Practical 4: Trend Analysis of US Population Time Series

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Practical 4: Trend Analysis of US Population Time Series

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1. Title

For a given dataset of the US Population (in millions), write the R code to: (a) Import the data as a time series object. (b) Identify the dominating component(s) in the data set. (c) Apply a square root transformation to the original data set. (d) Estimate the linear trend present in the data set. (e) Remove the estimated linear trend from the data set.

Year Population 1970 3929214 1971 5308483 1972 7239881 1973 9638453 1974 12860702 1975 17063353 1976 23191876 1977 31443321 1978 38558371 1979 50189209 1980 62979666 1981 76212168 1982 92228496 1983 106021537 1984 123202624 1985 132164569 1986 151325798 1987 179323175 1988 203302031 1989 226542203 1990 248709873 —

2. Objective

To analyze the US population time series by applying transformation, estimating the trend using linear regression, and examining the detrended series.

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3. R Code

```
# Clear workspace
rm(list = ls())

library(forecast)

year <- 1970:1990
population <- c(
  3929214, 5308483, 7239881, 9638453, 12860702,
```

```
  17063353, 23191876, 31443321, 38558371, 50189209,
  62979666, 76212168, 92228496, 106021537, 123202624,
  132164569, 151325798, 179323175, 203302031,
  226542203, 248709873
)

population_ts <- ts(population, start = 1970, frequency = 1)

plot(population_ts,
     main = "US Population Time Series",
     xlab = "Year",
     ylab = "Population")
```

```
population_sqrt <- sqrt(population_ts)

plot(population_sqrt,
     main = "Square Root Transformed Population",
     xlab = "Year",
     ylab = "Sqrt(Population)")
```

```
time_index <- time(population_ts)
trend_model <- lm(population_ts ~ time_index)

summary(trend_model)

estimated_trend <- trend_model$fitted.values

plot(population_ts,
     main = "US Population with Estimated Trend",
     xlab = "Year",
     ylab = "Population")
lines(estimated_trend, col = "red", lwd = 2)
```

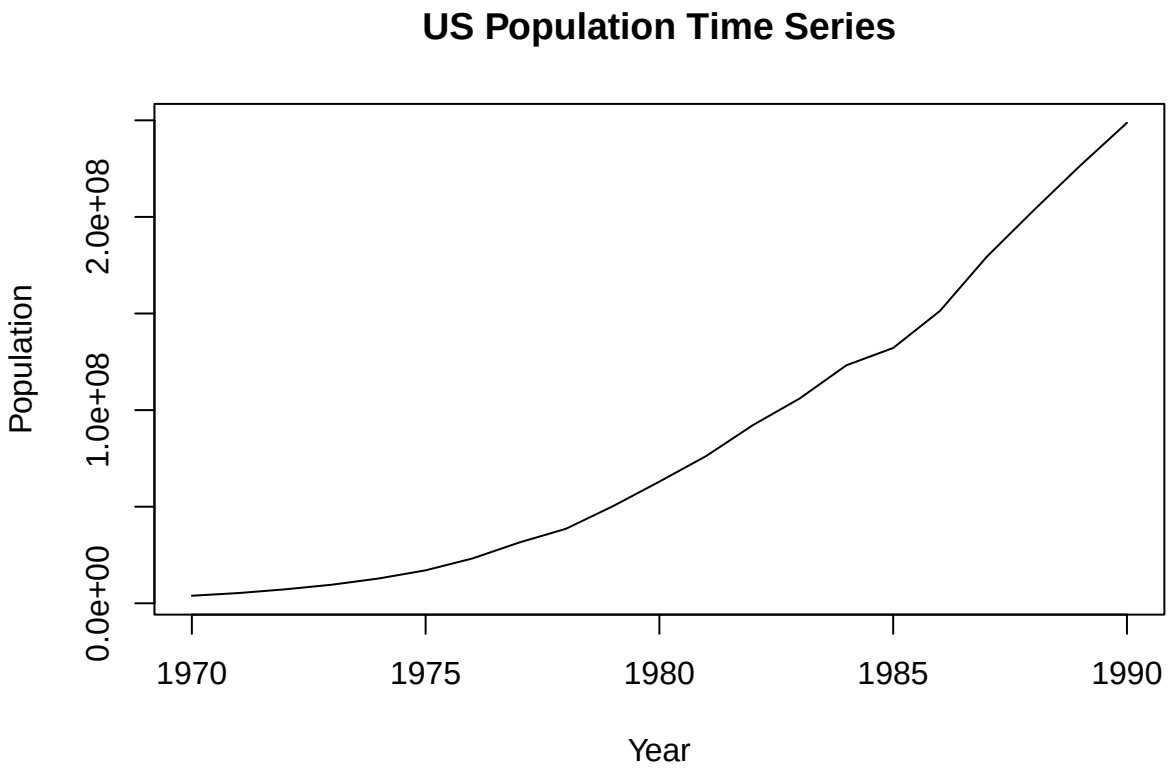
```
detrended_population <- population_ts - estimated_trend

plot(detrended_population,
     type = "o",
     main = "Detrended US Population",
     xlab = "Year",
     ylab = "Population (Detrended)")
```

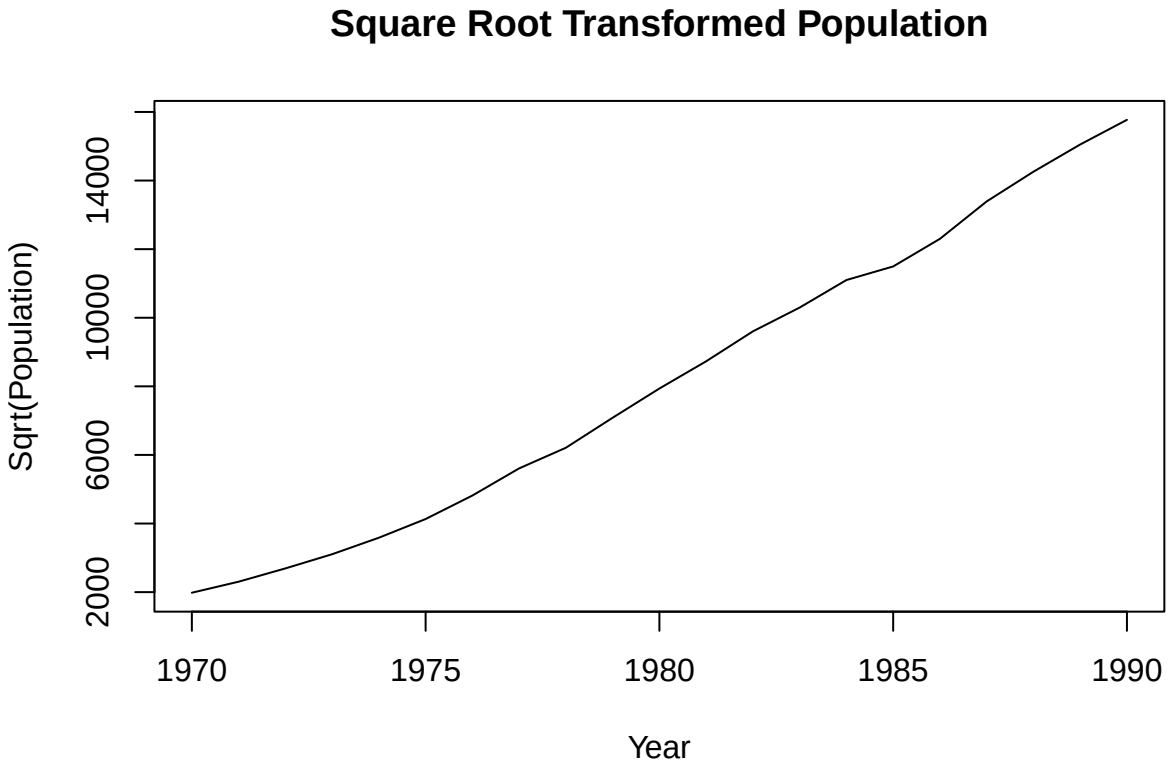
---

4. Output

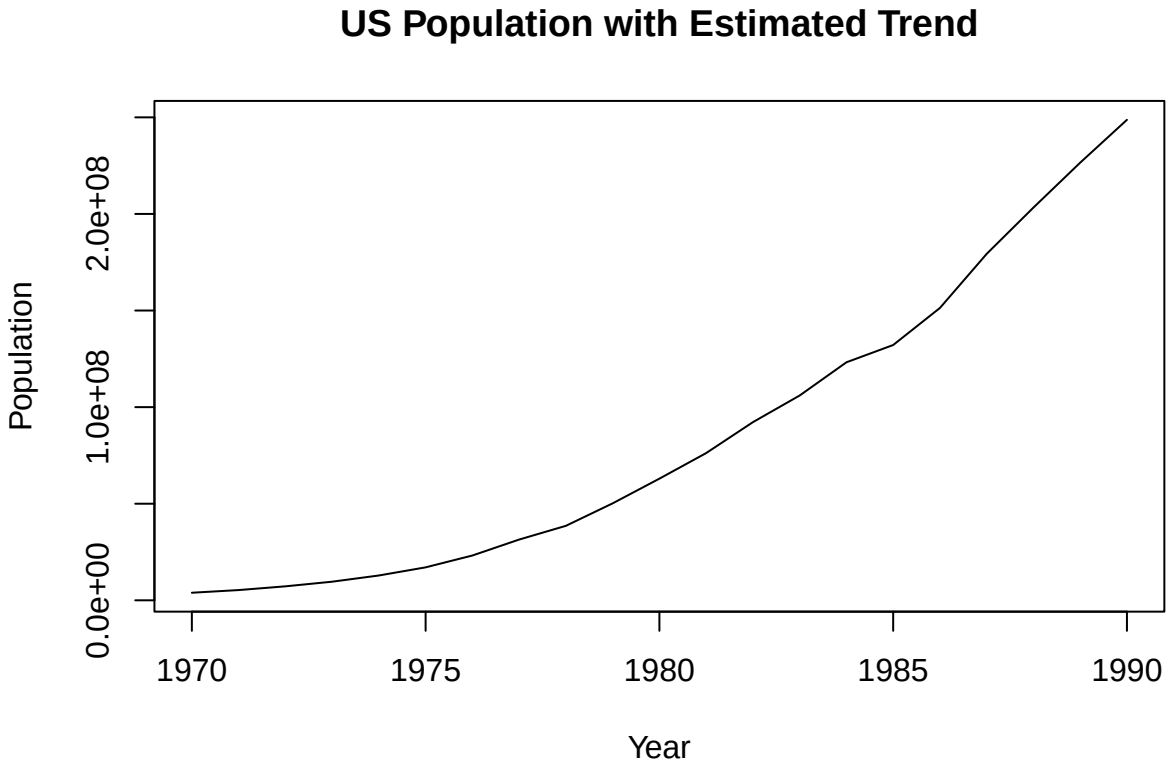
Original Time Series



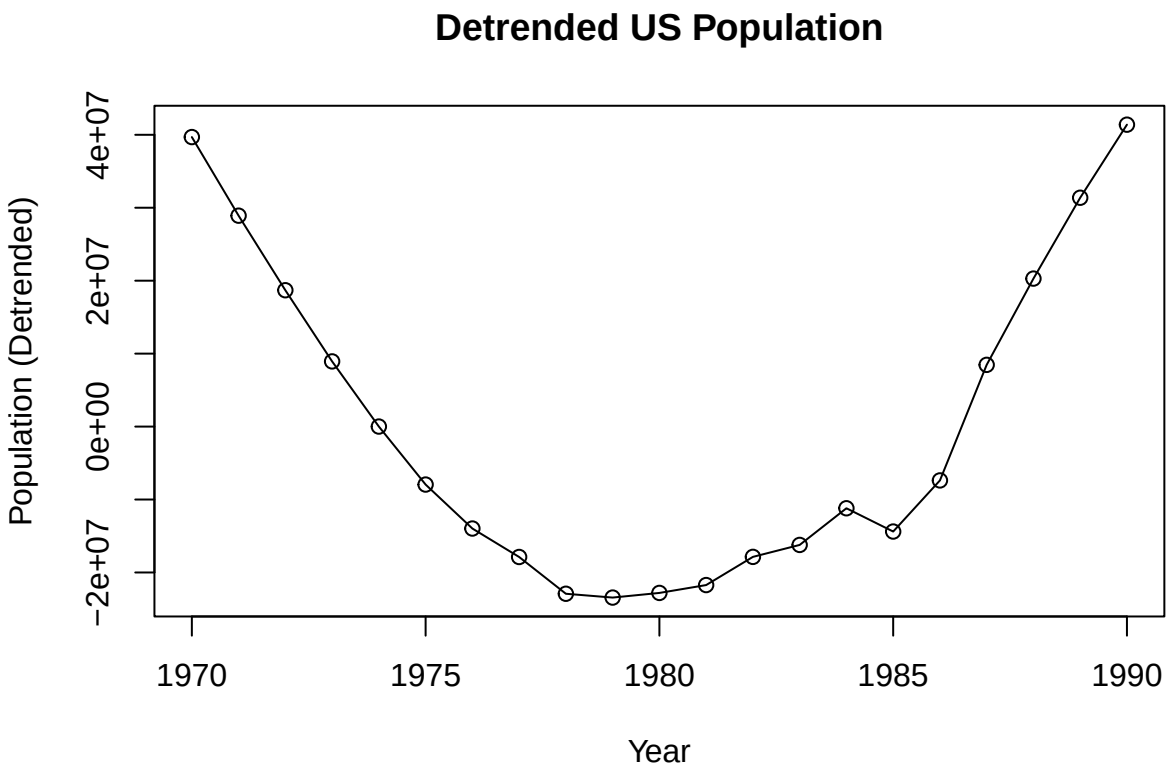
Square Root Transformation



Estimated Trend with Regression Line



Detrended Time Series



Regression Model Summary

```
##
## Call:
## lm(formula = population_ts ~ time_index)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -23439335 -17862273  -7948891  18689863  41386503
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) -2.398e+10  1.607e+09  -14.92 6.02e-12 ***
## time_index   1.215e+07  8.115e+05   14.98 5.65e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 22520000 on 19 degrees of freedom
## Multiple R-squared:  0.9219, Adjusted R-squared:  0.9178
## F-statistic: 224.3 on 1 and 19 DF,  p-value: 5.651e-12
```

5. Conclusion

The US population time series shows a strong upward linear trend. The square root transformation stabilizes variation in the data. Linear regression effectively estimates the trend component, and detrending removes long-term growth, allowing clearer observation of fluctuations. This analysis demonstrates how transformation and trend estimation help in understanding time series structure.