Study on the Mathematical Characterization of Emotional Individuality in Large Language Models Published in *Mathematics*

Large language models (LLMs) do not necessarily interpret emotions such as interest or sadness in the same way even when reading the same text. Professor Naruki Shirahama of the Faculty of Data Science, Shimonoseki City University, and his collaborators have conducted advanced research that mathematically characterizes these differences as “emotional individuality,” The resulting paper has been published in the international journal *Mathematics*. Building on earlier conference work that received the Best Paper Award at IIHMSP 2025, this study also offers a foundation for future AI evaluation design and educational applications.

Research Overview

This study aims to organize, in mathematical terms, how LLMs judge emotions in texts, including the ambiguity and variation in these judgments. The research team analyzed 4,067 valid numerical assessments obtained by asking 36 LLMs from seven vendors to read Japanese literary texts and rate four emotions—Interest, Surprise, Sadness, and Anger—on a scale from 0 to 100. In this study, “emotional individuality” does not mean that AI possesses human emotions; rather, it refers to model-specific tendencies in interpretation and response that appear even under the same conditions. This study also clarifies that the findings are based on a Japanese literary, text-only setting.

Key Points of the Study

What is temperature control

Temperature control is a setting that adjusts the amount of variation in AI-generated responses. In general, higher temperature settings produce a wider range of outputs, whereas lower settings tend to produce more stable responses. This study compared temperature settings with variations in emotion ratings and found that the models differed substantially in their reactions. The results suggest that when evaluating AI, it is important to consider not only which model is used but also the settings in which it is used.

What is fuzzy entropy

Emotions cannot always be divided neatly into simple categories such as “sad” or “not sad.” Therefore, this study used fuzzy set theory, which can handle gradual and overlapping boundaries, and quantified the ambiguity of judgments through fuzzy entropy. This made it possible to compare, within a common framework, which models tended to make relatively clear judgments, and which tended to produce more intermediate and fluctuating evaluations than others.

Persona diversity and “emotional individuality”

This study also examined how the standpoint affects emotional assessment using four personas: a university student, a literary researcher, an emotionally expressive poet, and an emotionless robot. The results showed that the personas did make a difference, but that the content of the text had an even stronger influence. This indicates that understanding how AI interprets emotion requires attention not only to the differences between models but also to the framing of the prompt and the nature of the text being read.

Significance of the Research, Award, and Publication

The significance of this study is that it provides a single mathematical framework for examining how stably LLMs respond to emotion-related tasks, how sensitive they are to changes in settings, and where ambiguity remains in their judgments. This paper positions this framework as a foundation for designing evaluation methods and selecting models for AI systems that require careful handling of emotional content. It may also serve as a basis for future validation in applications such as educational support and dialogue.

The conference paper that formed the basis of this research, “Characterizing ‘Emotional Individuality’ in 36 LLMs: Persona and Japanese Text Conditioning,” received the Best Paper Award at the IIHMSP 2025. This study extends that work by integrating temperature control, fuzzy entropy, and persona diversity into a unified mathematical framework. The paper was published in *Mathematics*, a peer-reviewed open-access journal published by MDPI, as part of the Special Issue “IIHMSP: Intelligent Information Hiding and Multimedia Signal Processing.” The journal is indexed in Scopus and, according to MDPI, has an Impact Factor of 2.2 and a CiteScore of 4.6.

Future Outlook

The framework presented in this study provides a basis for examining LLMs’ emotional understanding in mathematical rather than purely intuitive terms. In this sense, it also contributes to the mathematical framework of the JSPS KAKENHI Grant-in-Aid for Scientific Research (C) project, “Uncertainty Evaluation of Emotional Intelligence in LLMs Based on Fuzzy Entropy and Persona Diversity” (Grant Number: 26K14983).

Looking ahead, the findings are expected to inform not only further research development but also educational practice, including teaching materials and research supervision, which cultivate the ability to evaluate AI outputs from statistical and mathematical perspectives. For students in data science and AI education, exposure to this kind of research can help foster not only the ability to use AI but also the perspective needed to critically examine and assess it.

Paper Information

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- Special Issue: IIHMSP: Intelligent Information Hiding and Multimedia Signal Processing (https://www.mdpi.com/journal/mathematics/special_issues/PRMHD6O3MK)
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