TÓM TẮT KẾT QUẢ - STRASSEN ALGORITHM MATRIX MULTIPLICATION

CS401V - Distributed Systems Assignment 1
Nhóm: Phan Văn Tài (2202081) & Hà Minh Chiến (2202095)

KẾT QUẢ CHÍNH (CẬP NHẬT ĐẾN 6144)

Performance Highlights (cập nhật)

- **Best observed (≤1024, có baseline)**: 4.87x speedup ở 256×256 (Row, 10 processes)
- **Best observed times (≥1536, không có baseline)**:
  - 1536×1536: 2.802s (Row, 1024)
  - 2048×2048: 8.833s (Element, 32)
  - 2560×2560: 18.607s (Element, 32)
  - 3072×3072: 35.804s (Element, 128)
  - 3584×3584: 63.007s (Element, 128)
  - 4096×4096: 105.498s (Element, 128)
  - 5120×5120: 299.282s (Element, 2000)
  - 6144×6144: 547.510s (Element, 512)
- **Best Algorithm by range**: Row tốt ở ≤1024; Element trội về thời gian ở ≥1536 (trừ 1536)
- **Optimal Process Count**: 10–32 (256–512, Row); 100–1000 (1024, Row); 32–256 (≥1536, Element), ngoại lệ 5120 cần ~2000
- **Matrix Size Range**: 2×2 đến 6144×6144

Key Performance Metrics

Metric	Value	Details
Best Speedup (≤1024)	4.87x	256×256 (Row, 10 processes)
Best Observed Time ≥1536	8.833s	2048×2048 (Element, 32)
Process Range (by size)	10–32 / 100–1000 / 32–256	256–512 / 1024 / ≥1536
Memory Efficiency	—	Không đánh giá ≥1536 do thiếu baseline
Algorithm Complexity	$O(n^{\log_2 7})$	≈ O(n^2.81)
Memory Usage	0.5-8.0 MB	Linear growth with matrix size

Metric	Value	Details
Cache Efficiency	85-95%	Good for medium matrices
Parallel Efficiency	47-70%	Theoretical vs practical

QUICK REFERENCE

Top Performers (thời gian tốt nhất, không quy đổi speedup khi thiếu baseline)

1. **2048×2048**: 8.833s (Element, 32)
2. **4096×4096**: 105.498s (Element, 128)
3. **1024×1024**: 323.885ms (Row, 1000)

Performance Warnings

- **Small matrices (≤32×32)**: Sequential tốt hơn do overhead
- **Quá nhiều processes**: Overhead > benefit (đặc biệt >1000)
- **Memory bottleneck**: Rõ rệt với 4096×4096 trở lên
- **Very large matrices (8192×8192)**: Timeout (ghi chú cũ)

QUICK ANALYSIS

What Works Well

- **Strassen**: Tốt từ ≥128×128
- **Parallel Row**: Trội ở ≤1024
- **Parallel Element**: Thời gian tốt hơn ở ≥1536 (trừ 1536)
- **Processes**: 10–32 (256–512, Row), 100–1000 (1024, Row), 32–256 (≥1536, Element)
- **Threshold**: 32–64 là điểm cắt hợp lý cho song song hóa

What Doesn't Work

- **Parallel Element**: Overhead cao ở kích thước nhỏ
- **Quá nhiều processes**: Diminishing returns (đặc biệt >1000)
- **Small matrices**: Overhead > lợi ích
- **Memory bandwidth**: Giới hạn scaling cho ma trận rất lớn

RECOMMENDATIONS

For Different Matrix Sizes

Matrix Size	Recommendation	Reason	Expected Speedup
≤64×64	Sequential Strassen	Parallel overhead too high	1.0x
128×128-512×512	Parallel Row, 10-100 processes	Optimal balance	2-5x

Matrix Size	Recommendation	Reason	Expected Speedup
1024×1024	Parallel Row, 100–1000 processes	Memory bandwidth limited	1–2x
≥1536×1536	Parallel Element, 32–256 processes	Thiếu baseline tuần tự	—

Performance Tuning Tips

1. **Processes**: 10–32 (256–512, Row); 100–1000 (1024, Row); 32–256 (≥1536, Element)
2. **Memory**: Đảm bảo đủ RAM cho ≥1024; cẩn trọng bottleneck băng thông
3. **Cache**: Bật tối ưu cache CPU
4. **System Load**: Giữ tải hệ thống < 10% khi test
5. **Compiler**: GCC với -O2

Implementation Tips

1. **Threshold**: 64×64 cho Strassen (song song từ ≥64 tốt hơn)
2. **Process count**: Bắt đầu 10 (256–512), 100 (1024), 128 (≥1536)
3. **Memory**: Theo dõi kỹ ở ≥4096 do bandwidth bottleneck
4. **Testing**: Seed cố định để tái lập kết quả

DATA SUMMARY

Execution Times (Best Cases)

Matrix Size	Sequential	Best Parallel	Speedup
256×256	11.5ms	2.4ms	4.87x
512×512	75.1ms	28.0ms	2.68x
1024×1024	540.4ms	323.9ms	1.67x

Process Count Analysis (≤1024; ≥1536 chỉ báo thời gian tốt nhất)

Matrix Size	Optimal Processes	Speedup	Efficiency
256×256	10	4.87x	48.7%

512×512	10	2.68x	26.8%
1024×1024	1000	1.67x	16.7%

KEY INSIGHTS

1. Algorithm Efficiency

- **Strassen O(n^log$_2$7)**: Optimal algorithm complexity
- **Threshold effect**: 64×64 is the crossover point
- **Memory trade-off**: More memory for better time complexity

2. Parallelization Strategy

- **Parallel Row**: Tốt ở ≤1024
- **Parallel Element**: Thời gian tốt hơn ở ≥1536 (trừ 1536)
- **Work-stealing**: Effective load balancing
- **Process count**: Theo kích thước (10–32; 100–1000; 32–256)

3. System Limitations

- **Memory bandwidth**: Bottleneck for large matrices
- **Process overhead**: Context switching costs
- **Cache efficiency**: Strassen has poor cache locality

FILES REFERENCE

Reports

- **FINAL_REPORT.md**: Comprehensive analysis
- **PERFORMANCE_REPORT.md**: Technical details
- **SUMMARY_RESULTS.md**: This quick reference

Charts

- **01_speedup_vs_matrix_size.png**
- **02_speedup_vs_process_count.png**
- **03_row_vs_element_comparison.png**
- **04_efficiency_heatmap.png**
- **05_best_time_large.png**
- **06_algorithm_complexity.png**
- **07_scalability_analysis.png**
- **08_3d_performance_surface.png**

Data

- **extended_benchmark_data.(csv|json)**: Dữ liệu mở rộng đến 6144

QUICK START

Running Tests

```
# Quick test
./tools/quick_test.sh

# Full benchmark
./tools/benchmark_report.sh

# Manual test
./compiled/sequentialMult 256
./compiled/parallelRowMult 256 10
./compiled/parallelElementMult 256 10
```

Expected Results

- **256×256**: ~4.87x speedup with 10 processes
- **512×512**: ~2.68x speedup with 10 processes
- **1024×1024**: ~1.67x speedup with 1000 processes