CS 402 Homework 1

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Question 1

(a) Using trace files, i.e. files that contain addresses issued by some CPU to execute some application(s), draw the histogram of address distribution for each of them (2x20 points). On the Ox axis of the plot you will have the address number (don't start with zero, rather with the smallest address you find in the file and go up to the maximum address in the file). On the Oy axis you will have the number of occurrences for each particular address.

NOTE: the range of addresses is vast, attempting to plot everything will result in a histogram with very little detail. Instead, select a range of addresses (a few hundreds of them) where you have non-zero values on Oy.

Spice.din

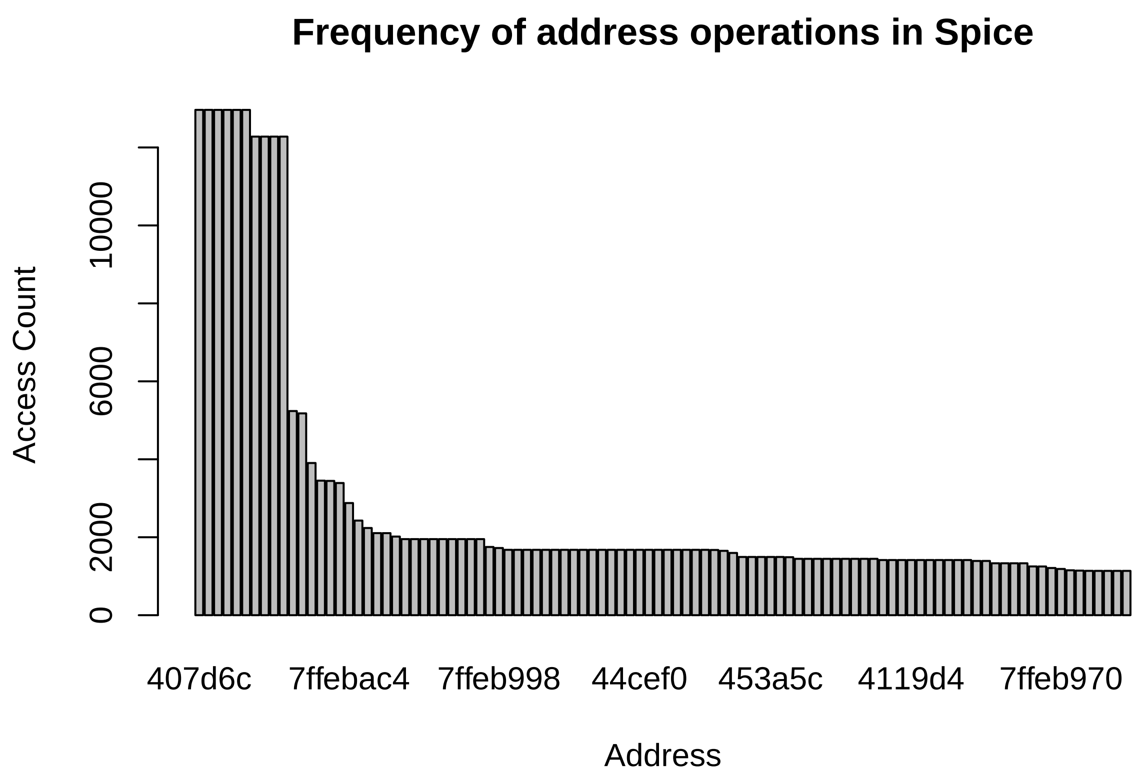
As per the note above, the following histogram plots only the 100 non-zero addresses and their access counts.

```r
data1 <- read.csv("spice.din", sep=" ", header=F, stringsAsFactors = F)
addressFreq1 <- table(data1[,2])

intervalToPlot = 100

# Sort by decreasing frequency and fetch top 100 values
sortedMaxAddressesFreq1withInterval =
  addressFreq1[order(addressFreq1, decreasing=TRUE)][1:intervalToPlot]

barplot(sortedMaxAddressesFreq1withInterval,
        main="Frequency of address operations in Spice",
        xlab = "Address", ylab = "Access Count")
```

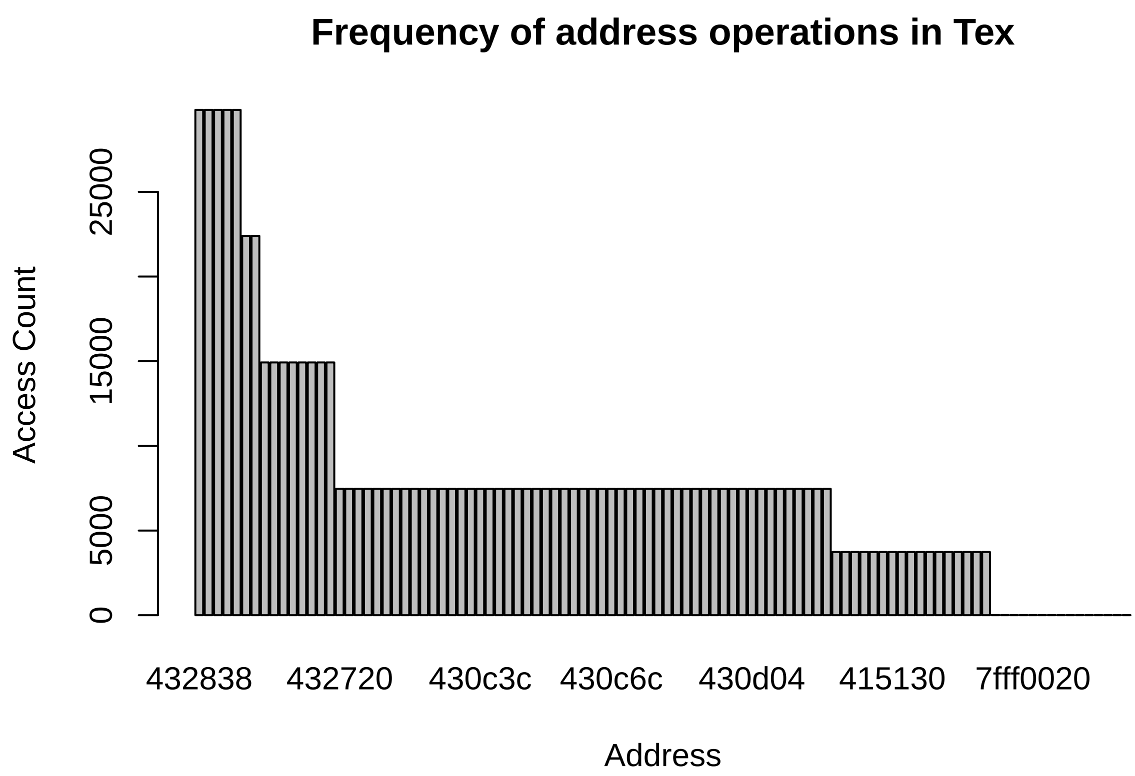


Tex.din

```
data2 <- read.csv("tex.din", sep=" ", header=F, stringsAsFactors = F)
addressFreq2 <- table(data2[,2])

# Sort by decreasing frequency and fetch top 100 values
sortedMaxAddressesFreq2withInterval =
  addressFreq2[order(addressFreq2, decreasing=TRUE)][1:intervalToPlot]

barplot(sortedMaxAddressesFreq2withInterval,
        main="Frequency of address operations in Tex",
        xlab = "Address", ylab = "Access Count")
```

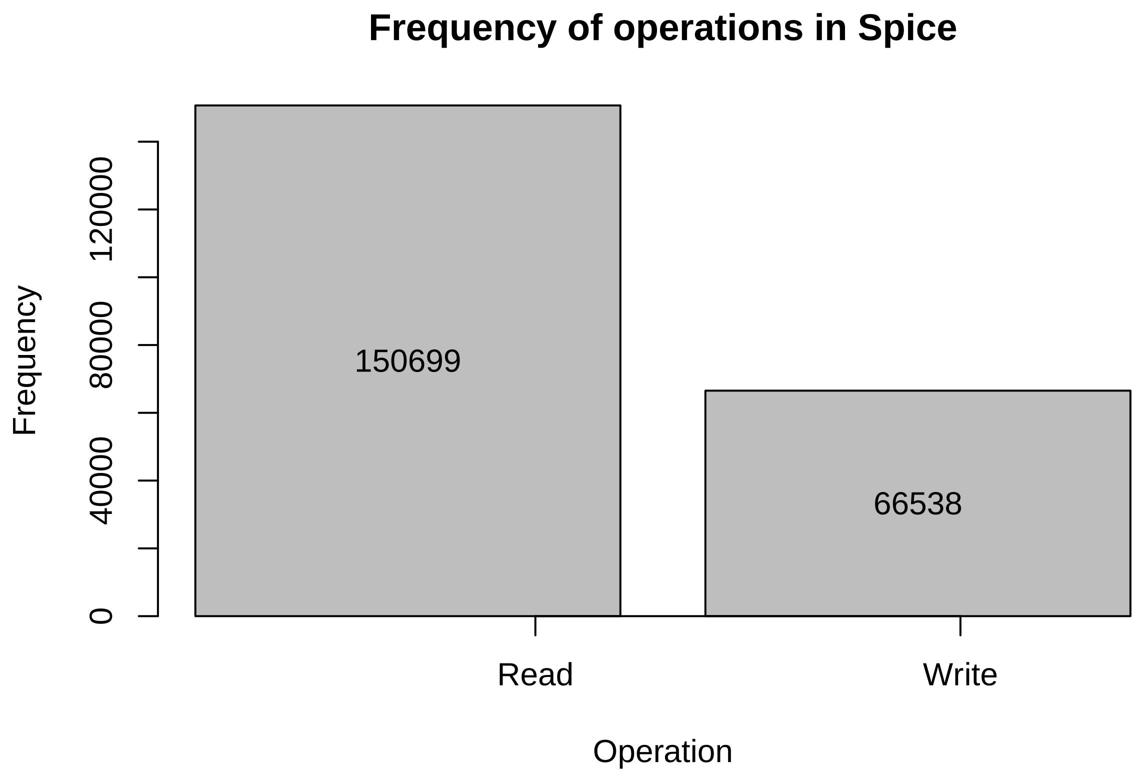



```
# Sort as frequency table as descending and fetch the first name
spiceMaxName<-names(sortedMaxAddressesFreq1withInterval[1])
texMaxName<-names(sortedMaxAddressesFreq2withInterval[1])
```

Comment based on the histograms (5). The most highest operation count for an address in spice.din was 0x407d6c while for tex.din, it was 0x432838. There are overall more accesses in the case of tex.din. In both cases, majority of accesses are concentrated around the address range of 0x40000 to 0x41000.

(b) What is the frequency of writes (5)? What is the frequency of reads (5)? Spice.din

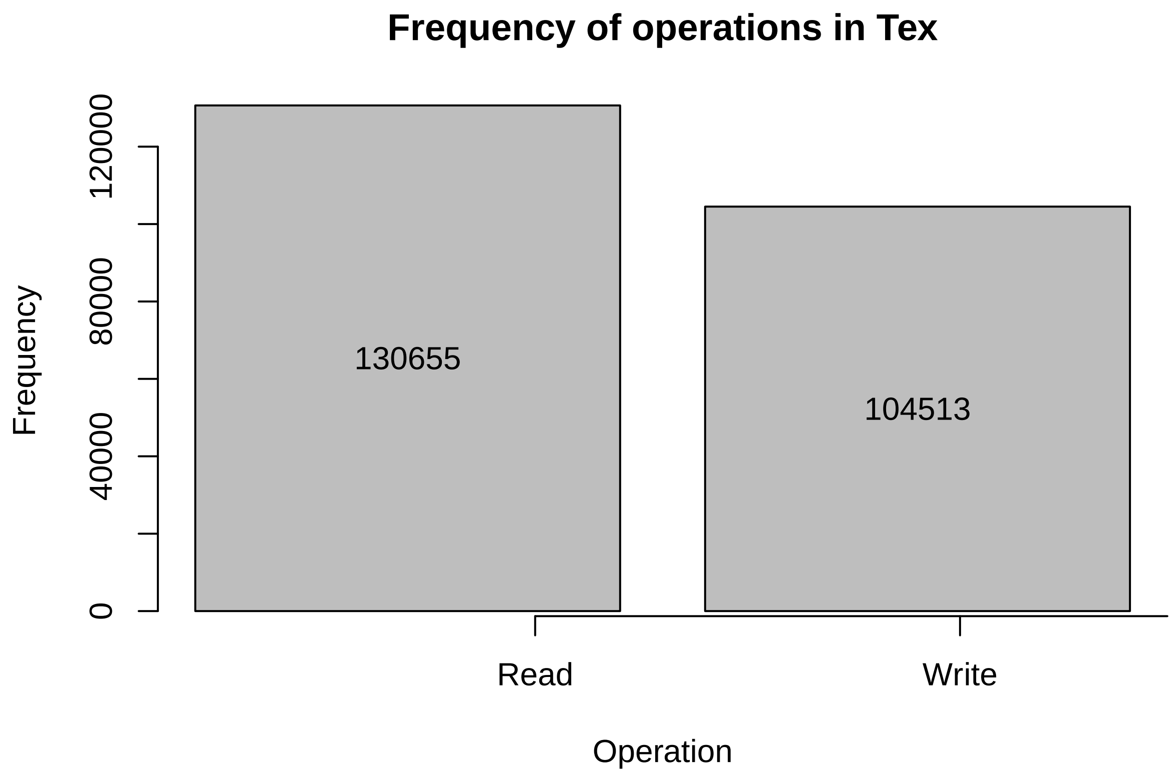
```
x1<-data1$V1
maxX1<-max(table(x1)[1:2])
{bp1 <- barplot(
  table(data1$V1)[1:2], xaxt="n", main="Frequency of operations in Spice",
  ylim=(c(0,maxX1)), xlab="Operation", ylab="Frequency"
  )
  axis(1, at=1:2, labels=c("Read","Write"))
  options(scipen = 6)
  text(x=bp1, y= table(x1)[1:2]/2, labels=as.character(table(x1)[1:2]))
}
```



The frequency of writes is 66538 while the frequency of reads is 150699 in the spice file.

Tex.din

```
x2<-data2$V1
maxX2<-max(table(x2)[1:2])
{bp2 <- barplot(
  table(data2$V1)[1:2], main="Frequency of operations in Tex",
  xlab="Operation", ylab="Frequency", xaxt="n"
  )
  options(scipen = 5)
  axis(1, at=1:3, labels=c("Read","Write","Fetch"))
  text(x=bp2, y= table(x2)[1:2]/2, labels=as.character(table(x2))[1:2])
}
```



The frequency of writes is 104513 while the frequency of reads is 130655 in the tex file.

Please comment on these results (5).

Both spice.din and tex.din files show that read instruction was the most common operation with spice having 150699 operations and tex having 130655 operations. They both have more read operations than write. This makes sense as data at an address has to be read and then performing a write to perhaps update the same address or a different one is optional.

Table 1: Machine 1 vs Machine 2 time taken in seconds

Runs	Integer	Float	Runs	Integer	Float
1	4.96672	5.70465	1	6.73228	7.62045
2	5.29337	5.20660	2	6.66859	7.11992
3	5.33969	5.51428	3	7.09571	6.77833
4	5.05501	5.34071	4	7.21846	7.00182
5	5.34676	5.58114	5	7.44075	6.97693
6	5.02560	5.48730	6	7.10797	7.28310
7	5.39096	5.60357	7	7.33325	6.87675
8	5.41396	5.64611	8	6.88468	6.80096
9	5.37972	5.73424	9	6.89846	7.76262
10	5.26595	5.46428	10	6.84239	6.87293

Question 2

(a) Write a program, using your favorite programming language, that multiplies two rectangular matrices – please no square matrices – whose elements are randomly generated. You will have two versions of the program, one in which matrix elements are integers and another one where they are real numbers (double) (2x15 points). Measure the time it takes each program to complete (2x5) and then compare the performance of the two systems (5). Please find the matrix calculator C++ programs in the repository

Performance Comparison

Matrix Type	Machine 1 Average	Machine 2 Average
Integer	5.247774	7.022254
Float	5.528288	7.109381

On average, Integer operations are 28.3% slower on the 2nd machine while float operations are 37.8% slower.

Is the performance ratio the same as the clock rate ratio of the two systems (5)? Explain. No, the clock rate of the first machine is 150% greater (3.3 GHz versus 2.2 Ghz of the second) while the difference in performance is less than 40% on average.

This is because clock rates are not the determining factor of computer performance but cycles per instruction is. Other factors such as available cache, type of storage (NVME SSD vs SATA SSD), type of RAM depending on architecture (DDR4 vs LPDDR3) all affect cycles per instruction.

Based on the retail price of the two systems, which one is more cost effective (5)? The first machine is a GT73VR with a Skylake i7 (6th generation) running at 3.3GHz clock rate with a M2 NVMe SSD and costs approximately $1500 today. The second machine is a 15 inch Macbook Pro 2015 equipped with a Broadwell i7 (5th generation) running at 2.2Ghz clock speed with a M2 SSD and costs approximately $1100 today.

The first machine is 36% more expensive while the difference of performance is greater than 38%.

Hence, the first machine (MSI GT73VR) is slightly more cost effective.

Table 3: Machine 1 vs Machine 2 time taken in seconds (rows in inner loop)

Runs	Integer	Float	Runs	Integer	Float
1	4.80913	5.40437	1	6.75647	7.42215
2	5.23265	5.16091	2	7.34534	7.28856
3	4.88205	4.99780	3	6.89118	7.33798
4	5.08705	5.22991	4	6.97223	7.11317
5	5.04049	5.07952	5	7.05036	7.36661
6	5.10803	5.24946	6	6.91155	7.57345
7	5.11938	5.42984	7	6.76589	7.48034
8	5.13538	5.33022	8	6.73468	7.48641
9	5.06068	5.28904	9	7.58147	7.50841
10	5.28394	5.30617	10	6.96372	7.38413

(b) Change your multiplication algorithm and repeat the steps above; for instance, if you used the the naive multiplication algorithm with the column in the inner loop, then just use the same algorithm with the row in the inner loop (same scoring as part a).

Matrix Type	Machine 1 Average	Machine 2 Average
Integer	5.075878	6.997289
Float	5.247724	7.396121

On average, Integer operations are 37.85% slower on the 2nd machine while float operations are 40.94% slower.

Is the performance ratio the same as the clock rate ratio of the two systems (5)? Explain. The performance ratio is not the same as clock rate ratio. The clock rate ratio comes to 150% (3.3 vs 2.2 GHz) while the performance difference is 139.4223644% using the average time taken for integer and float operations, which is less than the clock rate difference.

Based on the retail price of the two systems, which one is more cost effective (5)? The first machine is a GT73VR with a Skylake i7 (6th generation) running at 3.3GHz clock rate with a M2 NVMe SSD and costs approximately $1500 today. The second machine is a 15 inch Macbook Pro 2015 equipped with a Broadwell i7 (5th generation) running at 2.2Ghz clock speed with a M2 SSD and costs approximately $1100 today.

The first machine is 36% more expensive while the difference of performance is greater than 39%.

Hence, the first machine (MSI GT73VR) is slightly more cost effective, as concluded previously.

Machine Description

Attribute	Machine 1	Machine 2
Manufacturer	MSI	Apple
CPU Type	i7-6820HK	i7 Broadwell (5th generation)
Clock Speed	3.3GHz	2.2 GHz
RAM	32GB	16 GB
OS	Windows 10	macOS Catalina
Compiler	G++ MinGW	LLVM-g++
SSD Random Read Speeds	39.24 MB/s	19.27 MB/s
SSD Random Write Speeds	88.6 MB/s	30.98 MB/s
Price	$1,500	$1100

The SSD read/write speeds were taken using Crystal Disk Mark's random 4kb read/write single-thread test