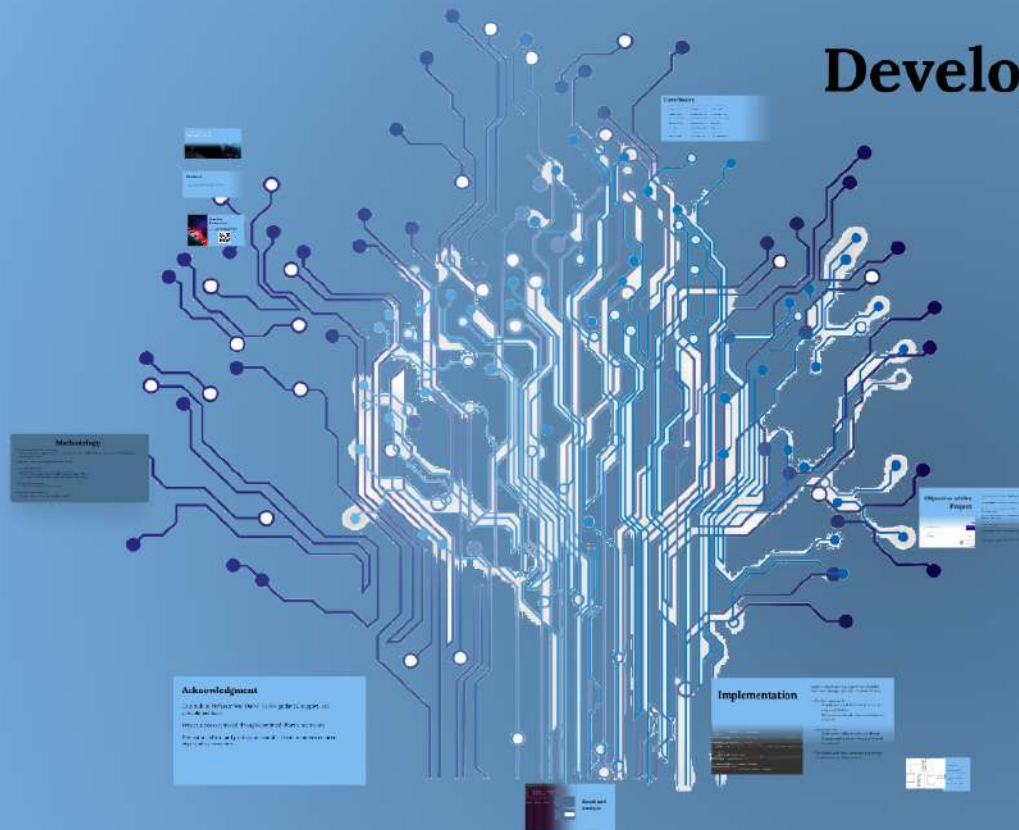


Course Project - 1

Developing a Memory Database with Sorting Algorithms

A comprehensive guide to creating a memory database with various sorting algorithms, utilizing real student data, and conducting performance analysis.



Purdue University northwest - Fall 2025

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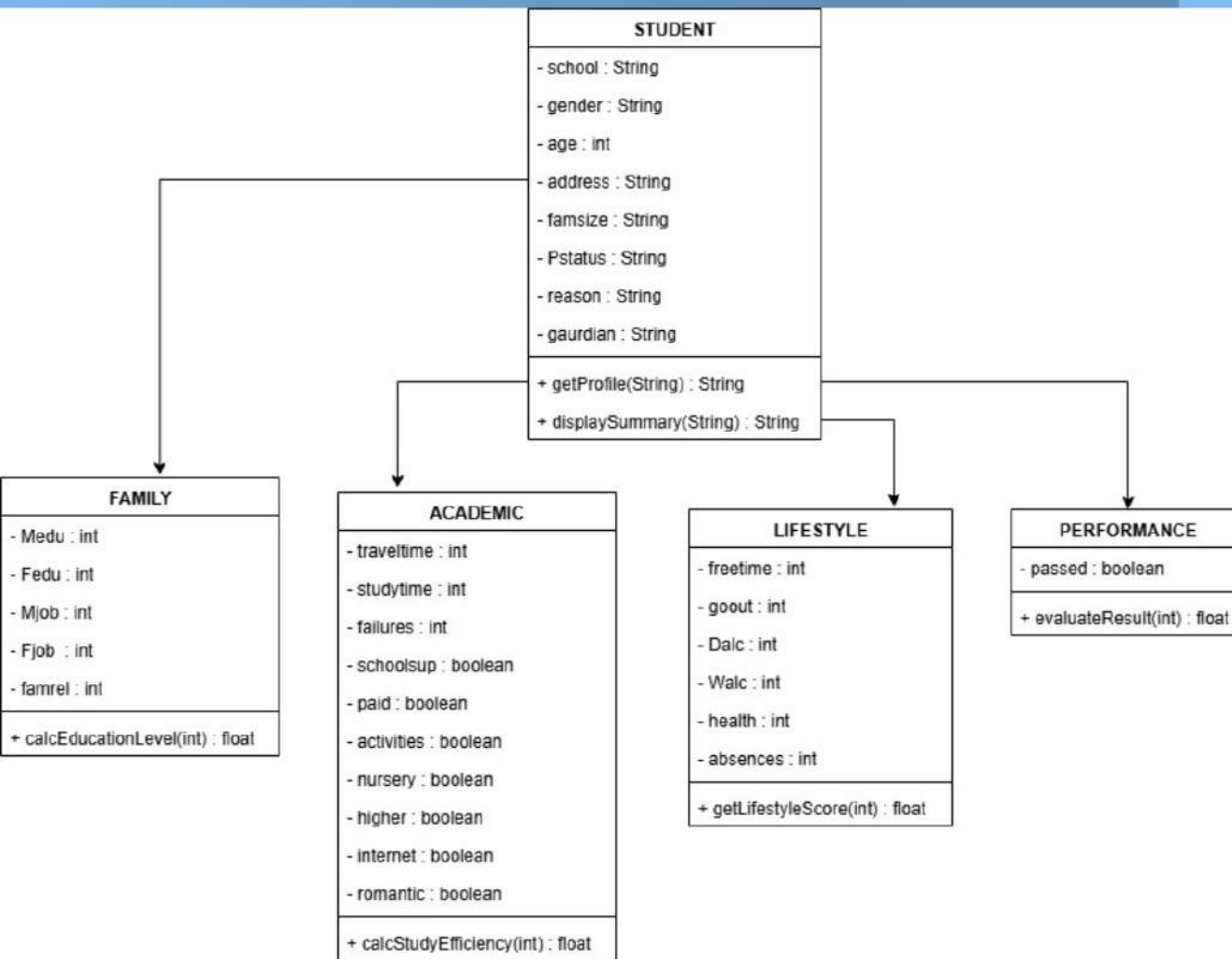
Objective of the Project



- Implemented an in-memory database using linked lists.
- Loaded student-data.csv dataset for testing.
- Developed sorting algorithms: Bubble, Insertion, Merge, Quick sort.
- Extended system with SQL-like grammar and recursive CSV export.
- Added recursive export function to write sorted data back to CSV
- Conducted performance benchmarking in Ubuntu Linux
- Performance evaluated using Ubuntu Linux benchmarking tools.

Methodology

- Dataset Acquisition & Pre-processing
 - student-data.csv (Kaggle) selected - structured, machine-readable, Parsed into tokens (ID, demographics, performance data)
- htop, time, iostat, pidstat for performance metrics
- Core Implementation
 - Built singly linked list database in Python & Java
 - Python - class-based, recursion, CSV export via built-in library
 - Java - object-oriented, explicit node handling, strong typing
- SQL Grammar Extension
 - Simulated SQL queries in toy database
- Recursive Export Function
 - Recursive traversal - write sorted data to CSV



- Creating a UML Diagram Representation
- Visualized structure, process flow, and system integration
- Performance Benchmarking
- Compared Bubble/Insertion (quadratic) vs. Merge/Quick (efficient)
- Python vs. Java ▢ highlighted interpreted vs. compiled trade-offsMemory Database

Implementation

```
tor {  
  
yDB db) { this.db = db; }  
ng sql, String outfile) throws IOException {  
l.trim();  
erCase().startsWith("select ")) throw new IllegalArgumentException("Only SELECT su  
  
indexOfWord(s.toLowerCase(), " from ");  
indexOfWord(s.toLowerCase(), " order by ");  
|| orderby < 0) throw new IllegalArgumentException("Missing FROM or ORDER BY clau  
  
SELECT columns  
= s.substring(7, from).trim();  
Empty()) throw new IllegalArgumentException("No columns specified in SELECT!!!");  
ectedColsRaw = selcol.split(",");  
  
= s.substring(from + 6, orderby).trim();  
qualsIgnoreCase("t1")) {  
IllegalArgumentExcep("Unknown table: " + table);  
}
```

Implemented sorting algorithms (Bubble, Insertion, Merge, Quick) in Python & Java

- Python approach
 - Simple syntax & built-in structures - easy readability
 - Minimal overhead - fast validation of outputs
- Java approach
 - Structured, object-oriented design
 - Strong emphasis on encapsulation & modularity
- Validated with test cases (empty arrays, single element, duplicates)

```
prasanth@prasanth-VMware-Virtual-Platform: ~/Documents/groupproject
atform:~/Documents/groupproject$ ps -ef | grep java
ts/1      00:00:00 java MemDBSortJava
ts/0      00:00:00 grep --color=auto java
atform:~/Documents/groupproject$ pidstat -o 5000
Mware-Virtual-Platform)
```

Performance Evaluation
 Metrics: CPU utilization, disk I/O, memory usage

Performance Evaluation

Metric: (TAS) utilization, disk I/O, execution time

Quadratic-time algorithms (bubble, insertion) slower with higher CPU usage.

Wetp and Quick sort more efficient with large datasets.

Language Effects

Python - interpreted, slower runtime but easier prototyping

doi:10.1016/j.jmb.2006.05.018

Performance Analysis

* Δ HK/VO = minimal differences, relative to % export, consistent

- system Commands Used
time top, ps, cat, ls, cd - for running, CPU, and disk monitoring

• **Champion's Warm Hugs®**

Agent Test	Avg CPU %	Elapsed Time (s)	Max Memory (MB)	Disk Reads (MB/s)	Disk Writes (MB/s)
threads	1%	100.8	49	8.33	0.12
image	0%	116.1	48	8.01	0.80
quick	3%	30.9	22	6.9982	0.004
image	12%	2.8	43	6.06	0.00

[illegible]

language class iff $\text{occurrence probability}$

Leif Johansson, *University of Gothenburg, Sweden*

Result and Analysis

Performance Evaluation

Metrics: CPU utilization, disk I/O, execution time

Quadratic-time algorithms (Bubble, Insertion) slower with higher CPU usage.

Merge and Quick sort more efficient with large datasets.

Language Effects

Python - interpreted, slower runtime but easier prototyping

Java - compiled, faster execution, stable resource usage

Performance Analysis

- Disk I/O - minimal differences, recursive CSV export consistent
- System Commands Used
time, top, pidstat, iostat - for runtime, CPU, and disk profiling

- Example Runs (Java)

Run 1: 190.9s, CPU 1%, Mem ~49 MB
Run 2: 116.1s, CPU 0%, Mem ~46 MB
Run 3: 36.9s, CPU 3%, Mem ~52 MB
Run 4: 2.8s, CPU 12%, Mem ~43 MB

Algorit hm	Avg CPU %	Elapsed Time (s)	Max Memory (MB)	Disk Reads (MB/s)	Disk Writes (MB/s)
Bubble Sort	1%	190.9	49	0.55	0.12
Merge Sort	0%	116.1	46	0.01	0.00
Quick Sort	3%	36.9	52	0.0002	0.004
Heap Sort	12%	2.8	43	0.00	0.00

- Key Insights

Algorithm choice = biggest factor in performance
Language choice influences runtime predictability
Careful memory management crucial in in-memory systems

Acknowledgment

Gratitude to Professor Wei "David" Dai for guidance, support, and valuable feedback

Project success achieved through combined effort & teamwork

Dedication, effort, and professionalism of all team members ensured high-quality outcomes

Conclusion

- Successfully built a toy in-memory database system.
- Reinforced knowledge of linked lists, recursion, and algorithms.
- Benchmarked performance in Python and Java.
- Project emphasized collaboration and reproducibility.



Thank You! Demonstration

Python: <https://onlinegdb.com/bMV17hnXx>

Java: https://onlinegdb.com/WA_w1BH9ZU

