EE5373: Data Modeling Using R

Fall 2025

LAB 4 REPORT

Multiple Linear Regression

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1 Model 1: int95 Benchmark

1.1 Pair-wise Comparisons

Note: column L3cache had to be dropped before pairwise comparison could be done.

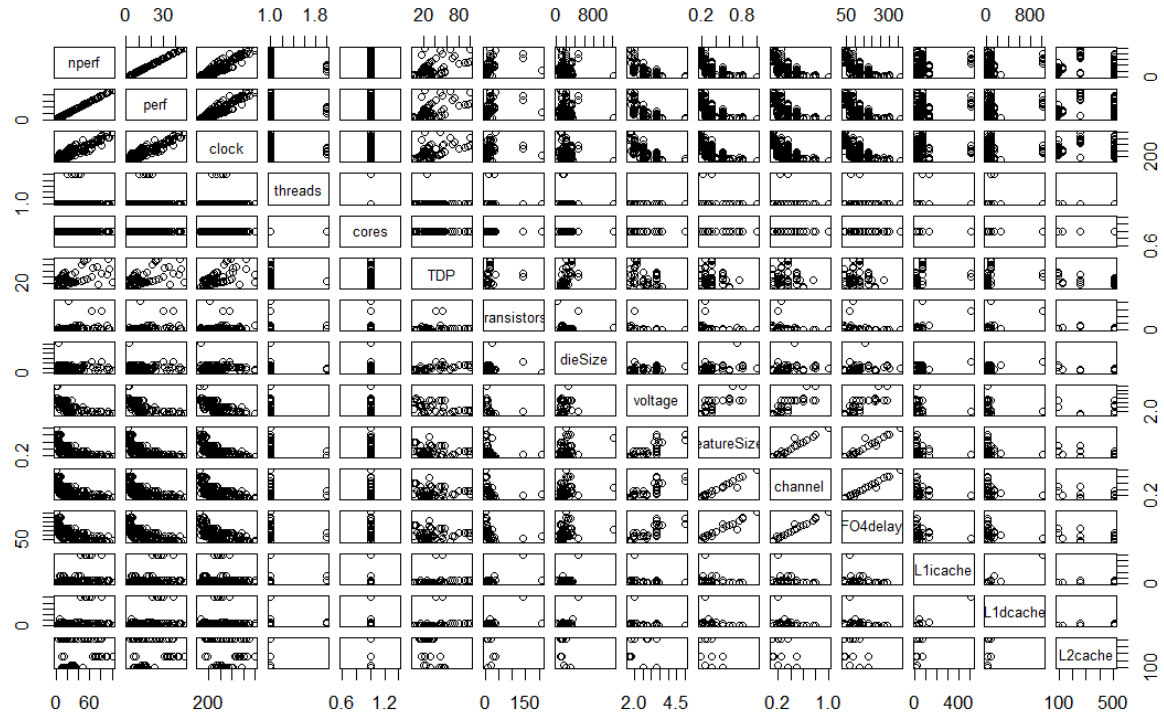

Figure 1: Pair-wise comparisons for int95 benchmark

1.2 Potential Predictors

I planned to use almost all variables except for the following:

1. L1dcache removed as all data point are 64
2. L2cache removed as all data point are 512
3. Threads and cores removed as all data point are 1

1.3 Backward Elimination Process

- **Step 1:** Eliminated transistors with p-value = 0.57891
- **Step 2:** Eliminated channel with p-value = 0.37887

1.4 Final Model

1.4.1 Model Equation

The final regression model for int95 benchmark performance is:

$$\hat{y}_{int95} = -20.848 + 0.0864 \cdot \text{clock} + 0.0197 \cdot \text{dieSize} - 3.055 \cdot \text{voltage} + 83.991 \cdot \text{featureSize} - 0.230 \cdot \text{FO4delay} - 0.141 \cdot \text{L1icache} + 5.091 \cdot \sqrt{\text{L1icache}}$$

1.4.2 Coefficients and Significance

```
Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)   -20.847819   4.769051  -4.371 3.21e-05 ***
clock           0.086435   0.003767  22.946  < 2e-16 ***
dieSize         0.019719   0.008139   2.423 0.017333 *
voltage        -3.054909   1.496346  -2.042 0.044026 *
featureSize    83.990853  23.847477   3.522 0.000666 ***
FO4delay       -0.230491   0.061426  -3.752 0.000305 ***
L1icache       -0.141105   0.025469  -5.540 2.80e-07 ***
sqrt(L1icache)  5.091441   0.588400   8.653 1.44e-13 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 2: Final model coeffieicient for int95 benchmark

1.5 Model Quality Evaluation

1.5.1 Overall Model Statistics

- Residual Standard Error: 5.399 on 93 degrees of freedom
- Multiple R-squared: 0.954
- Adjusted R-squared: 0.9505
- F-statistic: 275.4 on 7 and 93 DF (p-value: $<$ 2.2e-16)

1.5.2 Residual Analysis

Residual Analysis: The residuals are not normally distributed around 0, as indicated by the red line. The Q-Q plot shows that the residuals indicate a strong right skew for higher values but general normal conformity. All predictors are statistically significant ($p < 0.05$), and the model explains 95.05 % of the variance in performance (adjusted $R^2 = 0.9505$) with

an overall significance confirmed by the F-statistic ($p < 2.2e\text{-}16$).

Conclusion: Hence, it is a good fit and a reliable inference.

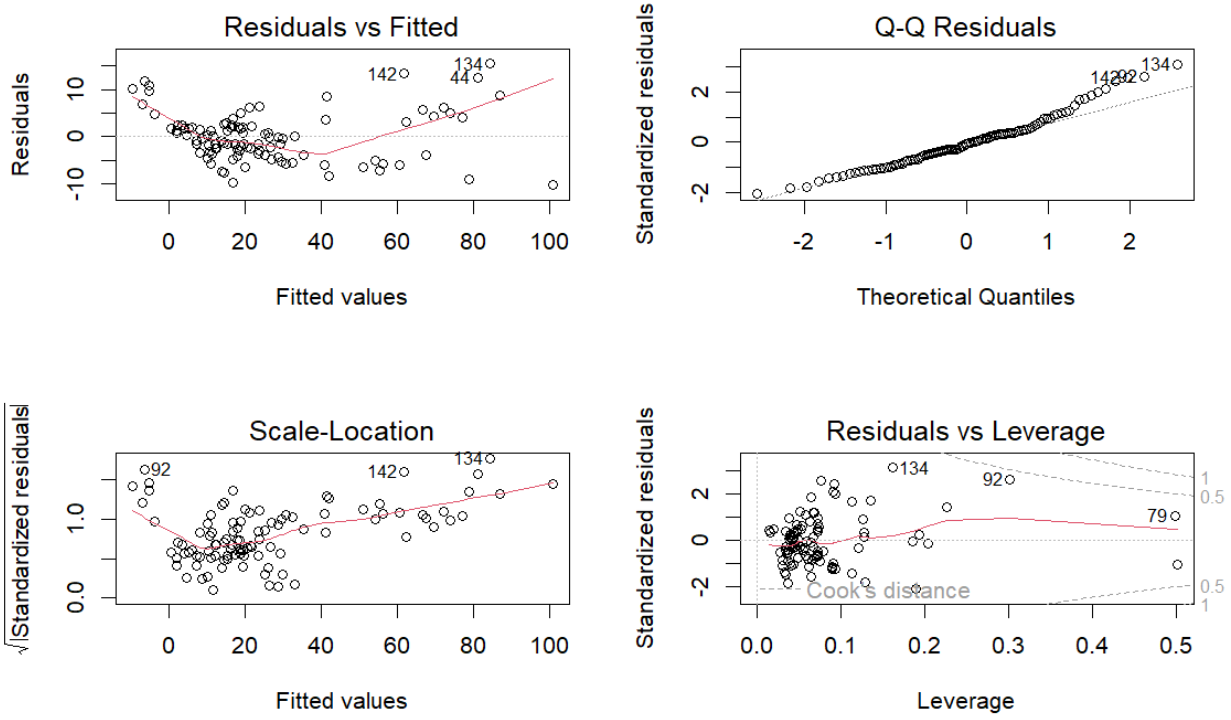

Figure 3: Residual analysis for int95 model

2 Model 2: int06 Benchmark

2.1 Pair-wise Comparisons

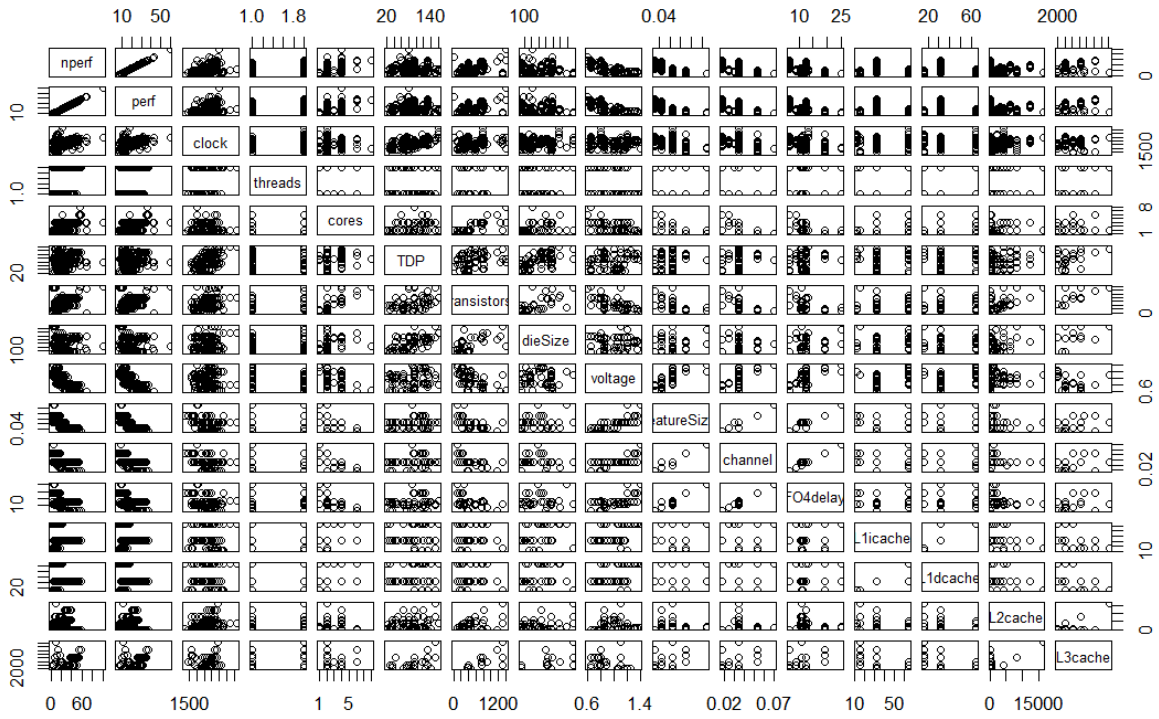

Figure 4: Pair-wise comparisons for int06 benchmark

2.2 Potential Predictors

I started with all variable except TDP.

2.3 Backward Elimination Process

1. **Step 1:** Eliminated sqrt(L1icache) with p-value = NA as I suspected it caused multi-collinearity
2. **Step 2:** Eliminated sqrt(L1dcache) and L1dcache with p-value = NA
3. **Step 3:** Eliminated cores with p-value = 0.974348
4. **Step 4:** Eliminated dieSize with p-value = 0.119823
5. **Step 5:** Eliminated threads with p-value = 0.218503

2.4 Final Model

2.4.1 Model Equation

$$\begin{aligned}\hat{y}_{int06} = &-91.85 + 0.01323 \cdot \text{clock} + 0.06592 \cdot \text{transistors} - 14.26 \cdot \text{voltage} \\ &+ 3211 \cdot \text{featureSize} - 21060 \cdot \text{channel} + 50.73 \cdot \text{FO4delay} \\ &- 1.337 \cdot \text{L1icache} + 0.02499 \cdot \text{L2cache} - 3.619 \cdot \sqrt{\text{L2cache}} \\ &- 0.02385 \cdot \text{L3cache} + 3.350 \cdot \sqrt{\text{L3cache}}\end{aligned}$$

2.4.2 Coefficients and Significance

```
Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)   -9.185e+01  3.530e+01  -2.602 0.012576 *
clock          1.323e-02  1.024e-03  12.922  < 2e-16 ***
transistors    6.592e-02  1.792e-02   3.678 0.000636 ***
voltage       -1.426e+01  6.478e+00  -2.201 0.032998 *
featureSize    3.211e+03  8.095e+02   3.967 0.000265 ***
channel       -2.106e+04  4.863e+03  -4.330 8.49e-05 ***
FO4delay       5.073e+01  1.234e+01   4.111 0.000169 ***
L1icache      -1.337e+00  2.182e-01  -6.128 2.19e-07 ***
L2cache        2.499e-02  8.251e-03   3.029 0.004096 **
sqrt(L2cache) -3.619e+00  1.186e+00  -3.050 0.003862 **
L3cache       -2.385e-02  7.856e-03  -3.036 0.004013 **
sqrt(L3cache)  3.350e+00  1.085e+00   3.088 0.003481 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 5: Final model coeffieicient for int06 benchmark

2.5 Model Quality Evaluation

2.5.1 Overall Model Statistics

- Residual Standard Error: 2.151 on 44 degrees of freedom
- Multiple R-squared: 0.9838
- Adjusted R-squared: 0.9797
- F-statistic: 242.2 on 11 and 44 DF (p-value: $<$ 2.2e-16)

2.5.2 Residual Analysis

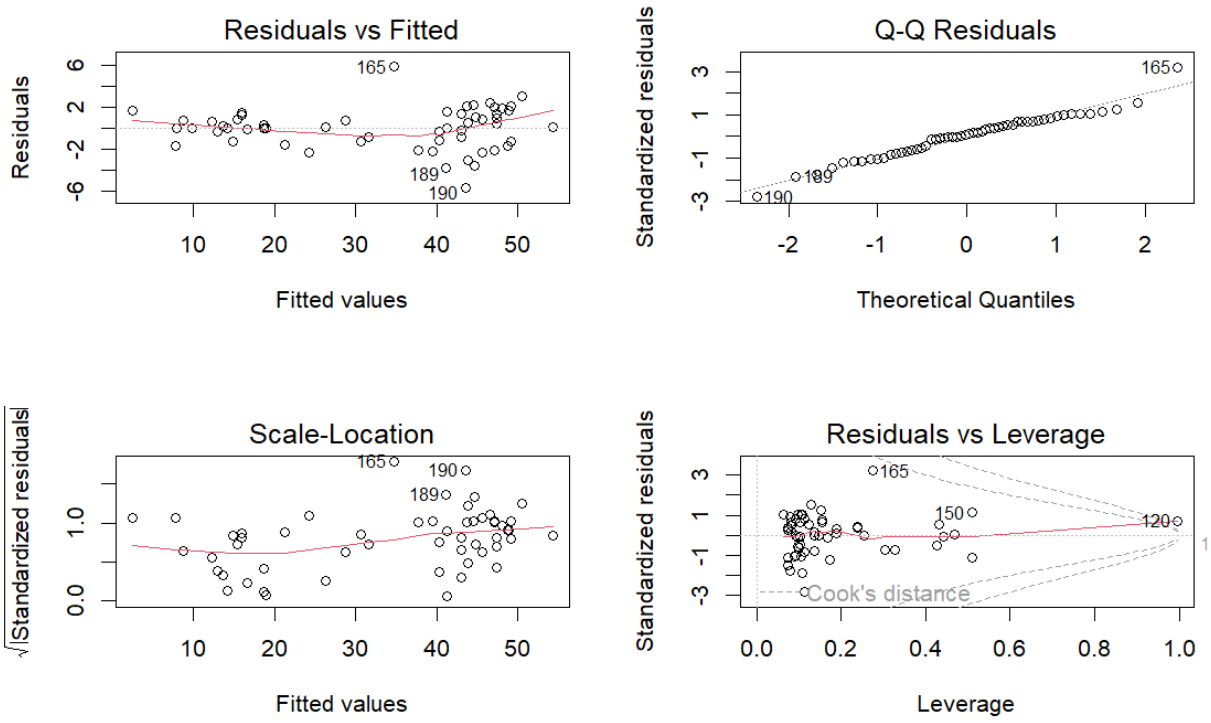

Figure 6: Residual analysis for int06 model

Residual Analysis: The residuals exhibit a uniform distribution around 0 in and approximate normality in the Q-Q plot. All predictors are statistically significant ($p < 0.05$), and the model explains 97.97 % of the variance in performance (adjusted $R^2 = 0.9797$) with an overall significance confirmed by the F-statistic ($p < 2.2e\text{-}16$).

Conclusion: Hence it is an excellent fit and reliable inference.

3 Model 3: fp95 Benchmark

3.1 Pair-wise Comparisons

Note: L3cache had to be removed due to all NA values

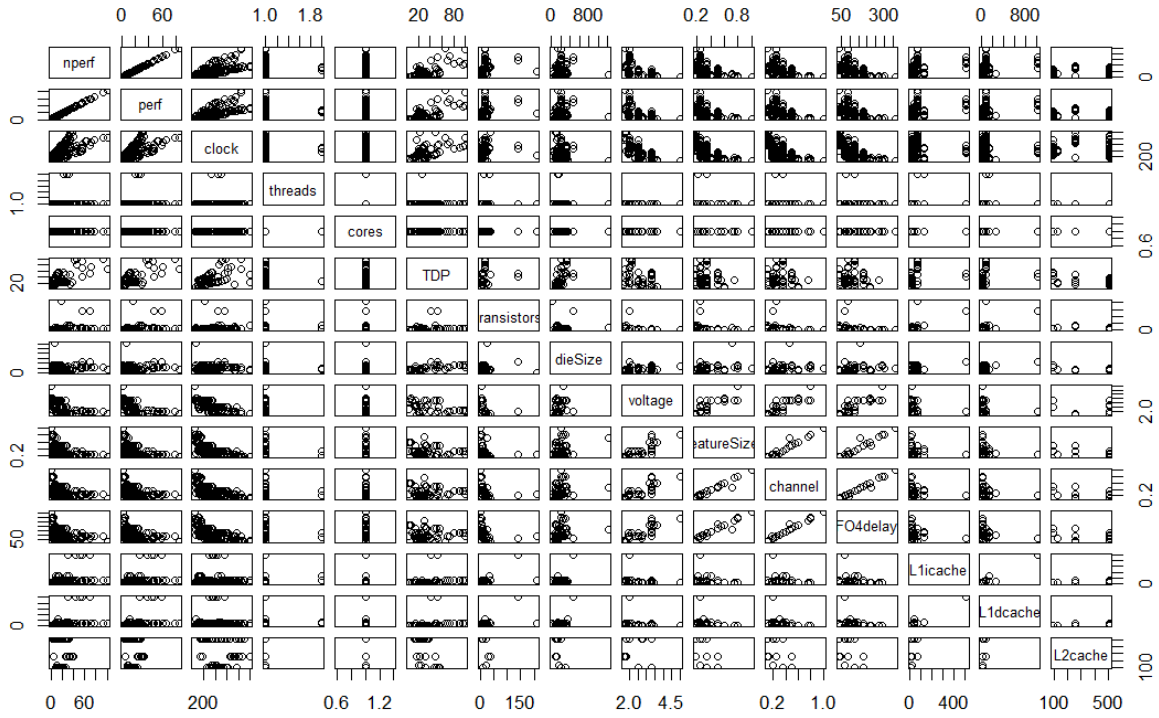

Figure 7: Pair-wise comparisons for fp95 benchmark

3.2 Potential Predictors

I kept all predictor initially except TDP and L3cache.

1. **Step 1:** Eliminated cores with p-value = NA, as all data was 172
2. **Step 2:** Eliminated L2cache and sqrt(L2cache) with p-value = NA as it only had 4 unique values
3. **Step 3:** Eliminated featureSize with p-value = 0.86678
4. **Step 4:** Eliminated channel with p-value = 0.81853
5. **Step 5:** Eliminated L1icache with p-value = 0.6879
6. **Step 6:** Eliminated FO4delay with p-value = 0.686
7. **Step 7:** Eliminated sqrt(L1dcache) with p-value = 0.2848

3.3 Final Model

3.3.1 Model Equation

$$\hat{y}_{fp95} = -19.877 + 0.08923 \cdot \text{clock} - 1.488 \cdot \text{transistors} + 0.07436 \cdot \text{dieSize} - 5.329 \cdot \text{voltage} + 3.306 \cdot \sqrt{\text{L1icache}} + 0.1443 \cdot \text{L1dcache}$$

3.3.2 Coefficients and Significance

```
Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)    -19.87652    7.46354  -2.663  0.00945 **
clock            0.08923    0.00874  10.209 6.70e-16 ***
transistors     -1.48758    0.30491  -4.879 5.74e-06 ***
dieSize          0.07436    0.01431   5.196 1.66e-06 ***
voltage         -5.32855    2.26982  -2.348  0.02150 *
sqrt(L1icache)   3.30620    0.75650   4.370 3.88e-05 ***
L1dcache         0.14428    0.04676   3.086  0.00283 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 8: Final model coeffieicient for fp95 benchmark

3.4 Model Quality Evaluation

3.4.1 Overall Model Statistics

- Residual Standard Error: 8.195 on 76 degrees of freedom
- Multiple R-squared: 0.8675
- Adjusted R-squared: 0.857
- F-statistic: 82.92 on 6 and 76 DF (p-value: $< 2.2e\text{-}16$)

3.4.2 Residual Analysis

Residual Analysis: The model shows residuals approximately uniformly distributed around 0 in and approximate normality in the Q-Q plot. All predictors are statistically significant ($p < 0.05$), and the model explains 85.7 % of the variance in performance (adjusted $R^2 = 0.857$) with an overall significance confirmed by the F-statistic ($p < 2.2e\text{-}16$).

Conclusion: Hence, it is a good fit.

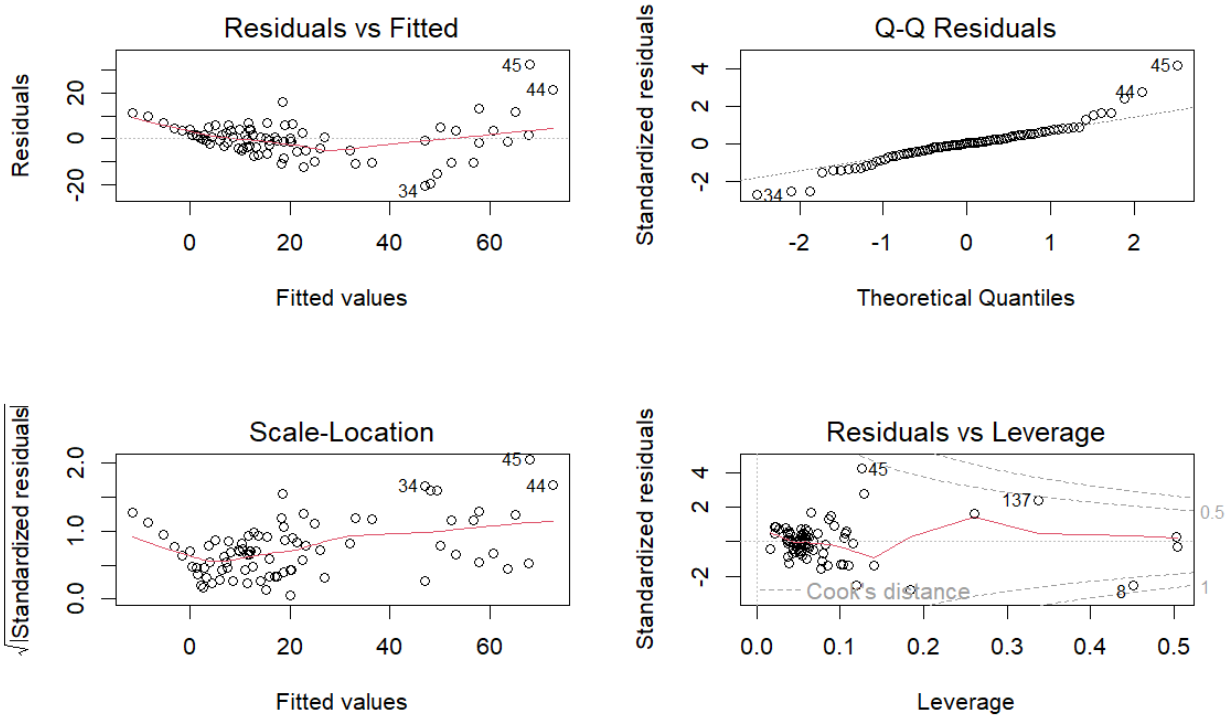

Figure 9: Residual analysis for fp95 model

4 Model 4: fp06 Benchmark

4.1 Pair-wise Comparisons

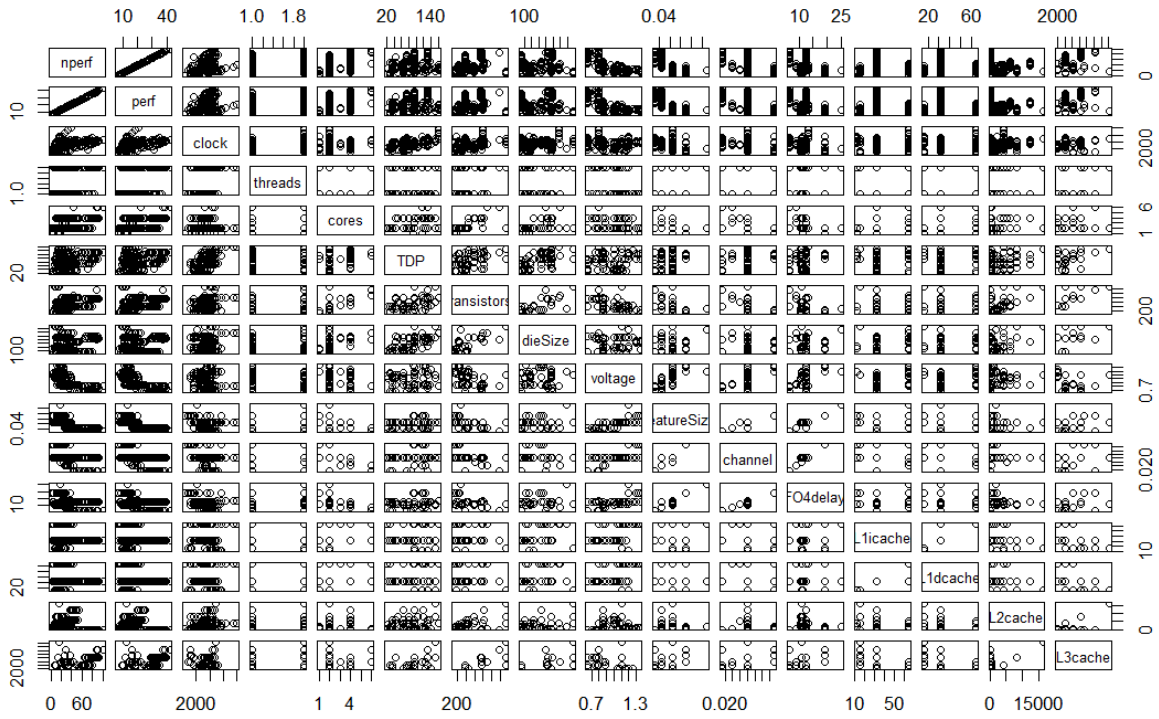

Figure 10: Pair-wise comparisons for fp06 benchmark

4.2 Potential Predictors

I started with all variables except TDP.

4.3 Backward Elimination Process

1. **Step 1:** Eliminated L1dcache and sqrt(L1dcache) with p-value = NA as only three unique values and hence not variable enough.
2. **Step 2:** Eliminated sqrt(L1icache) with p-value = NA as only 4 unique values and 70% of its data is concentrated at one point.
3. **Step 3:** Eliminated threads with p-value = 0.6433
4. **Step 4:** Eliminated dieSize with p-value = 0.60186
5. **Step 5:** Eliminated cores with p-value = 0.4698

6. **Step 6:** Eliminated voltage with p-value = 0.07188

4.4 Final Model

4.4.1 Model Equation

$$\begin{aligned}\hat{y}_{fp06} = &-181.8 + 0.01911 \cdot \text{clock} + 0.1295 \cdot \text{transistors} + 5339 \cdot \text{featureSize} \\ &- 38810 \cdot \text{channel} + 95.04 \cdot \text{FO4delay} - 2.491 \cdot \text{L1icache} \\ &+ 0.04989 \cdot \text{L2cache} - 7.010 \cdot \sqrt{\text{L2cache}} - 0.04871 \cdot \text{L3cache} \\ &+ 6.708 \cdot \sqrt{\text{L3cache}}\end{aligned}$$

4.4.2 Coefficients and Significance

```
Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)   -1.818e+02  5.750e+01  -3.162 0.002773 **
clock          1.911e-02  2.297e-03   8.316 1.02e-10 ***
transistors    1.295e-01  2.767e-02   4.679 2.56e-05 ***
featureSize    5.339e+03  1.437e+03   3.716 0.000546 ***
channel       -3.881e+04  9.695e+03  -4.004 0.000225 ***
FO4delay       9.504e+01  2.567e+01   3.702 0.000571 ***
L1icache      -2.491e+00  3.837e-01  -6.491 5.30e-08 ***
L2cache        4.989e-02  1.353e-02   3.687 0.000597 ***
sqrt(L2cache) -7.010e+00  2.062e+00  -3.399 0.001405 **
L3cache       -4.871e-02  1.220e-02  -3.993 0.000233 ***
sqrt(L3cache)  6.708e+00  1.735e+00   3.865 0.000346 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 11: Final model coeffieicient for fp06 benchmark

4.5 Model Quality Evaluation

4.5.1 Overall Model Statistics

- Residual Standard Error: 4.96 on 46 degrees of freedom
- Multiple R-squared: 0.9708
- Adjusted R-squared: 0.9644
- F-statistic: 152.9 on 10 and 46 DF (p-value: $<$ 2.2e-16)

4.5.2 Residual Analysis

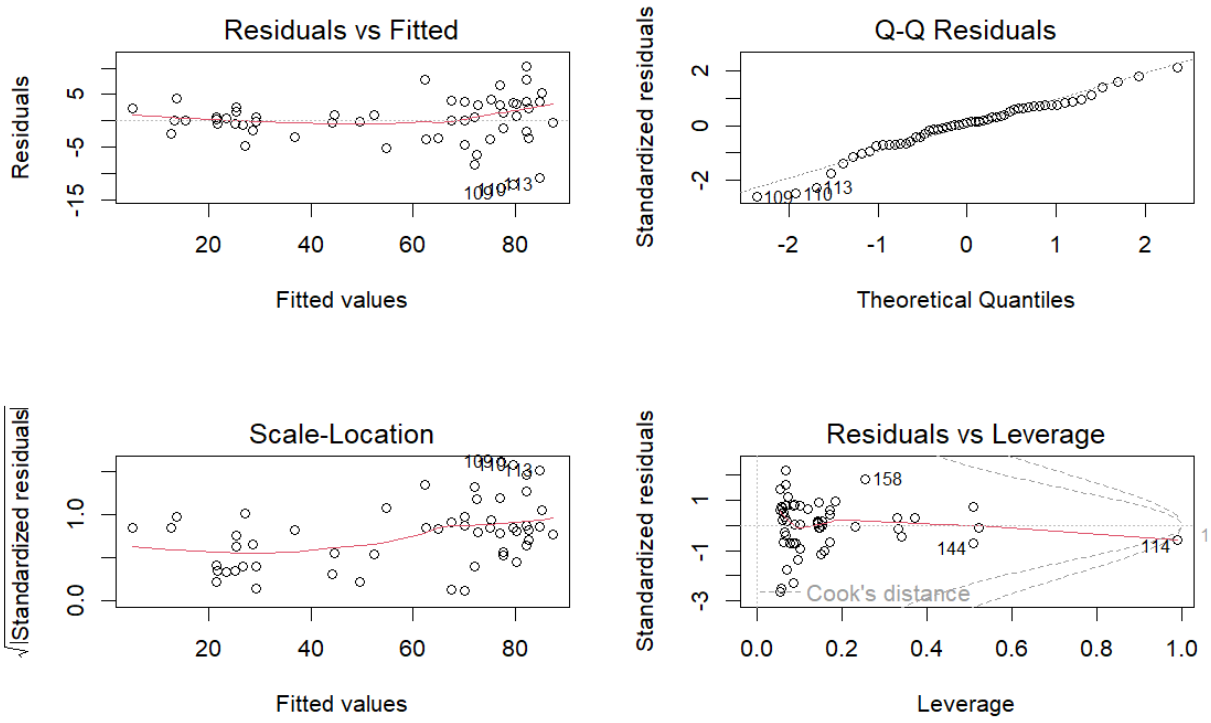

Figure 12: Residual analysis for fp06 model

Residual Analysis: The residuals are uniformly distributed around 0. There is approximate normality in the Q-Q plot, with a left skew for the first 10-20% of the data. All predictors are statistically significant ($p < 0.05$), and the model explains 96.44 % of the variance in performance (adjusted $R^2 = 0.8644$) with an overall significance confirmed by the F-statistic ($p < 2.2e\text{-}16$).

Conclusion: Hence, it is an excellent fit and reliable inference.