

CED17I021_ProblemSet7

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1 ASBD PRACTICE - PROBLEM SET 7 - MapReduce & SPARK

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```
[2]: !!apt-get update
!apt-get install openjdk-8-jdk-headless -qq > /dev/null
!wget -q https://downloads.apache.org/spark/spark-3.1.1/spark-3.1.1-bin-hadoop2.
→7.tgz
!tar xf spark-3.1.1-bin-hadoop2.7.tgz
!pip install -q findspark
```

```
[3]: import os
os.environ["JAVA_HOME"] = "/usr/lib/jvm/java-8-openjdk-amd64"
os.environ["SPARK_HOME"] = "/content/spark-3.1.1-bin-hadoop2.7"

import findspark
findspark.init()
from pyspark.context import SparkContext
sc = SparkContext('local')
```

1.0.1 Problem 1

For the given input file, calculate Wordcount using Hadoop MapReduce and Spark. Also, develop an equivalent conventional program (without spark RDDs) and compare the time taken by the two versions.

```
[4]: text_file = sc.textFile("WordCount_input.txt")
counts = text_file.flatMap(lambda line: line.split(" ")) \
    .map(lambda word: (word, 1)) \
    .reduceByKey(lambda a, b: a + b)
#counts.saveAsTextFile("hdfs://...")
output = counts.collect()
for (word, count) in output:
    print("%s: %i" % (word, count))
```

Lincoln's: 1

First: 1

Inaugural: 1

Address: 1
March: 1
4,: 1
1861: 1
: 119
Fellow: 1
citizens: 5
of: 145
the: 240
United: 5
States:: 1
in: 73
compliance: 1
with: 20
a: 53
custom: 1
as: 34
old: 3
government: 10
itself,: 1
I: 42
appear: 1
before: 3
you: 15
to: 130
address: 2
briefly: 1
and: 96
take,: 1
your: 3
presence,: 1
oath: 4
prescribed: 2
by: 40
Constitution: 14
States,: 6
be: 75
taken: 1
President: 2
"before: 1
he: 1
enters: 1
on: 12
execution: 1
his: 6
office.": 1
do: 14
not: 33

consider: 2
it: 31
necessary,: 1
at: 5
present,: 1
for: 24
me: 4
discuss: 1
those: 4
matters: 1
administration: 3
about: 2
which: 16
there: 14
is: 45
no: 29
special: 1
anxiety,: 1
or: 35
excitement.: 1
Apprehension: 1
seems: 2
exist: 2
among: 6
people: 14
Southern: 1
States: 8
that: 54
accession: 1
Republican: 1
their: 14
property: 2
peace: 1
personal: 2
security: 3
are: 20
endangered.: 1
There: 4
has: 6
never: 7
been: 4
any: 28
reasonable: 2
cause: 1
such: 13
apprehension.: 1
Indeed,: 1
most: 4

ample: 1
evidence: 2
contrary: 1
all: 28
while: 10
existed: 1
open: 1
inspection.: 1
It: 9
found: 1
nearly: 3
published: 1
speeches: 2
him: 4
who: 10
now: 14
addresses: 1
you.: 2
but: 15
quote: 1
from: 15
one: 11
when: 3
declare: 1
"I: 1
have: 18
purpose,: 2
directly: 1
indirectly,: 1
interfere: 2
institution: 1
slavery: 4
where: 2
exists.: 1
believe: 1
lawful: 1
right: 7
so,: 2
inclination: 1
so.": 1
Those: 1
nominated: 1
elected: 1
did: 1
so: 15
full: 1
knowledge: 1
had: 3

made: 4
this: 18
many: 3
similar: 1
declarations,: 1
recanted: 1
them.: 5
And,: 2
more: 4
than: 13
this,: 1
they: 13
placed: 1
platform: 1
my: 7
acceptance,: 1
law: 12
themselves: 2
me,: 2
clear: 1
emphatic: 1
resolution: 1
read:: 1
"Resolved:: 1
maintenance: 1
inviolable: 1
rights: 3
especially: 2
each: 5
State: 7
order: 1
control: 1
its: 11
own: 8
domestic: 2
institutions: 2
according: 3
judgment: 2
exclusively,: 1
essential: 1
balance: 1
power: 3
perfection: 1
endurance: 1
our: 13
political: 2
fabric: 1
depend,: 1

we: 7
denounce: 1
lawless: 1
invasion: 1
armed: 1
force: 4
soil: 1
Territory,: 1
matter: 2
under: 7
what: 4
pretext,: 1
gravest: 1
crimes.": 1
reiterate: 1
these: 6
sentiments;: 1
and,: 2
doing: 4
only: 9
press: 1
upon: 15
public: 2
attention: 1
conclusive: 1
case: 4
susceptible,: 1
property,: 1
peace,: 1
section: 4
wise: 2
endangered: 1
incoming: 1
administration.: 2
add,: 1
too,: 1
protection: 1
which,: 1
consistently: 1
laws,: 2
can: 18
given,: 1
will: 23
cheerfully: 2
given: 3
lawfully: 4
demanded,: 1
whatever: 1

cause--: 1
another.: 1
much: 5
controversy: 2
delivering: 1
up: 2
fugitives: 2
service: 4
labor.: 1
The: 15
clause: 5
read: 1
plainly: 4
written: 4
other: 5
provisions:: 1
"No: 1
person: 1
held: 4
labor: 3
State,: 1
laws: 5
thereof,: 1
escaping: 1
into: 3
another,: 1
shall: 15
consequence: 2
regulation: 1
therein: 1
discharged: 1
labor,: 1
delivered: 2
claim: 2
party: 4
whom: 1
may: 12
due.": 1
scarcely: 1
questioned: 1
provision: 6
was: 5
intended: 1
reclaiming: 1
call: 1
fugitive: 2
slaves;: 1
intention: 1

lawgiver: 1
law.: 1
All: 4
members: 1
Congress: 4
swear: 1
support: 1
whole: 4
Constitution--: 1
other.: 3
To: 3
proposition,: 1
then,: 3
slaves: 1
whose: 1
cases: 4
come: 1
within: 2
terms: 3
"shall: 1
up",: 1
oaths: 1
unanimous.: 1
Now,: 1
if: 12
would: 9
make: 6
effort: 1
good: 4
temper,: 1
could: 2
equal: 3
unanimity: 1
frame: 2
pass: 1
means: 1
keep: 1
unanimous: 1
oath?: 1
some: 4
difference: 2
opinion: 1
whether: 1
should: 5
enforced: 2
national: 8
authority;: 1
surely: 3

very: 4
material: 1
one.: 2
If: 7
slave: 1
surrendered,: 2
little: 3
others: 3
authority: 4
done.: 1
And: 4
content: 2
go: 3
unkept: 1
merely: 1
unsubstantial: 1
HOW: 1
kept?: 1
Again,: 2
subject,: 2
ought: 3
safeguards: 1
liberty: 1
known: 1
civilized: 1
humane: 1
jurisprudence: 1
introduced,: 1
free: 2
man: 1
not,: 1
case,: 4
surrendered: 3
slave?: 1
might: 2
well: 2
same: 4
time: 2
provide: 1
enforcement: 1
guarantees: 1
"the: 1
citizen: 2
entitled: 2
privileges: 1
immunities: 1
several: 1
States?": 1

take: 4
official: 2
today: 1
mental: 1
reservations,: 1
purpose: 3
construe: 1
hypercritical: 1
rules.: 1
choose: 1
specify: 1
particular: 3
acts: 3
proper: 2
enforced,: 2
suggest: 1
safer: 1
all,: 2
both: 4
private: 1
stations,: 1
conform: 1
abide: 2
stand: 1
unrepealed,: 1
violate: 2
them,: 2
trusting: 1
find: 2
impunity: 1
having: 4
them: 5
unConstitutional.: 1
seventy-two: 1
years: 2
since: 1
first: 1
inauguration: 1
Constitution.: 2
During: 1
period: 1
fifteen: 1
different: 3
greatly: 1
distinguished: 1
have,: 2
succession,: 1
administered: 1

executive: 1
branch: 1
government.: 2
They: 2
conducted: 1
through: 1
perils,: 1
generally: 1
great: 5
success.: 1
Yet,: 1
scope: 1
precedent,: 1
enter: 1
task: 1
brief: 1
Constitutional: 5
term: 1
four: 2
peculiar: 1
difficulty.: 2
A: 4
disruption: 1
Federal: 3
Union,: 2
heretofore: 1
menaced,: 1
formidably: 1
attempted.: 1
hold: 2
that,: 4
contemplation: 2
universal: 2
Constitution,: 6
Union: 15
perpetual.: 1
Perpetuity: 1
implied,: 1
expressed,: 1
fundamental: 1
governments.: 1
safe: 1
assert: 1
ever: 4
organic: 2
termination.: 1
Continue: 1
execute: 1

express: 3
provisions: 2
National: 1
endure: 1
forever--it: 1
being: 7
impossible: 1
destroy: 3
except: 1
action: 1
provided: 2
instrument: 2
itself.: 4
proper,: 2
an: 4
association: 1
nature: 1
contract: 2
merely,: 1
it,: 6
contract,: 1
peaceably: 1
unmade: 1
less: 1
parties: 3
it?: 4
One: 2
it--break: 1
speak;: 1
does: 4
require: 1
rescind: 1
Descending: 1
general: 1
principles,: 1
proposition: 1
legal: 3
perpetual: 1
confirmed: 1
history: 1
older: 1
formed,: 1
fact,: 1
Articles: 2
Association: 1
1774.: 1
matured: 1
continued: 1

Declaration: 1
Independence: 1
1776.: 1
further: 1
matured,: 1
faith: 2
then: 1
thirteen: 1
expressly: 5
plighted: 1
engaged: 1
perpetual,: 1
Confederation: 1
1778.: 1
finally,: 1
1787: 1
declared: 2
objects: 1
ordaining: 1
establishing: 1
"TO: 1
FORM: 1
MORE: 1
PERFECT: 1
UNION.": 1
But: 3
destruction: 2
part: 1
possible,: 3
LESS: 1
perfect: 3
lost: 2
vital: 4
element: 1
perpetuity.: 1
follows: 1
views: 1
mere: 2
motion: 1
get: 1
out: 2
Union;: 1
Resolves: 1
Ordinances: 1
effect: 3
legally: 1
void;: 1
violence,: 1

against: 2
insurrectionary: 1
revolutionary,: 1
circumstances.: 1
therefore: 1
view: 3
unbroken;: 1
extent: 2
ability: 1
care,: 1
itself: 1
enjoins: 1
faithfully: 2
executed: 1
States.: 1
Doing: 1
deem: 2
simple: 1
duty: 3
part;: 1
perform: 1
far: 3
practicable,: 1
unless: 4
rightful: 2
masters,: 1
American: 2
people,: 3
withhold: 1
requisite: 1
means,: 1
authoritative: 1
manner: 1
direct: 1
contrary.: 1
trust: 1
regarded: 1
menace,: 1
WILL: 1
Constitutionally: 1
defend: 2
maintain: 1
In: 3
needs: 1
bloodshed: 1
violence;: 1
none,: 1
forced: 1

authority.: 1
confided: 1
used: 1
hold,: 1
occupy,: 1
possess: 1
places: 1
belonging: 1
government,: 5
collect: 1
duties: 1
imposts,: 1
beyond: 2
necessary: 1
objects,: 1
invasion,: 1
using: 1
anywhere.: 1
Where: 1
hostility: 1
interior: 1
locality,: 1
prevent: 2
competent: 2
resident: 1
holding: 2
offices,: 2
attempt: 2
obnoxious: 1
strangers: 1
object.: 1
While: 3
strict: 1
enforce: 1
exercise: 2
irritating,: 1
impracticable: 1
withal,: 1
better: 4
forego: 1
uses: 1
offices.: 1
mails,: 1
repelled,: 1
continue: 2
furnished: 1
parts: 2
Union.: 1

So: 1
everywhere: 1
sense: 2
favorable: 1
calm: 1
thought: 1
reflection.: 1
course: 1
here: 1
indicated: 1
followed: 1
current: 1
events: 1
experience: 1
show: 1
modification: 1
change: 2
every: 4
exigency: 1
best: 2
discretion: 1
exercised: 2
circumstances: 1
actually: 1
existing,: 1
hope: 2
peaceful: 1
solution: 1
troubles: 1
restoration: 1
fraternal: 1
sympathies: 1
affections.: 1
That: 1
persons: 2
another: 1
seek: 2
events,: 1
glad: 1
pretext: 1
neither: 1
affirm: 1
nor: 4
deny;: 1
such,: 2
need: 1
word: 1
those,: 1

however,: 2
really: 1
love: 1
speak?: 1
Before: 1
entering: 1
grave: 2
fabric,: 1
benefits,: 1
memories,: 1
hopes,: 1
ascertain: 1
precisely: 3
why: 2
Will: 2
hazard: 1
desperate: 1
step: 2
possibility: 1
portion: 2
ills: 2
fly: 4
real: 2
existence?: 1
you,: 1
certain: 1
greater: 1
ones: 1
from--will: 1
risk: 1
commission: 1
fearful: 1
mistake?: 1
profess: 1
maintained.: 1
Is: 4
true,: 1
right,: 2
denied?: 1
think: 2
not.: 1
Happily: 1
human: 1
mind: 1
constituted: 1
reach: 2
audacity: 1
this.: 3

Think,: 1
can,: 1
single: 2
instance: 1
denied.: 1
numbers: 1
majority: 5
deprive: 1
minority: 4
clearly: 1
might,: 1
moral: 2
point: 1
view,: 1
justify: 1
revolution--certainly: 1
were: 2
case.: 1
minorities: 1
individuals: 1
assured: 1
affirmations: 1
negations,: 1
guaranties: 1
prohibitions,: 1
controversies: 1
arise: 1
concerning: 1
framed: 1
specifically: 1
applicable: 1
question: 1
occur: 1
practical: 1
No: 1
foresight: 1
anticipate,: 1
document: 1
length: 1
contain,: 1
possible: 2
questions.: 1
Shall: 1
authority?: 1
say.: 3
May: 1
prohibit: 1
Territories?: 2

MUST: 1
protect: 1
From: 1
questions: 4
class: 1
spring: 1
constitutional: 2
controversies,: 1
divide: 2
majorities: 1
minorities.: 1
acquiesce,: 2
must,: 1
must: 6
cease.: 1
alternative;: 1
continuing: 1
acquiescence: 1
side: 3
secede: 4
rather: 2
precedent: 2
turn: 2
ruin: 1
them;: 1
whenever: 1
refuses: 1
controlled: 1
minority.: 1
For: 1
instance,: 1
new: 3
confederacy: 1
year: 1
two: 1
hence: 1
arbitrarily: 1
again,: 1
portions: 1
present: 4
cherish: 1
disunion: 1
sentiments: 1
educated: 1
exact: 1
temper: 1
identity: 1
interests: 1

compose: 1
produce: 1
harmony: 1
only,: 1
renewed: 1
secession?: 1
Plainly,: 1
central: 1
idea: 1
secession: 1
essence: 1
anarchy.: 1
restraint: 1
checks: 1
limitations,: 1
always: 1
changing: 1
easily: 1
deliberate: 1
changes: 1
popular: 1
opinions: 1
sentiments,: 1
true: 1
sovereign: 1
people.: 2
Whoever: 1
rejects: 1
does,: 1
necessity,: 1
anarchy: 2
despotism.: 1
Unanimity: 1
impossible;: 1
rule: 1
minority,: 1
permanent: 1
arrangement,: 1
wholly: 1
inadmissible;: 1
rejecting: 1
principle,: 1
despotism: 1
form: 1
left.: 1
forget: 1
position,: 1
assumed: 1

some,: 1
decided: 1
Supreme: 2
Court,: 1
deny: 1
decisions: 3
binding,: 1
suit,: 2
object: 4
also: 2
high: 1
respect: 1
consideration: 1
parallel: 1
departments: 1
obviously: 1
decision: 1
erroneous: 1
still: 4
evil: 1
following: 1
limited: 1
chance: 1
overruled: 1
become: 1
cases,: 2
borne: 1
evils: 1
practice.: 1
At: 1
time,: 1
candid: 1
confess: 1
policy: 1
affecting: 1
irrevocably: 1
fixed: 1
Court,: 1
instant: 1
made,: 1
ordinary: 1
litigation: 1
between: 4
actions,: 1
ceased: 1
rulers,: 1
practically: 1
resigned: 1

hands: 2
eminent: 1
tribunal.: 1
Nor: 1
assault: 1
court: 1
judges.: 1
shrink: 1
decide: 1
properly: 1
brought: 1
fault: 1
theirs: 1
purposes.: 1
country: 2
believes: 2
RIGHT,: 1
extended,: 1
WRONG,: 1
extended.: 1
This: 2
substantial: 1
dispute.: 1
fugitive-slave: 1
suppression: 1
foreign: 2
slave-trade,: 2
perhaps,: 1
community: 1
imperfectly: 2
supports: 1
body: 1
dry: 1
obligation: 1
few: 1
break: 2
over: 3
each.: 1
This,: 1
think,: 1
cannot: 7
perfectly: 1
cured;: 1
worse: 1
AFTER: 1
separation: 3
sections: 2
BEFORE.: 1

suppressed,: 1
ultimately: 1
revived,: 1
without: 3
restriction,: 1
section,: 1
slaves,: 1
partially: 1
Physically: 1
speaking,: 1
separate.: 1
We: 3
remove: 1
respective: 1
other,: 1
build: 1
impassable: 1
wall: 1
husband: 1
wife: 1
divorced,: 1
presence: 1
other;: 1
remain: 1
face: 1
face,: 1
intercourse,: 1
either: 4
amicable: 1
hostile,: 1
intercourse: 2
advantageous: 1
satisfactory: 1
after: 2
before?: 1
Can: 2
aliens: 2
treaties: 2
easier: 1
friends: 1
laws?: 1
friends?: 1
Suppose: 1
war,: 1
fight: 1
always;: 1
when,: 1
loss: 1

sides,: 1
gain: 1
either,: 1
cease: 1
fighting,: 1
identical: 1
again: 2
country,: 1
institutions,: 1
belongs: 1
inhabit: 1
it.: 5
Whenever: 1
grow: 1
weary: 1
existing: 2
CONSTITUTIONAL: 1
amending: 1
REVOLUTIONARY: 1
dismember: 1
overthrow: 1
ignorant: 1
fact: 1
worthy: 1
patriotic: 1
desirous: 1
amended.: 1
recommendation: 1
amendments,: 1
fully: 1
recognize: 1
modes: 1
itself;: 1
should,: 1
circumstances,: 1
favor: 1
oppose: 1
fair: 1
opportunity: 1
afforded: 1
act: 1
venture: 1
add: 1
convention: 1
mode: 1
preferable,: 1
allows: 1
amendments: 2

originate: 1
themselves,: 1
instead: 1
permitting: 1
reject: 1
propositions: 1
originated: 1
chosen: 1
wish: 1
accept: 1
refuse.: 1
understand: 1
proposed: 1
amendment: 1
Constitution--which: 1
amendment,: 1
seen--has: 1
passed: 1
Congress,: 1
Government: 1
including: 1
service.: 1
avoid: 1
misconstruction: 1
said,: 1
depart: 1
speak: 1
say: 1
implied: 1
law,: 1
objection: 1
irrevocable.: 1
chief: 1
magistrate: 1
derives: 1
conferred: 1
none: 1
fix: 1
states.: 1
choose,: 1
executive,: 1
nothing: 1
His: 1
administer: 1
came: 1
hands,: 2
transmit: 1
unimpaired: 1

him,: 1
successor.: 1
Why: 1
patient: 1
confidence: 1
ultimate: 1
justice: 2
people?: 1
world?: 1
differences: 1
right?: 1
Almighty: 1
Ruler: 1
Nations,: 1
eternal: 1
truth: 2
justice,: 1
North,: 1
yours: 1
South,: 1
prevail,: 1
tribunal,: 1
By: 1
live,: 1
wisely: 1
servants: 1
mischief,: 1
wisdom,: 1
return: 1
short: 2
intervals.: 1
retain: 1
virtue: 1
vigilance,: 1
administration,: 1
extreme: 1
wickedness: 1
folly,: 1
seriously: 1
injure: 1
space: 1
years.: 1
My: 1
countrymen,: 1
calmly: 1
WELL: 1
subject.: 1
Nothing: 1

valuable: 1
taking: 2
time.: 1
HURRY: 1
hot: 1
haste: 1
DELIBERATELY,: 1
frustrated: 2
time;: 1
Such: 1
dissatisfied,: 1
unimpaired,: 1
sensitive: 1
point,: 1
framing: 1
it;: 1
immediate: 1
power,: 1
would,: 1
either.: 1
admitted: 1
dissatisfied: 2
dispute,: 1
reason: 1
precipitate: 1
action.: 1
Intelligence,: 1
patriotism,: 1
Christianity,: 1
firm: 1
reliance: 1
yet: 2
forsaken: 1
favored: 1
land,: 2
adjust: 1
way: 1
YOUR: 1
fellow-countrymen,: 1
MINE,: 1
momentous: 1
issue: 1
civil: 1
war.: 1
assail: 1
YOU.: 1
You: 1
conflict: 1

yourselfes: 1
aggressors.: 1
YOU: 1
registered: 1
heaven: 1
I: 1
solemn: 1
"preserve,: 1
protect,: 1
it.": 1
am: 1
loathe: 1
close.: 1
enemies,: 1
friends.: 1
enemies.: 1
Though: 1
passion: 1
strained,: 1
bonds: 1
affection.: 1
mystic: 1
chords: 1
memory,: 1
stretching: 1
battlefield: 1
patriot: 1
living: 1
heart: 1
hearthstone: 1
broad: 1
swell: 1
chorus: 1
touched,: 1
be,: 1
angels: 1
nature.: 1

1.0.2 Problem 2

Consider two 10*10 matrix and perform Matrix Multiplication using Hadoop Mapreduce and Pyspark. (Note: matrix elements can be randomly populated)

```
[13]: import numpy as np
from pyspark.mllib.linalg.distributed import RowMatrix
from pyspark.mllib.linalg.distributed import *

def as_block_matrix(rdd, rowsPerBlock=1024, colsPerBlock=1024):
```

```

return IndexedRowMatrix(
    rdd.zipWithIndex().map(lambda xi: IndexedRow(xi[1], xi[0]))
).toBlockMatrix(rowsPerBlock, colsPerBlock)

A = np.arange(10 ** 2, dtype = np.float64).reshape(10, 10)
B = np.arange(10 ** 2, dtype = np.float64).reshape(10, 10)

matrixA = as_block_matrix(sc.parallelize(A))
matrixB = as_block_matrix(sc.parallelize(B))
product = matrixA.multiply(matrixB)
product

```

[13]: <pyspark.mllib.linalg.distributed.BlockMatrix at 0x7f8556c22f10>

1.0.3 Problem 3

Randomly populate 1000 numbers and calculate mean, variance, standard deviation for the generated data.

```

[10]: import numpy as np

def func(x):
    return np.random.randint(1000)

rdd = sc.parallelize([0] * 1000).map(func)

print("rdd collect : ", rdd.collect())
print("rdd mean : ", rdd.mean())
print("rdd variance : ", rdd.variance())
print("rdd stdev : ", rdd.stdev())

```

```

rdd collect :  [340, 46, 360, 449, 625, 274, 793, 745, 273, 583, 746, 333, 158,
349, 3, 781, 672, 475, 452, 122, 73, 507, 222, 82, 183, 748, 40, 972, 663, 597,
951, 616, 40, 474, 142, 506, 988, 633, 113, 9, 602, 109, 439, 912, 987, 273,
948, 487, 187, 657, 177, 387, 364, 185, 822, 351, 426, 532, 2, 721, 372, 464,
860, 121, 32, 706, 831, 666, 725, 569, 519, 940, 987, 655, 836, 992, 357, 851,
936, 129, 146, 655, 384, 770, 446, 170, 26, 290, 997, 714, 924, 174, 240, 781,
296, 712, 515, 777, 666, 70, 941, 4, 551, 789, 38, 655, 949, 120, 966, 86, 377,
765, 774, 797, 314, 161, 726, 507, 28, 742, 567, 266, 612, 717, 86, 314, 248,
649, 814, 809, 508, 363, 20, 226, 608, 172, 16, 303, 337, 148, 641, 671, 608,
656, 780, 363, 227, 504, 3, 217, 944, 499, 302, 756, 395, 811, 332, 895, 291,
43, 342, 973, 914, 253, 890, 840, 266, 307, 49, 769, 287, 86, 785, 48, 457, 522,
794, 361, 104, 408, 468, 622, 902, 737, 927, 707, 15, 12, 4, 578, 467, 149, 340,
206, 258, 635, 273, 754, 605, 654, 810, 710, 819, 755, 686, 715, 885, 947, 381,
916, 142, 806, 417, 964, 13, 50, 265, 508, 679, 187, 604, 475, 884, 831, 764,
579, 234, 92, 486, 632, 931, 203, 422, 516, 208, 845, 966, 46, 371, 984, 796,
212, 751, 323, 242, 985, 407, 920, 114, 754, 30, 200, 732, 815, 4, 82, 380, 863,
80, 465, 638, 426, 830, 945, 277, 244, 89, 26, 174, 933, 661, 569, 159, 110,

```

571, 526, 295, 755, 989, 381, 267, 633, 134, 423, 950, 300, 950, 509, 923, 484, 960, 645, 20, 674, 79, 137, 993, 25, 44, 747, 28, 379, 735, 757, 378, 756, 440, 832, 952, 566, 752, 74, 315, 582, 584, 922, 929, 136, 207, 715, 336, 359, 950, 36, 138, 143, 54, 503, 906, 141, 402, 523, 645, 892, 361, 657, 767, 586, 307, 629, 707, 484, 890, 203, 280, 831, 624, 503, 266, 159, 259, 369, 669, 339, 715, 225, 124, 439, 213, 595, 900, 415, 786, 661, 630, 703, 96, 971, 61, 53, 758, 377, 798, 601, 773, 36, 493, 357, 119, 366, 117, 219, 625, 277, 918, 670, 536, 942, 731, 22, 654, 19, 300, 257, 456, 311, 175, 589, 411, 413, 963, 842, 235, 419, 413, 737, 791, 525, 97, 369, 833, 433, 638, 767, 783, 574, 284, 36, 803, 852, 743, 598, 111, 839, 172, 640, 764, 180, 748, 679, 152, 218, 374, 310, 295, 878, 849, 464, 756, 20, 489, 887, 45, 465, 198, 155, 77, 435, 89, 447, 483, 997, 415, 533, 860, 909, 264, 928, 526, 562, 184, 666, 460, 669, 659, 180, 161, 965, 202, 944, 1, 475, 228, 995, 367, 108, 277, 543, 322, 413, 478, 165, 747, 991, 80, 728, 872, 964, 323, 84, 378, 24, 605, 580, 160, 835, 2, 757, 362, 828, 999, 611, 777, 833, 886, 661, 114, 258, 354, 251, 793, 363, 446, 810, 511, 533, 205, 986, 653, 448, 694, 81, 448, 307, 47, 319, 896, 951, 807, 676, 774, 238, 40, 227, 163, 709, 660, 156, 181, 439, 294, 597, 297, 941, 574, 13, 492, 81, 108, 541, 897, 782, 859, 577, 533, 322, 767, 497, 370, 540, 157, 714, 957, 3, 786, 618, 765, 503, 135, 564, 991, 732, 267, 112, 829, 780, 941, 431, 458, 711, 568, 51, 65, 291, 534, 991, 452, 216, 746, 535, 641, 65, 327, 22, 626, 742, 268, 72, 459, 447, 334, 853, 232, 77, 139, 141, 71, 553, 480, 552, 356, 856, 414, 21, 112, 19, 498, 12, 316, 145, 750, 332, 687, 89, 623, 800, 360, 185, 444, 480, 237, 651, 942, 423, 208, 638, 863, 507, 605, 313, 987, 148, 451, 793, 129, 448, 113, 166, 267, 720, 966, 737, 722, 631, 166, 598, 478, 342, 998, 144, 614, 715, 859, 574, 21, 958, 285, 713, 124, 812, 661, 681, 228, 423, 874, 122, 294, 849, 417, 285, 260, 516, 517, 421, 334, 962, 430, 374, 785, 624, 680, 290, 49, 733, 680, 860, 910, 753, 114, 740, 39, 580, 826, 203, 937, 963, 430, 283, 687, 962, 573, 65, 872, 412, 109, 280, 245, 784, 548, 204, 534, 98, 714, 881, 588, 617, 990, 873, 537, 86, 331, 807, 862, 843, 129, 451, 688, 423, 962, 56, 106, 762, 164, 945, 374, 243, 620, 635, 448, 515, 848, 177, 705, 847, 224, 398, 954, 958, 561, 349, 978, 200, 339, 991, 179, 195, 789, 955, 138, 333, 934, 576, 427, 110, 342, 498, 636, 637, 606, 830, 611, 987, 246, 346, 958, 566, 240, 720, 622, 931, 675, 348, 312, 744, 135, 770, 634, 213, 635, 508, 911, 919, 391, 218, 682, 174, 297, 780, 484, 28, 644, 515, 579, 667, 624, 574, 807, 740, 759, 642, 996, 887, 159, 809, 510, 170, 568, 196, 149, 963, 667, 179, 95, 885, 188, 995, 22, 384, 261, 779, 698, 930, 554, 617, 415, 944, 759, 882, 817, 761, 233, 207, 184, 38, 276, 79, 531, 562, 215, 173, 152, 865, 59, 674, 120, 700, 574, 823, 806, 785, 179, 374, 199, 40, 141, 957, 212, 465, 143, 384, 809, 758, 213, 933, 888, 240, 971, 59, 252, 251, 367, 771, 213, 656, 578, 524, 677, 168, 898, 510, 775, 89, 463, 408, 325, 730, 196, 532, 214, 767, 312, 702, 227, 136, 644, 221, 493, 825, 419, 907, 476, 544, 772, 655, 714, 912, 963, 746, 867, 999, 825, 435, 179, 975, 119, 857, 938, 174, 803, 371, 57, 12, 316, 774, 889, 650, 105, 806, 73, 511, 329, 944, 222, 57, 115, 149, 496, 589, 530, 639, 542, 126, 701, 929, 100, 50, 929, 659, 151, 723, 131, 516, 533, 325, 384, 584, 66, 569, 574, 464, 506, 366, 39, 927, 592, 694, 711, 858, 761, 902, 271, 812, 37, 276, 579, 179, 91, 807, 473, 43]

rdd mean : 495.64199999999977

rdd variance : 83330.1367639999

```
rdd stdev : 291.66770365606146
```

1.0.4 Problem 4

Compute correlation between the given two series using Pearson's and Spearman's Method. (Use the Spark MLlib libraries and helper functions available)

Series A: 35, 23, 47, 17, 10, 43, 9, 6, 28

Series B: 30, 33, 45, 23, 8, 49, 12, 4, 31

```
[11]: from pyspark.context import SparkContext
      from pyspark.sql.session import SparkSession
      sc = SparkContext.getOrCreate()
      spark = SparkSession(sc)
      from pyspark.mllib.stat import Statistics

      seriesX = sc.parallelize([35, 23, 47, 17, 10, 43, 9, 6, 28])
      seriesY = sc.parallelize([30, 33, 45, 23, 8, 49, 12, 4, 31])

      print("Pearson Correlation is : " + str(Statistics.corr(seriesX, seriesY,
      ↪method = "pearson")))
      print("Spearman Correlation is : " + str(Statistics.corr(seriesX, seriesY,
      ↪method = "spearman")))
```

```
Pearson Correlation is : 0.9498663391552045
```

```
Spearman Correlation is : 0.9
```

1.0.5 Problem 5

Remove Stop words from the 'sentence' column given in the "StopWordRemoval_input" document.

1.0.6 Problem 6

In the given input file, binarize the column 'E' (fifth column). Set the threshold as 2.5

```
[19]: from pyspark.ml.feature import Binarizer

      da1 = spark.read.csv("Binarize_input.tsv", inferSchema = True, sep = ',')

      binarizer = Binarizer(threshold = 2.5, inputCol = "E", outputCol =
      ↪"binarized_feature")
      binarizer.getThreshold()
```

```
[19]: 2.5
```

1.0.7 Problem 7

- Randomly generate 10k numbers and apply the following functions on the generated random numbers. Also, develop an equivalent conventional program (without spark RDDs) and compare the time taken by the two versions.

Exponential Function, $f_1(x)=e^x$
Logarithmic Function, $f_2(x)=\log(x)$
Square root Function, $f_3(x)=\sqrt{x}$
Square function, $f_4(x)=x^2$

- b. Extension to the previous question: Instead of printing transformed values for all 10k words, print transformed values of the first 100 numbers only. Also, develop an equivalent conventional program (without spark RDDs) and compare the time taken by the two versions.

```
[27]: import numpy as np
import math

def f(x):
    return np.random.randint(1000)

def func(x):
    y = math.log(2.718, x)
    return y

rdd = sc.parallelize([0] * 10000).map(f)

print("rdd.collect() : ", rdd.collect())

# exp
print("\n2^x : ", rdd.map(lambda x: (x, math.pow(2,x))).collect())

# square root
print("\nsqrt(x) : ", rdd.map(lambda x: (x, math.sqrt(x))).collect())

# x^2
print("\nx^2 : ", rdd.map(lambda x: (x, x*x)).collect())

# logx
# print("\nlogx : ", rdd.map(lambda x: Func))
```

```
rdd.collect() : [127, 411, 296, 313, 264, 658, 651, 795, 268, 750, 666, 736,
764, 277, 846, 407, 995, 689, 486, 369, 64, 282, 598, 877, 451, 752, 158, 896,
459, 805, 674, 158, 53, 635, 558, 378, 592, 572, 921, 773, 985, 695, 321, 561,
590, 141, 37, 941, 396, 846, 198, 749, 601, 595, 3, 207, 477, 880, 365, 174,
599, 832, 866, 617, 238, 611, 418, 877, 363, 720, 340, 172, 183, 700, 343, 284,
160, 242, 842, 480, 516, 836, 315, 692, 123, 601, 959, 261, 409, 739, 887, 537,
652, 416, 663, 551, 198, 281, 702, 538, 80, 756, 407, 715, 107, 595, 516, 63,
405, 84, 198, 17, 770, 430, 456, 777, 524, 299, 9, 651, 661, 850, 354, 663, 919,
337, 523, 579, 197, 217, 816, 396, 54, 91, 276, 648, 331, 140, 807, 384, 971,
183, 260, 486, 57, 426, 576, 819, 711, 50, 938, 30, 231, 29, 965, 319, 311, 452,
857, 561, 710, 440, 495, 517, 279, 475, 748, 211, 820, 759, 368, 164, 256, 841,
539, 104, 615, 253, 862, 38, 250, 903, 385, 708, 586, 415, 438, 291, 862, 367,
363, 12, 860, 668, 399, 232, 523, 363, 809, 553, 280, 422, 292, 809, 712, 839,
```


49, 128, 485, 239, 629, 62, 512, 72, 281, 17, 379, 118, 964, 350, 8, 276, 94, 628, 661, 372, 960, 103, 501, 104, 970, 156, 354, 694, 903, 823, 463, 148, 344, 606, 171, 497, 424, 386, 20, 91, 19, 861, 478, 727, 186, 291, 325, 552, 314, 393, 241, 378, 706, 897, 280, 702, 568, 48, 649, 166, 522, 43, 386, 657, 638, 854, 865, 374, 126, 24, 762, 485, 936, 691, 3, 824, 923, 378, 785, 588, 287, 487, 660, 133, 530, 592, 650, 721, 850, 881, 308, 967, 541, 427, 409, 323, 915, 524, 375, 196, 138, 163, 266, 582, 329, 810, 298, 695, 364, 5, 791, 520, 324, 406, 255, 832, 603, 17, 669, 982, 628, 792, 923, 704, 33, 435, 200, 447, 469, 866, 79, 680, 873, 357, 3, 823, 312, 266, 654, 129, 848, 468, 671, 579, 520, 785, 840, 480, 423, 982, 974, 861, 696, 770, 956, 132, 391, 942, 227, 891, 68, 183, 430, 518, 273, 516, 400, 202, 48, 734, 639, 17, 288, 85, 916, 954, 606, 898, 702, 885, 493, 196, 368, 568, 478, 677, 350, 239, 517, 547, 334, 934, 392, 969, 328, 329, 815, 311, 246, 558, 472, 24, 474, 300, 909, 808, 483, 294, 189, 29, 697, 173, 391, 324, 445, 280, 36, 245, 984, 670, 414, 410, 585, 644, 470, 56, 167, 47, 145, 414, 76, 855, 420, 498, 124, 435, 20, 208, 906, 96, 185, 886, 414, 430, 960, 869, 570, 542, 91, 435, 605, 628, 830, 128, 421, 422, 702, 134, 681, 27, 338, 62, 910, 593, 324, 558, 748, 328, 555, 62, 84, 314, 726, 279, 206, 967, 796, 542, 10, 867, 649, 306, 327, 246, 151, 382, 384, 770, 44, 685, 334, 89, 332, 924, 379, 452, 299, 363, 441, 546, 240, 638, 824, 719, 315, 847, 744, 336, 570, 3, 729, 394, 241, 817, 900, 376, 545, 644, 582, 843, 18, 661, 160, 370, 280, 963, 879, 960, 17, 174, 126, 305, 753, 741, 946, 777, 887, 786, 379, 40, 954, 608, 319, 766, 866, 342, 155, 958, 0, 196, 319, 688, 645, 886, 522, 867, 834, 390, 894, 135, 270, 424, 389, 131, 84, 217, 975, 917, 137, 789, 570, 432, 624, 188, 461, 751, 151, 128, 951, 0, 294, 332, 198, 877, 925, 393, 268, 868, 68, 546, 405, 592, 433, 472, 66, 826, 673, 132, 123, 834, 858, 74, 518, 372, 82, 299, 997, 681, 500, 279, 344, 363, 19, 962, 701, 614, 230, 807, 994, 353, 751, 403, 759, 986, 60, 306, 681, 846, 22, 366, 903, 659, 637, 988, 863, 633, 273, 297, 319, 870, 170, 681, 267, 663, 954, 183, 988, 900, 672, 221, 531, 17, 863, 115, 845, 70, 425, 429, 363, 11, 173, 43, 114, 366, 42, 205, 576, 311, 624, 313, 34, 135, 83, 943, 905, 845, 177, 403, 633, 673, 850, 623, 885, 362, 100, 526, 870, 382, 188, 76, 841, 774, 494, 307, 67, 193, 96, 707, 735, 187, 975, 21, 494, 636, 7, 136, 486, 508, 769, 167, 997, 869, 300, 11, 33, 573, 902, 16, 365, 193, 549, 654, 612, 841, 141, 587, 200, 314, 374, 410, 117, 26, 910, 569, 707, 583, 550, 622, 138, 48, 329, 119, 642, 87, 808, 949, 538, 154, 979, 270, 82, 988, 317, 651, 370, 364, 171, 912, 798, 63, 975, 291, 591, 4, 789, 117, 538, 22, 259, 481, 744, 109, 809, 302, 428, 249, 594, 263, 538, 31, 696, 668, 782, 934, 738, 81, 970, 173, 55, 675, 461, 539, 119, 744, 343, 114, 616, 246, 415, 836, 629, 607, 81, 698, 11, 138, 576, 215, 898, 661, 598, 858, 262, 313, 97, 410, 302, 666, 298, 188, 785, 686, 796, 304, 326, 879, 23, 818, 745, 88, 941, 444, 708, 104, 252, 895, 347, 289, 447, 22, 370, 944, 450, 371, 682, 36, 821, 764, 84, 856, 910, 730, 32, 796, 694, 578, 448, 783, 282, 480, 539, 243, 547, 24, 876, 543, 537, 823, 981, 213, 733, 761, 749, 498, 867, 457, 449, 966, 176, 173, 236, 523, 87, 699, 563, 811, 792, 958, 643, 60, 178, 97, 401, 207, 956, 625, 181, 345, 941, 281, 294, 513, 38, 464, 334, 931, 592, 293, 576, 601, 710, 503, 498, 67, 507, 950, 177, 850, 781, 227, 908, 894, 964, 353, 758, 239, 546, 231, 455, 307, 789, 563, 517, 630, 785, 916, 325, 991, 213, 104, 112, 63, 487, 834, 739, 723, 125, 782, 947, 344, 852, 128, 261, 547, 716, 200, 846, 61, 358, 605, 660, 412, 253, 689, 691, 116, 678, 922, 183, 306, 324, 400, 647, 800,

52, 619, 59, 802, 320, 689, 554, 710, 23, 752, 631, 629, 298, 326, 721, 988, 49,
19, 407, 47, 329, 794, 651, 149, 515, 479, 715, 531, 673, 732, 430, 222, 177,
155, 439, 579, 523, 138, 287, 362, 729, 516, 201, 573, 634, 258, 840, 239, 487,
609, 235, 87, 674, 380, 63, 245, 767, 849, 66, 705, 703, 494, 959, 166, 264,
646, 968, 302, 724, 888, 622, 713, 925, 883, 978, 310, 584, 783, 46, 685, 317,
321, 221, 849, 924, 377, 306, 695, 633, 630, 786, 896, 617, 209, 865, 313, 925,
939, 279, 631, 422, 508, 500, 827, 747, 870, 605, 189, 374, 327, 434, 49, 111,
348, 332, 829, 656, 475, 419, 865, 674, 82, 658, 885, 260, 742, 683, 684, 253,
594, 432, 645, 516, 325, 585, 700, 292, 864, 638, 763, 514, 651, 26, 603, 148,
946, 79, 726, 763, 653, 998, 190, 674, 773, 78, 977, 968, 663, 332, 631, 381,
93, 415, 149, 418, 1, 913, 955, 668, 492, 810, 418, 813, 255, 498, 239, 743,
597, 517, 729, 284, 150, 617, 531, 96, 846, 79, 474, 566, 340, 127, 618, 37,
791, 90, 995, 304, 696, 509, 571, 444, 952, 754, 782, 123, 99, 696, 489, 107,
598, 202, 744, 81, 412, 743, 790, 154, 932, 613, 960, 289, 213, 849, 344, 162,
881, 457, 42, 484, 894, 83, 321, 264, 963, 495, 47, 118, 550, 813, 249, 699,
505, 322, 135, 3, 421, 804, 128, 265, 951, 460, 162, 484, 999, 895, 9, 833, 991,
459, 888, 550, 280, 51, 836, 694, 963, 258, 745, 934, 702, 721, 888, 505, 151,
728, 56, 578, 882, 552, 513, 596, 141, 244, 337, 670, 715, 475, 284, 137, 937,
755, 784, 908, 164, 715, 212, 584, 178, 308, 992, 280, 332, 756, 771, 706, 114,
424, 201, 443, 412, 107, 650, 623, 986, 910, 36, 497, 129, 565, 174, 982, 856,
996, 188, 602, 695, 154, 440, 46, 608, 341, 697, 155, 927, 654, 668, 785, 229,
552, 517, 817, 841, 257, 798, 639, 166, 24, 913, 803, 388, 278, 841, 221, 360,
257, 939, 680, 981, 530, 287, 772, 912, 105, 750, 897, 755, 387, 24, 225, 645,
58, 111, 183, 191, 310, 153, 220, 905, 248, 749, 618, 259, 142, 171, 181, 13,
708, 245, 236, 638, 986, 775, 86, 636, 519, 788, 539, 0, 848, 572, 2, 110, 889,
15, 816, 233, 306, 131, 131, 923, 157, 27, 590, 271, 88, 578, 220, 261, 0, 639,
179, 273, 286, 123, 887, 26, 288, 766, 756, 394, 738, 462, 548, 445, 303, 924,
474, 583, 266, 31, 949, 955, 6, 925, 343, 388, 735, 515, 922, 841, 258, 808,
455, 142, 253, 698, 141, 649, 716, 971, 267, 475, 379, 941, 963, 831, 853, 64,
426, 475, 122, 387, 159, 255, 820, 82, 104, 569, 726, 80, 876, 814, 243, 303,
142, 441, 786, 830, 715, 239, 493, 186, 37, 894, 310, 958, 360, 18, 964, 63,
204, 965, 993, 646, 880, 311, 863, 823, 919, 355, 342, 779, 68, 639, 748, 190,
693, 19, 421, 877, 71, 196, 418, 451, 128, 919, 247, 423, 156, 321, 70, 970,
674, 779, 527, 673, 934, 216, 344, 858, 495, 423, 66, 905, 215, 328, 349, 152,
91, 529, 935, 263, 13, 725, 295, 72, 130, 397, 169, 449, 247, 368, 585, 139,
999, 122, 727, 75, 398, 595, 947, 33, 274, 277, 275, 742, 56, 885, 44, 362, 852,
898, 902, 596, 276, 867, 161, 831, 431, 277, 261, 230, 526, 531, 281, 678, 526,
199, 922, 3, 152, 891, 446, 129, 497, 4, 139, 53, 72, 569, 433, 433, 743, 617,
611, 525, 483, 437, 70, 94, 456, 432, 708, 14, 148, 25, 151, 337, 966, 272, 769,
921, 467, 589, 645, 493, 710, 256, 196, 31, 437, 245, 308, 729, 7, 982, 209,
905, 996, 532, 566, 478, 938, 481, 490, 416, 445, 548, 748, 405, 25, 290, 857,
322, 931, 578, 133, 299, 266, 428, 290, 591, 699, 424, 981, 131, 465, 485, 524,
329, 309, 763, 818, 323, 334, 729, 498, 437, 431, 916, 655, 154, 719, 829, 450,
739, 239, 123, 955, 22, 384, 804, 794, 949, 33, 102, 833, 486, 992, 967, 830,
150, 420, 494, 431, 266, 975, 427, 289, 980, 852, 25, 713, 577, 72, 26, 817,
128, 228, 848, 504, 532, 653, 647, 147, 874, 186, 195, 444, 706, 716, 899, 667,
586, 927, 447, 93, 128, 211, 164, 377, 793, 558, 601, 651, 939, 90, 714, 671,
140, 957, 990, 503, 323, 551, 656, 976, 592, 733, 373, 481, 434, 509, 194, 119,

264, 158, 644, 453, 643, 45, 602, 946, 321, 23, 226, 33, 701, 281, 632, 201,
450, 860, 783, 950, 545, 880, 290, 959, 663, 739, 364, 840, 467, 572, 329, 405,
777, 712, 620, 999, 59, 731, 556, 5, 324, 304, 64, 802, 749, 817, 835, 624, 814,
962, 293, 450, 364, 452, 613, 585, 624, 645, 889, 776, 689, 983, 581, 39, 526,
861, 107, 568, 97, 287, 29, 756, 876, 613, 463, 858, 326, 434, 670, 43, 255,
249, 585, 25, 242, 187, 379, 348, 765, 69, 453, 110, 530, 9, 384, 799, 533, 185,
860, 372, 101, 250, 927, 899, 286, 742, 445, 206, 745, 746, 317, 606, 946, 159,
995, 820, 691, 823, 390, 318, 90, 102, 493, 545, 9, 799, 983, 989, 249, 584,
152, 251, 975, 608, 231, 459, 50, 315, 915, 639, 335, 173, 423, 746, 413, 629,
719, 2, 337, 154, 953, 826, 606, 928, 624, 318, 871, 477, 483, 703, 508, 517,
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