Harnessing Adaptive Networks and Machine Learning to Enhance Collective Decision-Making in Social Systems

Qianshuo Wang STATS201

Instructor: Luyao Zhang

昆山杜克大学
DUKE KUNSHAN UNIVERSITY

1. Background and Motivation

· **Key Problem:** Traditional group decision-making faces challenges in balancing diverse perspectives while avoiding inefficiencies and biases (Almaatouq et al., 2020).

- **Relevance to Social Science and ML:** Optimizing human-only and hybrid human-AI teams (Almaatouq et al., 2020), (Vaccaro et al., 2024)

2. Research Questions

How can adaptive feedback mechanisms and dynamic network configurations improve collective decision-making outcomes in social systems?

3. Application Scenario

Fields: Organizational decision-making, collaborative problem-solving, public policy

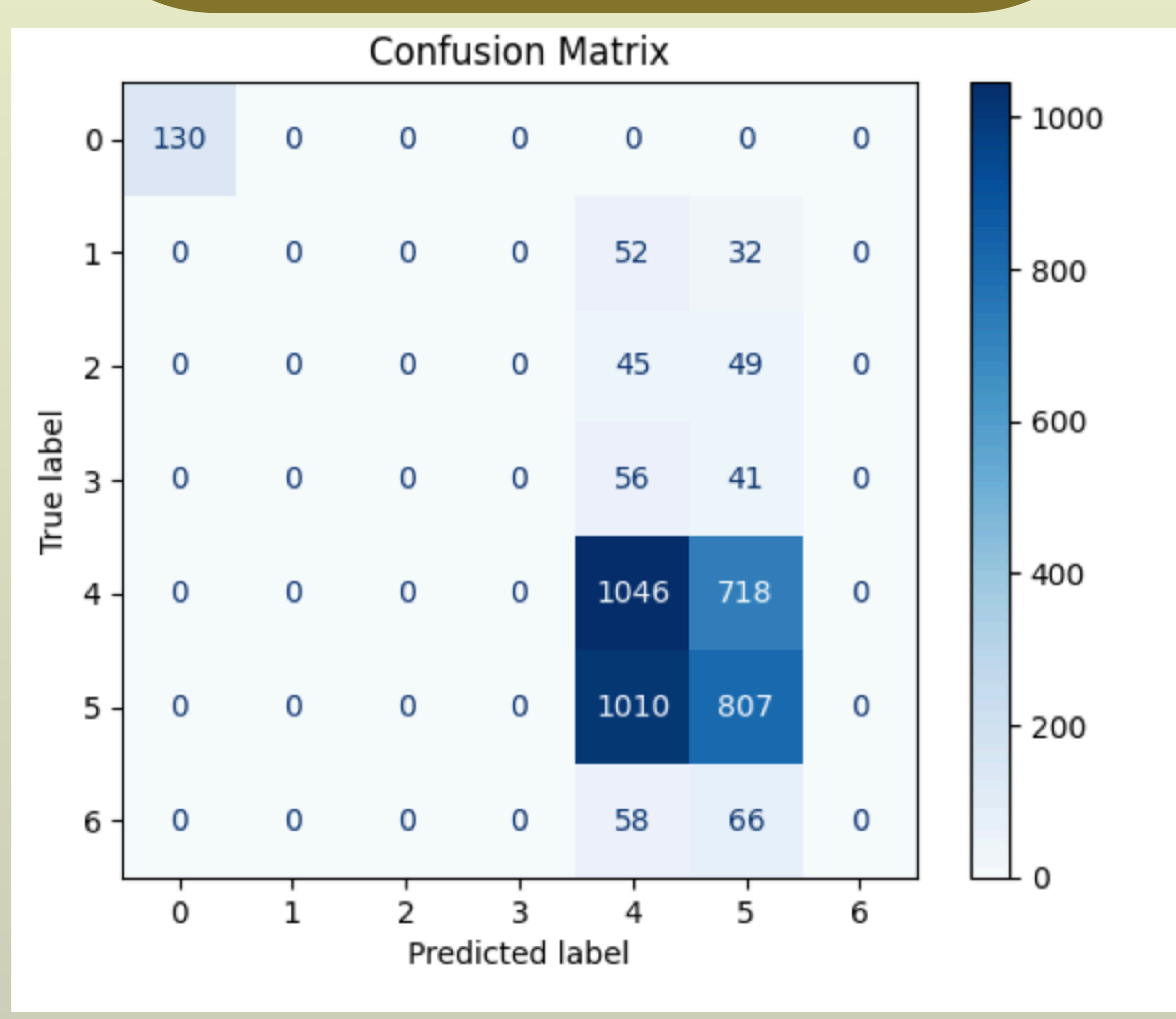


Table 1: Confusion Matrix

4. Methodologies

· **Overview:** The study compared static and adaptive network configurations through controlled decision-making experiments **(Static Networks:** Connections between participants were fixed **Adaptive Networks:** Connections evolved dynamically based on real-time performance feedback**)**

· **Machine Learning Methods Applied:**

1. Supervised Learning Models: Trained on group decision-making metrics to identify patterns correlating adaptability with improved outcomes

2. Network Dynamics Analysis: Explored how changes in connectivity influenced decision accuracy and efficiency

· **Confusion Matrix:** We use 'condition' from the dataset game_data to do the confusion matrix (Table 1), which will show the accuracy of the model in the classification task

· **Multiclassification ROC curve drawing:** ROC curve (Table 2) shows the true positive rate (TPR) and false positive case rate (FPR) of the model under different thresholds. By analyzing the ROC curve, we can find the best decision threshold to balance the sensitivity and specificity of the model

5. Results

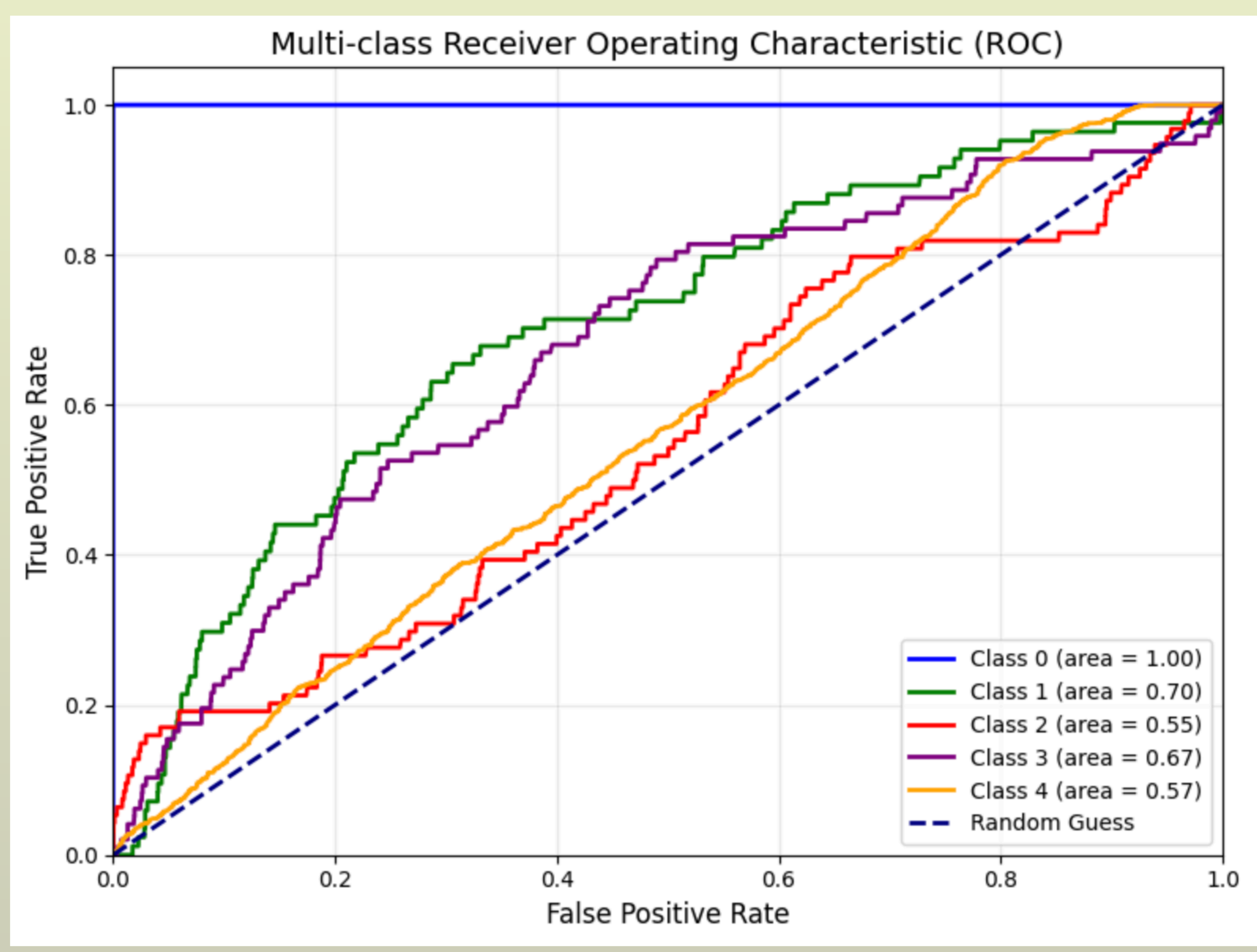
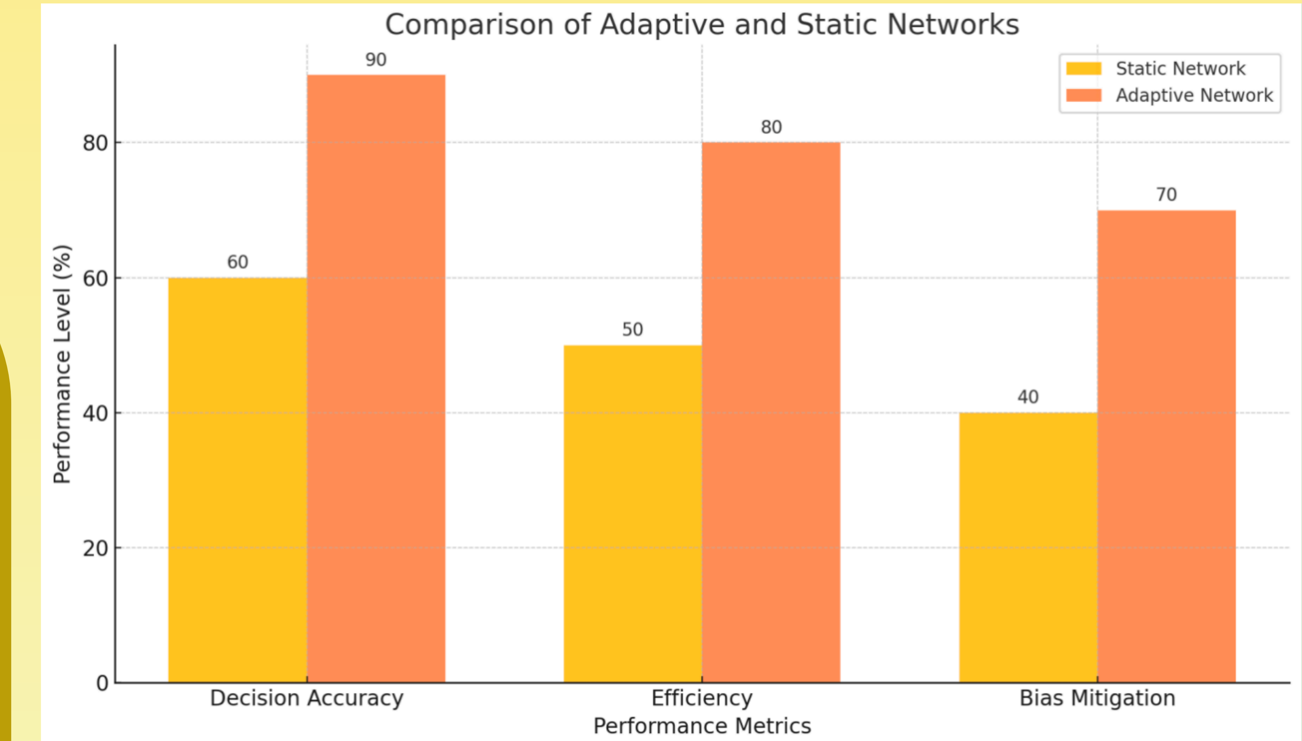


Table2: Multiclassification ROC curve drawing



Higher Accuracy: Adaptive networks significantly outperformed static ones in terms of decision accuracy. Participants leveraged performance feedback to refine their contributions, reducing errors.

Improved Efficiency: Groups operating in adaptive networks achieved convergence on accurate decisions more rapidly than those in static networks.

Bias Mitigation: Adaptive mechanisms helped minimize the influence of poorly performing participants, addressing a common limitation in static networks where errors from influential individuals can propagate unchecked.

Table1: Category 0 has the highest classification accuracy, with 130 correct predictions and no error classification, **Category 4** Despite 1,046 correct predictions, 718 instances were misclassified as category 5. This suggests a feature overlap or confusion between the two categories.

Table 2: The AUC of **Class 0** is 1.00, indicating that the classifier has a perfect discriminating performance for this class, while **Class 2** and **Class 4** performed poorly: AUC of 0.55 and 0.57, respectively, close to the level of a random guess (AUC = 0.50).

6. Intellectual Merits and Pratical Impacts

1. This can model how collective decision-making can be improved by dynamically adjusting network structures (for example, adjusting connections between groups based on performance). For example: If class 0 (the well-performing group) has a high accuracy rate, other groups may learn or align their behavior or strategy. Similarly, groups that perform poorly (low AUC) may be less connected or reconfigured.

2. Use frameworks like **networkx or PyTorch Geometric** to model social systems as dynamic networks, combined with the performance feedback provided by these codes to model network reconfiguration

7. References

1. Almaatouq, Abdullah, Alejandro Noriega-Campero, Abdulrahman Alotaibi, P. M. Krafft, Mehdi Moussaid, and Alex Pentland. 2020. "Adaptive social networks promote the wisdom of crowds." ***Proceedings of the National Academy of Sciences*** **117 (21): 11379–86. https://doi.org/10.1073/pnas.1917687117.**

2. Sherry Yang, Ofir Nachum, Yilun Du, Jason Wei, Pieter Abbeel, Dale Schuurmans. "Foundation Models for Decision Making: Problems, Methods, and Opportunities." ***Arxiv*** **(2023). https://arxiv.org/abs/2303.04129.**

3. 1. Vaccaro, Michelle, Abdullah Almaatouq, and Thomas Malone. 2024. "When Combinations of Humans and AI Are Useful: A Systematic Review and Meta-Analysis." ***Nature Human Behaviour.*** **https://www.nature.com/articles/s41562-024-02024-1.**