random-test-plots

June 18, 2025

1 Polars-Bio Performance Analysis

This notebook analyzes performance test results comparing polars-bio against other genomic interval tools. It creates visualizations showing: - Performance comparisons across different data sizes - Multi-core scaling analysis for polars-bio - Summary heatmaps of relative performance

[ ]:

[20]:
```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import os
from pathlib import Path
import re
from typing import Dict, List, Tuple

# Set style for better plots
plt.style.use('seaborn-v0_8')
sns.set_palette("husl")

# Configure matplotlib for better display
plt.rcParams['figure.dpi'] = 100
plt.rcParams['savefig.dpi'] = 300
plt.rcParams['font.size'] = 10
```

[21]:
```
def load_csv_files(results_dir: str) -> Dict[str, pd.DataFrame]:
    """Load all CSV files from results directory"""
    csv_files = {}
    results_path = Path(results_dir)

    for csv_file in results_path.glob("*.csv"):
        # Extract operation and type from filename
        filename = csv_file.stem
        csv_files[filename] = pd.read_csv(csv_file)
        print(f"Loaded: {filename} with {len(csv_files[filename])} rows")

    return csv_files
```

```
def parse_test_cases(df: pd.DataFrame, filename: str) -> pd.DataFrame:
    """Parse test case sizes from the filename and add thread info"""
    df = df.copy()

    # Extract data size from filename (e.g., "overlap-parallel_10000000" ->␣
 ↪10000000)
    parts = filename.split('_')
    if len(parts) >= 2:
        try:
            data_size = int(parts[-1])
            df['data_size'] = data_size
            #print(f"Extracted data_size: {data_size} from filename:␣
 ↪{filename}")
        except ValueError:
            df['data_size'] = 0
            print(f"Could not extract data_size from filename: {filename}")
    else:
        df['data_size'] = 0
        print(f"No data_size found in filename: {filename}")

    # Standardize column names
    if 'Library' in df.columns:
        df['tool'] = df['Library']
    if 'Mean (s)' in df.columns:
        df['execution_time'] = df['Mean (s)']

    # Extract thread count for parallel operations
    df['threads'] = 1  # default
    if 'tool' in df.columns:
        df['threads'] = df['tool'].apply(lambda x:
            int(x.split('-')[-1]) if '-' in str(x) and x.split('-')[-1].
 ↪isdigit() else 1
        )
        # Clean tool names (remove thread suffixes)
        df['tool_clean'] = df['tool'].apply(lambda x:
            x.split('-')[0] if '-' in str(x) and x.split('-')[-1].isdigit()␣
 ↪else x
        )


    return df
```

[22]:
```
def create_operation_comparison_plot(data: Dict[str, pd.DataFrame],
                                     operation: str,
                                     output_dir: str):
    """Create comparison plot for a specific operation"""
```

```
    # Find files for this operation (non-parallel) - use exact match to avoid␣
↪overlapping names
    operation_files = {}
    for k, v in data.items():
        if 'parallel' not in k and '-' in k:
            # Extract operation name (first part before first '-')
            file_operation = k.split('-')[0]
            if file_operation == operation:
                operation_files[k] = v

    if not operation_files:
        print(f"No data found for operation: {operation}")
        return

    plt.figure(figsize=(12, 8))

    # Collect all data points
    all_data = []
    for filename, df in operation_files.items():
        df = parse_test_cases(df, filename)  # Fixed: added filename parameter
        df['filename'] = filename
        all_data.append(df)

    if not all_data:
        print(f"No valid data for operation: {operation}")
        return

    combined_df = pd.concat(all_data, ignore_index=True)

    # Use data directly without grouping since each test is run once
    if 'tool_clean' in combined_df.columns:
        tool_col = 'tool_clean'
    else:
        tool_col = 'tool'

    # Plot each tool
    for tool in combined_df[tool_col].unique():
        tool_data = combined_df[combined_df[tool_col] == tool].
↪sort_values('data_size')

        # Highlight polars-bio
        if tool == 'polars_bio':
            plt.plot(tool_data['data_size'], tool_data['execution_time'],
                     'o-', linewidth=3, markersize=8, label=tool, color='red')
        else:
            plt.plot(tool_data['data_size'], tool_data['execution_time'],
```

```
                    'o-', alpha=0.7, label=tool)

    plt.xlabel('Dataset Size')
    plt.ylabel('Execution Time (s)')
    plt.title(f'Performance Comparison - Operation: {operation.upper()}')
    plt.legend(bbox_to_anchor=(1.05, 1), loc='upper left')
    plt.grid(True, alpha=0.3)
    plt.xscale('log')
    plt.yscale('log')
    plt.tight_layout()

    # Save plot
    os.makedirs(output_dir, exist_ok=True)
    plt.savefig(f"{output_dir}/{operation}_comparison.png", dpi=300,␣
↪bbox_inches='tight')
    plt.show()
```

[23]:
```
def create_parallel_analysis_plot(data: Dict[str, pd.DataFrame],
                                  operation: str,
                                  output_dir: str):
    """Create parallel performance analysis for polars-bio"""
    print(f"Creating parallel analysis plot for operation: {operation}")
    # Find parallel files for this operation - use exact match to avoid␣
↪overlapping names
    parallel_files = {}
    for k, v in data.items():
        if '-parallel' in k:
            # Extract operation name before '-parallel'
            file_operation = k.split('-parallel')[0]
            if file_operation == operation:
                parallel_files[k] = v

    if not parallel_files:
        print(f"No parallel data found for operation: {operation}")
        return

    plt.figure(figsize=(14, 6))

    # Collect all parallel data
    all_parallel_data = []
    for filename, df in parallel_files.items():
        df = parse_test_cases(df, filename)  # Fixed: added filename parameter
        df['filename'] = filename
        all_parallel_data.append(df)

    if not all_parallel_data:
        print(f"No valid parallel data for operation: {operation}")
```

```
        return

    combined_df = pd.concat(all_parallel_data, ignore_index=True)

    # Filter for polars-bio only (clean tool name)
    if 'tool_clean' in combined_df.columns:
        polars_data = combined_df[combined_df['tool_clean'] == 'polars_bio'].
↪copy()
    else:
        polars_data = combined_df[combined_df['tool'].str.
↪startswith('polars_bio')].copy()

    if polars_data.empty:
        print(f"No polars-bio data found for parallel operation: {operation}")
        return

    # Use data directly without grouping since each test is run once

    # Plot 1: Performance vs Data Size for different thread counts
    plt.subplot(1, 2, 1)
    for thread_count in sorted(polars_data['threads'].unique()):
        thread_data = polars_data[polars_data['threads'] == thread_count].
↪sort_values('data_size')
        plt.plot(thread_data['data_size'], thread_data['execution_time'],
                 'o-', label=f'{thread_count} threads', markersize=6)

    plt.xlabel('Dataset Size')
    plt.ylabel('Execution Time (s)')
    plt.title(f'Polars-bio: {operation.upper()} - Different Thread Counts')
    plt.legend()
    plt.grid(True, alpha=0.3)
    plt.xscale('log')
    plt.yscale('log')

    # Plot 2: Speedup analysis
    plt.subplot(1, 2, 2)

    # Calculate speedup relative to 1 thread
    for data_size in sorted(polars_data['data_size'].unique()):
        size_data = polars_data[polars_data['data_size'] == data_size]

        baseline_time_data = size_data[size_data['threads'] ==␣
↪1]['execution_time']

        if baseline_time_data.empty:
            continue
```

```
        baseline_time = baseline_time_data.iloc[0]

        speedups = []
        thread_counts = []

        for thread_count in sorted(size_data['threads'].unique()):
            thread_time_data = size_data[size_data['threads'] ==␣
↪thread_count]['execution_time']
            if thread_time_data.empty:
                continue
            thread_time = thread_time_data.iloc[0]
            speedup = baseline_time / thread_time
            speedups.append(speedup)
            thread_counts.append(thread_count)

        plt.plot(thread_counts, speedups, 'o-', label=f'Size: {data_size}',␣
↪markersize=6)

    # Add ideal speedup line
    max_threads = max(polars_data['threads'])
    ideal_threads = range(1, max_threads + 1)
    plt.plot(ideal_threads, ideal_threads, '--k', alpha=0.5, label='Ideal␣
↪Speedup')

    plt.xlabel('Number of Threads')
    plt.ylabel('Speedup vs 1 Thread')
    plt.title(f'Speedup Analysis - {operation.upper()}')
    plt.legend()
    plt.grid(True, alpha=0.3)

    plt.tight_layout()

    # Save plot
    os.makedirs(output_dir, exist_ok=True)
    plt.savefig(f"{output_dir}/{operation}_parallel_analysis.png", dpi=300,␣
↪bbox_inches='tight')
    plt.show()
```

[24]:
```
def create_summary_heatmap(data: Dict[str, pd.DataFrame], output_dir: str):
    """Create a summary heatmap showing relative performance"""

    # Collect all performance data
    summary_data = []

    for filename, df in data.items():
        if 'parallel' in filename:
            continue
```

```
        df = parse_test_cases(df, filename)  # Fixed: added filename parameter
        operation = filename.split('-')[0]  # e.g., "overlap-single_1000" ->␣
↪"overlap"

        # Use clean tool names - no grouping needed since each test is run once
        tool_col = 'tool_clean' if 'tool_clean' in df.columns else 'tool'

        for _, row in df.iterrows():
            summary_data.append({
                'operation': operation,
                'tool': row[tool_col],
                'data_size': row['data_size'],
                'execution_time': row['execution_time']
            })

    if not summary_data:
        print("No data available for summary heatmap")
        return

    summary_df = pd.DataFrame(summary_data)

    # Calculate relative performance (polars-bio as baseline)
    relative_performance = []

    for operation in summary_df['operation'].unique():
        for data_size in summary_df['data_size'].unique():
            subset = summary_df[
                (summary_df['operation'] == operation) &
                (summary_df['data_size'] == data_size)
            ]

            if subset.empty:
                continue

            polars_time = subset[subset['tool'] ==␣
↪'polars_bio']['execution_time']

            if polars_time.empty:
                continue

            polars_time = polars_time.iloc[0]

            for _, row in subset.iterrows():
                # Invert the calculation: polars_time / tool_time
                # Values < 1 mean the tool is slower than polars-bio
                # Values > 1 mean the tool is faster than polars-bio
```

```
                relative_perf = polars_time / row['execution_time']
                relative_performance.append({
                    'operation': operation,
                    'tool': row['tool'],
                    'data_size': row['data_size'],
                    'relative_performance': relative_perf
                })

    if not relative_performance:
        print("No relative performance data available")
        return

    rel_df = pd.DataFrame(relative_performance)

    # Create pivot table for heatmap
    pivot_table = rel_df.pivot_table(
        values='relative_performance',
        index=['operation', 'data_size'],
        columns='tool',
        aggfunc='mean'  # Keep this one since we might have duplicates from␣
↪different files
    )

    plt.figure(figsize=(12, 8))

    # Create custom colormap: red for polars-bio (=1), yellow/orange for slower␣
↪tools (<1), green for faster (>1)
    from matplotlib.colors import LinearSegmentedColormap
    colors = ['#FFEB3B', '#FFC107', '#FF5722', '#4CAF50']  # Yellow -> Orange␣
↪-> Red -> Green
    n_bins = 100
    custom_cmap = LinearSegmentedColormap.from_list('custom', colors, N=n_bins)

    sns.heatmap(pivot_table, annot=True, fmt='.2f', cmap=custom_cmap,
                center=1, vmin=0, vmax=2,
                cbar_kws={'label': 'Relative Performance (1.0 = polars-bio␣
↪baseline, >1 = faster, <1 = slower)'})
    plt.title('Performance Heatmap - Relative to Polars-bio')
    plt.ylabel('Operation and Data Size')
    plt.xlabel('Tool')
    plt.tight_layout()

    # Save plot
    os.makedirs(output_dir, exist_ok=True)
    plt.savefig(f"{output_dir}/performance_heatmap.png", dpi=300,␣
↪bbox_inches='tight')
    plt.show()
```

[25]:
```python
def run_complete_analysis(results_dir: str, output_dir: str):
    """Run complete performance analysis"""

    print("Loading data...")
    data = load_csv_files(results_dir)

    if not data:
        print("No CSV files found in results directory!")
        return

    # Identify operations
    operations = set()
    for filename in data.keys():
        # Extract operation name (e.g., "overlap-single_1000" -> "overlap")
        operation = filename.split('-')[0]
        operations.add(operation)

    print(f"Found operations: {operations}")

    # Create comparison plots for each operation
    print("\nCreating comparison plots...")
    for operation in operations:
        print(f"Processing operation: {operation}")
        create_operation_comparison_plot(data, operation, output_dir)
        create_parallel_analysis_plot(data, operation, output_dir)

    # Create summary heatmap
    print("\nCreating performance heatmap...")
    create_summary_heatmap(data, output_dir)

    print(f"\nAnalysis complete! Plots saved in: {output_dir}")
```

1.1 Configuration and Execution

Set the paths to your results directory and where you want to save the plots, then run the complete analysis.

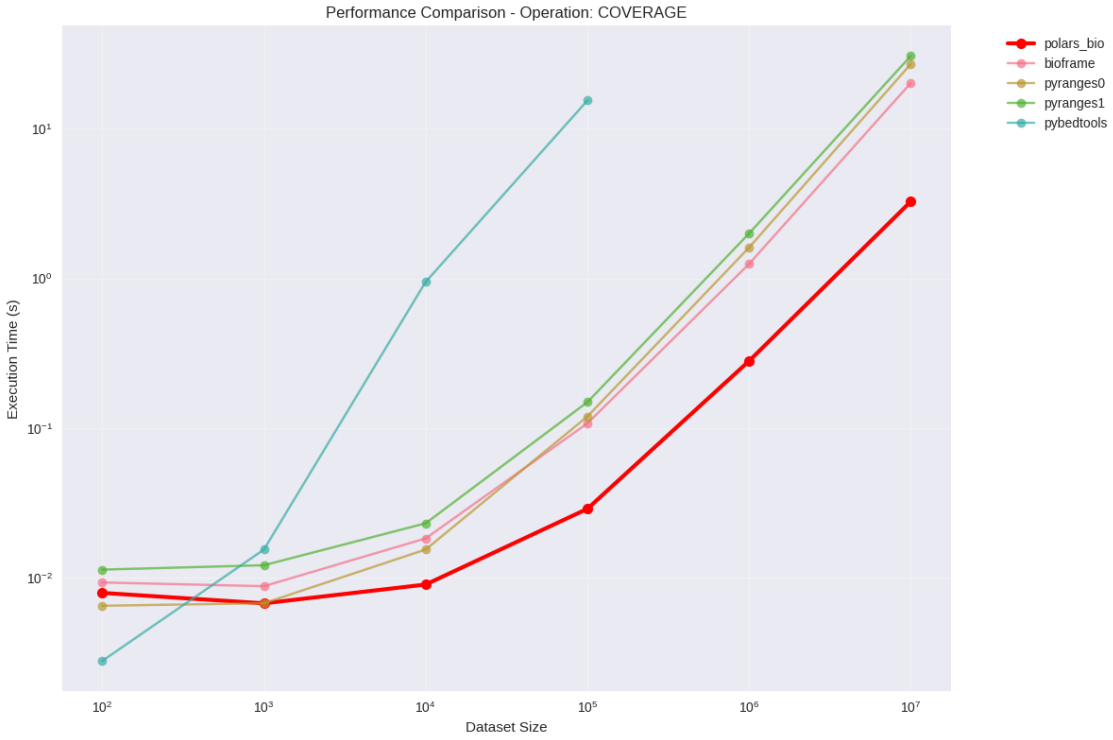
[26]:
```python
# Clear any previously loaded data
if 'data' in locals():
    del data
    print("Cleared previous data from memory")

# Set your data directory
results_directory = "/home/tgambin/workspace/polars-bio-bench/results/
 ↪2025-06-17 22:13:41/"
output_directory = "performance_plots"
```

```
# Load fresh data
print("Loading fresh data...")
data = load_csv_files(results_directory)

# Test with overlap-parallel files specifically
overlap_parallel_files = {}
for k, v in data.items():
    if '-parallel' in k:
        # Extract operation name before '-parallel'
        file_operation = k.split('-parallel')[0]
        if file_operation == 'overlap':
            overlap_parallel_files[k] = v

print(f"\nFound overlap-parallel files: {list(overlap_parallel_files.keys())}")

# Test with count_overlaps-parallel files
count_overlaps_parallel_files = {}
for k, v in data.items():
    if '-parallel' in k:
        # Extract operation name before '-parallel'
        file_operation = k.split('-parallel')[0]
        if file_operation == 'count_overlaps':
            count_overlaps_parallel_files[k] = v

print(f"Found count_overlaps-parallel files:␣
 ↪{list(count_overlaps_parallel_files.keys())}")


run_complete_analysis(results_directory, output_directory)
```

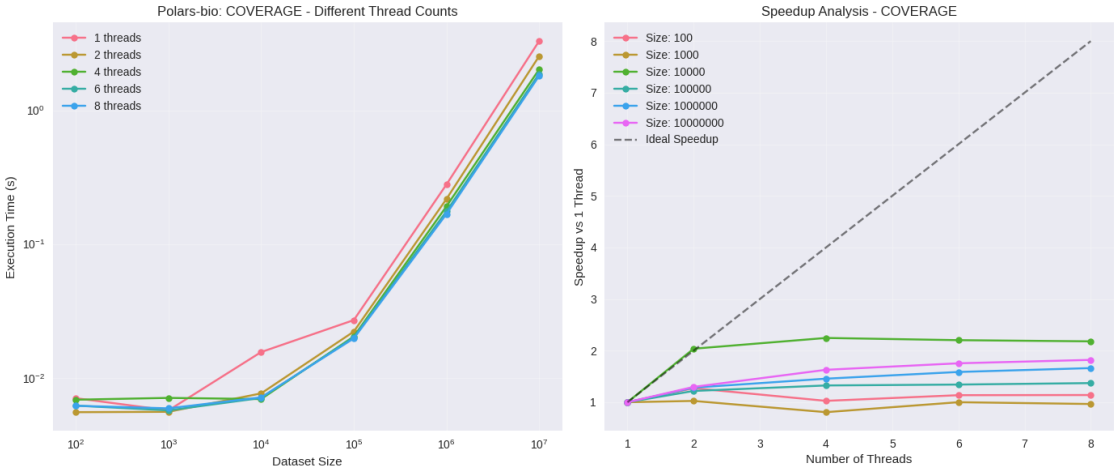
```
Cleared previous data from memory
Loading fresh data…
Loaded: coverage-parallel_1000000 with 5 rows
Loaded: coverage-parallel_100000 with 5 rows
Loaded: overlap-single-small_100 with 7 rows
Loaded: coverage-single-large_1000000 with 4 rows
Loaded: coverage-parallel_10000000 with 5 rows
Loaded: overlap-parallel_10000 with 5 rows
Loaded: count_overlaps-parallel_100 with 5 rows
Loaded: coverage-single-small_100 with 5 rows
Loaded: coverage-parallel_1000 with 5 rows
Loaded: nearest-single-large_10000000 with 4 rows
Loaded: count_overlaps-parallel_100000 with 5 rows
Loaded: coverage-parallel_10000 with 5 rows
Loaded: overlap-single-large_1000000 with 4 rows
Loaded: overlap-single-large_10000000 with 4 rows
Loaded: count_overlaps-parallel_10000000 with 5 rows
```

```
Loaded: coverage-single-large_10000000 with 4 rows
Loaded: nearest-parallel_10000 with 5 rows
Loaded: count_overlaps-single-large_1000000 with 4 rows
Loaded: nearest-parallel_100 with 5 rows
Loaded: nearest-single-small_100 with 5 rows
Loaded: nearest-parallel_100000 with 5 rows
Loaded: coverage-single-small_10000 with 5 rows
Loaded: nearest-single-small_1000 with 5 rows
Loaded: overlap-parallel_10000000 with 5 rows
Loaded: count_overlaps-parallel_1000 with 5 rows
Loaded: overlap-single-small_1000 with 7 rows
Loaded: overlap-parallel_100000 with 5 rows
Loaded: count_overlaps-single-large_10000000 with 4 rows
Loaded: count_overlaps-single-small_100000 with 6 rows
Loaded: nearest-parallel_10000000 with 5 rows
Loaded: overlap-single-small_10000 with 7 rows
Loaded: count_overlaps-parallel_1000000 with 5 rows
Loaded: count_overlaps-single-small_10000 with 6 rows
Loaded: coverage-single-small_1000 with 5 rows
Loaded: coverage-single-small_100000 with 5 rows
Loaded: nearest-parallel_1000 with 5 rows
Loaded: overlap-parallel_100 with 5 rows
Loaded: overlap-parallel_1000000 with 5 rows
Loaded: count_overlaps-parallel_10000 with 5 rows
Loaded: nearest-single-small_10000 with 5 rows
Loaded: nearest-single-small_100000 with 5 rows
Loaded: nearest-single-large_1000000 with 4 rows
Loaded: nearest-parallel_1000000 with 5 rows
Loaded: count_overlaps-single-small_1000 with 6 rows
Loaded: overlap-single-small_100000 with 7 rows
Loaded: overlap-parallel_1000 with 5 rows
Loaded: count_overlaps-single-small_100 with 6 rows
Loaded: coverage-parallel_100 with 5 rows

Found overlap-parallel files: ['overlap-parallel_10000', 'overlap-
parallel_10000000', 'overlap-parallel_100000', 'overlap-parallel_100', 'overlap-
parallel_1000000', 'overlap-parallel_1000']
Found count_overlaps-parallel files: ['count_overlaps-parallel_100',
'count_overlaps-parallel_100000', 'count_overlaps-parallel_10000000',
'count_overlaps-parallel_1000', 'count_overlaps-parallel_1000000',
'count_overlaps-parallel_10000']
Loading data…
Loaded: coverage-parallel_1000000 with 5 rows
Loaded: coverage-parallel_100000 with 5 rows
Loaded: overlap-single-small_100 with 7 rows
Loaded: coverage-single-large_1000000 with 4 rows
Loaded: coverage-parallel_10000000 with 5 rows
Loaded: overlap-parallel_10000 with 5 rows
```

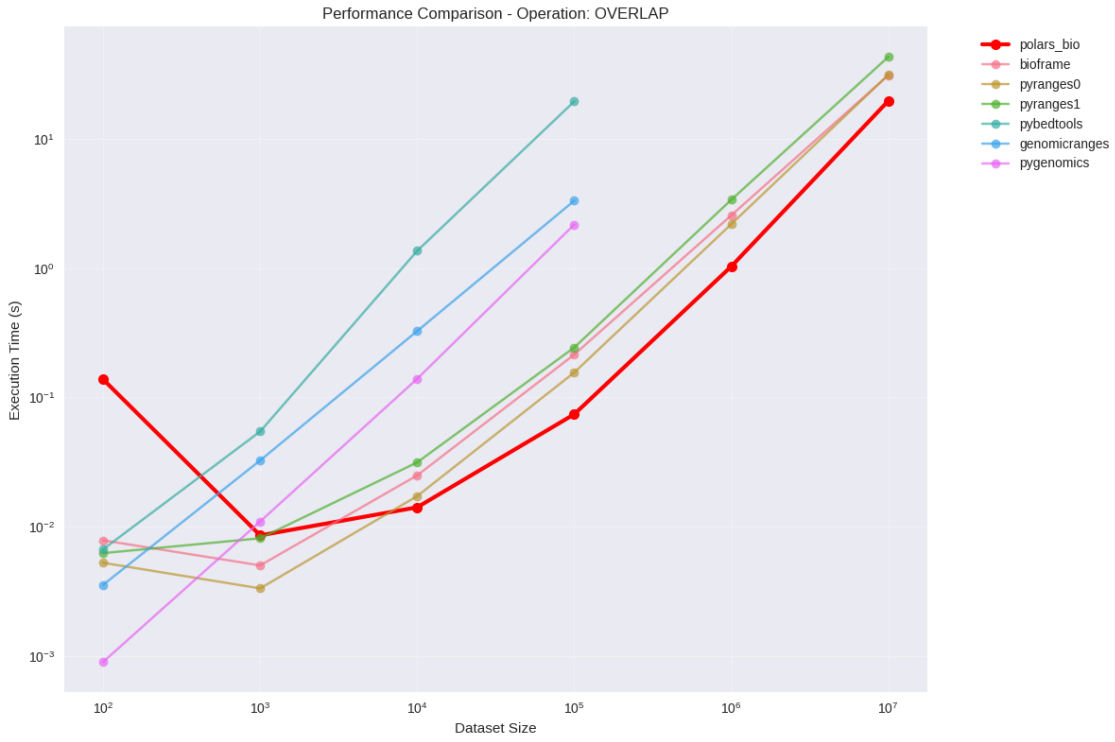
```
Loaded: count_overlaps-parallel_100 with 5 rows
Loaded: coverage-single-small_100 with 5 rows
Loaded: coverage-parallel_1000 with 5 rows
Loaded: nearest-single-large_10000000 with 4 rows
Loaded: count_overlaps-parallel_100000 with 5 rows
Loaded: coverage-parallel_10000 with 5 rows
Loaded: overlap-single-large_1000000 with 4 rows
Loaded: overlap-single-large_10000000 with 4 rows
Loaded: count_overlaps-parallel_10000000 with 5 rows
Loaded: coverage-single-large_10000000 with 4 rows
Loaded: nearest-parallel_10000 with 5 rows
Loaded: count_overlaps-single-large_1000000 with 4 rows
Loaded: nearest-parallel_100 with 5 rows
Loaded: nearest-single-small_100 with 5 rows
Loaded: nearest-parallel_100000 with 5 rows
Loaded: coverage-single-small_10000 with 5 rows
Loaded: nearest-single-small_1000 with 5 rows
Loaded: overlap-parallel_10000000 with 5 rows
Loaded: count_overlaps-parallel_1000 with 5 rows
Loaded: overlap-single-small_1000 with 7 rows
Loaded: overlap-parallel_100000 with 5 rows
Loaded: count_overlaps-single-large_10000000 with 4 rows
Loaded: count_overlaps-single-small_100000 with 6 rows
Loaded: nearest-parallel_10000000 with 5 rows
Loaded: overlap-single-small_10000 with 7 rows
Loaded: count_overlaps-parallel_1000000 with 5 rows
Loaded: count_overlaps-single-small_10000 with 6 rows
Loaded: coverage-single-small_1000 with 5 rows
Loaded: coverage-single-small_100000 with 5 rows
Loaded: nearest-parallel_1000 with 5 rows
Loaded: overlap-parallel_100 with 5 rows
Loaded: overlap-parallel_1000000 with 5 rows
Loaded: count_overlaps-parallel_10000 with 5 rows
Loaded: nearest-single-small_10000 with 5 rows
Loaded: nearest-single-small_100000 with 5 rows
Loaded: nearest-single-large_1000000 with 4 rows
Loaded: nearest-parallel_1000000 with 5 rows
Loaded: count_overlaps-single-small_1000 with 6 rows
Loaded: overlap-single-small_100000 with 7 rows
Loaded: overlap-parallel_1000 with 5 rows
Loaded: count_overlaps-single-small_100 with 6 rows
Loaded: coverage-parallel_100 with 5 rows
Found operations: {'coverage', 'overlap', 'count_overlaps', 'nearest'}

Creating comparison plots…
Processing operation: coverage
```



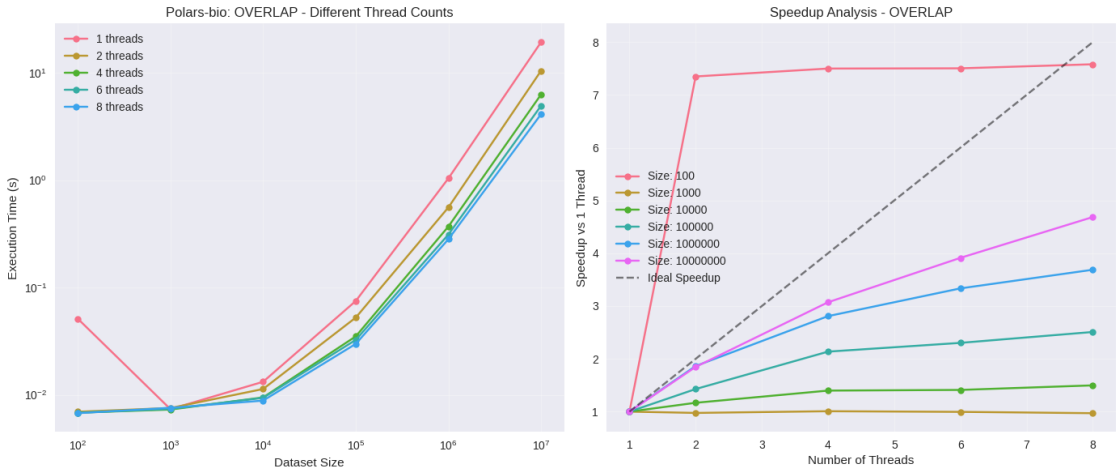

```
Creating parallel analysis plot for operation: coverage
```



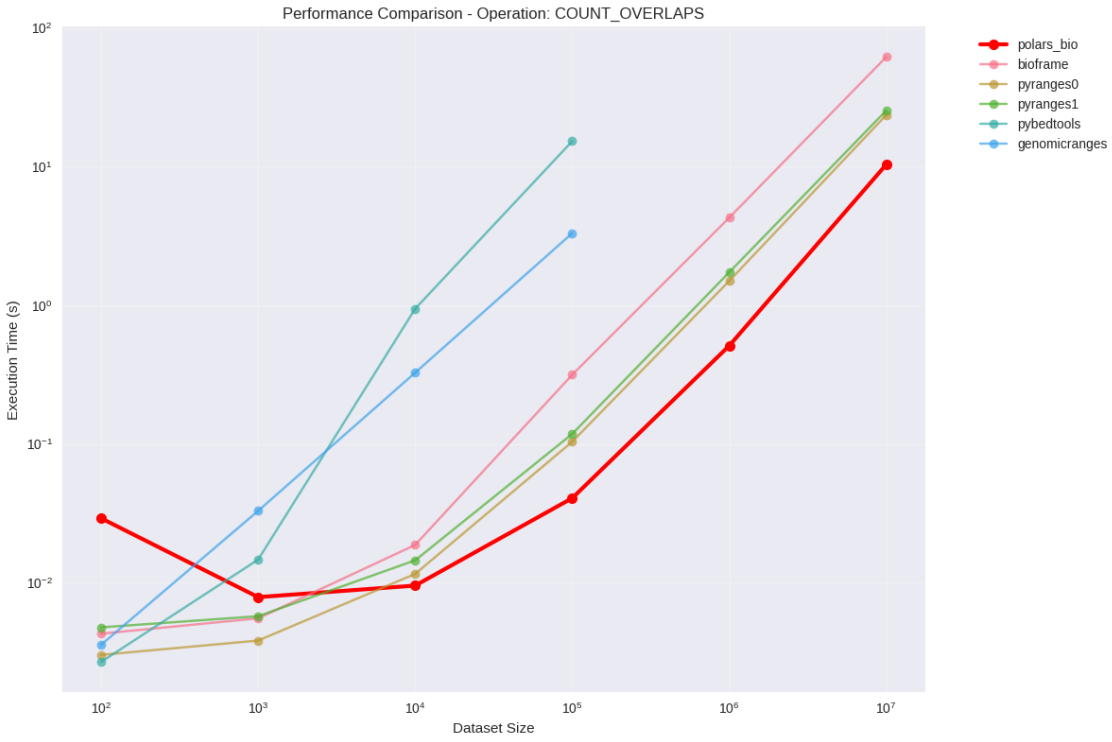

```
Processing operation: overlap
```



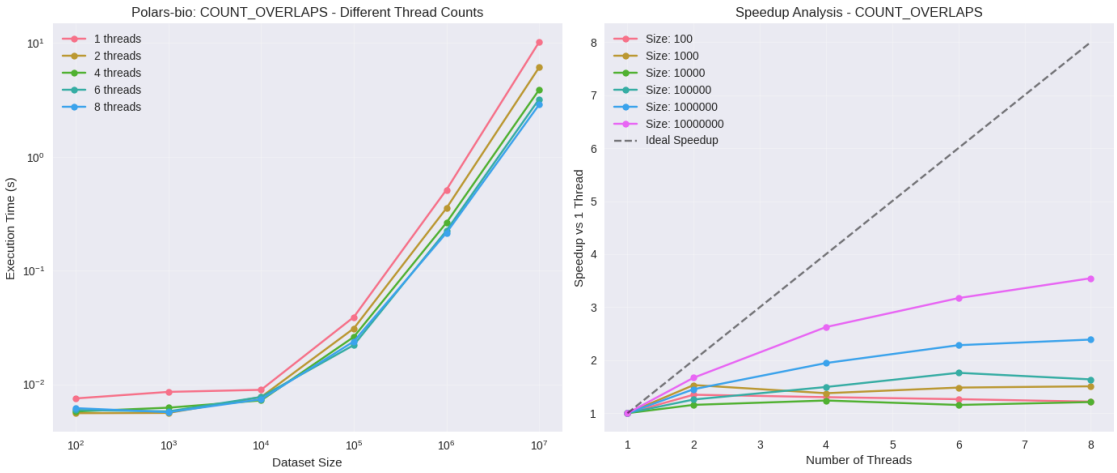

```
Creating parallel analysis plot for operation: overlap
```



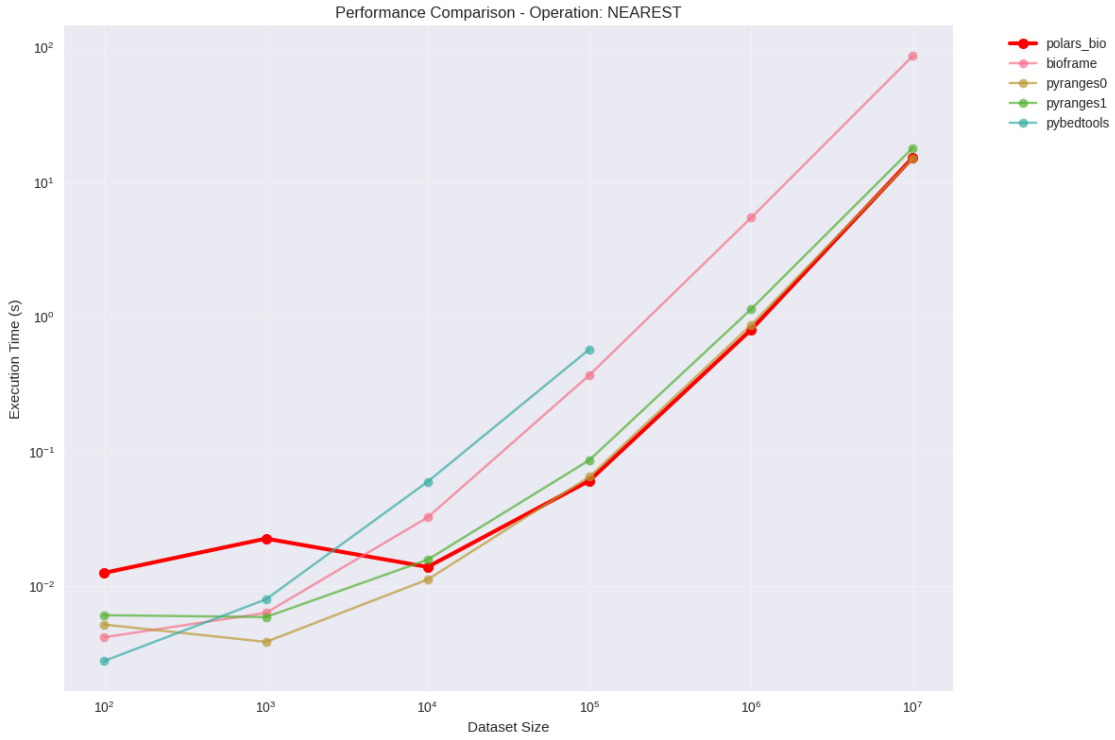

```
Processing operation: count_overlaps
```



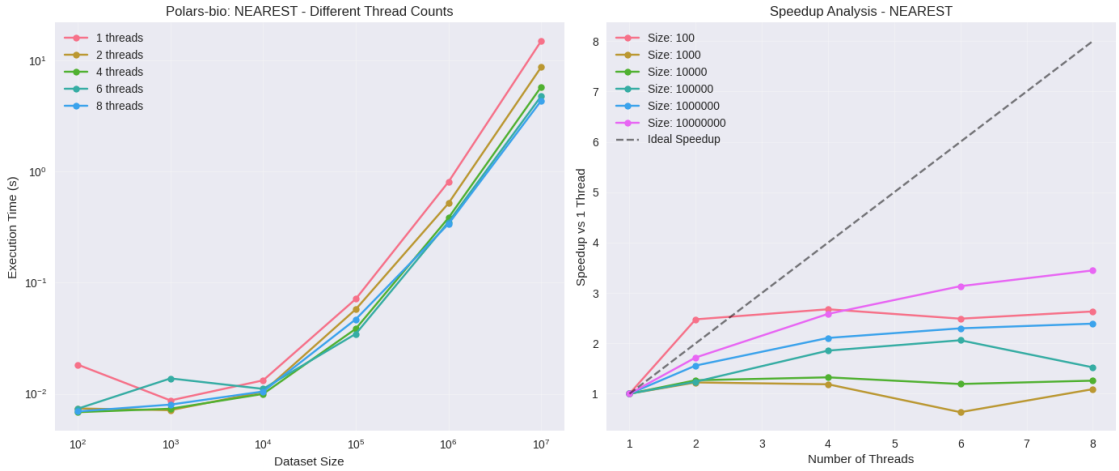

```
Creating parallel analysis plot for operation: count_overlaps
```




```
Processing operation: nearest
```




```
Creating parallel analysis plot for operation: nearest
```




```
Creating performance heatmap...
```


```
Analysis complete! Plots saved in: performance_plots
```

1.2 Individual Analysis Functions

You can also run individual analysis functions if you want to focus on specific aspects:

[27]:
```
# Load data first
data = load_csv_files(results_directory)

# Example: Create comparison plot for 'overlap' operation only
# create_operation_comparison_plot(data, 'overlap', output_directory)

# Example: Create parallel analysis for 'nearest' operation only
# create_parallel_analysis_plot(data, 'nearest', output_directory)

# Example: Create only the summary heatmap
# create_summary_heatmap(data, output_directory)

print("Individual analysis functions are ready to use!")
```

```
Loaded: coverage-parallel_1000000 with 5 rows
Loaded: coverage-parallel_100000 with 5 rows
```

```
Loaded: overlap-single-small_100 with 7 rows
Loaded: coverage-single-large_1000000 with 4 rows
Loaded: coverage-parallel_10000000 with 5 rows
Loaded: overlap-parallel_10000 with 5 rows
Loaded: count_overlaps-parallel_100 with 5 rows
Loaded: coverage-single-small_100 with 5 rows
Loaded: coverage-parallel_1000 with 5 rows
Loaded: nearest-single-large_10000000 with 4 rows
Loaded: count_overlaps-parallel_100000 with 5 rows
Loaded: coverage-parallel_10000 with 5 rows
Loaded: overlap-single-large_1000000 with 4 rows
Loaded: overlap-single-large_10000000 with 4 rows
Loaded: count_overlaps-parallel_10000000 with 5 rows
Loaded: coverage-single-large_10000000 with 4 rows
Loaded: nearest-parallel_10000 with 5 rows
Loaded: count_overlaps-single-large_1000000 with 4 rows
Loaded: nearest-parallel_100 with 5 rows
Loaded: nearest-single-small_100 with 5 rows
Loaded: nearest-parallel_100000 with 5 rows
Loaded: coverage-single-small_10000 with 5 rows
Loaded: nearest-single-small_1000 with 5 rows
Loaded: overlap-parallel_10000000 with 5 rows
Loaded: count_overlaps-parallel_1000 with 5 rows
Loaded: overlap-single-small_1000 with 7 rows
Loaded: overlap-parallel_100000 with 5 rows
Loaded: count_overlaps-single-large_10000000 with 4 rows
Loaded: count_overlaps-single-small_100000 with 6 rows
Loaded: nearest-parallel_10000000 with 5 rows
Loaded: overlap-single-small_10000 with 7 rows
Loaded: count_overlaps-parallel_1000000 with 5 rows
Loaded: count_overlaps-single-small_10000 with 6 rows
Loaded: coverage-single-small_1000 with 5 rows
Loaded: coverage-single-small_100000 with 5 rows
Loaded: nearest-parallel_1000 with 5 rows
Loaded: overlap-parallel_100 with 5 rows
Loaded: overlap-parallel_1000000 with 5 rows
Loaded: count_overlaps-parallel_10000 with 5 rows
Loaded: nearest-single-small_10000 with 5 rows
Loaded: nearest-single-small_100000 with 5 rows
Loaded: nearest-single-large_1000000 with 4 rows
Loaded: nearest-parallel_1000000 with 5 rows
Loaded: count_overlaps-single-small_1000 with 6 rows
Loaded: overlap-single-small_100000 with 7 rows
Loaded: overlap-parallel_1000 with 5 rows
Loaded: count_overlaps-single-small_100 with 6 rows
Loaded: coverage-parallel_100 with 5 rows
Individual analysis functions are ready to use!
```

1.3 Data Exploration

Explore the loaded data to understand its structure:

[28]:
```
# Explore the loaded data
if 'data' in locals():
    print("Available datasets:")
    for filename, df in data.items():
        print(f"\n{filename}:")
        print(f"  Shape: {df.shape}")
        print(f"  Columns: {list(df.columns)}")
        if not df.empty:
            print(f"  Tools: {df['tool'].unique() if 'tool' in df.columns else␣
 ↪'N/A'}")
            print(f"  Test cases: {df['test_case'].unique() if 'test_case' in␣
 ↪df.columns else 'N/A'}")
else:
    print("Data not loaded yet. Run the analysis cell first.")
```

```
Available datasets:

coverage-parallel_1000000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

coverage-parallel_100000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

overlap-single-small_100:
  Shape: (7, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

coverage-single-large_1000000:
  Shape: (4, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

coverage-parallel_10000000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
```

```
  Tools: N/A
  Test cases: N/A

overlap-parallel_10000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

count_overlaps-parallel_100:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

coverage-single-small_100:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

coverage-parallel_1000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

nearest-single-large_10000000:
  Shape: (4, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

count_overlaps-parallel_100000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

coverage-parallel_10000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

overlap-single-large_1000000:
  Shape: (4, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
```

```
  Tools: N/A
  Test cases: N/A

overlap-single-large_10000000:
  Shape: (4, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

count_overlaps-parallel_10000000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

coverage-single-large_10000000:
  Shape: (4, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

nearest-parallel_10000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

count_overlaps-single-large_1000000:
  Shape: (4, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

nearest-parallel_100:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

nearest-single-small_100:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

nearest-parallel_100000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
```

```
  Tools: N/A
  Test cases: N/A

coverage-single-small_10000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

nearest-single-small_1000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

overlap-parallel_10000000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

count_overlaps-parallel_1000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

overlap-single-small_1000:
  Shape: (7, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

overlap-parallel_100000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

count_overlaps-single-large_10000000:
  Shape: (4, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

count_overlaps-single-small_100000:
  Shape: (6, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
```

```
  Tools: N/A
  Test cases: N/A

nearest-parallel_10000000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

overlap-single-small_10000:
  Shape: (7, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

count_overlaps-parallel_1000000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

count_overlaps-single-small_10000:
  Shape: (6, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

coverage-single-small_1000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

coverage-single-small_100000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

nearest-parallel_1000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

overlap-parallel_100:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
```

```
  Tools: N/A
  Test cases: N/A

overlap-parallel_1000000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

count_overlaps-parallel_10000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

nearest-single-small_10000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

nearest-single-small_100000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

nearest-single-large_1000000:
  Shape: (4, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

nearest-parallel_1000000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

count_overlaps-single-small_1000:
  Shape: (6, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

overlap-single-small_100000:
  Shape: (7, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
```

```
  Tools: N/A
  Test cases: N/A

overlap-parallel_1000:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

count_overlaps-single-small_100:
  Shape: (6, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A

coverage-parallel_100:
  Shape: (5, 5)
  Columns: ['Library', 'Min (s)', 'Max (s)', 'Mean (s)', 'Speedup']
  Tools: N/A
  Test cases: N/A
```