

Lecture 1: Agentic AI for Bioinformatics

Title: Agentic AI for Bioinformatics: From Foundation Models to Autonomous Scientific Discovery

Abstract:

Recent advances in large language models and foundation models have enabled a fundamental shift in artificial intelligence from static, task-specific pipelines toward agentic AI systems, intelligent agents capable of reasoning, planning, tool use, and autonomous decision-making in complex environments. This lecture introduces the emerging paradigm of agentic AI and examines how it can transform bioinformatics and computational biology, where analytical workflows are often heterogeneous, iterative, and knowledge-intensive. The lecture presents a systems-level perspective on agentic AI architectures, emphasizing core components such as multi-agent coordination, memory and context management, tool invocation, and self-refinement. Particular attention is given to how agentic systems can be integrated with domain-specific priors, statistical models, and experimental constraints that are essential for scientific rigor. Through concrete case studies, the lecture illustrates how agentic AI can support complex tasks such as single-cell and spatial omics analysis, gene and variant interpretation, and automated hypothesis generation, enabling end-to-end analytical workflows that combine data preprocessing, modeling, interpretation, and validation. The lecture concludes by discussing key challenges and open research questions, including robustness, interpretability, trustworthiness, and human-AI collaboration. Future directions toward AI systems that function as autonomous scientific collaborators, rather than passive analytical tools, are highlighted, with implications for the broader development of intelligent, data-driven systems.

Lecture 2: Representation Learning in Modern AI

Title: Representation Learning in Modern AI: Principles, Systems, and Emerging Frontiers

Abstract:

Representation learning lies at the core of modern artificial intelligence, enabling machines to extract structured, meaningful, and transferable information from high-dimensional, heterogeneous, and noisy data. This lecture provides a unified and system-oriented perspective on representation learning, tracing its evolution from classical latent variable models to deep learning, self-supervised learning, and foundation models. The lecture frames representation learning as a cybernetic process in which abstraction, invariance, adaptability, and interpretability must be balanced to support perception, reasoning, and decision-making in intelligent systems. Key topics include representation learning under limited supervision, multimodal and multi-view representations, and the role of learned representations in enabling robustness, generalization, and autonomy. Connections to control, optimization, and human-machine interaction are highlighted, illustrating how representation learning serves as a foundational component of complex AI and cyber-physical systems. Emerging directions such as structured and causal representations, representation learning for agentic and autonomous systems, and the integration of learned representations with symbolic and probabilistic models are discussed. The lecture concludes with open challenges and future opportunities for representation learning in next-generation AI systems, emphasizing its central role in systems science, cybernetics, and human-centered artificial intelligence.