Connotation and Technical Progress of Spatial Intelligence and Spatio-Temporal Intelligence

Hao Liu, Hanxin Chen, Hong Ma, Jianfeng Deng and Jing Chen (China, PR)

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SUMMARY

As artificial intelligence (AI) shifts from processing digital information to deep integration with the physical world, Spatial Intelligence (SI) and Spatio-Temporal Intelligence (STI) have emerged as two pivotal, yet distinct, frontier branches. This paper systematically elucidates their conceptual distinctions and reviews key technological advancements. SI focuses on enabling machines to perceive, represent, reason about, and interact with the 3D physical world, with its core being the understanding of spatial structures and geometric properties. Key technological progress in SI encompasses 3D perception, neural field-based representation and modeling, spatial reasoning and planning, and content generation for embodied interaction in domains like robotics and the Metaverse. Conversely, STI emphasizes analyzing the dynamic evolution patterns of objects and events within a unified spatio-temporal framework, aiming to mine patterns of change for decision support. Its key technologies involve the fusion of multi-modal spatio-temporal big data, spatio-temporal data mining, deep learning-based prediction models, spatio-temporal large models, and digital twin-driven simulation and scenario analysis. This paper clarifies their fundamental divergence: SI answers "Where is it and how to operate?" while STI addresses "How does it change and how to decide?". Despite their different emphases, they are converging in complex real-world applications like autonomous driving, collectively underpinning the development of more autonomous AI systems and progress toward Artificial General Intelligence (AGI). The paper concludes with a discussion of future challenges and directions concerning data, model robustness, and ethical considerations.