# applyIMRMC

In this file, we will apply iMRMC on the reader data from the Cardio CT color scale study.

## Format the Input of doIMRMC

The doIMRMC requires the input dataframe contain both the groud truth and reader data.For more details on using doIMRMC see https://cran.r-project.org/web/packages/iMRMC/iMRMC.pdf.

We need to merge both **cardioCTGroundTruth**

| | caseID | truth |
|---|---|---|
| 1 | 1 | positive |
| 2 | 2 | positive |
| 3 | ... | ... |
| 209 | 209 | negative |
| 210 | 210 | negative |

and **cardioCTReaderData**

| | readerID | caseID | modalityID | confidenceScore |
|---|---|---|---|---|
| 1 | Low1 | 141 | Grayscale | 31 |
| 2 | Low1 | 142 | Grayscale | 54 |
| 3 | ... | ... | ... | ... |
| 1920 | Low8 | 139 | Rainbow | 55 |
| 1921 | Low8 | 140 | Rainbow | 65 |

into the format of cardioCTReaderData.

First, we reformat the ground truth data to add readerID and modalityID and change truth to numeric scores (positive = 1, negative = 0)

```
gt <- cardioCTGroundTruth
# Add new columns: readerID and modalityID
gt$readerID <- factor("truth")
gt$modalityID <- factor("truth")
# Change the name and value of the truth column
gt$truth <- as.numeric(gt$truth) - 1
names(gt)[names(gt) == 'truth'] <- "confidenceScore"
```

Now, the formated ground truth data looks like this:

| | caseID | confidenceScore | readerID | modalityID |
|---|---|---|---|---|
| 1 | 1 | 1 | truth | truth |
| 2 | 2 | 1 | truth | truth |
| 3 | ... | ... | ... | ... |
| 209 | 209 | 0 | truth | truth |
| 210 | 210 | 0 | truth | truth |

Then, we combine the ground truth data with the reader data

```
combinedDf <- merge.data.frame(gt, cardioCTReaderData, by = names(cardioCTReaderData),
                               all = TRUE, sort = FALSE)
# The order of the columns is as the same of the reader data and the data is not sorted
```

| | readerID | caseID | modalityID | confidenceScore |
|---|---|---|---|---|
| 1 | truth | 1 | truth | 1 |
| 2 | truth | 2 | truth | 1 |
| 3 | ... | ... | ... | ... |
| 2130 | Low8 | 139 | Rainbow | 55 |
| 2131 | Low8 | 140 | Rainbow | 65 |

## Apply the doIMRMC

```
library(iMRMC)
result <- doIMRMC(data = combinedDf)
#load("~/_R_code/Data package/Files for GitHub repository/result.RData")
```

In iMRMC, the AUC for different modalities (color scales) are estimated by different methods. **Ustat** present the result from an unbiased non-parametric estimation and **MLEstat** shows the maximum likelihood estimation of each parameter.

```
AUCDf <- data.frame(rbind(result$MLEstat$AUCA[1:3],result$MLEstat$varAUCA[1:3],
                          sqrt(result$MLEstat$varAUCA[1:3])),
                    row.names = c("AUC", "variance of AUC", "SE of AUC"))
names(AUCDf) <- result$MLEstat$modalityA[1:3]
kable(AUCDf, caption = "AUC for different modalities : MLEstat", align = 'c' )
```

Table 5: AUC for different modalities : MLEstat

| | Grayscale | Hot | Rainbow |
|---|---|---|---|
| AUC | 0.5902954 | 0.5671724 | 0.5176793 |
| variance of AUC | 0.0015535 | 0.0008297 | 0.0009073 |
| SE of AUC | 0.0394148 | 0.0288037 | 0.0301211 |

```
AUCDf <- data.frame(rbind(result$Ustat$AUCA[1:3],result$Ustat$varAUCA[1:3],
                          sqrt(result$Ustat$varAUCA[1:3])),
                    row.names = c("AUC", "variance of AUC", "SE of AUC"))
```

```
## Warning in sqrt(result$Ustat$varAUCA[1:3]): NaNs produced
```

```
names(AUCDf) <- result$Ustat$modalityA[1:3]
kable(AUCDf, caption = "AUC for different modalities : Ustat", align = 'c' )
```

Table 6: AUC for different modalities : Ustat

| | Grayscale | Hot | Rainbow |
|---|---|---|---|
| AUC | 0.5902954 | 0.5671724 | 0.5176793 |
| variance of AUC | 0.0010402 | -0.0000249 | 0.0000338 |
| SE of AUC | 0.0322528 | NaN | 0.0058162 |

From the above tables, we can see that one of the variance estimation in the Ustat is negative. This is because

this color scale study is a split-plot study but not fully crossed. That is, one reader only scored part of the cases, not all of them.

The difference of AUC among different modalities (color scales) are also estimated by the two different estimation methods.

```
AUCDf <- data.frame(rbind(result$MLEstat$AUCAminusAUCB[4:6],result$MLEstat$varAUCAminusAUCB[4:6],
                          sqrt(result$MLEstat$varAUCAminusAUCB[4:6]),
              result$MLEstat$AUCAminusAUCB[4:6] - 1.96 * sqrt(result$MLEstat$varAUCAminusAUCB[4:6]),
              result$MLEstat$AUCAminusAUCB[4:6] + 1.96 * sqrt(result$MLEstat$varAUCAminusAUCB[4:6])),
              row.names = c("difference of AUC", "variance of difference of AUC",
                            "SE of different of AUC", "95% CI lower bound", "95% CI upper bound"))
names(AUCDf) <- paste(result$MLEstat$modalityA[4:6], result$MLEstat$modalityB[4:6], sep = " vs. ")
kable(AUCDf, caption = "Difference of AUC among different modalities : MLEstat", align = 'c' )
```

Table 7: Difference of AUC among different modalities : MLEstat

| | Grayscale vs. Hot | Grayscale vs. Rainbow | Hot vs. Rainbow |
|---|---|---|---|
| difference of AUC | 0.0231230 | 0.0726161 | 0.0494932 |
| variance of difference of AUC | 0.0021459 | 0.0024036 | 0.0019731 |
| SE of different of AUC | 0.0463239 | 0.0490261 | 0.0444191 |
| 95% CI lower bound | -0.0676719 | -0.0234750 | -0.0375683 |
| 95% CI upper bound | 0.1139178 | 0.1687072 | 0.1365547 |

```
AUCDf <- data.frame(rbind(result$Ustat$AUCAminusAUCB[4:6],result$Ustat$varAUCAminusAUCB[4:6],
                          sqrt(result$Ustat$varAUCAminusAUCB[4:6]),
              result$Ustat$AUCAminusAUCB[4:6] - 1.96 * sqrt(result$Ustat$varAUCAminusAUCB[4:6]),
              result$Ustat$AUCAminusAUCB[4:6] + 1.96 * sqrt(result$Ustat$varAUCAminusAUCB[4:6])),
              row.names = c("difference of AUC", "variance of difference of AUC",
                            "SE of different of AUC", "95% CI lower bound", "95% CI upper bound"))
names(AUCDf) <- paste(result$Ustat$modalityA[4:6], result$Ustat$modalityB[4:6], sep = " vs. ")
kable(AUCDf, caption = "Difference of AUC among different modalities : Ustat", align = 'c' )
```

Table 8: Difference of AUC among different modalities : Ustat

| | Grayscale vs. Hot | Grayscale vs. Rainbow | Hot vs. Rainbow |
|---|---|---|---|
| difference of AUC | 0.0231230 | 0.0726161 | 0.0494932 |
| variance of difference of AUC | 0.0012101 | 0.0014347 | 0.0010837 |
| SE of different of AUC | 0.0347870 | 0.0378770 | 0.0329203 |
| 95% CI lower bound | -0.0450596 | -0.0016227 | -0.0150307 |
| 95% CI upper bound | 0.0913055 | 0.1468550 | 0.1140170 |