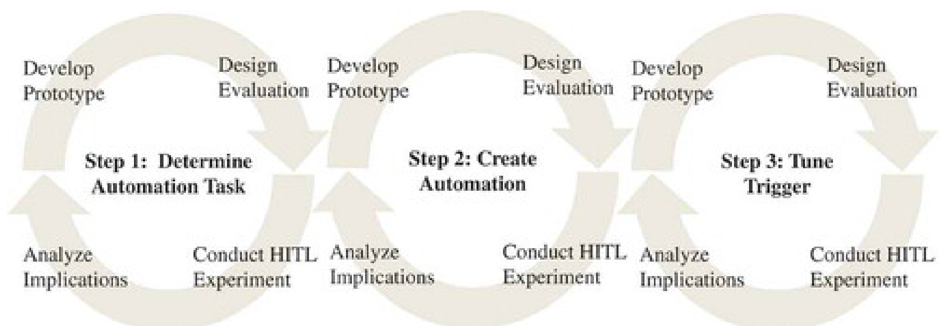
The next few papers I examined used many different ML models to help CPs analyze data and perform decisions and patterns based on this. Some of the ML models used are random forest classifiers, Gradient Boost, and decision trees. The goal of the decision-tree models is to help establish a model that predicts the value of the target variable based on several inputs.

Overall, the basic structure follows that data is divided into training and testing. The training data helps with understanding behavior and how the experiment takes place. This training data is analyzed and ran in various models. The model that fits the training data is taken and the predictions and observed behavior is utilized in the testing data. (towards data science)

A paper that is established as experimental economics and uses random forest classifiers and Natural Language Process modeling is “Using machine learning for communication classification,” by Stefan P. Penczynski. The author discusses how text is analyzed and communication transcripts are studied and analyzed to understand behavior and obtain insights. Text analysis is represented by a bag-of-words model and classification methods combining NLP and ML models like random forest classifiers.

The random forest model classification had regression and classification. The results show that machine learning and NLP can help with the researching and going through experimental economic studies. The cost of implementing a model is also not high. This is a great example of how automation and ML can be economical in research projects and can help improve consistency in the experiment.

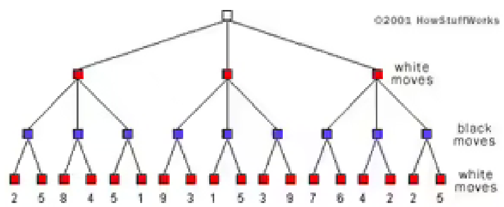
Another paper that showed automation to help with user engagement is an article called "Creating Effective Automation to Maintain Explicit User Engagement," by Bindewald and Miller. The article discusses how Human-centered automation strives to provide work environments in which humans and machines collaborate cooperatively to balance system performance while maintaining adequate human engagement. There are main designs that need to be made in order to effect adaptation. Automation helps with increasing effectiveness and time in terms of performing the experiment. They describe the process outlined through this diagram.



Preliminary Ideation of Automation

After going through the experiment again and understanding how automation in experimental designs work, I had a better understanding of what needed to be done. I came up with a few ideas. In all of these articles, the articles didn't delve into how computer automation was working with users as well as "learning" and wanted to figure out a specific example on exactly the methodology I would use to go about automating an experiment. I decided to research the basics and delve deep into how chess automation works.

As the skill of the player increases, the computer seems to almost learn and analyze players' moves and guide their strategies accordingly. The approach is first a three-level tree diagram:



From there we use the minimax algorithm and alpha beta pruning, which I learned its effectiveness on Pacman. I know how this game theory works and after learning about this again in terms of chess, I can visualize it helping with the automation for the experiment.

For example, in terms of the irrigation experiment, we can use this chess analogy and say that the farmers are the human chess players and the providers are the CP. Using this analogy, we can use:

1. Decision trees to help figuring out the accuracy of the model and learning behavior for the CP to model
2. Incorporate minimax and alpha beta pruning into the algorithm of the provider/ CP so that the provider is also trying to attain the optimal path while following a path that the CP has learned from machine learning.
3. A more complex stage of the experiment would be to have different levels of difficulty set for farmers and the provider/CP will react in ways that are more ambitious and possibly choose greedy paths. This can be done by changing the alpha beta pruning levels and figuring out parameters that we can change in order to limit or increase the level of strength of the provider/ CP. For instance, CP would have
    - Limited time to respond in easier rounds
    - Conditional cooperation and real-time learning (to be more empathetic or to be more selfish)
    - Have a goal set and only have actions planned to perform the end goal regardless of human consequences/ farmers lives. The goal can differ from monetary greed to maintenance of proper infrastructure.

Personally, I don't think there is only one particular way to automate the provider's role as there are so many variables and factors to consider. I do think that the overarching theme would be to perform machine learning on a model and using game theory in AI like zero-sum game or minimax algorithms to help model the role of the provider keeping parameters as factors that can be changed.

In-Depth Literature Review

Understanding the details of Prisoner's Dilemma games and Public Goods games in the paper, "The behavioral economics of artificial intelligence: Lessons from experiments with computer players," by Christoph March

First, we look at the Prisoner's Dilemma papers.

Prisoner's Dilemma:

Paper 1: "Rational Cooperation in the Finitely Repeated Prisoner's Dilemma: Experimental Evidence" by Andreoni and Miller (1993)

a) Purpose of CP: The purpose of the CP is Inducing Types. This means that the theories tested aren't replicative of human subjects' behavior but indicative of how the experiment will work. There are two players and each one can either choose to cooperate or defect. It is not replicative of human behavior because no player is strictly "irrational" or "altruistic" to exist. These are the types to be induced or represented by the CP. Each model has an altruism parameter of alpha (α). The first model designed to replicate in the CP is "Pure Altruism." In this case, players care about the payoff of the other player. Next, the CP model is "Duty," where the CP feels obligated to cooperate. Lastly, the third model is "Reciprocal Altruism," where both the CP and the opponent cooperate and it is 0 otherwise. This is why Marche's paper categorized it as Inducing Type since the CP is induced by a specific behavior type of altruism and the models are created after that.

b) Strategy of CP: The strategy of the CP is adaptive. This was because the choice of the previous player was against a human player. It is an adaptive algorithm. The last two conditions of the game are computer50 and computero. Computer50 enables the users to go against a computer 50% of the time. Subjects in this group should be more keen to play as they may receive an altruistic opponent. The last condition of the gamer would make the CP play against the human in a tit-for-tat manner. This is why the strategy is adaptive since the CP is constantly reacting to the opponent.

c) Info to Subjects: The experiment fully informed the subjects about the strategies and the CP. The game informed all the subjects of the conditions of the experiment and the four main strategies. In each iteration, they were told their last round round decision and their opponents' decisions in the last round of the iteration. In all four conditions, after the subjects played with each other, they were given a 10-period game where they were playing against a computer.

Paper 2: "Group cooperation under uncertainty." by Gong et al.

a) Purpose of CP: The purpose of the CP was to exclude Social Preferences. The experiment was conducted where two games were played: a stochastic prisoner's dilemma and a deterministic prisoner's dilemma. Each individual or group used one computer to make their decisions. The study examines the degree of group cooperation when there are uncertain outcomes involved. The understanding of the study was to exclude social preferences and have subjects decide on their choice not based on cooperation or any human tendencies. The main motivations that were trying to be reduced by human subjects by automation were greed, fear and persuasion. Guilt aversion and blame avoidance in terms of trust is likely to reduce when uncertainty is present.

b) Strategy of CP: The strategy was to mimic humans. The computer was programmed to invest with a certain probability in each round. The strategy was similar to the other exclude social preference experiments where the computer mimicked human behavior of greed, fear, etc. All the other variables are the same. The strategy is presented in a way where the study is understanding how human subjects will behave when they know they are playing against a computer (even if the computer behaves like a human player). In this sense, the CP behavior of mimicking human decisions makes sense.

c) Info to Subjects: The players were completely informed of the strategies and instructions of the game. With the same study instructions, the players were told that they would play with a computer player instead of a real player. The players were fully aware that they were playing against a CP or whether they were playing against other human subjects. This design adopted the basic structure and incentives in Study 1 (without computer automated players), but removed any interactive motivations for cooperation: such as social pressure to be nice, expectation of future cooperation, etc.

Paper 3: "Group size and cooperation among strangers" by Duffy and Xie.

a) Purpose of CP: The purpose of the CP is to remove strategic uncertainty. The CP is designed to isolate the impact of strategic uncertainty on decisions. When the subject performs the treatment with the CP, the presence of strategic uncertainty is no longer. In this experiment, achieving equilibrium means that in the experiment, a social norm of cooperation is sustained and all players adopt the "contagious strategy." The baseline design of the robots are programmed to play according to the contagious strategy which will help with cleaner tests of the monotonicity results. A main hypothesis that surrounds robots in this experiment is that the cooperation rate is lower with an increase in the ratio of human subjects to robots playing the contagious strategy. When there is more automation, the cooperation rate is lower.

b) Strategy of CP: The strategy of the CP is adaptive. This means that the CP Robots are programmed to make choices according to the given rules. The robot keeps choosing X until one of the other members chooses Y. Then, the robot chooses Y. Otherwise, the robot continues to choose X. This strategy is adaptive. Since the CP is taking into account what the other subjects in his team are doing and then making a decision, it is an adaptive algorithm. This replicates a tit-for-tat behavior.

c) Info to Subjects: The subjects of this experiment have been fully informed that they are playing with humans or robots and the contagious strategy that they are employing for the experiment. In this study, it makes sense that this is adaptive to humans since the robots need to know what the subject chooses in order to make this choice. The article does hypothesize that it may be concerning that explicitly telling subjects about the contagious strategy used by robots will create a need in the subjects to also follow the same contagious strategy. However, if that were the case, then the hypotheses that the group size n matters would not find any support since subjects in all of our treatments were told the same information about the contagious strategy played by the robot players. On the other hand, if the observation holds true that a higher cooperation rate under a group size of n = 6 than under a group size of n = 2 or n = 3, then it implies that subjects rationally choose to follow the contagious strategy more frequently when the equilibrium conditions were satisfied.

Next, we look at Public Goods papers.

Public Goods:

Paper 1: "Revisiting Kindness and Confusion in Public Goods Experiments," by Houser and Kurzban.

a) Purpose of CP: The strategy is excluding social preferences. The experimental design consisted of two conditions. First condition is the "human condition" which is a standard linear public goods game. The second condition is the "computer condition" which is the same as the first condition but each group consists of one human player and 3 CP players. The CP condition reported was subsequent to the human condition. This was created to provide subjects with this information to limit the chance that the path created by the CP is a response to their own actions. If players believed that their decisions could influence the computer players' moves, the inferences about confusion effects would be confounded. The way the subjects view the experiment is really important since confusion is the key element to the experiment. This is why the CP is designed in a way to help with this aspect.

b) Strategy of CP: The strategy of CP is to mimic humans. Subjects are either assigned to humans or CP conditions in 6 out of 9 experimental sessions. Each session had between 4 to 12 subjects. Everything, including instructions provided to subjects, was left unchanged in the sessions. This strategy closely followed mimicking human subjects. All the subjects draw a sequence of choices made by a single human subject for each CP. The CP mimics other humans. The instructions follow those of Andreoni (1995) closely but differ in adding the aspect of computer interface. The instructions describe the ROI and their experimental earnings are the sum of their earnings over all ten rounds in the game.

c) Info to Subjects: The subjects were fully informed about whether they were playing against a human or a computer. Since confusion contribution and game play were the main highlights of the experimental design, the game's incentives may be more open to the computer condition. Confusion in treatment may be systematic. The instructions specified to the subjects are similar to the water irrigation experiment. It is about investment behavior. Between each round of instruction, it was noted to the subjects that there are also three computer players. Each subjects' play does not affect the computers' play in the experiment.

Paper 2: "Detecting Other-Regarding Behavior with Virtual Players," Ferraro et al.

a) Purpose of CP: The purpose of CP is to exclude social preferences. The article states how cooperative behavior is contradictory to self-interested individuals. Discrimination among three different things such as other behavior, self-interested play and decision errors in the lab experiments. "Virtual players" or CP in public goods experiments are placed to remove concerns of human subjects for other players which creates empathy and cooperation. Subjects are then motivated by fairness. Virtual-player techniques can discriminate against other experiments. The control experiment is humans playing against humans and the treatment is humans playing against virtual players to create strategic incentives and isolate other-regarding behavior. The non-human virtual players have actions that reflect past human play and this is informed to the subjects. This is why the purpose of the CP was to exclude social preferences.

b) Strategy of CP: The strategy of CP is to mimic humans. The VCM environment has virtual players where the main strategy was to contribute nothing to the public account. Overall though, the virtual players strategy was exactly replicating other human subjects which is why it falls under mimic humans. The only difference is that the subjects are told the virtual players are not behaving like humans so they act differently and it takes away from other-regarding behavior.

c) Info to Subjects: The info to subjects is partial. If subjects are told that they are playing against non-human or virtual players that behave exactly like humans, they tend to play differently because subjects will still show other-behavior towards CP. However, if subjects are informed that the non-human players play by pre-defined decision rules not associated with actions of other players, subjects behave in a non-strategic, non-other-regarding behavior towards the CP. In virtual-player treatments, a single human subject plays with N − 1 virtual players, which are characterized in the instructions as non-human agents. The human subject also receives information on the way in which the virtual players' actions are determined so they behave in the least other-behavior way.

Paper 3: "The Source and Significance of Confusion in Public GoodsExperiments," by Ferraro and Vossler.

a) Purpose of CP: The purpose of the study is to exclude social preferences. Since this study is similar to the previous one, it also focuses on confusion. The main purpose of the CP is important since minimizing the confusion would result in subjects being able to participate in the public goods experiment with a more clear and meaningful incentive. The CP method distinguishes between confusion and other-regarding behavior in single-round public goods experiments. It also discriminates between confusion and other-regarding behavior or self-interested strategic play in repeated-round experiments. The method relies on the introduction of nonhuman or virtual players. They are programmed to execute pre-determined contribution sequences made by human players in an otherwise comparable treatment. Each participant is knowingly grouped with either humans or with virtual players. The procedure that ensures that human participants understand how the virtual players are programmed. Subjects gain no benefit by being altruistic to CP, using this key aspect to the experiment's research. Strategic play in a repeated-game has no impact on the predetermined decisions of virtual players. The random assignment of participants to an all-human or a virtual-player group allows the researcher to net out confusion contributions by subtracting contributions by human participants in the virtual-player treatment from all-human treatment contributions.

b) Strategy of CP: The strategy of the CP is to mimic humans. This strategy also works in the same way as the previous one since it mimics human conditions. The CP is trying to replicate the human actions without the human subject they are playing against having to feel altruism or any other cooperative feelings towards it. The virtual-player instructions are similar with the exception that they emphasize that participants are matched with pre-determined contributions.

c) Info to Subjects: The information provided to subjects is partial. The subjects are informed that there are virtual players in the game as well as other human players. In the CP method, they are informed they will be playing against a CP. However, in the repeated-round experiment, the human subjects are exposed to both virtual and human players and they are not aware of the distinction. This is why there is partial information given to the subjects. In single-round experiments where the decisions of other players are not known, the use of virtual players should have no effect on human contributions nor should they confound any comparison between all-human and virtual-player treatments. Thus, randomly selecting the contribution sequence of any previous human participant, with replacement, as the contribution sequence for a virtual player ensures comparability.

Paper 3: "Inducing efficient conditional cooperation patterns in public goods games, an experimental investigation," by Guillen et al. (2010)

a) Purpose of CP: The purpose of CP is to exclude social preferences. This means that the strategy of the CP is predetermined. When the CP is predetermined, subjects will not think of the CP in mind when considering their decisions as their decisions do not affect the CP decisions or actions in mind. This study analyses behavior where subjects know the existence of strict conditional cooperators. The CP or automata plays a grim trigger strategy. The automata in the threat treatment contribute to 90% of the endowment or units in the public goods game as long as subjects have contributed a similar amount previously. The purpose of the CP is to ensure the subjects make decisions that are not corresponding to how they will be received by the other player.

b) Strategy of CP: The strategy of the game is mimicking humans. The strategy of the game is grim strategy. The CP plays a grim trigger strategy. In the grim trigger strategy, a player cooperates in the first round and in the subsequent rounds as long as his opponent does not defect from the agreement of 45 units. Once the player finds that the opponent has betrayed in the previous game, he will then defect until the end of the game.

c) Info to Subjects: The subjects were fully informed about the experimental structure. The subjects are informed that there may or may not be computer simulated subjects. Any number of CP players can be in the game ranging from 0-3. The players are not informed of how many players there will be in the group. The subjects are informed about the strategy played by the CP.

Paper 4:"Detecting motives for cooperation in public goods experiments," by Yamakwa and Okano (2016)

a) Purpose of CP: The purpose of the CP is excluding social preferences. Reciprocity will not affect subjects' choices since they are playing against a CP. This is to determine how subjects' choices change when they are playing with a CP versus a human. Understanding this difference is vital to understand why humans behave the way they do when they are in real life. Is there a difference in the way they interact with CP versus human subjects? The altruism factor is one of the key components that might potentially change. This experiment determines whether multi-round motives play an important role in cooperative behavior. These behaviors are altruism, warm-glow, reciprocity and other social factors. This study separates these motives into confusion, one-shot and multi-round motives. The experiment attempts to remove confusion while maintaining the social dilemma. When the subjects are playing with the condition called "C condition", the subjects are playing with a human and a computer player.

b) Strategy of CP: The strategy is to mimic humans. The choices of the computer actions are derived from human actions' data in H condition. The H condition is where the subjects play with other human players. The strategy is that they examined human conditions and the choice of the computer is half the average aggregate contribution in H condition. The response is a real choice of subject exclusive of social preferences.

c) Info to Subjects: The subjects are fully informed of the game strategy. In the beginning of each round, the subjects are informed on the computer screen on the number of tokens the computer will invest in the round. The subjects are also informed of the strategy of the CP and the game, where the subjects can make a comprehensive decision that will be different with CP and with other human players.

Goals

Over the course of the semester, I learned about how automation works with experimental economics and how social feedback affecting declining public infrastructure quality creates an impact. The main premise of the experiment was the dynamic between the user (farmer) and provider.

The main question of my research was asking how the farmer-provider interaction surrounding public infrastructure of a water irrigation system would be affected when the provider or the farmer is controlled by an artificial intelligent algorithm instead of a human subject. Developing a conceptual model surrounding this use case was extremely helpful in implementing my code and development for the project. Figuring out the development was important and I did a lot of research surrounding this. A lot of experimental economics and treatments were designed where researchers substituted human subjects for automated or CP subjects instead. This was to eliminate social preferences or induce different types of behavior from the human subjects in the experiment. Understanding how the CP worked with these experimental designs helped me theorize a conceptual plan for automating the experiment. I discuss my findings and theoretical implementation in Assignment 2.

The main strategies that I decided was needed in the experiment were:

1. Tit for Tat
2. Altruistic
3. Nash Equilibrium
4. Randomized Decisions

Tit for tat would involve the decision to be made by the provider when the CP is the provider, and also when the CP is a farmer. Altruistic and Nash equilibrium decisions are focussed on the Provider's decisions when the CP is a provider.

I also performed a logistic regression model and created a predictive analysis model for finding randomized decisions by both user and provider in terms of the experiment.

Description of Data

The initial dataset given to me was an excel file with the columns showcasing Group #, Treatment, Role, Baseline Rounds, and Treatment Rounds. The rows contained information of Farmer 1, Farmer 2, Farmer 3 which provided information for the decisions made by human subjects in each round of whether they paid the provider (1) or did not pay (0) in each round. The Infra. State row is the outcome variable- also represented by 1 and 0. 1 if the irrigation state was good and 0 if it was not functioning efficiently in each round. Next, the Provider row showcased whether the provider human subject invested the money or kept the money to themselves in each round. Finally, there was the Threshold Payment column which showcased 1 or 0 as well. 1 signified if two or more farmers paid in that round, and 0 specified whether two or more farmers did not pay in that round.

This is a snapshot of a portion of the entire dataset:

			Baseline Rounds									
group #	Treatment	Role	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Round 7	Round 8	Round 9	Round 10
1	Alternative	Farmer 1	pay	hold	hold	hold	hold	hold	hold	hold	pay	hold
1	Alternative	Farmer 2	pay	hold	hold	pay	pay	hold	pay	pay	hold	pay
1	Alternative	Farmer 3	pay	pay	hold	hold	pay	pay	pay	pay	hold	hold
1	Alternative	Infra. State	0	0	0	0	0	0	0	0	0	0
1	Alternative	Provider	keep	keep	keep	invest	keep	keep	keep	keep	keep	keep
1	Alternative	Threshold payment	1	0	0	0	1	0	1	1	0	0
2	Alternative	Farmer 1	pay	pay	pay	pay	pay	pay	pay	pay	pay	pay
2	Alternative	Farmer 2	pay	pay	pay	pay	pay	pay	pay	pay	pay	pay
2	Alternative	Farmer 3	pay	pay	pay	pay	pay	pay	pay	pay	pay	pay
2	Alternative	Infra. State	1	1	1	1	1	1	1	1	1	1
2	Alternative	Provider	invest	invest	invest	invest	invest	invest	invest	invest	invest	invest
2	Alternative	Threshold payment	1	1	1	1	1	1	1	1	1	1

Analyzing data is inefficient in terms of rows so I took the time to pre-process the data and convert the columns necessary for coding and analyses into column form. I also performed one-hot encoding to convert the Provider values into binary values to help with data analysis. I converted the Infra. State row into a column called Outcome to better understand the dataset just by visualizing, and understanding the structure when implementing models on the dataset.

This is a snapshot of a portion of the entire dataset that I worked with:

Out[9]:

	Baseline or Treatment	Group #	Rounds	Provider	Threshold Payment	invest	keep	Outcome
0	Baseline	1	Round 1	keep	1	0	1	0
1	Baseline	1	Round 2	keep	0	0	1	0
2	Baseline	1	Round 3	keep	0	0	1	0
3	Baseline	1	Round 4	invest	0	1	0	0
4	Baseline	1	Round 5	keep	1	0	1	0
...	...	...	...	...	...	...	...	...
475	Treatment	24	Round 16	invest	1	1	0	1
476	Treatment	24	Round 17	invest	1	1	0	1
477	Treatment	24	Round 18	invest	1	1	0	1
478	Treatment	24	Round 19	invest	1	1	0	1
479	Treatment	24	Round 20	invest	1	1	0	1

480 rows × 8 columns

Analysis of Code

I performed logistic regression as my data analysis process to understand the accuracies and help with making predictions in the data. This aspect helped with making predictions based on randomized decisions by both user and provider. Using yhat and np.random tool, I showed how user provider input is randomized and the infrastructure state outcome is predicted accurately.

Random Value Predictions

Make predictions based on randomized decisions by both users and provider

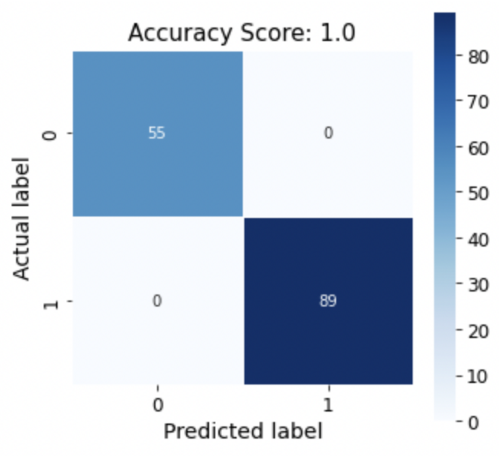
In [179]:
```
random = np.random.choice([0, 1], size=(20,3))
random
```

Out[179]:
```
array([[1, 0, 1],
       [1, 0, 1],
       [1, 0, 0],
       [0, 1, 1],
       [1, 0, 0],
       [1, 1, 0],
       [0, 0, 0],
       [1, 0, 1],
       [1, 1, 0],
       [0, 0, 0],
       [1, 0, 0],
       [1, 0, 1],
       [1, 1, 1],
       [1, 1, 1],
       [1, 0, 0],
       [0, 0, 1],
       [0, 1, 0],
       [0, 0, 1],
       [0, 1, 1],
       [0, 0, 0]])
```

In [180]:
```
# make predictions on the entire training dataset
yhat = model.predict(random)
# connect predictions with outputs
for i in range(10):
    print(random[i], yhat[i])
```

```
[1 0 1] 0
[1 0 1] 0
[1 0 0] 1
[0 1 1] 0
[1 0 0] 1
[1 1 0] 1
[0 0 0] 0
[1 0 1] 0
[1 1 0] 1
[0 0 0] 0
```

Next, I looked at performing predictive analyses to better understand the data with Confusion Matrix and Decision Trees. The confusion matrix shows that there are high True Positive and True Negative values. This is really great in understanding our data because True Positive (upper left) is an outcome where the model correctly predicts the positive class. True Negative (lower right) is an outcome where the model correctly predicts the negative class.



Following the sequence of instructions and the decisions made by either the Provider or the Farmer, the code functions take into account the automation of decisions of both parties. Throughout the code, I used the column Threshold Payment instead of individual farmers in order to predict the decision of the third farmer aka the CP. I used the Threshold Payment to understand the decision made by two farmers in order to predict the third farmer. Each individual round's analysis is done when T is used and the next round is shown as T+1.

First, the code performs operations that the Provider performs.
The first is the Nash Equilibrium behavior.
The **nashEquilibrium()** function looks through the Threshold Payment column of the dataset and maintains payment of the provider to be 0. This function makes the provider corrupt and does not allow the Provider to maintain the irrigation system regardless of whether the farmers pay or not. This correlates with the function of round T.

The second is the Altruistic behavior.
The **altruistic()** function performs the opposite behavior of the NashEquilibrium() function. The provider invests money regardless of the behavior of the farmers. This shows that the provider is investing money in an altruistic way.

The third is the Tit for Tat Behavior. If the Threshold Payment (farmers pay) is 1, which means they paid, the provider will also invest money in the irrigation plant. This is represented and shown in the function as farmer_pay. However, if the farmer_pay = 0, the provider will also not invest and we append 0 to the result1 array which shows that the provider did not invest. This is shown by the function **ttProvider()**

There is also a Tit-for-Tat function that is represented which involves the previous rounds, and shows adaptive behavior. This function creates the knowledge of understanding how the provider works when knowing the infrastructure state. If the provider chose to invest in Round T and infrastructure State was 0 in Round T, the provider responds by NOT investing in Round T+1. Next, if the provider chose to invest in Round T and infrastructure State was 1 in Round T, the provider responds by investing in Round T+1.

To start the next round's function, we need preliminary functions to help guide the decisions of farmers or providers in round T in order to establish their decisions for round T+1.
We have **farmer_decison(T)** and **provider_decison(T)** to help establish basic logic which will be called in the functions ttDecisionT1(group, r1) and ttAll(). This logic shows the decisions made by the farmer and provider in round T.

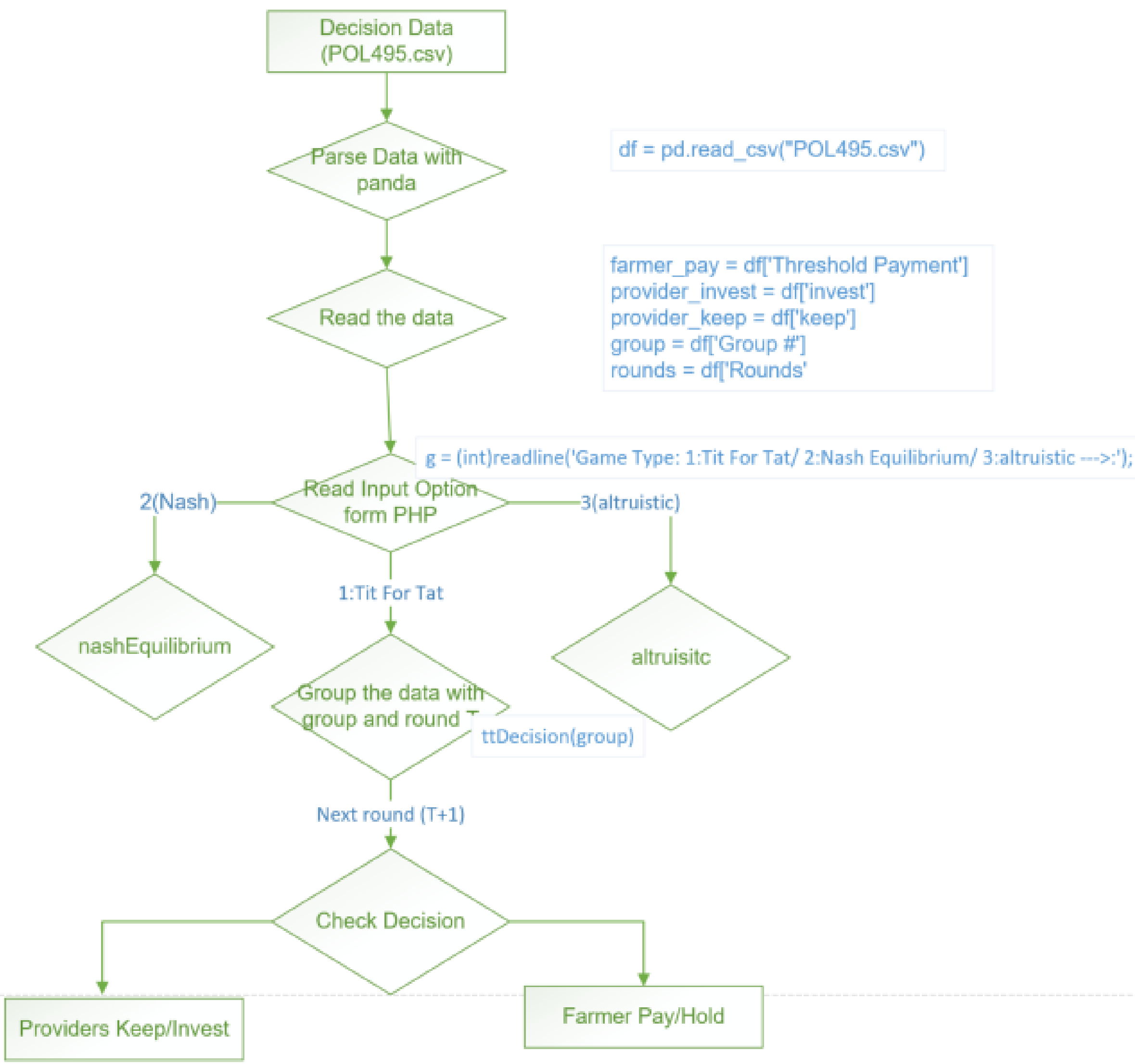
The function **ttDecision(group)** helps with understanding how farmers and providers decisions are played out in regards to groups. Each group correlates to the group made with human subjects acting as the farmers and provider. This function helps the user control and view decisions based on Group 1, 2, 3, etc. Since the code is utilizing the dataset to model the predictions, each group can be separated in order to analyze behavior per group, or combined and looked as a whole where all the groups are together.

The combination of the tit-for-tat behavior of the farmers' decisions and the provider's decision creates the final function. This function has the objective of implementing farmers' decisions for the next round, as well as the provider's decision for the next round. These are the functions **ttDecisionT1(group, r1)** and **ttAll()**. These functions help analyze how everything works in conjugation with each other. This involves the logic of next rounds as well as groups to create a function that has predictive functioning of both the farmer and the provider's decisions. The main logic of rounds is as follows:
If the provider chose to invest in Round T and infrastructure State was 0 in Round T, Provider responds by NOT investing in Round T+1.
If the provider chose to invest in Round T and infrastructure State was 1 in Round T, Provider responds by investing in Round T+1.
If the farmers chose to pay or the Threshold Payment is 1 in Round T and infrastructure state is 0, farmer holds (does not pay) in Round T+1.
If the farmers chose to pay or the Threshold Payment is 0 in Round T and infrastructure state is 1, farmer pays in Round T+1.
Both the farmer and the provider Tit-For-Tat decision-making is happening simultaneously.

The **main()** function runs the code. When executed, if the user plays 3, the provider is altruistic in their choices. If the user plays 2, the provider executes Nash Equilibrium qualities. And if the

user plays 8, the function shows Tit for Tat involving rounds for both decisions of farmer and provider.
This means, both the farmer and the provider Tit-For-Tat decision-making is happening simultaneously. This logic is implemented by the final function ttDecisionT1(group, r1). This is called by the main() function and the automation is complete.
Video Recording of Main Function:
https://www.loom.com/share/cbca28671b034392b609de8794bb252e

I have outlined the main functions and the steps taken by the program to follow this using an Entity-Relationship Diagram. The ERD Diagram shows how the decision data is processed, read, and the functions are created to showcase the decisions made by the Farmer or Provider.



Conclusion:

Over the course of the semester I learned a lot about user-provider dynamics affecting public infrastructure quality and how it can create an impact in the community over a long term. Understanding and evaluating how different automation can help with this question of evaluating public infrastructure quality was very interesting and thought-provoking. Delving deep into the main question that was explored in the behavioral experiment by Dr. Yu and understanding this in terms of automation helped me look at the experiment in a different perspective. The main premise of the experiment was the dynamic between the user (farmer) and provider affecting the infrastructure state. Exploring how individual decisions can create a big impact on the community was eye-opening and taught me a lot about how public infrastructure can change with simple decisions.

Connecting computer science with experimental automation helped me see how these concepts can impact behavioral economics and experimental design in terms of researching real-life decisions in a more conscientious way. Implementing these automations in the experiment created by Dr. Yu and his team will lead to more discovery and research on how automation can impact human subjects while playing the game. This in turn, will lead to creating better solutions for water conservation and decisions made by providers and farmers in real life affecting their water irrigation system and other public infrastructure systems.

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