MANIPAL UNIVERSITY
JAIPUR

**DEPARTMENT OF INFORMATION TECHNOLOGY**

**Assignment for Advanced Learners**

**Automata and Compiler Design (IT3202)**

**B. Tech (IT), VI sem., Even 2023-24**

**Due Date: Complete and submit 5 days before ETE exam.**

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## Part 1

Scenario: You are a lead researcher working on the development of a cutting-edge artificial intelligence system that utilizes a combination of natural language processing and machine learning techniques to interact with users through conversation. The system aims to understand and generate human-like responses in real-time, leveraging advanced computational models and linguistic analysis.

Question:

1. As part of the system's design, you need to implement a component responsible for analyzing and interpreting natural language queries from users. Describe how you would utilize finite automata, particularly deterministic finite automata (DFA), to tokenize and parse input sentences effectively. Discuss the advantages of DFA in handling lexical analysis tasks within the context of natural language processing.
2. The system's conversational engine relies on context-free grammars (CFGs) to generate coherent and contextually appropriate responses. Design a CFG that captures the syntactic structure of conversational English, incorporating rules for sentence formation, noun phrases, verb phrases, and clauses. Provide examples of sentences generated by your CFG and explain how it facilitates the generation of diverse and grammatically correct responses.
3. To enhance the system's linguistic understanding capabilities, you decide to implement a part-of-speech tagging module using probabilistic finite automata (PFAs). Explain how PFAs can be employed to assign probabilities to different part-of-speech tags for words in a sentence, considering factors such as word context and syntactic dependencies. Discuss the challenges and potential solutions in training PFAs for part-of-speech tagging tasks.
4. As the system evolves, you aim to incorporate more advanced computational models to handle complex linguistic phenomena. Propose a methodology for integrating pushdown automata (PDA) into the system architecture to support parsing of context-sensitive grammars. Describe how PDAs can be used to recognize and analyze linguistic structures that extend beyond the capabilities of CFGs, such as cross-sentence dependencies and anaphora resolution.
5. In pursuit of achieving human-level conversational intelligence, you contemplate the utilization of Turing machines as a theoretical framework for modeling the system's cognitive processes. Discuss the feasibility and implications of employing Turing machines as a theoretical foundation for artificial intelligence systems, considering factors such as computational complexity, expressiveness, and practical limitations in implementation. Evaluate the potential benefits and challenges of adopting a Turing machine-based approach in the development of conversational AI systems.

## Part-2

Scenario: You are a software engineer tasked with developing a compiler for a new programming language designed specifically for modeling and simulating complex biological systems at the molecular level. The language is required to express intricate biochemical reactions, molecular interactions, and cellular behaviors, enabling scientists and researchers to simulate and analyze biological phenomena with high fidelity.

Question:1 Design a deterministic finite automaton (DFA) that recognizes a specific pattern of molecular interactions within a biological system. Describe the alphabet, states, transitions, and final states of the DFA, and explain how it captures the behavior of the molecular pattern.

Application: This DFA could be used as a part of a lexical analyzer to recognize specific biochemical motifs or sequences within DNA, RNA, or protein sequences, aiding in bioinformatics analysis and genetic engineering research.

Question: 2. Develop a pushdown automaton (PDA) that models the behavior of a cellular automaton representing the dynamics of a biological tissue undergoing morphogenesis. Describe how the PDA's stack is utilized to represent the cellular state and transitions between different cell types during tissue development.

Application: The PDA could be employed to simulate the emergent properties of tissue morphogenesis, such as cell differentiation, proliferation, and migration, facilitating research in developmental biology and regenerative medicine.

Question: 3. Construct a context-free grammar (CFG) that generates a language describing the hierarchical structure of protein folding patterns. Define the non-terminals, terminals, production rules, and start symbol of the CFG, illustrating how it captures the grammar of protein folding.

Application: The CFG could be utilized to generate structural representations of protein folding configurations, aiding in understanding protein folding dynamics, predicting protein structures, and designing therapeutic interventions for protein-related diseases.

Question: 4. Design a Turing machine (TM) that simulates the process of DNA sequence alignment for genomic analysis. Specify the TM's tape alphabet, states, transitions, and computational steps required to align two DNA sequences, considering factors such as sequence similarity and evolutionary conservation.

Application: The Turing machine could be employed to perform pairwise sequence alignments, facilitating comparative genomics studies, identifying functional elements in genomes, and elucidating evolutionary relationships between species.