

**Minimization Of DFA**

| **Evaluation Metrics** | **Total marks** | **Received marks** |
| --- | --- | --- |
| Comprehension | 3 |  |
| Originality, Clarity and timely submission | 3 |  |
| Understanding and critical thinking | 4 |  |

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 **Guidelines for Summary Assignment**

You are required to write a structured summary of **three research papers** relevant to your area of study. For **each paper**, your summary must include the following components:

1. **Problem Definition** – Clearly state the main problem or challenge addressed by the study.
2. **Importance of the Study** – Explain why this problem is significant and worth investigating.
3. **Objectives** – Identify the specific goals or aims of the research.
4. **Research Gap** – Describe what gaps or limitations in existing literature the study attempts to address.
5. **Methodology** – Summarize the methods and approaches used by the researchers to conduct their study.
6. **Conclusion** – Highlight the key findings or conclusions drawn in the paper.
7. **Future Scope** – Mention any suggestions for future work or further research provided by the authors.

After summarizing all three papers individually, include a **final paragraph** reflecting your **own understanding and insights**. This paragraph should synthesize what you learned from the papers, how they relate to each other (if applicable), and any critical remarks or observations you wish to share.

Ensure that you include **proper citations and references** for all three papers using IEEE format

\*Note that paper wont exceeds two pages.

\* Please ensure that your summary is submitted **by [26/05/2025]**. Topics should be nominated by 21-0502025.

**Timely submission will be considered as part of your evaluation**.

## Paper 1: DFA Minimization: From Brzozowski to Hopcroft (2023)

**Authors:** Pedro García, Damián López, Manuel Vázquez de Parga

**Problem Definition:**This paper analyzes and bridges two classical deterministic finite automaton (DFA) minimization algorithms—Brzozowski’s and Hopcroft’s methods.

**Importance:**DFA minimization is a fundamental problem in automata theory with significant applications in compilers, formal language processing, and pattern matching. Efficient minimization reduces computational resources and improves performance.

**Objectives:**To derive a polynomial-time variant of Brzozowski’s minimization method and establish a connection to Hopcroft’s algorithm, which is known for its optimal time complexity.

**Research Gap:**Existing literature lacked a computational understanding that clearly relates Brzozowski’s approach, which involves reversal and determinization, to Hopcroft’s partition refinement algorithm.

**Methodology:**The authors reformulated Brzozowski’s method by redefining the transitions and partition refinement steps to produce a polynomial-time algorithm. This variant is shown to be equivalent in effect to Hopcroft’s method.

**Conclusion:**The study concludes that both algorithms compute the same equivalence relation on states, and Brzozowski’s method can be optimized to achieve the same efficiency as Hopcroft’s algorithm.

**Future Scope:**The authors suggest the development of hybrid or intermediate algorithms that combine features of both approaches, potentially tailored for specific classes of automata or applications.

## Paper 2: Incremental NFA Minimization (2022)

**Authors:** Christian Bianchini, Alberto Policriti, Brian Riccardi, Riccardo Romanello

**Problem Definition:**Minimizing nondeterministic finite automata (NFA) is PSPACE-complete, making exact minimization computationally infeasible. This paper addresses approximate minimization using bisimilarity and incremental algorithms.

**Importance:**Efficient NFA minimization improves memory and runtime efficiency in applications such as compilers and formal verification models where NFAs are prevalent.

**Objectives:**To propose a corrected incremental bisimulation algorithm that overcomes inefficiencies and redundancies in previous incremental minimization attempts.

**Research Gap:**Earlier incremental algorithms lacked practical efficiency, often reprocessing states unnecessarily, which limited their usability.

**Methodology:**The authors introduced a graph-coloring-based incremental approach that tracks bisimilarity relations and supports early aggregation of states, optimizing the minimization process.

**Conclusion:**The algorithm achieves a time complexity of O(n2⋅r⋅∣Σ∣) *O*(*n*2⋅*r*⋅∣Σ∣), supports early termination, and outperforms prior incremental algorithms in practice.

**Future Scope:**Future work includes extending the approach to probabilistic or weighted automata and integrating the algorithm into practical formal verification tools.

## Paper 3: Fast Coalgebraic Bisimilarity Minimization (2022)

**Authors:** Jules Jacobs, Thorsten Wißmann

**Problem Definition:**There is a lack of a generic, scalable automaton minimization algorithm applicable across various automata types, including deterministic, nondeterministic, weighted, and probabilistic automata.

**Importance:**A universal minimization algorithm is valuable in diverse domains such as model checking, concurrent systems, and probabilistic verification, where automata minimization enhances performance and clarity.

**Objectives:**To design a generic and efficient coalgebraic minimization algorithm that works for any computable Set-functor, enabling broad applicability.

**Research Gap:**Existing generic algorithms were either memory-intensive, slow, or limited to specific functors, restricting their practical use.

**Methodology:**The authors employed coalgebra theory and category-theoretic functors to generalize automaton behaviors. They applied optimized partition refinement using “Hopcroft’s trick” to reduce recomputation. The approach is implemented in the tool Boa, allowing users to define or compose functors for various automata types.

**Conclusion:**The algorithm achieves O(mlog⁡n)*O*(*m*log*n*) time complexity, drastically reduces memory usage (up to 100x), and outperforms specialized algorithms on benchmarks, making it practical for large-scale automata.

**Future Scope:**The authors plan to apply the algorithm to real-time and large-scale systems, explore probabilistic and game-based models, and develop distributed implementations.

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## Final Reflection

These three papers collectively illustrate the evolution and diversity of automata minimization techniques. The first paper revisits classical DFA minimization, bridging two foundational algorithms and enhancing computational understanding. The second paper tackles the challenging problem of NFA minimization with an incremental and practical approach, highlighting the importance of bisimulation in approximate minimization. The third paper advances the field by proposing a generic, coalgebraic framework that unifies and generalizes minimization across automata types, demonstrating significant improvements in scalability and efficiency.

From these studies, I learned that automata minimization is not only a theoretical problem but also deeply connected to practical concerns such as scalability, memory usage, and applicability to various system types. Key concepts such as bisimulation, partition refinement, and functor-based system representation are central to modern algorithm design in this area. The research also underscores the trend towards generic, reusable algorithms that can adapt to new automata models without reinventing the wheel.

**References**

[1](https://ppl-ai-file-upload.s3.amazonaws.com/web/direct-files/attachments/56643903/23f1ddfd-3593-45c6-b1e4-3e61bf8dc033/CY44_AssignmentTemplate.docx) P. García, D. López, and M. Vázquez de Parga, "DFA Minimization: From Brzozowski to Hopcroft," 2023.  
[2](https://ppl-ai-file-upload.s3.amazonaws.com/web/direct-files/attachments/56643903/0566e3ae-41db-4332-80de-408fe9d41579/2204.12368v3.pdf) C. Bianchini, A. Policriti, B. Riccardi, and R. Romanello, "Incremental NFA Minimization," 2022.  
[3](https://ppl-ai-file-upload.s3.amazonaws.com/web/direct-files/attachments/56643903/6a55dc39-d1eb-48ea-ae0d-c5396ef35e32/9606.pdf) J. Jacobs and T. Wißmann, "Fast Coalgebraic Bisimilarity Minimization," 2022.