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Multi-Layer Semantic Network Modeling of AI Governance as a Complex Adaptive System

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Motivation: The governance of artificial intelligence (AI) is shaped by heterogeneous, interdependent, and dynamically evolving discourses spanning public policy, corporate strategy, academic research, legal adjudication, and social media communication. These interacting domains collectively constitute a complex adaptive system [1], characterized by distributed actors, feedback loops, and evolving narratives. However, existing practices of AI regulation remain fragmented and domain specific. There is a need for an integrative, data driven framework that can capture cross-domain interactions, systemic misalignments, and emergent dynamics in AI governance. This paper proposes a multi-layer semantic network [2,3] modeling approach of the AI governance data that will enable development of adaptive AI regulation [4,5].

Approach and Methodology: We construct a multiplex semantic network from the data across five layers: government policy documents, corporate AI frameworks, social media discourse (e.g., YouTube [6], Reddit), academic publications, and legal case texts. The semantic network analysis pipeline follows: (I) large-scale data acquisition and corpus construction; (ii) preprocessing including tokenization, normalization, and entity recognition; (iii) semantic embedding using transformer-based models; (iv) network construction via co-occurrence thresholds and similarity-based edge formation; (v) multiplex integration through shared semantic spaces; (vi) network analysis using community detection, centrality measures, and temporal dynamics; and (vii) inequality analysis to quantify network heterogeneity. This pipeline operationalizes the transformation of distributed, unstructured discourse into a formal representation of a complex system.

Results: Using modularity-based community detection and centrality analysis, we identify emergent thematic structures, influential ethical concepts, and cross-domain bridging nodes within the system. Temporal network dynamics captures the evolution of discourse and detects

shifts in regulatory attention and public concern. Comparative analysis across layers reveals interesting patterns and interdependencies between regulatory frameworks, corporate practices, public narratives, and legal interpretations, particularly around key governance issues.

Conclusions and Outlook: By viewing AI governance as a multi-layer, evolving complex system, this study advances computational approaches to policy analysis and demonstrates how network science can inform the design of adaptive, inclusive, and ethically grounded AI regulatory frameworks, with particular relevance to rapidly transforming AI ecosystems. In summary, we propose: (1) a scalable multi-layer semantic network framework for modeling AI governance as a complex system; (2) a method for transforming multi-domain discourse into policy-relevant knowledge; and (3) empirical identification of critical trends in AI ethics to develop the fundamentals of adaptive AI regulation.

References

1. Chakrabarti, A. S., Bakar, K. S., & Chakraborti, A. (2023). Data science for complex systems. Cambridge University Press.
2. Floridi, L., & Cowls, J. (2019). A unified framework of five principles for AI in society. Harvard Data Science Review, 1(1). https://doi.org/10.1162/99608f92.8cd550d1
3. Ivanitskaya, L. V., & Erzikova, E. (2025). Visualizing YouTube commenters' conceptions of the US health care system: Semantic network analysis method for evidence-based policy making. JMIR Infodemiology, 5, e58227. https://doi.org/10.2196/58227
4. Kivelä, M., Arenas, A., Barthelemy, M., Gleeson, J. P., Moreno, Y., & Porter, M. A. (2014). Multilayer networks. Journal of Complex Networks, 2(3), 203–271. https://doi.org/10.1093/comnet/cnu016
5. Nulty, P. (2017). Semantic network analysis of contested political concepts. In Proceedings of the Workshop on Natural Language Processing and Computational Social Science (pp. 270–275). Association for Computational Linguistics. https://aclanthology.org/W17-6930.pdf
6. Sanyal, S., Bhaskar, V., & Mishra, S. K. (2023). A complex adaptive system framework to regulate artificial intelligence (Working Paper No. 26). Economic Advisory Council to the Prime Minister, Government of India. https://eacpm.gov.in/wp-content/uploads/2024/01/EACPM_AI_WP-1.pdf