DeFi Example Notebook:

DAR Assignment 1 (Fall 2021)

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Introductory Decentralized Finance (DeFi) Research Notebook

This notebook is broken into two main parts:

```
* Part 1 is a basic introduction to github and RStudio Server
* Part 2 is an introduction to the DeFi transaction dataset
```

This R Notebook and its related R scripts provide a very basic introduction to an interesting **Decentralized Finance (DeFi)** dataset. All data was obtained by querying an API on The Graph, an indexing protocol for querying networks like Ethereum, for transaction data based on the AAVE protocol. For more information on AAVE see the AAVE developer notes. The AAVE protocol is based on Ethereum, an important cryptocurrency platform.

The RPI github repository for all the code required for this notebook, including a snapshots of AAVE transaction and user data, may be found at:

- https://github.rpi.edu/DataINCITE/IDEA-Blockchain

The IDEA-Blockchain github also contains notebooks used to harvest the AAVE dataset, which you are welcome to examine.

BEFORE YOU BEGIN

To contribute or submit to any RPI github repository you must validate your RPI github.com ID and send a confirmation email to John Erickson at `erickj4@rpi.edu`. Please do the following **now**:

- Browse to http://github.rpi.edu
- Login using your RPI credentials
- **PLEASE DO THIS IMMEDIATELY BEFORE READING ANY FURTHER!!**

DAR ASSIGNMENT 1: CLONING A NOTEBOOK AND UPDATING THE REPOSITORY

In this assignment we're asking you to…

- clone the `IDEA-Blockchain` github repository…
- create a personal branch using git, and…
- make additions to the repository by creating a new, customized notebook.

The instructions which follow explain how to accomplish this.

For DAR Fall 2021 you *must* be using RStudio Server on the IDEA Cluster. Instructions for accessing "The Cluster" appear at the end of this notebook. Don't forget to validate your RPI github ID as above and email `erickj4@rpi.edu`

Cloning an RPI github repository

The recommended procedure for cloning and using this repository is as follows:

- Access the RPI network via VPN
  - See https://itssc.rpi.edu/hc/en-us/articles/360008783172-VPN-Connection-and-Installation for information
- Access RStudio Server on the IDEA Cluster at http://lp01.idea.rpi.edu/rstudio-ose/
  - You must be on the RPI VPN!!
- Access the Linux shell on the IDEA Cluster by clicking the **Terminal** tab of RStudio Server (lower left panel).
  - You now see the Linux shell on the IDEA Cluster
  - `cd` (change directory) to enter your home directory using: `cd ~`
  - Type `pwd` to confirm
  - NOTE: Advanced users may use `ssh` to directly access the Linux shell from a macOS or Linux command line
- Type `git clone https://github.rpi.edu/DataINCITE/IDEA-Blockchain.git` from within your `home` directory
  - This will create a new directory `IDEA-Blockchain`
- In the Linux shell, `cd` to `IDEA-Blockchain/DefiResearch/StudentNotebooks`
  - Type `ls -al` to list the current contents
  - Don't be surprised if you see many files!
- In the Linux shell, type `git checkout -b dar-yourrcs` where `yourrcs` is your RCS id
  - For example, if your RCS is `erickj4`, your new branch should be `dar-erickj4`
  - It is *critical* that you include your RCS id in your branch id
- Now in the RStudio Server UI, navigate to the `IDEA-Blockchain/DefiResearch/StudentNotebooks` directory via the **Files** panel (lower right panel)
  - Under the **More** menu, set this to be your R working directory
  - Setting the correct working directory is essential for interactive R use!

REQUIRED FOR ASSIGMENT 1

1. In RStudio, make a **copy** of `blockchain-notebook-f21.Rmd` file using a *new, original, descriptive* filename that **includes your RCS ID!**
   - Open `blockchain-notebook-f21.Rmd`
   - **Save As...** using a new filename
   - Example filename for user `erickj4`: `erickj4-assignment1-f21.Rmd`
2. Edit your new notebook using RStudio and save
   - Change the `title:` and `subtitle:` headers (at the top of the file)
   - Change the `author:`
   - Change the `date:`
   - **Save** your changes
3. Use the RStudio `Knit` command to create an HTML file; repeat as necessary
   - Use the down arrow next to the word `Knit` and select **Knit to HTML**
   - You may also knit to PDF...
4. In the Linux terminal, use `git add` to add each new file you want to add to the repository
   - Type: `git add yourfilename.Rmd`
   - Type: `git add yourfilename.html` (created when you knitted)
   - Add your PDF if you also created one...
5. When you're ready, in Linux commit your changes:
   - Type: `git commit -m "some comment"` where "some comment" is a useful comment describing your changes
   - This commits your changes to your local repo, and sets the stage for your next operation.
6. Finally, push your commits to the RPI github repo
   - Type: `git push origin dar-yourrcs` (where `dar-yourrcs` is the branch you've been working

in)
- Your changes are now safely on the RPI github.

7. **REQUIRED:** On the RPI github, submit a pull request.
   - In a web browser, navigate to https://github.rpi.edu/DataINCITE/IDEA-Blockchain
   - In the branch selector drop-down (by default says **master**), select your branch
   - **Submit a pull request for your branch**
   - One of the DAR instructors will merge your branch, and your new files will be added to the master branch of the repo.

Confirm what you just did

For this assignment you will be asked to confirm the following in LMS:

- The location of the github: https://github.rpi.edu/DataINCITE/IDEA-Blockchain/
- Your github ID: bennek
- The name of your new branch: dar-bennek
- The name of your new (copied) notebook: bennek-assignment1-f21.Rmd

Please also see this handy github “cheatsheet”: https://education.github.com/git-cheat-sheet-education.pdf

Exploring a DeFi Transaction Dataset using AAVE

What is AAVE?

From the developer site: *Aave is a decentralised non-custodial liquidity protocol where users can participate as depositors or borrowers. Depositors provide liquidity to the market to earn a passive income, while borrowers are able to borrow in an over-collateralised (perpetually) or under-collateralised (one-block liquidity) fashion. . . The (Aave) protocol is implemented as a set of smart contracts on top of the Ethereum blockchain. Smart contracts guarantee safety and do not require a middleman.*

For (much) more detail refer to the AAVE Protocol V2.0 Whitepaper

Prepare Transaction Data

We begin by loading our prepared AAVE transaction data into a dataframe. The dataset has over 400,000 rows, and 27 columns.

We are directly loading the dataframe from an Rds archive instead of a CSV file to conserve space.

```r
#load Rds (binary version of csv file) into dataframe
df<-read_rds('../Data/transactions.Rds')

# Let's take a quick look
head(df)
```

```
##       amount borrowRate borrowRateMode   onBehalfOf         pool reserve
## 1   41501.63   6.274937       Variable 8.502518e+47 1.034668e+48     DAI
## 2 7000000.00   2.589628       Variable 4.635974e+47 1.034668e+48    USDT
## 3   15000.00   8.802541       Variable 3.735263e+47 1.034668e+48    USDC
## 4    8193.19  48.747052         Stable 6.896232e+47 1.034668e+48    USDC
## 5   11000.00   3.225055       Variable 1.089455e+48 1.034668e+48    USDT
## 6   40000.00   5.739208       Variable 2.178337e+47 1.034668e+48    USDT
##    timestamp         user   type reservePriceETH reservePriceUSD  amountUSD
## 1 1621340435 8.502518e+47 borrow    2.852900e+14       0.9948044   41286.00
## 2 1622477822 4.635974e+47 borrow    3.812835e+14       1.0000000 7000000.00
## 3 1619775984 3.735263e+47 borrow    3.611000e+14       1.0043389   15065.08
## 4 1615481632 6.896232e+47 borrow    5.562201e+14       0.9993909    8188.20
## 5 1626914745 1.089455e+48 borrow    4.971100e+14       1.0000000   11000.00
## 6 1620936688 2.178337e+47 borrow    2.725248e+14       1.0000000   40000.00
##   collateralAmount collateralReserve principalAmount principalReserve
## 1               NA                                NA
## 2               NA                                NA
## 3               NA                                NA
## 4               NA                                NA
## 5               NA                                NA
## 6               NA                                NA
##   reservePriceETHPrincipal reservePriceUSDPrincipal reservePriceETHCollateral
## 1                       NA                       NA                        NA
## 2                       NA                       NA                        NA
## 3                       NA                       NA                        NA
## 4                       NA                       NA                        NA
## 5                       NA                       NA                        NA
## 6                       NA                       NA                        NA
##   reservePriceUSDCollateral amountUSDPincipal amountUSDCollateral
## 1                        NA                NA                  NA
## 2                        NA                NA                  NA
## 3                        NA                NA                  NA
## 4                        NA                NA                  NA
## 5                        NA                NA                  NA
## 6                        NA                NA                  NA
##   borrowRateModeFrom borrowRateModeTo stableBorrowRate variableBorrowRate
## 1                                                   NA                 NA
## 2                                                   NA                 NA
## 3                                                   NA                 NA
## 4                                                   NA                 NA
## 5                                                   NA                 NA
## 6                                                   NA                 NA
```

```r
str(df)
```

```
## 'data.frame':    481519 obs. of  26 variables:
##  $ amount                   : num  41502 7000000 15000 8193 11000 ...
##  $ borrowRate               : num  6.27 2.59 8.8 48.75 3.23 ...
##  $ borrowRateMode           : Factor w/ 3 levels "","Stable","Variable": 3 3 3 2 3 3 3 3 3 2 ...
##  $ onBehalfOf               : num  8.50e+47 4.64e+47 3.74e+47 6.90e+47 1.09e+48 ...
##  $ pool                     : num  1.03e+48 1.03e+48 1.03e+48 1.03e+48 1.03e+48 ...
##  $ reserve                  : Factor w/ 50 levels "","AAVE","AmmBptBALWETH",..: 29 45 44 44 45 45 44
##  $ timestamp                : int  1621340435 1622477822 1619775984 1615481632 1626914745 1620936688
##  $ user                     : num  8.50e+47 4.64e+47 3.74e+47 6.90e+47 1.09e+48 ...
##  $ type                     : Factor w/ 6 levels "borrow","deposit",..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ reservePriceETH          : num  2.85e+14 3.81e+14 3.61e+14 5.56e+14 4.97e+14 ...
##  $ reservePriceUSD          : num  0.995 1 1.004 0.999 1 ...
##  $ amountUSD                : num  41286 7000000 15065 8188 11000 ...
##  $ collateralAmount         : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ collateralReserve        : Factor w/ 25 levels "","AAVE","AmmBptBALWETH",..: 1 1 1 1 1 1 1 1 1 1
##  $ principalAmount          : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ principalReserve         : Factor w/ 27 levels "","AmmDAI","AmmUSDC",..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ reservePriceETHPrincipal : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ reservePriceUSDPrincipal : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ reservePriceETHCollateral: num  NA NA NA NA NA NA NA NA NA NA ...
##  $ reservePriceUSDCollateral: num  NA NA NA NA NA NA NA NA NA NA ...
##  $ amountUSDPincipal        : num  NA NA NA NA NA NA NA NA NA NA ...
## $ amountUSDCollateral      : num  NA NA NA NA NA NA NA NA NA NA ...
## $ borrowRateModeFrom       : Factor w/ 3 levels "","Stable","Variable": 1 1 1 1 1 1 1 1 1 1 ...
## $ borrowRateModeTo         : Factor w/ 3 levels "","Stable","Variable": 1 1 1 1 1 1 1 1 1 1 ...
## $ stableBorrowRate         : num  NA NA NA NA NA NA NA NA NA NA ...
## $ variableBorrowRate       : num  NA NA NA NA NA NA NA NA NA NA ...
```

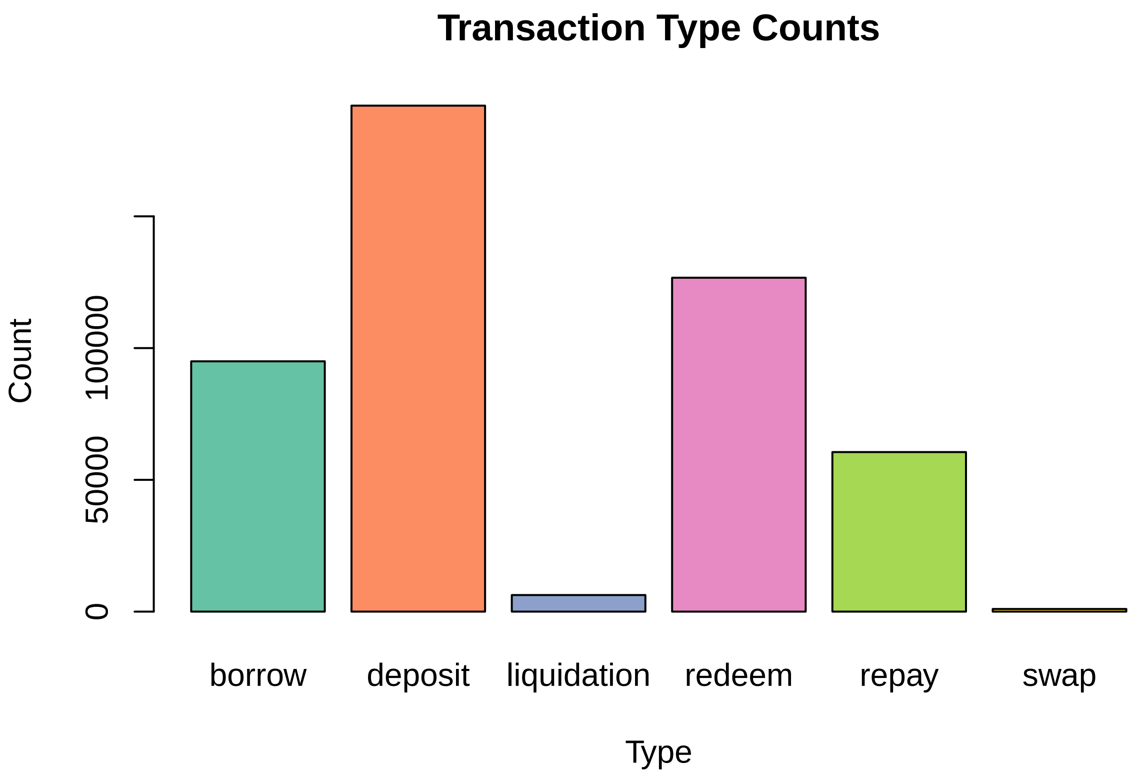
```
summary(df)
```

```
##      amount            borrowRate       borrowRateMode     onBehalfOf
##  Min.   :        0   Min.   :    0.0           :386542   Min.   :2.578e+33
##  1st Qu.:       24   1st Qu.:    3.3   Stable  : 18408   1st Qu.:4.174e+47
##  Median :     1427   Median :    3.9   Variable: 76569   Median :7.522e+47
##  Mean   :   191103   Mean   :    9.5                     Mean   :7.592e+47
##  3rd Qu.:    24382   3rd Qu.:   10.8                     3rd Qu.:1.168e+48
##  Max.   :600000000   Max.   :10002.0                     Max.   :1.461e+48
##  NA's   :7289        NA's   :386542                      NA's   :7289
##       pool              reserve         timestamp             user
##  Min.   :9.862e+47   USDC   :105937   Min.   :1.607e+09   Min.   :2.578e+33
##  1st Qu.:1.035e+48   WETH   :105279   1st Qu.:1.615e+09   1st Qu.:4.199e+47
##  Median :1.035e+48   USDT   : 58266   Median :1.621e+09   Median :8.697e+47
##  Mean   :1.034e+48   DAI    : 55211   Mean   :1.620e+09   Mean   :8.082e+47
##  3rd Qu.:1.035e+48   LINK   : 26404   3rd Qu.:1.624e+09   3rd Qu.:1.173e+48
##  Max.   :1.035e+48   WBTC   : 26344   Max.   :1.629e+09   Max.   :1.461e+48
##                      (Other):104078
##           type        reservePriceETH     reservePriceUSD
##  borrow     : 94977   Min.   :1.000e+00   Min.   :0.000e+00
##  deposit    :192006   1st Qu.:2.865e+14   1st Qu.:1.000e+00
##  liquidation:  6289   Median :4.652e+14   Median :1.000e+00
##  redeem     :126705   Mean   :3.458e+23   Mean   :6.774e+08
##  repay      : 60542   3rd Qu.:9.411e+14   3rd Qu.:1.000e+00
##  swap       :  1000   Max.   :1.647e+28   Max.   :4.252e+13
##                       NA's   :7289        NA's   :7289
##    amountUSD         collateralAmount  collateralReserve principalAmount
##  Min.   :        0   Min.   :      0          :475230    Min.   :      0
##  1st Qu.:       70   1st Qu.:      1   WETH   :  2665    1st Qu.:    962
##  Median :     5836   Median :     14   LINK   :  1312    Median :   4362
##  Mean   :   245851   Mean   :   5451   WBTC   :   686    Mean   :  66005
##  3rd Qu.:    49871   3rd Qu.:    250   AAVE   :   333    3rd Qu.:  21533
##  Max.   :754379487   Max.   :4638724   UNI    :   230    Max.   :4475668
##  NA's   :7289        NA's   :475230    (Other):  1063    NA's   :475230
##  principalReserve reservePriceETHPrincipal reservePriceUSDPrincipal
##         :475230   Min.   :1.000e+00        Min.   :    0.0
##  USDC   :  2142   1st Qu.:4.062e+14        1st Qu.:    1.0
##  USDT   :  1549   Median :4.682e+14        Median :    1.0
##  DAI    :  1459   Mean   :1.556e+17        Mean   :  295.6
##  GUSD   :   242   3rd Qu.:5.363e+14        3rd Qu.:    1.0
##  TUSD   :   175   Max.   :4.203e+19        Max.   :83819.1
##  (Other):   722   NA's   :475230           NA's   :475230
##  reservePriceETHCollateral reservePriceUSDCollateral amountUSDPincipal
##  Min.   :1.000e+00         Min.   :0.000e+00         Min.   :      0
##  1st Qu.:1.000e+00         1st Qu.:0.000e+00         1st Qu.:   1022
##  Median :5.110e+14         Median :1.000e+00         Median :   4481
##  Mean   :2.177e+21         Mean   :4.543e+06         Mean   :  67361
##  3rd Qu.:1.110e+16         3rd Qu.:2.600e+01         3rd Qu.:  22066
##  Max.   :9.116e+23         Max.   :2.509e+09         Max.   :4571839
##  NA's   :475230            NA's   :475230            NA's   :475230
##  amountUSDCollateral borrowRateModeFrom borrowRateModeTo  stableBorrowRate
##  Min.   :      0             :480519            :480519   Min.   :  0.0
##  1st Qu.:      0     Stable  :   471    Stable  :   529   1st Qu.:  9.0
##  Median :    476     Variable:   529    Variable:   471   Median : 10.9
##  Mean   :  37060                                          Mean   : 11.7
##  3rd Qu.:   7457                                          3rd Qu.: 12.0
##  Max.   :5029023                                          Max.   :154.7
##  NA's   :475230                                           NA's   :480519
##  variableBorrowRate
##  Min.   :  0.0
##  1st Qu.:  3.8
##  Median :  3.9
##  Mean   :  5.7
##  3rd Qu.:  5.1
##  Max.   :148.7
##  NA's   :480519
```

Analyze Transaction Types

Next, we will examine the different types of transactions present in the data. We make a bar plot to visualize the number of each transaction types. Deposit is the most common type of transaction, whereas swaps are the most rare.

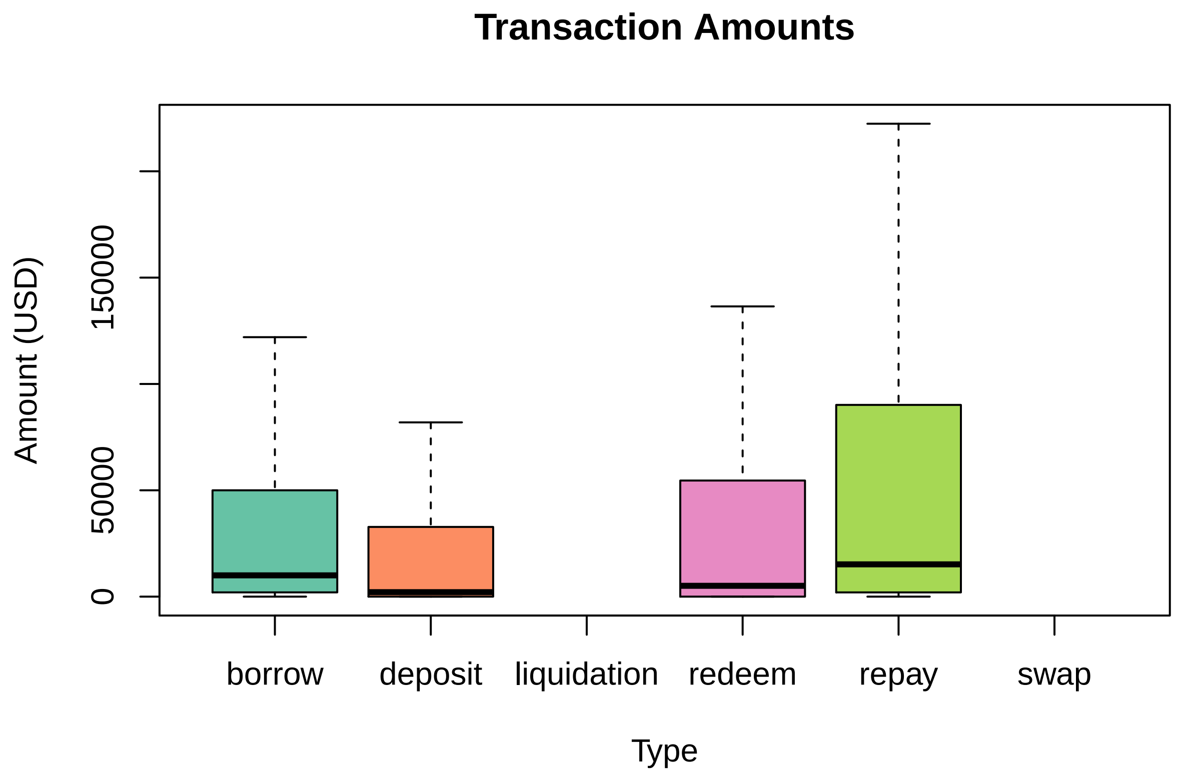
```r
#set color palette
colors = brewer.pal(6,"Set2")

#create barplot
barplot(table(df$type), main='Transaction Type Counts', xlab='Type',ylab='Count',col=colors)
```



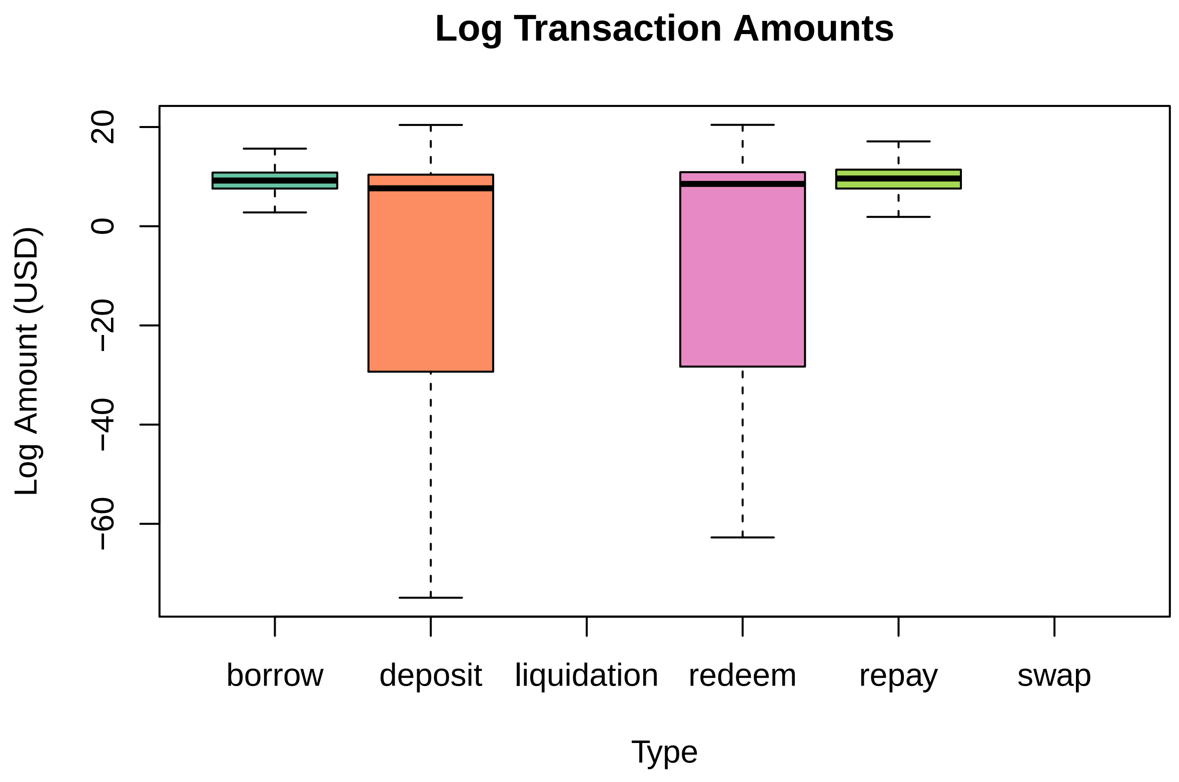
There are more deposits than borrows, because users often need to overcollateralize for loans.

Now, we will examine the amount of US dollars being used in the different types of transactions. We create box plots for the 4 types of transactions that have the amount feature associated with them, and visualize the distribution of that column for the different transactions. We can see that most transactions are completed with very little money.

```
#create boxplot
boxplot(amountUSD~type,data=df,outline=FALSE,col=colors,main="Transaction Amounts",xlab="Type",ylab="Am
```



```
boxplot(log(amountUSD)~type,data=df,outline=FALSE,col=colors,main="Log Transaction Amounts",xlab="Type"
```



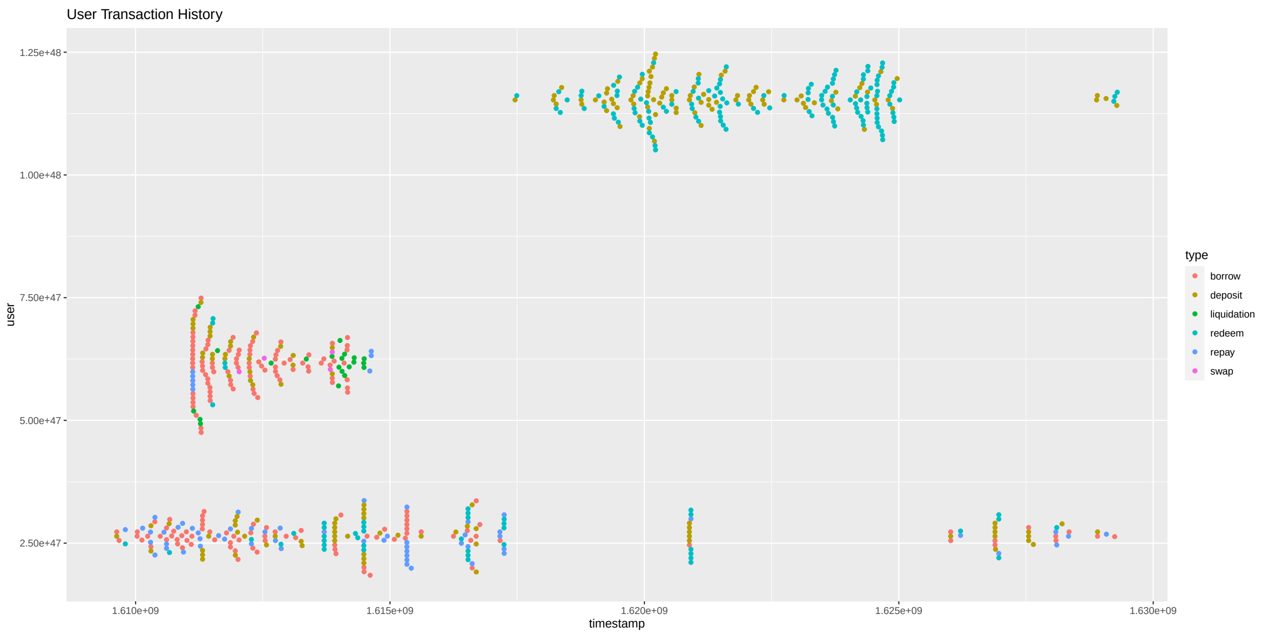
There are many borrows and repays with high transactions amounts, but deposits and redeems have much lower transactions amounts.

Look at Sample User Transaction Histories

Finally, we will examine the transaction history of different users. To do this, we will select 3 random users from the data who have completed between 100 and 300 transactions. Then, we create swarmplots displaying the different types of transactions those users made over time.

```
#set seed
set.seed(1)

#get 3 random users that have between 100 and 300 transactions
users<-vector(length=3)
count<-0
while(count<=3){
  success<-FALSE
  while(!success){
    #get random user
    ruser<-sample(df$user,1)

    #check for valid number of transactions
    length<-nrow(filter(df,user==ruser))
    if (length>100 && length<300){
      users[count]=ruser
      success<-TRUE
      count<-count+1
    }
  }
}
df.rusers<-filter(df, user %in%users)
```

```r
#create swarmplot

#liquidations
#borrow
#deposit
#redeem
#repay
#swap

ggplot(df.rusers,aes(user, timestamp,color=type)) +
        geom_beeswarm(cex=1)+
        coord_flip()+
        ggtitle("User Transaction History")
```

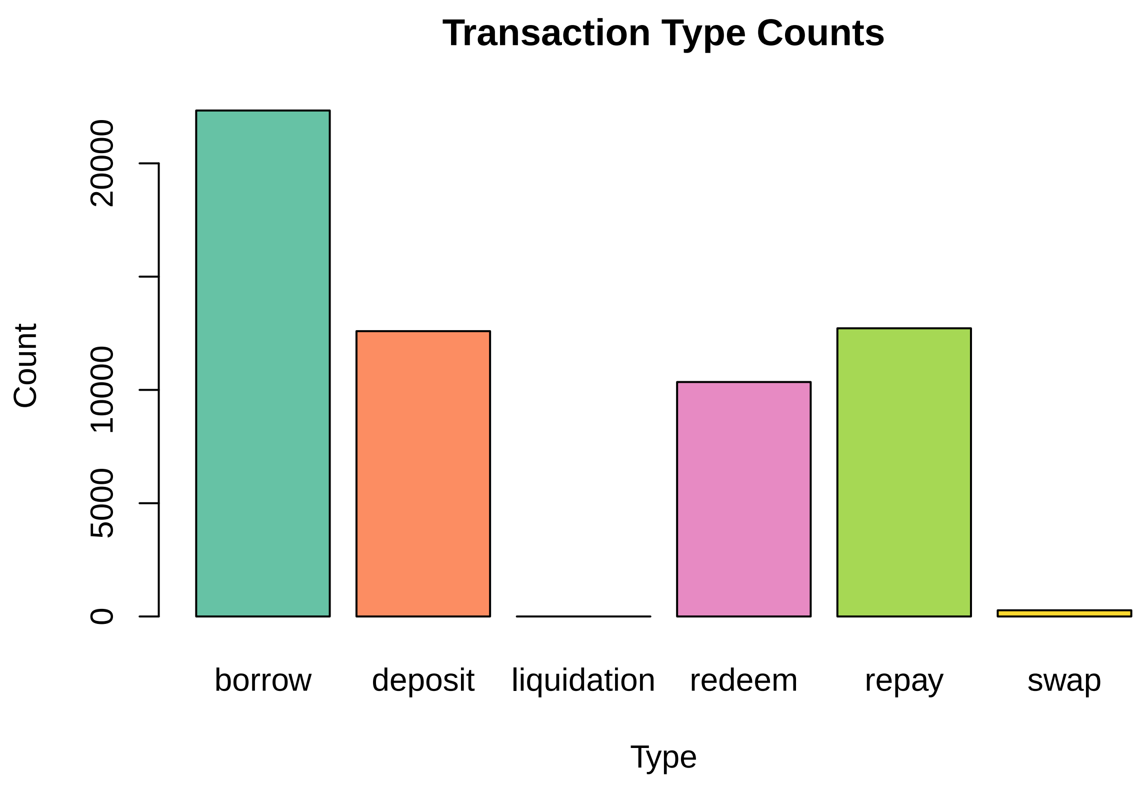


Users have very different transactions patterns, which we will try to better understand.

Analyze Individual Currencies (USDT)

USDT is interesting because it has more borrows than deposits. This may be because it is a stable coin.

```r
df.usd<-filter(df,reserve=="USDT")
barplot(table(df.usd$type), main='Transaction Type Counts', xlab='Type',ylab='Count',col=colors)
```



APPENDIX: Accessing RStudio Server on the IDEA Cluster

The IDEA Cluster provides five compute nodes (4x 48 cores, 1x 80 cores, 1x storage server)

- The Cluster requires RCS credentials, enabled via registration in class
  - email John Erickson for problems `erickj4@rpi.edu`
- RStudio, Jupyter, MATLAB, GPUs (on two nodes); lots of storage and computes
- Access via RPI physical network or VPN only

RStudio GUI Access:

- http://lp01.idea.rpi.edu/rstudio-ose/ or http://lp01.idea.rpi.edu/rstudio-ose-3/ (RStudio)
- Linux terminal accessible from within RStudio "Terminal" or via ssh (below)

Shared Data on Cluster:

- Users enrolled in DAR have access to `/academics/MATP-4910-F21`
  - Usually DAR users will see a symbolic ("soft") link in their home directories
  - If you do not, type the following in the **Terminal** via RStudio: `ln -s /academics/MATP-4910-F21/ MATP-4910-F21`
- All idea_users have access to shared storage via `/data` ("data" in your home directories)
  - You might wish to use this for data sharing in team projects…
  - …but we recommend using github for shared code development
- Shell access to nodes: You must access "landing pad" first, then compute node:
- `ssh your_rcs@lp01.idea.rpi.edu` For example: `ssh erickj4@lp01.idea.rpi.edu`
- Then, `ssh` to the desired compute node, e.g.: `ssh idea-node-02`