Tony Maldonado
CS 471
September 28, 2020

Programming #4 – Comparing Interpreted and Compiled Codes

GaussWithNumpy.py

```
# Name: Tony Maldonado
# Date: September 27, 2020
#
# Description: This program is an implementation of
#       the Gaussian Elimination algorithm in Python
#       using the Numpy module.
#
# Input: A number n for the size of the matrix
#
# Output: The time t for which it took to compute
#       the matrix elimination
#
# Preconditions: The input (for matrix size) must be a
#       positive integer
#
# Postconditions: None.
#
# Source code: https://learnche.org/3E4/Assignment_2_-_2010_-
_Solution/Bonus_question

import numpy as np
import random
import time

def main():

    n = input("Enter a positive integer n for matrix size: ")
    n = int(n)

    # Fill matrix with random numbers
    A = np.random.rand(n,n)
    b = np.random.rand(n)

    print('')
    print("Starting Gaussian Elimination on matrix..")
    print("Starting timer...")
    # Start timer; BEFORE Gaussian Elimination
    start = time.time()
    # Run Gaussian Elimination on matrix
    x = np.linalg.solve(A,b)

    print("Stopping timer...")
    print('')

    # Stop the timer
    end = time.time()

    # Output the time solution took
    print('Time it took to run was: ', end - start, 'seconds.')
    print('')

if __name__ == '__main__':
    main()
```

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GaussNoNumpy.py

```
# Name: Tony Maldonado
# Date: September 27, 2020
#
# Description: This program is a modification of the
#       implementation of the Gaussian Elimination
#       algorithm in Python, /without/ using the Numpy module.
#
# Note: This program uses a no pivoting method.
#
# Input: A number n for the size of the matrix
#
# Output: The time t for which it took to compute
#       the matrix elimination
#
# Preconditions: The input (for matrix size) must be a
#       positive integer
#
# Postconditions: None.
#
# Source code: https://learnche.org/3E4/Assignment_2_-_2010_-_Solution/Bonus_question


import random
import time

# Calculates the forward part of Gaussian Elimination
def forward_elimination (A, b, n):

    for row in range(0, n-1):
        for i in range(row + 1, n):

            factor = A[i][row]/A[row][row]
            for j in range(row, n):
                A[i][j] = A[i][j] - factor * A[row][j]

            b[i] = b[i] - factor * b[row]

    return A, b

# Calculates the back substitution part of Gaussian Elimination
def back_substitution(a, b, n):
    x = [[0. for i in range(n)] for k in range(n)]
    x[n-1] = b[n-1] / a[n-1][n-1]

    for row in range (n-2, -1, -1):
        sums = b[row]
        for j in range(row + 1, n):
            sums = sums - a[row][j] * x[j]

        x[row] = sums / a[row][row]

    return x

# Calculates the Gaussian Elimination without pivoting
def gauss(A,b,n):

    A, b = forward_elimination(A,b,n)
    return back_substitution(A,b,n)

def main():

    n = input("Enter a positive integer n for matrix size: ")
    n = int(n)
    A = []

    # Fill matrix with random numbers
    for i in range(n):
        b = []
        for j in range(n):
            b.append(random.random())

        A.append(b)

    print('')
    print("Starting Gaussian Elimination on matrix..")
    print("Starting timer...")

    # Start timer
    start = time.time()

    gauss(A,b,n) #solving

    print("Stopping timer...")
    print('')
    # Stop the timer
    end = time.time()

    # Output the time solution took
    print('Time it took to run was: ', end - start, 'seconds.')
    print('')

if __name__ == '__main__':
    main()
```

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GaussFortan.f90

```
! Name: Tony Maldonado
! Date: September 27, 2020
!
! Description: This program is an implementation of
!       the Gaussian Elimination algorithm in Fortran.
!
! Input: A number n for the size of the matrix
!
! Output: The time t for which it took to compute
!       the matrix elimination
!
! Preconditions: The input (for matrix size) must be a
!       positive integer
!
! Postconditions: None.
!
! Source code: https://labmathdu.wordpress.com/gaussian-elimination-without-pivoting/

program gauss
   IMPLICIT NONE

   REAL:: start, finish !time vars

   INTEGER::i,j,n !loop vars

   REAL::s
   REAL,allocatable,DIMENSION(:,:)::a !Allocating space
   REAL,allocatable,DIMENSION(:)::x !Allocating space

   PRINT  '("Enter a positive integer n for matrix size: ")'

   READ *, n !Reading in matrix size

   allocate(a(n,n+1)) !Allocating space
   allocate(x(n)) !Allocating space


   CALL RANDOM_NUMBER(a) !Filling matrix
   CALL RANDOM_NUMBER(x) !Filling matrix

   CALL cpu_time(start) !Starting timer
```

```
    do j=1,n !Calculations
        do i=j+1,n
            a(i,:)=a(i,:)-a(j,:)*a(i,j)/a(j,j)
        end do
    end do

    do i=n,1,-1 !Calculation part 2
        s=a(i,n+1)
        do j=i+1,n
            s=s-a(i,j)*x(j)
        end do
        x(i)=s/a(i,i)
    end do

    CALL cpu_time(finish) !stopping timer

    print '("Time to run is ",f6.3," seconds.")',finish-start !printing formatted time

end program gauss
```

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Tables:

All times are in milliseconds.

Fortran	250	500	1000	1500	2000
	16.00	154.00	1,266.00	7,026.00	16,719.00
	16.00	154.00	1,276.00	7,040.00	16,680.00
	15.00	154.00	1,272.00	7,033.00	12,632.00
	16.00	154.00	1,269.00	7,070.00	11,808.00
	16.00	154.00	1,265.00	7,101.00	16,793.00
AVG	15.80	154.00	1,269.60	7,054.00	14,926.40
STDEV	0.45	-	4.51	31.17	2,488.04

Python No Numpy	250	500	1000	1500	2000
	488.55	3,928.63	34,122.69	194,762.08	663,206.39
	489.17	3,863.75	37,016.80	205,631.85	481,076.08
	487.78	3,918.82	38,749.51	216,648.38	517,794.55
	486.95	3,942.84	39,152.58	215,641.46	522,325.99
	494.98	3,979.33	37,893.88	215,271.96	669,401.51
AVG	489.49	3,926.67	37,387.09	209,591.14	570,760.90
STDEV	3.18	42.01	2,001.46	9,410.89	88,700.17

Python With Numpy	250	500	1000	1500	2000
	6.20	41.16	248.51	819.87	1,904.80
	6.30	41.37	252.08	845.85	1,920.52
	7.97	41.26	252.38	813.08	1,913.84
	6.68	42.72	250.01	814.51	1,913.90
	7.12	44.34	252.58	811.66	1,941.14
AVG	6.85	42.17	251.11	820.99	1,918.84
STDEV	0.72	1.37	1.78	14.24	13.66

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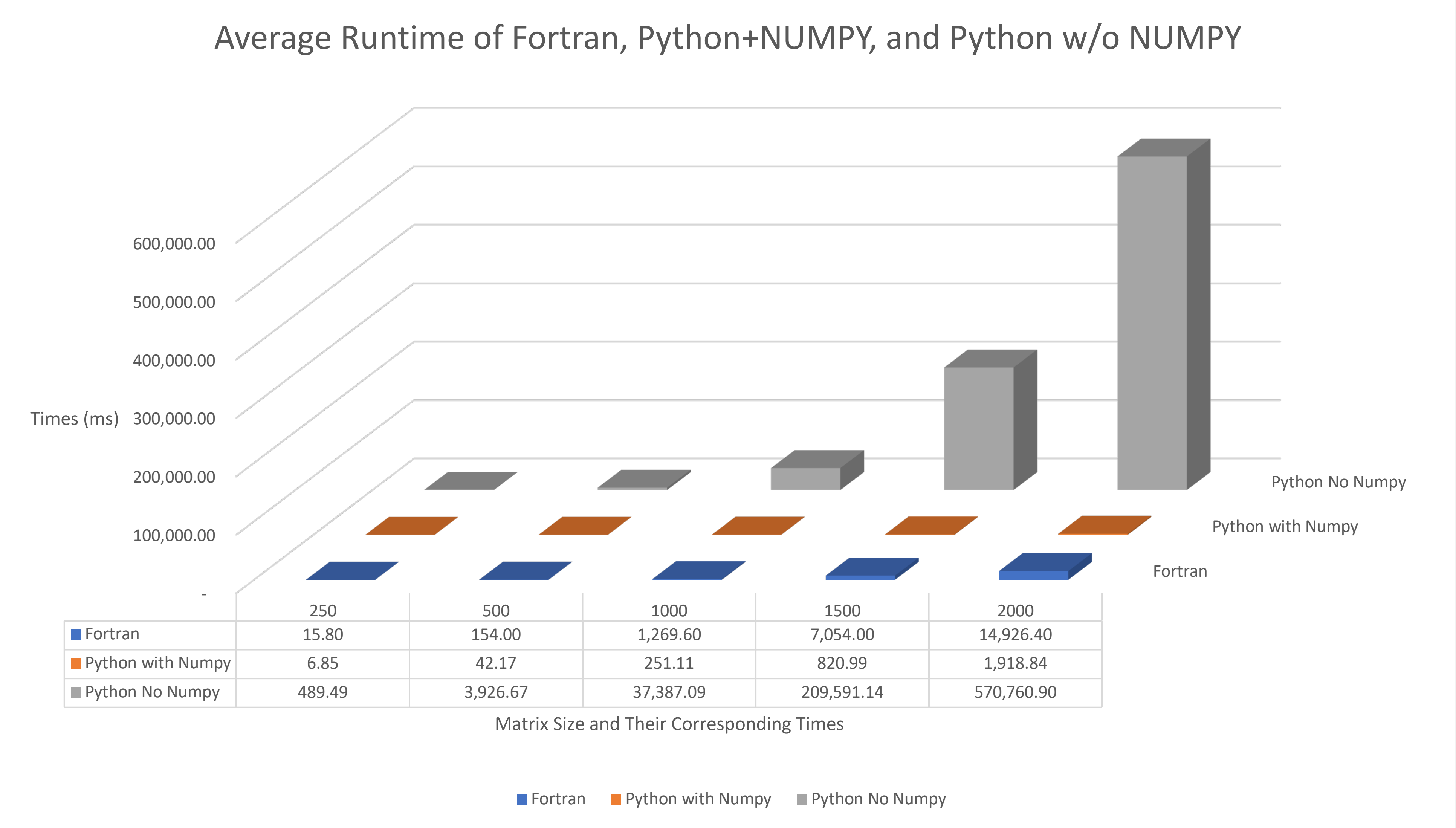
Comparison Graph:



Average Runtime of Fortran, Python+NUMPY, and Python w/o NUMPY

	250	500	1000	1500	2000
Fortran	15.80	154.00	1,269.60	7,054.00	14,926.40
Python with Numpy	6.85	42.17	251.11	820.99	1,918.84
Python No Numpy	489.49	3,926.67	37,387.09	209,591.14	570,760.90

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Comparison and Summary:

- When looking at the data, and especially the data represented in a 3D bar graph, it is clear which implementations run faster than the others. After a quick analysis, it is very clear that the fastest implementation of the Gaussian Elimination is using Python and NUMPY. While the slowest was Python without NUMPY. Fortran came in at a close second after Python with NUMPY, with promising results. In conclusion, when implementing a Gaussian Elimination, it is much wiser and easier to use Python with the NUMPY module imported.