Making better decisions: why we communicate and how languages come to be

Our paper, Federated inference and belief sharing, shows how sharing knowledge helps groups of agents make better decisions and better understand their world. These agents can be biological and artificial (i.e., AIs). For example, think of a herd (group) of animals (agents) on the lookout for predators; they work better together by telling each other their beliefs about what they see. We explain how this ability comes from agents trying to guess better – by reducing uncertainty or "free energy" – what's happening around them. By analyzing simulations of this process (using a generative model), we show that this can lead to the creation and learning of language among these agents.

Analysis

This paper focuses on four main topics, each exploring increasingly sophisticated methods of how agents (biological and artificial) learn and share knowledge:

Active inference: The first part introduces the concept of active inference, a process where agents update their beliefs or understanding based on new information. It focuses on active inference applied to a generative model with distinct, clear-cut states (or “discrete state spaces”). It explains how these models help predict and interpret data by considering states or variables that are not directly observable but influence outcomes (or “hidden states”). This section can be thought of as an introductory guide for

readers interested in the process of how beliefs are updated, a key theme explored throughout the rest of the paper.

Active inference and sharing beliefs: The second part examines how agents share their beliefs, enhancing their collective understanding. It uses an example of three agents who communicate what they see and hear from their own perspectives, allowing them to combine their observations and improve their understanding of their environment.

Active inference and learning: This section builds upon the prior one and develops a model to explore whether a new, inexperienced agent (e.g., an infant) can learn the common language or way of interpreting the world just by observing and listening to other, more experienced agents (e.g., parents). The paper shows that this learning process naturally occurs as the new agent tries to make sense of its surroundings, aiming to make its experiences as predictable as possible.

Active inference and language: The final section questions whether minimizing uncertainty (or “free energy”) alone can lead to developing a new communication system among agents. The findings suggest that a shared language can emerge among agents as they interact with their environment, leading to a consistent way of interpreting and communicating their experiences.

Discussion

We then discuss the findings from the perspective of various disciplines:

Physics perspective: The paper examines how patterns of behavior emerge from minimizing energy, drawing parallels with physical systems. It suggests that as agents learn more about their environment, their internal models become more complex. In physics, this process is known as self-organization.

Quantum information theory perspective: It discusses how communication among agents is inherently linked to their spatial arrangement, with agents' positions influencing their perspectives and the information they share. In other words, agents occupying different positions in space have unique perspectives and also the beliefs they share.

Computer science perspective: The paper relates the concept to distributed machine learning, where agents share information to learn a model without sharing their raw data, enhancing privacy and efficiency.

Neuroethology perspectives: It looks at how shared knowledge and communication contribute to cultural development and evolutionary processes, influencing both individual learning and group dynamics.

Evolutionary biology perspective: The discussion extends to how group decision-making and intelligence emerge from agents asynchronously sharing information, even without direct communication.

Complex dynamical systems perspective: We discuss how collective intelligence and group cognition in natural and artificial systems can be understood through shared beliefs and collective decision-making,

emphasizing the importance of efficient information sharing for optimal group performance.

Psychology perspective: We describe the human tendency to share knowledge and align with others as a fundamental aspect of social interaction and language development.

Linguistics perspective: It explores linguistic theories, suggesting that the structure of language and its constraints may naturally arise from the processes agents use to model and interact with their world.

In summary, the discussion section combines concepts from various disciplines to reinforce the hypothesis that shared learning and communication among agents lead to more sophisticated understanding and interactions with the environment, which mirrors human cultural and linguistic evolution.

Conclusions

Our paper demonstrates through generative models that a group's ability to learn and make inferences together (i.e., federated inferences) comes from the pursuit of reducing uncertainty or "free energy." This highlights how individuals can share knowledge and learn from each other, and hints at the underlying principles that could explain consciousness and language development. It also suggests that how intelligent biological or artificial systems can work together effectively is grounded in this shared effort to understand and predict the world around them.

In other words, the findings suggest agents develop a common system for interpreting what they see and hear, which helps them work together more effectively. This shared system can adapt and become more sophisticated as agents gain experience.