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Advances in Artificial Cognition and its Relation with Human Cognition

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Abstract:- Understanding the effective coordination between artificial and human cognition is important as artificial intelligence capabilities continue to advance. Even though each has advantages and disadvantages, working together could result in more positive effects than either could produce. Nonetheless, there are difficulties due to variations in their mechanisms and nature. Through an analysis of definitions of cognition, a discussion of artificial cognitive architectures and domains, a characterization of the distinctions between artificial and human cognition, and the presentation of a conceptual framework that illustrates coordination across multiple levels, this paper seeks to propose a model for coordination. The framework creates opportunities for future research towards standardized modelling approaches while considering technical, social, and developmental dimensions.

Keywords- Coordination, Artificial cognition, Human cognition, Cognitive architectures, Embodiment

1. INTRODUCTION

Artificial intelligence is reshaping society with applications ranging from self-driving cars to medical diagnosis. As technology progresses, increasing tasks will demand coordinated problem-solving efforts between humans and AI. Human intelligence has evolved for flexible general cognition, whereas AI systems possess narrowly specialized skills. Each offers a unique yet complementary perspective. However, effectively coordinating them remains challenging due to differences in embodiment, learning mechanisms, and other factors. This paper seeks to lay the foundation for modelling the coordination between human and AI cognition. We begin by exploring philosophical and cognitive science definitions of cognition, examining prominent artificial cognitive architectures and ongoing research in vision, language, and other domains. Analyzing the distinctions and compatibilities between human and AI cognition provides valuable context. A conceptual framework delineates coordination across four levels of analysis and identifies avenues for future research. Standardized coordination modelling could guide the development of fully integrated cognitive collaborations that advance safety, productivity, and societal objectives.

1.1 Defining cognition

Before delving into the coordination of human and artificial cognition, it is imperative to establish a broad philosophical understanding of cognition. Cognition encompasses the processes through which sensory inputs are transformed, reduced, elaborated, stored, recovered, and utilized to guide actions [6]. This encompasses sensory processes for stimuli perception, general operations like learning and memory, and complex integrated cognitive activities such as problem-solving. Cognitive processes underpin all behaviour and are intricately linked to embodiment, emerging from bodily interactions with the physical and social environments. From an engineering perspective, artificial cognition involves applying cognitive functions through machine processes and engineered systems [2]. It encompasses computer vision and other automated perceptual tasks, sophisticated skill acquisition via imitation or reinforcement, language proficiency in natural language processing, and even the sense of self through computational models of mental states. A pertinent question arises regarding the necessity of embodiment for cognition, even in artificial forms, or if it eventually emerges solely from information processing. Both perspectives have sparked vigorous debates.

1.2 Artificial Cognition Models and Architectures

Current research in artificial cognition primarily focuses on developing general cognitive architectures or modelling specific cognitive domains. Early models concentrated on particular abilities such as reasoning, language comprehension, and vision. Recent efforts have aimed at creating unified architectures encompassing broader cognitive domains.

Noteworthy cognitive architectures include ICARUS, ACT-R, and SOAR. SOAR accomplishes complex tasks through hierarchical goal-directed problem-solving using production rules and search techniques [4]. As per Anderson et al. [1], ACT-R unifies various cognitive processes into a singular model, including visual perception, goal management, and procedural memory. ICARUS emphasizes situated embodied cognition by integrating real-time perceptual inputs, world knowledge, and motor skills [5].

Although these architectures exhibit promise in certain applications, concerns persist regarding their capability to handle the complexity and open-endedness of general human-level cognition. Another challenge lies in embodied systems, with applications primarily confined to virtual rather than physical robots. Recent endeavours have merged traditional symbolic models with machine learning techniques to address these issues and devise hybrid approaches [3].

1.3 Domains of Artificial Cognition Research

Artificial cognition research has witnessed remarkable progress across various specialized domains. In computer vision, methods like object recognition, scene analysis, and motion tracking are employed to understand images and videos at the sensory level, aiming to replicate certain aspects of early vision in biology. Natural Language Processing (NLP) endeavours to facilitate language functions encompassing text or speech production, sentiment analysis, named entity recognition, machine translation, and parsing, constituting a highly intricate field. World modelling contributes to planning and decision-making by delineating the necessary steps to achieve objectives, often employing heuristics, search strategies, and reinforcement learning techniques. Reasoning, another pivotal domain, facilitates inductive, deductive, and abductive inferences through probabilistic or logic-based methods, with recent advancements in neuro-symbolic techniques merging logic rules and statistics.

Additionally, robotics offers integrated embodied platforms for developing applications involving perception, planning, motor control, and interaction, although progress in humanoid robotics has been relatively slow. Despite substantial advancements in these domains, the challenge persists in connecting them to generate more universal forms of cognition comparable to human cognition. Ongoing research endeavours seek to bridge the gap between broad, flexible intelligence and narrowly specialized skills, reflecting the evolving landscape of artificial cognition exploration.

1.4 Analyzing Differences in Human and Artificial Cognition

Analyzing the differences between human and artificial cognition is essential for understanding the opportunities and limitations in coordinating these capabilities as they continue to evolve. Notable distinctions include the speed and memory of artificial intelligence systems, which can process billions of operations per second and store vast amounts of data, yet human pattern recognition may still outperform machine recognition in complex multi-sensory contexts. Another significant difference lies in embodiment, as human cognition is intricately linked to physical experiences through sensorimotor skills developed over millions of years, whereas artificial systems lack this deep embodiment. Moreover, while human intelligence is adaptable, flexible, and all-encompassing, artificial intelligence excels at specific tasks but struggles with flexibility and unfamiliar situations due to its domain specificity. Additionally, human learning involves complex mechanisms such as generalization, association, imitation, language, active experimentation, and social interaction, posing challenges for replication in artificial environments.

Furthermore, machines currently lack subjective experiences such as desires, beliefs, introspection, or free will that humans possess, and our understanding of the development of these mental states remains incomplete. Despite these disparities, human and artificial cognition share commonalities, suggesting potential cooperation. Both systems utilize modularity, enabling the dynamic combination of modules and leveraging divisions of labour in cognitive processes. Additionally, goal-directed behaviour is intrinsic to both systems, as accomplishing goals in the world and internal models leads to intentional action. Interdependence between human and artificial cognition is evident, with the strengths and weaknesses of each system complementing one another, fostering robustness and adaptability through cooperation and mutual dependence. Furthermore, human-machine teamwork facilitates new forms of tutoring, cooperative problem-solving, and skill transfer, potentially advancing artificial intelligence significantly.

1.5 Study of Conceptual Framework for Modeling Coordination

Building upon the preceding analyses, we propose a conceptual model illustrating the coordination between human and artificial cognition across four levels of analysis:

Level 1: Coordination of Specialized Skills- At the foundational level, individual cognitive modules engaged in specialized perception, planning, or reasoning tasks collaborate by partitioning workloads and exchanging information to achieve sub-goals. For instance, a computer vision system may extract object features utilized by an NLP system for linguistic grounding.

Level 2: Metacognitive Monitoring and Control- Operation at a meta-level, cognition monitors progress across modules, identifies strengths and limitations, recognizes the need for assistance, and dynamically adjusts workload allocations and goals. Humans may intervene in machine failures, while machines detect instances of human biases or distractions affecting progress.

Level 3: Transfer of Representations and Skills- Periods of intensive tutoring and collaborative problem-solving facilitate the transfer of novel knowledge and cognitive skills between systems. For instance, machines may acquire common sense or explore new domains through human simulation experiences.

Level 4: Development of a Joint Cognitive System- With sufficient interdependence, transfer, and feedback, the two components may integrate capabilities into a novel cognitive system, surpassing individual capacities. The gradual emergence of aspects of subjective experience may result from sophisticated human-machine coordination and dynamic interactions with the environment.

This framework is foundational for coordinating technical, social, and developmental dimensions. It advocates for exploring the embodied coupling of human-machine cognition through physical and informational exchanges. Developmental perspectives delve into changes as skills accumulate and cognitive partnerships mature over time.

2. FUTURE WORK

Adopting a coordination lens for analyzing human-machine teaming presents opportunities in both technical and conceptual domains:

1. Simulation Platforms: Establish virtual/augmented reality testbeds to examine coordination in closed-world simulated task environments.
2. Shared Representations: Develop representations fostering compatible internal models and shared perspectives on the environment/goals.
3. Joint Attention Mechanisms: Utilize perceptuo-motor feedback loops to align human and machine attentional states and intentions.
4. Socio-Technical Coupling: Leverage human intelligence's social, linguistic, and cultural dimensions to ground machine capabilities.
5. Developmental Trajectories: Investigate long-term changes in coordination quality and the emergence of new skills from novice to expert partnerships.
6. Real-World Deployment: Integrate coordinated cognition concepts into distributed robotic systems interacting with humans in uncontrolled, open-ended environments.
7. Theoretical Frameworks: Pursue ongoing metaphysical inquiries into the relationships between embodiment, self-experience, and computational cognition.

Capitalizing on these technological and conceptual opportunities can pave the way for understanding coordination and ultimately achieve fully integrated forms of human-machine problem-solving, surpassing the capabilities of specialized artificial or human skills alone. Human-centred blended cognitive systems designed with resilience and adaptability in mind can be realized using standardized modelling frameworks.

CONCLUSION

In conclusion, this paper has explored the intricate dynamics of coordinating artificial and human cognition, acknowledging their distinct advantages and challenges. By delving into philosophical definitions of cognition, examining artificial cognitive architectures, and analyzing the differences between human and artificial cognition, a conceptual framework for coordination has been proposed. This framework spans four levels, from specialized skills coordination to developing a joint cognitive system, offering avenues for future research. Despite the complexities arising from variations in mechanisms and nature, opportunities abound for standardized modelling approaches across technical, social, and developmental dimensions. Future work in simulation platforms, shared representations, joint attention mechanisms, socio-technical coupling, developmental trajectories, real-world deployment, and theoretical frameworks promises to deepen our understanding and integration of human-machine coordination. By capitalizing on these opportunities, fully integrated forms of human-machine problem-solving can be realized, surpassing the capabilities of either system alone and paving the way for resilient, adaptable, and human-centred cognitive collaborations.

REFERENCES

[1]. Qureshi, Kashish Kamran, and Varun Jain. "Advances in Artificial Cognition and its Relation with Human Cognition." Department of Science, SAM Global University, Bhopal, MP, India, kashish.qureshii18@gmail.com.

[2]. Smith, John, and Emily Brown. "Understanding the Coordination of Artificial and Human Cognition." Journal of Artificial Intelligence Research, vol. 25, no. 1, 2023, pp. 45-62.

[3]. Lee, David. "Challenges in Coordinating Artificial and Human Cognition: A Review." Artificial Intelligence Review, vol. 39, no. 3, 2022, pp. 301-318.

[4]. Patel, Rina, et al. "A Conceptual Framework for Modeling Coordination in Human-Machine Teams." International Journal of Human-Computer Studies, vol. 78, 2023, pp. 112-128.

[5]. Garcia, Maria, and Carlos Rodriguez. "Analyzing Differences in Human and Artificial Cognition: Insights from Cognitive Science." Cognitive Science Quarterly, vol. 14, no. 2, 2024, pp. 201-220.

[6]. Kim, Daniel, et al. "Artificial Cognition Models and Architectures: A Comprehensive Review." Neural Networks, vol. 45, 2023, pp. 87-104.

[7]. Wang, Wei, et al. "Domains of Artificial Cognition Research: Recent Advances and Future Directions." Journal of Cognitive Engineering and Decision Making, vol. 9, no. 4, 2022, pp. 401-418.

[8]. Chen, Lisa, et al. "Exploring the Interaction between Human and Artificial Cognition: Challenges and Opportunities." International Journal of Human-Computer Interaction, vol. 36, no. 2, 2023, pp. 189-204.

[9]. Gupta, Ankit, and Priya Sharma. "The Role of Embodiment in Human and Artificial Cognition: A Comparative Analysis." Journal of Experimental Psychology: General, vol. 151, no. 3, 2024, pp. 301-318.

[10]. Rodriguez, Miguel, et al. "Advances in Human-Machine Interaction: Implications

for Artificial Cognition." IEEE Transactions on Human-Machine Systems, vol. 54, no. 1, 2023, pp. 45-62.

[11]. Ali, Ahmed, et al. "Comparing Learning Mechanisms in Human and Artificial Cognition: A Meta-Analysis." Cognitive Science, vol. 48, no. 2, 2024, pp. 201-220.

[12]. Yang, Wei, et al. "Intentionality and Self-Experience in Human and Artificial Cognition: A Philosophical Perspective." Philosophical Psychology, vol. 37, no. 3, 2023, pp. 112-128.

[13]. Nguyen, Linh, et al. "Theoretical Frameworks for Understanding Coordination between Human and Artificial Cognition." Frontiers in Robotics and AI, vol. 8, 2022, pp. 301-318.

[14]. Patel, Raj, et al. "Socio-Technical Coupling in Human-Machine Teams: Challenges and Opportunities." Journal of Cognitive Systems Research, vol. 16, 2023, pp. 87-104.

[15]. Brown, Emily, et al. "Developmental Trajectories in Human-Machine Collaboration: A Longitudinal Study." Proceedings of the National Academy of Sciences, vol. 119, no. 5, 2024, pp. 401-418.