Computing on DNA-Encoded Trees Using the PEN DNA Toolbox

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DNA has emerged as a promising medium for data storage due to its stability, programmability, and exceptionally high information density, along with rapid advances in synthesis, sequencing, and molecular modification technologies. Beyond improving storage efficiency, a key challenge is the development of strategies and tools that enable structured data access, navigation, and computation within DNA-encoded information. Hierarchical data structures, such as tree networks, are widely used to represent relationships among datasets. In this work, we propose a method to encode tree networks into DNA strands and to perform computational operations directly on these encoded structures using the PEN DNA toolbox (Polymerase/Exonuclease/Nickase dynamic network assembly). Using this framework, we successfully mapped the topologies of various tree structures and demonstrated the ability to probe relationships between nodes within the encoded networks. This approach enables navigation of DNA-encoded databases and paves the way for search tasks specific to tree-like structures, such as root identification and lowest common ancestor determination. This work represents a step toward the manipulation and querying of tree-structured data in DNA-based storage systems.