ME5470 : Introduction to Parallel Scientific Computing

HOMEWORK 1 Report

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1.

Explanation:

1. Input Reading: The program reads the matrix size n from the file input.in.
2. Dynamic Allocation: A 2D array of size n×n is dynamically allocated using malloc.
3. Array Filling: Each element of the array is filled using the formula A[i][j]= i+j
4. File Writing: The function print_to_file writes the array to either an ASCII or binary file based on the format_flag.
   - For ASCII, the data is written using fprintf with 15-decimal precision.
   - For binary, the data is written using fwrite.
5. Filename Generation: The filename includes a zero-padded representation of n.
6. Memory Deallocation: Allocated memory is freed after use.

After compiling we use commands

du -sh array_004000_asc.out

du -sh array_004000_bin.out

output is

123M array_004000_bin.out

320M array_004000_asc.out

1. Binary File (array_004000_bin.out):
   - Size: 123 MB
   - Reason: Each element in the 4000 × 4000 array is a double (8 bytes). The size calculation is: 4000×4000 × 8=128,000,000 bytes (approx. 123 MB).
   - This matches the observed size of the binary file.
2. ASCII File (array_004000_asc.out):
   - Size: 320 MB

- Reason: Each double is stored as a human-readable number with 15 decimal places. On average, a number like 12345.678901234567 takes approximately 20 bytes (including spaces or newline characters). The size calculation is: $4000 \times 4000 \times 20 = 320{,}000{,}000$ bytes (approx. 320 MB).
- This aligns with the observed size of the ASCII file.

Memory Size of the Array:

- In Memory:
  - The array is stored as raw double values in memory, so the size is: $4000 \times 4000 \times 8 = 128{,}000{,}000$ bytes (128 MB).

Comments on File Sizes:

1. Binary Format:
   - Much smaller on disk since it directly stores raw data without extra characters for formatting.
   - Faster to write and read, but not human-readable.
2. ASCII Format:
   - Larger due to extra characters (spaces, newline) and conversion of binary data to human-readable form.
   - Slower to write and read but easier for debugging and manual inspection.

2.

The program implements an algorithm to verify eigenvectors of a n×n matrix and find their corresponding eigenvalues. Here's the analysis:

Program Structure and Implementation:

- The program reads a n×n matrix and multiple test vectors from separate input files

- Uses a numerical approach with epsilon tolerance (1e-6) for floating-point comparisons

- Implements efficient matrix-vector multiplication and eigenvector verification

Test Results for n = 3:

1. Vector [1, 1, 1]:

   - Result: Not an eigenvector

- Verification: Av = [3, 4, 3] which is not a scalar multiple of v

2. Vector [1, 0, -1]:
   - Result: Is an eigenvector
   - Eigenvalue: 2.000000
   - Verification: Av = [2, 0, -2] = 2[1, 0, -1]

3. Vector [1, 2, 1]:
   - Result: Not an eigenvector
   - Verification: Av = [4, 6, 4] is not a scalar multiple of v

Key Mathematical Findings:

- The matrix has at least one eigenvector [1, 0, -1] with eigenvalue 2
- The symmetric nature of the matrix guarantees all eigenvalues are real
- The program successfully distinguishes between true eigenvectors and non-eigenvectors

Test Results for n=5

1. Vector [1, 0, 0, 0, 0] (vec000005_1.in):
   - Result: Is an eigenvector
   - Eigenvalue: 2.000000
   - Verification:
     A × v = [2,0,0,0,0], which is 2 × [1,0,0,0,0]
2. Vector [0, 1, 0, 0, 0] (vec000005_2.in):
   - Result: Is an eigenvector
   - Eigenvalue: 3.000000
   - Verification:
     A × v = [0,3,0,0,0], which is 3 × [0,1,0,0,0]
3. Vector [1, 1, 1, 1, 1] (vec000005_3.in):
   - Result: Not an eigenvector
   - Verification:
     A × v = [2,3,4,5,6], which is not a scalar multiple of [1,1,1,1,1]

4. Vector [1, 0, 1, 0, 1] (vec000005_4.in):

- Result: Not an eigenvector
- Verification:
  A × v=[2,0,4,0,6], which is not a scalar multiple of [1,0,1,0,1]

Key Mathematical Findings:

- The matrix has eigenvectors with eigenvalues 2 and 3.
- The vectors [1, 0, 0, 0, 0] and [0, 1, 0, 0, 0] are confirmed eigenvectors with corresponding eigenvalues 2 and 3, respectively.
- The vectors [1, 1, 1, 1, 1] and [1, 0, 1, 0, 1] do not satisfy the eigenvector conditions, as their matrix products are not scalar multiples of the original vectors.

File Handling:

- Successfully processes sequential vector files

- Appends eigenvalues to vector files when eigenvectors are identified

- Handles file I/O errors appropriately

The program demonstrates robust numerical computation and accurate eigenvector verification for the given n×n matrix case.