Statistical analysis module

Statistical Method 1: Overall Behavioural Tracking

**Purpose:** To quantify the frequency of cooperation and betrayal behaviours in order to assess the effectiveness of strategies in social interactions.

**Implementation:** Introduce global variables to the model to track the overall frequency of co-operation and betrayal and update at each model iteration.

**Visualisation:** use monitors to display the ratio of cooperation to betrayal in real time and use graphs to track trends over time.

**Results:** the interactions between different strategies and their collective impact on the system dynamics are taken into account.

Statistical Method 2: Average Returns over Time

**Purpose:** To measure the sustainable profitability of strategies over time, in keeping with the economic concept of ergodicity, which emphasises cumulative results over time.

**Implementation:** Calculate and track the cumulative returns of each strategy over multiple iterations to assess its effectiveness over time.

**Visualisation:** Produce charts showing cumulative returns over time, highlighting strategies that show consistent returns.

**Results:** Determine which strategies ensure consistent long-term benefits, taking into account variability of returns and time preference.

Statistical Method 3: Tracking Winning Rates of Individual Agents/Teams

**Purpose:** To assess the overall effectiveness of different strategies over multiple interactions to reflect long-term success consistent with the principle of ergodicity.

**Implementation:** Record and analyse the frequency of wins for each strategy over multiple rounds of play to provide a comprehensive measure of success.

**Visualisation:** Use charts and graphs to display win rates over time, revealing the most consistently successful strategies.

**Results:** Understanding which strategies are likely to lead to sustained success helps provide a deeper grasp of strategy stability over repeated interactions.

Specifically, we illustrate the third approach in particular, linking it to the notion of Ergodicity discussed in class, and exploring what win rate data can tell us about understanding strategy stability in the following ways:

In the short term, strategies such as always betraying (defecting) may provide the greatest immediate payoff because it maximizes self-interest without the cooperation of an opponent. However, this approach can lead to a reduction in the effectiveness of the betrayal strategy in the long run, as other individuals learn to prevent and react to this aggressive strategy.

On the other hand, the tit-for-tat strategy demonstrates superior long-term stability through its adaptive nature. It responds based on the opponent's last action, creating a mutually beneficial dynamic. If the opponent co-operates, it co-operates; if the opponent betrays, it betrays. This strategy consistently maintains a high win rate when encountering different opponents because it encourages cooperation while effectively deterring betrayal.

In contrast, the unforgiving strategy employs a more extreme memory model, where once an opponent has betrayed, even once, it betrays that opponent forever. This can lead to rapid destabilization in environments where cooperation predominates, as it is difficult to return to a mutually beneficial state once the cycle of betrayal has been entered.

When considering the interaction of multiple strategies, complex interactions between different strategies can be observed. If the majority of individuals tend to cooperate, individuals adopting a betrayal strategy may find themselves sidelined, as cooperators tend to support each other and work together to punish the betrayer. This dynamic interaction may lead to a decrease in the win rate of the betrayal strategy.

The win rate data also reveal how environmental changes can affect the stability of strategies. In highly competitive or resource-limited environments, betrayal strategies may briefly prevail. However, in environments with a more entrenched culture of cooperation, strategies such as tit-for-tat and unforgivable may exhibit greater stability.

Ultimately, the success of strategies is largely consistent with the principle of ergodicity, which states that only those strategies that can adapt and accumulate positive outcomes over time will survive multiple games. This view echoes the theory of survival of the fittest in biology and reflects the importance of stability in market dynamics. By analyzing win rates over time, we can better understand which strategies are more likely to lead to stable long-term results.