Visualizing Data Center Temperature in R

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This is a hypothetical examination of a typical data center environment based on my 10+ years working in facilities as a data scientist. This examination performed in R looks at trends that one might see when examining temperature trends in a data center.

We Examine:

- Differences between isle and inlet temperature
- Rack location within a row and the influence on temperature
- Does location influence temperature differential between isle and inside a server
- What are the differences among temperatures for various server platforms, and their location in the isle?

Start by importing our libraries

[ ]:
```
library("dplyr")
library("ggplot2")
library("tidyverse")
library("openxlsx")
options(repr.plot.width=20, repr.plot.height=8)
```

Ingest Data

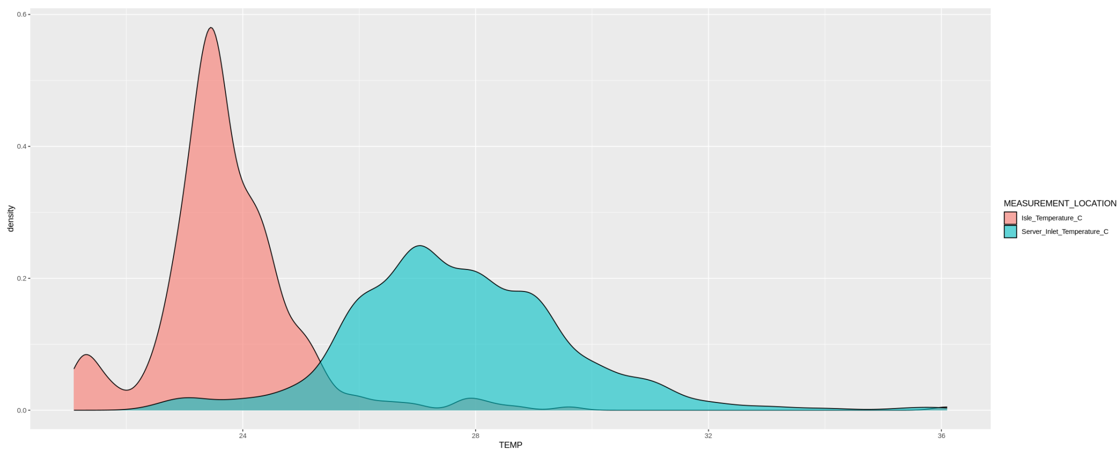
[18]:
```
df <- read.xlsx('DC_DATA.xlsx', sheet='Data', detectDates=TRUE)
df <- pivot_longer(df, cols=9:10, names_to="MEASUREMENT_LOCATION",␣
 ↪values_to="TEMP")
original_df <- read.xlsx('DC_DATA.xlsx', sheet='Data', detectDates=TRUE)
#Set DIFF values that are below 0 to 0
df$Temperature_Difference[df$Temperature_Difference < 0] <- 0
original_df$Temperature_Difference[original_df$Temperature_Difference < 0] <- 0
# Convert the rack positions to numbers
original_df$RACK_POS_NUM <- unclass(factor(original_df$Rack_Position))

df$RACK_POS_NUM <- unclass(factor(df$Rack_Position))
```

The overall shape of the distributions of external and internal temperatures.

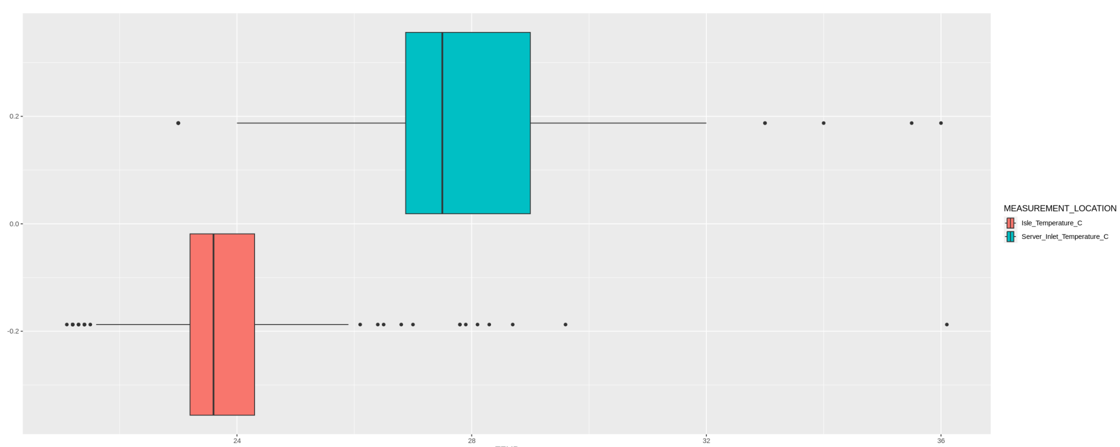
- External measurements are much tighter with less variance

[8]:
```
ggplot(df, aes(TEMP, fill = MEASUREMENT_LOCATION)) + geom_density(alpha=0.6)
```



Boxplot measurements are another greaet way of visualizing the data. It's easier to see the outliers, too.

[10]:
```
ggplot(df, aes(TEMP, fill = MEASUREMENT_LOCATION)) + geom_boxplot()
```

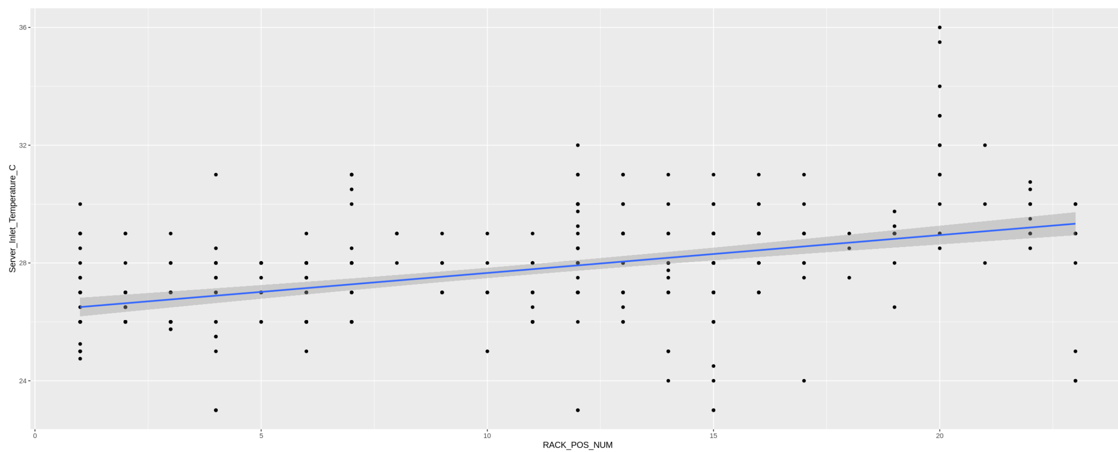


[ ]:
```
```

Let's take a look at if there are any trends of average temperatures based on position within the row

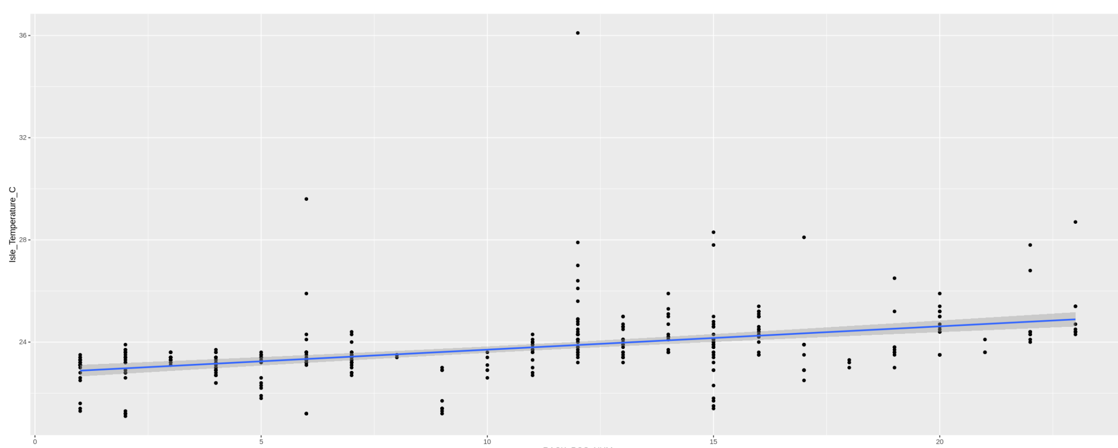
What we can see is the higher the number in rack position, the higher the temperature is. This is because in this particular configuration the isle is cooled from rack position 1 upward with blowers at the start of all the rows.

[11]:
```
ggplot(original_df, aes(x=RACK_POS_NUM, y=Server_Inlet_Temperature_C)) +
    geom_point() +
    geom_smooth(method=lm) #add linear trend line
```



[12]:
```
ggplot(original_df, aes(x=RACK_POS_NUM, y=Isle_Temperature_C)) +
    geom_point() +
    geom_smooth(method=lm) #add linear trend line
```

```
`geom_smooth()` using formula = 'y ~ x'
```



Let's generate a list of the averages by row just so we have them, using dplyr

[14]:
```
averages <- original_df %>%
    group_by(RACK_POS_NUM) %>%
    dplyr::summarize(Mean = mean(Isle_Temperature_C))
```

[39]:
```
averages
```

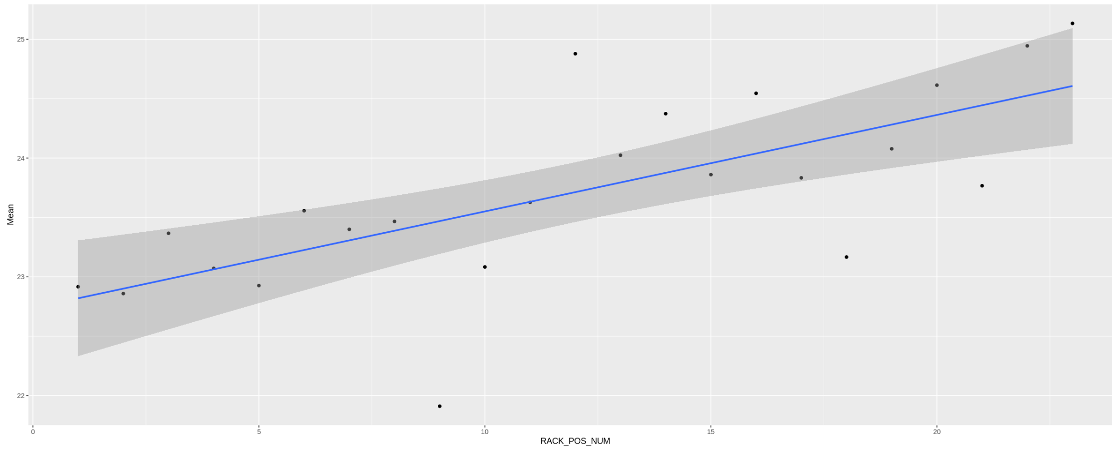
A tibble: 23 × 2

RACK_POS_NUM <int>	Mean <dbl>
1	22.91667
2	22.85926
3	23.36667
4	23.07143
5	22.92667
6	23.55652
7	23.40000
8	23.46667
9	21.91111
10	23.08333
11	23.62667
12	24.87813
13	24.02381
14	24.37333
15	23.86061
16	24.54500
17	23.83333
18	23.16667
19	24.07778
20	24.61333
21	23.76667
22	24.94444
23	25.13333

Again these averages trend upward

[15]:
```
ggplot(averages, aes(x=RACK_POS_NUM, y=Mean)) +
    geom_point() +
    geom_smooth(method=lm) #add linear trend line
```

```
`geom_smooth()` using formula = 'y ~ x'
```



We can do a simple linear model to express this

[38]:
```
model <- lm(original_df$EXTERNAL_TEMP_C~original_df$RACK_POS_NUM)
summary(model)
```

```
Call:
lm(formula = original_df$EXTERNAL_TEMP_C ~ original_df$RACK_POS_NUM)

Residuals:
    Min      1Q  Median      3Q     Max 
-2.7595 -0.4857 -0.0157  0.4143 12.2143 

Coefficients:
                         Estimate Std. Error t value Pr(>|t|)    
(Intercept)              22.79074    0.12342 184.660   <2e-16 ***
original_df$RACK_POS_NUM  0.09125    0.01012   9.015   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.207 on 355 degrees of freedom
Multiple R-squared:  0.1863,	Adjusted R-squared:  0.184 
F-statistic: 81.27 on 1 and 355 DF,  p-value: < 2.2e-16
```

Can we use the internal temperature sensors on a server to determine the ambient temperature of a room?

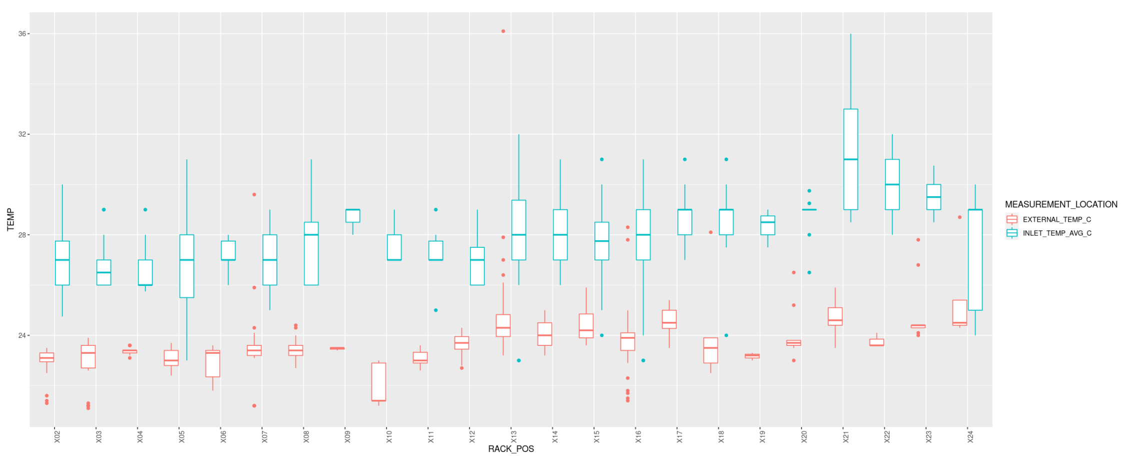
The answer is really no. Based on my experience, there's too much variation and theoretically, the server itself can be creating an 'oven' effect based on the load of the system on those sensors.

Charts

- Variance in the spread of temperature data of internal probes, they are very wide, the variation in temperature of the isle is very low
- Temperature is not dependent on the elevation location of a server on a rack
- Difference does not matter based on where in the row it is

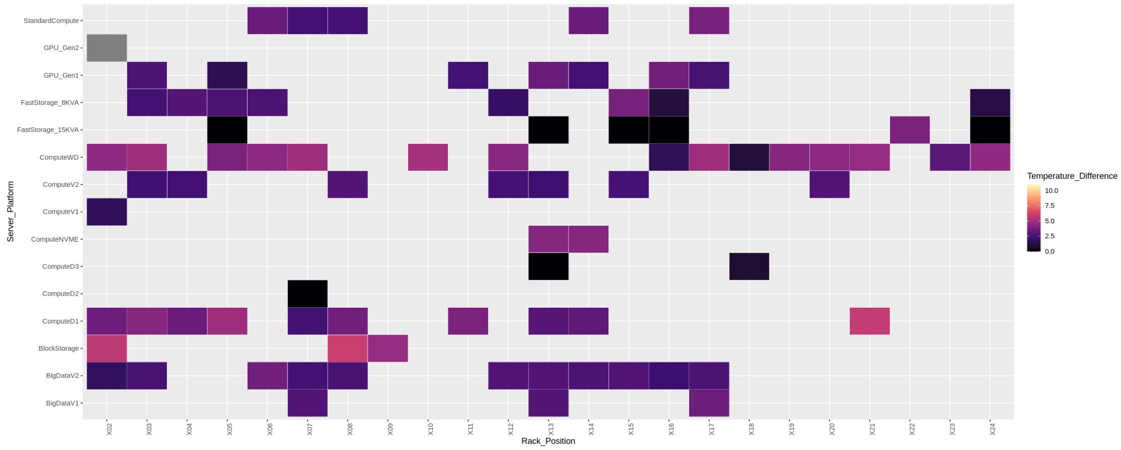
The inlet temperatures do have a greater variation. This is an interesting plot showing the offset and distribution of inlet temperature and external measured temperature

[136]:
```
ggplot(df, aes(x=RACK_POS, y=TEMP, color=MEASUREMENT_LOCATION)) + geom_boxplot() + theme(axis.text.x = element_text(angle = 90))
```



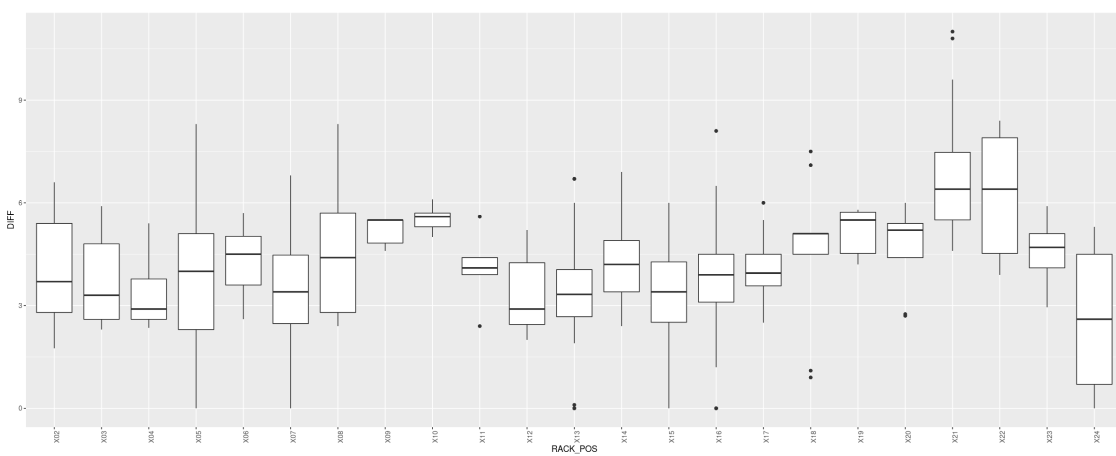
Is the temperature difference dependent on location in the row, by platform? No. We can see there's no discernable pattern across the rack positions

[20]:
```
ggplot(df, aes(Rack_Position, Server_Platform)) +
  geom_tile(aes(fill = Temperature_Difference), colour = "white") +
    scale_fill_viridis_c(option = "magma") +
 theme(axis.text.x = element_text(angle = 90))
```



Difference in Temperature by Rack Position

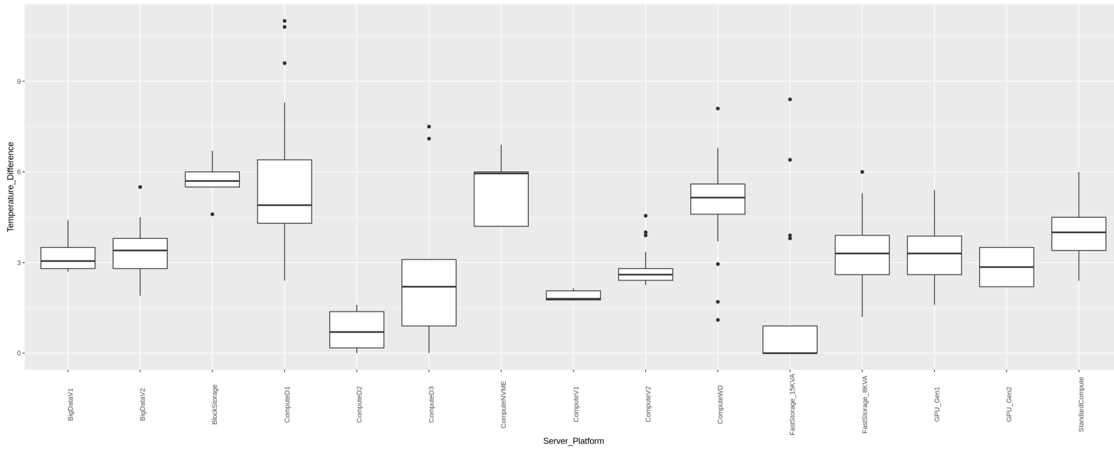
[148]:
```
ggplot(df, aes(x=RACK_POS, y=DIFF)) + geom_boxplot() + theme(axis.text.x =
    element_text(angle = 90))
```



Difference in Temperature by Platform

Different platforms run different loads, and because of configuration generate different amounts of heat.

[35]:
```
ggplot(df, aes(x=Server_Platform, y=Temperature_Difference)) + geom_boxplot() +
    theme(axis.text.x = element_text(angle = 90))
```



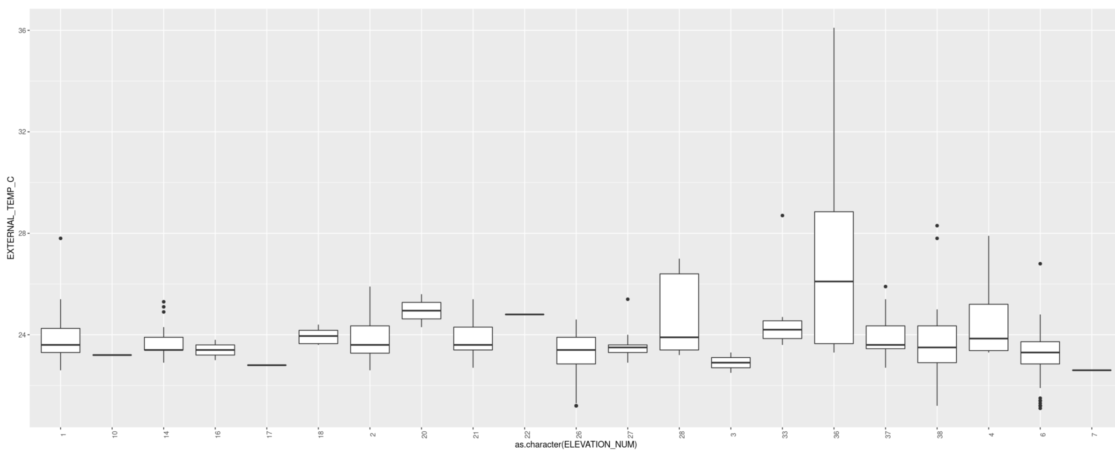
Temperature Variation by location within a rack

Variations exist in temperature by elevation at the front of a rack directly at the server's air intake.

Racks tend to have network switches mounted towards the top. Hot air containment is not as good because of the gaps created for cabling and it tends to get recirculated from rear to the front of the servers.

[ ]:
```
p <- ggplot(original_df, aes(x=as.character(ELEVATION_NUM), y=EXTERNAL_TEMP_C))␣
↪+ geom_boxplot() + theme(axis.text.x = element_text(angle = 90))
```

[ ]:
```
p
```



Thank you for taking the time to read my research!

Feel free to reach out if you have any questions

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