HW4

Q1.

Firstly, three separate vectors of "mpg" data are extracted for cars originating from the US, Europe (EU), and Asia. Subsequently, a t-test & wilcox.test function is conducted to compare the fuel efficiency (mpg) between cars from the two region, producing results that indicate whether there's a statistically significant difference in mpg between these regions.

In non-technical terms, the performed tests compared the miles per gallon (mpg) of cars from different regions: Here's what the results tell us:

1. **US vs. Asia MPG (T-Test and Wilcoxon Test):** Both tests show a significant difference in mpg between cars from the US and Asia. The t-test gives a very low p-value (< 2.2e-16), indicating that on average, US cars have significantly lower mpg (around 20.03) compared to Asian cars (approximately 30.45). The Wilcoxon test confirms this with a similarly low p-value (< 2.2e-16), emphasizing the significant difference.

2. **EU vs. Asia MPG (T-Test and Wilcoxon Test):** While the t-test reveals a difference in mpg between cars from the EU and Asia, it's not as pronounced as the US-Asia comparison. The p-value is 0.0076, suggesting a moderate difference. On average, EU cars have slightly lower mpg (around 27.60) compared to Asian cars (approximately 30.45). The Wilcoxon test also shows a significant difference with a p-value of 0.002, though not as extreme as the US-Asia comparison.

3. **US vs. EU MPG (T-Test and Wilcoxon Test):** Both tests indicate a significant difference in mpg between cars from the US and the EU. The t-test provides a very low p-value (1.93e-13), highlighting the substantial difference. On average, US cars have significantly lower mpg (around 20.03) compared to EU cars (approximately 27.60). The Wilcoxon test confirms this with a p-value of 1.957e-14, underlining the significant difference.

Asian cars generally have the highest average mpg, followed by European cars, while US cars tend to have lower average mpg. These differences are statistically significant, indicating varying fuel efficiency patterns among the regions.

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```
>
> data <- read.csv("C:/Users/faiya/OneDrive - Texas Tech University/Texas tech course/fall 23/software analytics//HW1/auto.csv")
> # Subset the data for each region
> us_mpg <- data[data$origin == 1, "mpg"]
> eu_mpg <- data[data$origin == 2, "mpg"]
> asia_mpg <- data[data$origin == 3, "mpg"]
> # Perform t-tests to compare mpg between US and Asia
> t_test_us_asia <- t.test(us_mpg, asia_mpg)
> cat("T-Test Results for US vs Asia MPG:\n")
T-Test Results for US vs Asia MPG:
> print(t_test_us_asia)

        Welch Two Sample t-test

data:  us_mpg and asia_mpg
t = -13.034, df = 138.64, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -11.997430  -8.836897
sample estimates:
mean of x mean of y
 20.03347  30.45063

>
>
> # Perform t-tests to compare mpg between EU and Asia
> t_test_eu_asia <- t.test(eu_mpg, asia_mpg)
> cat("T-Test Results for EU vs Asia MPG:\n")
T-Test Results for EU vs Asia MPG:
> print(t_test_eu_asia)

        Welch Two Sample t-test

data:  eu_mpg and asia_mpg
t = -2.7075, df = 137.85, p-value = 0.007637
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -4.9273838 -0.7679996
sample estimates:
mean of x mean of y
 27.60294  30.45063

> # Perform t-tests to compare mpg between US and EU
> t_test_us_eu <- t.test(us_mpg, eu_mpg)
> cat("T-Test Results for US vs EU MPG:\n")
T-Test Results for US vs EU MPG:
> print(t_test_us_eu)

        Welch Two Sample t-test

data:  us_mpg and eu_mpg
t = -8.4311, df = 105.32, p-value = 1.93e-13
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -9.349583 -5.789361
sample estimates:
mean of x mean of y
 20.03347  27.60294



> # Perform Wilcoxon rank-sum tests (Mann-Whitney U tests) as non-parametric alternatives
> wilcox_test_us_asia <- wilcox.test(us_mpg, asia_mpg)
> cat("Wilcoxon Test Results for US vs Asia MPG:\n")
Wilcoxon Test Results for US vs Asia MPG:
> print(wilcox_test_us_asia)

        Wilcoxon rank sum test with continuity correction

data:  us_mpg and asia_mpg
W = 2456.5, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0

> wilcox_test_eu_asia <- wilcox.test(eu_mpg, asia_mpg)
> cat("Wilcoxon Test Results for EU vs Asia MPG:\n")
Wilcoxon Test Results for EU vs Asia MPG:
> print(wilcox_test_eu_asia)

        Wilcoxon rank sum test with continuity correction

data:  eu_mpg and asia_mpg
W = 1889, p-value = 0.001962
alternative hypothesis: true location shift is not equal to 0

> wilcox_test_us_eu <- wilcox.test(us_mpg, eu_mpg)
> cat("Wilcoxon Test Results for US vs EU MPG:\n")
Wilcoxon Test Results for US vs EU MPG:
> print(wilcox_test_us_eu)

        Wilcoxon rank sum test with continuity correction

data:  us_mpg and eu_mpg
W = 3279, p-value = 1.957e-14
alternative hypothesis: true location shift is not equal to 0
```

Q2.

1.**4-Cylinder vs. 8-Cylinder (T-Test and Wilcoxon Test):**For the t-test, the p-value is practically zero (p-value < 2.2e-16), which means there's a substantial difference in mpg between these two groups. On average, 4-cylinder cars have significantly higher fuel efficiency, with a mean mpg of approximately 29.28, compared to around 19.97 for 6-cylinder cars.

The Wilcoxon test echoes this finding with an extremely low p-value (p-value < 2.2e-16), confirming a significant difference in fuel efficiency between the groups. In both tests, the p-values are much smaller than the typical significance level of 0.05, strongly suggesting that 4-cylinder cars are more fuel-efficient than their 6-cylinder counterparts by a substantial margin.

2. **4-Cylinder vs. 8-Cylinder (T-Test and Wilcoxon Test):** Both tests show highly significant differences in mpg. The t-test yields a very low p-value (< 2.2e-16), indicating a substantial difference in fuel efficiency. On average, 4-cylinder cars have significantly higher mpg (around 29.28) compared to 8-cylinder cars (approximately 14.96). The Wilcoxon test corroborates this with an equally low p-value (< 2.2e-16), confirming that 4-cylinder cars are considerably more fuel-efficient than 8-cylinder ones.

3. **6-Cylinder vs. 8-Cylinder (T-Test and Wilcoxon Test):** Similar to the previous comparison, both tests indicate significant differences in mpg. The t-test shows a very low p-value (< 2.2e-16), signifying a substantial difference in fuel efficiency. On average, 6-cylinder cars have higher mpg (around 19.97) compared to 8-cylinder cars (approximately 14.96). The Wilcoxon test echoes this finding with a low p-value (< 2.2e-16), confirming that 6-cylinder cars are notably more fuel-efficient than 8-cylinder cars.

In all cases, the p-values are much smaller than the typical significance level of 0.05, strongly indicating significant differences in fuel efficiency between the different cylinder-sized cars. Specifically, 4-cylinder and 6-cylinder cars are more fuel-efficient than their 8-cylinder counterparts by substantial margins.

```
> # Subset the data for cars with 4, 6, and 8 cylinders
> mpg_4cyl <- data[data$cylinders == 4, "mpg"]
> mpg_6cyl <- data[data$cylinders == 6, "mpg"]
> mpg_8cyl <- data[data$cylinders == 8, "mpg"]
> # Perform t-tests to compare mpg between different cylinder counts
> # For example, between 4-cylinder and 6-cylinder cars
> t_test_4vs6 <- t.test(mpg_4cyl, mpg_6cyl)
> cat("T-Test Results for 4-Cylinder vs 6-Cylinder MPG:\n")
T-Test Results for 4-Cylinder vs 6-Cylinder MPG:
> print(t_test_4vs6)

        Welch Two Sample t-test

data:  mpg_4cyl and mpg_6cyl
t = 16.01, df = 223.27, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
  8.164385 10.456466
sample estimates:
mean of x mean of y
 29.28392  19.97349

> # Perform Wilcoxon rank-sum tests as non-parametric alternatives
> wilcox_test_4vs6 <- wilcox.test(mpg_4cyl, mpg_6cyl)
> cat("Wilcoxon Test Results for 4-Cylinder vs 6-Cylinder MPG:\n")
Wilcoxon Test Results for 4-Cylinder vs 6-Cylinder MPG:
> print(wilcox_test_4vs6)

        Wilcoxon rank sum test with continuity correction

data:  mpg_4cyl and mpg_6cyl
W = 15347, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0

> t_test_4vs8 <- t.test(mpg_4cyl, mpg_8cyl)
> cat("T-Test Results for 4-Cylinder vs 6-Cylinder MPG:\n")
T-Test Results for 4-Cylinder vs 6-Cylinder MPG:
> print(t_test_4vs8)

        Welch Two Sample t-test

data:  mpg_4cyl and mpg_8cyl
t = 29.251, df = 299.73, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 13.35737 15.28426
sample estimates:
mean of x mean of y
 29.28392  14.96311

> # Perform Wilcoxon rank-sum tests as non-parametric alternatives
> wilcox_test_4vs8 <- wilcox.test(mpg_4cyl, mpg_8cyl)
> cat("Wilcoxon Test Results for 4-Cylinder vs 6-Cylinder MPG:\n")
Wilcoxon Test Results for 4-Cylinder vs 6-Cylinder MPG:
> print(wilcox_test_4vs8)

        Wilcoxon rank sum test with continuity correction

data:  mpg_4cyl and mpg_8cyl
W = 20338, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0

> 
```

```
> t_test_6vs8 <- t.test(mpg_6cyl, mpg_8cyl)
> cat("T-Test Results for 4-Cylinder vs 6-Cylinder MPG:\n")
T-Test Results for 4-Cylinder vs 6-Cylinder MPG:
> print(t_test_6vs8)

        Welch Two Sample t-test

data:  mpg_6cyl and mpg_8cyl
t = 9.9274, df = 147.39, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 4.012997 6.007778
sample estimates:
mean of x mean of y
 19.97349  14.96311

> # Perform Wilcoxon rank-sum tests as non-parametric alternatives
> wilcox_test_6vs8 <- wilcox.test(mpg_6cyl, mpg_8cyl)
> cat("Wilcoxon Test Results for 4-Cylinder vs 6-Cylinder MPG:\n")
Wilcoxon Test Results for 4-Cylinder vs 6-Cylinder MPG:
> print(wilcox_test_6vs8)

        Wilcoxon rank sum test with continuity correction

data:  mpg_6cyl and mpg_8cyl
W = 7656.5, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0
```

Q3.

Dataset	**Algorithm 1 Accuracy**	**Algorithm 2 Accuracy**	**Algorithm 1 Time (seconds)**	**Algorithm 2 Time (seconds)**
Dataset 1	**0.85**	**0.82**	**120**	**110**
Dataset 2	**0.78**	**0.79**	**95**	**100**
Dataset 3	**0.91**	**0.89**	**150**	**140**
...	**...**	**...**	**...**	**...**
Dataset 10	**0.87**	**0.86**	**125**	**130**

In this table, we have columns for each dataset, showing the average accuracy and running time for both Algorithm 1 and Algorithm 2.

To utilize a t-test for comparing the performance of two machine learning algorithms across multiple datasets, I can employ paired t-tests for each dataset individually. This approach is suitable because I have measurements for the same datasets, and my goal is to directly compare the algorithms within each dataset. Here's how I would go about it:

For each dataset, such as Dataset 1, I would conduct a paired t-test to compare Algorithm 1's accuracy with Algorithm 2's accuracy. Simultaneously, I would conduct a paired t-test to compare Algorithm 1's running time with Algorithm 2's running time.

I would repeat this process for all 10 datasets, conducting paired t-tests separately for accuracy and running time.

After conducting the tests, I would collect the p-values obtained from each paired t-test.

Finally, I would analyze these p-values to determine whether there exist statistically significant differences in performance between the two algorithms. To make this determination, I could use a chosen significance level, such as 0.05. This allows me to decide whether the observed differences are statistically meaningful.

It's important to note that a paired t-test assumes certain conditions, including the normal distribution of data and the approximate normal distribution of differences between the two algorithms. If these assumptions are not met, I might explore alternative non-parametric tests like the Wilcoxon signed-rank test.