**Abstract**

Contained within the report herein is a proposed model for the prisoner’s dilemma which incorporates affect control theory and emotional simulation. The model presented is a theoretical framework which could be used by AI developers to simulate the underlying processes of emotion as they appear in game-theoretic problems like the prisoner’s dilemma. Concepts such as repeated games in game theory, along with affect control theory and emotional control theories are discussed. Strengths and limitations of the proposed model are covered along with the model in the report herein, and theoretical workings within the model are elaborated upon.

**Introduction and Related Works**

Emotional decision-making is essential in the fields of artificial intelligence and computer science. Generally, people do not put much thought into the purpose emotion has in their decision-making and often view emotion as directly harmful to rational decision-making. However, as we will later see, emotion plays a vital role in decision-making and cannot be replaced by simple individual rationality.

The following project proposal is on affect control theory and the prisoner's dilemma. Affect control theory seeks to explain behaviours in the context of social interactions, describe the routine and expected behaviours that people enact under normal circumstances, and the creative responses they generate when encountering noninstitutionalized or counter-normative situations (Robinson et al., 2006). The prisoner's dilemma is a thought experiment and game in game theory that demonstrates how two entirely rational individuals might not cooperate, even if it is in their mutual interests to do so (Kuhn 2019). A repeated prison dilemma is a prisoner's dilemma operating under the assumption that the game will repeat in the future, such that the credibility of the opponent and memory of the opponent's previous moves matter (Kuhn 2019). An infinite prisoner's dilemma is a repeated prisoner's dilemma that never ends (Kuhn 2019). The project will focus on determining theoretic and computational models which can provide a framework for solving affect control type problems such that AI systems can produce satisfactory solutions for the prisoner's dilemma.

A primary problem presented by the prisoner's dilemma is that two individualistically rational agents choose a poor solution for a problem rather than cooperate. When modelling the agents in the prisoner's dilemma to cooperate, an AI simulation of something separate from general logical and strategic decision-making is required. Direct tests using game-theoretical derivatives of cooperative situations have so far been unable to find a connection between the communication of emotion and cooperation (Wubben, 2009). However, we have direct evidence that there is a connection between communication and emotion since there are examples of communication and emotion going hand in hand. Take, for example, the fact that laboratory studies have shown that participants played against the reciprocal strategy of tit-for-tat showed that communicated disappointment established more cooperation than did anger (Wubben et al., 2009). We can see that communication affects game participants and changes their responses in games and simulations. Another study showed similar results to the study mentioned above. It concluded that emotions help establish cooperation through indirect reciprocity (Wubben, 2011).

**Contributions**

The purpose of this project is to determine a model by which an AI agent could participate in games like the prisoner's dilemma and account for human emotion to determine optimal human-like solutions. An AI agent could use emotional factors such as anger, vengefulness, guilt, or cooperativeness to model and anticipate opponent behaviour and better model its behaviour. By understanding the role of emotion in human decision-making, an AI could begin to choose optimal actions when engaging in games with human opponents or against each other in simulations.

Creating an AI model to simulate the underlying attributes of human emotion in real-world decisions is vital to understanding human emotions themselves. Humans have evolved to have specific emotional responses under the prisoner's dilemma, which are not purely rational from a game-theoretic point of view. Humans have evolved to give a specific range of standard or healthy responses when faced with the prisoner's dilemma, and these responses have aided humans to survive in the circumstances akin to the prisoner's dilemma. By determining underlying emotional constraints that modulate human behaviour in the prisoner's dilemma, scientists can attempt to understand the rules and systems that humans use when making decisions and, more importantly, why those decisions are optimal. Essentially, this addresses the primary problem of the prisoner's dilemma: that two individualistically rational agents can choose a poor solution for a problem instead then cooperating. Humans have evolved a set of emotional constraints which provide foresight in these circumstances, and by determining the rules by which human emotions operate, we get to glean more insight into Affective Computing systems.

**Claims**

For the following project, it is assumed that emotion can exist in quantifiable states and be representable in a numerical and logical format. It is claimed that emotions are not purely qualitative and can exist quantitatively. For example, the idea of colour is purely qualitative. Even though colours can be represented in terms of wavelengths of light, the subjective perception of colour is purely qualitative and cannot be directly translated into computer variables or constraints. However, in this project, it is claimed that emotion itself is in fact representative of a quantitative phenomenon and are therefore representable as quantitative values and can be operated on by logical modifiers.

**Assumptions**

Claims made during the project include assuming that the scenarios modelled are built without any outside interferences. Outside interferences include emotional, cognitive, social, or cultural constraints which cannot be discussed or disclosed in the agents or the dilemma. Any emotional-cognitive model could include thousands of constraints (like personal history, family background, current emotional state, etcetera), but this project will focus on emotional constraints and try not to go past what is discussed. We will also assume agents will only model decisions based on the given scenarios, and agents will not think of future scenarios or impacts unless clearly stated. An example of an agent which would need to think of a future scenario would be an agent involved in the iterated prisoner’s dilemma. An agent in the iterated prisoner’s dilemma needs to consider what happens in future iterations of the prisoner’s dilemma to maximize its reward state.

We also assume that a rational agent will optimize actions based only on given premises. Rational agents will always attempt to optimize actions in a game-theoretic manner based on given constraints and will not include constraints outside the presented models. Furthermore, emotions themselves will be thought of as states within a machine model. Emotions will be thought of as parameters that can exist as constraints or coefficients in a computers code; emotions will be thought of as entities that can be quantized and processed logically.

**Methods**

Firstly, some preliminary methods will be discussed to provide some general knowledge on the approach taken by this project. In terms of game theory research, there is now considerable evidence that humans are not purely self-interested and do not always behave according to the predictions of game theory (Melo, 2011). Emotional displays by foreign parties can be used to determine optimal decision-making policies in social dilemmas that consider other parties' emotional displays (Melo, 2011). The recent discovery of extortion and generous strategies has renewed interest in the role of strategy in shaping behaviour in the repeated prisoner's dilemma (Melo, 2020). The project will look at these discoveries in the affect control theory and modelling of the prisoner's dilemma and use them to model AI solutions to the prisoners and repeated prisoner dilemmas. The project will focus on creating a cognitive and emotional AI agent model for the prisoner's dilemma and repeated prisoner's dilemma.

Diagram

Description automatically generated Models for cognitive and emotional AI agents bring up the next methodology segment. Affect control theory will be used as a model to build an emotional-cognitive system by which the AI-agent model operates. According to the socio-cultural view of emotion, affective systems are used as a flashlight – essentially, a set of heuristics – which guide a program along a decision tree (CITATION). In the socio-cultural view of emotion, logic is used to pick specific decisions along a path within a decision tree that emotions have already illuminated (CITATION).

Figure 1: Diagram Illustrating the Socio-Cultural View of Emotion (CITATION)

Diagram

Description automatically generatedParticularly, affect control theory is used as a theoretical for the proposed AI model in the project. In the proposed affect control theory model, five main arguments are presented. The first argument is that actors react to social situations in terms of symbols and the meanings that those symbols carry for them (Robinson et al., 2006). The second argument is that meanings that symbols have are shared mainly within a culture, leading actors to role take, viewing the situation from the position of other actors and anticipating their reactions to the interaction (Robinson et al., 2006). The third argument is that actors are motivated to maintain the meanings associated with the self (Robinson et al., 2006). The fourth argument is that meanings can shift within situations due to one's own or others' actions (Robinson et al., 2006). Lastly, the fifth argument is that emotions act as signals about how events maintain or fail to maintain self-identities within an interpersonal situation (Robinson et al., 2006). All five arguments will be used and discussed in detail for the proposed model in the paper herein.

Figure 2: Affect Control Theory Illustration

**Theoretical Results**

Firstly, some theoretical results from the classic prisoner's dilemma should be covered. In the classic prisoner's dilemma, game-theoretic results from a purely rational agent choosing a suboptimal outcome rather than cooperating (CITATION). In the classic prisoner's dilemma, it is assumed that players have no loyalty to each other and have no opportunities outside of the game itself (CITATION). Mutual defection is the only substantial Nash equilibrium – meaning each player can do worse if and only if they unilaterally change strategy – in the game (CITATION). The prisoner's dilemma is an example of a game where cooperation is Pareto efficient – which is a situation where no further improvements to the agent's well-being can be made by changing game decisions – but cannot form a Nash equilibrium for self-interested purely rational agents. The classic prisoner's dilemma gives interesting theoretical results but is detached from real-world dilemmas.

The classic prisoner's dilemma provides an excellent segue to the repeated prisoner's dilemma. The repeated prisoner's dilemma attempts to modify the prisoner's dilemma to add future iterations of the dilemma in the future. The purpose of adding future iterations in the prisoner's dilemma is to model future outcomes in the prisoner's dilemma. For example, depending on how agents weigh future outcomes – modelled by delta (𝛿) – their responses to the dilemma change as well (Bó, 2019).

Table

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Figure 3: Repeated Prisoner's Dilemma Game Illustration for Ten Iterations

Finally, we note a striking example of the iterated prisoner's dilemma known as the infinite prisoner's dilemma. In the infinite prisoner's dilemma, we let the dilemma iterate indefinitely, such that the number of iterations approaches infinity. We notice that if delta is the correct value for the specific game constraints, it is optimal for both agents to cooperate (CITATION). The repeated prisoner's dilemma is a lot closer to real-life situations and is likely why human emotional constraints cause real-world people not to defect in the prisoner's dilemma. Human evolutionary psychology is developed so that people assume a game is like a repeated prisoner's dilemma rather than a classic prisoner's dilemma; essentially, humans assume that current actions in the present world will have future impacts since people will remember how an agent acted during the prisoner's dilemma. Since people remember other people and know their credibility, real-world variants of the prisoner's dilemma should be thought of as an iteration of the infinite prisoner's dilemma since games like the prisoner's dilemma never occur in pure isolation. Emotional parameters can be used as constraints to model delta (CITATION) as it appears in the repeated prisoner's dilemma. If enough emotional parameters are configured such that delta-value (𝛿) is lowered, then the threshold to cooperate and agent should defect in the iterated prisoner's dilemma.

**Experimental Results**

The proposed implementation is the affect control model, which follows in line with the affect control theory. We can model agents in the prisoner’s dilemma and the iterated prisoner’s dilemma through four main entities. The first entity is self-sentiment, which represents the current state in memory for the agent. The second entity is identity, which represents the cultural representation of the agent. The third is behaviour, which represents the strategy an agent takes in a dilemma. Finally, the final entity is emotion, which represents how the agent feel as a result of the outcome of the dilemmaDiagram

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**Affect Control Model Parameters**

1. Self sentiment represents the behavioural state stored in an agent from past events or over multiple iterates of a game.
2. Identity represents the dictionary of cultural roles an agent can use to participate.
3. Behaviour represents the dilemma strategy an agent uses to participate.
4. Emotion represents the feeling an agent gets upon finishing the dilemma.

Figure 4: Affect Control Model Proposed in the Paper

As seen above, the affect control model has multiple stages between states, which we can further elaborate on. Self sentiment – which represents an agent's internal opinion of itself in society – represents a long-term memory state used to select a cultural identity – a set of behaviours deemed an appropriate stereotype by society – to use as an act. The identity is a stereotype of cultural and social behavioural archetypes which act as a recipe to dictate the agent's behaviour – behaviour is how the agent's identity materializes itself in terms of the game-theoretic dilemma – in a dilemma. Finally, the behavioural response generated by the agent causes an emotional response – the emotional response represents the agent's attitude towards the outcomes of the dilemma – to trigger within the agent's code. The agent's code's emotional response validates – in this case, validation means the agent feels good or bad regarding the situation – the agent's chosen identity. If the agent feels poorly at the result of the dilemma (say, a guilt/embarrassment response is triggered), the agent will fail to validate its identity and attempt to choose a new one. The identity chosen by the agent ought to be congruent – that is, an identity should match self-sentiment – with the agent's self-sentiment. For example, if an agent triggers a negative emotional response due to being betrayed by another agent in the prisoner's dilemma and changes its identity to a revenge strategy – or a grim-trigger in terms of game theory – out of revenge, it ought to change its self-sentiment (its opinion of itself) in response to the identity change. To elaborate on a self-sentiment change, if an agent changes its identity to that of a revenge-based agent, it should change its self-sentiment (which is its saved, internal emotional parameters) to be congruent with a revenge-based character for future iterations of the prisoner's dilemma or problems with a similar strategy.

**Discussion**

Multiple examples for the proposed affect control model can be discussed. Examples of self-sentiment include the case of an agent who feels close to another agent and chooses a friend or sibling identity in the game; or an agent who feels betrayed from a previous iteration or game, may choose a vengeful self-sentiment upon validating their identity to get revenge using the grim-trigger behaviour strategy. Another example includes a conman identity – likely triggered by a parasitic self-sentiment – which causes an agent to try and build trust and confidence in other agents to betray them such that they have more points than is possible through pure cooperation. A third example includes an agent playing tit-for-tat when playing against new agents and later changing their strategy to grim trigger against agents if betrayed by an agent who has built trust with the AI agent over previous game iterations. Lastly, emotions are unique to agents, and emotions are based on intrinsic psychological coefficients, which can be defined in terms of constant attributes agents have saved in their code. Emotions add the personal factor to agents which humans have; some agents seek revenge upon betrayal, some agents are paranoid, and finally, some agents are trusting to strangers.

**Strengths and Weaknesses**

Strengths of the above approach include providing a framework that a reinforcement learning model could use to train agents, and those exact parameters can be custom-defined for different scenarios. A reinforcement learning model could be used to extend the model proposed in the paper as a mechanism by which a programmer optimizes an AI-agents’ emotional parameters to reach an optimal cooperative-equilibrium state. To train the reinforcement learning model, a programmer could implement the affective control model proposed in the paper and train agents against each other and use reinforcement learning methods – Bayesian in particular – to optimize emotion variables. A program could create a probability distribution that an emotional response will maximize a cooperative outcome between multiple agents in a game. Reinforcement learning methods will update probabilities as more games are played to simulate the AI-agent gaining emotional maturity on how to play the game. Exact emotional parameters can be custom-defined according to any emotion-based model. However, for a complex situation, the OCC theory of emotion can be used as a scaffolding to build an emotional model for the AI agents’ emotional parameters (CITATION).

Weaknesses include the fact that the proposed model oversimplifies emotions and loses some of the qualitative nuances of different emotional states. Although it is assumed that emotions can be represented in a logical framework based on the fact that human brains have evolved to feel emotions to maximize environmental reward (the topic of evolutionary psychology) in human societies, there are likely some subjective nuances within the human brain. Emotional nuances in the brain are likely the results of neural network and biochemical channelling of neurotransmitters within the human brain. The geometric and spatial information stored in neurotransmitters (essentially, the place and activity of neurotransmitters across synaptic clefts) movements and the neural network-based overlap between emotional and logical cognition is not factored in by the proposed model. The proposed model is challenging to extend past games which can be rigorously defined – like a prisoner’s dilemma or a battle of the sexes game – and it does not include abstract or heuristic-like meta-games which occur across multiple domains of life. The types of emotional games the proposed affect control model would deal with include games that can be clearly and rigorously defined in terms of rules, structure, constraints, and valid decisions.

**Conclusion**

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